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July 14, 2015

VIA RESS, EMAIL and COURIER

Kirsten Walli
Board Secretary
Ontario Energy Board
2300 Yonge Street
Suite 2700
Toronto, ON M4P 1E4

Dear Ms. Walli

**Re: Enbridge Gas Distribution Inc. (the "Company" or "Enbridge")
Ontario Energy Board (the "Board") File: EB-2015-0049
Multi-Year Demand Side Management Plan (2015 to 2020)
Undertaking Responses**

Enclosed please find the following undertaking responses:

- JT1.15 to 17
- JT1.20 to 23
- JT1.25 and 26
- JT1.29
- JT1.31
- JT1.33
- JT1.35
- JT1.38
- JT1.41

The submission has been filed through the Board's Regulatory Electronic Submission System ("RESS") and will be available on the Company's website under the "Other Regulatory Proceedings" tab at www.enbridgegas.com/ratecase.

If you require further information, please contact the undersigned.

Yours truly,

(Original Signed)

Bonnie Jean Adams
Regulatory Coordinator

cc: Mr. Dennis O'Leary, Aird & Berlis
EB-2015-0049 Intervenors

UNDERTAKING JT1.15

UNDERTAKING

Technical Conference TR, page 75

Enbridge to provide more clarity as to what is going into the avoided gas costs for the numbers shown on B-2- 5, page 3.

RESPONSE

The 2015 Gas Avoided Costs are based on avoided gas costs that were determined in EB-2012-0394 and adjusted annually in accordance with the 2012 to 2014 Demand Side Management Guidelines for Natural Gas Utilities.

The input parameter information that was used in SENDOUT to determine the EB-2012-0394 avoided gas costs included demand forecasts, commodity price forecasts at various receipt points, transportation tolls and fuel, and storage unit costs.

The annual demand forecasts are included in EB-2012-039, Exhibit B, Tab 2, Schedule 2, page 7 of 10. The monthly distribution of annual demand forecasts is included in Attachment 1 of this response.

The forecasted annual commodity prices were provided in EB-2012-0394, Exhibit B, Tab 2, Schedule 2, page 8 of 10. The monthly distribution of annual commodity prices is included in Attachment 2 of this response.

The transportation tolls are discussed in EB-2012-0394, Exhibit B, Tab 2, Schedule 2, page 2 of 10. The tolls and related fuel ratios are summarized in Attachment 3 of this response.

The storage unit costs are determined by commercial arrangements that cannot be disclosed as requested absent an order from the Board requiring the information to be treated confidentially and not disclosed publicly. The Company is therefore not at liberty to provide the storage unit cost information being requested.

The updated Commodity costs which account for over 95% of the Total Avoided Gas costs have been updated on an annual basis and filed with the Board in the following applications:

Witness: A. Welburn

- 2012 Avoided Costs: EB-2012-0394, Update to the 2012 to 2014 Demand Side Management ("DSM") Plan, Exhibit B, Tab 2, Schedule 2.
- 2013 Avoided Costs: EB-2014-0277 2013 EGD DSM Clearance of Accounts, Exhibit B, Tab 1, Schedule1, Page 130
- 2014 Avoided Costs: 2014 Draft Evaluation Report – (not yet filed with the Board and still subject to Clearance of Accounts application

Attachment 1 – Demand Inputs

Avoided Cost SENDOUT Input: Demand

	Base Case	Space Heating	Industrial	Water Heating	Space & Water Heating
	10 ⁶ m ³	10 ⁶ m ³	10 ⁶ m ³	10 ⁶ m ³	10 ⁶ m ³
November-11	1194.902	1187.615	1173.646	1175.465	1186.790
December-11	1666.863	1655.170	1645.626	1644.848	1655.870
January-12	1961.781	1947.966	1936.211	1938.541	1948.310
February-12	1760.595	1748.319	1734.855	1738.424	1748.880
March-12	1536.240	1526.074	1510.557	1512.308	1526.270
April-12	1003.161	997.745	983.445	981.890	997.230
May-12	590.668	588.682	572.648	570.510	587.430
June-12	402.026	401.777	385.704	382.878	400.580
July-12	362.463	362.463	349.445	342.468	361.370
August-12	360.520	360.487	344.681	340.439	359.500
September-12	413.880	412.947	397.177	394.686	411.950
October-12	806.346	802.468	788.317	787.470	801.630
November-12	1211.122	1203.778	1189.713	1191.548	1202.950
December-12	1684.639	1672.859	1663.246	1662.462	1673.560
January-13	1941.986	1928.175	1916.419	1918.750	1928.510
February-13	1695.405	1683.315	1670.535	1673.992	1683.900
March-13	1519.397	1509.223	1493.707	1495.464	1509.430
April-13	995.225	989.804	975.509	973.951	989.300
May-13	582.129	580.145	564.109	561.971	578.880
June-13	395.008	394.758	378.685	375.856	393.560
July-13	359.223	359.223	346.210	339.226	358.130
August-13	358.177	358.146	342.337	338.097	357.150
September-13	408.841	407.910	392.139	389.646	406.910
October-13	797.030	793.154	779.000	778.154	792.310
November-13	1206.182	1198.840	1184.777	1186.609	1198.020
December-13	1679.527	1667.749	1658.138	1657.353	1668.450
January-14	1948.865	1934.899	1923.016	1925.373	1935.240
February-14	1701.592	1689.370	1676.443	1679.939	1689.960
March-14	1525.390	1515.108	1499.424	1501.196	1515.320
April-14	1000.984	995.504	981.046	979.481	994.980
May-14	585.637	583.628	567.421	565.260	582.350
June-14	395.125	394.872	378.618	375.760	393.660
July-14	359.224	359.224	346.071	339.009	358.120
August-14	358.194	358.163	342.187	337.902	357.160
September-14	408.385	407.443	391.498	388.979	406.440
October-14	801.369	797.446	783.139	782.281	796.600
November-14	1211.280	1203.858	1189.639	1191.492	1203.020
December-14	1685.288	1673.382	1663.664	1662.872	1674.090
January-15	1964.088	1949.966	1937.956	1940.337	1950.320
February-15	1714.467	1702.111	1689.043	1692.580	1702.710
March-15	1537.028	1526.633	1510.775	1512.572	1526.840
April-15	1010.047	1004.508	989.896	988.308	1003.990
May-15	590.905	588.875	572.491	570.306	587.590
June-15	395.098	394.842	378.417	375.528	393.620
July-15	359.208	359.208	345.910	338.771	358.090
August-15	358.170	358.137	341.981	337.649	357.120
September-15	408.369	407.415	391.292	388.749	406.400
October-15	808.594	804.634	790.167	789.303	803.770

	Base Case	Space Heating	Industrial	Water Heating	Space & Water Heating
	10 ⁶ m ³	10 ⁶ m ³	10 ⁶ m ³	10 ⁶ m ³	10 ⁶ m ³
November-15	1222.267	1214.769	1200.390	1202.264	1213.920
December-15	1700.608	1688.569	1678.747	1677.947	1689.280
January-16	1984.260	1969.983	1957.838	1960.248	1970.340
February-16	1780.510	1767.824	1753.914	1757.602	1768.400
March-16	1552.739	1542.230	1526.200	1528.011	1542.430
April-16	1012.833	1007.232	992.459	990.854	1006.700
May-16	592.103	590.051	573.483	571.274	588.740
June-16	391.929	391.672	375.063	372.144	390.430
July-16	356.499	356.499	343.052	335.835	355.370
August-16	355.306	355.274	338.943	334.560	354.250
September-16	404.768	403.802	387.509	384.934	402.770
October-16	810.886	806.877	792.255	791.378	806.010
November-16	1225.849	1218.262	1203.729	1205.624	1217.410
December-16	1705.383	1693.214	1683.283	1682.470	1693.940
January-17	2004.102	1989.672	1977.391	1979.828	1990.030
February-17	1749.280	1736.653	1723.295	1726.908	1737.260
March-17	1568.170	1557.545	1541.340	1543.169	1557.750
April-17	1030.088	1024.425	1009.489	1007.868	1023.890
May-17	602.550	600.478	583.728	581.498	599.170
June-17	395.045	394.784	377.999	375.042	393.540
July-17	359.174	359.174	345.576	338.282	358.040
August-17	358.136	358.103	341.589	337.161	357.060
September-17	408.316	407.340	390.865	388.261	406.300
October-17	824.592	820.541	805.754	804.870	819.660
November-17	1246.563	1238.095	1224.198	1226.115	1238.030
December-17	1734.473	1722.169	1712.129	1711.309	1722.900
January-18	2024.311	2009.718	1997.308	1999.770	2010.080
February-18	1766.748	1753.983	1740.476	1744.133	1754.590
March-18	1583.884	1573.144	1556.761	1558.615	1573.360
April-18	1041.261	1035.534	1020.431	1018.800	1035.000
May-18	609.045	606.951	590.019	587.762	605.620
June-18	395.017	394.755	377.778	374.791	393.490
July-18	359.157	359.157	345.410	338.041	358.010
August-18	358.125	358.091	341.397	336.920	357.040
September-18	408.293	407.309	390.650	388.021	406.250
October-18	833.512	829.417	814.472	813.574	828.530
November-18	1260.113	1252.360	1237.504	1239.443	1251.490
December-18	1753.377	1740.934	1730.785	1729.957	1741.670
January-19	2044.293	2029.545	2016.993	2019.484	2029.910
February-19	1783.993	1771.088	1757.433	1761.130	1771.710
March-19	1599.397	1588.539	1571.972	1573.846	1588.740
April-19	1052.483	1046.696	1031.429	1029.774	1046.160
May-19	615.552	613.434	596.318	594.032	612.090
June-19	394.983	394.715	377.558	374.539	393.440
July-19	359.135	359.135	345.241	337.783	357.970
August-19	358.093	358.059	341.183	336.653	356.990
September-19	408.268	407.269	390.431	387.772	406.200
October-19	842.463	838.327	823.218	822.310	837.430
November-19	1273.734	1265.898	1250.880	1252.836	1265.020
December-19	1772.381	1759.806	1749.547	1748.708	1760.550
January-20	2067.902	2052.991	2040.303	2042.821	2053.350
February-20	1855.226	1841.973	1827.444	1831.296	1842.590
March-20	1617.893	1606.915	1590.168	1592.063	1607.140
April-20	1057.971	1052.121	1036.686	1035.010	1051.570
May-20	618.298	616.156	598.850	596.538	614.800
June-20	391.680	391.412	374.060	371.011	390.120
July-20	356.308	356.308	342.262	334.724	355.130
August-20	355.102	355.068	338.006	333.425	353.990
September-20	404.499	403.493	386.472	383.782	402.420
October-20	846.913	842.727	827.453	826.534	841.810

Witness: A. Welburn

Attachment 2 –Commodity Forecast Cost Inputs

Avoided Cost SENDOUT Input: Commodity Prices

Forecast Date: October 18, 2011

	NYMEX	Alliance	Empress	Dawn	Chicago
	C\$/10 ³ m ³	C\$/10 ³ m ³	C\$/10 ³ m ³	C\$/10 ³ m ³	C\$/10 ³ m ³
November-11	156.330	135.205	118.736	169.533	159.974
December-11	156.330	135.205	118.736	169.533	159.974
January-12	156.330	135.205	118.736	169.533	159.974
February-12	156.330	135.205	118.736	169.533	159.974
March-12	156.330	135.205	118.736	169.533	159.974
April-12	140.888	121.850	107.008	152.787	144.172
May-12	140.888	121.850	107.008	152.787	144.172
June-12	140.888	121.850	107.008	152.787	144.172
July-12	140.888	121.850	107.008	152.787	144.172
August-12	140.888	121.850	107.008	152.787	144.172
September-12	140.888	121.850	107.008	152.787	144.172
October-12	140.888	121.850	107.008	152.787	144.172
November-12	169.431	147.380	131.838	182.477	173.159
December-12	169.431	147.380	131.838	182.477	173.159
January-13	169.431	147.380	131.838	182.477	173.159
February-13	169.431	147.380	131.838	182.477	173.159
March-13	169.431	147.380	131.838	182.477	173.159
April-13	152.695	132.822	118.815	164.453	156.055
May-13	152.695	132.822	118.815	164.453	156.055
June-13	152.695	132.822	118.815	164.453	156.055
July-13	152.695	132.822	118.815	164.453	156.055
August-13	152.695	132.822	118.815	164.453	156.055
September-13	152.695	132.822	118.815	164.453	156.055
October-13	152.695	132.822	118.815	164.453	156.055
November-13	178.101	155.582	140.507	190.746	181.841
December-13	178.101	155.582	140.507	190.746	181.841
January-14	178.101	155.582	140.507	190.746	181.841
February-14	178.101	155.582	140.507	190.746	181.841
March-14	178.101	155.582	140.507	190.746	181.841
April-14	160.509	140.214	126.628	171.905	163.879
May-14	160.509	140.214	126.628	171.905	163.879
June-14	160.509	140.214	126.628	171.905	163.879
July-14	160.509	140.214	126.628	171.905	163.879
August-14	160.509	140.214	126.628	171.905	163.879
September-14	160.509	140.214	126.628	171.905	163.879
October-14	160.509	140.214	126.628	171.905	163.879
November-14	190.386	167.105	152.792	202.761	194.193
December-14	190.386	167.105	152.792	202.761	194.193
January-15	190.386	167.105	152.792	202.761	194.193
February-15	190.386	167.105	152.792	202.761	194.193
March-15	190.386	167.105	152.792	202.761	194.193
April-15	171.580	150.599	137.700	182.733	175.012
May-15	171.580	150.599	137.700	182.733	175.012
June-15	171.580	150.599	137.700	182.733	175.012
July-15	171.580	150.599	137.700	182.733	175.012
August-15	171.580	150.599	137.700	182.733	175.012
September-15	171.580	150.599	137.700	182.733	175.012
October-15	171.580	150.599	137.700	182.733	175.012

	NYMEX	Alliance	Empress	Dawn	Chicago
	C\$/10 ³ m ³	C\$/10 ³ m ³	C\$/10 ³ m ³	C\$/10 ³ m ³	C\$/10 ³ m ³
November-15	207.365	182.747	169.771	219.600	211.305
December-15	207.365	182.747	169.771	219.600	211.305
January-16	207.365	182.747	169.771	219.600	211.305
February-16	207.365	182.747	169.771	219.600	211.305
March-16	207.365	182.747	169.771	219.600	211.305
April-16	186.882	164.696	153.002	197.908	190.433
May-16	186.882	164.696	153.002	197.908	190.433
June-16	186.882	164.696	153.002	197.908	190.433
July-16	186.882	164.696	153.002	197.908	190.433
August-16	186.882	164.696	153.002	197.908	190.433
September-16	186.882	164.696	153.002	197.908	190.433
October-16	186.882	164.696	153.002	197.908	190.433
November-16	225.012	199.256	187.419	237.500	229.062
December-16	225.012	199.256	187.419	237.500	229.062
January-17	225.012	199.256	187.419	237.500	229.062
February-17	225.012	199.256	187.419	237.500	229.062
March-17	225.012	199.256	187.419	237.500	229.062
April-17	202.786	179.574	168.906	214.041	206.437
May-17	202.786	179.574	168.906	214.041	206.437
June-17	202.786	179.574	168.906	214.041	206.437
July-17	202.786	179.574	168.906	214.041	206.437
August-17	202.786	179.574	168.906	214.041	206.437
September-17	202.786	179.574	168.906	214.041	206.437
October-17	202.786	179.574	168.906	214.041	206.437
November-17	243.349	216.465	205.755	256.003	247.486
December-17	243.349	216.465	205.755	256.003	247.486
January-18	243.349	216.465	205.755	256.003	247.486
February-18	243.349	216.465	205.755	256.003	247.486
March-18	243.349	216.465	205.755	256.003	247.486
April-18	219.312	195.084	185.431	230.716	223.040
May-18	219.312	195.084	185.431	230.716	223.040
June-18	219.312	195.084	185.431	230.716	223.040
July-18	219.312	195.084	185.431	230.716	223.040
August-18	219.312	195.084	185.431	230.716	223.040
September-18	219.312	195.084	185.431	230.716	223.040
October-18	219.312	195.084	185.431	230.716	223.040
November-18	257.872	230.255	220.278	270.379	261.998
December-18	257.872	230.255	220.278	270.379	261.998
January-19	257.872	230.255	220.278	270.379	261.998
February-19	257.872	230.255	220.278	270.379	261.998
March-19	257.872	230.255	220.278	270.379	261.998
April-19	232.400	207.512	198.520	243.672	236.119
May-19	232.400	207.512	198.520	243.672	236.119
June-19	232.400	207.512	198.520	243.672	236.119
July-19	232.400	207.512	198.520	243.672	236.119
August-19	232.400	207.512	198.520	243.672	236.119
September-19	232.400	207.512	198.520	243.672	236.119
October-19	232.400	207.512	198.520	243.672	236.119
November-19	277.552	248.837	239.958	290.042	281.715
December-19	277.552	248.837	239.958	290.042	281.715
January-20	277.552	248.837	239.958	290.042	281.715
February-20	277.552	248.837	239.958	290.042	281.715
March-20	277.552	248.837	239.958	290.042	281.715
April-20	250.136	224.258	216.256	261.392	253.888
May-20	250.136	224.258	216.256	261.392	253.888
June-20	250.136	224.258	216.256	261.392	253.888
July-20	250.136	224.258	216.256	261.392	253.888
August-20	250.136	224.258	216.256	261.392	253.888
September-20	250.136	224.258	216.256	261.392	253.888
October-20	250.136	224.258	216.256	261.392	253.888

Witness: A. Welburn

Attachment 3 – Transportation Cost Inputs

Avoided Cost SENDOUT Input: Transportation Costs

Date Range: 2012-2021

	Transportation Costs		
	Demand Charge (C\$/GJ/Mth)	Commodity Charge (C\$/GJ)	Fuel Ratio (%)
TCPL Empress to CDA/EDA	63.848	0.144	2.54
TCPL STS to CDA	1.697	0.000	0.07
TCPL STS to EDA	4.845	0.008	0.40
TCPL Dawn to CDA	7.493	0.014	0.12
TCPL Dawn to EDA	15.525	0.032	0.56
TCPL Empress to Iroquois	62.154	0.140	2.54
TCPL Parkway to CDA	3.145	0.004	0.07
Union M12 - Dawn to Parkway	2.342	N/A	0.83
Union M12 - Dawn to Kirkwall	1.977	N/A	0.83
Union C1 - Parkway to Dawn (Westerly)	0.548	N/A	0.34
Vector	7.495	N/A	1.12
Alliance	41.874	N/A	4.76

Witness: A. Welburn

UNDERTAKING JT1.16

UNDERTAKING

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To connect with Navigant and respond accordingly re: Avoided Costs reviewed in EBRO 492 and 495, and to break down by load type the transmission costs, and to identify what portion of those avoided energy costs are in fact commodity versus what portion are avoided transmission, capital investments.

RESPONSE

During the course of the Avoided Distribution Cost study and during the initial workshop discussions with Enbridge, it was determined early on in that discussion, that the transmission portion of the Avoided T&D costs were already captured within Enbridge's upstream cost component of the Avoided Gas Costs used for screening purposes within the TRC test. For further information on the above noted discussions, please see the workshop presentations attached in response to JT1.23.

It was out of the scope of the study for Navigant to review all aspects of the Avoided Gas Cost methodology. Based on the workshop discussions with Enbridge staff and given the fact that Enbridge's Avoided Gas Costs have been subject to scrutiny over the past number of years, Navigant determined that Enbridge had accurately captured all upstream costs including transmission.

Please see response to Undertaking JT1.15 for selected component inputs used in Enbridge's Sendout model, including forecasted commodity prices and transportation costs.

Witnesses: S. Mills
F. Oliver-Glasford
H. Thompson
A. Welburn
T. Winstone

UNDERTAKING JT1.17

UNDERTAKING

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To provide a breakdown of how the various projects were dealt with, in terms of how much of each actual and projected project the company decided was attributable to load growth.

RESPONSE

The GTA Project and Ottawa Reinforcement Project have multiple project drivers. The scope of each project was developed to meet the respective objectives identified for each project, such as the ability to provide additional security of supply, improve operational flexibility, and meet anticipated load growth. The purpose and need for each project can be found at:

- GTA Project: EB-2012-0451, Exhibit A, Tab 3
- Ottawa Reinforcement Project: EB-2012-0099, Exhibit A, Tab 3

Enbridge uses Synergi Gas, a pipeline simulation software produced by DNV GL, to simulate the pressures and flows in the gas distribution network. Forecasted growth, both short term and long term, are incorporated into these models to predict system performance. The results are assessed to ensure that all system minimum pressures are maintained and all stations are operating within design parameters.

The Synergi Gas software was used to determine the portion of project (i.e. pipe size and length) that would be required to maintain minimum system pressures in relation to load growth only for each of the above noted projects.

For the GTA Project, please see the response to EB-2012-0451 Association of Power Producers of Ontario Interrogatory #3 found at Exhibit I.A1.EGD.APPrO.3 and Environmental Defence Interrogatory #20 found at I.A4.EGD.ED.20 for the minimum pipe requirement and estimated cost to support 10 years of anticipated growth. In summary, the minimum pipe required a NPS 36 build from Sheppard Avenue to McNicoll Avenue, paralleling the existing Don Valley line, to support 10 years of anticipated load growth. This pipeline segment was estimated to cost \$40M to \$50M¹.

¹ Unclassified estimate (based on the original project estimate since the project is currently in progress).

Witness: H. Thompson

This pipeline segment is a portion of the total scope of the GTA Project (which includes Segment A, Segment B, and facilities).

For the Ottawa Reinforcement Project, it was estimated that 19 km of NPS 16 would be required from Richmond Gate Station, including a rebuild of the gate station, to support load growth only. This project scope was estimated to cost \$46M². It should be noted that this is the same alignment as the approved reinforcement project. The rationale and need for the larger diameter was discussed in EB-2012-0099, Exhibit A, Tab 3.

² Unclassified estimate (based on actual project expenditures).

Witness: H. Thompson

UNDERTAKING JT1.20

UNDERTAKING

Technical Conference TR, page 91

Enbridge to provide some clarification as to why transportation costs or some of the load shapes fall so dramatically by the storage costs for space and water heating. Also to provide the inputs that went into the supply transportation and storage columns in this cost.

RESPONSE

Further analysis will be required in order to adequately address the above request. Enbridge will file a subsequent response upon completion of the required analysis.

Witness: A. Welburn

UNDERTAKING JT1.21

UNDERTAKING

Technical Conference TR, page 97

Enbridge to amend the response to provide monthly prices rather than annual prices

RESPONSE

The requested information is provided in response to undertaking number JT1.15.

Witnesses: S. Mills
F. Oliver-Glasford

UNDERTAKING JT1.22

UNDERTAKING

Technical Conference TR, page 109

Enbridge to explain better why the stock turnover would lead to shrinking numbers of units turning over each year

RESPONSE

On page 109 of the transcripts, GEC asked why the 2015 total achievable potential from condensing and near-condensing boilers is roughly 62,000 m³/year, whereas in 2024 it is roughly 44,000 m³/year. Navigant provides an explanation for the declining achievable potential in the following paragraphs.

As replace-on-burnout measures, these boilers' achievable potential is limited by turnover of the stock of existing boilers. Navigant's model assumes an exponential decay (i.e., failure) of a stock, where the expected equipment life determines the mean failure time. In each year, a constant fraction of the *remaining* stock (i.e., stock that has not yet already turned over) is assumed to require replacement, and that fraction is one divided by the measure lifetime (e.g., 1/25 for the boilers having a measure life of 25 years). This distribution is characterized by greater turnover in nearer years and lesser turnover in distant years. For example, if the 2015 stock were 1000 boilers, then 40 boilers ($1,000 * 1/25$) would be expected to fail in that year. In 2016 the turnover would be about 38 boilers ($960 * 1/25$) because only 960 initial boilers were *remaining in that year*. By year 2024, only 692 of the initial boilers would be remaining, which would lead to turnover of about 28 boilers in that year. Thus the declining rate of boiler turnover, driven by the exponential decay of the stock, leads to declining *incremental* achievable potential over time. This method of simulating stock turnover is more realistic than assuming a perfectly linear decay of the stock (which would have an identical incremental turnover each year), with every measure failing at *exactly* the expected lifetime, since there is always a distribution of failures around an expected value. The mechanics of simulating the exponential decay of a stock are justified and detailed in Sterman, John D. (2000). *Business Dynamics. Systems Thinking and Modeling for a Complex World*. Irwin-McGraw-Hill. 2001. Chapter 8.3 (Negative Feedback and Exponential Decay). page 274.

A second phenomenon impacting the boilers' achievable potential is declining customer willingness to adopt the measures over time. Navigant models customer willingness

Witnesses: F. Oliver-Glasford
B. Ott
C. Welch

through payback acceptance curves, which indicate the fraction of customers willing to adopt as a function of various payback times on their investment. The payback times for the boilers fell on the steepest section of the payback acceptance curves, meaning that modest increases in payback times led to appreciable reduction in customer willingness to adopt.

Given the combined effects of declining turnover rates and customer willingness to adopt, the declining *incremental* achievable potential for the boiler measures coincides with Navigant's expectations of appropriate model performance.

Witnesses: F. Oliver-Glasford
B. Ott
C. Welch

UNDERTAKING JT1.23

UNDERTAKING

Technical Conference TR, page 111

To provide communications of relevance between the company and Navigant.

RESPONSE

Enbridge has included draft for discussion presentations used during three workshops between Navigant and the Company on June 6, June 25 and July 16 of 2014. These presentations have been included as attachments to this undertaking and round out the Company's relevant communications in the development of the Avoided Distribution Costs study.

The information provided in Workshop 3 slides 9 – 11 and Slide 13 was provided on an informational and investigative basis only by Navigant, and was not meant to inform the Avoided Distribution Cost study objective of determining an Avoided Distribution Cost adder for the purposes of inclusion in the Avoided Gas Costs.

The slides referenced refer to a scenario that has not been fully explored or proven and will be the subject of a greater Integrated Resource Planning study expected to commence in January 2015 or upon decision from the Board.

Enbridge expects that the Avoided Gas Costs assumptions that will be used for targeted Integrated Resource Planning purposes will be different than those Avoided Gas Costs assumptions used currently which look at the Avoided Gas Costs on a franchise wide basis. As indicated above this will also be subject to the greater Integrated Resource Planning study.

As indicated in the response to GEC interrogatory #49 a) found at I.T9.EGDI.GEC.49 and included below for convenience:

- (a) Exhibit C, Tab 1, Schedule 4 is the final report and captures the data provided by Enbridge and the methodology and conclusions as determined by Navigant. The data provided by Enbridge to Navigant is captured in the final report at the following locations:

Witnesses: S. Mills
F. Oliver-Glasford
T. Winstone

- Actual and Forecast Reinforcement – Exhibit C, Tab 1, Schedule 4, Figure 3 (page 17)
- Actual and Forecast Peak Day Demand – Exhibit C, Tab 1, Schedule 4, Figure 4 (page 18)
- Load Shapes – Exhibit C, Tab1, Schedule 4, Appendix B

The instructions provided by Enbridge to Navigant are summarized in the “Background and Objectives” at Exhibit C, Tab 1, Schedule 4, page 5.

Witnesses: S. Mills
F. Oliver-Glasford
T. Winstone

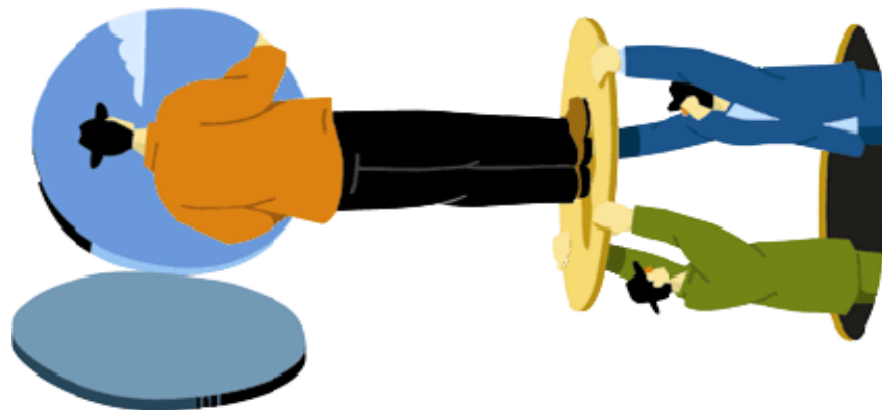
DRAFT FOR DISCUSSION



ENERGY

Avoided T&D Cost Methodology

Workshop #1



June 6, 2014

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DISPUTES & INVESTIGATIONS • ECONOMICS • FINANCIAL ADVISORY • MANAGEMENT CONSULTING

Agenda

- » Review of Secondary Research Completed to Date
 - Review of other jurisdictions – gas and electric
 - Hampton Strategies, Avoided Gas Cost Study
 - Enbridge Methodologies in prior years
- » Open for Discussion
 - Potential for deferring or avoiding transmission & distribution costs
 - Focus on peak day or peak hour analysis and appropriateness of each given primary drivers of load-related capex, and
 - Identify key issues to be addressed in final report and analysis

New England calculates avoided gas costs using a marginal cost approach using two components: (1) avoided cost of gas delivered to the LDC and (2) avoided cost of delivering gas on the LDC system

- (1) Avoided cost of gas delivered to the LDC (developed for each end use and region, for example Residential Heating, Southern New England \$5.64/MMBtu)
- Representative load shape of each retail customer type by dividing annual gas requirements into six load segments (Representative Segmented Load Duration Curves) that correspond to types of gas supply resources:

Annual base load (365 days per year)	90-day load
Winter/shoulder load (280 days per year)	30-day load
Winter base load (151 days per year)	10-day load

- LDC develops a portfolio of supply resources (lowest cost), marginal supply is determined by the characteristics of the LDCs gas portfolio and the opportunities to add or eliminate resources (when LDCs hold contracts, supply cannot be avoided until the end of the contract term)
- Calculate cost of using each resource to supply the six load segments
- Determine the marginal gas supply resource for each load segment by matching the available gas supply resources to the LDC firm requirements (LDCs take a least cost approach, thus the highest price resource would be on the margin).

*Two utilities in New York use a similar methodology developed by Synapse

Synapse Energy Economics, Inc. Avoided Energy Supply Costs in New England: 2013 Report. July 12, 2013.

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New England LDCs calculate the “retail margin” of gas, if applicable

- (2) Avoided cost of delivering gas on the LDC system (the “retail margin”)
 - Values vary by LDC, some estimate this amount as their incremental or marginal cost of distribution (the change in the cost of distribution as demand increases or decreases)
 - Measure the embedded costs as the difference between the city gate price of gas in a state and the price charged to each of the retail customer types (residential, commercial, industrial, and all)
 - For some LDCs it is assumed that the “retail margin” is not avoidable due to reductions in gas use from efficiency measures, in this case the LDC’s avoided cost of gas is their avoided cost of gas delivered to their city gate
 - Developed for each region and end use, values range from \$0.15/MMBtu (Vermont, Commercial and Industrial, non heating loads) to \$1.59/MMBtu (Vermont, Residential, all loads)

The resulting avoided costs are volumetric with no capacity component

California determines the avoided commodity and T&D cost using a marginal cost approach

- Avoided Commodity Cost Calculated by utility, month and year
 - 1) forecasted market price (commodity cost) multiplied by
 - 2) one plus the avoided compression gas (expressed as a market price) and multiplied by
 - 3) reduced loss and unaccounted for gas percentages (losses in the system, expressed as a percentage of market price)
- Avoided T&D Costs
 - Estimate of the marginal transportation cost for delivering gas to end-users, calculated for each utility, service (customer) class, and year using the product of:
 - 1) the T&D marginal cost (average incremental T&D cost per therm of delivering gas to each service class; the marginal gas transmission cost is not based on peak throughput but the average delivery cost per therm based on the usage profile for each class)
 - 2) the monthly T&D allocation (assigns the natural gas capacity cost to the winter season based on the volumetric throughput on each utility system)
- In 2004 the average annual avoided gas costs were \$0.02/therm

The resulting avoided costs are volumetric with no capacity component

Energy and Environmental Economics, Inc. Methodology and Forecast of Long Term Avoided Cost for the Evaluation of California Energy Efficiency Programs. October 25, 2004.

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Colorado calculates the avoided cost of gas using a \$/Dth rate capturing three components

- To calculate a \$/Dth rate the following components are used
- Avoided commodity cost of gas: developed using price forecasts
 - 2012 \$4.89/Dth
- Avoided capacity costs: avoided reservation costs (to determine the cost of service to transport incremental gas supplies to the metropolitan Denver area, CIG firm transportation rate)
 - 2012 – 2030 \$56.37/Dth
- Avoided variable O&M costs: internal data from “public service pricing and planning department”
 - 2012 – 2030 \$0.05/Dth

The resulting avoided costs are volumetric with no capacity component

Public Service Company of Colorado. Demand-Side Management Annual Status Report. April 1, 2013.

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Puget Sound Energy develops a per unit rate which is applied to the appropriate load and end use and also considers deferred upgrades

- Per unit rate applied to either peak or non-peak gas saved
 - Weighted Average Cost of Gas, by end-use (WA commodity cost accounting for varying time of savings for six representative end uses)
 - Avoided Pipeline Demand Charge (avoided contract costs, dependent upon savings which occur on peak day, for each dekatherm of additional daily peak capacity not needed) – capacity charge
 - Avoided Pipeline Variable Transportation Charge (O&M on the pipeline, flat charge per dekatherm, does not vary by end-use)
 - Pipeline Fuel Reimbursement (additional savings on the fuel used by compressors that move natural gas through pipelines, 2.9% rate applied)
- **Avoided Distribution Capacity Upgrades (deferred cost of reinforcements) – capacity charge**
 - Estimate the cost of pipeline reinforcements through the planning period (from system planning group), assumed to be one time costs that can be deferred
 - Yearly costs are represented as an avoided payment, yearly value of the levelized cost calculated over a time period advised by their planning group.

The resulting avoided costs include both volumetric and capacity components

Puget Sound Energy. Avoided Cost Calculations for Natural Gas Energy Efficiency Programs. November 9, 2012.

NAVIGANT

Methodologies to determine avoided electricity costs vary by jurisdiction

- New England: determines the value of avoided capacity (\$/kW-year) using revenues gained from and the value of generating capacity avoided by demand reductions no longer bid into the Forward Capacity Market, other components to avoided electricity costs include:
 - Electric Energy Costs (\$/kWh): reduction in the annual quantity of electric energy that LSEs will have to acquire
 - Local T&D infrastructure costs avoided due to delays in the timing and/or reductions in the size of new projects
 - Avoided costs due to reductions in wholesale market prices
- Colorado: assume a proxy resource on the margin
 - Avoided Generation Capacity Costs: current generic capacity cost estimates for gas-fired combustion turbine (CT) and gas-fired combined-cycle plant (CC)
 - Avoided Transmission and Distribution Capacity Costs: assumed flat rate for avoided transmission and distribution capacity costs developed by their resource planning group and increased by an annual escalation rate
 - Avoided Marginal Energy Costs: gas-fired combustion turbine (CT) and gas-fired combined-cycle plant (CC)
- California: costs from utility rate case filing used for proxy long-run marginal cost T&D investment, T&D capacity costs are based on hourly temperature data, which proxy for local loads in the analysis (hottest hours will likely be where the system is most constrained and will require upgrades)

Overview of Avoided Cost Methodologies

- » The methodologies identified can in general be categorized as Marginal or Decremental
 1. Marginal Avoided Cost – projection of the marginal energy supply costs avoided due to a reduction in the use of electricity or natural gas.
 2. Decremental Avoided Costs – the difference in gas supply costs from a Base Case scenario excluding DSM, compared to a reduction (or decrement) in demand resulting from a DSM program (Hampton Report recommendation). Enbridge's 1995/96 DSM filing used this methodology for commodity and transmission avoided costs.
- » Distribution Avoided Costs – Enbridge's 95/96 DSM filing estimation based on the average avoided cost of reinforcement mains (i.e. reinforcement mains cost divided by the increase in demand over a period of time).
 - No avoided cost identified beyond the 96 DSM filing.
- » There is a clear distinction between “upstream costs” (gas supply/ commodity and transmission) and “downstream” costs within the distribution utility.
- » Not all include downstream or distribution utility avoided costs
- » Upstream avoided costs are primarily calculated in terms of a volumetric charge and not capacity (NE calculates a charge for 6 load segments)
- » Downstream avoided costs are volumetric or capacity based (Puget Sound)

Recommendations in the Hampton Strategies Avoided Gas Cost Study (1994) are based on several key concepts

- Avoided Gas Costs (AGC) methodologies should be based upon the planning and operation of LDC's system and the cost of decisions at the margin
- AGCs should be calculated by evaluating the change in costs that result from a change in the peak demand and the change in volume of gas consumed
- Planners consider: duration of load and opportunities to manage gas supplies between seasons, thus different supply mixes will meet different load shapes
- LDCs plan to meet the entire annual load duration curve, not the load at any single point along the supply curve, therefore unit AGCs at any point along the supply curve may vary between customers
- The gas system is dispatched to accommodate the total expected load on a given day, therefore unit short run marginal costs (SRMC) at any point along the load duration curve are the same for all customers
- AGC methodologies should be forward looking

The recommended approach revolves around the utility planning process with varying supply cost scenarios

- AGCs are calculated as the difference between the costs in a base case supply plan and alternative supply plans
- Alternative supply plans are calculated for distinctive end-use load shapes applicable to DSM programs, as opposed to decrementing the total sendout curve
- Alternative supply plans in the Avoided Gas Cost Study are based on the following load shape scenarios, each scenario has a different effect on gas supply costs:

<u>Peak load reduction</u>	Annual constant load reduction
Winter heating load reduction	Residential cooling load increase
Water heating load reduction	Commercial cooling load increase
Off peak load reduction	

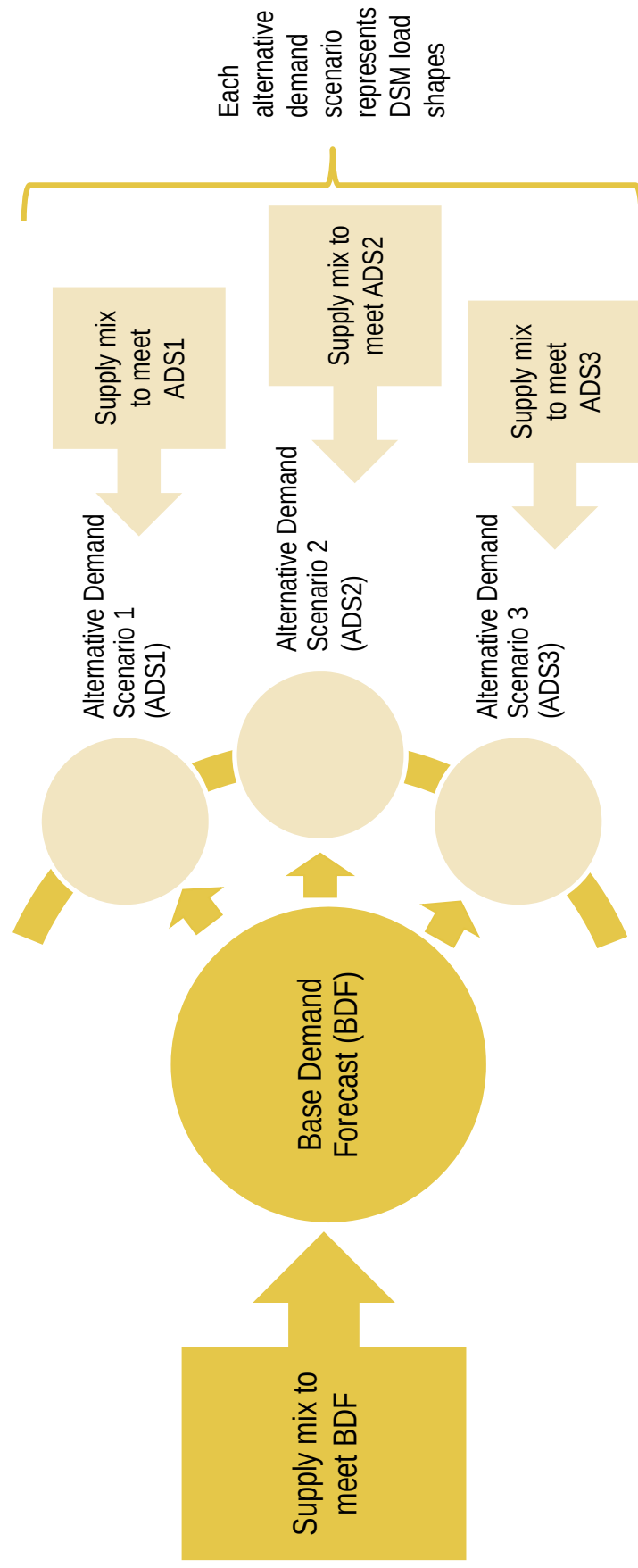
- AGCs are unitized by the differential revenue requirements

The recommended approach follows a process to add or remove gas requirements from a base case demand forecast

1. Develop base case supply scenario to serve the requirements of a base case demand forecast
 - a) Estimate annual, monthly, and daily firm demand for natural gas
 - b) Estimate available supplies and unit gas supply costs over 10 year planning horizon
 - c) Estimate supply maximum daily quantities appropriate for demands in step 1 and types of supply and unit costs in step 2
 - d) Estimate volumes from each type of supply identified in step 3 under demand conditions specified in step 1
 - e) Estimate cost of gas supplies from unit costs in step 2, the contract entitlements in step 3 and volumes in step 4
2. Add or remove gas supply requirements and modify supply mix to meet the seven alternative demand scenarios
3. The difference in total fixed and variable charges between the base supply scenario and each alternative supply plan is divided by the annual difference in demand requirements for the corresponding case to arrive at the AGC for that particular load shape
4. The gas cost savings relate to the annual change in load

The base demand forecast is modified to reflect alternate demand scenarios and a supply mix is developed for each scenario

Avoided gas costs for each ADS = difference in total fixed and variable charges between BDF and each ADS divided by the annual difference in demand requirements for the corresponding ADS



Enbridge has implemented the recommended methodology in the Hampton Avoided Gas Cost Study with fewer end-use scenarios

Plan	Avoided Gas Supply Cost Methodology	Avoided Distribution Cost Methodology
1995 DSM Plan	Decrement method with proxy resources where necessary, 3 decrement scenarios included: <u>peak day</u> , winter season, and summer season	Reinforcement mains only using historical relationship between annual expenditures and increases in demand over two 10 year periods, converted to levelized cost and <u>added to the avoided peak day costs</u>
1996 DSM Plan	Updated to reflect recommended methodology with 3 DSM measures using 1995 inputs, decrement scenarios include: water heating, space heating, industrial process, space and water heating	Distribution Gas Costs: same as 1995
2007 DSM Plan	Same methodology, 4 decrement scenarios: water heating, space heating, industrial process, space and water heating	
2012 DSM Plan	Same methodology, 4 decrement scenarios: water heating, space heating, industrial process, space and water heating	
2013-2014 Update	Same methodology, 4 DSM measures (demand scenarios) , updated inputs	

Questions for discussion

- » Upstream Avoided Costs - based on Enbridge's current avoided cost methodology, are all upstream costs included?
- » Downstream Avoided Costs – Enbridge did not continue the LDC avoided costs beyond the 1996 DSM Plan - why?
 - Included reinforcement mains, excluded sales, relocation and replacement mains
 - See next slide for illustrative example of Space Heating
- » What is Enbridge looking for in avoided T&D capacity costs
 - Upstream avoided cost that is volumetric or capacity based?
 - Looking to include Distribution avoided costs “downstream”
- » Potential for deferring or avoiding transmission & distribution costs
- » Focus on peak day or peak hour analysis and appropriateness of each given primary drivers of load-related capex,
- » Recommended Approach – to be discussed (may not be resolved today)
- » Identify key issues to be addressed in final report and analysis

Enbridge 95 DSM Plan – Space Heating Illustrative Example

AVOIDED GAS SUPPLY COSTS

Period	Decrement (1,000 m3)	Unit Avoided Cost (\$/1,000 m3)	(3)	Annual Avoided Cost (\$)	(%)
Peak Day (capacity and energy)	3.52	\$1,974.17	=	\$6,949.08	15%
Winter Season Days (energy)	207.38	\$158.77	=	\$32,925.72	69%
Summer Season Days (energy)	74.1	\$102.01	=	\$7,558.94	16%
	285.00			\$47,433.74	100%
Average (\$ per year / 10 ³ m ³ per day)				\$166.43	

AVOIDED DISTRIBUTION SYSTEM COSTS

Period	Decrement (1,000 m3)	Unit Avoided Cost (\$/1,000 m3)	(4)	Annual Avoided Cost (\$)	(%)
Peak Day (capacity and energy)	3.52	\$622.00	=	\$2,189.44	100%
Winter Season Days (energy)	207.38	\$0.00	=	\$0.00	0%
Summer Season Days (energy)	74.1	\$0.00	=	\$0.00	0%
	285.00			\$2,189.44	100%
Average (\$ per year / 10 ³ m ³ per day)				\$7.68	

Key CONTACTS



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DRAFT FOR DISCUSSION



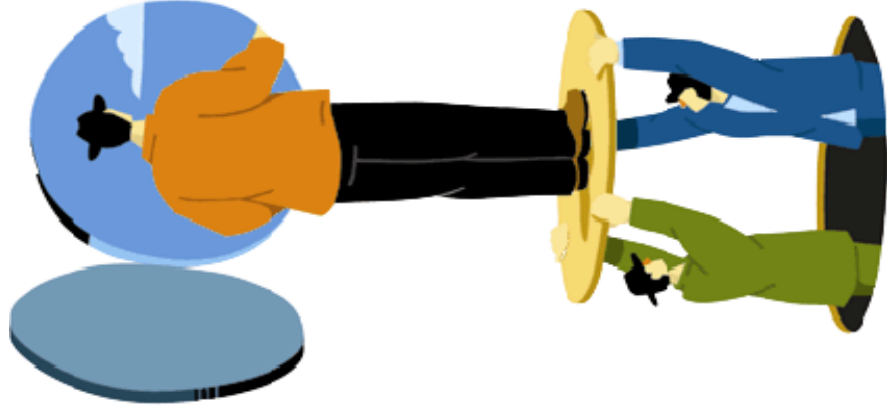
ENERGY

Avoided T&D Cost Methodology

Workshop #2

June 25, 2014

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Agenda

- » Purpose of Workshop 2
- » Recap of Workshop 1
- » Workshop 2: Presentation of avoided T&D analysis
 - Overview (peak day demand to annual volume)
 - Prior Enbridge methodology
 - Updated methodology
 - Summary
- » Open Discussion: avoided T&D calculation linkage to Peak Day Demand

Workshop 2 presents the results of Navigant's analysis and preliminary estimate of avoided T&D costs

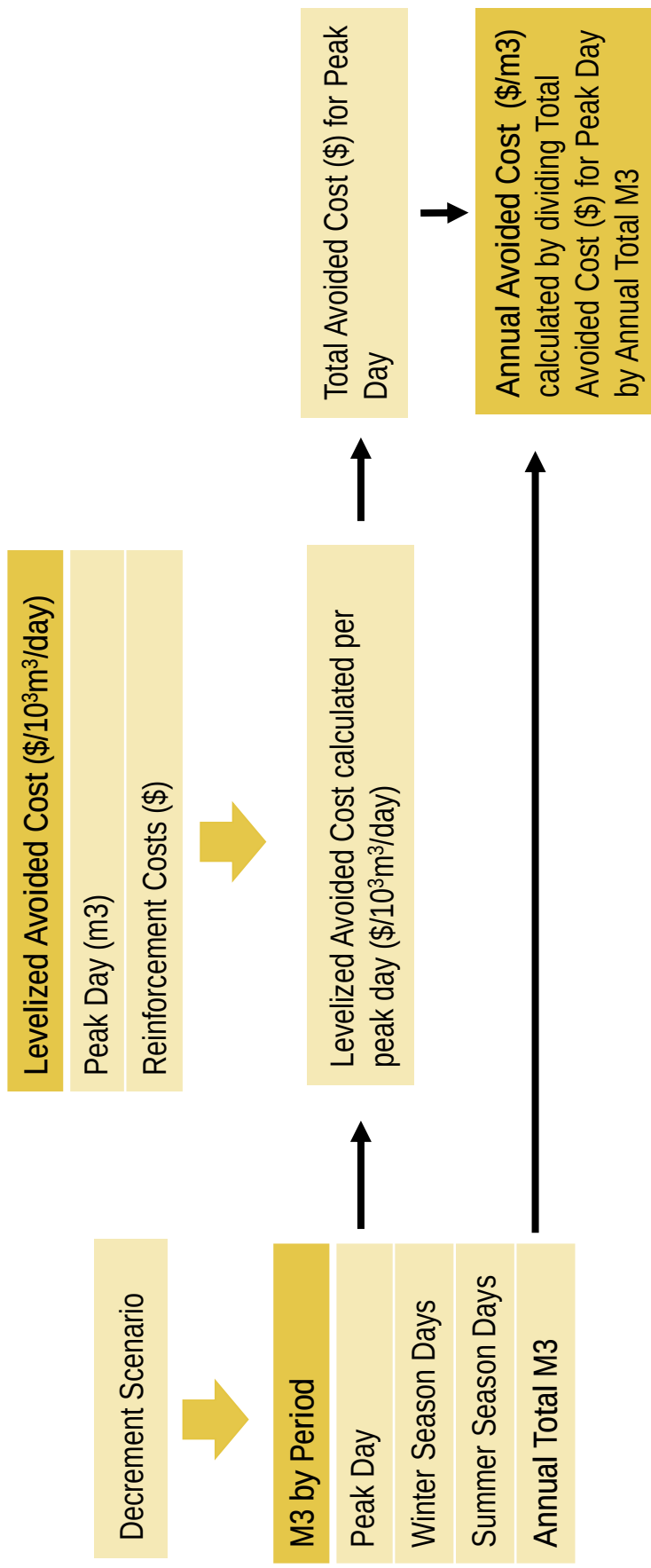
- » Based on the discussion and decisions in Workshop 1, Navigant will undertake the necessary analysis for developing a preliminary estimate of avoided T&D costs
- » In this workshop, Navigant will present and discuss the preliminary estimate of avoided T&D costs developed

Workshop 1 consisted of discussions of current methodologies and assumptions and discussions of avoided cost analyses going forward

- » Enbridge's existing avoided cost calculation methodology (using Sendout) captures all upstream costs
- » The focus of this study is to estimate downstream avoided costs associated with Enbridge's distribution system
- » The downstream cost is to be calculated as an adder to the existing upstream avoided cost
- » The peak day load will be used as a proxy for the peak hour load
- » Data for System Wide Avoided cost calculation
 - Reinforcement Costs \$ - historical 2010 to 2013, budget 2014 and forecast 2015 to 2019
 - Peak Day Demand (gross load) – historical 2009 to 2013, forecast 2014 to 2019 (Navigant extrapolation for 2017 to 2019 based on customer adds)

Load profiles are used to convert an avoided cost in terms of a peak day to an annual volume

- » Levelized (or unit) avoided costs ($\$/10^3\text{m}^3/\text{day}$) can be converted to annual avoided costs ($\$/\text{m}^3$) using load profiles for different decrement scenarios (e.g., space heating, water heating, etc.)



The methodology used in the Enbridge 1995 DSM plan developed an historical relationship between reinforcement costs and peak day demand

- » Developed an historical relationship between reinforcement costs and peak day demand
 - Based on data from two ten-year periods
 - The DSM program impact on peak day demand is used as a proxy for peak hour
 - Assumes a 5 year time horizon for the DSM plan
- » Levelized cost is \$622/10³m³/day

Period	Peak Day Increase (10 ³ m ³ /day)	Reinforcement Cost (1993 dollars)	Cost (10 ³ m ³ /day)
1982 – 1992	17,219	\$69,267,042	\$4,023
1983 – 1993	14,898	\$71,800,780	\$4,820
Average			\$4,422

	1995	1996	1997	1998	1999	Average
Facilities Cost (\$/10 ³ m ³ /day)	4,601	4,693	4,787	4,882	4,980	4,789
Fixed Charge Factor	12.98%	12.98%	12.98%	12.98%	12.98%	12.98%
Levelized Cost (\$/10 ³ m ³ /day)	597	609	621	634	646	<u>622</u>

The methodology used in the 1996 DSM plan maintained the avoided reinforcement cost from 1995 and estimated other avoided costs

- » Determined avoided costs for sales mains, replacement and relocation mains using a similar methodology
 - Data was broken down by category: subdivisions, residential, commercial/industrial
 - DSM penetration and expected reduction in peak demand, by program, was developed for each category
 - Costs of downsized facilities were derived for sales, replacement and relocation mains to calculate the value of the avoided costs
- » A large capacity reduction is required to justify downsizing, only the residential category produced avoided costs of sales mains
- » Avoided replacement costs were also significant enough to produce an avoided cost value
- » The two avoided costs were only 5% of the avoided reinforcement costs and only 1% of total avoided costs (including commodity) and were not included in the analysis

The same methodology was applied to both historical and forecast data to determine a comparable cost

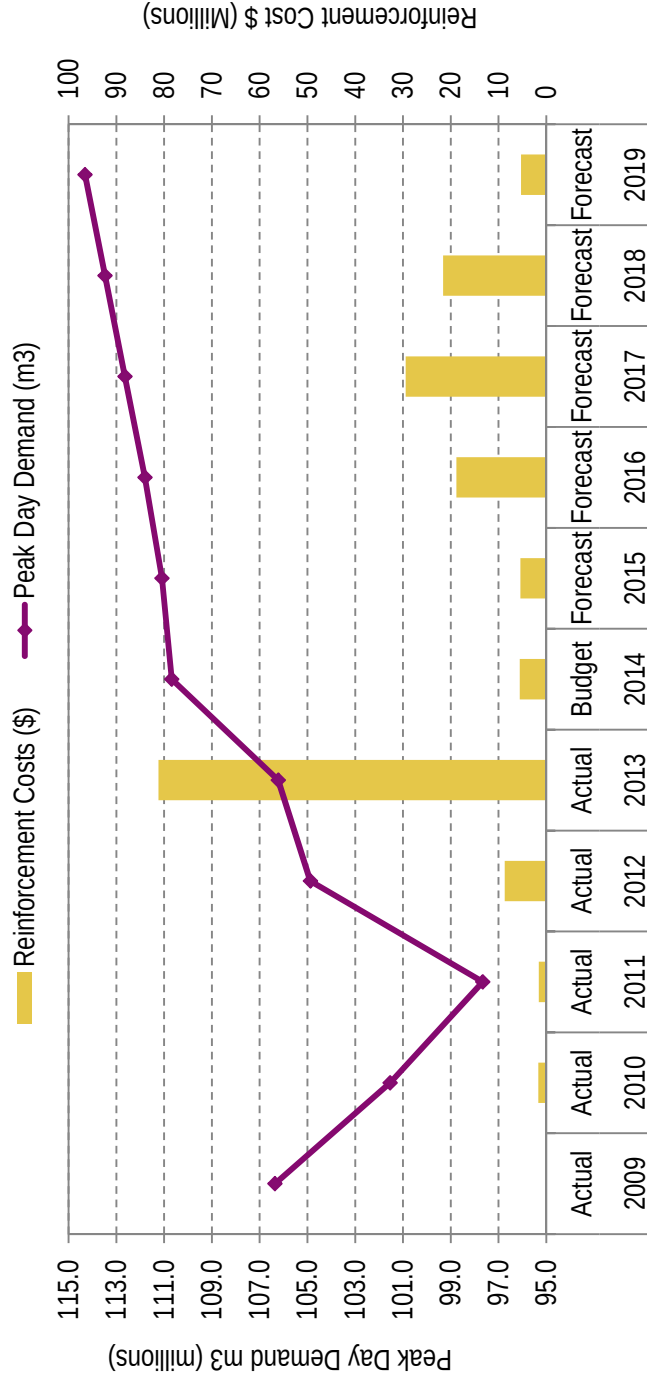
- » The peak day demand increases are similar to the past, however the total reinforcement cost is much higher
 - Based on actual data from 2010 to 2013 and forecast data from 2014 – 2019
 - Significantly less actual data than the 1995 approach
- » Levelized cost is \$1,739/10³m³/day

Period	Peak Day Increase (10 ³ m ³ /day)	Reinforcement Cost (2014 dollars)	Cost (10 ³ m ³ /day)
2010 - 2018	11,936	\$173,947,515	14,574
2011 - 2019	16,650	\$177,582,465	10,666
Average			\$12,620

	2015	2016	2017	2018	2019	Average
Facilities Cost (\$/10 ³ m ³ /day)	12,872	13,129	13,392	13,660	13,933	13,397
Fixed Charge Factor	12.98%	12.98%	12.98%	12.98%	12.98%	12.98%
Levelized Cost (\$/10 ³ m ³ /day)	1,671	1,704	1,738	1,773	1,809	<u>1,739</u>

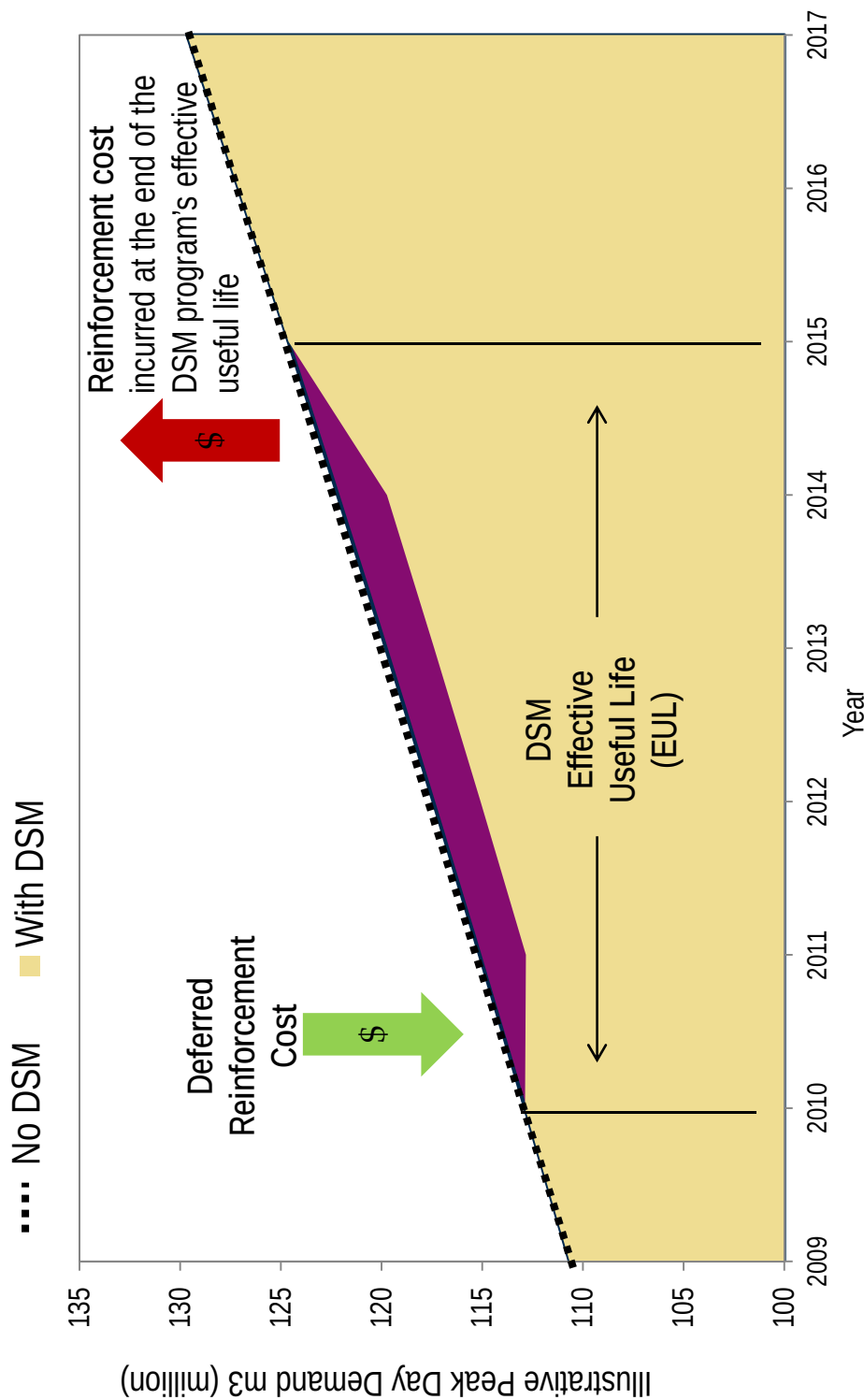
The proposed methodology uses averages to dampen the variability in reinforcement costs and incremental peak day demand year over year

- » Reinforcement costs vary widely year over year



- » Using an average reinforcement cost data from 2010 to 2019 and average incremental peak day demand data a levelized cost was developed
 - Average reinforcement cost: \$17.7 million
 - Average yearly increase in demand 795 10³ M³ (2009 to 2019)

Methodology assumes a DSM program that avoids 1 year of demand increases (2010 to 2011), and defers the need for 1 year of reinforcement costs (green arrow). This cost is deferred until the end of the DSM program's effective useful life (red arrow)



The resulting avoided cost is \$1,165 /10³ M3/day

Calculated as follows:

- » The present value (PV) of the deferred reinforcement capex (\$17.7 M in year 1 and (\$21.1) M in year 10 - inflation adjusted) **\$6.68 M**

Divided by

- » The PV of the peak day demand reduction 795 10³ M3 for the 10 year EUL **5,848 10³ M3**

Equals

$$\frac{\$1,165}{10^3} \text{ M3/day}$$

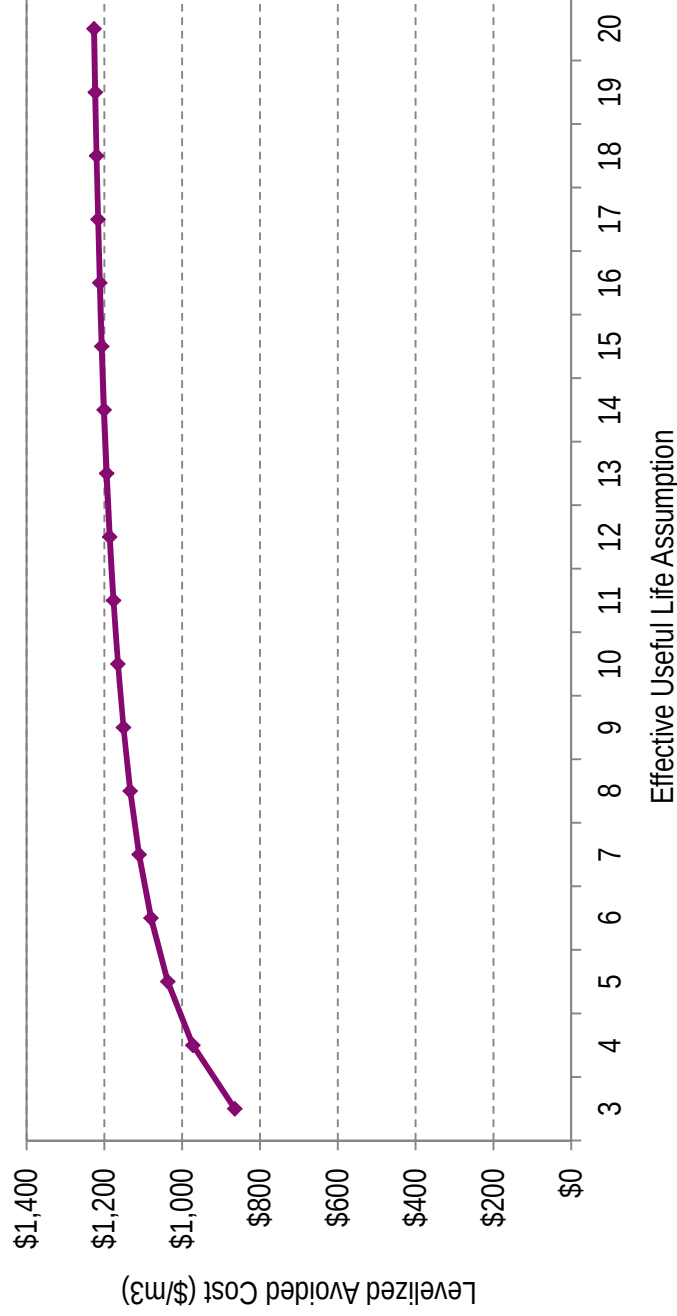
Can also consider the ratepayer's perspective and calculate taking into account capital recovery

Assumptions:

- » Assumed EUL of 10 years (to be revised to reflect Enbridge's DSM programs)
- » Average annual reinforcement cost \$17.7 million
- » Average peak day demand increase 794,936 M3
- » Discount rate 8.13%
- » Inflation rate 2%

The resulting levelized cost is relatively insensitive to the DSM program effective useful life assumption

- >> Typical DSM effective useful life's range from 3–5 years up to 20 years
- >> The assumed effective useful life (EUL) to be used in the avoided cost calculation should reflect Enbridge's DSM programs
- >> A larger EUL will result in a higher avoided cost (longer reinforcement cost deferral)

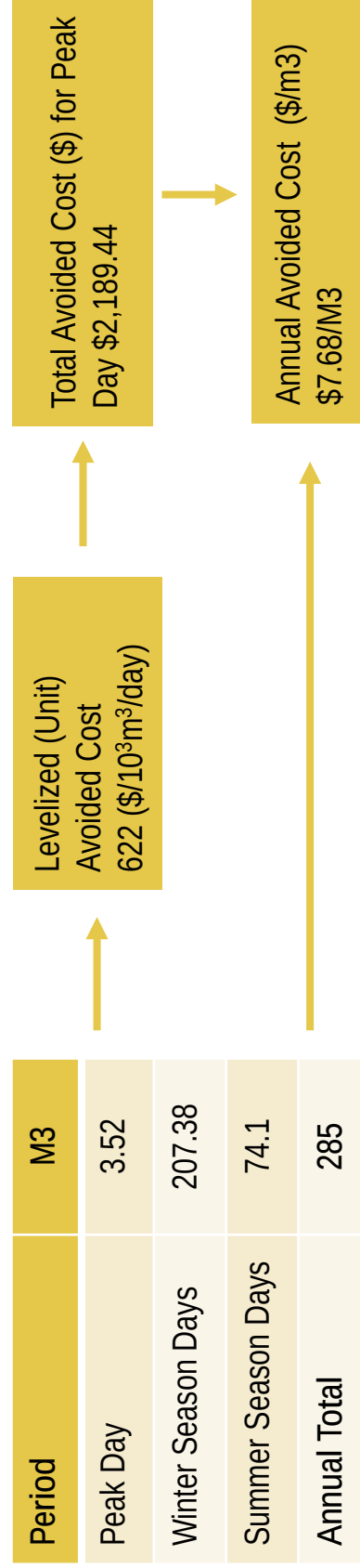


To convert a calculated avoided cost from a peak day reduction (\$/10³m³/day) to a reduction in annual volume, a ratio of peak day to annual volume is used

- » The example below was calculated for residential space heating in the 1995 DSM plan

AVOIDED DISTRIBUTION SYSTEM COSTS

Period	Decrement (1,000 m ³)	Unit Avoided Cost (\$/1,000 m ³)	(4)	Annual Avoided Cost (\$)	(%)
Peak Day (capacity and energy)	3.52	\$622.00	=	\$2,189.44	100%
Winter Season Days (energy)	207.38	\$0.00	=	\$0.00	0%
Summer Season Days (energy)	74.1	\$0.00	=	\$0.00	0%
	<u>285.00</u>			<u>\$2,189.44</u>	<u>100%</u>
Average (\$ per year / 10 ³ m ³ per day)				\$7.68	



The annual volume was calculated using the 1995 ratio of peak day to annual volume for residential space heating

- » Updated ratios can be applied to the proposed 2014 peak day demand \$ / 10³ M³ / day to calculate the annual volume associated with residential space heating

Method / Data (Residential Space Heating)	\$ / 10 ³ M ³ / day (Peak Day Demand)	\$ / 10 ³ M ³ (Annual Volume)
95 DSM for 1993	\$ 622	\$ 7.68
95 DSM for 2014	\$ 1,739	\$ 21.48
Proposed for 2014	\$ 1,165	

Ratios of peak day to annual volume for four load shapes are used to convert avoided cost from peak day to annual volume reduction

- » To convert the calculated avoided cost from a peak day reduction ($\$/10^3\text{m}^3/\text{day}$) to a reduction in annual volume the updated ratios of peak day to annual volume for four load shapes (decrement scenarios) are needed

Load Shape (Decrement Scenarios)	Ratio (1995 DSM Study)	Ratio (Updated)
Space Heating	1.235%	
Water Heating	0.339%	
Space and Water Heating		
Industrial Processes		

Open Discussion

- » Avoided T&D calculation linkage to Peak Day Demand

Key CONTACTS



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DRAFT FOR DISCUSSION

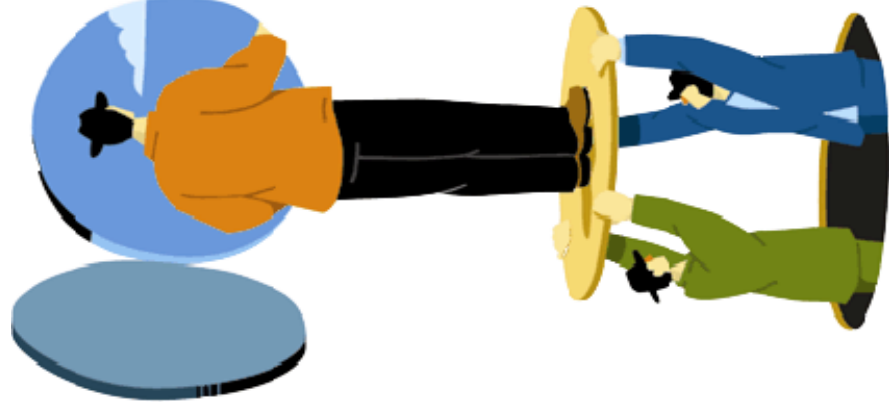


Avoided Gas Distribution Cost Methodology

Workshop #3

July 21, 2014

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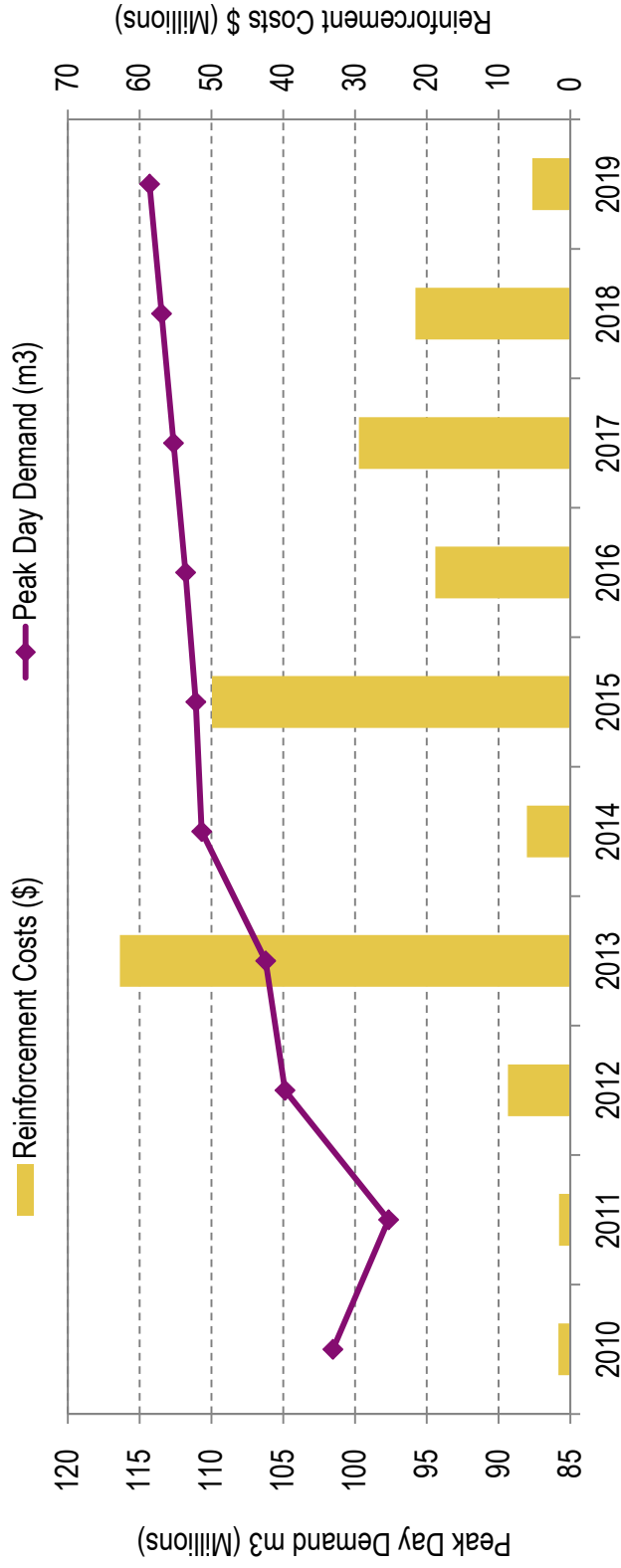
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Agenda

- » Presentation of updated avoided gas distribution analysis
 - Updated components
 - Updated results
 - Volumetric conversion
 - Scenarios
 - Summary
- » Workshop 3: review of draft report – open discussion
- » Appendix

The proposed methodology uses averages to dampen the variability in reinforcement costs and incremental peak day demand year over year

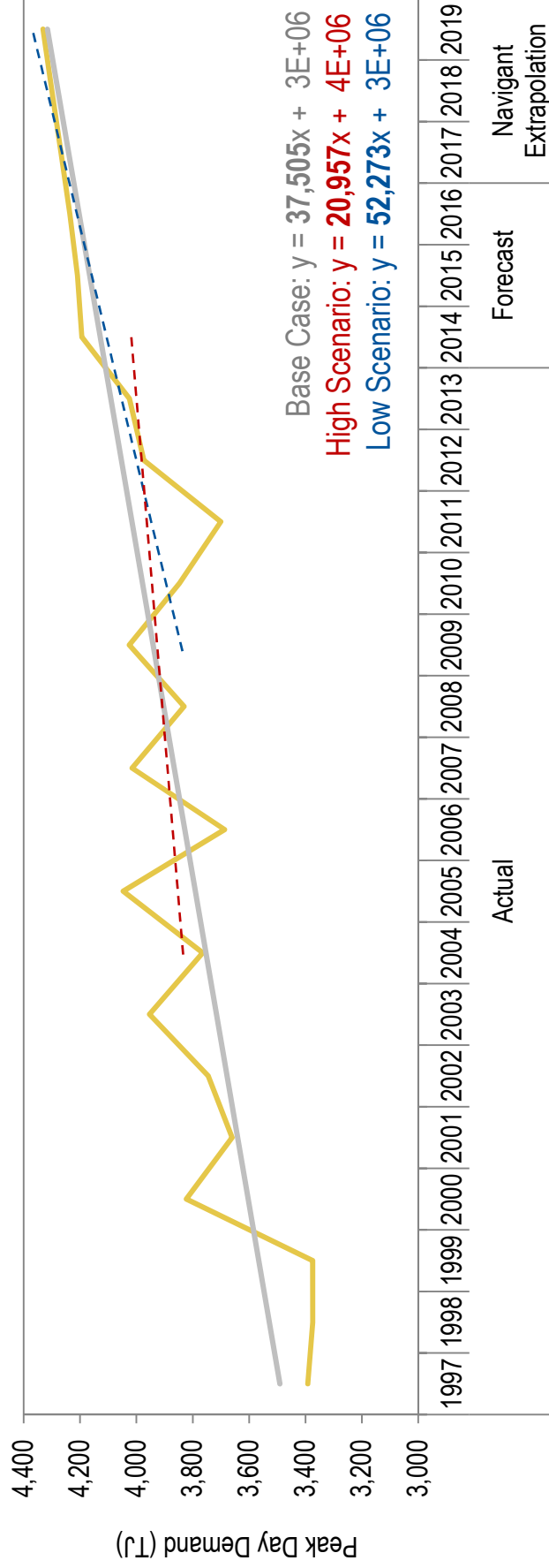
- » Reinforcement costs vary widely year over year



- » Using an average reinforcement cost data from 2010 to 2019 and average incremental peak day demand data from 1997 to 2019 an avoided distribution cost was developed
 - Average reinforcement cost: **\$20.2 million** (2010 to 2019)
 - Average “expected” annual increase in demand **990 10³ M³** (1997 to 2019)

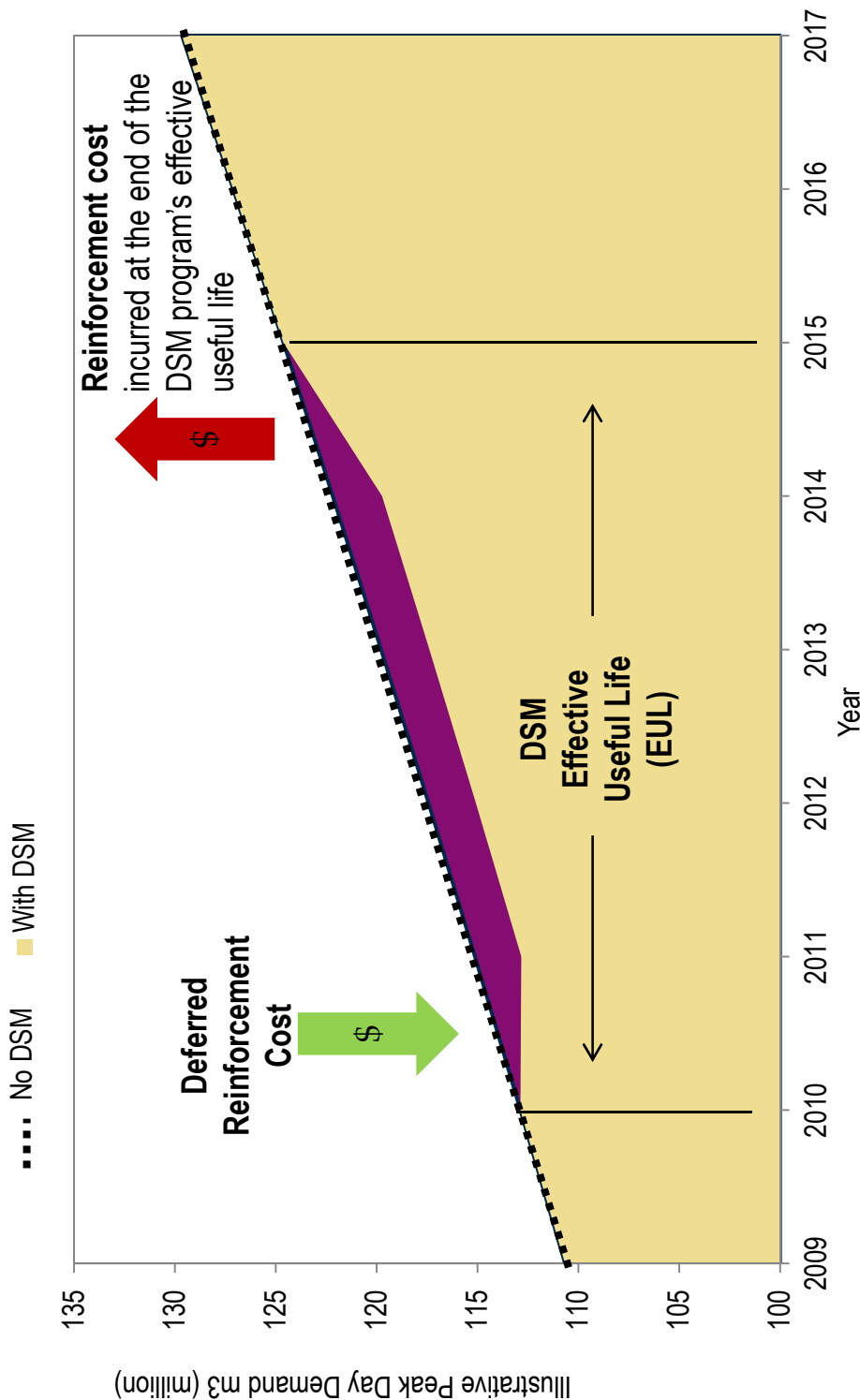
The base case peak day demand is determined by calculating the slope of the peak day demand data points from 1997 to 2019

- » Peak day demand for the base case is illustrated in the slope of the grey line in the graph below (37,505 GJ which translates to 990 10³m³)



- » A “high scenario” is illustrated in the slope of the red dotted line in the graph above using data from only 2004 to 2014 (20,957 GJ which translates to 553 10³m³)
- » A “low scenario” is illustrated in the slope of the blue dotted line in the graph above using data from only 2009 to 2019 (52,273 GJ which translates to 1,380 10³m³)

Methodology assumes a DSM program that avoids 1 year of demand increases (2010 to 2011), and defers the need for 1 year of reinforcement costs (green arrow). This cost is deferred until the end of the DSM program's effective useful life (red arrow)



Several changes were made to the analysis presented at workshop 2 that ultimately increased the resulting avoided distribution cost

	Workshop 2	Workshop 3	↑/↓	Description of Change
Assumptions				
Average reinforcement cost (\$M)	\$17.7 M	\$20.2 M	↑	Added proportion of large projects attributable to reinforcement mains
Average peak demand day increase (M ³)	794,936	989,832	↓	Expanded time period of data used (1997 – 2019 vs. 2009 – 2019)
EUL (years)	10	18	↑	Updated to reflect current programs
Discount rate	8.13%	8.20%	↑	Updated to reflect current Enbridge assumptions
Inflation rate	2%	2%	--	No change
O&M	0	1%	↑	O&M costs were added to revenue requirement

Calculation Components

PV of average reinforcement cost (\$M)	\$6.68 M	\$15.1 M
PV peak demand day reduction (10 ³ M ³)	5,848	9,902

The capex vs. revenue requirement methodology alone increased the avoided distribution cost from \$1,165 10³ M³/day to \$1,392 10³ M³/day (\$2014)

Result

Avoided distribution cost (\$/10 ³ m ³ /day) (\$2014)	\$1,165	\$1,523

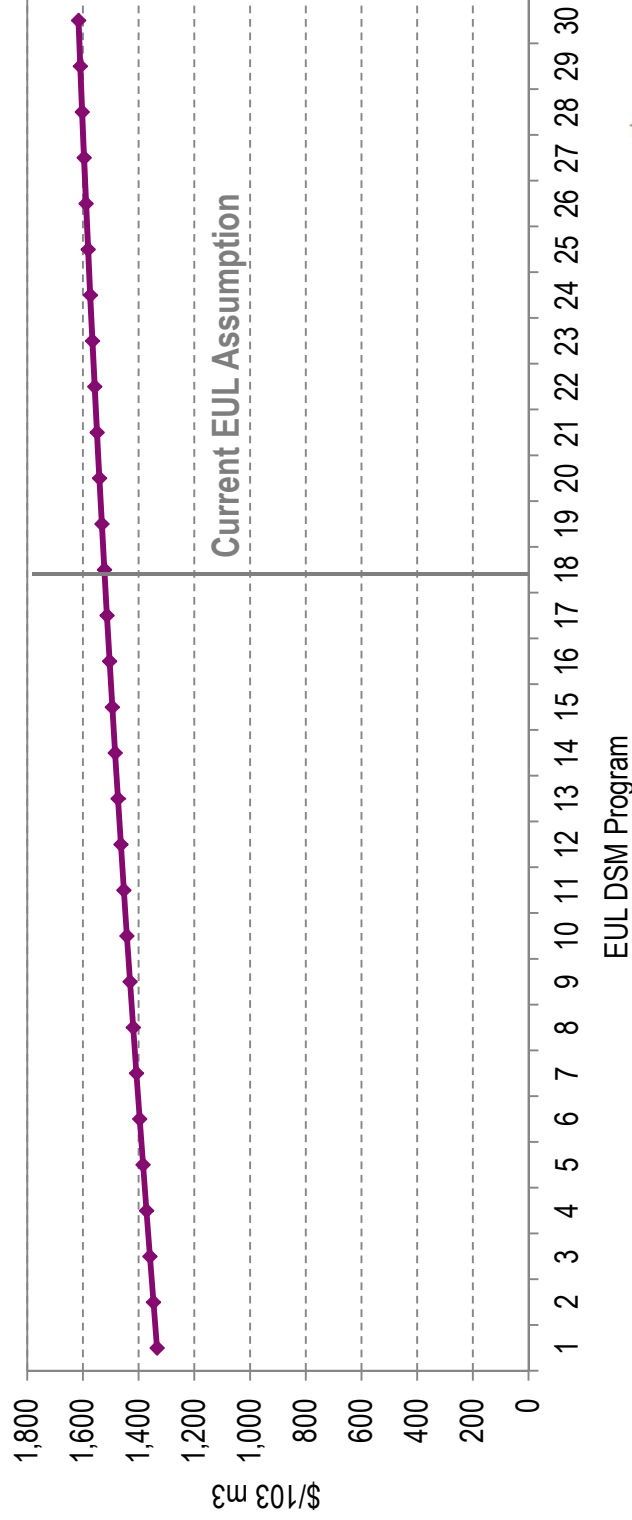
Ratios of peak day to annual volume for four load shapes are used to convert avoided cost from peak day to annual volume reduction

- » To convert the calculated avoided distribution cost from a peak day reduction (\$/10³m³/day) to a reduction in annual volume the updated ratios of peak day to annual volume for four load shapes (decrement scenarios) are needed

Load Shape (Decrement Scenarios)	Ratio
Space Heating	1.13%
Water Heating	0.37%
Space and Water Heating	1.04%
Industrial Processes	0.44%

The resulting avoided distribution cost is relatively insensitive to the DSM program effective useful life assumption

- >> Typical DSM effective useful life's range from 3–5 years up to 20 years
- >> The assumed effective useful life (EUL) to be used in the avoided cost calculation should reflect Enbridge's DSM programs
- >> A larger EUL will result in a higher avoided distribution cost (longer reinforcement cost deferral)



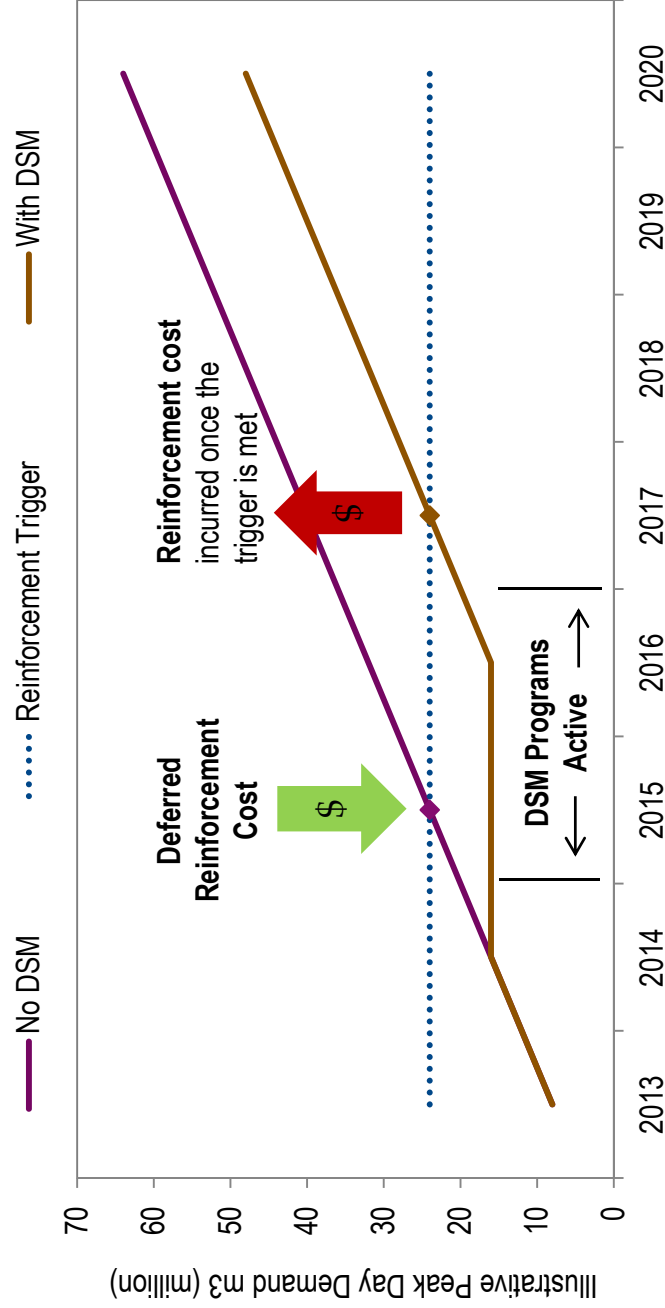
The analysis at the system level is summarized below using average annual costs and peak demand day growth

- » High and low scenarios were developed based on peak day demand growth (higher peak demand growth results in a lower avoided distribution cost)
- » The avoided distribution cost is most sensitive to changes in peak day demand growth

Metric	Base Case	High	Low
Reinforcement cost (\$)	\$20,216,628	\$20,216,628	\$20,216,628
Peak day demand growth (10 ³ m ³)	990	553	1,380
Avoided distribution cost (peak) (\$/10 ³ m ³ /day) (\$2014)	\$1,523	\$2,723	\$1,093
Avoided distribution cost (volumetric) (\$/10 ³ m ³) (\$2014)			
Industrial processing	\$6.77	\$12.12	\$4.86
Residential space heating	\$17.28	\$30.93	\$12.40
Residential water heating	\$5.62	\$10.05	\$4.03
Residential space and water heating	\$15.90	\$28.45	\$11.41

Project-level avoided distribution costs were also developed using a similar methodology as system-level with some key differences

- » Assume that each reinforcement has a trigger point, a DSM program is not likely defer the reinforcement costs for the entire life of the DSM program (18 years)
- » However, it is possible that targeted DSM programs may reduce/slow growth and defer the reinforcement for 1 to 3 years
- » In the illustrative example below, DSM programs defer the reinforcement cost for 2 years



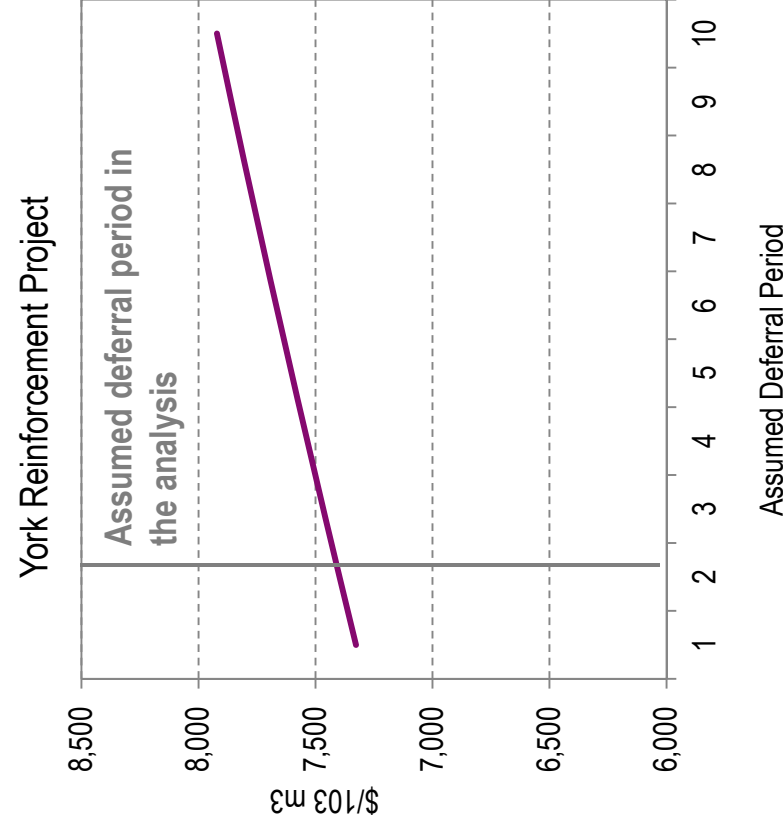
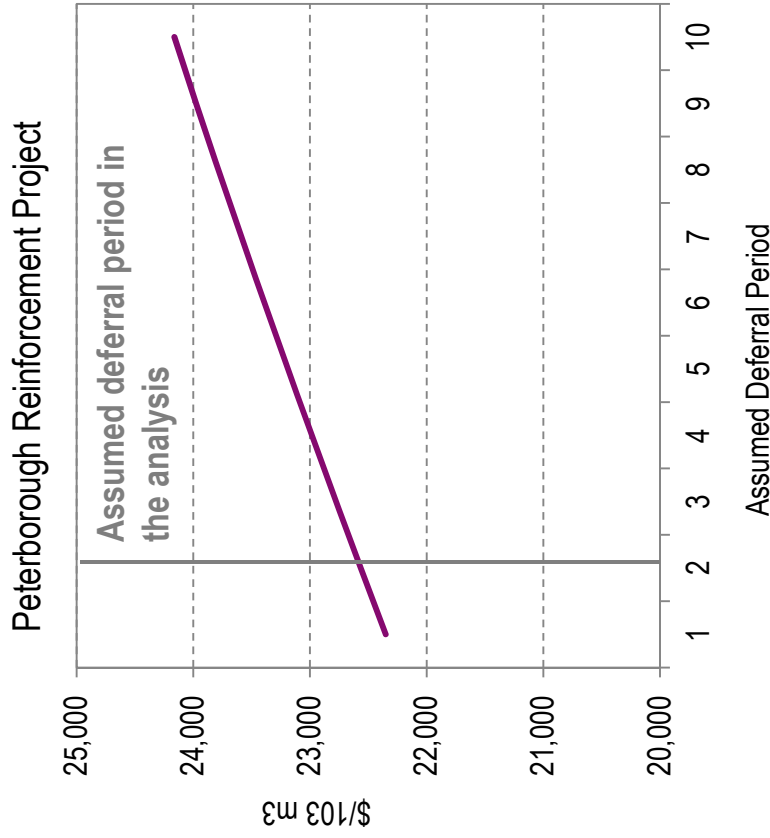
The project-level analysis was undertaken and avoided distribution costs were developed for two projects

- » Two projects were assessed:
 - York Region reinforcement project (2016) expected cost of \$10.5 million
 - Peterborough reinforcement project (2015) expected cost of \$1.7 million
- » It was assumed that the reinforcement projects could be deferred 2 years
- » Question: Are 100% of the total capital costs attributable to reinforcement costs? Is it more appropriate to use the attributable proportion only?

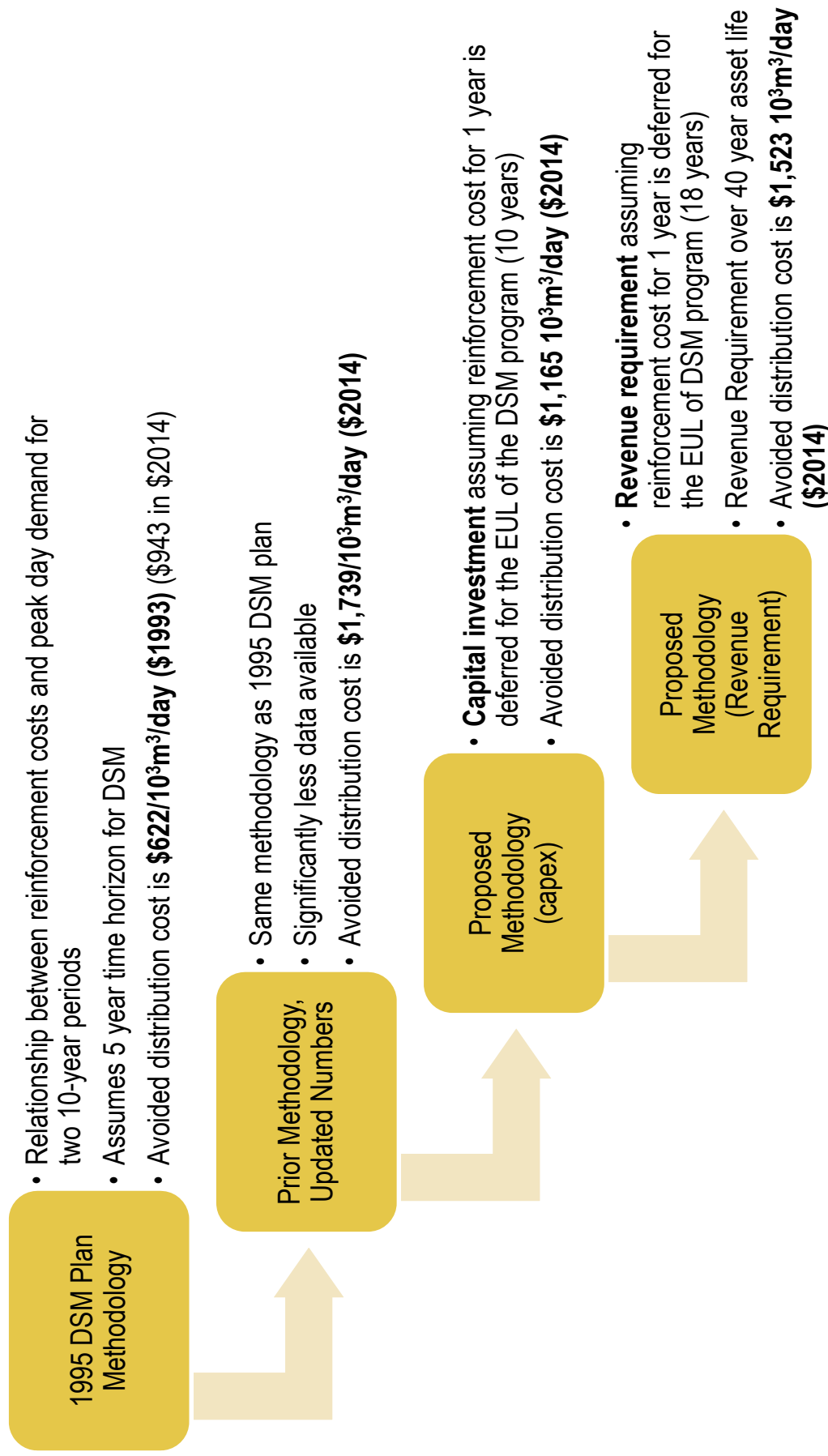
Metric	York	Peterborough
Reinforcement cost (\$)	\$10,500,000	\$1,700,000
Peak day demand growth (10 ³ m ³)	93.60	4.97
Avoided distribution cost (peak) (\$/10 ³ m ³ /day) (\$2014)	\$7,397	\$22,565
Avoided distribution cost (volumetric) (\$/10 ³ m ³) (\$2014)		
Industrial processing	\$32.89	\$100.32
Residential space heating	\$83.95	\$256.07
Residential water heating	\$27.28	\$83.21
Residential space and water heating	\$77.21	\$235.52

The avoided distribution cost at the project-level is relatively insensitive to the assumed deferral period

- » As the assumed deferral period changes between 1 and 10 years, the avoided distribution cost:
 - Varies less than \$2,000/10³m³ for the Peterborough reinforcement project
 - Varies less than \$1,000/10³m³ for the York reinforcement project



The proposed methodology using a revenue requirement perspective arrives at an avoided distribution cost of \$1,523 10³m³/day



The avoided T&D cost metric can be translated into high and low scenarios and project-specific metrics were developed for two projects

(\$2014)	System			Project-Specific	
	Base Case	High	Low	York	Peterborough
Avoided distribution cost (peak) (\$/10 ³ m ³ /day) (\$2014)	\$1,523	\$2,723	\$1,093	\$7,397	\$22,565
Avoided distribution cost (volumetric) (\$/10 ³ m ³) (\$2014)					
Industrial processing	\$6.77	\$12.12	\$4.86	\$32.89	\$100.32
Residential space heating	\$17.28	\$30.93	\$12.40	\$83.95	\$256.07
Residential water heating	\$5.62	\$10.05	\$4.03	\$27.28	\$83.21
Residential space and water heating	\$15.90	\$28.45	\$11.41	\$77.21	\$235.52

DRAFT FOR DISCUSSION

Open Discussion – Workshop 3: Draft Report

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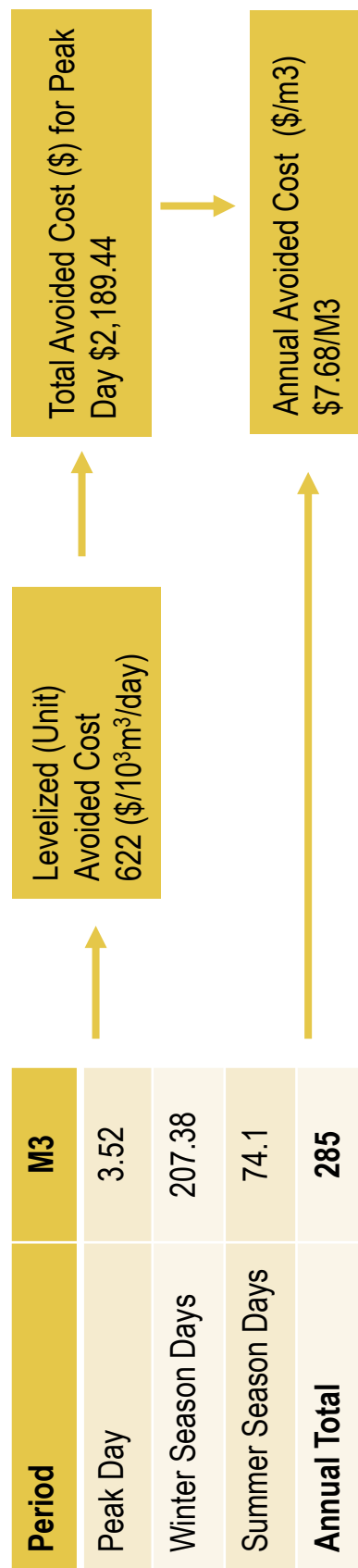
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APPENDIX: To convert a calculated avoided cost from a peak day reduction (\$/10³m³/day) to a reduction in annual volume, a ratio of peak day to annual volume is used

» The example below was calculated for residential space heating in the 1995 DSM plan

AVOIDED DISTRIBUTION SYSTEM COSTS

Period	Decrement (1,000 m3)	Unit Avoided Cost (\$/1,000 m3)	(4)	Annual Avoided Cost (\$)	(%)
Peak Day (capacity and energy)	3.52	\$622.00	=	\$2,189.44	100%
Winter Season Days (energy)	207.38	\$0.00	=	\$0.00	0%
Summer Season Days (energy)	74.1	\$0.00	=	\$0.00	0%
	<u>285.00</u>			<u>\$2,189.44</u>	<u>100%</u>
Average (\$ per year / 10 ³ m ³ per day)				\$7.68	



APPENDIX: The annual volume was calculated using the 1995 ratio of peak day to annual volume for residential space heating

- » Updated ratios can be applied to the proposed 2014 peak day demand \$ / 10³ M³ / day to calculate the annual volume associated with residential space heating

Method / Data (Residential Space Heating)	\$ / 10 ³ M ³ / day (Peak Day Demand)	\$ / 10 ³ M ³ (Annual Volume)
95 DSM for 1993 (\$1993)	\$622	\$7.68
95 DSM for 1993 (\$2014)	\$943	\$11.64
95 DSM for 2014 (\$2014)	\$1,739	\$21.48
Proposed for 2014 (\$2014)	\$1,523	\$17.28

UNDERTAKING JT1.25

UNDERTAKING

Technical Conference TR, page 118

Enbridge to provide a response to GEC IR 53 and 54

RESPONSE

In the Demand Side Management Framework for Natural Gas Distributors (2015-2020), the Board made their expectations clear around the matter of considering DSM in the context of infrastructure planning. Essentially they outline three main expectations:

- 1) consideration of DSM in the preliminary stage of project development;
- 2) completion of a preliminary study scope with inclusion into the multi-year plan application, with the study to be completed in time to inform the mid-term review of the multi-year plan; and,
- 3) a preliminary transition plan outlining how the gas utility plans to begin to include DSM within its future infrastructure planning efforts.

Enbridge has been responsive in all three of the Board outlined expectations.

The area of discussion, being one of the questions identified in the Company's IRP scope in "Intersection 3 – Targeted DSM and Reinforcement Projects" which states as question four "*Is it Cost Effective? Would targeted DSM to defer infrastructure reinforcement result in savings for ratepayers?*" requires thorough and balanced review over the coming two years with a number of stakeholders and experts given its complexity and gravity. It is an area of study that is cutting edge and in the capacity of targeted deferral or offsets of infrastructure development, largely untested for natural gas utilities worldwide. Where utilities have started to embark on Integrated Resource Planning, efforts are preliminary and very much a formalization of the current approach in Ontario with broad based DSM programming and related outcomes. In summary, the Company believes that exhaustive discussion on Avoided Costs in the context of DSM are premature at this point, and instead should be undertaken with appropriate insight from many stakeholders and experts in the coming two years in the context of IRP study.

Sales, relocation, and replacement mains have not been evaluated or determined to be relevant in the Avoided Distribution Costs since 1995. Further, Enbridge does not feel it is relevant to provide capital expenditures for sales, relocation and replacement mains

Witnesses: S. Mills
F. Oliver-Glasford
T. Winstone

as the Avoided Distribution Cost study did not include or explore those expenditures originally. As stated in GEC Interrogatory's 53 and 54, filed as Exhibits I.T9.EGDI.GEC.53 and I.T9.EGDI.GEC.54 respectively, and subsequently by Ms. Oliver-Glasford on page 117 of the July 6, 2015 technical conference transcript relevant to this proceeding, only reinforcement mains were examined as they represent the primary category of distribution system costs that would be affected by reductions in load. The Company believes this is the appropriate approach given its first priority is to provide customers with a safe and reliable source of natural gas.

For the purposes of the Avoided Distribution Cost study reinforcement mains were included in order to determine an Avoided Distribution Cost adder to be included in the Avoided Gas Costs.

The Avoided Distribution Cost Adder represents 1.5 – 5% of the overall Avoided Gas Costs depending on the corresponding load profile.

Witnesses: S. Mills
F. Oliver-Glasford
T. Winstone

UNDERTAKING JT1.26

UNDERTAKING

Technical Conference TR, page 118

Enbridge to provide a response to GEC IR 55, the capital budgets for 2008 to 2012

RESPONSE

Please see response to Undertaking JT1.25.

Witnesses: S. Mills
F. Oliver-Glasford
T. Winstone

UNDERTAKING JT1.29

UNDERTAKING

Technical Conference TR, page 121

To provide the breakdown and basis for the reinforcement projects in Ottawa and the GTA.

RESPONSE

Please see Enbridge's response to Undertaking JT1.17.

UNDERTAKING JT1.31

UNDERTAKING

Technical Conference TR, page 125

Enbridge to provide the date of the analysis, and if the date of the analysis is not consistent with its current outlook, to either identify if there will be a material difference or rerun it with current price forecasts in place .

RESPONSE

The avoided costs analysis was originally completed in 2012 which rebases all elements of the avoided costs. However, the updated commodity costs which account for over 95% of the Total Avoided Gas costs have been updated on an annual basis and filed with the Board in the following applications:

- 2012 Avoided Costs: EB-2012-0394 Update to the 2012 to 2014 Demand Side Management ("DSM") Plan, Exhibit B, Tab 2, Schedule 2.
- 2013 Avoided Costs: EB-2014-0277 2013 EGD DSM Clearance of Accounts, Exhibit B, Tab 1, Schedule1, Page 130.
- 2014 Avoided Costs: 2014 Draft Evaluation Report – (not yet filed with the Board and still subject to Clearance of Accounts application).
- The Company will be filing updated avoided costs results in Q4 of 2015. At this time, the exact impact that the updated analysis will have on the overall avoided costs will not be known until the analysis is completed.

Witnesses: S. Mills
F. Oliver-Glasford
A. Welburn

UNDERTAKING JT1.33

UNDERTAKING

Technical Conference TR, page 132

Enbridge to provide answers to the questions posted by Environmental Defence on July 2nd, 2015

RESPONSE

Environmental Defence Question #1

Re Exhibit I.T3.EGDI.ED.3: This interrogatory requested the following: "Please re-calculate the rate allocation of the Large C/I Resource Acquisition Program's for each year from 2016 to 2020 inclusive assuming that the Program's expenditures are rate based and amortized over the expected lives of their lifetime cubic metre savings." Enbridge indicated that it was unable to provide a response. However, Union was able to make appropriate assumptions and provide a response (see Exhibit B.T3.Union.ED.5). Environmental Defence asks that Enbridge provide a similar analysis as did Union.

Enbridge provides the following response:

Further to Enbridge's original response (Exhibit I.T3.EGDI.ED.3), a re-calculation of rate allocation of Large C/I Resource Acquisition programs required Enbridge to make a series of untested assumptions with respect to accounting treatment and tax implications in the revenue requirement calculation. In sharing the following hypothetical accounting treatment (for illustrative purposes only), Enbridge does not endorse the notion of rate-basing DSM expenditures.

Witnesses: K. Mark
R. Small

ILLUSTRATIVE RATE BASE TREATMENT OF LARGE C/I RESOURCE ACQUISITION PROGRAM COSTS

		(\$000's)				
Line No.		2016	2017	2018	2019	2020
	Cost of capital					
1.	Rate base	948.2	8,284.1	15,371.7	22,291.4	28,818.7
2.	Required rate of return	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>
3.	Cost of capital	61.8	540.1	1,002.2	1,453.4	1,879.0
	Cost of service					
4.	Gas costs	-	-	-	-	-
5.	Operation and Maintenance	-	-	-	-	-
6.	Depreciation and amortization	42.2	550.1	1,076.6	1,627.2	2,237.6
7.	Municipal and other taxes	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
8.	Cost of service	42.2	550.1	1,076.6	1,627.2	2,237.6
	Misc. & Non-Op. Rev					
9.	Other operating revenue	-	-	-	-	-
10.	Other income	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
11.	Misc. & Non-operating Rev.	-	-	-	-	-
	Income taxes on earnings					
12.	Excluding tax shield	(2,014.0)	(2,080.3)	(2,186.3)	(2,231.3)	(2,276.4)
13.	Tax shield provided by interest expense	<u>(7.9)</u>	<u>(68.7)</u>	<u>(127.5)</u>	<u>(184.9)</u>	<u>(239.0)</u>
14.	Income taxes on earnings	(2,021.9)	(2,149.0)	(2,313.8)	(2,416.2)	(2,515.4)
	Taxes on (def.) / suff.					
15.	Gross (def.) / suff.	2,609.4	1,440.4	320.0	(903.8)	(2,180.0)
16.	Net (def.) / suff.	<u>1,917.9</u>	<u>1,058.7</u>	<u>235.2</u>	<u>(664.3)</u>	<u>(1,602.3)</u>
17.	Taxes on (def.) / suff.	(691.5)	(381.7)	(84.8)	239.5	577.7
18.	Revenue requirement	<u>(2,609.4)</u>	<u>(1,440.5)</u>	<u>(319.8)</u>	<u>903.9</u>	<u>2,178.9</u>

Notes / Assumptions:

- (1) Annual expenditures of \$7.60M in 2016, \$7.85M in 2017, \$8.25M in 2018, \$8.42M in 2019, and \$8.59M in 2020 are assumed to close into service in November each year.
- (2) The required rate of return assumed in this analysis is EGD's 2015 Approved rate from EB-2014-0276.
- (3) Depreciation expense is calculated based on a useful life of 15 years (annual depreciation rate of 6.67%).
- (4) Taxes are calculated using an assumed tax rate of 26.5%.
- (5) For tax purposes, annual expenditures (\$7.60M in 2016, \$7.85M in 2017, \$8.25M in 2018, \$8.42M in 2019, and \$8.59M in 2020) are assumed to be immediately deductible in the year of spend.

Witnesses: K. Mark
R. Small

Environmental Defence Question #2

Re Exhibit I.T3.EGDI.ED.6: This interrogatory requested the following: "Please re-calculate the rate allocation of the Small C/I Resource Acquisition Program's for each year from 2016 to 2020 inclusive assuming that the Program's expenditures are rate based and amortized over the expected lives of their lifetime cubic metre savings." Enbridge indicated that it was unable to provide a response. However, Union was able to make appropriate assumptions and provide a response (see Exhibit B.T3.Union.ED.5). Environmental Defence asks that Enbridge provide a similar analysis as did Union.

Enbridge provides the following response:

Similarly to Enbridge's response to Question #1, a re-calculation of rate allocation of Small C/I Resource Acquisition programs required Enbridge to make a series of untested assumptions with respect to accounting treatment and tax implications in the revenue requirement calculation. In sharing the following hypothetical accounting treatment (for illustrative purposes only), Enbridge does not endorse the notion of rate basing DSM expenditures.

Witnesses: K. Mark
R. Small

ILLUSTRATIVE RATE BASE TREATMENT OF SMALL C/I RESOURCE ACQUISITION PROGRAM COSTS

(\$000's)						
Line No.		2016	2017	2018	2019	2020
	Cost of capital					
1.	Rate base (1)	919.6	8,146.0	15,940.2	23,841.2	31,289.3
2.	Required rate of return (2)	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>
3.	Cost of capital	60.0	531.1	1,039.3	1,554.4	2,040.1
	Cost of service					
4.	Gas costs	-	-	-	-	-
5.	Operation and Maintenance	-	-	-	-	-
6.	Depreciation and amortization (3)	41.0	539.3	1,111.3	1,732.7	2,420.0
7.	Municipal and other taxes	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
8.	Cost of service	41.0	539.3	1,111.3	1,732.7	2,420.0
	Misc. & Non-Op. Rev					
9.	Other operating revenue	-	-	-	-	-
10.	Other income	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
11.	Misc. & Non-operating Rev.	-	-	-	-	-
	Income taxes on earnings (4)					
12.	Excluding tax shield (5)	(1,953.1)	(2,257.8)	(2,464.5)	(2,512.2)	(2,562.6)
13.	Tax shield provided by interest expense	<u>(7.6)</u>	<u>(67.6)</u>	<u>(132.2)</u>	<u>(197.7)</u>	<u>(259.5)</u>
14.	Income taxes on earnings	(1,960.7)	(2,325.4)	(2,596.7)	(2,709.9)	(2,822.1)
	Taxes on (def.) / suff. (4)					
15.	Gross (def.) / suff.	2,530.2	1,707.9	607.2	(785.0)	(2,226.4)
16.	Net (def.) / suff.	<u>1,859.7</u>	<u>1,255.3</u>	<u>446.3</u>	<u>(577.0)</u>	<u>(1,636.4)</u>
17.	Taxes on (def.) / suff.	(670.5)	(452.6)	(160.9)	208.0	590.0
18.	Revenue requirement	<u>(2,530.2)</u>	<u>(1,707.6)</u>	<u>(607.0)</u>	<u>785.2</u>	<u>2,228.0</u>

Notes / Assumptions:

- (1) Annual expenditures of \$7.37M in 2016, \$8.52M in 2017, \$9.30M in 2018, \$9.48M in 2019, and \$9.67M in 2020 are assumed to close into service in November each year.
- (2) The required rate of return assumed in this analysis is EGD's 2015 Approved rate from EB-2014-0276.
- (3) Depreciation expense is calculated based on a useful life of 15 years (annual depreciation rate of 6.67%).
- (4) Taxes are calculated using an assumed tax rate of 26.5%.
- (5) For tax purposes, annual expenditures (\$7.37M in 2016, \$8.52M in 2017, \$9.30M in 2018, \$9.48M in 2019, and \$9.67M in 2020) are assumed to be immediately deductible in the year of spend.

Witnesses: K. Mark
R. Small

Environmental Defence Question #3

Re Exhibit I.T3.EGDI.ED.7 (a): The CCM increases indicated in the interrogatory response are dramatically lower than the budget increases. Does Enbridge have any evidence and/or analysis to support this pessimistic scenario? If yes, please provide the evidence and analysis.

Enbridge provides the following response:

The CCM values shown in the above noted interrogatory response are a function of the sensitivity analysis which Enbridge undertook first in response to the Board's DSM Framework and later in response to intervenor requests. For more detail regarding the approach and formulae behind the Company's sensitivity analyses please see Enbridge's response to GEC Interrogatory #42, filed as Exhibit I.T9.EGDI.GEC.42.

Environmental Defence Question #4

Re Exhibit I.T3.EGDI.ED.7 (b): Please provide the requested rate basing analysis using an analysis similar to the one used by Union in Exhibit B.T3.Union.ED.5.

Enbridge provides the following response:

Exhibit I.T3.EGDI.ED.7 (b) requested the impacts of budget increases on the Large C/I Resource Acquisition program CCM and net TRC benefits, by way of a sensitivity analysis to calculate the impact of 25%, 50% and 100% increases in the budgets for each year from 2016 to 2020. The requested budget analysis for each scenario are as follows. In sharing the following hypothetical accounting treatment (for illustrative purposes only), Enbridge does not endorse the notion of rate basing DSM expenditures:

Witnesses: K. Mark
R. Small

ILLUSTRATIVE RATE BASE TREATMENT OF LARGE C/I RESOURCE ACQUISITION PROGRAM COSTS (25% BUDGET INCREASE)

(\$000's)						
Line No.		2016	2017	2018	2019	2020
	Cost of capital					
1.	Rate base	1,185.9	10,359.0	19,214.4	27,866.8	36,021.7
2.	Required rate of return	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>
3.	Cost of capital	77.3	675.4	1,252.8	1,816.9	2,348.6
	Cost of service					
4.	Gas costs	-	-	-	-	-
5.	Operation and Maintenance	-	-	-	-	-
6.	Depreciation and amortization	52.8	688.1	1,345.0	2,034.9	2,797.6
7.	Municipal and other taxes	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
8.	Cost of service	52.8	688.1	1,345.0	2,034.9	2,797.6
	Misc. & Non-Op. Rev					
9.	Other operating revenue	-	-	-	-	-
10.	Other income	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
11.	Misc. & Non-operating Rev.	-	-	-	-	-
	Income taxes on earnings					
12.	Excluding tax shield	(2,518.9)	(2,598.9)	(2,733.7)	(2,788.3)	(2,844.3)
13.	Tax shield provided by interest expense	<u>(9.8)</u>	<u>(85.9)</u>	<u>(159.4)</u>	<u>(231.1)</u>	<u>(298.8)</u>
14.	Income taxes on earnings	(2,528.7)	(2,684.8)	(2,893.1)	(3,019.4)	(3,143.1)
	Taxes on (def.) / suff.					
15.	Gross (def.) / suff.	3,263.4	1,798.4	402.6	(1,133.6)	(2,724.9)
16.	Net (def.) / suff.	<u>2,398.6</u>	<u>1,321.8</u>	<u>295.9</u>	<u>(833.2)</u>	<u>(2,002.8)</u>
17.	Taxes on (def.) / suff.	(864.8)	(476.6)	(106.7)	300.4	722.1
18.	Revenue requirement	<u>(3,263.4)</u>	<u>(1,797.9)</u>	<u>(402.0)</u>	<u>1,132.8</u>	<u>2,725.2</u>

Notes / Assumptions:

- (1) Annual expenditures of \$9.50M in 2016, \$9.81M in 2017, \$10.32M in 2018, \$10.52M in 2019, and \$10.73M in 2020 are assumed to close into service in November each year.
- (2) The required rate of return assumed in this analysis is EGD's 2015 Approved rate from EB-2014-0276.
- (3) Depreciation expense is calculated based on a useful life of 15 years (annual depreciation rate of 6.67%).
- (4) Taxes are calculated using an assumed tax rate of 26.5%.
- (5) For tax purposes, annual expenditures (\$9.50M in 2016, \$9.81M in 2017, \$10.32M in 2018, \$10.52M in 2019, and \$10.73M in 2020) are assumed to be immediately deductible in the year of spend.

Witnesses: K. Mark
R. Small

Large C/I - Forecasted Revenue Requirement Allocation (25% Budget Increase)					
Rate Class	2016	2017	2018	2019	2020
Rate 1	\$0	\$0	\$0	\$0	\$0
Rate 6	-\$2,685,118	-\$1,479,308	-\$330,765	\$932,065	\$2,242,289
Rate 9	\$0	\$0	\$0	\$0	\$0
Rate 100	\$0	\$0	\$0	\$0	\$0
Rate 110	-\$190,320	-\$104,853	-\$23,444	\$66,064	\$158,932
Rate 115	-\$195,928	-\$107,942	-\$24,135	\$68,011	\$163,615
Rate 125	\$0	\$0	\$0	\$0	\$0
Rate 135	-\$49,862	-\$27,471	-\$6,142	\$17,308	\$41,639
Rate 145	-\$70,230	-\$38,692	-\$8,651	\$24,378	\$58,648
Rate 170	-\$71,942	-\$39,635	-\$8,862	\$24,973	\$60,077
Rate 200	\$0	\$0	\$0	\$0	\$0
Rate 300	\$0	\$0	\$0	\$0	\$0
Total Spending	-\$3,263,400	-\$1,797,900	-\$402,000	\$1,132,800	\$2,725,200

1. Large C/I spending includes Large C/I Custom, Large C/I Prescriptive, Large C/I Direct Install, and Energy Leaders
2. Large C/I is forecasted to receive 50% of total Energy Leaders budget
3. Spending excludes Overheads and DSMI

Witnesses: K. Mark
R. Small

ILLUSTRATIVE RATE BASE TREATMENT OF LARGE C/I RESOURCE ACQUISITION PROGRAM COSTS (50% BUDGET INCREASE)

(\$000's)						
Line No.		2016	2017	2018	2019	2020
Cost of capital						
1.	Rate base	1,423.2	12,430.6	23,057.1	33,439.9	43,226.8
2.	Required rate of return	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>
3.	Cost of capital	92.8	810.5	1,503.3	2,180.3	2,818.4
Cost of service						
4.	Gas costs	-	-	-	-	-
5.	Operation and Maintenance	-	-	-	-	-
6.	Depreciation and amortization	63.4	826.2	1,614.4	2,441.4	3,356.8
7.	Municipal and other taxes	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
8.	Cost of service	63.4	826.2	1,614.4	2,441.4	3,356.8
Misc. & Non-Op. Rev						
9.	Other operating revenue	-	-	-	-	-
10.	Other income	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
11.	Misc. & Non-operating Rev.	-	-	-	-	-
Income taxes on earnings						
12.	Excluding tax shield	(3,022.6)	(3,118.8)	(3,280.5)	(3,346.2)	(3,413.0)
13.	Tax shield provided by interest expense	<u>(11.8)</u>	<u>(103.1)</u>	<u>(191.3)</u>	<u>(277.4)</u>	<u>(358.5)</u>
14.	Income taxes on earnings	(3,034.4)	(3,221.9)	(3,471.8)	(3,623.6)	(3,771.5)
Taxes on (def) / suff.						
15.	Gross (def.) / suff.	3,915.8	2,156.3	483.1	(1,355.8)	(3,269.9)
16.	Net (def.) / suff.	<u>2,878.1</u>	<u>1,584.9</u>	<u>355.1</u>	<u>(996.5)</u>	<u>(2,403.4)</u>
17.	Taxes on (def.) / suff.	(1,037.7)	(571.4)	(128.0)	359.3	866.5
18.	Revenue requirement	<u>(3,915.9)</u>	<u>(2,156.6)</u>	<u>(482.1)</u>	<u>1,357.4</u>	<u>3,270.2</u>

Notes / Assumptions:

- (1) Annual expenditures of \$11.41M in 2016, \$11.77M in 2017, \$12.38M in 2018, \$12.63M in 2019, and \$12.88M in 2020 are assumed to close into service in November each year.
- (2) The required rate of return assumed in this analysis is EGD's 2015 Approved rate from EB-2014-0276.
- (3) Depreciation expense is calculated based on a useful life of 15 years (annual depreciation rate of 6.67%).
- (4) Taxes are calculated using an assumed tax rate of 26.5%.
- (5) For tax purposes, annual expenditures (\$11.41M in 2016, \$11.77M in 2017, \$12.38M in 2018, \$12.63M in 2019, and \$12.88M in 2020) are assumed to be immediately deductible in the year of spend.

Witnesses: K. Mark
R. Small

Large C/I - Forecasted Revenue Requirement Allocation (50% Budget Increase)					
Rate Class	2016	2017	2018	2019	2020
Rate 1	\$0	\$0	\$0	\$0	\$0
Rate 6	-\$3,221,994	-\$1,774,446	-\$396,671	\$1,116,866	\$2,690,713
Rate 9	\$0	\$0	\$0	\$0	\$0
Rate 100	\$0	\$0	\$0	\$0	\$0
Rate 110	-\$228,373	-\$125,772	-\$28,116	\$79,163	\$190,716
Rate 115	-\$235,102	-\$129,478	-\$28,944	\$81,495	\$196,336
Rate 125	\$0	\$0	\$0	\$0	\$0
Rate 135	-\$59,832	-\$32,951	-\$7,366	\$20,740	\$49,966
Rate 145	-\$84,272	-\$46,411	-\$10,375	\$29,212	\$70,376
Rate 170	-\$86,326	-\$47,542	-\$10,628	\$29,924	\$72,092
Rate 200	\$0	\$0	\$0	\$0	\$0
Rate 300	\$0	\$0	\$0	\$0	\$0
Total Spending	-\$3,915,900	-\$2,156,600	-\$482,100	\$1,357,400	\$3,270,200

1. Large C/I spending includes Large C/I Custom, Large C/I Prescriptive, Large C/I Direct Install, and Energy Leaders
2. Large C/I is forecasted to receive 50% of total Energy Leaders budget
3. Spending excludes Overheads and DSMI

Witnesses: K. Mark
R. Small

ILLUSTRATIVE RATE BASE TREATMENT OF LARGE C/I RESOURCE ACQUISITION PROGRAM COSTS (100% BUDGET INCREASE)

(\$000's)						
Line No.		2016	2017	2018	2019	2020
	Cost of capital					
1.	Rate base	1,897.5	16,574.4	30,742.9	44,586.5	57,635.3
2.	Required rate of return	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>
3.	Cost of capital	123.7	1,080.7	2,004.4	2,907.0	3,757.8
	Cost of service					
4.	Gas costs	-	-	-	-	-
5.	Operation and Maintenance	-	-	-	-	-
6.	Depreciation and amortization	84.5	1,101.3	2,153.3	3,255.6	4,476.0
7.	Municipal and other taxes	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
8.	Cost of service	84.5	1,101.3	2,153.3	3,255.6	4,476.0
	Misc. & Non-Op. Rev					
9.	Other operating revenue	-	-	-	-	-
10.	Other income	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
11.	Misc. & Non-operating Rev.	-	-	-	-	-
	Income taxes on earnings					
12.	Excluding tax shield	(4,030.1)	(4,158.4)	(4,374.1)	(4,461.5)	(4,550.6)
13.	Tax shield provided by interest expense	<u>(15.7)</u>	<u>(137.5)</u>	<u>(255.0)</u>	<u>(369.8)</u>	<u>(478.1)</u>
14.	Income taxes on earnings	(4,045.8)	(4,295.9)	(4,629.1)	(4,831.3)	(5,028.7)
	Taxes on (def) / suff.					
15.	Gross (def.) / suff.	5,221.1	2,875.1	640.0	(1,813.7)	(4,359.9)
16.	Net (def.) / suff.	<u>3,837.5</u>	<u>2,113.2</u>	<u>470.4</u>	<u>(1,333.1)</u>	<u>(3,204.5)</u>
17.	Taxes on (def.) / suff.	(1,383.6)	(761.9)	(169.6)	480.6	1,155.4
18.	Revenue requirement	<u>(5,221.2)</u>	<u>(2,875.8)</u>	<u>(641.0)</u>	<u>1,811.9</u>	<u>4,360.5</u>

Notes / Assumptions:

- (1) Annual expenditures of \$15.21M in 2016, \$15.69M in 2017, \$16.51M in 2018, \$16.84M in 2019, and \$17.17M in 2020 are assumed to close into service in November each year.
- (2) The required rate of return assumed in this analysis is EGD's 2015 Approved rate from EB-2014-0276.
- (3) Depreciation expense is calculated based on a useful life of 15 years (annual depreciation rate of 6.67%).
- (4) Taxes are calculated using an assumed tax rate of 26.5%.
- (5) For tax purposes, annual expenditures (\$15.21M in 2016, \$15.69M in 2017, \$16.51M in 2018, \$16.84M in 2019, and

Witnesses: K. Mark
R. Small

\$17.17M in 2020) are assumed to be immediately deductible in the year of spend.

Large C/I - Forecasted Revenue Requirement Allocation (100% Budget Increase)					
Rate Class	2016	2017	2018	2019	2020
Rate 1	\$0	\$0	\$0	\$0	\$0
Rate 6	-\$4,295,992	-\$2,366,202	-\$527,413	\$1,490,827	\$3,587,810
Rate 9	\$0	\$0	\$0	\$0	\$0
Rate 100	\$0	\$0	\$0	\$0	\$0
Rate 110	-\$304,498	-\$167,715	-\$37,383	\$105,669	\$254,302
Rate 115	-\$313,470	-\$172,657	-\$38,484	\$108,783	\$261,795
Rate 125	\$0	\$0	\$0	\$0	\$0
Rate 135	-\$79,776	-\$43,940	-\$9,794	\$27,684	\$66,625
Rate 145	-\$112,363	-\$61,889	-\$13,795	\$38,993	\$93,840
Rate 170	-\$115,102	-\$63,397	-\$14,131	\$39,943	\$96,128
Rate 200	\$0	\$0	\$0	\$0	\$0
Rate 300	\$0	\$0	\$0	\$0	\$0
Total Spending	-\$5,221,200	-\$2,875,800	-\$641,000	\$1,811,900	\$4,360,500

1. Large C/I spending includes Large C/I Custom, Large C/I Prescriptive, Large C/I Direct Install, and Energy Leaders
2. Large C/I is forecasted to receive 50% of total Energy Leaders budget
3. Spending excludes Overheads and DSMI

Witnesses: K. Mark
R. Small

Environmental Defence Question #5

Re Exhibit I.T3.EGDI.ED.8 (a): The CCM increases indicated in the interrogatory response are dramatically lower than the budget increases. Does Enbridge have any evidence and/or analysis to support this pessimistic scenario? If yes, please provide.

Enbridge provides the following response:

The CCM values shown in the above noted interrogatory response are a function of the sensitivity analysis which Enbridge undertook first in response to the Board's DSM Framework and later in response to intervenor requests. For more detail regarding the approach and formulae behind the Company's sensitivity analyses please see Enbridge's response to GEC interrogatory #42, filed as Exhibit I.T9.EGDI.GEC.42.

Environmental Defence Question #6

Re Exhibit I.T3.EGDI.ED.8 (b): Please provide the requested rate basing analysis using an analysis similar to the one used by Union in Exhibit B.T3.Union.ED.5.

Enbridge provides the following response:

Exhibit B.T3.Union.ED.5 requests revenue requirement impacts from Union Gas for specified budget scenarios over 2016 and 2017, assuming the budgets are rate-based and amortized over the expected lives of the lifetime cubic metre savings.

Exhibit I.T3.EGDI.ED.8 (b) requests the following:

"For each year please show the impacts of the budget increases on the Program's CCM and net TRC benefits", building on ED 8 (a) which requests "a sensitivity analysis to calculate the impact of 25%, 50% and 100% increases in the budgets of the Small C/I Resource Acquisition Program for each year from 2016 to 2020."

Please see the requested scenarios below. In sharing the following hypothetical accounting treatment (for illustrative purposes only), Enbridge does not endorse the notion of rate basing DSM expenditures:

Witnesses: K. Mark
R. Small

ILLUSTRATIVE RATE BASE TREATMENT OF SMALL C/I RESOURCE ACQUISITION PROGRAM COSTS (25% BUDGET INCREASE)

(\$000's)						
Line No.		2016	2017	2018	2019	2020
	Cost of capital					
1.	Rate base	1,148.9	10,178.2	19,919.7	29,792.7	39,106.4
2.	Required rate of return	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>
3.	Cost of capital	74.9	663.6	1,298.8	1,942.5	2,549.7
	Cost of service					
4.	Gas costs	-	-	-	-	-
5.	Operation and Maintenance	-	-	-	-	-
6.	Depreciation and amortization	51.2	673.6	1,389.4	2,165.8	3,024.2
7.	Municipal and other taxes	-	-	-	-	-
8.	Cost of service	51.2	673.6	1,389.4	2,165.8	3,024.2
	Misc. & Non-Op. Rev					
9.	Other operating revenue	-	-	-	-	-
10.	Other income	-	-	-	-	-
11.	Misc. & Non-operating Rev.	-	-	-	-	-
	Income taxes on earnings					
12.	Excluding tax shield	(2,440.1)	(2,822.0)	(3,079.6)	(3,141.1)	(3,204.2)
13.	Tax shield provided by interest expense	<u>(9.5)</u>	<u>(84.4)</u>	<u>(165.2)</u>	<u>(247.1)</u>	<u>(324.4)</u>
14.	Income taxes on earnings	(2,449.6)	(2,906.4)	(3,244.8)	(3,388.2)	(3,528.6)
	Taxes on (def.) / suff.					
15.	Gross (def.) / suff.	3,161.2	2,135.4	756.2	(981.0)	(2,782.7)
16.	Net (def.) / suff.	<u>2,323.5</u>	<u>1,569.5</u>	<u>555.8</u>	<u>(721.0)</u>	<u>(2,045.3)</u>
17.	Taxes on (def.) / suff.	(837.7)	(565.9)	(200.4)	260.0	737.4
18.	Revenue requirement	<u>(3,161.2)</u>	<u>(2,135.1)</u>	<u>(757.0)</u>	<u>980.1</u>	<u>2,782.7</u>

Notes / Assumptions:

- (1) Annual expenditures of \$9.21M in 2016, \$10.65M in 2017, \$11.62M in 2018, \$11.85M in 2019, and \$12.09M in 2020 are assumed to close into service in November each year.
- (2) The required rate of return assumed in this analysis is EGD's 2015 Approved rate from EB-2014-0276.
- (3) Depreciation expense is calculated based on a useful life of 15 years (annual depreciation rate of 6.67%).
- (4) Taxes are calculated using an assumed tax rate of 26.5%.
- (5) For tax purposes, annual expenditures (\$9.21M in 2016, \$10.65M in 2017, \$11.62M in 2018, \$11.85M in

Witnesses: K. Mark
R. Small

2019, and \$12.09M in 2020) are assumed to be immediately deductible in the year of spend.

Small C/I - Forecasted Revenue Requirement Allocation (25% Budget Increase)					
Rate Class	2016	2017	2018	2019	2020
Rate 1	\$0	\$0	\$0	\$0	\$0
Rate 6	-\$2,601,028	-\$1,756,756	-\$622,858	\$806,424	\$2,289,599
Rate 9	\$0	\$0	\$0	\$0	\$0
Rate 100	\$0	\$0	\$0	\$0	\$0
Rate 110	-\$184,360	-\$124,518	-\$44,148	\$57,159	\$162,286
Rate 115	-\$189,792	-\$128,187	-\$45,449	\$58,843	\$167,067
Rate 125	\$0	\$0	\$0	\$0	\$0
Rate 135	-\$48,301	-\$32,623	-\$11,566	\$14,975	\$42,518
Rate 145	-\$68,031	-\$45,948	-\$16,291	\$21,092	\$59,885
Rate 170	-\$69,689	-\$47,068	-\$16,688	\$21,606	\$61,345
Rate 200	\$0	\$0	\$0	\$0	\$0
Rate 300	\$0	\$0	\$0	\$0	\$0
Total Spending	-\$3,161,200	-\$2,135,100	-\$757,000	\$980,100	\$2,782,700

1. Small C/I spending includes Small C/I Custom, Small C/I Prescriptive, Small C/I Direct Install, Small Commercial New Construction, and Energy Leaders
2. Small C/I is forecasted to receive 50% of total Energy Leaders budget
3. Spending excludes Overheads and DSMI

Witnesses: K. Mark
R. Small

ILLUSTRATIVE RATE BASE TREATMENT OF SMALL C/I RESOURCE ACQUISITION PROGRAM COSTS (50% BUDGET INCREASE)

(\$000's)						
Line No.		2016	2017	2018	2019	2020
	Cost of capital					
1.	Rate base	1,378.5	12,213.5	23,903.3	35,751.8	46,928.6
2.	Required rate of return	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>
3.	Cost of capital	89.9	796.3	1,558.5	2,331.0	3,059.7
	Cost of service					
4.	Gas costs	-	-	-	-	-
5.	Operation and Maintenance	-	-	-	-	-
6.	Depreciation and amortization	61.4	807.8	1,666.3	2,597.9	3,629.4
7.	Municipal and other taxes	-	-	-	-	-
8.	Cost of service	61.4	807.8	1,666.3	2,597.9	3,629.4
	Misc. & Non-Op. Rev					
9.	Other operating revenue	-	-	-	-	-
10.	Other income	-	-	-	-	-
11.	Misc, & Non-operating Rev.	-	-	-	-	-
	Income taxes on earnings					
12.	Excluding tax shield	(2,928.0)	(3,386.2)	(3,695.5)	(3,769.4)	(3,844.6)
13.	Tax shield provided by interest expense	<u>(11.4)</u>	<u>(101.3)</u>	<u>(198.3)</u>	<u>(296.5)</u>	<u>(389.3)</u>
14.	Income taxes on earnings	(2,939.4)	(3,487.5)	(3,893.8)	(4,065.9)	(4,233.9)
	Taxes on (def) / suff.					
15.	Gross (def.) / suff.	3,793.5	2,562.3	910.6	(1,172.2)	(3,339.3)
16.	Net (def.) / suff.	<u>2,788.2</u>	<u>1,883.3</u>	<u>669.3</u>	<u>(861.6)</u>	<u>(2,454.4)</u>
17.	Taxes on (def.) / suff.	(1,005.3)	(679.0)	(241.3)	310.6	884.9
18.	Revenue requirement	<u>(3,793.4)</u>	<u>(2,562.4)</u>	<u>(910.3)</u>	<u>1,173.6</u>	<u>3,340.1</u>

Notes / Assumptions:

- (1) Annual expenditures of \$11.05M in 2016, \$12.78M in 2017, \$13.95M in 2018, \$14.22M in 2019, and \$14.51M in 2020 are assumed to close into service in November each year.
- (2) The required rate of return assumed in this analysis is EGD's 2015 Approved rate from EB-2014-0276.
- (3) Depreciation expense is calculated based on a useful life of 15 years (annual depreciation rate of 6.67%).
- (4) Taxes are calculated using an assumed tax rate of 26.5%.
- (5) For tax purposes, annual expenditures (\$11.05M in 2016, \$12.78M in 2017, \$13.95M in 2018, \$14.22M in 2019, and \$14.51M in 2020) are assumed to be immediately deductible in the year of spend.

Witnesses: K. Mark
R. Small

Small C/I - Forecasted Revenue Requirement Allocation (50% Budget Increase)					
Rate Class	2016	2017	2018	2019	2020
Rate 1	\$0	\$0	\$0	\$0	\$0
Rate 6	-\$3,121,201	-\$2,108,337	-\$748,993	\$965,635	\$2,748,227
Rate 9	\$0	\$0	\$0	\$0	\$0
Rate 100	\$0	\$0	\$0	\$0	\$0
Rate 110	-\$221,229	-\$149,438	-\$53,088	\$68,444	\$194,793
Rate 115	-\$227,748	-\$153,841	-\$54,653	\$70,460	\$200,533
Rate 125	\$0	\$0	\$0	\$0	\$0
Rate 135	-\$57,960	-\$39,152	-\$13,909	\$17,932	\$51,034
Rate 145	-\$81,636	-\$55,144	-\$19,590	\$25,256	\$71,881
Rate 170	-\$83,626	-\$56,488	-\$20,068	\$25,872	\$73,633
Rate 200	\$0	\$0	\$0	\$0	\$0
Rate 300	\$0	\$0	\$0	\$0	\$0
Total Spending	-\$3,793,400	-\$2,562,400	-\$910,300	\$1,173,600	\$3,340,100

1. Small C/I spending includes Small C/I Custom, Small C/I Prescriptive, Small C/I Direct Install, Small Commercial New Construction, and Energy Leaders
2. Small C/I is forecasted to receive 50% of total Energy Leaders budget
3. Spending excludes Overheads and DSMI

Witnesses: K. Mark
R. Small

ILLUSTRATIVE RATE BASE TREATMENT OF SMALL C/I RESOURCE ACQUISITION PROGRAM COSTS (100% BUDGET INCREASE)

(\$000's)						
Line No.		2016	2017	2018	2019	2020
	Cost of capital					
1.	Rate base	1,838.1	16,284.6	31,871.0	47,669.1	62,571.6
2.	Required rate of return	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>	<u>6.52%</u>
3.	Cost of capital	119.8	1,061.8	2,078.0	3,108.0	4,079.7
	Cost of service					
4.	Gas costs	-	-	-	-	-
5.	Operation and Maintenance	-	-	-	-	-
6.	Depreciation and amortization	81.9	1,077.5	2,222.5	3,464.3	4,839.8
7.	Municipal and other taxes	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
8.	Cost of service	81.9	1,077.5	2,222.5	3,464.3	4,839.8
	Misc. & Non-Op. Rev					
9.	Other operating revenue	-	-	-	-	-
10.	Other income	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
11.	Misc. & Non-operating Rev.	-	-	-	-	-
	Income taxes on earnings					
12.	Excluding tax shield	(3,904.0)	(4,515.1)	(4,927.4)	(5,026.0)	(5,126.5)
13.	Tax shield provided by interest expense	<u>(15.2)</u>	<u>(135.1)</u>	<u>(264.4)</u>	<u>(395.4)</u>	<u>(519.0)</u>
14.	Income taxes on earnings	(3,919.2)	(4,650.2)	(5,191.8)	(5,421.4)	(5,645.5)
	Taxes on (def) / suff.					
15.	Gross (def.) / suff.	5,057.7	3,416.5	1,214.1	(1,563.0)	(4,452.4)
16.	Net (def.) / suff.	<u>3,717.4</u>	<u>2,511.1</u>	<u>892.4</u>	<u>(1,148.8)</u>	<u>(3,272.5)</u>
17.	Taxes on (def.) / suff.	(1,340.3)	(905.4)	(321.7)	414.2	1,179.9
18.	Revenue requirement	<u>(5,057.8)</u>	<u>(3,416.3)</u>	<u>(1,213.0)</u>	<u>1,565.1</u>	<u>4,453.9</u>

Notes / Assumptions:

- (1) Annual expenditures of \$14.73M in 2016, \$17.04M in 2017, \$18.59M in 2018, \$18.97M in 2019, and \$19.34M in 2020 are assumed to close into service in November each year.
- (2) The required rate of return assumed in this analysis is EGD's 2015 Approved rate from EB-2014-0276.
- (3) Depreciation expense is calculated based on a useful life of 15 years (annual depreciation rate of 6.67%).
- (4) Taxes are calculated using an assumed tax rate of 26.5%.
For tax purposes, annual expenditures (\$14.73M in 2016, \$17.04M in 2017, \$18.59M in 2018, \$18.97M in 2019, and \$19.34M in 2020) are assumed to be immediately deductible in the year of spend.
- (5)

Witnesses: K. Mark
R. Small

Small C/I - Forecasted Revenue Requirement Allocation (100% Budget Increase)					
Rate Class	2016	2017	2018	2019	2020
Rate 1	\$0	\$0	\$0	\$0	\$0
Rate 6	-\$4,161,547	-\$2,810,924	-\$998,054	\$1,287,761	\$3,664,659
Rate 9	\$0	\$0	\$0	\$0	\$0
Rate 100	\$0	\$0	\$0	\$0	\$0
Rate 110	-\$294,968	-\$199,237	-\$70,742	\$91,276	\$259,749
Rate 115	-\$303,660	-\$205,108	-\$72,826	\$93,965	\$267,403
Rate 125	\$0	\$0	\$0	\$0	\$0
Rate 135	-\$77,279	-\$52,198	-\$18,534	\$23,914	\$68,052
Rate 145	-\$108,846	-\$73,520	-\$26,104	\$33,682	\$95,850
Rate 170	-\$111,500	-\$75,313	-\$26,741	\$34,503	\$98,187
Rate 200	\$0	\$0	\$0	\$0	\$0
Rate 300	\$0	\$0	\$0	\$0	\$0
Total Spending	-\$5,057,800	-\$3,416,300	-\$1,213,000	\$1,565,100	\$4,453,900

1. Small C/I spending includes Small C/I Custom, Small C/I Prescriptive, Small C/I Direct Install, Small Commercial New Construction, and Energy Leaders
2. Small C/I is forecasted to receive 50% of total Energy Leaders budget
3. Spending excludes Overheads and DSMI

Witnesses: K. Mark
R. Small

Environmental Defence Question #7

Re Exhibit I.T3.EGDI.ED.9: This interrogatory requested “Enbridge’s best estimate of its 2016 distribution revenue requirement and throughput volumes by rate class.” Enbridge indicated that this information will be available in its rate adjustment application in September. However, we requested Enbridge’s “best estimate” and it was not provided. Environmental Defence requests (a) Enbridge’s best estimate for 2016 and (b) the 2015 distribution revenue requirement and throughput volumes by rate class (actuals and board approved).

Enbridge provides the following response:

To provide a best estimate / proxy of 2016 Distribution Revenue Requirement by rate class, the Total Distribution Revenue Requirement is allocated to the various rate classes in proportion to Rate Base by rate class as filed in EB-2012-0459.

Witnesses: K. Mark
R. Small

2016 Placeholder (EB-2012-0459)	Total	Rate 1	Rate 6	Rate 9	Rate 100	Rate 110	Rate 115	Rate 125	Rate 135	Rate 145	Rate 170	Rate 200	Rate 300	Rate 332
Distribution Revenue Requirement	1,142.1	782.2	311.9	1.2	0.0	10.7	4.5	10.2	0.7	3.0	3.1	2.4	0.4	11.9
Total Delivered Volumes	11,318.3	4,708.6	4,659.6	0.8	0.0	619.6	471.6	0.0	56.5	162.6	453.0	185.9	0.0	0.0

To provide a best estimate / proxy of 2015 Distribution Revenue Requirement by rate class, the Total Distribution Revenue Requirement is allocated to the customer rate classes in proportion to Rate Base by rate class as approved in EB-2014-0276.

2015 Board-Approved (EB-2014-0276)	Total	Rate 1	Rate 6	Rate 9	Rate 100	Rate 110	Rate 115	Rate 125	Rate 135	Rate 145	Rate 170	Rate 200	Rate 300	Rate 332
Distribution Revenue Requirement	1,034.0	705.8	295.0	0.8	0.0	8.1	4.3	8.8	0.5	2.5	3.2	2.6	0.3	2.1
Total Delivered Volumes	11,257.3	4,675.7	4,695.0	0.5	0.0	495.3	531.9	0.0	57.9	138.9	492.9	169.1	0.0	0.0

Witnesses: K. Mark
R. Small

Environmental Defence Question #8

Re Exhibit I.T3.EGDI.ED.10: Please provide a response to this interrogatory on a “best estimate” basis.

Enbridge provides the following response:

Exhibit I.T3.EGDI.ED.10 requests Enbridge’s forecast of the average gas commodity cost (\$ per thousand cubic metres) for its customers in 2016. If the average gas commodity costs are forecast to vary by rate class, price forecasts by rate class are requested.

On June 24, 2015, the Ontario Energy Board approved EB-2015-0163 (July 1, 2015 QRAM), ordering that rates filed in that application be effective July 1, 2015 until June 30, 2016. The commodity price at Empress, inclusive of fuel, in EB-2015-0163 is equal to \$118.378/10³m³, which translates to a gas supply charge of 12.1794 cents/m³ for Rate 1 (Residential) customers. This is the Company’s best forecast / estimate of commodity price at this time.

Witnesses: K. Mark
R. Small

UNDERTAKING JT1.35

UNDERTAKING

Technical Conference TR, page 145

With reference to CCC IR T3.EGD.CCC.5, to further break down the categories.

RESPONSE

As per the Board's direction in Section 15.1 of the DSM Framework, Enbridge has rolled forward all of its 2014 budgets to create 2015 budgets based on the escalation used from 2013 to 2014 and approved by the Board in EB-2012-0394. On this basis, Enbridge has provided a formulaic overhead budget of \$6.6 million. As outlined in Exhibit I.T3.EGD.CCC.5 the overhead budget consists of many items such as consulting, salaries, memberships, etc. The chart below provides the most recent forecast for the 2015 overheads:

Item	Overhead Forecast
Salaries	\$6.96
Consulting / Research	\$0.11
Memberships & Sponsorships	\$0.32
General Business Expenses (incl. Training & Supplies)	\$0.06
TOTAL	\$7.45

Witnesses: M. Lister
S. Moffat
F. Oliver-Glasford
J. Paris

UNDERTAKING JT1.38

UNDERTAKING

Technical Conference TR, page 169

To take the tables on pages 2 and 3 and just add the budget line for each year

RESPONSE

The tables referred to in the question relate to the tables on pages 2 and 3 in SEC Interrogatory Response#12 filed at Exhibit I.T5.EGDI.SEC.12. The tables below present the budget for incentive payouts for both the Residential and Commercial Savings by Design offers over the 2012 to 2020 time period.

Residential

	<u>2012</u>	<u>2013</u>	<u>2014</u>	<u>2015</u>	<u>2016</u>	<u>2017</u>	<u>2018</u>	<u>2019</u>	<u>2020</u>
Builder Target	12	14	16	20	30	20	22	23	25
Budget for incentive payouts	\$ -	\$1,530,000	\$1,620,000	\$1,619,000	\$2,050,000	\$2,300,000	\$2,250,000	\$2,295,000	\$2,315,000

Commercial

	<u>2012</u>	<u>2013</u>	<u>2014</u>	<u>2015</u>	<u>2016</u>	<u>2017</u>	<u>2018</u>	<u>2019</u>	<u>2020</u>
Development Target	8	8	12	18	30	15	20	21	28
Budget for incentive payouts	\$-	\$-	\$100,000	\$280,000	\$300,000	\$350,000	\$330,000	\$320,000	\$130,000

Note that the values for the incentive payouts budget for the Commercial Savings by Design offer for the period 2015 to 2020 were incorrectly presented in the response to SEC Interrogatory Response#12.

Witnesses: S. Bertuzzi
M. Lister

UNDERTAKING JT1.41

UNDERTAKING

Technical Conference TR, page 185

Enbridge to make best efforts to provide the e-tool used to calculate the 325 million cubic metres of savings.

RESPONSE

As identified in the Enbridge response Exhibit I.T7.EGDI.SEC.1 filed 2015-06-23 the e-Tools software is a process tool. The tool was developed to simplify, standardize, and expedite Commercial Custom projects. To this end, the contents of the software are mainly setup to generate documents used specifically in DSM record keeping, and additional customer documents to provide guidance during pre-application work and to produce customer contractual documents.

E-Tools, at its core, is a whole building natural gas energy evaluation and estimation tool which uses standard engineering practices to estimate the pre-conversion building distribution of energy use into end uses, such as space heating, domestic hot water, and ventilation. The tool then allows several built-in analytical components to upgrade the existing uses with higher efficiency technologies or control strategies. This process includes:

- Downloading customer consumption data (linking to separate database);
- Sorting the data (adjusting for actual meter readings);
- Integrating with localized actual weather data;
- Establishing reasonable non-seasonal load;
- Establishing a balance point and statistical relationship between consumption and outdoor temperature;
- Estimating seasonal mechanical ventilation load, based on equipment (if required);
- Normalizing all gas loads to Environment Canada Climate Design Year for a specific location (sometimes referred to as the “30 year average”);
- Calculating appropriate efficiencies and savings for separate measures / technologies;

Witnesses: R Sigurdson
T Whitehead

- Integrating the separate measures onto one gas saving sheet to ensure appropriate measures are cascaded and not double counted;
- Providing the final results needed to determine TRC and CCM with appropriate cost and measure life inputs;
- Creating documents that summarize the specific steps, and different measures; and
- Creating documents for customer contracts and letters.

The benefit of having this all built into one processing tool is that it facilitates expedited and consistent processing of an application, but more importantly it ensures savings are cascaded when multiple measures are employed at the same time. This cascading effect helps to ensure accuracy.

The undertaking specifically requested best efforts on a list of broad based assumptions underlying e-Tools; therefore Enbridge has provided reference and user manual documents for the following measures that are incorporated into the e-Tools software:

- Boilers (hot water only);
- Ventilation (Air Handling Units & Make-Up-Air Units);
- Pipe and surface Insulation;
- Infrared;
- Door Cover (air curtains);
- Destratification;
- Infiltration; and
- Climatic Data.

Witnesses: R Sigurdson
T Whitehead



BOILER REFERENCE DOCUMENTATION

15-Oct-2014



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Appendices

Appendix A: Enbridge - Commercial Boiler Database

Introduction

The current commercial boiler test standard does not provide an accurate picture of the seasonal efficiency nor does it necessarily provide an in-situ value for thermal or combustion efficiency. Measurements of Combustion and Thermal Efficiency are done at full load with steady-state operation using specific conditions as per testing standards. Seasonal Efficiency or Application Seasonal Efficiency (ASE) accounts for operation during various loads, including heat losses when the boiler is off.

ASHRAE Standard 155P was started in 1994 to provide a method of testing to determine the ASE of commercial space heating boiler systems. The latest feedback from the 155P committee is for this standard to be released for public review in the summer of 2014. The Standard only provides a testing methodology. Development of algorithms and software for determining ASE is part of an ASHRAE funded research project (1196-RP). This software is tied to the completion of the Standard and is yet to be released.

The 155P Standard has been in various stages of development over the past 20 years with many delays. In the absence of an industry standard, and realizing the unrealistic values provided by current efficiency standards, Enbridge developed its own methodology for estimating the ASE of commercial boiler systems. Development was a combined effort of 3rd party consultants with expert knowledge of boiler systems and operation using concepts from 155P, ASHRAE research and industry estimates.

The original customised version of their own ASE calculation was developed in 2000. It was then incorporated into Version 1.0 of the Commercial ETools-Boiler software program in 2002. Various updates and revisions of the software have been released since the initial version.

Natural gas savings from the ETools Software are based on the difference in ASE between the existing and proposed boiler plant applied to the existing gas consumption. The software does not just consider solely the packaged boiler but rather the entire boiler system including equipment and operation.

This report defines the methodology used by the ETools Software in calculating the ASE and resultant natural gas savings of existing and proposed commercial boiler systems.

Nomenclature

A listing of nomenclature used throughout this report includes:

SWT	boiler supply water temperature
RWT	boiler return water temperature
155P	ASHRAE Standard 155P
ASE	Application Seasonal Efficiency
Mbh	1000 Btu/hr
Mbtu	1000 Btu
DHW	Domestic Hot Water

Boiler Efficiency

A number of terms are used to define the “efficiency” of a boiler” and presented for various purposes including: publishing ratings, marketing information, and systems design. The three efficiency terms as defined by the ASHRAE 2012 HVAC Systems and Equipment Handbook¹⁶ are as follows:

- **Combustion Efficiency:** is input minus stack (flue gas outlet) loss, divided by input. Values generally range from 75 to 86% for non-condensing boilers and from 88 to 95% for condensing boilers. This efficiency is measured for non-condensing boilers using a device measuring flue-gas temperature and percentage of CO₂ or O₂. Condensing boiler combustion efficiency must also include the energy transferred by condensation in the flue gas.
- **Thermal Efficiency:** is the gross energy output divided by energy input and is also termed ‘Overall’, ‘Fuel-To-Water’ or ‘Fuel-To-Steam’ efficiency depending on the medium being heated. This value is determined by measuring the fuel input and the energy absorbed by the water or steam. Thermal efficiency is lower than combustion efficiency by the percentage of heat lost from the outside surface of the boiler as well as off-cycle energy loss.
- **Seasonal Efficiency:** is the actual operating efficiency that the boiler will achieve during the heating season at various loads. This is also termed Application Seasonal Efficiency (ASE) [Butcher, Celebi, Wei, 2006¹]. Weil-McLain [Energy Management with Commercial Hydronic Heating Systems²²] calculates seasonal efficiency as the ratio of the total seasonal heating output to total seasonal heating input.

Measurements of Combustion and Thermal Efficiency are done at full load with steady-state operation using specific conditions as per testing standards. Seasonal Efficiency accounts for operation during various loads, including heat losses when the boiler is off.

Performance Codes and Standards

Commercial heating boilers are defined by the ASHRAE 2012 Handbook¹⁶ as being boilers with inputs of 300,000 Btu/h and larger.

The 2012 Ontario Building Code²⁰ which is in force as of January 1st, 2014 provides different energy efficiency requirements for buildings depending on the date of permit application. A brief synopsis of the OBC requirements is included as pertaining to this report.

Prior to January 1st, 2017 (OBC Division 2: 1.1.2.1) buildings must achieve the energy efficiency levels attained by conforming to ANSI/ASHRAE/IES Standard 90.1-2010¹⁷. The test procedure is that provided by ASHRAE 90.1 or as listed in the 2011 NECB or in an applicable Ontario Regulation. ASHRAE 90.1 Table 6.8.1F requires, as of 3/2/2010, a Thermal Efficiency of 80% for boilers greater and including 300,000 Btu/h and less than and including 2,500,000 Btu/h. Boilers over 2,500,000 Btu/h require a Combustion Efficiency of 82%. The test procedure is referenced by the DOE’s Code of Federal Regulations’ 10 CFR Part 431¹⁶ as using the BTS-2000 Testing Standard¹⁸.

The BTS-2000 Testing Standard tests the full-load, steady-state efficiency of boilers at the specified water temperatures:

- Non-condensing Boilers: This test uses an inlet temperature between 35F to 80F and an outlet temperature of 180F.
- Condensing Boilers: The outlet temperature for condensing boilers is 180F with an inlet temperature of 80F at all times during the test.

The BTS Standard does not account for the presence of condensate in either type of boiler. Efficiencies published under this test procedure are generally not achieved in actual operation [ASHRAE Handbook 2012¹⁶].

Existing codes and standards for commercial boilers solely address the Thermal Efficiency requirements. They do not address the ASE of the boiler system.

Literature Review: ASE Variables

The ASE incorporates more of the boiler system components and operation than solely the boiler itself. There exist numerous published papers and discussion pieces on the variables that affect boiler system ASE. A summary of a literature review of the relevant papers and industry related articles on variables affecting ASE is included.

A complete listing of supporting documentation used within this report is included in the References. The Bibliography includes other resource documentation not specifically referenced.

Butcher, Celebi, Wei 2006¹

This paper models the annual fuel use of combination heating and domestic hot water boilers using steady state efficiency, idle loss, oversize factor and BIN numbers for a selected location. If the system changes supply water temperature then control strategy must also be considered. This paper shows the effect idle losses have on annual efficiency of baseline, high efficiency and condensing systems as illustrated in Table 1.

Table 1: SE Variables – Butcher 2006 (Table 3)

System	SS Efficiency (%)	Idle Loss (%)	Oversize Factor	Annual Efficiency (%)	Reduction from Baseline Case
1 – Baseline	82	3	2	68.7	0
2 – HE	88	3	2	73.7	6.8
3 - Cond	92	1	2	86.4	20.5
4 – HE	88	0.15	2	87.2	21.1
5 - Cond	92	0.15	2	91.1	24.6

Katrakis and Zawacki 1993⁵

Katrakis and Zawacki state that the part-load efficiency of the heating plant is a significant component of the system efficiency. Outdoor air temperature and oversizing strongly affect the part-load efficiency. Seasonal efficiency may be defined as the weighted average of part-load efficiency over the appropriate range of outdoor air temperatures. An analysis of intermediate sized steam boilers presented seasonal efficiencies, on page 434, in the range of 55-74%. Higher boiler efficiency in the range of 75-83% can be achieved by boilers having very low off-cycle losses including systems with variable firing rate power burners, modulating air intake dampers closed during the off-cycle, and condensing type boilers (page 437).

Landry 1993⁶

Two boilers (one hot water and one steam) were monitored for cycling flue losses and seasonal efficiencies in apartment building central heating systems. Estimated seasonal efficiencies of 66% and 54% for the hot water and steam compared to steady state stack efficiencies of 81.5% and 73%. Varying the boiler temperature with an outdoor reset control on the hot water boiler improved the seasonal efficiency to 70% as described on page 452 of the paper.

Dutt 1990²

Dutt determined typical systems having a pilot light and no vent damper with at a steady-state efficiency of 75% will have a seasonal efficiency of 57% as presented in Appendix III-1 of the paper.

Although existence of the variables are well known, the number of variables and corresponding numerous combinations, has added to the difficulty in creating an industry standardized ASE test method.

Tierney 1994⁸

This paper reviews the seasonal efficiency of gas-fired steam boiler plants. Seasonal efficiency determination must take into account; the effects of varying loads, boiler plant age, design, and the effects of boiler maintenance and water treatment. The arithmetic mean of 23 annual efficiency values collected of steam boiler plants was 57.1% ranging from 50-65%. Estimates of efficiency losses are included in Exhibit 1 as included on page 893 of the paper.

Exhibit 1: SE Variables – Tierney 1994 – Seasonal Efficiency Values

Variable	Seasonal Efficiency Values
Combustion Efficiency	86% to 75%
Radiation and convection losses	0.3% to 6%
Effects of boiler plant design and efficiency losses at light loads	2% to 7%
Effect of scale in the boiler	7% to 11%
Effects of boiler blowdown	0.1% to 1%
Effects of too much excess air	0 to 7.5%
Potential range of seasonal efficiency	76.6 % to 42.5%

Butcher 2011¹⁰

Thomas provides additional work on the analysis of idle loss and oversizing on annual fuel use of combination heating and hydronic systems. Calculated annual efficiency values are included in Exhibit 2 through Exhibit 5.

Exhibit 2: SE Variables – Butcher 2011 (Table 1)

Thermal Efficiency (%)	Idle Loss (%)	Calculated Annual Efficiency (%)	Estimated DHW Production Efficiency (%)
72	4	54	20
83	2	71	36
88	1	81	53
88	0.5	85	67
88	0.15	87	80

Table 1: Example analysis of the performance of combination hydronic systems. (Location is Albany, N.Y.; design day maximum space heat load is 40,000 Btu/h, hydronic system rated maximum output is 110,000 Btu/h.)

Exhibit 3: SE Variables – Butcher 2011 (Table 2)

Thermal Efficiency (%)	Idle Loss (%)	Calculated Annual Efficiency (%)	Estimated DHW Production Efficiency (%)
72	4	62	30
83	2	77	49
88	1	85	65
88	0.5	86	75
88	0.15	87	84

Table 2: Example analysis of the performance of combination hydronic systems. (Location is Albany, N.Y.; design day maximum space heat load is 40,000 Btu/h, hydronic system rated maximum output is 60,000 Btu/h.)

Exhibit 4: SE Variables – Butcher 2011 (Table 3)

Thermal Efficiency (%)	Idle Loss (%)	Calculated Annual Efficiency (%)	Estimated DHW Production Efficiency (%)
72	4	55	30
83	2	72	49
88	1	82	65
88	0.5	85	75
88	0.15	87	84

Table 3: Example analysis of the performance of combination hydronic systems. (Location is Hampton, Va.; design day maximum space heat load is 25,000 Btu/h, hydronic system rated maximum output is 60,000 Btu/h.)

Exhibit 5: SE Variables – Butcher 2011 (Table 4)

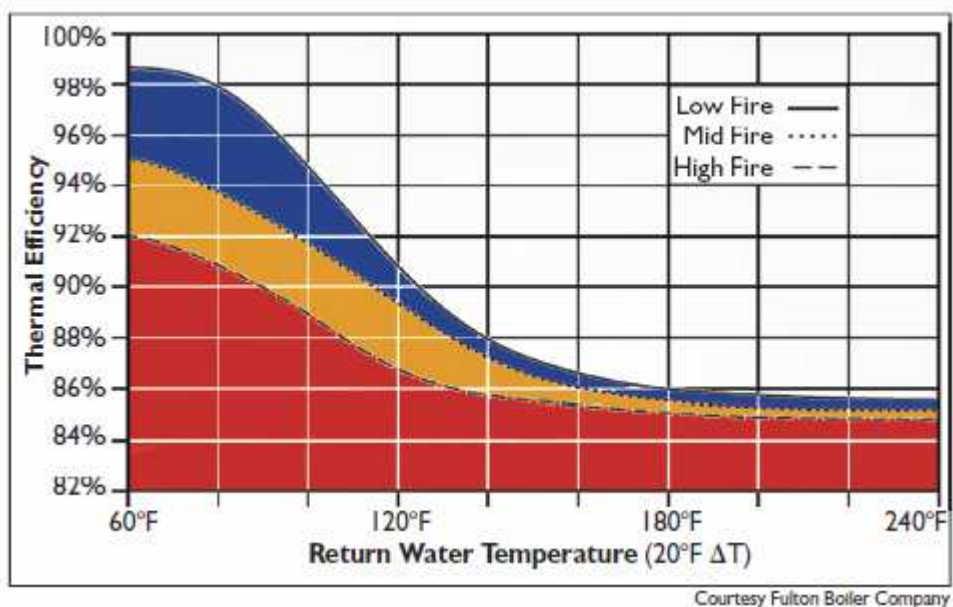
Thermal Efficiency (%)	Idle Loss (%)	Calculated Annual Efficiency (%)	Estimated DHW Production Efficiency (%)
72	4	52	13
83	2	69	25
88	1	80	40
88	0.5	84	55
88	0.15	87	75

Table 4: Example Analysis of the Performance of Combination Hydronic Systems. (Location is Portland, Maine, design day maximum space heat load is 60,000 Btu/h, hydronic system rated maximum output is 200,000 Btu/h.)

Durkin 2006¹¹

Durkin suggests that the boiler is only one piece of the total building system. Other factors that detract from seasonal efficiency include; jacket losses, purge losses at startup, combustion air losses, stand-by losses, pipe system radiant losses, pumping energy, and the part-load effect. Some of these are very difficult to model or measure without a sophisticated research study. On page 54 of the Journal article, Durkin presents an 'industry standard' water supply/return water temperature of 180/160F for conventional boilers with a minimum return of 140F required for safe operation. Condensing boiler system temperatures are limited by the building heating system and not by a manufacturer's mandated low limit. Durkin also suggests that possibly the second largest contributor affecting seasonal efficiency after combustion efficiency is the part-load effect. This is a combination of operating at reduced loads while reducing the entering water temperature as illustrated in Exhibit 6.

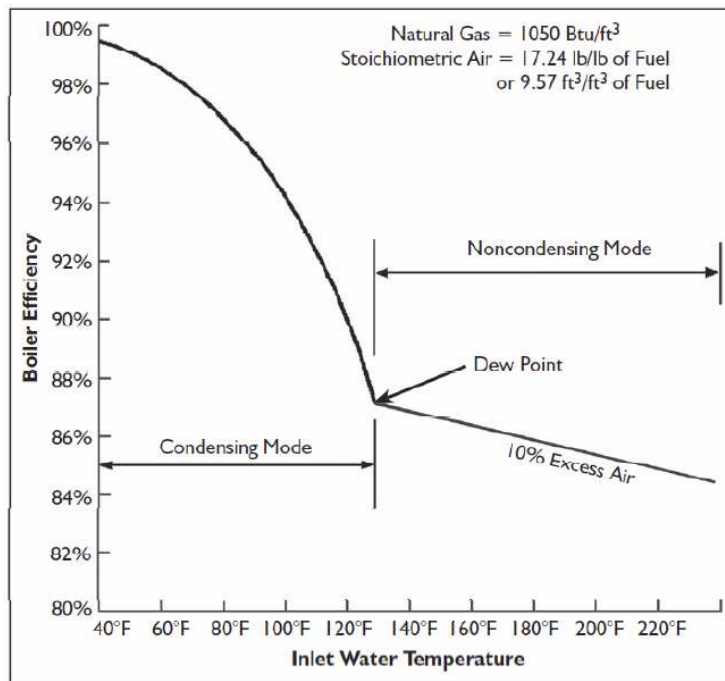
Exhibit 6: Durkin 2006 – Part-Load Effects And Entering Water Temperature



ASHRAE 2012 Handbook¹⁶

The current test standard does not provide an accurate picture of the seasonal efficiency nor does it necessarily provide an in-situ value for thermal or combustion efficiency. Inlet water temperature has a substantial effect on boiler efficiency as shown in Section 32.4, Figure 6 of the ASHRAE 2012 Handbook¹⁶ and provided in Exhibit 7.

Exhibit 7: ASHRAE 2012 – Effect of Inlet Water Temperature on Efficiency of Condensing Boilers

**Raypak²²**

Raypak provides a discussion paper describing exaggerated claims regarding commercial boiler efficiency [Raypak: Beware²²]. The American Boiler Manufacturers Association (ABMA) suggests the performance ratings derived from laboratory testing are likely to differ from actual performance due to differences in operating and test conditions.

Weil-McLain Energy Management²³

This document shows, on page 8, the effects of boiler sizing on seasonal efficiency. Other variables affecting ASE include; control differentials, standby losses, short-cycling losses, vent losses and variable temperature.

Collver 2010²⁴

Roy Collver wrote an article for Canmet in which he provided his extensive knowledge of hydronic systems in determining estimated savings for such variables as; type of venting, reset control, boiler sizing, modulation, supply temperature and system temperature delta. This article was aimed at

residential boiler systems, however, the variables are common for commercial systems. On page 6 of the article, Roy shows projected savings relating to several ASE variables as displayed in Exhibit 8, Exhibit 9, and Exhibit 10 of this report. The work for this article was originally undertaken for Natural Resources Canada's Canmet-Energy, with funding from the Program of Energy Research and Development. It is in Draft review and is not for widespread distribution or publication.

Exhibit 8: SE Variables – Collver 2010 – Estimated Savings

New System	Old System	% Savings
(1) Subtract output from input = new boiler efficiency	Subtract output from input = old boiler efficiency, then Subtract old from new rating	5% to 15%
(2) Power venting	- Atmospheric venting - Power venting	3% to 6% 1% to 2%
(3) Full outdoor re-set from boiler	No outdoor reset Partial outdoor reset (boiler) Full outdoor reset (mixing)	6% to 10% 3% to 6% 1% to 3%
(4) Correct size for design conditions	Correct size Oversized by 20% Oversized by 30% Oversized by 50% Oversized by 70%	0% 2% to 3% 3% to 4% 4% to 8% 8% to 10%
(5) Modulation		
None	None 2:1	0% -2 to -6%
2:1	None 2:1	2% to 4% 0%
4:1	None 2:1	6% to 8% 2% to 4%
5:1	None 2:1	8% to 10% 4% to 6%
More than 6:1	None 2:1	10% to 12% 6% to 8%

Exhibit 9: SE Variables – Collver 2010 – Estimated Savings

New System	Old System	% Savings
(6) T - Supply at design outdoor temperature	180°F old vs. 180°F new 180°F old vs. 170°F new 180°F old vs. 160°F new 180°F old vs. 150°F new 180°F old vs. 140°F new	0% 1% to 2% 2% to 4% 4% to 6% 6% to 8%
(7) ΔT - System	20°F old vs. 20°F new 20°F old vs. 30°F new 20°F old vs. 40°F new	0% 1% to 3% 2% to 4%
(8) Auxiliary load Conversion	DHW, Pool/Spa, Forced air-furnace, air make-up, snow melt, etc.	5% to 25%

Exhibit 10: SE Variables – Collver 2010 – Estimated Savings

Function	Range	Estimate
(1) Efficiency gain	5% to 15%	6%
(2) Venting	1% to 6%	4%
(3) Reset	2% to 10%	6%
(4) Boiler Sizing	0% to 10%	3%
(5) Modulation	0% to 12%	6%
(6) T - Supply	0% to 8%	2%
(7) ΔT - System	0% to 4%	1%
Total	8% to 65%	28%
(8) Aux. Load	5% to 25%	

Although this is not a research based refereed article, it does demonstrate what industry experts affirm.

Hewett 2005²⁸

Martha Hewett provides a discussion and update of Standard 155P. Seasonal efficiency of a boiler depends on several factors including; efficiency of the boiler, the load profile, oversizing, the boiler temperature drop and leaving temperature, the use of reset or cutout control, staging of boilers, and type of pumping. ASE values produced with a preliminary version of the Standard 155P related software show sample boiler systems in Exhibit 11 (page 20 of the article) having thermal efficiencies of 79-81% with resultant ASE values between 65-74%. This software has not been released for public review or use. It may be available upon release of the Standard. This Exhibit was provided by Hewett 2005²⁸ for demonstration purposes.

Exhibit 11: SE Variables - Hewett 2005 – Sample Computed ASE Values

Thermal efficiency, percent	Idling input rate/ steady-state input rate, percent	Sizing ratio	Number of boilers	Sequencing and isolation	ASE, percent
Effect of thermal efficiency					
79	2.0	1.33	1	NA	68.5
80	2.0	1.33	1	NA	69.3
81	2.0	1.33	1	NA	70.0
Effect of idling-energy input rate					
80	1.0	1.33	1	NA	74.0
80	2.0	1.33	1	NA	69.3
80	3.0	1.33	1	NA	65.1
Effect of sizing					
80	2.0	1.33	1	NA	69.3
80	2.0	1.50	1	NA	68.0
80	2.0	1.70	1	NA	66.6
Effect of multiple boilers					
80	2.0	1.33	1	NA	69.3
80	2.0	0.67	2	Ganged	69.3
80	2.0	0.67	2	Staged	70.0
80	2.0	0.67	2	Staged, P/S	73.9

Notes:

- Combustion efficiency 82 percent for all examples.
- These results are preliminary and subject to change.

ASHRAE Standard 155P

Standard 155P was started in 1994 to provide a method of testing to determine the ASE of commercial space heating boiler systems. The title, purpose and scope are included. The latest feedback from the 155P committee is for this standard to be released for public review in the summer of 2014.

Martha Hewett of the Center for Energy and Environment in Minnesota was the Standard Committee Chairperson from inception to 2012. Tom Butcher of Brookhaven National Laboratory is the current Committee Chair.

Title, Purpose & Scope

SPC 155P - Proposed standard project authorized 6/25/1994. (Revised TPS approved March 24, 2010.)

Method of Testing for Rating Commercial Space Heating Boiler Systems

1. PURPOSE

This standard provides procedures for determining the steady state thermal efficiency, part load efficiency and idling energy input rate of space heating boilers.

2. SCOPE

2.1 This standard applies to steam and hot water boiler systems (individual, modular or multiple boilers) for use in space heating applications and having individual boilers or modules with gas, oil, electric or multiple fuel inputs of at least 300,000 Btu/h but less than 12,500,000 Btu/h.

Exception. Custom-designed, field-assembled boilers are not covered by this standard.

2.2 This standard provides methods to compare energy consumption measures of various boiler systems. It is not intended to provide an absolute measure of performance in any specific installation configuration.

2.3 This standard includes:

- (a) test methods for determining full load and part load steady state thermal efficiency, idling energy input rate and through-flow loss rate of individual boilers,
- (b) methods for interpolating and extrapolating test data,
- (c) rating conditions to be used in executing tests and calculations for a range of classes of space heating applications.

2.4 This standard applies to the space heating performance of boiler systems used for multiple functions including space heating.

2.5 This standard does not cover methods of testing boiler systems used only in service water heating applications.

Current Documentation

Since its inception, persons involved with the Standard development have produced several documents providing some insight into the testing and calculation methodologies being used or considered. The documentation, however, does not outline a process for ASE calculation. A summary of this documentation is provided.

Hewett 2000¹³

Martha gave a presentation of some examples of Application Seasonal Efficiencies at the ASHRAE conference in February 2000. In this she illustrated several variations in boiler performance parameters using a sample load profile:

- ASE as a function of steady state efficiency and idling energy input rate. [Exhibit 12]
- Gain in ASE using modulation with a 2:1 turndown. [Exhibit 13]
- ASE as a function of sizing ratio and idling energy input rate. [Exhibit 14]
- Gain in ASE using multiple boilers for staging. [Exhibit 15]
- Gain in ASE using cutout control. [Exhibit 16]

Exhibit 12: 155P - Hewett 2000 – ASE as a Function of SSE and Idling Energy Input Rate

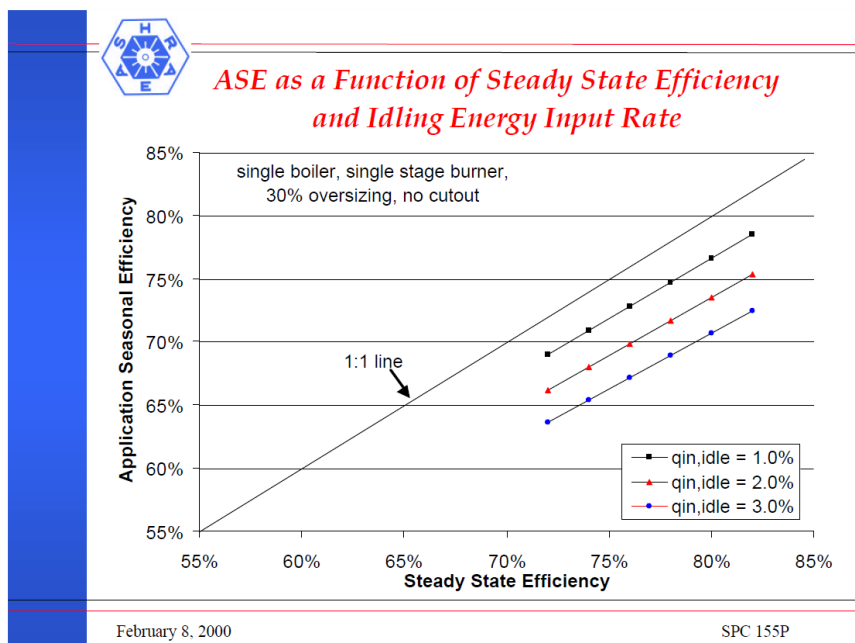


Exhibit 13: 155P - Hewett 2000 – Gain in ASE Using Modulation

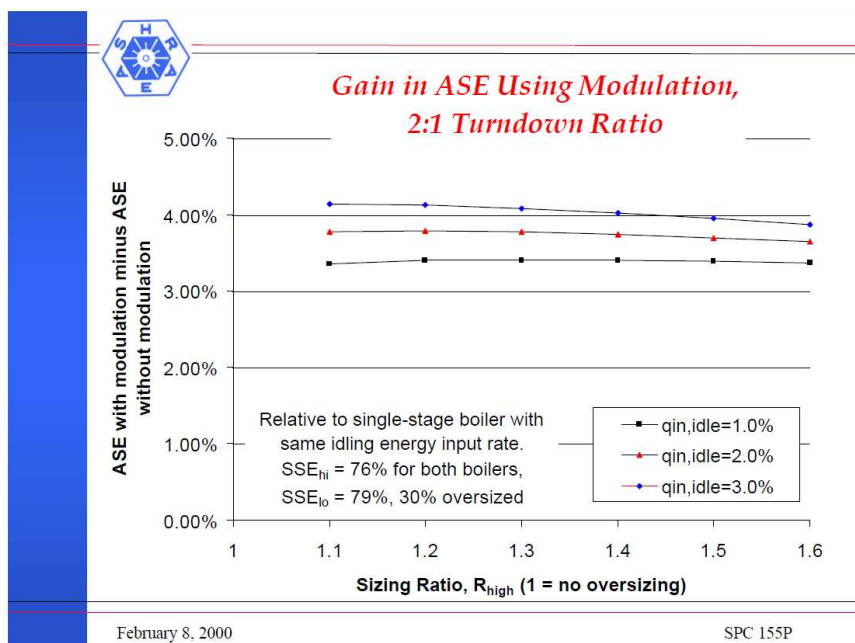


Exhibit 14: 155P - Hewett 2000 – ASE as a Function of Sizing and Idling Energy Input

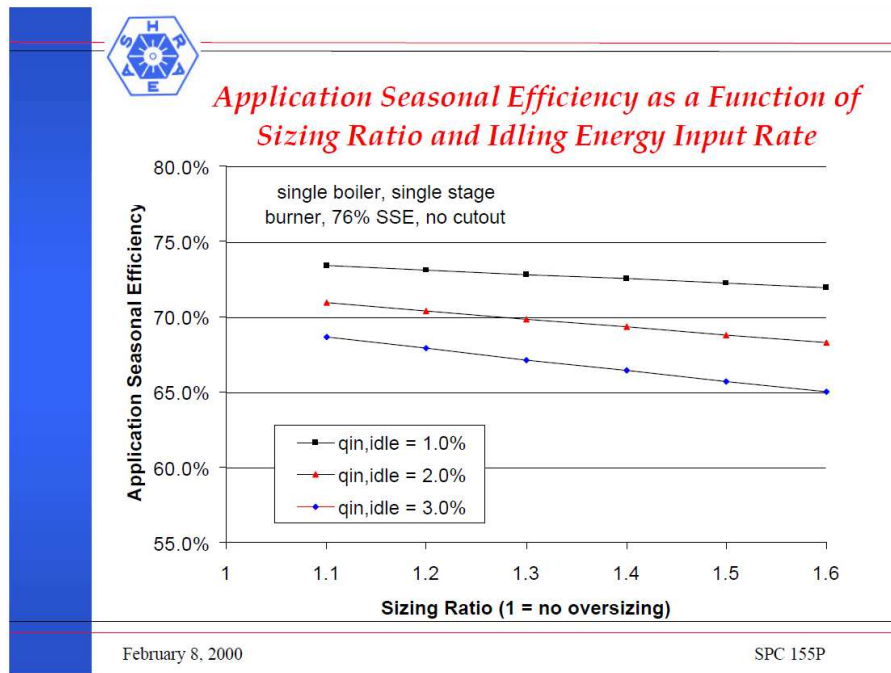


Exhibit 15: 155P - Hewett 2000 – Gain in ASE Using 4 Boilers with P/S Pumping

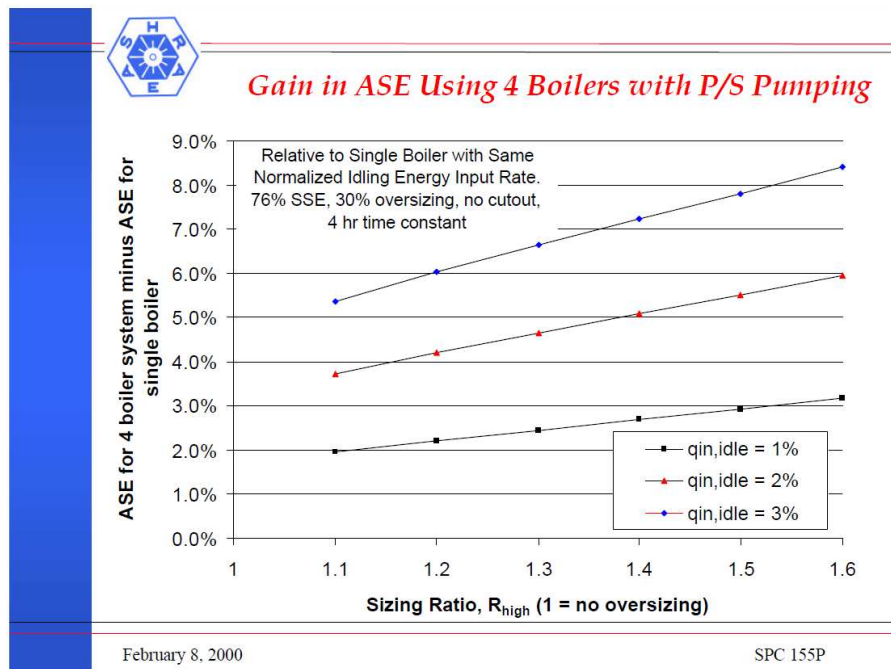
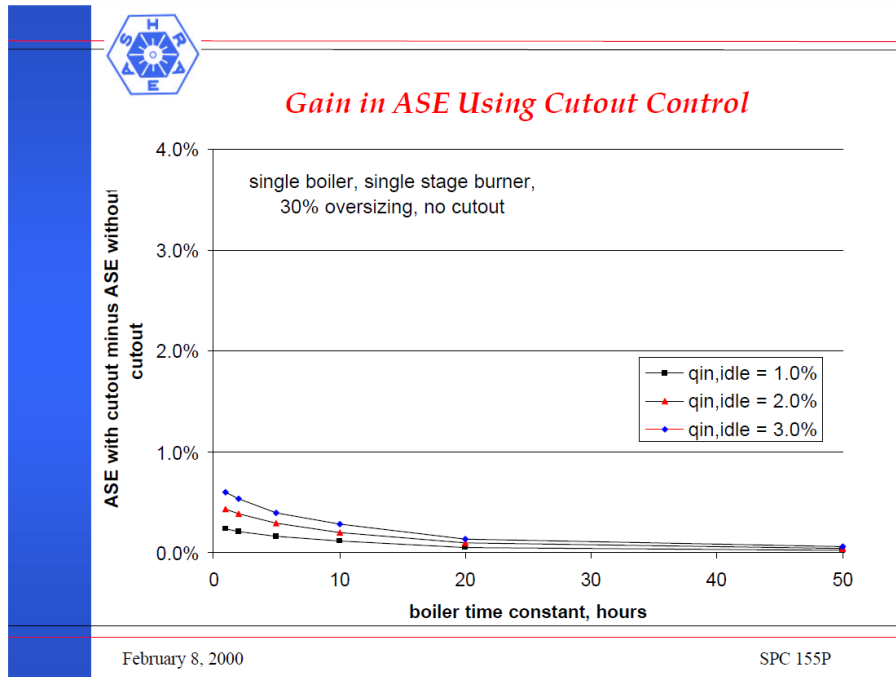


Exhibit 16: 155P - Hewett 2000 – Gain in ASE Using Cutout Control



Katipamula 2000¹⁴

Srinivas also presented at the ASHRAE conference in February 2000 where she provided an outline of the development of load profiles for ASE calculations.

Bixby 2004⁹

An article was included in the July 2004 edition of the ASHRAE Journal providing a brief description of new software that is being developed for calculating ASE.

Hewett 2005²⁸

Martha wrote this article to provide a snapshot of the purpose of 155P and some of the methodology being used in development. The testing burden on manufacturers was a concern of the standards committee. Exhibit 17 shows the efficiency versus output of a boiler, as a fraction of full-load output, having a single stage atmospheric burner. This type of relationship is very difficult to interpolate for energy calculations. However, plotting the same relationship as input rate versus output rate produces a highly linear line and simplifies use for energy calculations as illustrated in Exhibit 18. Plot points on the graph are derived from one at steady-state, full fire operation and a second from an idling test value. Multi-staged or modulating boilers can have additional points such as at low or mid-range output and even with varying water temperatures as per Exhibit 19.

Exhibit 17: 155P - Hewett 2005 – Boiler Efficiency vs. Part-Load Output

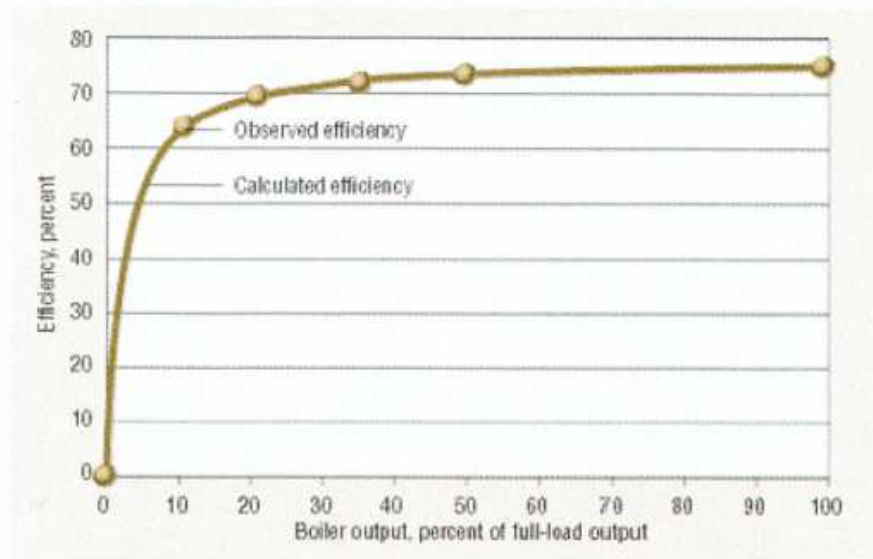


FIGURE 2A. Efficiency vs. output (as a fraction of full-load output) for a cast-iron hot-water boiler with a single-stage atmospheric burner. The circles are test points, taken at 180-F leaving-water temperature and a constant flow rate. The line was calculated by linear interpolation on an input-output graph between the steady-state point and the idling point.

Exhibit 18: 155P - Hewett 2005 – Boiler Part-Load Input vs. Output

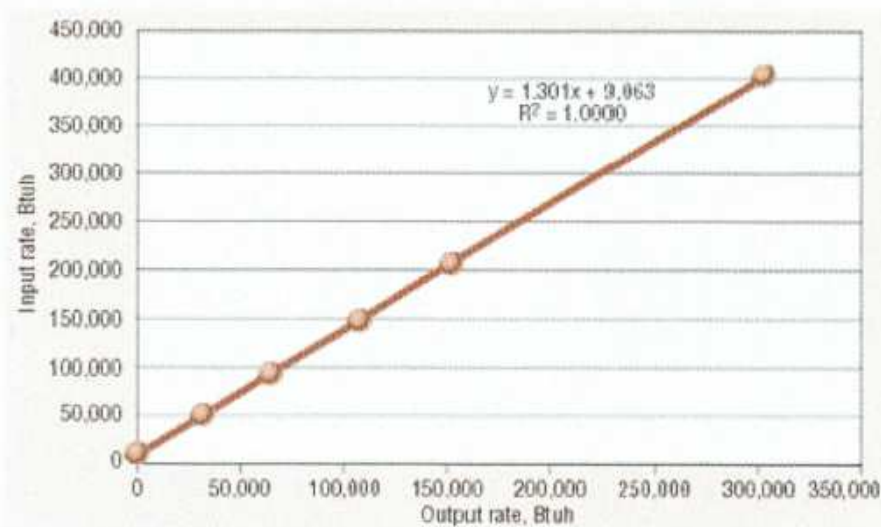


FIGURE 2B. Input vs. output for the boiler in Figure 2a. The steady-state thermal efficiency is about 75 percent, while the idling-energy input rate is about 2.2 percent of the steady-state input rate.

Exhibit 19: 155P - Hewett 2005 – Input Load Fraction Plot Points

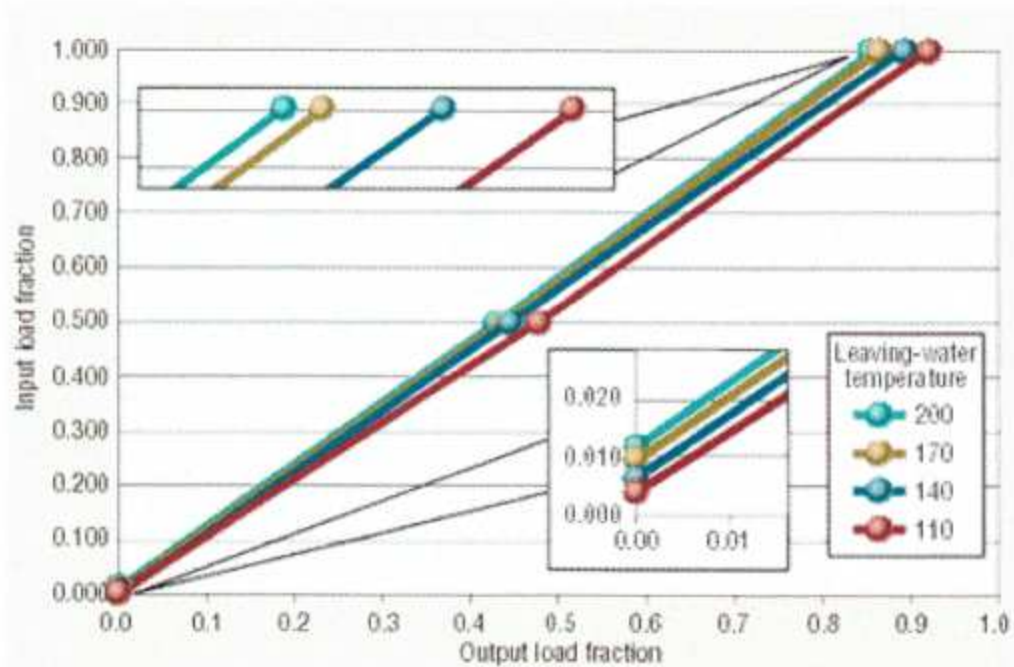


FIGURE 7. Assumed linear relationship between input and output for two regimes; the cycling regime from idling to low fire and the modulating regime from low fire to high fire. The turndown ratio is 2-to-1.

ASE calculation in Standard 155P is a bin-based calculation whereas the heating load is divided into 100 bins with a 'zero' bin containing that portion of the heating season with zero load. In any bin, boilers may be operating:

- o Operating at steady-state high fire.
- o Operating at steady-state low fire.
- o Modulating
- o Cycling
- o Idling
- o Off with through-flow from active boilers.
- o Off and isolated.
- o Each bin may also have varying water temperatures.

ASE is the sum of all outputs to a building over the bin range divided by all inputs over the same total bin range.

Taylor, Elliot, Stein and Zhou 2012¹⁵

Boiler Research Project – ASHRAE Standard 155P was completed by PG&E and Taylor Engineering. This project tested 3 boilers using the test methodology in Standard 155P. Further discussion of this research project is provided.

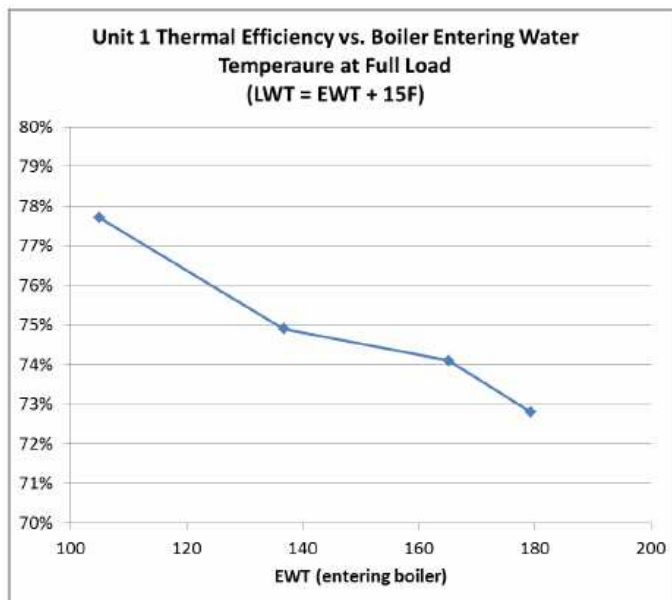
Boiler Research Project – ASHRAE Standard 155P

The Boiler Research Project tested 3 boilers:

- Unit 1. An atmospheric copper fin tube boiler with a simple on/off controller and an internal recirculation pump for maintaining minimum flow. The rated energy input was 715,000 Btu/hr.
- Unit 2. A condensing cast iron boiler having a turndown of 5:1 and a rated energy input of 600,000 Btu/hr. There was no internal recirculation pump. Air supply was forced draft with the intake fan on a VFD controlled by the boiler control.
- Unit 3. A condensing stainless steel boiler with a turndown of 20:1, a rated energy input of 1,500,000 Btu/hr and did not include an internal recirculation pump. Air supply was forced draft with the intake fan on a VFD controlled by the boiler control.

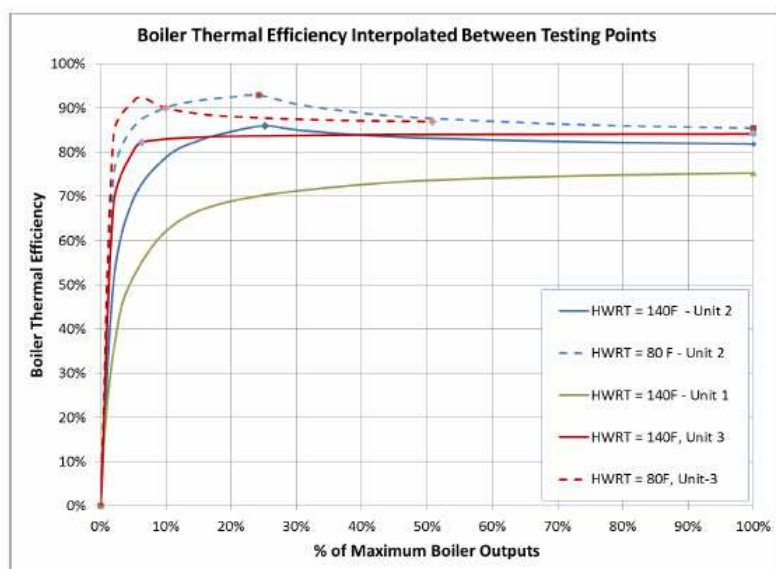
Exhibit 20 shows results of testing Unit #1 for thermal efficiency at full load and varying boiler entering temperatures. The recirculation pump on this boiler maintained a delta temperature of 15F. The normal 155P test procedure calls for a deltaT of 40F unless otherwise provided by an internal recirculation pump.

Exhibit 20: 155P Boiler Research Project - Unit 1 Thermal Efficiency



The rated thermal efficiency of this boiler (as provided by BTS-2000) is not stated in the document, however, this exhibit illustrates differences in thermal efficiency between a projected 80F EWT versus 140 to 180F.

Exhibit 21 shows the tested thermal efficiency of each Unit interpolated between testing points. This figure further illustrates differences in thermal efficiency on condensing boilers having varied return water temperatures.

Exhibit 21: 155P Boiler Research Project – Unit 1, 2, 3 Thermal Efficiency

ETools – Boiler

The 155P Standard has been in various stages of development over the past 20 years with many delays. Other standards or codes such as the Ontario Building Code provide a requirement for Thermal Efficiency but do not address Seasonal Efficiency. In the absence of an industry standard or code related document, and realizing the unrealistic values provided by current efficiency standards, Enbridge developed its own methodology for estimating the ASE of commercial boiler systems. Development was a combined effort of 3rd party consultants with expert knowledge of boiler systems and operation.

The original customised version of their own ASE calculation was developed in 2000. It was then incorporated into Version 1.0 of the Commercial ETools-Boiler software program in 2002. The software is updated/revised on an as-needed basis. Each new version generally will include updated boiler information. A brief summary of major updates is included in Table 2.

Table 2: ETools – Update Summary

Version	Update/Revision
1.00, 2002	Initial Release
2.01, 14-May-10	The % of Condensing is calculated and shown for the Lead-Lag analysis. A separate section for Lag Seasonal Efficiency was added. Thermal Efficiency now uses Output/Input instead of manufacturer's published value.
3.00, 03-Jul-10	Boiler savings are calculated from either a Base Case (Replacement) boiler scenario or the existing (Advancement) boilers depending on the reasons for boiler change-out.
3.23, 06-Oct-11	Space Heating Seasonal Efficiency was changed to allow 4 levels of I/O

	Controls: None, Traditional, Characterized, BAS instead of previous None, Old, New.
4.21, 01-Feb-14	Current version.

General Methodology

The software starts with historical gas consumption from the customer. The user collects information from the customer regarding the boiler system and operation of the existing boiler plant as well as proposed equipment and operation of the new plant. Natural gas savings are based on the difference in ASE between the existing and proposed boiler plant applied to the existing gas consumption.

The software does not just consider solely the packaged boiler itself but rather the entire boiler system including equipment and operation.

There are circumstances when the ASE for a 'Base Case' boiler plant is used instead of that from the actual existing plant. This occurs for the following reasons:

- New construction.
- Boiler is beyond its effective life.
- Boiler is inoperable.
- Owner has planned and budgeted to replace in the current year.

Base Case values have been determined in the Markbek 2011²⁵ report on pages 21-26 prepared for Enbridge. This report had four objectives:

1. background research into boiler technology, codes and standards
2. boiler market study
3. review of Enbridge's ETools software, and development of a baseline methodology for the ETools inputs.

The Marbek study determined baseline values by a combination of published research, market study feedback, and industry knowledge.

All software calculations are done using Imperial values and equations.

The software includes individual calculations for both space heating and domestic hot water boiler plants. The ASE methodology used within the ETools software was developed in consideration of work being done on Standard 155P. ETools does however use its own methodology as 155P had not been completed at the time of ETool development (or since),

Standard 155P does not include domestic hot water applications. However, it is logical that many of the same variables that effect system efficiency on a seasonal basis will similarly do so on a non-seasonal basis. Calculations are similar with any differences noted throughout.

ETools – Boiler Selection Tool

The Boiler Selection Tool allows the user to select the boiler information for an existing system as well as either a new or lead-lag type system. Inputs include; manufacturer, model and quantity of boilers. A database of commercially available boiler manufacturers and models with rated inputs and thermal efficiencies is built into the software and is updated on an annual basis. A listing of this database is included in the Appendices. The user also has the ability to enter boiler information not included within the database.

Two boilers can be input for each system, ie., Existing #1 and Existing #2 for the Existing System. This allows the user to define up to two different types of boilers within the same boiler plant. These systems are herein referred to as System #1 and System #2 throughout this section.

Figure 1: Sample Screen Shot of Boiler Selection Tool

The screenshot shows the 'Boiler Selection Tool' interface. At the top, there are tabs for 'Boiler Selection', 'Seasonal Efficiency', and 'Base Case'. Below these, the 'Existing System' section is highlighted in green. It contains a table with columns: Manufacturer, Model, Qty, Unit Input ('000 Btu/h), Total Input ('000 Btu/h), Thermal Efficiency (%), Heating Output ('000 Btu/h), Seasonal Efficiency (%), Estimated Annual Gas Usage (m3), and Base Case Gas Usage (m3). The table is divided into 'Space Heating (Seasonal)' and 'Domestic Hot Water (Non-Seasonal)' sections. Each section has rows for 'Existing #1' and 'Existing #2' with dropdown menus for Manufacturer and Model, and input fields for Qty and Unit Input. The 'Total Input' and 'Thermal Efficiency' columns show calculated values. The 'Seasonal Efficiency' column shows a value of 0.00%. The 'Estimated Annual Gas Usage' and 'Base Case Gas Usage' columns show values of 0.0 and 0.0 respectively. A 'Sub-Total' row is also present. The 'New System' section is highlighted in yellow and has a similar table structure, but with an additional 'Est. Annual Gas Savings (m3)' column. The interface also includes a 'Project ID' field and a 'Business Partner' field.

Total System Input

The total input is calculated as the sum of the inputs as shown in equation #1.

Equation 1: Boiler Selection – Total Input

$$Total\ Input = (Qty \times Unit\ Input)_{System\#1} + (Qty \times Unit\ Input)_{System\#2}$$

where,

Total Input = ('000 Btu/h)
 Qty = number of boilers
 Unit Input = the unit input of each boiler ('000 Btu/h)

Thermal Efficiency

The thermal efficiency is calculated from the unit output and input values read from the database as in equation #2. This is done individually for System #1 and #2.

Equation 2: Boiler Selection – Thermal Efficiency

$$\text{Thermal Eff} = \frac{\text{Unit Output}}{\text{Unit Input}} \times 100\%$$

where,

Thermal Eff	= steady state thermal efficiency as per BTS-2000 (%)
Unit Output	= the unit output of each boiler ('000 Btu/h)
Unit Input	= the unit input of each boiler ('000 Btu/h)

Combined Thermal Efficiency

The combined thermal efficiency is calculated based on the ratio of System #1 and System #2 proportional total input as shown in equation #4.

Equation 3: Boiler Selection – Combined Thermal Efficiency

$$\text{CombinedThermEff} = \frac{\text{UnitInput}_{\text{System\#1}}}{\text{TotalSysInput}} \times \text{ThermEff}_{\text{System\#1}} + \frac{\text{UnitInput}_{\text{System\#2}}}{\text{TotalSysInput}} \times \text{ThermEff}_{\text{System\#2}}$$

where,

CombinedThermEff	= Combined Thermal Efficiency (%)
Unit Input	= the unit input of System #1 or #2 ('000 Btu/h)
TotalSysInput	= the total system input ('000 Btu/h)
ThermEff	= thermal efficiency of System #1 or #2 (%)

ETools – ASE

The estimated Annual Seasonal Efficiency is based on several variables encompassing system design, management, control and operation as included in Figure 2 and Figure 3. A description of each variable, the methodology used for ETool calculation and supporting reference documentation is included in this section. Page or figure numbers of supporting documents have been provided throughout for ease of reference data location.

In general, supporting documentation does not specifically present prescriptive values for the variables. Values are determined from a combination of information provided by published literature and combined knowledge by industry experts during development.

Figure 2: ASE – Boiler Heating Selection

ETool Version: 0-Jan-00

Seasonal Efficiency							
Project ID: 0		Business Partner: 0		Address: 0		Customer: 0	
ESC Name: 0		Date: 0-Jan-00					
Space Heating							
Return To Selection	Existing Selection	Loss %	New Selection	Loss %	LEAD Selection	Loss %	LAG Selection
Boiler Thermal Efficiency	0.0 %		0.0 %		0.0 %		0.0 %
Boiler Pumping**	Continuous		Intermittent		Intermittent		Intermittent
Flue Damping*	None		None		None		None
Oversizing Ratio [Calculated]	1.0	[N/A]	1		1		1
Total # Heating Stages	1		1		1		1
Max Design Supply Water Temperature**	180 F	14.40 %	140 F	2.75 %	160 F	4.71 %	180 F
Max Design Return Water Temperature**	160 F	0.00 %	120 F	0.00 %	130 F	0.00 %	160 F
NO Control with Reset**	Traditional	2.00 %	BAS	0.00 %	BAS	0.00 %	BAS
A/F Control*	None	3.20 %	None	3.20 %	None	3.20 %	None
Purge Cycles**	None	0.00 %	None	0.00 %	None	0.00 %	None
Total losses		19.60 %		5.95 %		7.91 %	
Control Portion [Savings]	Control Portion	14.80 %	Control Savings	13.65 %	Control Savings	11.69 %	Control Savings
Estimated Seasonal Efficiency		0.00 %		0.00 %		0.00 %	

* Values set from Database, ** Values Used For Control Upgrade

Figure 3: ASE – Boiler DHW Selection

Domestic Hot Water							
Return To Selection	Existing Selection	Loss %	New Selection	Loss %	LEAD Selection	Loss %	LAG Selection
Boiler Thermal Efficiency	0.0 %		0.0 %		0.0 %		0.0 %
Boiler Pumping**	Continuous		Intermittent		Intermittent		Intermittent
Flue Damping*	None		None		Burner Fan		None
Oversizing Ratio	1		1		1		1
Total # Heating Stages	1		1		1		1
Supply Water Temperature**	150 F	7.33 %	140 F	2.75 %	140 F	1.10 %	140 F
Return Water Temperature**	130 F	0.00 %	120 F	0.00 %	120 F	0.00 %	120 F
Controls**	Old	1.40 %	New	0.00 %	New	0.00 %	New
A/F Control*	None	3.20 %	None	3.20 %	Modulating	0.00 %	None
Purge Cycles**	None	0.00 %	None	0.00 %	Pre and Post	1.80 %	None
DHW Tank Insulation	None	10.00 %	Good	4.00 %	Good	4.00 %	Good
Total losses		21.93 %		9.95 %		6.90 %	
Control Portion [Savings]	Control Portion	7.13 %	Control Savings	5.98 %	Control Savings	5.98 %	Control Savings
Estimated Seasonal Efficiency		0.00 %		0.00 %		0.00 %	

* Values set from Database, ** Values Used For Control Upgrade

Values for ASE variables are developed as a percentage loss subtracted from the boiler thermal efficiency.

Temperature Factor

A number of ASE variables are grouped together under the term ‘Temperature Factor’. These include:

- Boiler Pumping: the type of system pumping.
- Flue Damping: the method of boiler flue damping.
- Boiler Oversizing: the estimated boiler oversize versus design load.
- Flue Temperature: a value based on maximum supply water temperature.
- Maximum Supply Water Temperature: the maximum design supply water temperature.
- Number of Stages: the total combined number of stages for the boiler plant.

A factor is assigned to each variable then all factors are collated to provide a combined ASE reduction value. This factor, in part, addresses idle losses associated with a boiler system. Actual idle losses are difficult to determine other than by testing or monitoring. Standard 155P will provide an idle loss value to be used for ASE calculation.

A description of each variable is provided. A summary of supporting reference documentation is included at the end of this section.

Boiler Pumping

The user must select the method of boiler system pumping as either:

- Continuous: a flow-through system where water is continuously pumped through all boilers.
- Intermittent: a primary/secondary arrangement where water is only pumped through operating boilers.

Values for Boiler Pumping are as shown in Table 3.

Table 3: ASE – Boiler Pump Factor

User Selection	Boiler Pump Factor	Notes
Continuous	1	The supporting documentation does not provide specific values based on boiler pumping. In general, documentation reports on changes in idle losses due in part to boiler pumping.
Intermittent	0.5	

Flue Damping

The user must select the method of boiler flue damping. These values are included in the Boiler Database from information provided by the manufacturer. The options are:

- None: no flue damping is installed. This is largely for atmospheric boilers.
- Burner Fan: fan assisted combustion.
- Mechanical: mechanical damper.

Values for Flue Damping are provided in Table 4.

Table 4: ASE – Flue Damp Factor

User Selection	Flue Damp Factor	Notes
None	1	The supporting documentation does not provide specific values based on flue damping. In general, documentation reports on changes in idle losses due in part to flue damping.
Burner Fan	0.4	
Mechanical Damper	0.2	

Boiler Oversizing

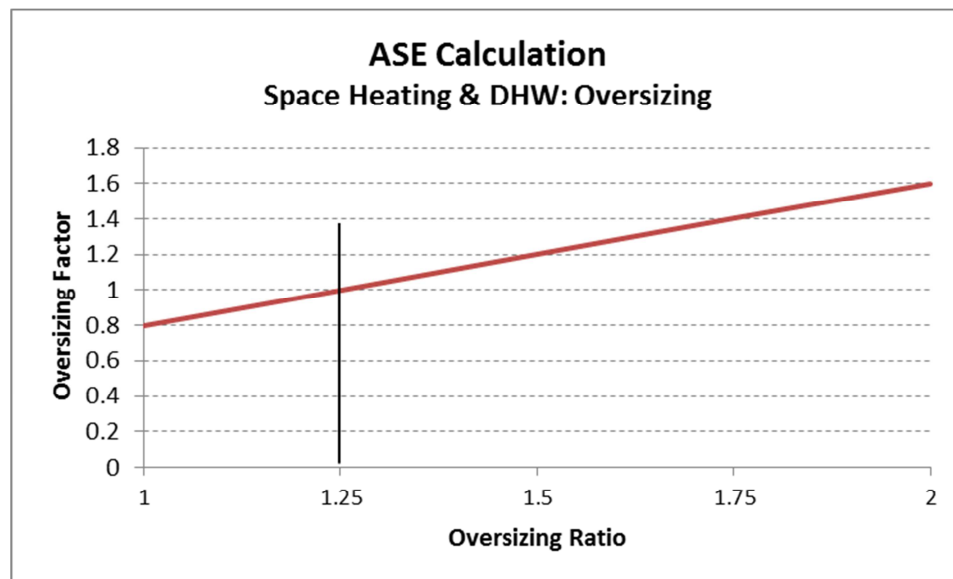
A factor is included for entering the boiler oversizing allowing a value between 1 and 2. This factor is adjusted by 0.8 as per Equation 4.

Equation 4: ASE – Boiler Oversize Factor

$$\text{BoilerOversizeFactor} = \text{Oversize Ratio} \times 0.8$$

This equation gives an Oversizing Factor of 1.0 with a boiler system having a design oversize of 1.25.

Figure 4: ASE – Oversizing Factor



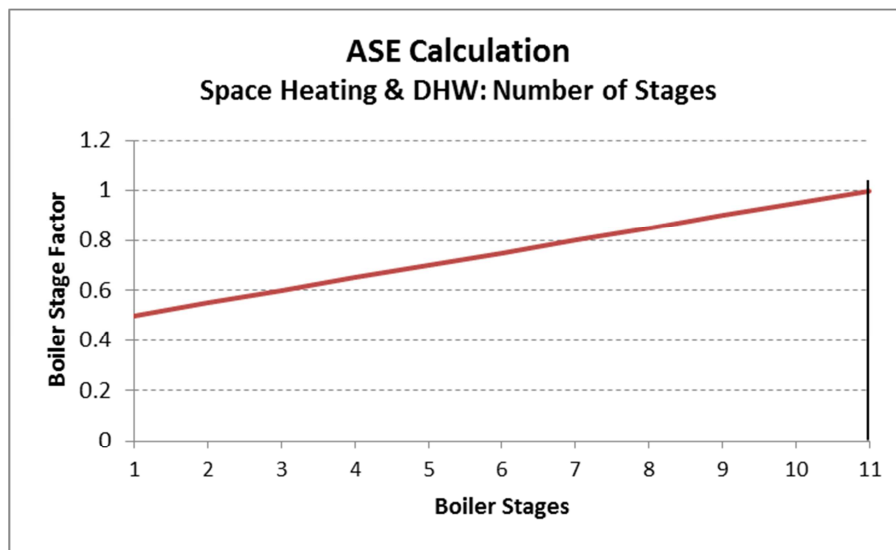
Number of Stages

The number of boiler stages is taken as a combination of the total number of boilers within the boiler plant as well as individual stages from each boiler read from the boiler database. For example, there are 4 stages in a boiler plant with 2 boilers each having 2-stage burners. Modulating boilers are assigned a value 11 and is the total maximum number of stages. A loss factor for the number of stages is calculated in Equation 5 and shown in Figure 5.

Equation 5: ASE – Boiler Stages Factor

$$BoilerStagesFactor = 0.5 + (0.05 \times \{NumStgs - 1\})$$

Figure 5: ASE – Number of Stages Factor



The other variables used in the Temperature Factor are divided by the Boiler Stages Factor. A higher number of stages thus reduce the combined loss from the ASE.

Max Design Supply Water Temperature

Two factors are provided for the maximum design supply water temperature and have been termed; Flue Loss Factor and SWT Loss Factor. These are itemized as separate equations for simplicity of accounting ASE within the calculations.

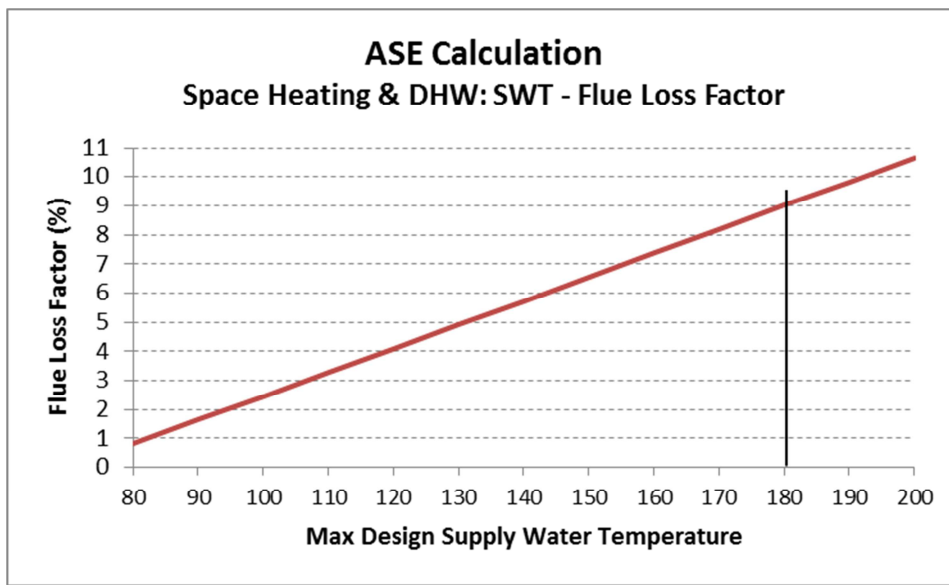
Flue Loss Factor

A value is included for flue losses based on the maximum design supply water temperature. Equation 6 and Figure 6 illustrate the Flue Loss Factor calculation and values.

Equation 6: ASE – Flue Loss Factor

$$FlueLossFactor = \frac{(SupplyWaterTemperature - 70)}{110} \times 9$$

Figure 6: ASE – Flue Loss Factor



Supply Water Temperature Loss Factor

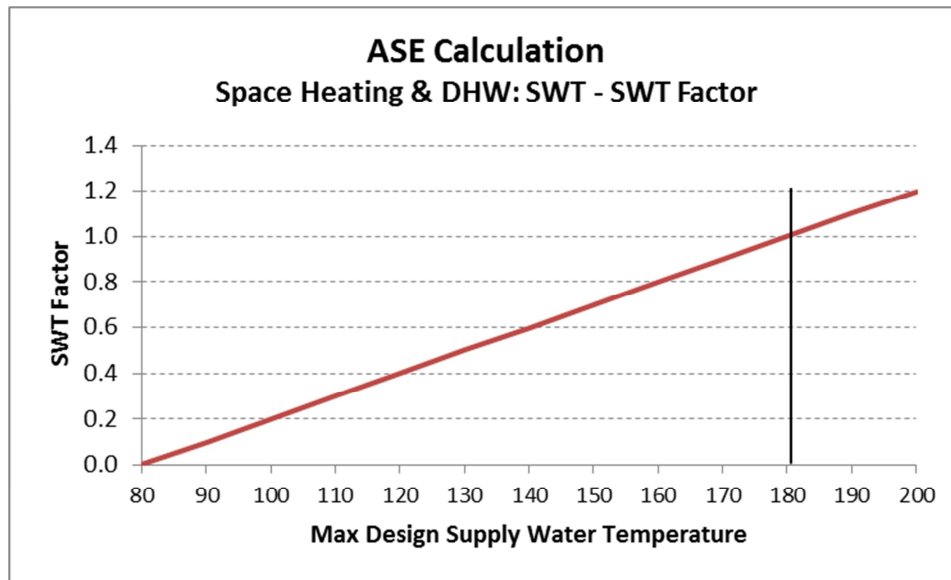
An additional adjustment value for the supply water temperature is included for further assessment of ASE. Values are shown in Equation 7 and Figure 7.

Equation 7: ASE – SWT Factor

$$SWTfactor = 0.1 + \left(\frac{MaxSupplyWaterTemp - 90}{100} \right)$$

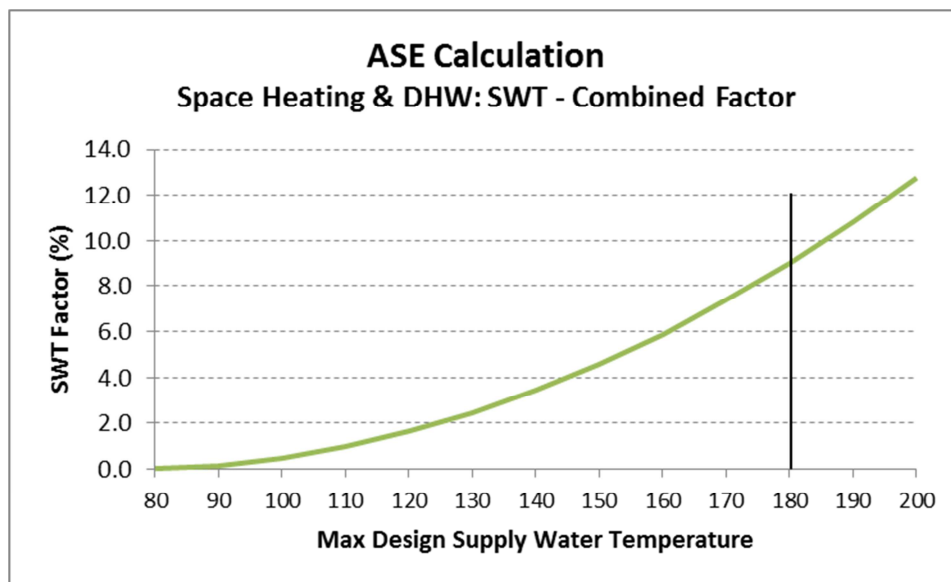
This equation has the effect of providing a value of 0.1 for a maximum supply water temperature of 90°F and proportionally to a value of 1.2 for a water temperature of 200°F. A maximum supply water temperature of 80°F has a value of 0.05.

Figure 7: ASE – SWT Factor



The combination of Flue Loss Factor and SWT Factor based on supply water temperature is shown in Figure 8.

Figure 8: ASE – SWT – Combined Factor



Temperature Factor Calculation

The total Temperature Factor Loss is developed from a combination of all the above factors into Equation 8.

Equation 8: ASE – Temperature Factor Loss

$$\text{TemperatureFactor} = \frac{\text{BoilerPump} \times \text{FlueDamp} \times \text{OversizeFactor} \times \text{SWTfactor}}{\text{NumStagesFactor}} \times \text{FlueFactor}$$

Figure 9 shows Temperature Factors for several sample systems as provided in Table 5. This is intended to show the range of Temperature Factor values between low efficiency (System A), mid efficiency (System B) and high efficiency (System C) systems.

Figure 9: ASE – Temperature Factor

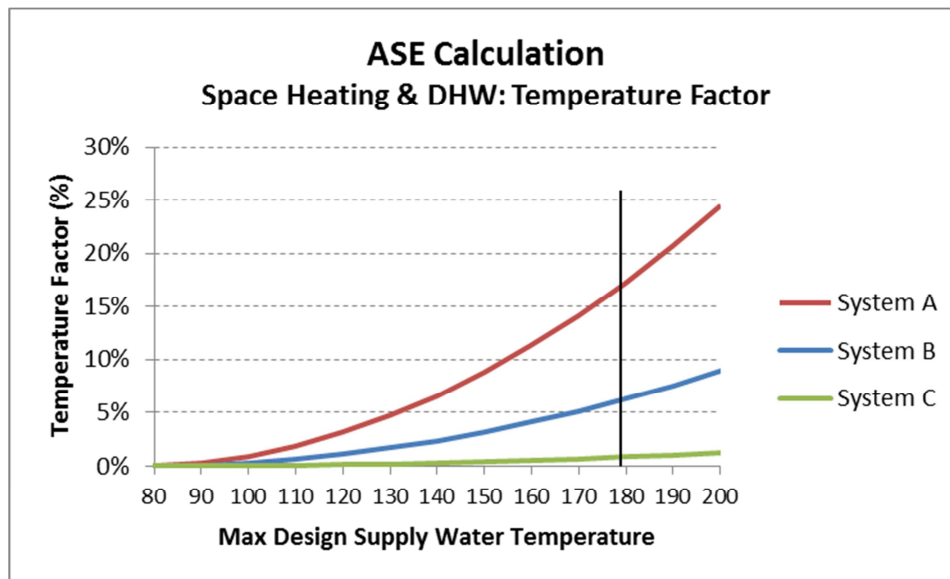


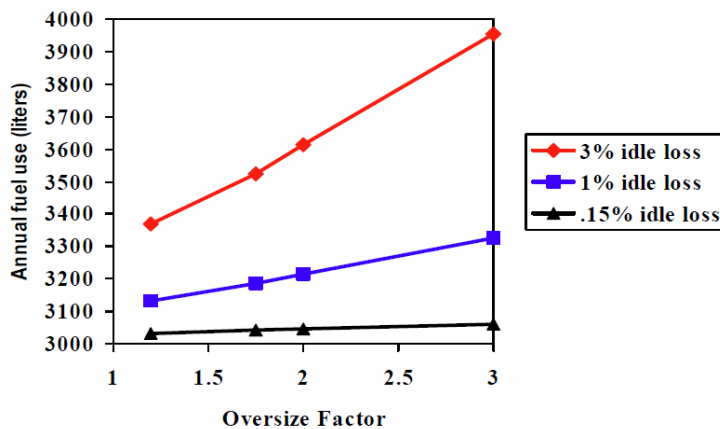
Table 5: ASE – Temperature Factor Loss – Sample Systems

Variable	System A	System B	System C
Oversize	1.2	1.2	1.2
Staging	Single	2-stage	Modulating
Pumping	Continuous	Continuous	Intermittent
Flue Damping	None	Burner Fan	Mech Damper

Supporting Documentation

Butcher et al 2006¹ performed a seasonal efficiency assessment of combination space heating and DHW systems considering idle losses. Idle losses were demonstrated to have a considerable impact on annual fuel use. A high efficiency system having 0.15% idle loss resulted in an annual efficiency 13.5% higher than the same system having an idle loss of 3%. A condensing system having 0.15% idle loss resulted in an annual efficiency 4.7% higher than the same system with a 1% idle loss. Butcher et al also showed the effects of oversize factor on annual fuel use as illustrated in Exhibit 22. Boiler systems with an idle loss of 3% had an annual fuel use of over 6% comparing an oversize factor of 2 versus about 1.2. The oversize factor had considerably less influence on a system having a very low idle loss.

Exhibit 22: ASE – Temperature Factor – Butcher 2006 Oversize (Figure 10)



Dutt 1990² presents that the California Energy Commission recommends no more than 30% over-sizing (page 41). When the boiler is operating, the system loses heat from exhaust gases up the stack, losses from the jacket, and the distribution system. When the burner is off, heat losses continue both from losses up the stack and from continuously burning pilots. With an oversized system, the burner is off for a greater proportion of time and off-cycle losses are higher resulting in higher overall losses. Higher efficiency systems having a vent damper or fan assist and intermittent ignition reduce off-cycle losses and effect of over-sizing (page 41). A study conducted by the Oak Ridge National Laboratory (ORNL) found that electronic ignition and electric vent dampers resulted in a 5% net reduction in the Normalized Annual Consumption (page 55). Of the 5%, the electronic ignition savings is 4% and 1% for vent damper retrofit.

Kweller and Mullis 1981⁴ show annual efficiency increases between 1% and 9% using vent dampers on gas-fired space heaters and furnaces for single-stage or modulating operation (page 753).

Katrakis and Zawacki 1993⁵ illustrate the impact of oversizing by showing the dramatic reduction in part-load efficiency of intermediate sized steam boilers as the fraction on-time goes below 20%. Three of five buildings with seasonal efficiencies below 65% had fraction on-times of less than 15%. These buildings were oversized by an average of 78%. Average oversizing of the 11 buildings monitored was 61% (page 434).

Landry, Maddoz and Bohac 1993⁶ found significant variations in off-cycle loss rates from changes in boiler temperature, outside temperature, and boiler cycling frequency. The increase in modeled loss rate with decreasing outside temperature is caused by increasing load effects and/or changing heat loss from external forces (page 452).

Macriss and Zawacki 1981⁷ present results of a field study to assess the effectiveness of energy conservation measures on residential boilers. A group of 11 sites showed steady-state efficiency savings of 4.5% when the boiler size was reduced by 18% (Table 3, page 813).

Butcher 2011¹⁰ further demonstrates the effects of idle loss and oversize factor on annual efficiency as provided on page 40 of the article and shown in Exhibit 23 below.

Exhibit 23: ASE – Temperature Factor – Butcher 2011 Idle & Oversize

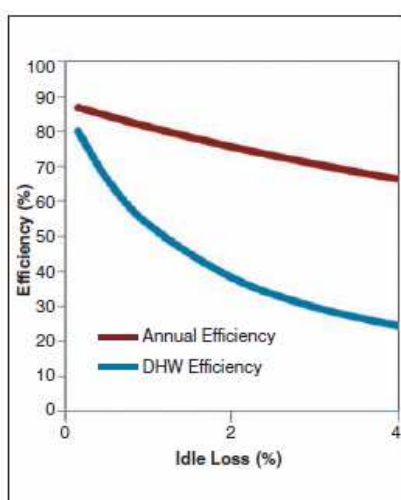


Figure 3: Example results of the impact of idle loss. (Assumed thermal efficiency is 88%; location is Albany, N.Y.; design day heat load is 40,000 Btu/h [11.7 kW], system maximum output is 110,000 Btu/h [32.2 kW], domestic hot water load is 64.3 gallons/day [243 L].)

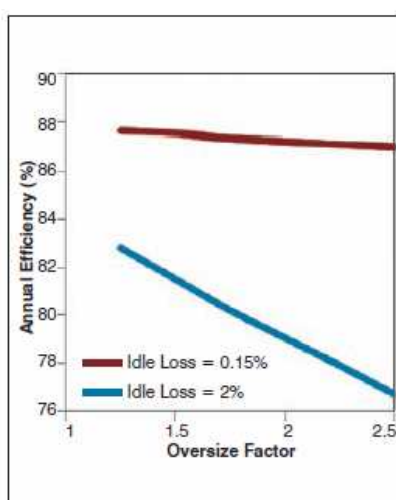


Figure 4: Example results. Effect of system oversize on annual efficiency at two different idle loss levels. (Assumed thermal efficiency is 86%; location is Albany, N.Y.; design day heat load is 40,000 Btu/h [11.7 kW]; domestic hot water load is 64.3 gallons/day [243 L].)

Durkin 2006¹¹ states that existing buildings were originally designed around a traditional SWT of 180F with a deltaT of around 20F (page 54).

Eoff 2008¹² projects that boilers tend to be oversized typically 5% for every engineer who touches the design (page 43).

Exhibits by Hewett 2000¹³ provide support for several ASE variables. Exhibit 12 indicates a change in ASE of about 3%, 6%, and 9% for idle energy input rates of 1.0%, 2.0% and 3.0% respectively from a single boiler having a single stage burner and 30% oversizing with no cutout. Exhibit 14 indicates the difference between ASE and Steady-State Efficiency is affected by sizing ratio and idling energy input rate with values between 2-11% for idle input rates between 1.0% and 3.0% and oversizing up to 1.6. Exhibit 15 illustrates changes in ASE using multiple boilers with P/S Pumping versus a single boiler with the same

idling energy input rate, 76% SSE and 30% oversizing. Changes range from 2.0% to about 8.5% with oversizing from 1.1 to 1.6 and idle energy input from 1-3%.

Max Design Return Water Temperature

The ASE loss from the Max Design Return Water Temperature is based on several system parameters including:

- SWT: the Max Design Supply Water Temperature as defined by the user.
- RWT_{ave} : a weighted average of the Max Design Return Water Temperature. This value is dependent on the type of control being used. Further description of this value is provided below.
- Thermal Efficiency: the Boiler Thermal Efficiency.

RWT_{ave}

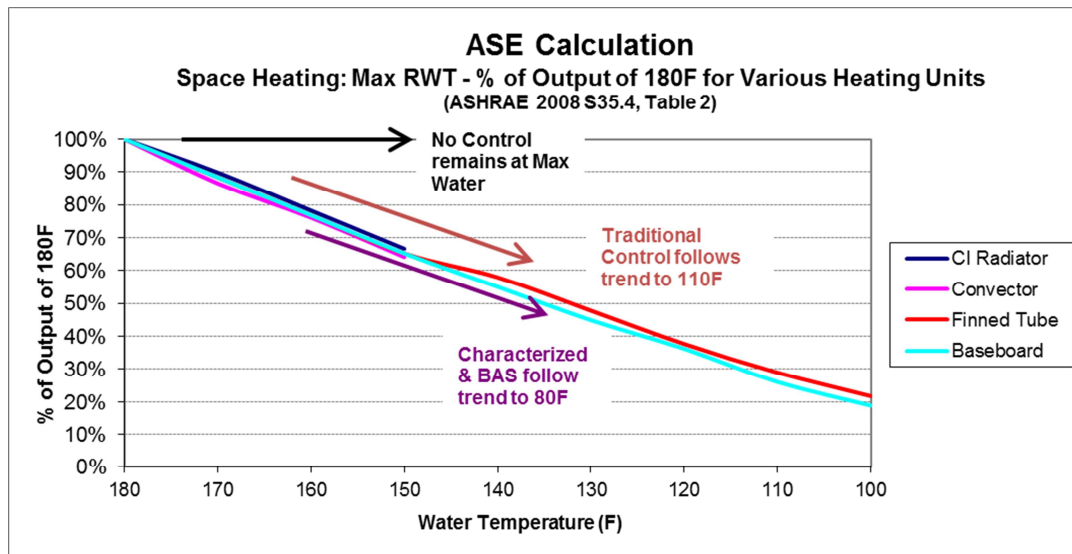
For space heating applications; the RWT_{ave} value accounts for the type of control being used as follows:

For None/None Functioning controls; The RWT_{ave} value equals the selected Max Design Return Water Temperature.

For Traditional, Characterized and BAS Controls, the SWT is allowed some adjustment based on building load. The RWT is correspondingly adjusted. For Traditional Controls, the RWT ranges from a maximum RWT at the specified Max Design Return Water Temperature for 100% building load, to a minimum RWT of 110F at 0% building load. Characterized and BAS Controls allow the RWT to go to a minimum of 80F at 0% building load.

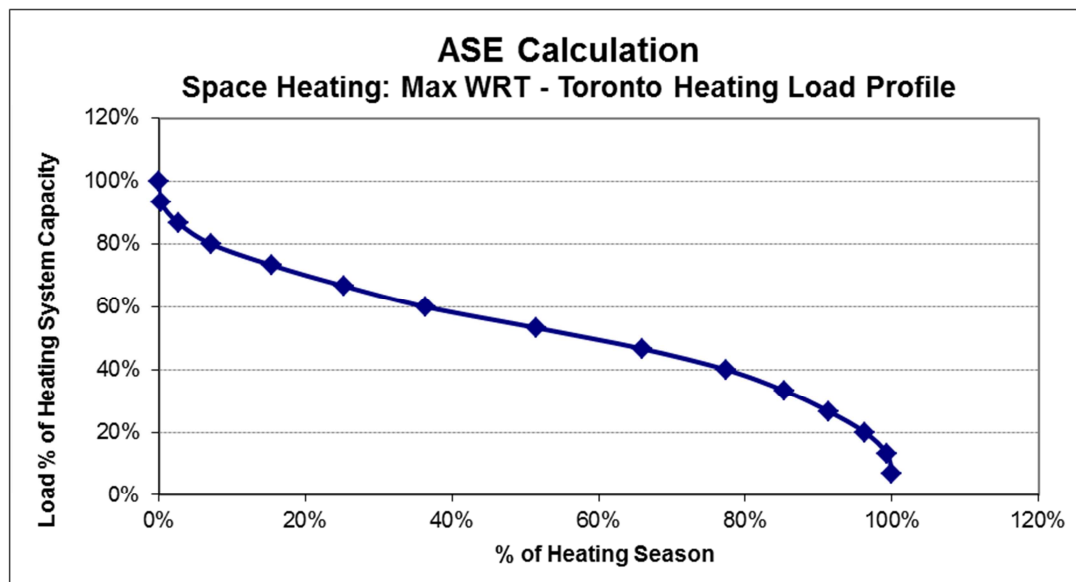
The output for various terminal units from a rated temperature of 180F is shown in Figure 12. These values are provided by ASHRAE 2008 S35.4, Table 2 for various heating units using an inlet air temperature of 65F.

Figure 10: ASE – Max RWT - % of Terminal Unit Output



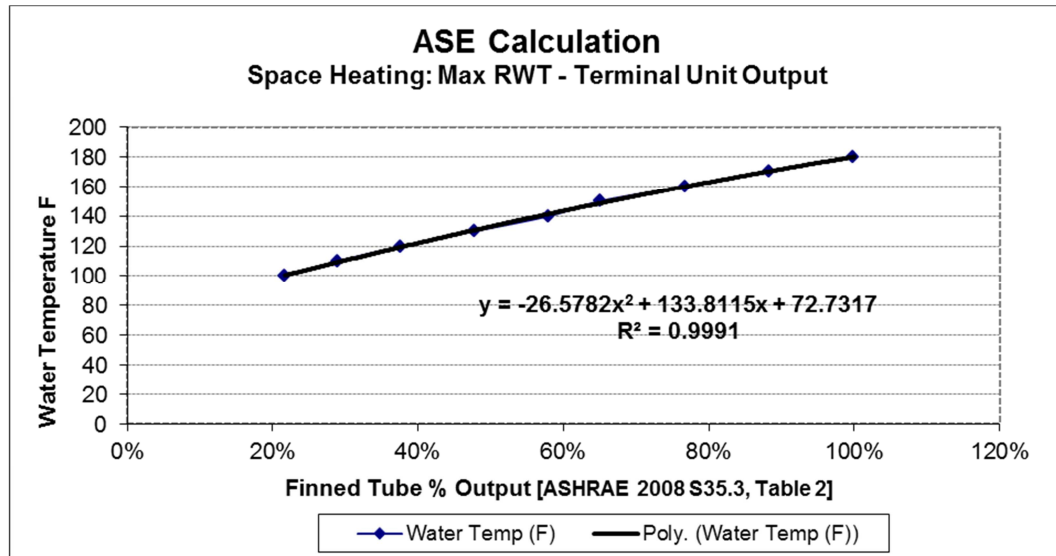
BIN temperatures and hours are used to define the load profile from 100% load to 0% load. The load profile for Toronto (for example) is provided in Figure 11.

Figure 11: ASE – Toronto BIN Heating Load Profile



An equation for a finned tube convector with an inlet air temperature of 65F was developed relating water temperature to percentage of output as provided in Figure 12. The water temperature from the terminal unit is considered at each BIN temperature and a weighted average temperature is determined over the entire load profile. This weighted water temperature becomes the RWT_{ave} value used as a parameter for the Max Design Return Water Temperature.

Figure 12: ASE – Max RWT - Terminal Unit Water Temperature



Sample values are provided in Table 6 for determining the RWT_{ave} of 101F for a system having Characterized Controls and a Max RWT of 160F.

Table 6: ASE – Max RWT – Weighted Ave

Bin Temperatures			Existing Boiler: Characterized Control, 160F Max RWT	
°F	Hrs/Year	% of Bldg Heat Loss	Design RWT (F)	Weighted RWT (F-hrs)
-25	0	0%	0	-
-20	0	0%	0	-
-15	0	0%	0	-
-10	0	0%	0	-
-5	1	100%	160	160
0	6	93%	154	927
5	67	87%	149	9,966
10	138	80%	143	19,702
15	274	73%	137	37,418
20	366	67%	130	47,628
25	463	60%	123	57,158
30	707	53%	117	82,390
35	789	47%	109	86,311
40	741	40%	102	75,585
45	629	33%	94	59,364
50	624	27%	87	53,994
55	724	20%	80	57,920
60	749	13%	80	59,920
65	669	7%	80	53,520
Sum:	6947	Weighted Ave RWT:		101

For Domestic Hot Water, the RWT_{ave} value equals the selected Max Design Return Water Temperature.

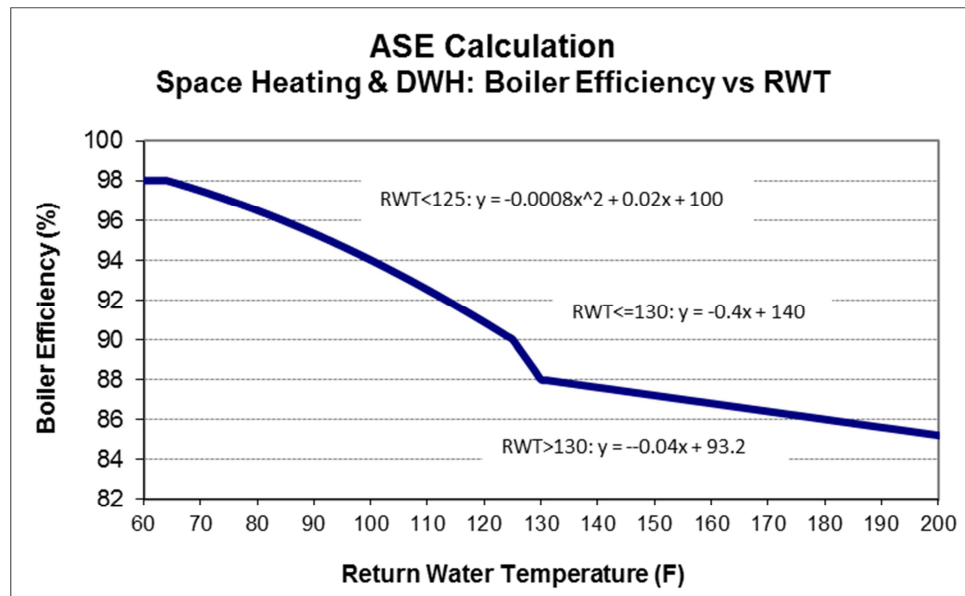
Max RWT Calculation

The calculation for the Max RWT, in part, accounts for the efficiency of a boiler plant based on the RWT as per Exhibit 7. Equations were developed for three sections of the boiler efficiency versus RWT relationship as shown in Figure 13 and Table 7.

Table 7: ASE – Boiler Efficiency vs RWT Equations

RWT Section	Boiler Efficiency (y) vs RWT (x) Equation
< 125F	$y = -0.0008x^2 + 0.02x + 100$
125F to ≤130F	$y = -0.4x + 140$
> 130F	$y = -0.04x + 93.2$

Figure 13: ASE – Boiler Efficiency vs RWT

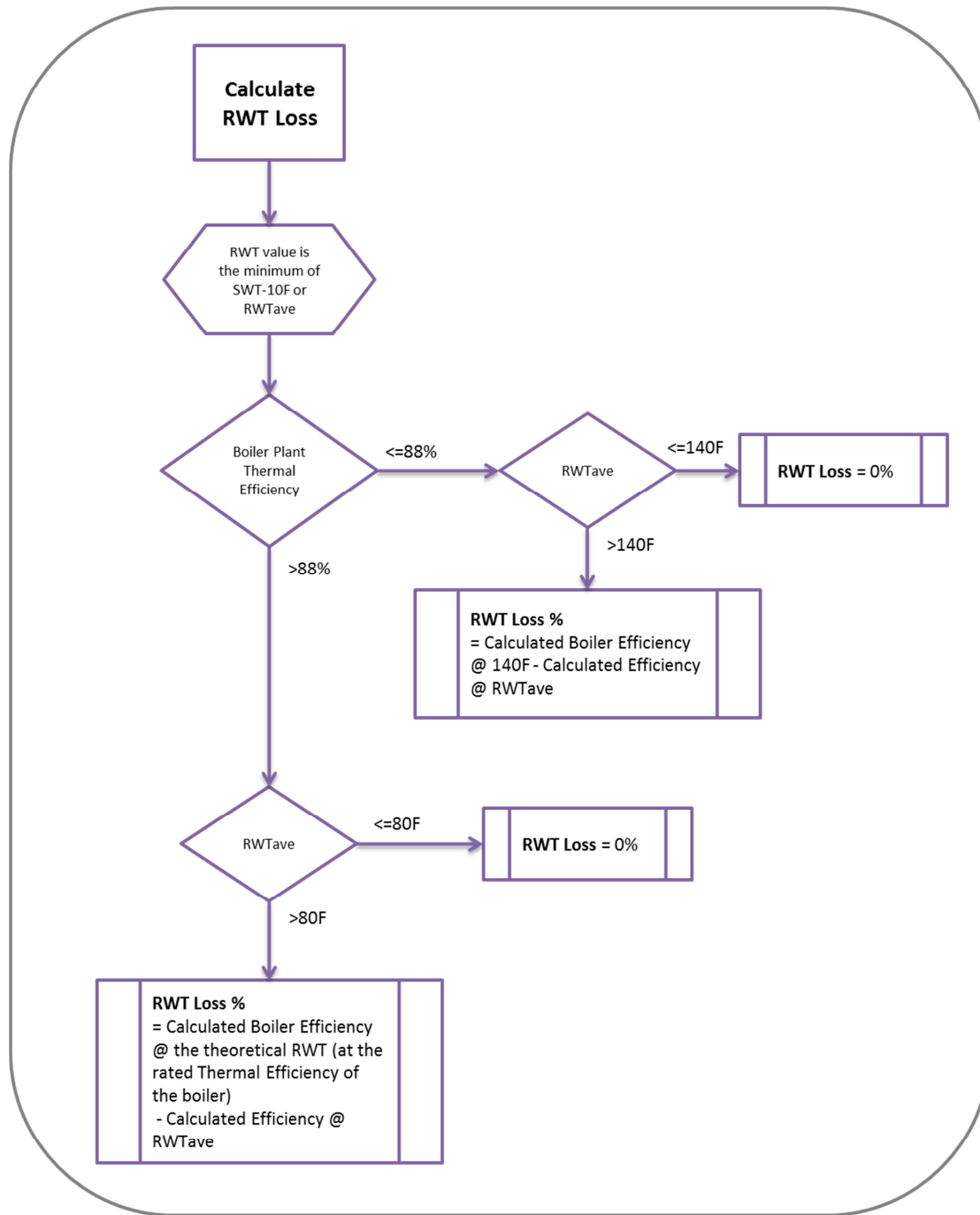


The process used for the calculation of the ASE loss based on the Max RWT is as illustrated in the flow chart of Figure 14. The calculated boiler efficiency at various return water temperatures uses the equations developed in Table 7.

For boilers less than 88% thermal efficiency; losses are based on the difference in theoretical efficiency between RWT's of 140 and RWT_{ave} .

For boilers above 88% thermal efficiency; losses are determined as the difference in efficiency from that at the theoretical RWT and RWT_{ave} . The theoretical RWT (at the rated Thermal Efficiency of the boiler) is that RWT which results from the equations above. For example; a boiler with a rated Thermal Efficiency of 90% would have a theoretical RWT of 122F.

Figure 14: ASE – RWT Loss Flowchart



Supporting Documentation

From Durkin 2006¹¹, Standard 90.1 says that the heating system should operate at its lowest possible water temperature, which for conventional boilers would be 140F RWT. Condensing boilers can operate at low RWT and would be limited by the building heating system design (page 53).

Controls

Control selection is unique for space heating and domestic hot water systems.

Space Heating: I/O Control with Reset

There are four control selections:

- None/Non-Functioning: the boiler has basic on/off control.
- Traditional: on/off control with some ability to adjust supply water temperature.
- Characterized: control includes characterized reset curves allowing full adjustment of SWT.
- BAS: Building Automation System with reset capability allowing full adjustment of SWT.

The reduction in ASE is dependent on both the type of control and the maximum supply water temperature. Initial reduction values are assigned to each type of control using a supply water temperature of 180F and then adjusted with a loss factor based on changing water temperature. This gives the effect of increasing the loss for higher temperatures and less loss for lower temperatures. The reduction at 180F for each control type is shown in Table 8. Values over the entire water temperature range are included in Table 9 and Figure 15.

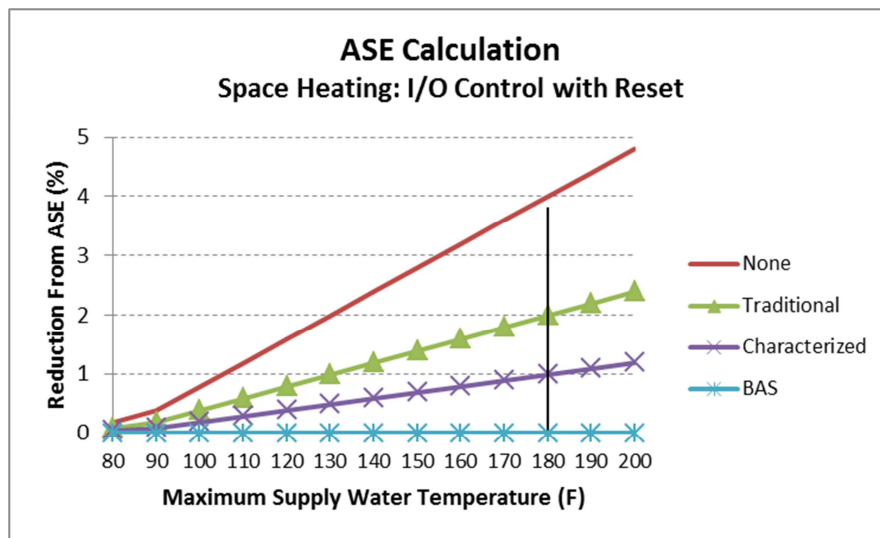
Table 8: ASE – Space Heating - I/O Controls with Reset Selection

User Selection	ASE Reduction @ 180F (%)	Notes
None/Non-functioning	4%	Hewett shows savings between 13-18% for reset controls. Landry shows savings of 4%. ACEEE suggests savings of 6-8% for reset on conventional boilers and up to 20% on condensing boilers.
Traditional	2%	
Characterized	1%	
BAS	0%	

Table 9: ASE – Space Heating – Controls Factor

SWT (F)	% Loss Factor	ASE Reduction (%)			
		None	Traditional	Characterized	BAS
80	5%	0.2	0.1	0.05	0
90	10%	0.4	0.2	0.1	0
100	20%	0.8	0.4	0.2	0
110	30%	1.2	0.6	0.3	0
120	40%	1.6	0.8	0.4	0
130	50%	2	1	0.5	0
140	60%	2.4	1.2	0.6	0
150	70%	2.8	1.4	0.7	0
160	80%	3.2	1.6	0.8	0
170	90%	3.6	1.8	0.9	0
180	100%	4	2	1	0
190	110%	4.4	2.2	1.1	0
200	120%	4.8	2.4	1.2	0

Figure 15: ASE – Space Heating – I/O Control Factor



Supporting Documentation

Hewett 1984³ monitored eight multi-residential buildings to determine savings from reset and temperature cutout controls versus constant temperature control over two heating seasons. Constant temperature controls maintained water temperatures at 165F while the reset controls had fixed one-to-one reset ratios starting at 95F water for an outside temperature of 70F. All eight buildings had cast iron boilers ranging in input from 290,000 to 710,000 Btu/hr. Annual space heating savings for three of the buildings having combined automatic reset and cutout control was 18%. The five other buildings which previously had cutout control and varying degrees of manual reset control averaged 13% annual space heating savings (abstract).

Landry 1993⁶ estimated seasonal efficiency of 66% for a hot water boiler operated at a constant temperature versus 70% when the boiler temperature was varied using an outdoor reset control (page 452). The boiler was a cast iron, gas-fired water boiler with an input rate of 480,000 Btu/h having a stack efficiency of 81.5%. The boiler aquastat was set to maintain the boiler at a constant temperature of 180F. The reset control adjusted water temperature in such a manner that the sum of boiler water and outside temperature was 180F.

ACEEE 2006²⁶ suggests variable control savings based on the type of boiler, control and system. Reset controls on conventional boilers can save up to 6-8% while sophisticated controls on condensing boilers can save up to 20% (page 3).

Domestic Hot Water: Controls

There are four control selections:

- None/Non-Functional: the boiler is operating off of its limit switches.
- Old: standard, simple on/off control.
- New: new updated controls.

Similar to Space Heating, the reduction in ASE is dependent on both the type of control and the maximum supply water temperature. Initial reduction values are assigned to each type of control using a supply water temperature of 180F and then adjusted with a loss factor based on changing water temperature. This gives the effect of increasing the loss for higher temperatures and less loss for lower temperatures. The reduction at 180F for each control type is shown in Table 10. Values over the entire water temperature range are included in Table 11 and Figure 16.

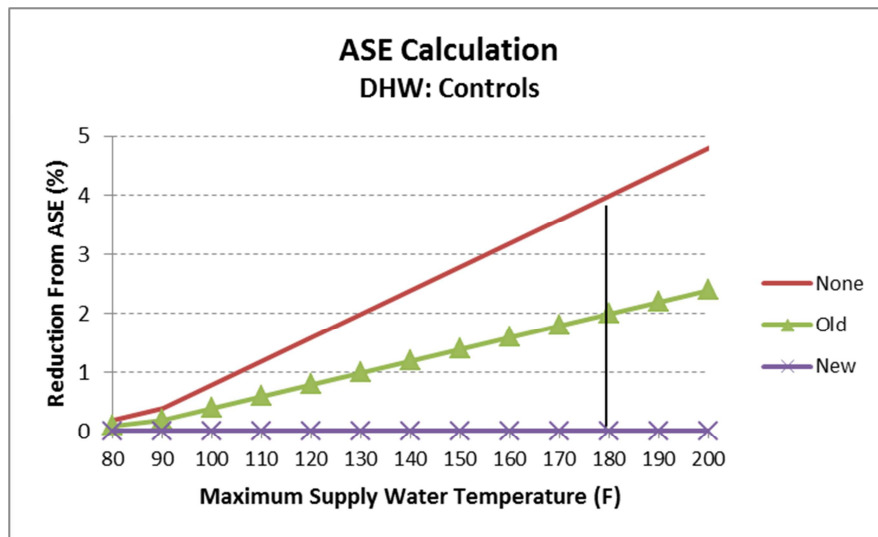
Table 10: ASE – DHW – Controls Selection

User Selection	ASE Reduction @ 180F (%)	Notes
None/Non-functional	4%	Hewett shows savings between 13-18% for reset controls. Landry shows savings of 4%. ACEEE suggests savings of 6-8% for reset on conventional boilers and up to 20% on condensing boilers. These were all for space heating systems but the intent remains.
Old	2%	
New	0%	

Table 11: ASE – DHW – Controls Factor

SWT (F)	% Loss Factor	ASE Reduction (%)		
		None	Old	New
80	5%	0.2	0.1	0
90	10%	0.4	0.2	0
100	20%	0.8	0.4	0
110	30%	1.2	0.6	0
120	40%	1.6	0.8	0
130	50%	2	1	0
140	60%	2.4	1.2	0
150	70%	2.8	1.4	0
160	80%	3.2	1.6	0
170	90%	3.6	1.8	0
180	100%	4	2	0
190	110%	4.4	2.2	0
200	120%	4.8	2.4	0

Figure 16: ASE – DHW – Controls Factor

**Supporting Documentation**

The same supporting documentation as for space heating is considered for domestic hot water.

Although reset control is not applicable to DHW there remains the intent that improved controllability results in improved seasonal efficiency.

A/F Control

An allowance is provided for the method of air/fuel control of the boiler plant. ASE losses based on the type of A/F control are included in Table 12. The determination for A/F Control is obtained from the Number of Stages of the boiler plant.

Table 12: ASE - A/F Control Factor

A/F Control	AF Control Loss (%)	Description	Notes
None	3.2	Number of Stages = 1	The supporting documentation does not provide specific values based on A/F Control. Collver 2010 ²⁴ provides estimates between 2-4% when increasing from 1 to 2 stages and 10-12% with stages over 6.
Staged	2	Number of Stages >1 and <11	
Modulating	0	Number of Stages = 11 (Modulating)	

Supporting Documentation

ASHRAE 2012¹⁶ states that traditionally, most burner installations used a single actuator to adjust both air and fuel control. Current technology allows individual actuators to ensure efficient combustion throughout the firing range (page 32.7).

Collver 2010²⁴ estimates savings from Staged to None at 2-4% and 10-12% from more than 6 stages to None (page 6).

Purge Cycles

The type of boiler purge is considered as a variable for ASE. The method of boiler purge is contained in the boiler database from information provided by the manufacturer. This variable is based on the method of purge as defined in Table 13.

Table 13: ASE - Purge Cycles

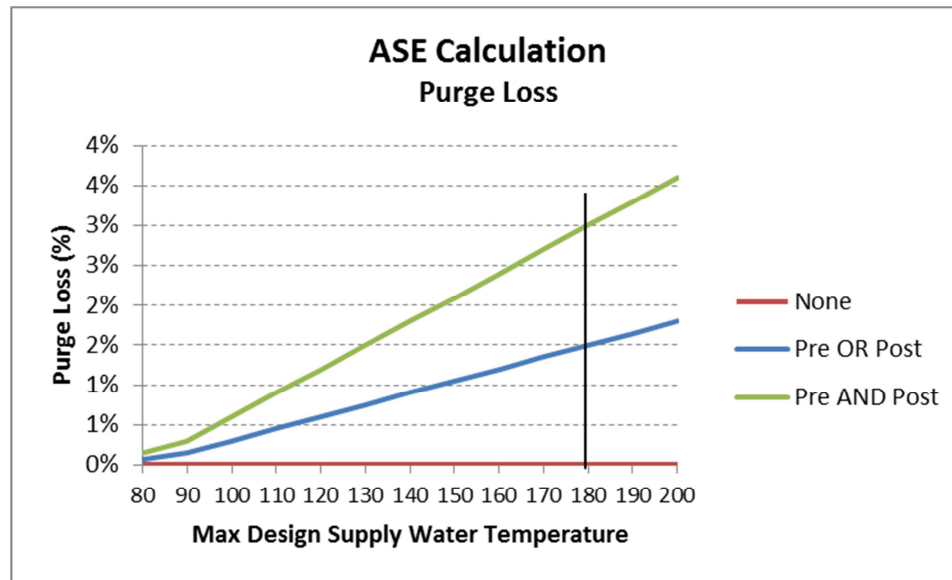
Purge Method	Purge Loss Factor	Notes
None	0	The supporting documentation does not provide specific values based on Purge cycles. In general, documentation reports on changes in idle losses due in part to purge losses.
Pre OR Post	1.5	
Pre AND Post	3	

The Purge Loss Factor is multiplied by the Supply Water Temperature Factor from Equation 7. Values over the entire water temperature range are included in Table 14 and Figure 17.

Table 14: ASE – Purge Loss

SWT (F)	Purge Loss (%)		
	None	Pre OR Post	Pre AND Post
80	0.0%	0.1%	0.2%
90	0.0%	0.2%	0.3%
100	0.0%	0.3%	0.6%
110	0.0%	0.5%	0.9%
120	0.0%	0.6%	1.2%
130	0.0%	0.8%	1.5%
140	0.0%	0.9%	1.8%
150	0.0%	1.1%	2.1%
160	0.0%	1.2%	2.4%
170	0.0%	1.4%	2.7%
180	0.0%	1.5%	3.0%
190	0.0%	1.7%	3.3%
200	0.0%	1.8%	3.6%

Figure 17: ASE – Purge Loss



Supporting Documentation

Purge loss is based on the boiler requiring either a Pre and/or Post purge. Pre purge ensures adequate airflow in the gas chamber before the burner fires while Post purge ensure the exhausting of flue gas gases immediately after the burner turns off. Purge times are generally in the 15 to 60 second range. Losses result since these gases contain boiler heat. Quantifying the purge loss is entirely dependent on the amount of boiler cycling. Documentation has not been found which isolates the purge losses, however, the purge losses as provided in Table 13 allow a conservative estimate of savings between traditional boilers and high efficiency or condensing boilers. Traditional boilers generally do not have purge cycles while high efficiency boilers will have either Pre and/or Post and Condensing boilers will have Pre and Post.

Eoff 2008¹² discusses purge operation such that each time a boiler cycles off, it drafts cold combustion air during the post purge and standby periods. When the boiler is cycled on, more cold air is moved through the boiler to purge the boiler of possible combustibles prior to ignition. All the heat lost to purging has to be recouped by the boiler. It is not uncommon to see small boilers cycle up to 10 times per hour (page 43).

DHW – Tank Insulation

The method of storage and quality of tank insulation of DHW systems is considered for the ASE. This is based on selections and losses included in Table 15. The quality of tank insulation is a subjective value as determined by the user.

Table 15: ASE – DHW – Tank Insulation

Tank Insulation	Loss (%)	Notes
None	10	The supporting documentation does not provide specific values for condition of tank insulation. It does indicate ranges in DHW efficiency between 13 and 80% based on changes in idle losses caused in part from insulation conditions.
Nominal	6	
Good	4	
Instantaneous / No Tank	0	

Supporting Documentation

Butcher 2011¹⁰ shows the effects of idle loss on annual and DHW efficiency of combination systems as in Exhibit 2, Exhibit 3, Exhibit 4, and Exhibit 5. Idle losses with ranges from 4% to 0.15% resulted in estimated DHW production efficiency between 13 and 80%. This document does not specifically isolate condition of insulation to idle loss but states that idle losses can be controlled through a combination of better insulation of boilers and indirect tanks and control strategies (page 41).

Total Losses

The total losses are the sum of all ASE variable losses as included in Equation 9.

Equation 9: ASE – Total ASE Losses

$$TotalASELosses = TempFactor + MaxRWT + Controls + AFcontrol + Purge + TankInsul.(DHW)$$

Calculated ASE

The calculated ASE is the resultant of the Combined Thermal Efficiency minus the Total ASE Losses as per Equation 10.

Equation 10: ASE – Calculated ASE

$$ASE = CombinedThermalEff - TotalASELosses$$

Comparison of Calculated ASE to Supporting Documentation

A comparison of ASE values calculated in ETools to those in the supporting documentation has been performed. The ETools ASE values from a number of scenarios using different variables are shown in Table 16. These values show the range of efficiencies from systems having boilers with low to high thermal efficiencies. This table is intended to provide an overview of the effects of various system inputs on ASE.

Table 16: ETools ASE Scenarios

Thermal Efficiency (%)												
	80%	81%	82%	83%	84%	85%	86%	87%	90%	91%	92%	93%
Application Seasonal Efficiency [ASE] (%)												
Scenarios (1=low, 12=high efficiency)												
Supply Water Temp(F)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
100	75.1%	76.5%	78.4%	79.7%	80.6%	82.0%	83.4%	84.6%	88.5%	89.9%	91.1%	92.3%
110	73.7%	75.3%	78.1%	79.6%	79.7%	81.3%	83.1%	84.4%	87.7%	89.3%	90.6%	91.9%
120	72.1%	73.9%	77.8%	79.5%	78.7%	80.5%	82.7%	84.1%	86.9%	88.7%	90.1%	91.5%
130	70.1%	72.1%	77.4%	79.3%	77.5%	79.5%	82.3%	83.8%	86.0%	88.0%	89.5%	91.0%
140	67.8%	70.0%	76.9%	79.1%	76.3%	78.5%	81.9%	83.5%	85.1%	87.3%	88.9%	90.5%
150	65.2%	67.6%	76.3%	78.9%	75.0%	77.4%	81.5%	83.2%	82.2%	86.6%	88.3%	90.0%
160	62.3%	64.9%	75.7%	78.7%	73.5%	76.1%	81.0%	82.8%	80.9%	85.9%	87.7%	89.5%
170	58.7%	61.9%	75.1%	78.4%	71.5%	74.7%	80.5%	82.4%	79.5%	85.1%	87.0%	88.9%
180	54.7%	58.5%	74.3%	78.1%	69.4%	73.2%	79.9%	81.9%	78.1%	84.3%	86.3%	88.3%
ASE Variables												
(TF) Oversize	1.2x	1.2x	1.2x	1.2x	1.2x	1.2x	1.2x	1.2x	1.2x	1.2x	1.2x	1.2x
(TF) Staging	single	single	single	single	2-stage	2-stage	2-stage	2-stage	modulating	modulating	modulating	modulating
(TF) Pumping	continuous	continuous	intermittent	intermittent	continuous	continuous	intermittent	intermittent	continuous	continuous	intermittent	intermittent
(TF) Flue Damping	none	none	burner	mechanical	burner	burner	mechanical	mechanical	mechanical	mechanical	mechanical	mechanical
I/O Control	None	Traditional	Characterized	BAS	None	Traditional	Characterized	BAS	None	Traditional	Characterized	BAS
A/F Control	None	None	None	None	Staged	Staged	Staged	Staged	Modulating	Modulating	Modulating	Modulating
Purge Cycles	None	None	None	None	Pre OR Post	Pre OR Post	Pre OR Post	Pre OR Post	Pre AND Post	Pre AND Post	Pre AND Post	Pre AND Post

Figure 18 provides a reference of how ASE values from ETools compare to those in the supporting documentation. The ETools data shows the boundary of all values included within the defined low and high efficiency systems. A linear trendline has been added of the Support Doc values.

Figure 18: ASE – ASE Comparison

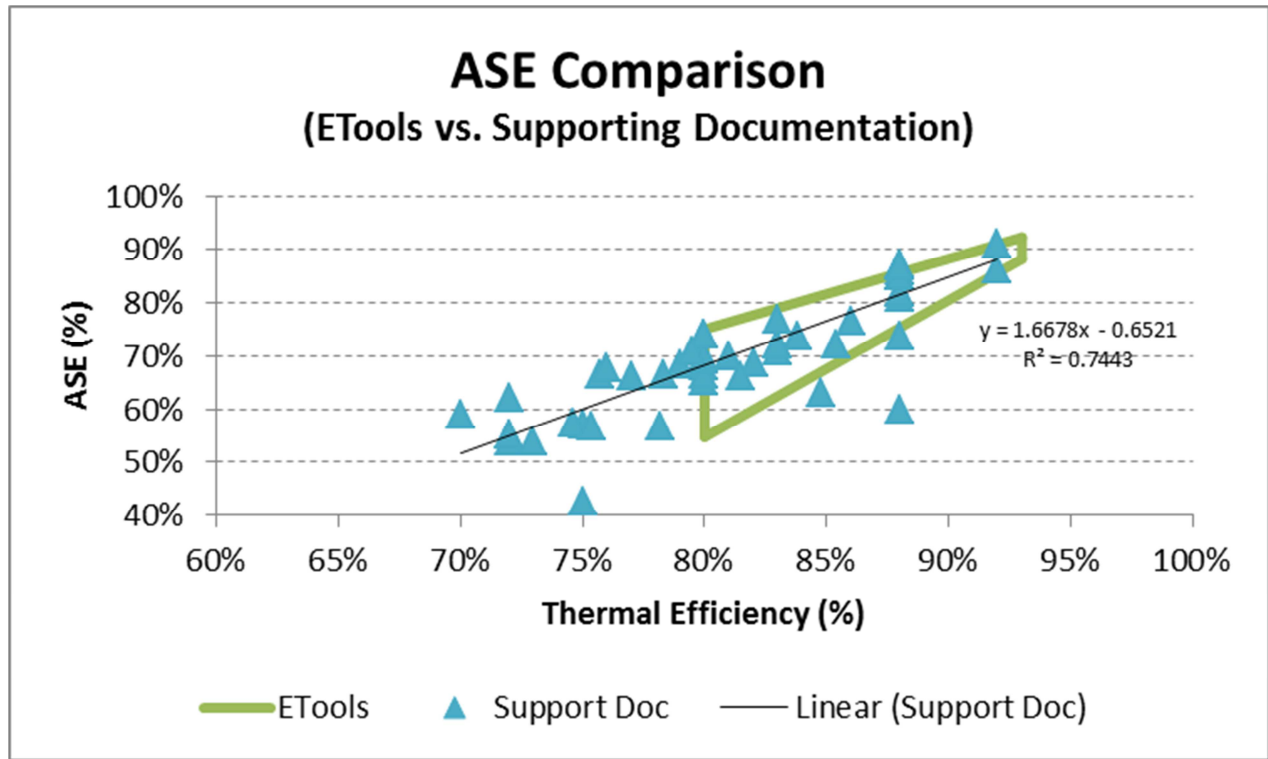


Table 17 shows the References used for the Support Doc values of Figure 18.

Table 17: ASE – ASE Comparison Supporting Documentation

ID	SS Eff (%)	ASE (%)	Reference	Ref #	Ref Location	Association
1	82.0%	68.7%	Butcher 2006	1	Table 3	proceedings Aachener Olwarne-Kolloquium
2	88.0%	73.7%	Butcher 2006	1	Table 3	proceedings Aachener Olwarne-Kolloquium
3	92.0%	86.4%	Butcher 2006	1	Table 3	proceedings Aachener Olwarne-Kolloquium
4	88.0%	87.2%	Butcher 2006	1	Table 3	proceedings Aachener Olwarne-Kolloquium
5	92.0%	91.1%	Butcher 2006	1	Table 3	proceedings Aachener Olwarne-Kolloquium
6	72.0%	54.0%	Butcher 2011	10	pg 39, Table 1	ASHRAE Journal
7	83.0%	71.0%	Butcher 2011	10	pg 39, Table 1	ASHRAE Journal
8	88.0%	81.0%	Butcher 2011	10	pg 39, Table 1	ASHRAE Journal
9	88.0%	85.0%	Butcher 2011	10	pg 39, Table 1	ASHRAE Journal
10	88.0%	87.0%	Butcher 2011	10	pg 39, Table 1	ASHRAE Journal
11	72.0%	62.0%	Butcher 2011	10	pg 39, Table 2	ASHRAE Journal
12	83.0%	77.0%	Butcher 2011	10	pg 39, Table 2	ASHRAE Journal
13	88.0%	85.0%	Butcher 2011	10	pg 39, Table 2	ASHRAE Journal
14	88.0%	86.0%	Butcher 2011	10	pg 39, Table 2	ASHRAE Journal
15	88.0%	87.0%	Butcher 2011	10	pg 39, Table 2	ASHRAE Journal
16	72.0%	55.0%	Butcher 2011	10	pg 39, Table 3	ASHRAE Journal
17	83.0%	72.0%	Butcher 2011	10	pg 39, Table 3	ASHRAE Journal
18	88.0%	82.0%	Butcher 2011	10	pg 39, Table 3	ASHRAE Journal
19	88.0%	85.0%	Butcher 2011	10	pg 39, Table 3	ASHRAE Journal
20	88.0%	87.0%	Butcher 2011	10	pg 39, Table 3	ASHRAE Journal
21	72.0%	55.0%	Butcher 2011	10	pg 39, Table 4	ASHRAE Journal
22	83.0%	72.0%	Butcher 2011	10	pg 39, Table 4	ASHRAE Journal
23	88.0%	82.0%	Butcher 2011	10	pg 39, Table 4	ASHRAE Journal
24	88.0%	85.0%	Butcher 2011	10	pg 39, Table 4	ASHRAE Journal
25	88.0%	87.0%	Butcher 2011	10	pg 39, Table 4	ASHRAE Journal
26	88.0%	60.0%	Collver 2010 (est 88TE - 28%)	24	pg 6	Canmet Energy
27	86.0%	76.6%	Tierney 1994	8	pg 893	ASHRAE Transactions Symposia
28	75.0%	42.5%	Tierney 1994	8	pg 893	ASHRAE Transactions Symposia
29	79.0%	68.5%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
30	80.0%	69.3%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
31	81.0%	70.0%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
32	80.0%	74.0%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
33	80.0%	69.3%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
34	80.0%	65.1%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
35	80.0%	69.3%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
36	80.0%	68.0%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
37	80.0%	66.6%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
38	80.0%	69.3%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
39	80.0%	69.3%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
40	80.0%	70.0%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
41	80.0%	73.9%	Hewett 2005	28	pg 20, Table 3	Heating/Piping/Air Conditioning Engineering
42	81.5%	66.0%	Landry 1993	6	pg 452	ASHRAE Transactions Symposia
43	73.0%	54.0%	Landry 1993	6	pg 452	ASHRAE Transactions Symposia
44	75.0%	57.0%	Dutt 1990	2	App III-1	The Centre for Energy and the Urban Environment
45	74.6%	57.4%	Katrakis 1993	5	pg 435, Table 2	ASHRAE Transactions Symposia
46	78.2%	56.6%	Katrakis 1993	5	pg 435, Table 2	ASHRAE Transactions Symposia
47	70.0%	58.8%	Katrakis 1993	5	pg 435, Table 2	ASHRAE Transactions Symposia
48	75.4%	56.6%	Katrakis 1993	5	pg 435, Table 2	ASHRAE Transactions Symposia
49	77.0%	66.2%	Katrakis 1993	5	pg 435, Table 2	ASHRAE Transactions Symposia
50	78.3%	66.6%	Katrakis 1993	5	pg 435, Table 2	ASHRAE Transactions Symposia
51	79.5%	70.8%	Katrakis 1993	5	pg 435, Table 2	ASHRAE Transactions Symposia
52	84.8%	63.0%	Katrakis 1993	5	pg 435, Table 2	ASHRAE Transactions Symposia
53	85.4%	72.0%	Katrakis 1993	5	pg 435, Table 2	ASHRAE Transactions Symposia
54	83.8%	73.7%	Katrakis 1993	5	pg 435, Table 2	ASHRAE Transactions Symposia
55	75.7%	66.6%	Katrakis 1993	5	pg 435, Table 2	ASHRAE Transactions Symposia
56	76.0%	67.6%	Katrakis 1993	5	pg 435, Table 2	ASHRAE Transactions Symposia

ETools – Boiler Lead Lag

Space Heating

The Lead-Lag calculation for space heating uses a Bin temperature analysis to estimate the portion of the total load provided by the Lead boiler versus the remaining load provided by the Lag boiler. Several assumptions are made:

- The boiler system operates such that the Lead boiler will operate to provide as much of the load as possible. The Lag boiler will only operate to fulfill all remaining load, regardless of Lag boiler size.
- The Lead boiler has higher thermal efficiency versus the Lag boiler. The Lead boiler is assumed to be condensing and the Lag boiler is assumed to be non-condensing.
- When both boilers are operating, the maximum thermal efficiency of that the Lead boiler can obtain is its own thermal efficiency or 87%.

The Seasonal Efficiency is calculated individually for the Lead and Lag boilers as per the ETools – ASE section of this document. Load factors for the percentage of Lead and Lag boilers are calculated using the following process. These % load factors are then applied to the individual seasonal efficiency values to provide a boiler system seasonal efficiency.

Example values are used throughout this section to simplify explanation of the process.

Boiler Selection

The Lead and Lag boiler selection is completed by the user similar to the Existing boiler selection. A sample Existing System has been selected as per Figure 19. Sample Lead-Lag boilers and their Seasonal Variables have been selected as per Figure 20 and Figure 21.

Figure 19: Boiler Lead Lag – Existing System Selection

Existing System		ESC Name: 0					Date: 0-Jan-00	
	Manufacturer	Model	Qty	Unit Input ('000 Btu/h)	Total Input ('000 Btu/h)	Thermal Efficiency (%)	Heating Output ('000 Btu/h)	Seasonal Efficiency (%)
Space Heating (Seasonal)								
Existing #1	Weil-McLain	LGB-7	2	780	1,560	79.40	1,239	
Existing #2	None		0	-	-	-	-	
Sub-Total					1,560	79.4	1,239	61.11

Figure 20: Boiler Lead Lag – Lead-Lag Selection

Lead - Lag								
	Manufacturer	Model	Qty	Unit Input ('000 Btu/h)	Total Input (MBH)	Thermal Efficiency (%)	Heating Output ('000 Btu/h)	Seasonal Efficiency (%)
Space Heating (Seasonal)								
Lead	Viessmann	CM2-186	1	663.0	663	97.0	643	91.26 %
Lead Boiler Condensing: 81.1%						Part Load Adjusted Eff:	94.6	
☐ New Lag	Weil-McLain	LGB-7	1	780	780	79.4	619	69.00 %
Lag								
Lead Portion of Load: 86.3%								
Sub-Total					1,443	92.5	1,262	88.20 %

Figure 21: Boiler Lead Lag – Seasonal Variable Selection

Space Heating		Lead-Lag			
Return To Selection					
Boiler Thermal Efficiency		LEAD Selection	Loss %	LAG Selection	Loss %
Boiler Thermal Efficiency		94.6 %		79.4 %	
Boiler Pumping**		Intermittent		Intermittent	
Flue Damping*		Burner Fan		None	
Oversizing Ratio [Calculated]		1		1	
Total # Heating Stages		11		1	
Max Design Supply Water Temperature**		160 F	0.94 %	180 F	7.20 %
Max Design Return Water Temperature**		130 F	0.00 %	160 F	0.00 %
HD Control with Reset**		BAS	0.00 %	BAS	0.00 %
A/F Control*		Modulating	0.00 %	None	3.20 %
Purge Cycles*,**		Pre and Post	2.40 %	None	0.00 %
Total losses			3.34 %		10.40 %
Control Portion [Savings]		Control Savings	10.81 %	Control Savings	8.55 %
Estimated Seasonal Efficiency			91.26 %		69.00 %

System Seasonal Efficiency Calculation

1. Maximum Heat Loss

The maximum heat loss is assumed to be the output of the existing boilers with any oversizing factor considered. For example; 1,239 MBH. This is the heat loss at the lowest Bin temperature.

2. Bin Heat Loss

The Bin temperature hours for various locations are provided in Table 18.

Table 18: Boiler Lead Lag – Location Bin Hours

Temp (*F)	Range	TORONTO	OTTAWA	NIAGARA FALLS	Barrie	Peterborough
-30	-25	0	0	0	0	0
-25	-20	0	7	0	0	7
-20	-15	0	16	0	2.1	16
-15	-10	0	38	0	5.2	38
-10	-5	1	88	1	33.4	88
-5	0	6	161	5	66.8	161
0	5	67	207	60	112.7	207
6	10	138	252	124	199.3	252
11	15	274	322	247	323.5	322
16	20	366	382	330	411.1	382
21	25	463	441	417	491.5	441
26	30	707	487	637	585.4	487
31	35	789	766	710	736.7	766
36	40	741	706	667	713.7	706
41	45	629	594	566	675.1	594
46	50	624	613	562	698.1	613
51	55	724	626	652	585.4	626
56	60	749	728	674	733.6	728
61	65	669	732	602	849.4	732

Table 19 shows the percentage of maximum heat loss for the various locations and Bins.

Table 19: Boiler Lead Lag – Location Bin % of Building Heat Loss

Interval	TORONTO	OTTAWA	NIAGARA FALLS	BARRIE	PETERBOROUGH
19					
18		100%			100%
17		94.4%			94.4%
16		88.9%			88.9%
15	100%	83.3%	100%	100%	83.3%
14	93.3%	77.8%	93.3%	93.3%	77.8%
13	86.7%	72.2%	86.7%	86.7%	72.2%
12	80.0%	66.7%	80.0%	80.0%	66.7%
11	73.3%	61.1%	73.3%	73.3%	61.1%
10	66.7%	55.6%	66.7%	66.7%	55.6%
9	60.0%	50.0%	60.0%	60.0%	50.0%
8	53.3%	44.4%	53.3%	53.3%	44.4%
7	46.7%	38.9%	46.7%	46.7%	38.9%
6	40.0%	33.3%	40.0%	40.0%	33.3%
5	33.3%	27.8%	33.3%	33.3%	27.8%
4	26.7%	22.2%	26.7%	26.7%	22.2%
3	20.0%	16.7%	20.0%	20.0%	16.7%
2	13.3%	11.1%	13.3%	13.3%	11.1%
1	6.7%	5.6%	6.7%	6.7%	5.6%

The percentage of maximum heat loss is applied to Bins for the location selected. The Bin heat loss is then calculated as illustrated in Table 20 for Toronto.

Table 20: Boiler Lead Lag – Bin Heat Loss

Bin Temperatures				
*F	Hrs/Year	% of Bldg Heat Loss	Building Heat Loss Mbh	Annual Mbtu Output Req'd
-25	0	0.00%	0	0
-20	0	0.00%	0	0
-15	0	0.00%	0	0
-10	0	0.00%	0	0
-5	1	100.00%	1,239	1,239
0	6	93.33%	1,156	6,936
5	67	86.67%	1,074	71,926
10	138	80.00%	991	136,746
15	274	73.33%	908	248,873
20	366	66.67%	826	302,243
25	463	60.00%	743	344,094
30	707	53.33%	661	467,021
35	789	46.67%	578	456,100
40	741	40.00%	495	367,133
45	629	33.33%	413	259,676
50	624	26.67%	330	206,135
55	724	20.00%	248	179,355
60	749	13.33%	165	123,668
65	669	6.67%	83	55,271
	6947			

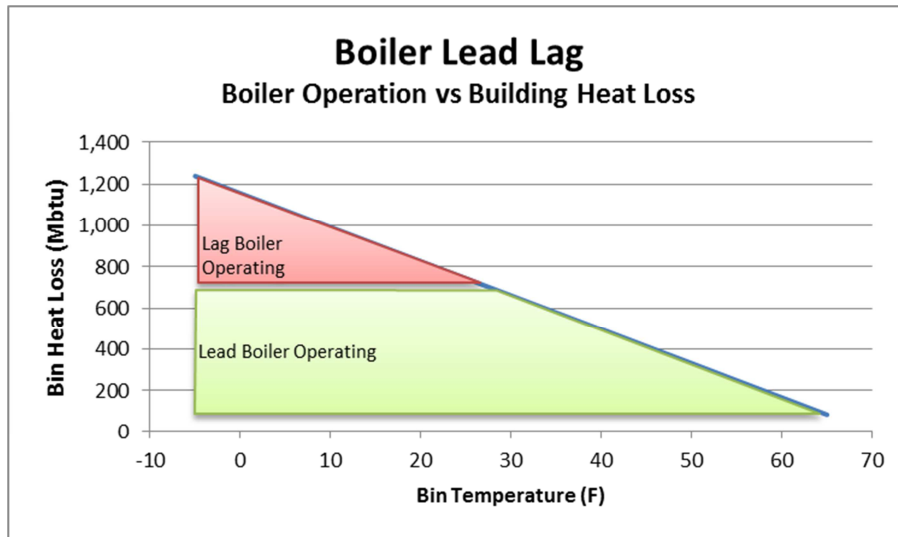
3. Lag Boiler Operating

The heat loss at each Bin is checked to determine if the Lead boiler can provide the required load. A 'hysteresis' factor of 10% is added to the Lead boiler output based on the reasoning that the Lag boiler will not operate until the Lead boiler has reached full output for a period of time. For this example; the Lag boiler will only operate when Bin heat loss is above 707 Mbh (643 Mbh x 110%) as shown in Table 21 and Figure 22.

Table 21: Boiler Lead Lag – Lag Boiler Operation

Bin Temperature (F)	Building Heat Loss (Mbh)	Lag Boiler Operating
-25	0	FALSE
-20	0	FALSE
-15	0	FALSE
-10	0	FALSE
-5	1,239	TRUE
0	1,156	TRUE
5	1,074	TRUE
10	991	TRUE
15	908	TRUE
20	826	TRUE
25	743	TRUE
30	661	FALSE
35	578	FALSE
40	495	FALSE
45	413	FALSE
50	330	FALSE
55	248	FALSE
60	165	FALSE
65	83	FALSE

Figure 22: Boiler Lead Lag – Boiler Operation vs Building Heat Loss



4. Maximum Lead Thermal Efficiency

The operational thermal efficiency of the Lead boiler is dependent on the system water temperature based on the method of control as per Figure 10. In addition, the assumption has been made that whenever the Lag boiler is operating, the system will operate up to a maximum thermal efficiency of 87% (non-condensing). For this example; the selected BAS control on the Lead boiler adjusts the RWT from 130F to 80F. The maximum Lead thermal efficiency ranges from 87% when the Lag boiler is operating, to the thermal efficiency as dictated by the RWT relationship in Figure 13.

Table 22: Boiler Lead Lag – Max Lead Thermal Efficiency

Bin Temperature (F)	Building Heat Loss (Mbh)	Lag Boiler Operating	BAS Controlled Design RWT	Calculated Max Lead Thermal Efficiency
-25	0	FALSE	0	0.0
-20	0	FALSE	0	0.0
-15	0	FALSE	0	0.0
-10	0	FALSE	0	0.0
-5	1,239	TRUE	130	87.0
0	1,156	TRUE	124	87.0
5	1,074	TRUE	119	87.0
10	991	TRUE	113	87.0
15	908	TRUE	107	87.0
20	826	TRUE	100	87.0
25	743	TRUE	93	87.0
30	661	FALSE	87	95.7
35	578	FALSE	80	96.5
40	495	FALSE	80	96.5
45	413	FALSE	80	96.5
50	330	FALSE	80	96.5
55	248	FALSE	80	96.5
60	165	FALSE	80	96.5
65	83	FALSE	80	96.5

The **Part Load Adjusted Efficiency** for the Lead Boiler as shown in Figure 20 is the weighted average of Calculated Max Lead Thermal Efficiency over the total Bin hours. The percentage that the **Lead Boiler is Condensing** is the portion of Bin hours that the Lead portion of the Calculated Max Lead Thermal Efficiency is equal or above 88% as included on the same figure.

5. Lead Boiler Portion

The Lead boiler portion of the annual load is determined from the sum total of the Bin operation as shown in Table 23 and described:

- **Available Mbh Output:** a product of the Lead boiler input and Calculated Max Lead Thermal Efficiency.
- **Available Mbtu/yr Output:** a product of the Available Mbh Output and the respective Bin hours.
- **Equivalent Mbtu/yr Input:** the Available Mbtu/yr Output divided by the rated Lead boiler thermal efficiency (ie., 97%).
- **Equivalent m³/yr Input:** the Equivalent Mbtu/yr Input divided by 35.301 Mbtu/m³ of natural gas.
- **Lead Portion:** is the Sum of the Equivalent m³/yr Input divided by the combined total Lead and Lag Sum. This equals 83,358 divided by (83,358 + 13,275) or 86.26%.

Table 23: Boiler Lead Lag – Lead Boiler Portion

Bin Temperatures		Lead Boiler Portion				
°F	Hrs/Year	Boiler Operating Capacity	Available Mbh Output	Available Mbtu/yr Output	Equivalent Mbtu/yr Input	Equivalent m ³ /yr Input
-25	0	0.0%	0	0	0	0
-20	0	0.0%	0	0	0	0
-15	0	0.0%	0	0	0	0
-10	0	0.0%	0	0	0	0
-5	1	100.0%	577	577	595	17
0	6	100.0%	577	3,461	3,568	101
5	67	100.0%	577	38,646	39,842	1,129
10	138	100.0%	577	79,600	82,062	2,325
15	274	100.0%	577	158,046	162,934	4,616
20	366	100.0%	577	211,112	217,642	6,165
25	463	100.0%	577	267,063	275,323	7,799
30	707	100.0%	634	448,491	462,362	13,098
35	789	90.4%	578	456,100	470,206	13,320
40	741	77.5%	495	367,133	378,488	10,722
45	629	64.5%	413	259,676	267,707	7,584
50	624	51.6%	330	206,135	212,511	6,020
55	724	38.7%	248	179,355	184,902	5,238
60	749	25.8%	165	123,668	127,493	3,612
65	669	12.9%	83	55,271	56,980	1,614
	6947			2,854,334	Sum:	83,358

Lead Portion: **86.26%**

6. Lag Boiler Portion

The Lag boiler portion of the annual load, similar to the Lead boiler portion, is determined from the sum total of the Bin operation as shown in Table 24 and described:

- **Heat Loss Mbh Remaining:** the difference between the Bin Building Heat Loss and the Lead boiler Available Mbh Output.
- **Remaining Mbtu/yr Output:** a product of the Heat Loss MBH Remaining and the respective Bin hours.
- **Equivalent Mbtu/yr Input:** the Available Mbtu/yr Output divided by the rated Lag boiler thermal efficiency (ie., 79.4%).
- **Equivalent m³/yr Input:** the Equivalent Mbtu/yr Input divided by 35.301 Mbtu/m³ of natural gas.
- **Lag Portion:** is the Sum of the Equivalent m³/yr Input divided by the combined total Lead and Lag Sum. This equals 13,275 divided by (83,358 + 13,275) or 13.74%.

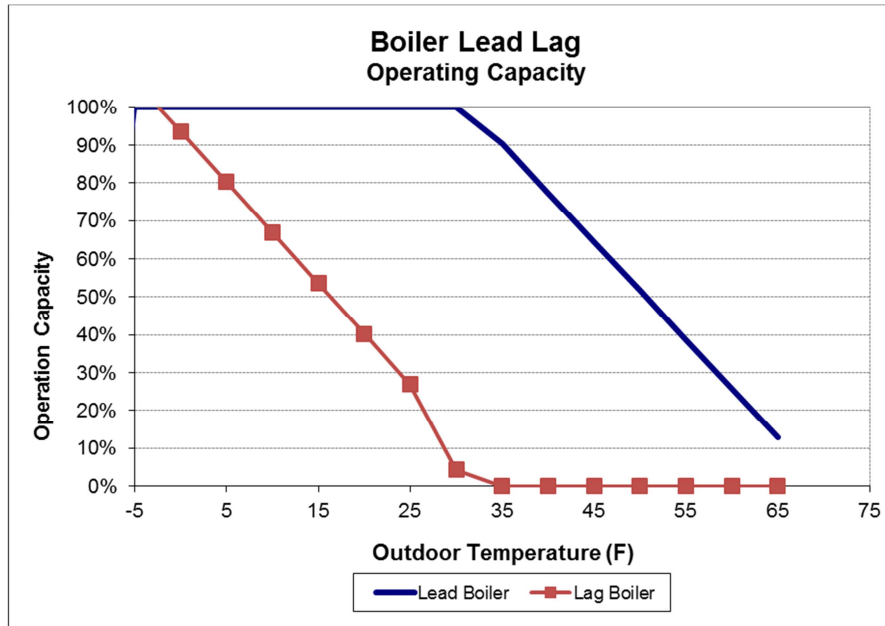
Table 24: Boiler Lead Lag – Lag Boiler Portion

Bin Temperatures		Lag Boiler Portion			
°F	Hrs/Year	Heat Loss Mbh Remaining	Remaining Mbtu/yr Output	Equivalent Mbtu Input	Equivalent m ³ /year Input
-25	0	0	0	0	0
-20	0	0	0	0	0
-15	0	0	0	0	0
-10	0	0	0	0	0
-5	1	662	662	834	24
0	6	579	3,475	4,377	124
5	67	497	33,280	41,915	1,187
10	138	414	57,146	71,972	2,039
15	274	331	90,827	114,391	3,240
20	366	249	91,131	114,774	3,251
25	463	166	77,031	97,017	2,748
30	707	26	18,529	23,337	661
35	789	0	0	0	0
40	741	0	0	0	0
45	629	0	0	0	0
50	624	0	0	0	0
55	724	0	0	0	0
60	749	0	0	0	0
65	669	0	0	0	0
	6947		372,081	Sum:	13,275
Lag Portion:					13.74%

7. Boiler Operating Capacity

Figure 23 illustrates the operational capacity of the lead and lag boiler for the entire range of outdoor temperatures.

Figure 23: Boiler Lead Lag – Operating Capacity



8. Equivalent System Seasonal Efficiency

The equivalent lead-lag system seasonal efficiency is calculated as a combination of the Lead and Lag seasonal efficiencies and load portions as per Equation 11.

Equation 11: Boiler Lead Lag – Equivalent System Seasonal Efficiency

$$ASE_{LLeq} = LeadPortion \times ASE_{Lead} + LagPortion \times ASE_{Lag}$$

Using the sample values, the equivalent system seasonal efficiency is 88.20% as demonstrated by

Equation 12: Boiler Lead Lag – Equivalent System Seasonal Efficiency Values

$$ASE_{LLeq} = 86.26\% \times 91.26\% + 13.74\% \times 69.00\% = 88.20\%$$

Supporting Documentation

Landry 1993⁶ calculated seasonal efficiency using a bin method. The total boiler energy input for each bin was the product of the input rate, the number of days in the bin and the fraction runtime of the bin. The bin boiler output was the product of the bin boiler input and the bin efficiency. The seasonal input and output were calculated as the sum of all temperature bins with seasonal efficiency being the ratio of seasonal output to input.

Eoff 2008¹² suggests multiple-boiler plants can save additional fuel by installing a modern lead/lag controller. A typical system operates the optimal number of boilers to meet the current plant load and fires the boilers at their most efficient firing rates to minimize fuel consumption. A modern lead/lag controller will keep the lag boiler off and only bring online if the lead boiler cannot handle the current load.

Cleaver Brooks²¹ defines a hybrid boiler plant is one which combines condensing and non-condensing boilers. This type of system maximizes energy savings and minimizes boiler costs. As the heating load increases, a change-over to the non-condensing boiler will provide heat for the incremental increase in demand. The outputs of the condensing boilers are driven up to at or above 140F to ensure the inlet of the non-condensing boiler will prevent condensing from occurring. The higher temperatures allow the existing heating system of legacy buildings to operate as per original design conditions.

Domestic Hot Water

The Lead-Lag calculation for DHW does not use a Bin method of calculation but rather allows the user to select the Lead Portion of the Load. This % Lead Portion factor is then applied to the individual Lead and Lag seasonal efficiency values to provide a boiler system seasonal efficiency.

Example values are used throughout this section to simplify explanation of the process.

Boiler Selection

The Lead and Lag boiler selection is completed by the user similar to the Existing boiler selection. A sample Existing System has been selected as per Figure 24. Sample Lead-Lag boilers and their Seasonal Variables have been selected as per Figure 25 and Figure 26. The 'New Lag' selection is for costing purposes only and does not affect the ASE calculation.

Figure 24: Boiler Lead Lag DHW – Existing System Selection

Domestic Hot Water (Non-Seasonal)							
Existing #1	Weil-McLain	LGB-14	2	1,690	3,380	79.5	2,687
Existing #2	None		0	-	-	-	-
Sub-Total				3,380	79.5	2,687	68.24

Figure 25: Boiler Lead Lag DHW – Lead Lag Selection

Domestic Hot Water (Non-Seasonal)							
Lead	Viessmann	CM2-186	0	663.0	-	97.0	-
Lead Portion of Load %	75						
☐ New Lag	Lag	Weil-McLain	LGB-14	1	1,690	1,690	79.5
Sub-Total				1,690	79.5	1,344	69.55 %
				1,690	79.5	1,344	80.37 %
				Totals			

Figure 26: Boiler Lead Lag DHW – Seasonal Variable Selection

Domestic Hot Water		Lead-Lag			
Return To Selection		LEAD Selection	Loss %	LAG Selection	Loss %
Boiler Thermal Efficiency		97.0		79.5 %	
Boiler Pumping**	Intermittent			Intermittent	
Flue Damping*	Burner Fan			None	
Oversizing Ratio	1			1	
Total # Heating Stages	1			1	
Supply Water Temperature**	140 F	1.10 %	140 F	2.75 %	
Return Water Temperature**	120 F	6.12 %	120 F	0.00 %	
Controls**	New	0.00 %	New	0.00 %	
A/F Control*	Modulating	0.00 %	None	3.20 %	
Purge Cycles*,**	Pre and Post	1.80 %	None	0.00 %	
DHW Tank Insulation	Good	4.00 %	Good	4.00 %	
Total losses		13.02 %		9.95 %	
Control Portion [Savings]	Control Savings	-0.55 %	Control Savings	5.57 %	
Estimated Seasonal Efficiency		83.98 %		69.55 %	

* Values set from Database, ** Values User

System Seasonal Efficiency Calculation

The equivalent lead-lag system seasonal efficiency is calculated as a combination of the Lead and Lag seasonal efficiencies and the entered Lead Portion of the load portions as per Equation 13.

Equation 13: Boiler Lead Lag DHW – Equivalent System Seasonal Efficiency

$$ASE_{LLeq} = LeadPortion \times ASE_{Lead} + LagPortion \times ASE_{Lag}$$

Using the sample values, the equivalent system seasonal efficiency is 88.20% as demonstrated by Equation 14.

Equation 14: Boiler Lead Lag DHW – Equivalent System Seasonal Efficiency Values

$$ASE_{LLeq} = 75\% \times 83.98\% + 25\% \times 69.55\% = 80.37\%$$

Supporting Documentation

The lead-lag calculations for DHW ASE are identical to those presented in the ETools - ASE section.

Boiler Database

The complete database of Commercial packaged boilers accessible to ETools is included in the Appendices. Information contained within the database includes a number of items specific to each boiler is defined in the various Categories of Table 25. The ASE variables reference this information based on boiler plant selection.

Table 25: Boiler Database – Boiler Categories

Category	Code	Selection	Notes
Application Class	h	hydronic or other	
	d	domestic hot water	Denotes potable water compatible heat exchanger, headers and connectors
Combustion Class	a	atmospheric	Natural draft
	p	power burner	Powered generally denotes fan assisted combustion
	i	induced draft	
Construction Class	i	cast iron	Denotes heat exchanger material
	s	steel	
	ss	stainless steel	
	c	copper	
	cn	cupro-nickel	
	a	aluminum	
	o	other	
	ms	multiple selection - different types are available - check with manufacturer	
Heat Exchanger Class	w	water tube	
	f	fire tube	
	s	sectional	Cast iron boilers are always sectional
	p	plate	Plate added to more accurately represent Viessmann Vertomat design
Number of stages	1 to 9		
	M	modulating	10+ stages or fully modulating are both classed as modulating
a/f control	1	none	Control implies less susceptibility to variable draft conditions rather than
	2	staged	any form of closed loop process control. This is typically realized by fan assisted combustion.
	3	modulating	
Damping	1	none	
	2	fan	Fan assisted combustion boilers have an inherent measure of damping by virtue of the fan
	3	damper	
Purge cycles	1	none	
	2	pre purge	Purge cycles are typically required for fan assisted combustion boilers.
	3	pre and post purge	
Vent Class	d	direct vent	Combustion air taken from outdoors without fan assistance
	f	forced or induced draft	
	n	natural draft	
	s	sealed combustion	Combustion air taken from outdoors with fan assistance
Vent Category	1	I	Non positive pressure, conventional (non-condensing) efficiency
	2	II	Non positive pressure, high (condensing) efficiency, requires corrosion resistant material
	3	III	Positive pressure, conventional (non-condensing) efficiency
	4	IV	Positive pressure, high (condensing) efficiency, requires airtight, corrosion resistant material

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Appendix A

Enbridge - Commercial Boiler Database

Enbridge: Commercial Boiler

Version	Change	Comment	1 Record	2 Manufacturer	3 Product Name	4 Model Number	5 Input MBH	6 Output MBH	7 Final Efficiency	8 Personal Efficiency	9 Justification	10 MSRP	11 Application	12 Combustion	13 Construction	14 Heat Exch.	15 Stages	16 AF Control	17 Damping	18 Purge Cycles	19 Vent Class	20 Vent Category	21 Tankless	22 Water Volume	23 Data Sour	24 Date	
V421	new	Current Date: V1.03 = 12-Oct-2005 V1.04 = 01-Jul-2006 V1.06 = 01-Jul-2007 V2.01 = 22-Oct-09 V4.21 = 15-Oct-13	1/AERCO	Benchmark	Benchmark	BMK 1.5LN	1500.0	969	95.4	96.8	95.4	96.8	h	p	ss	f	M	3	3	2	3	f	4			AHRI	7-Oct-13
V421	new		2/AERCO	Benchmark	Benchmark	BMK 1000	1000.0	989	96.8	96.8	h	p	p	ss	f	M	3	3	2	3	f	4			AHRI	7-Oct-13	
V421	new		3/AERCO	Benchmark	Benchmark	BMK 2.0 LN	2000.0	1846	91.0	92.3	h	p	p	ss	f	M	3	3	2	3	f	4			AHRI	7-Oct-13	
V421	new		4/AERCO	Benchmark	Benchmark	BMK 2500	2500.0	2337	93.5	94.0	h	p	p	ss	f	M	3	3	2	3	f	4			AHRI	7-Oct-13	
V421	new		5/AERCO	Benchmark	Benchmark	BMK 3.0 LN	3000.0	2856	93.9	95.2	h	p	p	ss	f	M	3	3	2	3	f	4			AHRI	7-Oct-13	
V421	new		6/AERCO	Benchmark	Benchmark	BMK 3000	3000.0	2805	93.0	94.0	h	p	p	ss	f	M	3	3	2	3	f	4			AHRI	7-Oct-13	
V421	new		7/AERCO	Benchmark	Benchmark	BMK 6000	6000.0	5670	94.5	95.0	h	p	p	ss	f	M	1	1	2	3	f	4			AHRI	7-Oct-13	
V421	new		8/AERCO	Benchmark	Benchmark	BMK 750	750.0	721	95.6	96.2	h	p	p	ss	f	M	3	3	2	3	f	4			AHRI	7-Oct-13	
V421	new		9/AERCO	Estiem	Estiem	EST399	399.0	379	95.1	94.1	h	p	p	ss	f	M	3	3	2	3	f	4			AHRI	7-Oct-13	
V421	new		10/AERCO	Modulux	Modulux	MLX1060	1060.0	975	92.0	92.0	h	p	p	p	a	f	M	3	3	2	3	s	4			AHRI	7-Oct-13
V421	new		11/AERCO	Modulux	Modulux	MLX303	303.0	279	92.0	92.0	h	p	p	p	a	f	M	3	3	2	3	s	4			AHRI	7-Oct-13
V421	new		12/AERCO	Modulux	Modulux	MLX454	454.0	418	92.0	92.0	h	p	p	p	a	f	M	3	3	2	3	s	4			AHRI	7-Oct-13
V421	new		13/AERCO	Modulux	Modulux	MLX606	606.0	558	92.0	92.0	h	p	p	p	a	f	M	3	3	2	3	s	4			AHRI	7-Oct-13
V421	new		14/AERCO	Modulux	Modulux	MLX757	757.0	696	92.0	92.0	h	p	p	p	a	f	M	3	3	2	3	s	4			AHRI	7-Oct-13
V107	new		15/AERCO	Modulux	Modulux	MLX909	909.0	835	92.0	92.0	h	p	p	p	a	f	M	3	3	2	3	s	4	L		AHRI	7-Oct-13
V107	new		16/Apix Boiler Inc.	Atlas Series	Atlas Series	GS 1.0	1000	930	93	93	h,d	p	p	c	W	M	2	2	2	2	s	4	L				
			17/Apix Boiler Inc.	AAE Series	AAE Series	AAE480	480	384	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			18/Allied Engineering	AAE Series	AAE Series	AAE600	600	480	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			19/Allied Engineering	AAE Series	AAE Series	AAE720	720	576	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			20/Allied Engineering	AAE Series	AAE Series	AAE840	840	672	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			22/Allied Engineering	AAE Series	AAE Series	AAE960	960	768	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			23/Allied Engineering	AAE Series	AAE Series	AAE1080	1080	864	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			24/Allied Engineering	AAE Series	AAE Series	AAE1200	1200	960	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			25/Allied Engineering	AAE Series	AAE Series	AAE1320	1320	1056	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			26/Allied Engineering	AAE Series	AAE Series	AAE1440	1440	1152	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			27/Allied Engineering	AAE Series	AAE Series	AAE1560	1560	1248	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			28/Allied Engineering	AAE Series	AAE Series	AAE1680	1680	1344	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			29/Allied Engineering	AAE Series	AAE Series	AAE1800	1800	1440	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			30/Allied Engineering	AAE Series	AAE Series	AAE1920	1920	1536	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			31/Allied Engineering	AAE Series	AAE Series	AAE2040	2040	1632	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			32/Allied Engineering	AAE Series	AAE Series	AAE2280	2280	1824	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			33/Allied Engineering	AAE Series	AAE Series	AAE2400	2400	1920	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			34/Allied Engineering	AAE Series	AAE Series	AAE2520	2520	2016	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			35/Allied Engineering	AAE Series	AAE Series	AAE2760	2760	2208	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			36/Allied Engineering	AAE Series	AAE Series	AAE3000	3000	2400	80	80	h	a	a	s	W	2	1	1	1	1	n	1					
			37/Allied Engineering	Mini Gas Series	Mini Gas Series	MG-50	50	42.3	84.6	81.94	h	a	a	s	W	1	1	1	3	1	n	1					
			38/Allied Engineering	Mini Gas Series	Mini Gas Series	MG-75	75	63.45	84.6	84.65	h	a	a	s	W	1	1	1	3	1	n	1					
			39/Allied Engineering	Mini Gas Series	Mini Gas Series	MG-100	100	84.6	84.6	84.65	h	a	a	s	W	1	1	1	3	1	n	1					
			40/Allied Engineering	Mini Gas Series	Mini Gas Series	MG-125	125	105.75	84.6	84.4	h	a	a	s	W	1	1	1	3	1	n	1					
			41/Allied Engineering	Mini Gas Series	Mini Gas Series	MS-150	150	126.9	84.32	84.32	h	a	a	s	W	1	1	1	3	1	n	1					
V107	new		42/Allied Engineering	Mini Star Series	Mini Star Series	MS-75	75	63.832	85.11	85.11	h	a	a	s	W	1	1	1	3	1	n	1		L			
V107	new		43/Allied Engineering	Mini Star Series	Mini Star Series	MS-100	100	85.18	85.18	85.18	h	a	a	s	W	1	1	1	3	1	n	1		L			
			44/Allied Engineering	Mini Star Series	Mini Star Series	MS-125	125	106.512	85.21	85.21	h	a	a	s	W	1	1	1	3	1	n	1		L			
V107	new		45/Allied Engineering	Mini Star Series	Mini Star Series	MS-150	150	127.845	85.23	85.23	h	a	a	s	W	1	1	1	3	1	n	1		L			
			46/Allied Engineering	Satum Series	Satum Series	SG135	135	113.67	84.2	83.56	h	a	a	s	W	1	1	1	3	1	n	1		L			
			47/Allied Engineering	Satum Series	Satum Series	SG180	180	151.56	84.2	83.44	h	a	a	s	W	1	1	1	3	1	n	1					
			48/Allied Engineering	Satum Series	Satum Series	SG225	225	189.45	84.2	83.61	h	a	a	s	W	1	1	1	3	1	n	1					
			49/Allied Engineering	Satum Series	Satum Series	SG270	270	227.34	84.2	83.82	h	a	a	s	W	1	1	1	3	1	n	1					
			50/Allied Engineering	Satum Series	Satum Series	SG315	315	266.23	84.2	84.2	h	a	a	s	W	1	1	1	3	1	n	1					
			51/Allied Engineering	Satum Series	Satum Series	SG360	360	303.12			h	a	a	s	W	1	1	1	1	1	n	1					
			52/Allied Engineering	Satum Series	Satum Series	SG400	400	336.8	84.2	84.2	h	a	a	s	W	1	1	1	1	1	n	1					
			53/Allied Engineering	Satum Series	Satum Series	SG450	450	378.9	84.2	84.2	h	a	a	s	W	1	1	1	1	1	n	1					
			54/Allied Engineering	Satum Series	Satum Series	SG495	495	416.79	84.2	84.2	h	a	a	s	W	1	1	1	1	1	n	1					
			55/AO Smith	Conservationist	Conservationist	BTC 120	120	96			d,h	a	a	g	W	1	1	1	3	1	n	1					
			56/AO Smith	Conservationist	Conservationist	BTC 154	154	124			d,h	a	a	g	W	1	1	1	3	1	n	1					
			57/AO Smith	Conservationist	Conservationist	BTC197	197	158			d,h	a	a	g	W	1	1	1	3	1	n	1					
			58/AO Smith	Conservationist	Conservationist	BTC 199	199	152			d,h	a	a	g	W	1	1	1	3	1	n	1					
			59/AO Smith	Conservationist	Conservationist	BTC 251	251	201			d,h	a	a	g	W	1	1	1	3	1	n	1					
			60/AO Smith	Conservationist	Conservationist	BTC 365	365	292			d,h	a	a	g	W	1	1	1	3	1	n	1					
			61/AO Smith	Conservationist	Conservationist	BTC 500	500	400			d,h	a	a	g	W	1	1	1	3	1	n	1					
			62/AO Smith	Conservationist	Conservationist	BTX 80	80	64			d,h	i	i	i			1	1	3	1	f	3					
			63/AO Smith	Conservationist	Conservationist	BTX 120	120	96			d,h	i	i	i			1	1	3	1	f	3					
			64/AO Smith	Conservationist	Conservationist	BTX 154	154	124			d,h	i	i	i			1	1	3	1	f	3					
			65/AO Smith	Conservationist	Conservationist	BTX 197	197	159			d,h	i	i	i			1	1	3	1	f	3					
			66/AO Smith	Conservationist	Conservationist	BTX 199	199	152			d,h	i	i	i			1	1	3	1	f	3					
			67/AO Smith	Conservationist	Conservationist	BTX 251	251	201			d,h	i	i	i			1	1	3	1	f	3					
			68/AO Smith	Conservationist	Conservationist	BTX 365	365	292			d,h	i	i	i			1	1	3	1	f	3					
			69/AO Smith	Conservationist	Conservationist	BTX 500	500	400			d,h	i	i	i</													

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Personal Efficiency	Justification Effici	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sourc	Date
			95/AO Smith	Cyclone XHE		BTH 400	399.9	376					d	p	g		1	1	2	3	d,s					
			96/AO Smith	Duramax Hot Water		DW 720 S	720	839.2	81			8392	d	a	c	w	1	1	1	1	n	1				
			97/AO Smith	Duramax Hot Water		DW 840 S	840	860.4	81			9047	d	a	c	w	1	1	1	1	n	1				
			98/AO Smith	Duramax Hot Water		DW 960 S	960	777.6	81			10194	d	a	c	w	1	1	1	1	n	1				
			99/AO Smith	Duramax Hot Water		DW 1080 S	1080	885.6	82			10471	d	a	c	w	1	1	1	1	n	1				
			100/AO Smith	Duramax Hot Water		DW 1210 S	1210	992.2	82			10918	d	a	c	w	1	1	1	1	n	1				
			101/AO Smith	Duramax Hot Water		DW 1350 S	1350	1107	82			11296	d	a	c	w	1	1	1	1	n	1				
			102/AO Smith	Duramax Hot Water		DW 1480 S	1480	1184	80			11908	d	a	c	w	1	1	1	1	n	1				
			103/AO Smith	Duramax Hot Water		DW 1610 S	1610	1288	80			12720	d	a	c	w	1	1	1	1	n	1				
			104/AO Smith	Duramax Hot Water		DW 1810 S	1810	1448	80			13728	d	a	c	w	1	1	1	1	n	1				
			105/AO Smith	Duramax Hydronic		DB 720 S	720	583.2	81			8171	h	a	c	w	1	1	1	1	n	1				
			106/AO Smith	Duramax Hydronic		DB 840 S	840	680.4	81			8639	h	a	c	w	1	1	1	1	n	1				
			107/AO Smith	Duramax Hydronic		DB 960 S	960	777.6	81			9954	h	a	c	w	1	1	1	1	n	1				
			108/AO Smith	Duramax Hydronic		DB 1080 S	1080	885.6	82			10282	h	a	c	w	1	1	1	1	n	1				
			109/AO Smith	Duramax Hydronic		DB 1210 S	1210	992.2	82			10792	h	a	c	w	1	1	1	1	n	1				
			110/AO Smith	Duramax Hydronic		DB 1350 S	1350	1107	82			11144	h	a	c	w	1	1	1	1	n	1				
			111/AO Smith	Duramax Hydronic		DB 1480 S	1480	1184	80			11712	h	a	c	w	1	1	1	1	n	1				
			112/AO Smith	Duramax Hydronic		DB 1610 S	1610	1288	80			12354	h	a	c	w	1	1	1	1	n	1				
			113/AO Smith	Duramax Hydronic		DB 1810 S	1810	1448	80			13426	h	a	c	w	1	1	1	1	n	1				
			114/AO Smith	Genesis Hot Water		GW-200	199	167.916	84.4			9379	d	p	c	w	1	2	2	3	f,s	1,3				
			115/AO Smith	Genesis Hot Water		GW-300	300	252	84			10644	d	p	c	w	1	2	2	3	f,s	1,3				
			116/AO Smith	Genesis Hot Water		GW-400	399	335.916	84.2			13482	d	p	c	w	1	2	2	3	f,s	1,3				
			117/AO Smith	Genesis Hot Water		GW-500	500	420	84			14837	d	p	c	w	1	2	2	3	f,s	1,3				
			118/AO Smith	Genesis Hot Water		GW-650	650	546	84			16018	d	p	c	w	1	2	2	3	f,s	1,3				
			119/AO Smith	Genesis Hot Water		GW-750	750	630	84			16744	d	p	c	w	1	2	2	3	f,s	1,3				
			120/AO Smith	Genesis Hot Water		GW-1000	990	831.6	84				d	p	c	w	3	2	2	3	f,s	1,3				
			121/AO Smith	Genesis Hot Water		GW-1300	1300	1092	84				d	p	c	w	3	2	2	3	f,s	1,3				
			122/AO Smith	Genesis Hot Water		GW-1500	1500	1260	84				d	p	c	w	3	2	2	3	f,s	1,3				
			123/AO Smith	Genesis Hot Water		GW-1850	1850	1554	84				d	p	c	w	3	2	2	3	f,s	1,3				
			124/AO Smith	Genesis Hot Water		GW-2100	2100	1764	84				d	p	c	w	4	2	2	3	f,s	1,3				
			125/AO Smith	Genesis Hot Water		GW-2500	2500	2091.6	83.7				d	p	c	w	4	2	2	3	f,s	1,3				
			126/AO Smith	Genesis Hydronic		GB-200	199	167.916	84.4			7075	h	p	c	w	1	2	2	3	f,s	1,3				
			127/AO Smith	Genesis Hydronic		GB-300	300	252	84			7974	h	p	c	w	1	2	2	3	f,s	1,3				
			128/AO Smith	Genesis Hydronic		GB-400	399	335.916	84.2			10324	h	p	c	w	1	2	2	3	f,s	1,3				
			129/AO Smith	Genesis Hydronic		GB-500	500	420	84			12050	h	p	c	w	1	2	2	3	f,s	1,3				
			130/AO Smith	Genesis Hydronic		GB-650	650	546	84			12917	h	p	c	w	1	2	2	3	f,s	1,3				
			131/AO Smith	Genesis Hydronic		GB-750	750	630	84			13309	h	p	c	w	1	2	2	3	f,s	1,3				
			132/AO Smith	Genesis Hydronic		GB-1000	990	831.6	84				h	p	c	w	3	2	2	3	f,s	1,3				
			133/AO Smith	Genesis Hydronic		GB-1300	1300	1092	84				h	p	c	w	3	2	2	3	f,s	1,3				
			134/AO Smith	Genesis Hydronic		GB-1500	1500	1260	84				h	p	c	w	3	2	2	3	f,s	1,3				
			135/AO Smith	Genesis Hydronic		GB-1850	1850	1554	84				h	p	c	w	4	2	2	3	f,s	1,3				
			136/AO Smith	Genesis Hydronic		GB-2100	2100	1764	84				h	p	c	w	4	2	2	3	f,s	1,3				
			137/AO Smith	Genesis Hydronic		GB-2500	2500	2091.6	83.7				h	p	c	w	4	2	2	3	f,s	1,3				
			138/AO Smith	Legend		LB500	500	450	90			24952	d	p	c	w	1	2	2	3	f,s	1,3				
			139/AO Smith	Legend		LB500	500	450	90			20863	h	p	c	w	1	2	2	3	f,s	1,3				
			140/AO Smith	Legend		LB750	750	675	90			26437	d	p	c	w	1	2	2	3	f,s	1,3				
			141/AO Smith	Legend		LB750	750	675	90			21067	h	p	c	w	1	2	2	3	f,s	1,3				
			142/AO Smith	Legend		LB1000	1000	900	90			27497	d	p	c	w	1	2	2	3	d					
			143/AO Smith	Legend		LB1000	1000	900	90			22984	h	p	c	w	1	2	2	3	v					
			144/AO Smith	Masterfit		BTRC 120	120	96					d,h	i			1	1	3	1	f	3				
			145/AO Smith	Masterfit		BTRC 154	154	124					d,h	i			1	1	3	1	f	3				
			146/AO Smith	Masterfit		BTRC 180	180	144					d,h	i			1	1	3	1	f	3				
			147/AO Smith	Masterfit		BTRC 197	199	158					d,h	i			1	1	3	1	f	3				
			148/AO Smith	Masterfit		BTRC 199	190	152					d,h	i			1	1	3	1	f	3				
			149/AO Smith	Masterfit		BTRC 200	199	158					d,h	i			1	1	3	1	f	3				
			150/AO Smith	Masterfit		BTRC 250	250	200					d,h	i			1	1	3	1	f	3				
			151/AO Smith	Masterfit		BTRC 251	251	201					d,h	i			1	1	3	1	f	3				
			152/AO Smith	Masterfit		BTRC 275	275	220					d,h	i			1	1	3	1	f	3				
			153/AO Smith	Masterfit		BTRC 305	305	244					d,h	i			1	1	3	1	f	3				
			154/AO Smith	Masterfit		BTRC 365	365	292					d,h	i			1	1	3	1	f	3				
			155/AO Smith	Masterfit		BTRC 400	399	319					d,h	i			1	1	3	1	f	3				
			156/AO Smith	Masterfit		BTRC 500	500	400					d,h	i			1	1	3	1	f	3				
V106	new	tankless																								
V106	new	tankless	157 Bosch	Pro Tankless		GWH63ES-N	175	151	86.5				d	p	c	w	M	3	2	1	d,s	Y				
V106	new	tankless	158 Bosch	Pro Tankless		GWH63ESON-N	175	151	86.5				d	p	c	w	M	3	2	1	d,s	Y				
V106	new	tankless	159 Bosch	Pro Tankless		GWH425HN-N	117	96	82				a	c	c	w	M	3	1	1	n	Y				
V106	new	tankless	160 Bosch	Pro Tankless		GWH425HNO-N	117	96	82				d	a	c	w	M	3	1	1	n	Y				
V104	review		161 Bosch	Pro Tankless		GWH425EF-N	130	107	82				d	p	c	w	M	3	2	1	d,s	Y				
V104	review		162 Bryan	Forced Draft Boiler		AB90	900	720				\$21,000	h	p	s	w	1	1	1	1	d					
V104	review		163 Bryan	Forced Draft Boiler		AB120	1200	960	80			\$24,500	h	p	s	w	1	1	1	1	d					
V104	review		164 Bryan	Forced Draft Boiler		AB150	1500	1,200	80			\$27,500	h	p	s	w	1	1	1	1	d					
V104	review		165 Bryan	Forced Draft Boiler		AB200	2000	1,600	80			\$29,000	h	p	s	w	1	1	1	1	f					
V104	review		166 Bryan	Forced Draft Boiler		AB250	2500	2,000	80			\$33,500	h	p	s	w	1	1	1	1	f					
V104	update		167 Bryan	AB Series		AB90-W	900	752					h	p	s	w	1	1	1	1	n	1				
V104	update		168 Bryan	AB Series		AB120-W	1200	1002	83.5																	

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Justification Effici	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sourc	Date	
		F-Series are gone	192	Bryan	F Series	F-350-W	350	280	80			h	a	s	w	1	1	1	1	1	n					
		F-Series are gone	193	Bryan	F Series	F-450-W	450	360	80			h	a	s	w	1	1	1	1	1	n					
		F-Series are gone	194	Bryan	F Series	F-650-W	650	520	80			h	a	s	w	1	1	1	1	1	f					
		F-Series are gone	195	Bryan	F Series	F-850-W	850	680	80			h	a	s	w	1	1	1	1	1	f					
V107	new		196	Bryan	HE-AB Series	HE-AB90	900	765	0.85			h	p	s	w	1	1	2	2	2	f					
V107	new		197	Bryan	HE-AB Series	HE-AB120	1200	1020	0.85			h	p	s	w	1	1	2	2	2	f					
V107	new		198	Bryan	HE-AB Series	HE-AB150	1500	1275	0.85			h	p	s	w	1	1	2	2	2	f					
V107	new		199	Bryan	HE-AB Series	HE-AB200	2000	1700	0.85			h	p	s	w	1	1	2	2	2	f					
V107	new		200	Bryan	HE-AB Series	HE-AB250	2500	2125	0.85			h	p	s	w	1	1	2	2	2	f					
V107	new		201	Bryan	HE-AB Series	HE-AB300	3000	2550	0.85			h	p	s	w	1	1	2	2	2	f					
			202	Bryan	HED Series	HED-305	305	256.2	84			h	p	s	w	1	1	2	1	2	f					
			203	Bryan	HED Series	HED-350	350	294	84			h	p	s	w	1	1	2	1	2	f					
			204	Bryan	HED Series	HED-450	450	378	84			h	p	s	w	1	1	2	1	2	f					
			205	Bryan	HED Series	HED-650	650	546	84			h	p	s	w	1	1	2	1	2	f					
			206	Bryan	HECL Series	HECL-75	750	637.5	85			h	p	s	w	1	1	2	1	2	f					
			207	Bryan	HECL Series	HECL-90	900	765	85			h	p	s	w	1	1	2	1	2	f					
			208	Bryan	HECL Series	HECL-120	1200	1020	85			h	p	s	w	1	1	2	1	2	f					
			209	Bryan	HECL Series	HECL-150	1500	1275	85			h	p	s	w	1	1	2	1	2	f					
			210	Bryan	HECL Series	HECL-180	1800	1530	85			h	p	s	w	1	1	2	1	2	f					
			211	Bryan	HECL Series	HECL-210	2100	1785	85			h	p	s	w	1	1	2	1	2	f					
			212	Bryan	HECL Series	HECL-240	2400	2040	85			h	p	s	w	1	1	2	1	2	f					
			213	Bryan	HECL Series	HECL-270	2700	2295	85			h	p	s	w	1	1	2	1	2	f					
			214	Bryan	HECL Series	HECL-300	3000	2550	85			h	p	s	w	1	1	2	1	2	f					
V107	new		215	Bryan	HE-RV Series	HE-RV350	3500	2975	0.85			h	p	s	w	1	1	2	3	3	f					
V107	new		216	Bryan	HE-RV Series	HE-RV400	4000	3400	0.85			h	p	s	w	1	1	2	3	3	f					
V107	new		217	Bryan	HE-RV Series	HE-RV450	4500	3825	0.85			h	p	s	w	1	1	2	3	3	f					
V107	new		218	Bryan	HE-RV Series	HE-RV500	5000	4250	0.85			h	p	s	w	1	1	2	3	3	f					
V107	new		219	Bryan	HE-RV Series	HE-RV550	5500	4675	0.85			h	p	s	w	1	1	2	3	3	f					
V107	new		220	Bryan	HE-RV Series	HE-RV600	6000	5100	0.85			h	p	s	w	1	1	2	3	3	f					
V107	new		221	Bryan	HE-RV Series	HE-RV700	7000	5950	0.85			h	p	s	w	1	1	2	3	3	f					
V107	new		222	Bryan	HE-RV Series	HE-RV800	8000	6800	0.85			h	p	s	w	1	1	2	3	3	f					
V107	review		223	Bryan	Forced Draft, Modulating	RV500	5000	4,000	80	\$49,600		h	p	s	w	1	1	2	3	3	f					
V104	review		224	Bryan	Forced Draft, Modulating	RV650	5500	4,400	80	\$53,500		h	p	s	w	1	1	1	1	1	f					
V104	review		225	Bryan	Forced Draft, Modulating	RV600	6000	4,800	80	\$55,700		h	p	s	w	1	1	1	1	1	f					
V104	review		226	Bryan	Forced Draft, Modulating	RV700	7000	5,600	80	\$66,400		h	p	s	w	1	1	1	1	1	f					
V104	review		227	Bryan	Forced Draft, Modulating	RV800	8000	6,400	80	\$72,900		h	p	s	w	1	1	1	1	1	n					
V104	update	-W means Water (vs Steam)	228	Bryan	RV Series	RV250-W	2500	2000	80			h	p	s	w	1	1	2	3	3	f					
V104	update	-W means Water (vs Steam)	229	Bryan	RV Series	RV300-W	3000	2400	80			h	p	s	w	1	1	2	3	3	f					
V104	update	-W means Water (vs Steam)	230	Bryan	RV Series	RV350-W	3500	2940	84			h	p	s	w	1	1	2	3	3	f					
V104	update	-W means Water (vs Steam)	231	Bryan	RV Series	RV400-W	4000	3360	84			h	p	s	w	1	1	2	3	3	f					
V104	update	-W means Water (vs Steam)	232	Bryan	RV Series	RV450-W	4500	3780	84			h	p	s	w	1	1	2	3	3	f					
V104	update	-W means Water (vs Steam)	233	Bryan	RV Series	RV500-W	5000	4200	84			h	p	s	w	1	1	2	3	3	f					
V104	update	-W means Water (vs Steam)	234	Bryan	RV Series	RV550-W	5500	4620	84			h	p	s	w	1	1	2	3	3	f					
V104	update	-W means Water (vs Steam)	235	Bryan	RV Series	RV600-W	6000	5040	84			h	p	s	w	1	1	2	3	3	f					
V104	update	-W means Water (vs Steam)	236	Bryan	RV Series	RV700-W	7000	5880	84			h	p	s	w	1	1	2	3	3	f					
V104	update	-W means Water (vs Steam)	237	Bryan	RV Series	RV800-W	8000	6720	84			h	p	s	w	1	1	2	3	3	f					
V104	new		238	Bryan	RV Series	RV850W	8500	7140	84			h	p	s	w	1	1	2	3	3	f					
V104	new		239	Bryan	RV Series	RV1050W	10500	8820	84			h	p	s	w	1	1	2	3	3	f					
V104	new		240	Bryan	RV Series	RV1260W	12600	10584	84			h	p	s	w	1	1	2	3	3	f					
V104	new		241	Bryan	RV Series	RV1500W	15000	12600	84			h	p	s	w	1	1	2	3	3	f					
V104	new		242	Bryan	RV Series	RV1700W	17000	14280	84			h	p	s	w	1	1	2	3	3	f					
V104	new		243	Bryan	RV Series	RV1900W	19000	15960	84			h	p	s	w	1	1	2	3	3	f					
V104	new		244	Bryan	RV Series	RV2100W	21000	17640	84			h	p	s	w	1	1	2	3	3	f					
V421	te		245	Bryan	TF Series	TF 150	1500.0	1350	92.8			h	p	ss	w	1	3	2	3	4	f			AHRI	7-Oct-13	
V421	te		246	Bryan	TF Series	TF 200	2000.0	1800	92.3			h	p	ss	w	1	3	2	3	4	f				AHRI	7-Oct-13
V421	te		247	Bryan	TF Series	TF 250	2500.0	2250	91.8			h	p	ss	w	1	3	2	3	4	f				AHRI	7-Oct-13
V421	te		248	Bryan	TF Series	TF 300	3000.0	2700	91.3	89.3		h	p	ss	w	1	3	2	3	4	f				AHRI	7-Oct-13
			249	Buderus	GA124 Series	GA124/17	70	59	84.3	85.2		h	i	i	s	1	1	2	3	3	s					
			250	Buderus	GA124 Series	GA124/23	94	79	84	85.1		h	i	i	s	1	1	2	3	3	f					
			251	Buderus	GA124 Series	GA124/30	123	104	84.6	85		h	i	i	s	1	1	2	3	3	f					
			252	Buderus	GA244 Series	GA244/37	156	128				d,h	i	i		1	1	3	1	3	s					
			253	Buderus	GA244 Series	GA244/44	182	148				d,h	i	i		1	1	3	1	3	s					
			254	Buderus	GA244 Series	GA244/53	220	181				d,h	i	i		1	1	3	1	3	s					
			255	Buderus	GA244 Series	GA244/62	262	212				d,h	i	i		1	1	3	1	3	s					
			256	Buderus	G124X Series	G124X/18	74	61.4	82.97	85		i	i	i		1	1	3	1	3	s					
			257	Buderus	G124X Series	G124X/25	103	85.5	83	85		h	i	i	s	1	1	2	3	3	f					
			258	Buderus	G124X Series	G124X/32	132.5	110	83	85		h	i	i	s	1	1	2	3	3	n					
			259	Buderus	G234X Series	G234X/38	160	130	81.25	84.3		h	a	i	s	1	1	1	1	1	n					
			260	Buderus	G234X Series	G234X/45	187	154	82.4	84.1		h	a	i	s	1	1	1	1	1	n					
			261	Buderus	G234X Series	G234X/55	228	188	82.5	84.8		h	a	i	s	1	1	1	1	1	f					
			262	Buderus	G234X Series	G234X/64	266	219	82.3	84.3		h	a	i	s	1	1	1	1	1	f					
			263	Buderus	G315 Series	G315/5	433	350	80.8			h	p	a	i	s	1	1	2	2	3					
			264	Buderus	G315 Series	G315/6	556	454	81.7	84.3		h	p	a	i	s	1	1	2	2	3					
			265	Buderus	G315 Series	G315/7	678	559	82.4	84.4		h	p	a	i	s	1	1	2	2	3					
			266	Buderus	G315 Series	G315/8																				

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Seasonal Efficiency	AFUE Eff	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sour	Date
			289	Buderus	SB615 Series	model 310	1080	1022		94.6			d,h	i	ss	f	1	1	3	1	1	d,s				
			290	Buderus	SB615 Series	model 400	1393	1317					d,h	i	ss	f	1	1	3	1	1	d,s				
			291	Buderus	SB615 Series	model 510	1776	1678		94.5			d,h	i	ss	f	1	1	3	1	1	d,s				
V107	new		292	Buderus	SB615 Series	640	2228	2104	94.4	96.2			h	p	ss	f	1	2	2	2	2	f		H		
			293	Buderus	SB735 Series	model 790	2751	2605		96.9			d,h	i	ss	f	1	1	3	1	1	d,s				
			294	Buderus	SB735 Series	model 970	3378	3251		96.3			d,h	i	ss	f	1	1	3	1	1	d,s				
V320	new		295	Buderus	SB735 Series	model 1200	4179	4079		97.6			d,h	i	ss	f	1	1	3	1	1	d,s				
V320	new		296	Burnham	Apex Series	APX399	399	377		95			d	p	ss	w	M	3	2	3	3	s				
V310	new		297	Burnham	Apex Series	APX500	500	475		95			d	p	ss	w	M	3	2	3	3	s				
V310	new		298	Burnham	MPC	MPC4	500	424	84.8			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		299	Burnham	MPC	MPC5	773	652	84.3			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		300	Burnham	MPC	MPC6	995	837	84.1			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		301	Burnham	MPC	MPC7	1216	1023	84.1			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		302	Burnham	MPC	MPC8	1438	1209	84.1			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		303	Burnham	MPC	MPC9	1660	1395	84.0			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		304	Burnham	MPC	MPC10	1881	1580	84.0			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		305	Burnham	MPC	MPC11	2103	1766	84.0			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		306	Burnham	MPC	MPC12	2325	1951	83.9			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		307	Burnham	MPC	MPC13	2547	2137	83.9			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		308	Burnham	MPC	MPC14	2769	2322	83.9			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		309	Burnham	MPC	MPC15	2991	2508	83.9			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		310	Burnham	MPC	MPC16	3213	2694	83.8			h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		311	Burnham	MPC	MPC17	3435	2880				h	p	p	i	s	M	3	3	3	f	1.3				
V310	new		312	Burnham	MPC	MPC18	3657	3065	83.8			h	p	p	i	s	M	3	3	3	f	1.3				
			313	Burnham	Series 2	S2-202	37.5	31	82.7	82.3			h	a	i	s	1	1	3		n	1				
			314	Burnham	Series 2	S2-202X	50	42	84	83.2			h	a	i	s	1	1	3		n	1				
			315	Burnham	Series 2	S2-203	62	52	83.9	82.6			h	a	i	s	1	1	3	1	n	1				
			316	Burnham	Series 2	S2-204	96	80	83.3	82.3			h	a	i	s	1	1	3	1	n	1				
			317	Burnham	Series 2	S2-205	130	108	83.1	82			h	a	i	s	1	1	3	1	n	1				
			318	Burnham	Series 2	S2-206	164	136	82.9	81.7			h	a	i	s	1	1	3	1	n	1				
			319	Burnham	Series 2	S2-207	198	163	82.3	81.4			h	a	i	s	1	1	3	1	n	1				
			320	Burnham	Series 2	S2-208	232	191	82.3	81.2			h	a	i	s	1	1	3	1	n	1				
			321	Burnham	Series 2	S2-209	266	218	81.95	80.9			h	a	i	s	1	1	3	1	n	1				
			322	Burnham	Series 2	S2-210	299	244	81.6	80.6			h	a	i	s	1	1	3	1	n	1				
			323	Burnham	Series 2	S2-203H	62	52	83.9	84			h	a	i	s	1	1	3	1	n	1				
			324	Burnham	Series 2	S2-204H	96	80	83.3	84			h	a	i	s	1	1	3	1	n	1				
			325	Burnham	Series 2	S2-205H	130	108	83.1	84			h	a	i	s	1	1	3	1	n	1				
			326	Burnham	Series 2	S2-206H	164	136	82.9	84			h	a	i	s	1	1	3	1	f	3				
			327	Burnham	Series 2PV	S2-203PV	62	51	82.3	82.1			h	i	i	s	1	1	3	1	f	3				
			328	Burnham	Series 2PV	S2-204PV	96	79	82.3	82			h	i	i	s	1	1	2	3	f	3				
			329	Burnham	Series 2PV	S2-205PV	130	107	82.3	82			h	i	i	s	1	1	2	3	f	3				
			330	Burnham	Series 2PV	S2-206PV	164	135	82.3	82			h	i	i	s	1	1	2	3	f	3				
			331	Burnham	Spacemaster	SM3	70	58	82.9	82.5			h	i	i	s	1	1	2	3	s	3				
			332	Burnham	Spacemaster	SM4	105	85	80.95	80.3			h	i	i	s	1	1	2	3	s	3				
			333	Burnham	Spirit	SP3	62	52	83.9	84			h	i	i	s	1	1	2	3	s	3				
			334	Burnham	Spirit	SP4	96	81	84.4	84			h	i	i	s	1	1	2	3	s	3				
			335	Burnham	Spirit	SP5	130	108	83.1	83			h	i	i	s	1	1	2	3	f,s	3				
			336	Burnham	Spirit	SP6	164	137	83.5	83			h	i	i	s	1	1	2	3	f,s	3				
			337	Burnham	Revolution	RV3	62	55	88.7	88			h	i	i	s	1	1	2	3	f,s	3				
			338	Burnham	Revolution	RV4	96	84	87.5	87.6			h	i	i	s	1	1	2	3	f,s	3				
			339	Burnham	Revolution	RV5	130	114	87.7	87.4			h	i	i	s	1	1	2	3	f,s	3				
			340	Burnham	Revolution	RV6	164	143	87.2	87.2			h	i	i	s	1	1	2	3	s	3				
			341	Burnham	Revolution	RV7	190	166	87.4	87			h	i	i	s	1	1	2	3	s	3				
			342	Burnham	MMIII 4-70		70	58	82.9	83.3			h	i	i	s	1	1	2	3	s	3				
			343	Burnham	MMIII 4-105		105	84	80	80.2			h	i	i	s	1	1	2	3	s	3				
			344	Burnham	MMIII 5-105		105	88	83.8	83.3			h	i	i	s	1	1	2	3	n	1				
			345	Burnham	MMIII 5-140		140	112	80.1	80.1			h	i	i	s	1	1	2	3	n	1				
			346	Burnham	Independence	IN3	62	51	82.3	83.1			h	a	i	s	1	1	3	1	n	1				
			347	Burnham	Independence	IN4	105	87	82.9	83.1			h	a	i	s	1	1	3	1	n	1				
			348	Burnham	Independence	IN5	140	115	82.1	83.1			h	a	i	s	1	1	3	1	n	1				
			349	Burnham	Independence	IN6	175	144	82.3	83.2			h	a	i	s	1	1	3	1	n	1				
			350	Burnham	Independence	IN7	210	173	82.4	83.2			h	a	i	s	1	1	3	1	n	1				
			351	Burnham	Independence	IN8	245	202	82.5	83.2			h	a	i	s	1	1	3	1	n	1				
			352	Burnham	Independence	IN9	280	231	82.5	83.2			h	a	i	s	1	1	3	1	n	1				
			353	Burnham	Independence	IN10	315	259.87	82.5	83.5			h	a	i	s	1	1	1	1	1	n	1			
			354	Burnham	Independence	IN11	349	287.92	82.5	83.5			h	a	i	s	1	1	1	1	1	f	3			
			355	Burnham	Independence	IN12	385	317.62	82.5	83.5			h	a	i	s	1	1	1	1	1	f	3			
			356	Burnham	Independence PV	PIN3PV	62	52	83.9	83.2			h	i	i	s	1	1	2	3	f	3				
			357	Burnham	Independence PV	PIN4PV	105	87	82.9	82.2			h	i	i	s	1	1	2	3	f	3				
			358	Burnham	Independence PV	PIN5PV	140	116	82.9	82.2			h	i	i	s	1	1	2	3	f	3				
			359	Burnham	Independence PV	PIN6PV	175	145	82.9	82.2			h	i	i	s	1	1	2	3	n	1				
			360	Burnham	Series 5B	K-5006B	401	320.8	80	82.2			h	a	i	s	1	1	1	1	n	1				
			361	Burnham	Series 5B	K-5007B	468	374.4	80			h	a	i	s	1	1	1	1	1	n	1				
			362	Burnham	Series 5B	K-5008B	546	436.8	80			h	a	i	s	1	1	1	1	1	n	1				
			363	Burnham	Series 5B	K-5009B	624	499.2																		

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			386	Burnham	FD Series	FD-9	397	315		79.4		d,h	p	i	s	1	1	2	1	n	1				
			387	Burnham	FD Series	FD-10	447	355		79.4		d,h	p	i	s	1	1	2	1	n	1				
			388	Burnham	FD Series	FD-12	577	459		79.6		d,h	p	i	s	1	1	2	1	n	1				
			389	Burnham	FD Series	FD-14	649	516		79.5		d,h	p	i	s	1	1	2	1	n	1				
			390	Burnham	FD Series	FD-15	721	574		79.6		d,h	p	i	s	1	1	2	1	n	1				
			391	Burnham	FD Series	FD-19	865	688		79.5		d,h	p	i	s	1	1	2	1	n	1				
			392	Burnham	FD Series	FD-24	1082	881		79.6		d,h	p	i	s	1	1	2	1	n	1				
			393	Burnham	FD Series	FD-30	1370	1090		79.6		d,h	p	i	s	2	1	2	1	n	1				
			394	Burnham	FD Series	FD-38	1730	1377		79.6		d,h	p	i	s	2	1	2	1	n	1				
			395	Burnham	FD Series	FD-45	2019	1607		79.6		d,h	p	i	s	2	1	2	1	n	1				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	396	Burnham	V-903A	V-903A	447	346	77.4	82.6		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	397	Burnham	V-904A	V-904A	606	483	79.7	83.4		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	398	Burnham	V-905A	V-905A	808	646	79.95	82.9		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	399	Burnham	V-906A	V-906A	1010	808	80	82.7		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	400	Burnham	V-907A	V-907A	1198	969	80.05	82.5		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	401	Burnham	V-908A	V-908A	1286	1110	80.1	82.4		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	402	Burnham	V-909A	V-909A	1674	1342	80.2	82.3		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	403	Burnham	V-910A	V-910A	1905	1528	80.2	82.2		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	404	Burnham	V-911A	V-911A	2136	1714	80.2	82.2		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	405	Burnham	V-912A	V-912A	2367	1900	80.3	82.1		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	406	Burnham	V1104	V1104	837	667	82.8	82.8		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	407	Burnham	V1105	V1105	1068	857	80.2	82.6		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	408	Burnham	V1106	V1106	1328	1069	80.5	82.5		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	409	Burnham	V1107	V1107	1588	1281	80.7	82.4		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	410	Burnham	V1108	V1108	1876	1517	80.9	82.3		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	411	Burnham	V1109	V1109	2136	1729	80.9	82.3		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	412	Burnham	V1110	V1110	2396	1941	81	82.2		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	413	Burnham	V1111	V1111	2656	2154	81.1	82.2		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	414	Burnham	V1112	V1112	2887	2334	80.8	82.1		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	415	Burnham	V1113	V1113	3103	2503	80.7	82		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	416	Burnham	V1114	V1114	3392	2730	80.5	81.9		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	417	Burnham	V1115	V1115	3680	2957	80.4	81.8		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	418	Burnham	V1116	V1116	3897	3129	80.3	81.7		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	419	Burnham	V1117	V1117	4186	3353	80.1	81.7		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	420	Burnham	V1118	V1118	4474	3680	80	81.6		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	421	Burnham	V1119	V1119	4691	3739	79.7	81.4		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	422	Burnham	V1120	V1120	4979	3957	79.5	81.2		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	423	Burnham	V1121	V1121	5268	4174	79.2	81		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	424	Burnham	V1122	V1122	5485	4334	79	80.8		d,h	p	i	s	1	1	3	2	f	1.3				
V310	review	Pureg (t1o3), Damp(t1o3), VntClass (	425	Burnham	V1123	V1123	5773	4551	78.8	80.7		d,h	p	i	s	1	1	3	2	f	1.3				
V107	new		426	Burnham	SCG Series	SCG3	70	60	85.7	85.5		h	i	i	s	1	1	2	1	s	3		M		
V107	new		427	Burnham	SCG Series	SCG4	105	90	85.7	85.4		h	i	i	s	1	1	2	1	s	3		M		
V107	new		428	Burnham	SCG Series	SCG5	140	120	85.7	85.3		h	i	i	s	1	1	2	1	s	3		M		
V107	new		429	Burnham	SCG Series	SCG6	175	150	85.7	85.2		h	i	i	s	1	1	2	1	s	3		M		
V107	new		430	Burnham	SCG Series	SCG7	210	179	85.2	85		h	i	i	s	1	1	2	1	s	3		M		
V107	new		431	Burnham	SCG Series	SCG8	245	208	84.9	84.5		h	i	i	s	1	1	2	1	s	3		M		
V107	new		432	Burnham	SCG Series	SCG9	280	238	85.0	84		h	i	i	s	1	1	2	1	s	3		M		
V107	new		433	Burnham	PVG Series	PVG3	70	60	85.7	85.5		h	i	i	s	1	1	2	1	s	3		M		
V107	new		434	Burnham	PVG Series	PVG4	105	90	85.7	85.4		h	i	i	s	1	1	2	1	s	3		M		
V107	new		435	Burnham	PVG Series	PVG5	140	120	85.7	85.3		h	i	i	s	1	1	2	1	s	3		M		
V107	new		436	Burnham	PVG Series	PVG6	175	150	85.7	85.2		h	i	i	s	1	1	2	1	s	3		M		
V107	new		437	Burnham	PVG Series	PVG7	210	179	85.2	85		h	i	i	s	1	1	2	1	s	3		M		
V107	new		438	Burnham	PVG Series	PVG8	245	208	84.9	84.5		h	i	i	s	1	1	2	1	s	3		M		
V107	new		439	Burnham	PVG Series	PVG9	280	238	85.0	84		h	i	i	s	1	1	2	1	s	3		M		
			440	Camus	Blue Flame	BF-480	480	398.4				d,h	a	c		2	2	2	1	f	1				
			441	Camus	Blue Flame	BF-660	660	547.8				d,h	a	c		2	2	2	1	s	1				
			442	Camus	Blue Flame	BF-840	840	697.2				d,h	a	c		2	2	2	1	s	1				
			443	Camus	Blue Flame	BF-1020	1020	846.6				d,h	a	c		2	2	2	1	s	1				
			444	Camus	Blue Flame	BF-1200	1200	996				d,h	a	c		2	2	2	1	s	1				
			445	Camus	Blue Flame	BF-1380	1380	1145.4				d,h	a	c		2	2	2	1	s	1				
			446	Camus	Blue Flame	BF-1560	1560	1294.8				d,h	a	c		2	2	2	1	s	1				
			447	Camus	Blue Flame	BF-1740	1740	1444.2				d,h	a	c		2	2	2	1	s	1				
			448	Camus	Blue Flame	BF-1950	1950	1618.5				d,h	a	c		2	2	2	1	s	1				
			449	Camus	CeraFlame Series	CF-450	450	382.5	85			d,h	p	c	w	1	1	2	3	n	1				
			450	Camus	CeraFlame Series	CF-550	550	467.5	85			d,h	p	c	w	1	1	2	3	n	1				
			451	Camus	CeraFlame Series	CF-650	650	552.5	85			d,h	p	c	w	1	1	2	3	n	1				
			452	Camus	DynaFlame Series	DF-500	500.0	425	85.0			d,h	p	c	w	1	3	2	3	f	1.3				
			453	Camus	DynaFlame Series	DF-750	750.0	638	85.0			d,h	p	c	w	1.3	3	2	3	f	1.3				
			454	Camus	DynaFlame Series	DF-1100	1100.0	935	85.0			d,h	p	c	w	1.3	3	2	3	f	1.3				
			455	Camus	DynaFlame Series	DF-1200	1200.0	1020	95.0			d,h	p	c	w	1.3	3	2	3	f	1.3				
			456	Camus	DynaFlame Series	DF-1500	1500.0	1275	85.0			d,h													

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Exhaustion Effici	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Date Sourc	Date
V421	update from AHRI		483 Camus		DynaFlame Series	DF-6024 Condensing	6000.0	5664	94.4			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		484 Camus		DFX Series	DFX501	5000.0	436	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		485 Camus		DFX Series	DFX751	750.0	654	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		486 Camus		DFX Series	DFX1101	1100.0	959	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		487 Camus		DFX Series	DFX1201	1200.0	1046	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		488 Camus		DFX Series	DFX1501	1500.0	1308	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		489 Camus		DFX Series	DFX1751	1750.0	1526	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		490 Camus		DFX Series	DFX2001	2000.0	1744	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		491 Camus		DFX Series	DFX2501	2500.0	2180	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		492 Camus		DFX Series	DFX3001	3000.0	2616	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		493 Camus		DFX Series	DFX3501	3500.0	3052	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		494 Camus		DFX Series	DFX4001	4000.0	3488	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		495 Camus		DFX Series	DFX4514	4500.0	3924	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		496 Camus		DFX Series	DFX4501	4500.0	3924	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		497 Camus		DFX Series	DFX5001	5000.0	4360	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		498 Camus		DFX Series	DFX5014	5000.0	4360	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		499 Camus		DFX Series	DFX6014	6000.0	5232	87.2			d, h	p	c	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		500 Camus		Dyna Force	DRH0300	300.0	282	94.0	94.0		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		501 Camus		Dyna Force	DRH0350	350.0	329	94.0	94.0		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		502 Camus		Dyna Force	DRH0400	400.0	376	94.0	94.0		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		503 Camus		Dyna Force	DRH0500	500.0	470	94.0	94.0		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		504 Camus		Dyna Force	DRH0600	600.0	564	94.0	94.0		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		505 Camus		Dyna Force	DRH0800	800.0	752	94.0	94.0		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		506 Camus		Dyna Force	DRH1000	1000.0	940	94.0	94.0		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		507 Camus		Dyna Force	DRH11200	1200.0	1137	94.8	94.8		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		508 Camus		Dyna Force	DRH1400	1400.0	1327	94.8	94.8		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		509 Camus		Dyna Force	DRH1600	1600.0	1516	94.8	94.8		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		510 Camus		Dyna Force	DRH1800	1800.0	1706	94.8	94.8		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		511 Camus		Dyna Force	DRH2000	2000.0	1896	94.8	94.8		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		512 Camus		Dyna Force	DRH2500	2500.0	2362	94.5	94.5		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		513 Camus		Dyna Force	DRH3000	3000.0	2835	94.5	94.5		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		514 Camus		Dyna Force	DRH3500	3500.0	3307	94.5	94.5		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		515 Camus		Dyna Force	DRH4000	4000.0	3780	94.5	94.5		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		516 Camus		Dyna Force	DRH4500	4500.0	4252	94.5	94.5		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		517 Camus		Dyna Force	DRH5000	5000.0	4725	94.5	94.5		h	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		518 Camus		Dyna Force	DRW0300	300.0	282	94.0	94.0		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		519 Camus		Dyna Force	DRW0350	350.0	329	94.0	94.0		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		520 Camus		Dyna Force	DRW0400	400.0	376	94.0	94.0		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		521 Camus		Dyna Force	DRW0500	500.0	470	94.0	94.0		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		522 Camus		Dyna Force	DRW0600	600.0	564	94.0	94.0		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		523 Camus		Dyna Force	DRW0800	800.0	752	94.0	94.0		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		524 Camus		Dyna Force	DRW1000	1000.0	940	94.0	94.0		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		525 Camus		Dyna Force	DRW1200	1200.0	1137	94.8	94.8		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		526 Camus		Dyna Force	DRW1400	1400.0	1327	94.8	94.8		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		527 Camus		Dyna Force	DRW1600	1600.0	1516	94.8	94.8		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		528 Camus		Dyna Force	DRW1800	1800.0	1706	94.8	94.8		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		529 Camus		Dyna Force	DRW2000	2000.0	1896	94.8	94.8		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		530 Camus		Dyna Force	DRW2500	2500.0	2362	94.5	94.5		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		531 Camus		Dyna Force	DRW3000	3000.0	2835	94.5	94.5		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		532 Camus		Dyna Force	DRW3500	3500.0	3307	94.5	94.5		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		533 Camus		Dyna Force	DRW4000	4000.0	3780	94.5	94.5		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		534 Camus		Dyna Force	DRW4500	4500.0	4252	94.5	94.5		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		535 Camus		Dyna Force	DRW5000	5000.0	4725	94.5	94.5		d	p	ss	w	M	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		536 Camus		Dyna Max	DM-0391	399.0	383	95.9	95.9		h	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		537 Camus		Dyna Max	DM-0392	399.0	383	95.9	95.9		d	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		538 Camus		Dyna Max	DM-0393	399.0	383	95.9	95.9		c	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		539 Camus		Dyna Max	DM-0501	500.0	479	95.9	95.9		h	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		540 Camus		Dyna Max	DM-0502	500.0	479	95.9	95.9		d	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		541 Camus		Dyna Max	DM-0603	600.0	479	95.9	95.9		c	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		542 Camus		Dyna Max	DM-0601	600.0	575	95.9	95.9		h	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		543 Camus		Dyna Max	DM-0602	600.0	575	95.9	95.9		d	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		544 Camus		Dyna Max	DM-0603	600.0	575	95.9	95.9		c	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		545 Camus		Dyna Max	DM-0701	700.0	671	95.9	95.9		h	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		546 Camus		Dyna Max	DM-0702	700.0	671	95.9	95.9		d	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		547 Camus		Dyna Max	DM-0703	700.0	671	95.9	95.9		c	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		548 Camus		Dyna Max	DM-0801	800.0	767	95.9	95.9		h	p	ss	p	M	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		549 Camus		Dyna Max	DM-0802	800.0	767	95.9	95.9															

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Efficiency Adjustment	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Date Sourc	Date
V421	update from AHRI		580 Camus		MicoFlame Series 2	MF-1000-0	1000.0	850	85.0		d, h	p	p	c	w	1	1	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		581 Camus		MicoFlame Series 2	MF-1000-2	1000.0	850	85.0		d, h	p	p	c	w	2	2	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		582 Camus		MicoFlame Series 2	MF-1000-M	1000.0	850	85.0		d, h	p	p	c	w	1	1	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		583 Camus		MicoFlame Series 2	MF-1002-0	1000.0	950	95.0		d, h	p	p	c	w	1	1	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		584 Camus		MicoFlame Series 2	MF-1002-2	1000.0	950	95.0		d, h	p	p	c	w	2	2	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		585 Camus		MicoFlame Series 2	MF-1002-M	1000.0	950	95.0		d, h	p	p	c	w	2	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		586 Camus		MicoFlame Series 2	MF-1200-0	1200.0	1020	85.0		d, h	p	p	c	w	1	1	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		587 Camus		MicoFlame Series 2	MF-1200-2	1200.0	1020	85.0		d, h	p	p	c	w	2	2	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		588 Camus		MicoFlame Series 2	MF-1200-M	1200.0	1020	85.0		d, h	p	p	c	w	1	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		589 Camus		MicoFlame Series 2	MF-1202-0	1200.0	1140	95.0		d, h	p	p	c	w	1	1	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		590 Camus		MicoFlame Series 2	MF-1202-2	1200.0	1140	95.0		d, h	p	p	c	w	2	2	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		591 Camus		MicoFlame Series 2	MF-1202-M	1200.0	1140	95.0		d, h	p	p	c	w	1	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		592 Camus		MicoFlame Series 2	MF-1400-0	1400.0	1190	85.0		d, h	p	p	c	w	1	1	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		593 Camus		MicoFlame Series 2	MF-1400-2	1400.0	1190	85.0		d, h	p	p	c	w	2	2	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		594 Camus		MicoFlame Series 2	MF-1400-M	1400.0	1190	85.0		d, h	p	p	c	w	2	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		595 Camus		MicoFlame Series 2	MF-1402-0	1400.0	1330	95.0		d, h	p	p	c	w	1	1	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		596 Camus		MicoFlame Series 2	MF-1402-2	1400.0	1330	95.0		d, h	p	p	c	w	2	2	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		597 Camus		MicoFlame Series 2	MF-1402-M	1400.0	1330	95.0		d, h	p	p	c	w	1	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		598 Camus		MicoFlame Series 2	MF-1600-0	1600.0	1360	85.0		d, h	p	p	c	w	1	1	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		599 Camus		MicoFlame Series 2	MF-1600-2	1600.0	1360	85.0		d, h	p	p	c	w	2	2	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		600 Camus		MicoFlame Series 2	MF-1600-M	1600.0	1360	85.0		d, h	p	p	c	w	1	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		601 Camus		MicoFlame Series 2	MF-1602-0	1600.0	1520	95.0		d, h	p	p	c	w	1	1	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		602 Camus		MicoFlame Series 2	MF-1602-2	1600.0	1520	95.0		d, h	p	p	c	w	2	2	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		603 Camus		MicoFlame Series 2	MF-1602-M	1600.0	1520	95.0		d, h	p	p	c	w	2	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		604 Camus		MicoFlame Series 2	MF-1800-0	1800.0	1530	85.0		d, h	p	p	c	w	1	1	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		605 Camus		MicoFlame Series 2	MF-1800-2	1800.0	1530	85.0		d, h	p	p	c	w	2	2	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		606 Camus		MicoFlame Series 2	MF-1800-M	1800.0	1530	85.0		d, h	p	p	c	w	1	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		607 Camus		MicoFlame Series 2	MF-1802-0	1800.0	1710	95.0		d, h	p	p	c	w	1	1	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		608 Camus		MicoFlame Series 2	MF-1802-2	1800.0	1710	95.0		d, h	p	p	c	w	2	2	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		609 Camus		MicoFlame Series 2	MF-1802-M	1800.0	1710	95.0		d, h	p	p	c	w	1	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		610 Camus		MicoFlame Series 2	MF-2000-0	2000.0	1700	85.0		d, h	p	p	c	w	1	1	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		611 Camus		MicoFlame Series 2	MF-2000-2	2000.0	1700	85.0		d, h	p	p	c	w	2	2	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		612 Camus		MicoFlame Series 2	MF-2000-M	2000.0	1700	85.0		d, h	p	p	c	w	1	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		613 Camus		MicoFlame Series 2	MF-2002-0	2000.0	1900	95.0		d, h	p	p	c	w	1	1	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		614 Camus		MicoFlame Series 2	MF-2002-2	2000.0	1900	95.0		d, h	p	p	c	w	2	2	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		615 Camus		MicoFlame Series 2	MF-2002-M	2000.0	1900	95.0		d, h	p	p	c	w	1	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		616 Camus		MicoFlame Series Grande	MF-2010-0	2000.0	1700	85.0		d, h	p	p	c	w	1	1	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		617 Camus		MicoFlame Series Grande	MF-2010-2	2000.0	1700	85.0		d, h	p	p	c	w	2	2	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		618 Camus		MicoFlame Series Grande	MF-2010-M	2000.0	1700	85.0		d, h	p	p	c	w	1	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		619 Camus		MicoFlame Series Grande	MF-2012-0	2000.0	1868	93.4		d, h	p	p	c	w	1	1	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		620 Camus		MicoFlame Series Grande	MF-2012-2	2000.0	1868	93.4		d, h	p	p	c	w	2	2	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		621 Camus		MicoFlame Series Grande	MF-2012-M	2000.0	1868	93.4		d, h	p	p	c	w	1	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		622 Camus		MicoFlame Series Grande	MF-2500-0	2500.0	2125	85.0		d, h	p	p	c	w	1	1	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		623 Camus		MicoFlame Series Grande	MF-2500-2	2500.0	2125	85.0		d, h	p	p	c	w	2	2	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		624 Camus		MicoFlame Series Grande	MF-2500-M	2500.0	2125	85.0		d, h	p	p	c	w	1	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		625 Camus		MicoFlame Series Grande	MF-2502-0	2500.0	2335	93.4		d, h	p	p	c	w	1	1	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		626 Camus		MicoFlame Series Grande	MF-2502-2	2500.0	2335	93.4		d, h	p	p	c	w	2	2	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		627 Camus		MicoFlame Series Grande	MF-2502-M	2500.0	2335	93.4		d, h	p	p	c	w	1	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		628 Camus		MicoFlame Series Grande	MF-3000-0	3000.0	2550	85.0		d, h	p	p	c	w	1	1	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		629 Camus		MicoFlame Series Grande	MF-3000-2	3000.0	2550	85.0		d, h	p	p	c	w	2	2	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		630 Camus		MicoFlame Series Grande	MF-3000-M	3000.0	2550	85.0		d, h	p	p	c	w	1	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		631 Camus		MicoFlame Series Grande	MF-3002-0	3000.0	2802	93.4		d, h	p	p	c	w	1	1	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		632 Camus		MicoFlame Series Grande	MF-3002-2	3000.0	2802	93.4		d, h	p	p	c	w	2	2	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		633 Camus		MicoFlame Series Grande	MF-3002-M	3000.0	2802	93.4		d, h	p	p	c	w	1	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		634 Camus		MicoFlame Series Grande	MF-3500-0	3500.0	2975	85.0		d, h	p	p	c	w	1	1	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		635 Camus		MicoFlame Series Grande	MF-3500-2	3500.0	2975	85.0		d, h	p	p	c	w	2	2	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		636 Camus		MicoFlame Series Grande	MF-3500-M	3500.0	2975	85.0		d, h	p	p	c	w	1	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		637 Camus		MicoFlame Series Grande	MF-3502-0	3500.0	3269	93.4		d, h	p	p	c	w	1	1	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		638 Camus		MicoFlame Series Grande	MF-3502-2	3500.0	3269	93.4		d, h	p	p	c	w	2	2	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		639 Camus		MicoFlame Series Grande	MF-3502-M	3500.0	3269	93.4		d, h	p	p	c	w	1	3	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		640 Camus		MicoFlame Series Grande	MF-4000-0	4000.0	3400	85.0		d, h	p	p	c	w	1	1	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		641 Camus		MicoFlame Series Grande	MF-4000-2	4000.0	3400	85.0		d, h	p	p	c	w	2	2	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		642 Camus		MicoFlame Series Grande	MF-4000-M	4000.0	3400	85.0		d, h	p	p	c	w	1	3	2	3	f	1, 3			AHRI	7-Oct-13
V421	update from AHRI		643 Camus		MicoFlame Series Grande	MF-4002-0	4000.0	3736	93.4		d, h	p	p	c	w	2	1	2	3	f	2, 4			AHRI	7-Oct-13
V421	update from AHRI		644 Camus		MicoFlame Series Grande	MF-4002-2	4000.0	3736	93.4		d, h	p	p	c	w	1	2	2	3	f	2, 4			AHRI	7-Oct-13

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Efficiency Adjustment	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sourc	Date
			677	Cleaver Brooks	Model FLX	FLX 200	2000	1600				d,h	p		w	M	3	3	3	3	f				
			678	Cleaver Brooks	Model FLX	FLX250	2500	2000				d,h	p		w	M	3	3	3	3	f				
			679	Cleaver Brooks	Model FLX	FLX 300	3000	2400				d,h	p		w	M	3	3	3	3	f				
			680	Cleaver Brooks	Model FLX	FLX 350	3500	2800				d,h	p		w	M	3	3	3	3	f				
			681	Cleaver Brooks	Model FLX	FLX 400	4000	3200				d,h	p		w	M	3	3	3	3	f				
			682	Cleaver Brooks	Model FLX	FLX 450	4500	3600				d,h	p		w	M	3	3	3	3	f				
			683	Cleaver Brooks	Model FLX	FLX500	5000	4000				d,h	p		w	M	3	3	3	3	f				
			684	Cleaver Brooks	Model FLX	FLX 550	5500	4400				d,h	p		w	M	3	3	3	3	f				
			685	Cleaver Brooks	Model FLX	FLX 600	6000	4800				d,h	p		w	M	3	3	3	3	f				
			686	Cleaver Brooks	Model FLX	FLX 700	7000	5600				d,h	p		w	M	3	3	3	3	f				
			687	Cleaver Brooks	Model FLX	FLX 800	8000	6400				d,h	p		w	M	3	3	3	3	f				
			688	Cleaver Brooks	Model FLX	FLX 900	9000	7200				d,h	p		w	M	3	3	3	3	f				
			689	Cleaver Brooks	Model FLX	FLX 1000	10000	8000				d,h	p		w	M	3	3	3	3	f				
			690	Cleaver Brooks	Model FLX	FLX1100	11000	8800				d,h	p		w	M	3	3	3	3	f				
			691	Cleaver Brooks	Model FLX	FLX 1200	12000	9600				d,h	p		w	M	3	3	3	3	f				
V107	new		692	Cleaver Brooks	Clearfire Series	MCF160	750	720	96			h	p	ss	f	M	2	2	3	3	f, s	4	H		
V107	new		693	Cleaver Brooks	Clearfire Series	MCF1000	1000	960	96			h	p	ss	f	M	2	2	3	3	f, s	4	H		
V107	new		694	Cleaver Brooks	Clearfire Series	MCF1500	1500	1440	96			h	p	ss	f	M	2	2	3	3	f, s	4	H		
V107	new		695	Cleaver Brooks	Clearfire Series	MCF1800	1800	1728	96			h	p	ss	f	M	2	2	3	3	f, s	4	H		
V107	new		696	Crown Boiler Co.	Cabo2 CWD Series	CWD060	60	51	85.0	85.1		d, h	a	i	s	1	1	2	3	3	s	3	M		
V107	new		697	Crown Boiler Co.	Cabo2 CWD Series	CWD083	82.5	71	86.1	85.1		d, h	a	i	s	1	1	2	3	3	s	3	M		
V107	new		698	Crown Boiler Co.	Cabo2 CWD Series	CWD110	110	94	85.5	85.2		d, h	a	i	s	1	1	2	3	3	s	3	M		
V107	new		699	Crown Boiler Co.	Cabo2 CWD Series	CWD138	137.5	118	85.8	85.2		d, h	a	i	s	1	1	2	3	3	s	3	M		
V107	new		700	Crown Boiler Co.	Cabo2 CWD Series	CWD165	165	142	86.1	85.2		d, h	a	i	s	1	1	2	3	3	s	3	M		
V107	new		701	Crown Boiler Co.	Cabo2 CWD Series	CWD193	192.5	165	85.7	85.2		d, h	a	i	s	1	1	2	3	3	s	3	M		
V107	new		702	Crown Boiler Co.	Cabo2 CWD Series	CWD193	189	165	85.7	85.2		d, h	a	i	s	1	1	2	3	3	s	3	M		
V107	new		703	Crown Boiler Co.	Cabo2 CWD Series	CWD220	220	189	85.9	85.2		d, h	a	i	s	1	1	2	3	3	s	3	M		
V107	new		704	Crown Boiler Co.	Cabo2 CWD Series	CWD245	245	211	86.1	85.3		d, h	a	i	s	1	1	2	3	3	s	3	M		
V421	update from AHRI		705	De Dietrich	C230 ECO-A Series	C230-120 ECO-A	480.0	356	89.0	92.2		h	Forced Draft	Aluminum	s	M	3	2	3	3	f	2, 4		AHRI	7-Oct-13
V421	update from AHRI		706	De Dietrich	C230 ECO-A Series	C230-160 ECO-A	600.0	605	89.0	92.2		h	Forced Draft	Aluminum	s	M	3	2	3	3	f	2, 4		AHRI	7-Oct-13
V421	update from AHRI		707	De Dietrich	C230 ECO-A Series	C230-200 ECO-A	820.0	730	89.0	92.2		h	Forced Draft	Aluminum	s	M	3	2	3	3	f	2, 4		AHRI	7-Oct-13
V421	update from AHRI		708	De Dietrich	C230 ECO-A Series	C230-80 ECO-A	325.0	289	89.0	92.2		h	Forced Draft	Aluminum	s	M	3	2	3	3	f	2, 4		AHRI	7-Oct-13
V421	update from AHRI		709	De Dietrich	GAS 310 ECO	GAS 310-5 ECO	1017.0	962	97.4	97.4		h	Forced Draft	Aluminum	s	M	3	2	3	3	f	2, 4		AHRI	7-Oct-13
V421	update from AHRI		710	De Dietrich	GAS 310 ECO	GAS 310-6 ECO	1269.0	1205	97.4	97.4		h	Forced Draft	Aluminum	s	M	3	2	3	3	f	2, 4		AHRI	7-Oct-13
V421	update from AHRI		711	De Dietrich	GAS 310 ECO	GAS 310-7 ECO	1529.0	1457	97.4	97.4		h	Forced Draft	Aluminum	s	M	3	2	3	3	f	2, 4		AHRI	7-Oct-13
V421	update from AHRI		712	De Dietrich	GAS 310 ECO	GAS 310-8 ECO	1785.0	1703	97.4	97.4		h	Forced Draft	Aluminum	s	M	3	2	3	3	f	2, 4		AHRI	7-Oct-13
V421	update from AHRI		713	De Dietrich	GT 200 Series	GT 227A	2049.0	1955	85.2	85.2		h	Forced Draft	Aluminum	s	M	3	2	3	3	f	2, 4		AHRI	7-Oct-13
V421	update from AHRI		714	De Dietrich	GT 200 Series	GT 228A	324.0	276	85.2	85.2		h	Forced Draft	Cast Iron	s	2	2	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		715	De Dietrich	GT 300 Series	GT 334A	361.0	307	85.2	85.2		h	Forced Draft	Cast Iron	s	2	2	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		716	De Dietrich	GT 300 Series	GT 335A	404.0	343	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		717	De Dietrich	GT 300 Series	GT 336A	598.0	509	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		718	De Dietrich	GT 300 Series	GT 337A	808.0	686	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		719	De Dietrich	GT 300 Series	GT 338A	1024.0	870	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		720	De Dietrich	GT 300 Series	GT 339A	1226.0	1042	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		721	De Dietrich	GT 400 Series	GT 430A-10	1442.0	1226	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		722	De Dietrich	GT 400 Series	GT 430A-11	2278.0	1937	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		723	De Dietrich	GT 400 Series	GT 430A-12	2967.0	2182	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		724	De Dietrich	GT 400 Series	GT 430A-13	3100.0	2402	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		725	De Dietrich	GT 400 Series	GT 430A-14	3389.0	2635	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		726	De Dietrich	GT 400 Series	GT 430A-8	1730.0	2880	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		727	De Dietrich	GT 400 Series	GT 430A-9	1947.0	1471	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		728	De Dietrich	GT 500 Series	GT 530A-15	3749.0	1655	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		729	De Dietrich	GT 500 Series	GT 530A-16	3886.0	3194	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		730	De Dietrich	GT 500 Series	GT 530A-17	4254.0	3379	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		731	De Dietrich	GT 500 Series	GT 530A-18	4254.0	3624	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		732	De Dietrich	GT 500 Series	GT 530A-19	4470.0	3808	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		733	De Dietrich	GT 500 Series	GT 530A-20	4759.0	4054	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		734	De Dietrich	GT 500 Series	GT 530A-21	4875.0	4239	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		735	De Dietrich	GT 500 Series	GT 530A-22	5191.0	4423	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		736	De Dietrich	GT 500 Series	GT 530A-23	5480.0	4669	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		737	De Dietrich	GT 500 Series	GT 530A-24	5696.0	4853	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		738	De Dietrich	GT 500 Series	GT 530A-25	5884.0	5098	85.2	85.2		h	Forced Draft	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		739	Detson	HGRC AC Series	HGRC-68AC	68	54.4	80	85.2	1234	h	a	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		740	Detson	HGRC AC Series	HGRC-105AC	102	81.6	80	85.2	1192	h	a	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		741	Detson	HGRC AC Series	HGRC-136AC	136	106.8	80	85.2	1905	h	a	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		742	Detson	HGRC AC Series	HGRC-170AC	170	136	80	85.2	2060	h	a	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI		743	Detson	HGRC AC Series	HGRC-204AC	204	163.2	80	85.2	2186	h	a	Cast Iron	s	M	3	1	1	1	n	1		AHRI	7-Oct-13
V421	update from AHRI																								

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Seasonal Efficiency	Austion Effici	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sourc	Date
			774	Dettson	HGC Series	HGC-909AC	900	720		80	4340		h	a	c	w	2	1	1	1	1	n				
			775	Dettson	HGC Series	HGC-1010AC	1000	800		80	4676		h	a	c	w	2	1	1	1	1	n				
			776	Dettson	HGC Series	HGC-1111AC	1100	880		80	4877		h	a	c	w	2	1	1	1	1	n				
			777	Dettson	HGC Series	HGC-1212AC	1200	960		80	5079		h	a	c	w	2	1	1	1	1	n				
			778	Dettson	HGC Series	HGC-1313AC	1300	1040		80	5345		h	a	c	w	2	1	1	1	1	n				
			779	Dettson	HGC Series	HGC-1414AC	1400	1120		80	5524		h	a	c	w	2	1	1	1	1	n				
			780	Dettson	HGC Series	HGC-1515AC	1500	1200		80	5704		h	a	c	w	2	1	1	1	1	n				
			781	Dettson	HGC Series	HGC-404HW	404	323.2		80	3564		d	a	c	w	2	1	1	1	1	n				
			782	Dettson	HGC Series	HGC-505HW	505	404		80	3767		d	a	c	w	2	1	1	1	1	n				
			783	Dettson	HGC Series	HGC-606HW	606	484.8		80	3908		d	a	c	w	2	1	1	1	1	n				
			784	Dettson	HGC Series	HGC-707HW	707	565.6		80	4141		d	a	c	w	2	1	1	1	1	n				
			785	Dettson	HGC Series	HGC-808HW	808	646.4		80	4468		d	a	c	w	2	1	1	1	1	n				
			786	Dettson	HGC Series	HGC-909HW	909	727.2		80	4805		d	a	c	w	2	1	1	1	1	n				
			787	Dettson	HGC Series	HGC-1010HW	1010	808		80	5141		d	a	c	w	2	1	1	1	1	n				
			788	Dettson	HGC Series	HGC-1111HW	1111	888.8		80	5342		d	a	c	w	2	1	1	1	1	n				
			789	Dettson	HGC Series	HGC-1212HW	1212	969.6		80	5544		d	a	c	w	2	1	1	1	1	n				
			790	Dettson	HGC Series	HGC-1313HW	1313	1050.4		80	5810		d	a	c	w	2	1	1	1	1	n				
			791	Dettson	HGC Series	HGC-1414HW	1414	1131.2		80	5989		d	a	c	w	2	1	1	1	1	f				
			792	Dettson	HGC Series	HGC-1515HW	1515	1212		80	6169		d	a	c	w	2	1	1	1	1	f				
			793	Fulton	PulsePak	PHW300-PP	300	270		90			h	p	s	w	1	2	2	3	3	f				
			794	Fulton	PulsePak	PHW500-PP	500	440		88			h	p	s	w	1	2	2	3	3	f				
			795	Fulton	PulsePak	PHW750-PP	750	637.5		85			h	p	s	w	1	2	2	3	3	f				
			796	Fulton	PulsePak	PHW950-PP	1000	840		84			h	p	s	w	1	2	2	3	3	f				
			797	Fulton	PulsePak	PHW1400	1400	1204		86			h	p	s	w	M	3	2	3	3	v				
			798	Fulton	PulsePak	PHW1680	2000	1680		84			h	p	s	w	M	3	2	3	3	v				
			799	Fulton	Pulse Plus	PHW300	300	269		89.5	\$8,500		h	p	s	w	1	3	2	3	3	v				
			800	Fulton	Pulse Plus	PHW650	650	553		85			h	p	s	w	1	3	2	3	3	v				
			801	Fulton	Pulse Plus	PHW950	950	445		89	\$11,839		h	p	s	w	1	3	2	3	3	v				
			802	Fulton	Pulse Plus	PHW950	950	808		85			h	p	s	w	1	3	2	3	3	v				
			803	Fulton	Pulse Plus	PHW750	750	664		88.51	\$13,615		h	p	s	w	1	3	2	3	3	v				
			804	Fulton	Pulse Plus	PHW1400	1,400	1,190		85			h	p	s	w	1	3	2	3	3	v				
			805	Fulton	Pulse Plus	PHW1000	1,000	875		87.5	\$15,075		h	p	s	w	1	3	2	3	3	n				
			806	Fulton	Edge	4 HP	175	134		76.6			h	p	s	w	1	3	2	3	3	n				
			807	Fulton	Edge	6 HP	260	201		77.3			h	p	s	w	1	3	2	3	3	n				
			808	Fulton	Edge	10 HP	420	335		79.8			h	p	s	w	1	3	2	3	3	n				
			809	Fulton	Edge	15 HP	630	502		79.7			h	p	s	w	1	3	2	3	3	n				
			810	Fulton	Edge	20 HP	840	670		79.8			h	p	s	w	1	3	2	3	3	n				
			811	Fulton	Edge	30 HP	1260	1004		79.7			h	p	s	w	1	3	2	3	3	n				
			812	Fulton	Edge	50 HP	2100	1674		79.7			h	p	s	w	1	3	2	3	3	n				
			813	Fulton	Edge	60 HP	2520	2009		79.7			h	p	s	w	1	3	2	3	3	n				
V107	new		814	Fulton	Vantage	VTG 3000	3000	2610	87				h	p	c/ss	f	M	2	2	3	3	s			H	
V104	review		815	Gasmaster Industries	Radial Pulse	GMI-200	200	197		98.5	9200		d,h	p	ss	w	M	3	2	3	3	d				
V104	review		816	Gasmaster Industries	Radial Pulse	GMI-300	305	304.3		99.8	14,700		d,h	p	ss	w	M	3	2	3	3	d				
V104	review		817	Gasmaster Industries	Radial Pulse	GMI-400	395	383		99.7	15,200		d,h	p	ss	w	M	3	2	3	3	d				
V104	new		818	Gasmaster Industries	Radial Pulse	GMI-500	500	490		98	16,550		d,h	p	ss	w	M	3	2	3	3	d				
V104	review		819	Gasmaster Industries	Radial Pulse	GMI-800	600	588		98	22,100		d,h	p	ss	w	M	3	2	3	3	d				
V104	review		820	Gasmaster Industries	Radial Pulse	GMI-800	800	776		97	24,200		d,h	p	ss	w	M	3	2	3	3	d				
V104	review		821	Gasmaster Industries	Radial Pulse	GMI-1M	1000	970		97	31,200		d,h	p	ss	w	M	3	2	3	3	s				
V104	review		822	Gasmaster Industries	Radial Pulse	GMI-1.5M	1500	1470		98.8	33,600		d,h	p	ss	w	M	3	2	3	3	s				
V104	review		823	Gasmaster Industries	Radial Pulse	GMI-2M	2000	1960		98	33,600		d,h	p	ss	w	M	3	2	3	3	s				
V104	new		824	Gasmaster Industries	Radial Pulse	GMI-3M	3000	2949		98.3			d,h	p	ss	w	M	3	2	3	3	s				
V104	review		825	Gasmaster Industries	Radial Pulse	GMI-4M	4000	3840		98.3	66,200		d,h	p	ss	w	M	3	2	3	3	s				
V104	new		826	Gasmaster Industries	Radial Pulse	GMI-5M	5000	4825					d,h	p	ss	w	M	3	2	3	3	s				
V104	review		827	Gasmaster Industries	Radial Pulse	GMI-6M	6000	5850		97.5			d,h	p	ss	w	M	3	2	3	3	s				
V104	new		828	Gasmaster Industries	Radial Pulse	GMI-8M	8000	7720		96.5			d,h	p	ss	w	M	3	2	3	3	s				
			829	Glowcore	GB/GW Series	GB040A	40	35.52	88.8	94.1		h	p	cn	cn	w	1	1	2	2	2	s				
			830	Glowcore	GB/GW Series	GB060A	60	53.4	89	94.1		h	p	cn	cn	w	1	1	2	2	2	v				
			831	Glowcore	GB/GW Series	GB090A	90	79.92	88.8	92.6		h	p	cn	cn	w	1	1	2	2	2	v				
			832	Glowcore	GB/GW Series	GB130A	130	115.4	88.8	92.6		h	p	cn	cn	w	1	1	2	2	2	v				
			833	Glowcore	GB/GW Series	GB160A	160	142.1	88.8	92.5		h	p	cn	cn	w	1	1	2	2	2	v				
			834	Glowcore	GB/GW Series	GB0-407C	40	36		89	\$2,530		h	p	cn	w	1	2	2	2	3	v				
			835	Glowcore	GB/GW Series	GB0-607C	60	53		89	\$2,530		h	p	cn	w	1	2	2	2	3	v				
			836	Glowcore	GB/GW Series	GB0-907C	90	78		86.8	\$2,530		h	p	cn	w	1	2	2	2	3	s				
			837	Glowcore	GB/GW Series	GB 13010C	130	115		88.77	\$3,250		h	p	cn	w	1	2	2	2	3	s				
			838	Glowcore	GB/GW Series	GBWH 150C	150	132		88	\$3,250		h	p	cn	w	1	3	2	2	3	s				
			839	Glowcore	GB/GW Series	GB 16014C	160	141		88	\$3,250		h	p	cn	w	1	2	2	2	3	n				
V106	new	TanMess	840	Hamilton Engineering	EVO Duo/Micro	HW 129	136.3	132.89	97				d,h	p	ss	w	M	3	1	1	1	d,s				
V106	new	TanMess	841	Hamilton Engineering	EVO Duo/Micro	HW199	200	194	97				d,h	p	ss	w	M	3	1	1	1	d,s				
V106	new	TanMess	842	Hamilton Engineering	EVO Duo/Micro	HW 399	400	388	97				d,h	p	ss	w	M	3	1	1	1	d,s				
V106	review		843	Hamilton Engineering	EVO Duo/Micro	HW 599	630	611.1	97				d,h	p	ss	w	M	3	1	1	1	d,s				
V104	review		844	Heat Transfer Products	Munchkin	80M	80	74		96			h	p	ss	w	M	3	2	3	n					
V104	review		845	Heat Transfer Products	Munchkin	140M	140	129	92.1	92			h	p	ss	w	M	3	2	3	n					
V104	review		846	Heat Transfer Products	Munchkin	199M	199	183	92	96			h	p	ss	w	M	3	2	3	n					
V104	review		847	Heat Transfer Products	Munchkin	T 50	50	46					h	p	ss</											

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Seasonal Efficiency	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sourc	Date	
			871	HydroTherm	MR Series	MR-1000C	1000	824	82.4			d, h	a	i	s	1	1	3	1	n	1					
			872	HydroTherm	MR Series	MR-1200B	1200	960		80		d, h	a	i	s	1	1	3	1	n	1					
			873	HydroTherm	MR Series	MR-1500B	1500	1200		80		d, h	a	i	s	1	1	3	1	n	1					
			874	HydroTherm	MR Series	MR-1800B	1800	1440		80		d, h	a	i	s	1	1	3	1	n	1					
			875	HydroTherm	MR Series	MR-2100B	2100	1680		80		d, h	a	i	s	1	1	3	1	n	1					
			876	HydroTherm	MR Series	MR-2400B	2400	1920		80		d, h	a	i	s	1	1	3	1	n	1					
			877	HydroTherm	MG Series	MG-770	794	610		81.3		d, h	a	i	s	1	1	1	3	n	1					
			878	HydroTherm	MG Series	MG-1155	1191	915		81.3		d, h	a	i	s	1	1	1	1	n	1					
			879	HydroTherm	MG Series	MG-1540	1588	1220		81.3		d, h	a	i	s	1	1	1	1	n	1					
			880	HydroTherm	MG Series	MG-1925	1985	1525		81.3		d, h	a	i	s	1	1	1	1	n	1					
			881	HydroTherm	MG Series	MG-2310	2382	1830		81.3		d, h	a	i	s	1	1	1	1	n	1					
			882	HydroTherm	MG Series	MG-2695	2779	2135		81.3		d, h	a	i	s	1	1	1	1	n	1					
			883	HydroTherm	MG Series	MG-3080	3176	2440		81.3		d, h	a	i	s	1	1	1	1	n	1					
			884	HydroTherm	MG Series	MG-3465	3573	2745		81.3		d, h	a	i	s	1	1	1	1	n	1					
			885	HydroTherm	MG Series	MG-3850	3970	3050		81.3		d, h	a	i	s	1	1	1	1	n	1					
			886	HydroTherm	MG Series	MG-4235	4367	3355		81.3		d, h	a	i	s	1	1	1	1	n	1					
			887	HydroTherm	MG Series	MG-4620	4764	3660		81.3		d, h	a	i	s	1	1	1	1	n	1					
			888	HydroTherm	MG Series	MG-5005	5161	3965		81.3		d, h	a	i	s	1	1	1	1	n	1					
			889	HydroTherm	MG Series	MG-5390	5558	4270		81.3		d, h	a	i	s	1	1	1	1	n	1					
			890	HydroTherm	MG Series	MG-5775	5955	4575		81.3		d, h	a	i	s	1	1	1	1	f	4					
			891	HydroTherm	MG Series	MG-6160	6352	4880		81.3		d, h	a	i	s	1	1	1	1	f	4					
			892	HydroTherm	MG Series	MG-6545	6749	5185		81.3		d, h	a	i	s	1	1	1	1	f	4					
			893	HydroTherm	MG Series	MG-6930	7146	5490		81.3		d, h	a	i	s	1	1	1	1	n	1					
			894	HydroTherm	Multipulse	AM100	100	90	90.4			d, h	p	c	f	1	2	2	3	n	1					
			895	HydroTherm	Multipulse	AM150	150	135	90	90.6		d, h	p	c	f	1	2	2	3	n	1					
			896	HydroTherm	Multipulse	AM300	300	270		90	\$10,740	h	p	c	w	1	2	2	3	n	1					
			897	HydroTherm	HC-86E	HC-86E	65	53				h	a	i	s	1	1	3	1	n	1					
			898	HydroTherm	HC Series	HC-86E	85	70	82.4	81.6		h	a	i	s	1	1	3	1	n	1					
			899	HydroTherm	HC Series	HC-100E	100	82	82	81.5		h	a	i	s	1	1	3	1	n	1					
			900	HydroTherm	HC Series	HC-125E	125	102	81.6	81		h	a	i	s	1	1	3	1	n	1					
			901	HydroTherm	HC Series	HC-145E	145	120	82.8	82.5		h	a	i	s	1	1	3	1	n	1					
			902	HydroTherm	HC Series	HC-165E	165	136	82.4	81.3		h	a	i	s	1	1	3	1	f	3					
			903	HydroTherm	R Series	R-180C	180	149	82.8	82.2		h	a	i	s	1	1	3	1	f	3					
			904	HydroTherm	R Series	R-210C	210	171	81.4	81		h	a	i	s	1	1	3	1	f	3					
			905	HydroTherm	R Series	R-250C	250	206	82.4	82		h	a	i	s	1	1	3	1	f	3					
			906	HydroTherm	R Series	R-300B	300	240	80			h	a	i	s	1	1	3	1	f	3					
			907	HydroTherm	ID-HI Series	ID-85A	85	70	82.4	80.5		h	f	i	s	1	1	3	1	f	3					
			908	HydroTherm	ID-HI Series	ID-125A	125	102	81.6	80.1		h	f	i	s	1	1	2	3	n	1					
			909	HydroTherm	ID-HI Series	ID-165A	165	136	82.4	81.1		h	f	i	s	1	1	2	3	n	1					
			910	HydroTherm	ID-HI Series	HI-85/50B	85	69	81.2	82.5		h	f	i	s	2	1	2	3	n	1					
			911	HydroTherm	ID-HI Series	HI-125/75B	125	100	80	82.5		h	f	i	s	2	1	2	3	n	1					
			912	HydroTherm	ID-HI Series	HI-165/100B	165	132	80	82.5		h	f	i	s	2	1	2	3	n	1					
			913	HydroTherm	Sabre EW Series	EW-65-CON	65	52	80	80.4		h	a	i	s	1	1	3	1	n	1					
			914	HydroTherm	Sabre EW Series	EW-85-CON	85	69	81.2	81.6		h	a	i	s	1	1	3	1	n	1					
			915	HydroTherm	Sabre EW Series	EW-100-CON	100	82	82	81.5		h	a	i	s	1	1	3	1	n	1					
			916	HydroTherm	Sabre EW Series	EW-125-CON	125	101	80.8	81		h	a	i	s	1	1	3	1	n	1					
			917	HydroTherm	Sabre EW Series	EW-145-CON	145	120	82.8	82.5		h	a	i	s	1	1	3	1	n	1					
			918	HydroTherm	Sabre EW Series	EW-165-CON	165	134	81.2	81.3		h	a	i	s	1	1	3	1	n	1					
			919	HydroTherm	Sabre EW Series	EW-65-INT	65	53	81.5	81.4		h	a	i	s	1	1	3	1	n	1					
			920	HydroTherm	Sabre EW Series	EW-85-INT	85	70	82.4	82.6		h	a	i	s	1	1	3	1	f, s	3					
			921	HydroTherm	Sabre EW Series	EW-100-INT	100	82	82	82.5		h	a	i	s	1	1	3	1	s	3					
			922	HydroTherm	Sabre EW Series	EW-125-INT	125	102	81.6	82		h	a	i	s	1	1	3	1	s	3					
			923	HydroTherm	Sabre EW Series	EW-145-INT	145	121	83.4	83.5		h	a	i	s	1	1	3	1	s	3					
			924	HydroTherm	Sabre EW Series	EW-165-INT	165	135	81.8	82.3		h	a	i	s	1	1	3	1	s	3					
			925	HydroTherm	Sabre FX Series	FX-70	70	61	87.1	86.5		h	i	i	s	1	1	2	3	f, s	4					
			926	HydroTherm	Sabre FX Series	FX-105	105	91	86.7	86.3		h	i	i	s	1	1	2	3	f, s	4					
			927	HydroTherm	Sabre FX Series	FX-140	140	121	86.4	86.2		h	i	i	s	1	1	2	3	f, s	4					
			928	HydroTherm	Sabre FX Series	FX-175	175	151	86.3	86.1		h	i	i	s	1	1	2	3	f, s	4					
			929	HydroTherm	Sabre FX Series	FX-200	200	173	86.5	86.1		h	i	i	s	1	1	2	3	f, s	4					
V421	new		930	HydroTherm	KN Series	KN-4	399	370		87.7		h	i	i	s	M	3	2	3	f, s	2.4			M	AHRI	11-Dec-13
V421	revised	therm eff	931	HydroTherm	KN Series	KN-6	600	556	92.7	87		h	i	i	s	M	3	2	3	d, s	2.4			M	AHRI	11-Dec-13
V421	revised	therm eff	932	HydroTherm	KN Series	KN-10	1000	927	92.7	86.8		h	i	i	s	M	3	2	3	d, s	2.4			M	AHRI	11-Dec-13
V421	new		933	HydroTherm	KN Series	KN-16	1600	1376	92.7	86		h	p	i	s	M	3	2	3	d, s	2.4			M	AHRI	11-Dec-13
V421	revised	therm eff	934	HydroTherm	KN Series	KN-20	1999	1853	92.7	86.6		h	i	i	s	M	3	2	3	d, s	2.4			M	AHRI	11-Dec-13
V421	new		935	HydroTherm	KN Series	KN-26	2600	2236	92.7	86		h	p	i	s	M	3	2	3	d, s	2.4			M	AHRI	11-Dec-13
V421	new		936	HydroTherm	KN Series	KN-30	3000	2781	92.7	85.8		h	i	i	s	M	3	2	3	d, s	2.4			M	AHRI	11-Dec-13
			937	IBC Technologies	VFC Modulating	VFC 90-130	130	120		92		h	p	ss	w	M	3	2	3	f, s	4					
			938	IBC Technologies	VFC Modulating	VFC 35-90	90	83		92		h	p	ss	w	M	3	2	3	f, s	4					
			939	IBC Technologies	VFC Fixed Rate	VFC 60	60	55	92	92		h	p	ss	w	1	1	2	3	f, n, s	1.3					
			940	IBC Technologies	VFC Fixed Rate	VFC 90	90	83	92	92		h	p	ss	w	1	1	2	3	f, n, s	1.3					
			941	IBC Technologies	VFC Fixed Rate	VFC 130	130	120	92	92		h	p	ss	w	1	1	2	3	f, n, s	1.3					
			942	IBC Technologies	VFC Fixed Rate	VFC 160	160	147	92	92		h	p	ss	w	1	1	2	3	f, n, s	1.3					
			943	Laats	Mighty Max Domestic	VW0320MN	320	272		85		d	p	c	w	1	1	2	3	f, n, s	1.3					
			944	Laats	Mighty Max Domestic	VW0400MN	399	340		85.2		d	p	c	w	1	1	2	3	f, n, s	1.3					

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Seasonal Efficiency	Justification Effici	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sourc	Date
			968 Laars		Mighty Therm Domestic	VW-2000	2000	1639			81.95		d	a	c	w	1	1	1	1	1	n				
			969 Laars		Mighty Therm Domestic	VW-2450	2450	2009			82		d	a	c	w	1	1	1	1	1	n				
			970 Laars		Mighty Therm Domestic	VW-3050	3050	2501			82		d	a	c	w	1	1	1	1	1	n				
			971 Laars		Mighty Therm Domestic	VW-3500	3500	2870			82		d	a	c	w	1	1	1	1	1	n				
			972 Laars		Mighty Therm Domestic	VW-4050	4050	3321			82		d	a	c	w	1	1	1	1	1	n				
			973 Laars		Mighty Therm Domestic	VW-4500	4500	3690			82		d	a	c	w	1	1	1	1	1	n				
			974 Laars		Mighty Therm Domestic	VW-5000	5000	4100			82		d	a	c	w	1	1	1	1	1	n				
			975 Laars		Mighty Therm Hydronic	HH-125	125	101			80.8	\$1,800	d	a	c	w	1	1	1	1	1	n				
			976 Laars		Mighty Therm Hydronic	HH-175	175	142	81.1	80.4			h	a	c	w	1	1	3	1	1	n				
			977 Laars		Mighty Therm Hydronic	HH-250	250	203	81.2	80.4			h	a	c	w	1	1	3	1	1	n				
			978 Laars		Mighty Therm Hydronic	HH-325	325	263			80.9		h	a	c	w	1	1	1	1	1	n				
			979 Laars		Mighty Therm Hydronic	HH-400	400	324			81		h	a	c	w	1	1	1	1	1	n				
			980 Laars		Mighty Therm Hydronic	HH-500	500	405			81		h	a	c	w	1	1	1	1	1	n				
			981 Laars		Mighty Therm Hydronic	HH-600	600	486			81		h	a	c	w	1	1	1	1	1	n				
			982 Laars		Mighty Therm Hydronic	HH-715	715	579			80.98		h	a	c	w	1	1	1	1	1	n				
			983 Laars		Mighty Therm Hydronic	HH-850	850	689			81.1		h	a	c	w	1	1	1	1	1	n				
			984 Laars		Mighty Therm Hydronic	HH-1010	1010	818			80.99		h	a	c	w	1	1	1	1	1	n				
			985 Laars		Mighty Therm Hydronic	HH-1200	1200	972			81		h	a	c	w	1	1	1	1	1	n				
			986 Laars		Mighty Therm Hydronic	HH-1430	1430	1158			80.98		h	a	c	w	1	1	1	1	1	n				
			987 Laars		Mighty Therm Hydronic	HH-1670	1670	1353			81.02		h	a	c	w	1	1	1	1	1	n				
			988 Laars		Mighty Therm Hydronic	HH-1825	1825	1478			80.99		h	a	c	w	1	1	1	1	1	n				
			989 Laars		Mighty Therm Hydronic	HH-2000	2000	1639			81.95		h	a	c	w	1	1	1	1	1	n				
			990 Laars		Mighty Therm Hydronic	HH-2450	2450	2009			82		h	a	c	w	1	1	1	1	1	f	3			
			991 Laars		Mighty Therm Hydronic	HH-3050	3050	2501			82		h	a	c	w	1	1	1	1	1	f	4			
			992 Laars		Mighty Therm Hydronic	HH-3500	3500	2870			82		h	a	c	w	1	1	1	1	1	f	4			
			993 Laars		Mighty Therm Hydronic	HH-4050	4050	3321			82		h	a	c	w	1	1	1	1	1	f	4			
			994 Laars		Mighty Therm Hydronic	HH-4500	4500	3690			82		h	a	c	w	1	1	1	1	1	f	4			
			995 Laars		Mighty Therm Hydronic	HH-5000	5000	4100			82		h	a	c	w	1	1	1	1	1	f	4			
			996 Laars		Mighty Stack	TL00-199	199	165	82.9				d	i	c	w	1	1	1	1	1	f	4			
			997 Laars		9600 CB	CB-M2-150	150	135	90	88.6			h	p	ss	w	1	1	1	2	3	f	4			
			998 Laars		9600 CB	CB-M2-175	175	158	90.3	88.7			h	p	ss	w	1	1	1	2	3	f	4			
			999 Laars		9600 CB	CB-M2- 200	199.9	180	90.05	88.5			h	p	ss	w	1	1	1	2	3	f	4			
			1000 Laars		9600 CB	CB-M2-250	250	223	89.2	88.1			h	p	ss	w	1	1	1	2	3	f	4			
			1001 Laars		9600 HWG	HWG-M2-150	150	144	96				d	p	ss	w	1	1	1	2	3	f	4			
			1002 Laars		9600 HWG	HWG-M2-175	175	168	96				d	p	ss	w	1	1	1	2	3	f	4			
			1003 Laars		9600 HWG	HWG-M2-200	200	192	96				d	p	ss	w	1	1	1	2	3	f	4			
			1004 Laars		9600 HWG	HWG-M2-250	250	240	96				d	p	ss	w	1	1	1	2	3	f	4			
			1005 Laars		Pennant	PNCV/H 500	500	425		85			d,h	p	ms	w	2	2	2	2	3	f	1.3			
			1006 Laars		Pennant	PNCV/H 750	750	638		85			d,h	p	ms	w	2	2	2	2	3	f	1.3			
			1007 Laars		Pennant	PNCV/H 1000	1000	849		85			d,h	p	ms	w	3	2	2	2	3	f	1.3			
			1008 Laars		Pennant	PNCV/H 1250	1250	1062.5	85				d	p	ms	w	4	2	2	2	3	f	1.3			
V201	revised	Output changed from 1150	1009 Laars		Pennant	PNCV/H 1500	1500	1275	85				d,h	p	ms	w	4	2	2	2	3	f	1.3			
			1010 Laars		Pennant	PNCV/H 1750	1750	1485	85				d,h	p	ms	w	4	2	2	2	3	f	1.3			
			1011 Laars		Pennant	PNCV/H 2000	1999	1699	85				d,h	p	ms	w	4	2	2	2	3	f	1.3			
			1012 Laars		Rheos	RHC/H 1200	1200	1044	87				h	p	c	w	4	3	2	2	3	f	4			
			1013 Laars		Rheos	RHC/H 2400	2400	2088					h	p	c	w	4	3	2	2	3	f	4			
			1014 Laars		Rheos	RHCV 1200	1200	1044	87				d	p	c	w	4	3	2	2	3	f,n	1.3			
			1015 Laars		Rheos	RHCV 2400	2400	2088					d	p	c	w	4	3	2	2	3	f,n	1.3			
			1016 Laars		Summit	SMB-200	199.9	179	89.6	90.5			h	p	ss	w	3	2	2	2	3	f,n	1.3			
			1017 Laars		Summit	SMB-250	257	231	89.9	90.5			h	p	ss	w	3	2	2	2	3	f,n	1.3			
			1018 Laars		Summit	SMW-200	199.9	192	96.1				d	p	ss	w	3	2	2	2	3	f,n	1.3			
			1019 Laars		Summit	SMW-250	257	245	95.3				d	p	ss	w	3	2	2	2	3	f,n	1.3			
			1020 Laars		Mini-Therm JV	JVI 50	50	41.5	83	83.4			h	i	c	w	1	1	1	2	3	n				
			1021 Laars		Mini-Therm JV	JVI 75	75	62.3	83.1	83.2			h	i	c	w	1	1	1	2	3	n				
			1022 Laars		Mini-Therm JV	JVI 100	100	82	82	82.4			h	i	c	w	1	1	1	2	3	n				
			1023 Laars		Mini-Therm JV	JVI 125	125	102.5	82	82.4			h	i	c	w	1	1	1	2	3	n				
			1024 Laars		Mini-Therm JV	JVI 160	160	131.2	82	82.3			h	i	c	w	1	1	1	2	3	n				
			1025 Laars		Mini-Therm JV	JVI 225	225	184.5	82	82.2			h	i	c	w	1	1	1	2	3	n				
			1026 Laars		Mini-Therm JV	JV 50	50	42	84	84.4			h	a	c	w	1	1	3	1	3	s				
			1027 Laars		Mini-Therm JV	JV 75	75	63	84				h	a	c	w	1	1	3	1	3	s				
			1028 Laars		Mini-Therm JV	JV 100	100	83	83	84			h	a	c	w	1	1	3	1	3	s				
			1029 Laars		Mini-Therm JV	JV 125	125	104	83.2	83			h	a	c	w	1	1	3	1	3	f	1			
			1030 Laars		Mini-Therm JV	JV 160	160	133	83.1	83			h	a	c	w	1	1	3	1	3	f	1			
			1031 Laars		Mini-Therm JV	JV 225	225	186	82.7	83.2			h	a	c	w	1	1	3	1	3	f	1			
			1032 Laars		Endurance	EDP 110	108.2	94	86.9	85.5			h	a	ss	w	1	3	2	2	3	f	1			
			1033 Laars		Endurance	EDP 175	175.3	151	86.1	86.1			h	a	ss	w	1	3	2	2	3	f	1			
			1034 Lochinvar		Copperfin	CWN0495F	495	400.95		81			d	p	c	w	1	1	2	2	3	f	1			
			1035 Lochinvar		Copperfin	CBN0495F	495	400.95		81			h	p	c	w	1	2	2	2	3	f	1			
			1036 Lochinvar		Copperfin	CWN0645F	645	522.45		81			d	p	c	w	1	2	2	2	3	f	1			
			1037 Lochinvar		Copperfin	CBN0645F	645	522.45		81			h	p	c	w	1	2	2	2	3	f	1			
			1038 Lochinvar		Copperfin	CWN0745F	745	603.45		81			d	p	c	w	1	2	2	2	3	f	1			
			1039 Lochinvar		Copperfin	CBN0745F	745	603.45		81			h	p	c	w	1	2	2	2	3	f	1			
			1040 Lochinvar		Copperfin	CWN0985F	985	797.85		81			d	p	c	w	1	2	2	2	3	f	1			
			1041 Lochinvar		Copperfin	CBN0985F	985	797.																		

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			1065	Lochinvar	Coperfin II	CHN1260 PM	1260	1058.4	84				h	p	c	w	2	2	2	3	f	1					
			1066	Lochinvar	Coperfin II	CFN1440 PM	1440	1224			85			p	c	w	2	2	2	3	f	1					
			1067	Lochinvar	Coperfin II	CHN1440 PM	1440	1209.6			84		h	p	c	w	2	2	2	3	f	1					
			1068	Lochinvar	Coperfin II	CFN1800 PM	1800	1530			85		d	p	c	w	2	2	2	3	f	1					
			1069	Lochinvar	Coperfin II	CHN1800 PM	1800	1512			84		h	p	c	w	2	2	2	3	f	1					
			1070	Lochinvar	Coperfin II	CFN2070 PM	2070	1759.5			85		d	p	c	w	2	2	2	3	f	1					
			1071	Lochinvar	Coperfin II	CHN2070 PM	2070	1738.8			84		h	p	c	w	2	2	2	3	f	1					
			1072	Lochinvar	RW Models	RWN900PM	90	73.8					d	a	c	w	1	1	1	3	n	1					
			1073	Lochinvar	RW Models	RWN139PM	136	110.7					d	a	c	w	1	1	1	3	n	1					
			1074	Lochinvar	RW Models	RWN180PM	180	147.6					d	a	c	w	1	1	1	3	n	1					
			1075	Lochinvar	RW Models	RWN199PM	199	163.18					d	a	c	w	1	1	1	3	n	1					
			1076	Lochinvar	RW Models	RWN225PM	225	184.5					d	a	c	w	1	1	1	3	n	1					
			1077	Lochinvar	RW Models	RWN270PM	270	221.4					d	a	c	w	1	1	1	3	n,d	1					
			1078	Lochinvar	RW Models	RWN315PM	315	258.3					d	a	c	w	1	1	1	3	n,d	1					
			1079	Lochinvar	RW Models	RWN360PM	360	295.2					d	a	c	w	1	1	1	3	n,d	1					
			1080	Lochinvar	RW Models	RWN999PM	999	327.18					d	a	c	w	1	1	1	3	n,d	1					
			1081	Lochinvar	RW Models	RWN500PM	500	410					d	a	c	w	1	1	1	3	n,d	1					
			1082	Lochinvar	Efficiency Plus	EBN100	100	85		83.1			d	a	c	w	1	1	1	3	n,d	1					
			1083	Lochinvar	Efficiency Plus	EBN100	100	84		83.1			d	a	c	w	2	1	1	3	n,d	1					
			1084	Lochinvar	Efficiency Plus	EBN150	150	127.5		83.2			d	a	c	w	2	1	1	3	n,d	1					
			1085	Lochinvar	Efficiency Plus	EBN150	150	126		83.2			d	a	c	w	2	1	1	3	n,d	1					
			1086	Lochinvar	Efficiency Plus	EBN200	200	170		85			d	a	c	w	2	1	1	3	d						
			1087	Lochinvar	Efficiency Plus	EBN200	200	168		84			d	a	c	w	2	1	1	3	d						
			1088	Lochinvar	Efficiency Plus	EBN250	250	212.5		83.1			d	a	c	w	2	1	1	3	d						
			1089	Lochinvar	Efficiency Plus	EBN250	250	210		84			d	a	c	w	2	1	1	3	d						
			1090	Lochinvar	Efficiency Plus	EBN300	300	255		85			d	a	c	w	2	1	1	3	d						
			1091	Lochinvar	Efficiency Plus	EBN300	300	252		84			d	a	c	w	2	1	1	3	d						
			1092	Lochinvar	Efficiency Plus	EBN150PM-F9	150	128		85		\$4,815	h	a	c	w	1	1	1	1	f,s	2					
			1093	Lochinvar	Efficiency Plus	EBN200PM-F9	200	170		85		\$5,107	h	a	c	w	1	1	1	1	f,s	2					
			1094	Lochinvar	Efficiency Plus	EBN250PM-F9	250	213		85		\$5,664	h	a	c	w	1	1	1	1	f,s	2					
			1095	Lochinvar	Efficiency Plus	EBN300PM-F9	300	255		85		\$6,816	h	a	c	w	1	1	1	1	f,s	2					
			1096	Lochinvar	PowerFin	PFN 250	250	220		88			d	p	c	w	1	2	2	3	f,s	4					
			1097	Lochinvar	PowerFin	PFN 250	250	220		88			h	d	p	c	w	1	2	2	3	f,s	4				
			1098	Lochinvar	PowerFin	PFN 500	500	440					d	p	c	w	1	2	2	3	f,s	4					
			1099	Lochinvar	PowerFin	PFN 500	500	440					h	d	p	c	w	1	2	2	3	f,s	4				
			1100	Lochinvar	PowerFin	PFN 750	750	660					d	p	c	w	1	2	2	3	f,s	4					
			1101	Lochinvar	PowerFin	PFN 750	750	660					h	d	p	c	w	1	2	2	3	f,s	4				
			1102	Lochinvar	PowerFin	PFN 1000	1000	880					d	p	c	w	1	2	2	3	f,s	4					
			1103	Lochinvar	PowerFin	PFN 1000	1000	880					h	d	p	c	w	1	2	2	3	f,s	4				
			1104	Lochinvar	PowerFin	PFN1500	1500	1305					d	p	c	w	1	3	2	3	f,s	4					
			1105	Lochinvar	PowerFin	PFN1700	1700	1479					d	p	c	w	1	3	2	3	f,s	4					
			1106	Lochinvar	PowerFin	PFN2000	2000	1740					d	p	c	w	1	3	2	3	f,s	4					
			1107	Lochinvar	PowerFin	PFN1500	1500	1305					h	d	p	c	w	1	3	2	3	f,s	4				
			1108	Lochinvar	PowerFin	PFN1 700	1700	1479					h	d	p	c	w	1	3	2	3	f,s	1				
			1109	Lochinvar	PowerFin	PFN2000	2000	1740					h	d	p	c	w	1	3	2	3	f,s	1				
			1110	Lochinvar	Intelli-Fin	IBN1500	1500	1402.5			93.5		h	p	c	w	1	3	2	3	f,s	1					
			1111	Lochinvar	Intelli-Fin	IBN1700	1700	1589.5			93.5		h	p	c	w	1	3	2	3	n	1					
			1112	Lochinvar	Intelli-Fin	IBN2000	2000	1870			93.5		h	p	c	w	1	3	2	3	n	1					
			1113	Lochinvar	Intelli-Fin	IBN1500	1500	1402.5			93.5		d	p	c	w	1	3	2	3	n	1					
			1114	Lochinvar	Intelli-Fin	IBN1700	1700	1589.5			93.5		d	p	c	w	1	3	2	3	n	1					
			1115	Lochinvar	Intelli-Fin	IBN2000	2000	1870			93.5		d	p	c	w	1	3	2	3	n	1					
			1116	Lochinvar	Knight	KBN080	80	73		93			h	p	ss	w	1	2	2	3	s	4			L		
V107	new		1117	Lochinvar	Knight	KBN105	105	96		93			h	p	ss	w	1	2	2	3	s	4			L		
V107	new		1118	Lochinvar	Knight	KBN150	150	136		93			h	p	ss	w	1	2	2	3	s	4			L		
V107	new		1119	Lochinvar	Knight	KBN210	210	191		93			h	p	ss	w	1	2	2	3	s	4			L		
V107	new		1120	Lochinvar	Knight	KBN285	285	259		93			h	p	ss	w	1	2	2	3	s	4			L		
V107	new		1121	Lochinvar	Knight	KBN399	399	360	90.3				h	p	ss	w	1	2	2	3	s	4			L		
V107	new		1122	Lochinvar	Knight	KBN500	500	451	90.3				h	p	ss	w	1	2	2	3	s	4			L		
			1123	Lochinvar	Mini-Fin	RB045	45	36.9		84.2			h	a	c	w	1	1	3	1	f	1					
			1124	Lochinvar	Mini-Fin	RB075	75	61.5		82			h	a	c	w	1	1	3	1	n	1					
			1125	Lochinvar	Mini-Fin	RB090	90	73.8		83			h	a	c	w	1	1	3	1	n	1					
			1126	Lochinvar	Mini-Fin	RB135	135	110.7		82			h	a	c	w	1	1	3	1	n	1					
			1127	Lochinvar	Mini-Fin	RB180	180	147.6		82			h	a	c	w	1	1	3	1	n	1					
			1128	Lochinvar	Mini-Fin	RB225	225	184.5		82			h	a	c	w	1	1	3	1	f	1					
			1129	Lochinvar	Mini-Fin	RB270	270	221.4		82			h	a	c	w	1	1	3	1	f	1					
			1130	Lochinvar	Mini-Fin	RB315	315	258.3			82		h	a	c	w	1	1	3	1	f	1					
			1131	Lochinvar	Mini-Fin	RB360	360	295.2			82		h	a	c	w	1	1	3	1	f	3					
			1132	Lochinvar	Mini-Fin	RB399	400	327.18			81.8		h	a	c	w	1	1	3	1	f	3					
			1133	Lochinvar	Mini-Fin	RB500	500	410			82		h	a	c	w	1	1	3	1	df	4					
			1134	Marathon International	Bax Luna	310FI	126.2	108.5					d	p	ss	w	1	3	2	2	1	df	3				
			1135	Marathon International	Bax Luna	1.130FI	126.2	108.5					h	p	ss	w	1	3	2	2	1	df	3				
			1136	Marathon International	Bax Luna	HT330	126.4	125.1					d	p	ss	w	1	3	2	2	1	df	3				
			1137	Marathon International	Bax Luna	HT133	126.4	125.1					h	p	ss	w	1	3	2	2	1	df	3				
			1138	Marathon International	Bax Luna	HT145	167.3	165.6					h	p	ss	w	1	3	2	2	1	df	3				
			1139	Marathon International	Bax Luna	HT165	241.6	239.2					h	p	ss	w	1	3</									

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Seasonal Efficiency	Austion Effici	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sourc	Date
			1162	Olsen	OMGB Series	OMGB 150 HD	150	124	82.7	83	3042	h	a	i	s	s	1	1	3	1	n	4				
			1163	Olsen	OMGB Series	OMGB 175 HD	175	143	81.7	81	3563	h	a	i	s	s	1	1	3	1	n	4				
			1164	Olsen	OMGB Series	OMGB 200 HD	200	165	82.5	81.9	3763	h	a	i	s	s	1	1	3	1	n	4				
			1165	Olsen	OMGB Series	OMGB 250 HD	250	205	82.5	80.5	4314	h	a	i	s	s	1	1	3	1	n	4				
			1166	Olsen	OMGB Series	OMGB 300 HD	300	243	81	80	5063	h	a	i	s	s	1	1	3	1	n	1				
			1167	Olsen	OSC Series	OSC 3	50	44	88	87	3408	h	i	i	s	s	1	1	3	1	n	1				
			1168	Olsen	OSC Series	OSC 4	100	87	87	87	4034	h	i	i	s	s	1	1	2	3	n	1				
			1169	Olsen	OSC Series	OSC 5	140	122	87.1	87	4632	h	i	i	s	s	1	1	2	3	n	1				
			1170	Olsen	Quantum 90 Series	Q90-50	50	45	90	90	6060	h	i	o	s	s	1	2	2	3	n	1				
			1171	Olsen	Quantum 90 Series	Q90-75	75	68	90.7	90	6060	h	i	o	s	s	1	2	2	3	n	1				
			1172	Olsen	Quantum 90 Series	Q90-100	100	90	90	90	6060	h	i	o	s	s	1	2	2	3	n	1				
			1173	Olsen	OMAGB Series	OMAGB 500	500	410		82	5806	h	a	a	i	s	1	1	1	1	n	1				
			1174	Olsen	OMAGB Series	OMAGB 600	600	480		80	6314	h	a	i	i	s	1	1	1	1	n	1				
			1175	Olsen	OMAGB Series	OMAGB 750	750	615		82	8711	h	a	i	i	s	1	1	1	1	n	1				
			1176	Olsen	OMAGB Series	OMAGB 900	900	720		80	9472	h	a	i	i	s	1	1	1	1	n	1				
			1177	Olsen	OMAGB Series	OMAGB 1000	1000	820		82	11612	h	a	i	i	s	1	1	1	1	n	1				
			1178	Olsen	OMAGB Series	OMAGB 1200	1200	960		80	12629	h	a	i	i	s	1	1	1	1	n	1				
			1179	Olsen	OMAGB Series	OMAGB 1500	1500	1200		80	15785	h	a	i	i	s	1	1	1	1	n	1				
			1180	Olsen	OMAGB Series	OMAGB 1800	1800	1440		80	18943	h	a	i	i	s	1	1	1	1	n	1				
			1181	Olsen	OMAGB Series	OMAGB 2100	2100	1680		80	22100	h	a	i	i	s	1	1	1	1	n	1				
			1182	Olsen	OMAGB Series	OMAGB 2400	2400	1920		80	25256	h	a	i	i	s	1	1	1	1	n	1				
			1183	Olsen	OMAGB Series	OMAGB 500 HID	500	410		82	6675	h	a	i	s	s	1	1	3	1	n	1				
			1184	Olsen	OMAGB Series	OMAGB 600 HID	600	480		80	7384	h	a	i	s	s	1	1	3	1	n	1				
			1185	Olsen	OMAGB Series	OMAGB 750 HID	750	615		82	10294	h	a	i	s	s	1	1	3	1	n	1				
			1186	Olsen	OMAGB Series	OMAGB 900 HID	900	720		80	11076	h	a	i	s	s	1	1	3	1	n	1				
			1187	Olsen	OMAGB Series	OMAGB 1000 HID	1000	820		82	13751	h	a	i	s	s	1	1	3	1	n	1				
			1188	Olsen	OMAGB Series	OMAGB 1200 HID	1200	960		80	14786	h	a	i	s	s	1	1	3	1	n	1				
			1189	Olsen	OMAGB Series	OMAGB 1500 HID	1500	1200		80	18488	h	a	i	s	s	1	1	3	1	n	1				
			1190	Olsen	OMAGB Series	OMAGB 1800 HID	1800	1440		80	22150	h	a	i	s	s	1	1	3	1	n	1				
			1191	Olsen	OMAGB Series	OMAGB 2100 HID	2100	1680		80	25842	h	a	i	s	s	1	1	3	1	n	1				
			1192	Olsen	OMAGB Series	OMAGB 2400 HID	2400	1920		80	29533	h	a	i	s	s	1	1	3	1	n	1				
			1193	Patterson Kelley	Mach Series	C-300	300	276		92	C-450	h	p	a	s	M	3	2	3	2	3	4				
V106	new	change purge to pre&post V400					450	414		92		h	p	a	s	M	3	2	3	2	3	4				
V106	new	change purge to pre&post V400					750	712.5		95		h	p	a	s	M	3	3	2	3	4					
V106	new	change purge to pre&post V400					900	846		94		h	p	a	s	M	3	3	2	3	4					
V106	new	change purge to pre&post V400					1050	967		94		h	p	a	s	M	3	3	2	3	4					
V106	new	change purge to pre&post V400					1500	1400		93		h	p	a	s	M	3	3	2	3	4					
V106	new	change purge to pre&post V400					2000	1900		95		h	p	a	s	M	3	3	2	3	4					
V400	new	change purge to pre&post V400					2500	2375	95			h	p	a	s	M	3	3	2	3	4					
V400	new	change purge to pre&post V400					3000	2850	95			h	p	a	s	M	3	3	2	3	4					
V400	new	change purge to pre&post V400					4000	3800	95			h	p	a	s	M	3	3	2	3	4					
V400	new	change purge to pre&post V400					750	637.5	85			h	p	a	s	M	3	3	2	3	4					
V400	new	change purge to pre&post V400					1000	850	85			h	p	a	s	M	3	3	2	3	4					
V107	new	change purge to pre&post V400					1500	1275	85			h	p	a	s	M	3	3	2	3	4					
V107	new	change purge to pre&post V400					2000	1700	85			h	p	a	s	M	3	3	2	3	4					
V107	new	change purge to pre&post V400					2500	2200	88			h	p	a	s	M	3	3	2	3	4					
V400	new	change purge to pre&post V400					3000	2640	88			h	p	a	s	M	3	3	2	3	4					
			1209	Patterson Kelley	Thermiflic	N700	700	595		85	14537	h	p	c	w	1	1	2	3	1	n	1				
			1210	Patterson Kelley	Thermiflic	N1000	1000	850		85	15115	h	p	c	w	1	1	2	3	1	n	1				
			1211	Patterson Kelley	Thermiflic	N1500	1500	1275		85	22060	h	p	c	w	1	1	2	3	1	n	1				
			1212	Patterson Kelley	Thermiflic	N1700	1700	1445		85	23024	h	p	c	w	1	1	2	3	1	n	1				
			1213	Patterson Kelley	Thermiflic	N2000	2000	1700		85	24145	h	p	c	w	1	1	2	3	1	n	1				
			1214	Patterson Kelley	Thermiflic - 2 Stage	N1500-2	1500	1275		85	23006	h	p	c	w	1	2	2	3	2	3	1				
			1215	Patterson Kelley	Thermiflic - 2 Stage	N1700-2	1700	1445		85	23971	h	p	c	w	2	2	2	3	2	3	1				
			1216	Patterson Kelley	Thermiflic - 2 Stage	N2000-2	2000	1700		85	25091	h	p	c	w	2	2	2	3	2	3	1				
			1217	Patterson Kelley	Thermiflic	D700	700	595		85	17087	d	p	c	w	1	1	2	3	1	n	1				
			1218	Patterson Kelley	Thermiflic	D1000	1000	850		85	17640	d	p	c	w	1	1	2	3	1	n	1				
			1219	Patterson Kelley	Thermiflic	D1500	1500	1275		85	24911	d	p	c	w	1	1	2	3	1	n	1				
			1220	Patterson Kelley	Thermiflic	D1700	1700	1445		85	25986	d	p	c	w	1	1	2	3	1	n	1				
			1221	Patterson Kelley	Thermiflic	D2000	2000	1700		85	27062	d	p	c	w	1	1	2	3	1	n	1				
			1222	Patterson Kelley	Thermiflic - 2 Stage	D1000-2	1000	850		85	25856	d	p	c	w	2	2	2	3	2	3	1				
			1223	Patterson Kelley	Thermiflic - 2 Stage	D1500-2	1500	1275		85	26932	d	p	c	w	2	2	2	3	2	3	1				
			1224	Patterson Kelley	Thermiflic - 2 Stage	D2000-2	2000	1700		85	28008	d	p	c	w	2	2	2	3	2	3	1				
			1225	Patterson Kelley	Thermiflic	SN700	700	595		85	16188	d	p	c	w	2	2	2	3	3	3	1				
			1226	Patterson Kelley	Thermiflic	SN1000	1000	850		85	16764	d	p	c	w	2	2	2	3	3	3	1				
			1227	Patterson Kelley	Thermiflic	SN1200	1200	1020		85	18667	d	p	c	w	2	2	2	3	3	3	1				
			1228	Patterson Kelley	Thermiflic	SN1500	1500	1275		85	23993	d	p	c	w	2	2	2	3	3	3	1				
			1229	Patterson Kelley	Thermiflic	SN1700	1700	1445		85	24955	d	p	c	w	2	2	2	3	3	3	1				
			1230	Patterson Kelley	Thermiflic	SN2000	2000	1700		85	26075	d	p	c	w	2	2	2	3	3	3	1				
			1231	Patterson Kelley	Thermiflic - 2 Stage	SN1500-2	1500	1275		85	24353	d	p	c	w	2	2	2	3	3	3	1				
			1232	Patterson Kelley	Thermiflic - 2 Stage	SN1700-2	1700	1445		85	25314	d	p	c	w	2	2	2	3	3	3	1				
			1233	Patterson Kelley	Thermiflic - 2 Stage	SN2000-2	2000	1700		85	26435	d	p	c	w	2	2	2	3	3	3	1				
			1234																							

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Seasonal Efficiency	Austion Effici	MSRFP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sour	Date
			1259	Peerless	DE Series	DE-06	165	136	82.4	82	2855	h	h	i	i	s	1	1	2	3	s	1				
			1260	Peerless	PDE Series	PDE-03	65	56	86.2	85		h	h	i	i	s	1	1	2	3	s	1				
			1261	Peerless	PDE Series	PDE-04	97.5	84	86.2	85		h	h	i	i	s	1	1	2	3	n	1				
			1262	Peerless	PDE Series	PDE-05	130	111	85.4	85		h	h	i	i	s	1	1	2	3	n	1				
			1263	Peerless	PSC Series	PSC-03	70	58	82.9	83		h	h	i	i	s	1	1	2	3	n	1				
			1264	Peerless	PSC Series	PSC-04	105	88	83.8	83		h	h	i	i	s	1	1	2	3	n	1				
			1265	Peerless	PSC Series	PSC-05	140	117	83.6	83		h	h	i	i	s	1	1	2	3	n	1				
			1266	Peerless	PSC Series	PSC-06	175	146	83.4	83		h	h	i	i	s	1	1	2	3	n	1				
			1267	Peerless	Purefire	PF-399	399	373	93.4		95.5	d,h	p	ss	ss	w	M	3	2	3	s	4				
			1268	Peerless	Series 61	61-03	90	73	81.1	80.5		h	h	i	i	s	1	1	3	1	n	1				
			1269	Peerless	Series 61	61-04	120	98	81.7	81.7		h	h	a	i	s	1	1	3	1	n	1				
			1270	Peerless	Series 61	61-05	160	130	81.25	81.3		h	h	a	i	s	1	1	3	1	n	1				
			1271	Peerless	Series 61	61-06	200	161	80.5	81		h	h	a	i	s	1	1	3	1	n	1				
			1272	Peerless	Series 61	61-07	240	193	80.4	80.6		h	h	a	i	s	1	1	3	1	n	1				
			1273	Peerless	Series 61	61-08	225	180	80.4	80.3		h	h	a	i	s	1	1	3	1	n	1				
			1274	Peerless	Series 62	62-09	320	256		80		h	h	a	i	s	1	1	1	1	n	1				
			1275	Peerless	Series 62	62-10	360	288		80		h	h	a	i	s	1	1	1	1	n	1				
			1276	Peerless	Series 62	62-11	400	320		80		h	h	a	i	s	1	1	1	1	n	1				
			1277	Peerless	Series 62	62-12	440	352		80		h	h	a	i	s	1	1	1	1	n	1				
			1278	Peerless	Series 62	62-13	480	384		80		h	h	a	i	s	1	1	1	1	n	1				
			1279	Peerless	Series 62	62-14	520	416		80		h	h	a	i	s	1	1	1	1	n	1				
			1280	Peerless	Series 62	62-15	560	448		80		h	h	a	i	s	1	1	1	1	n	1				
			1281	Peerless	Series 63	63-03	99		82.1		2300	h	h	a	i	s	1	1	3	1	n	1				
			1282	Peerless	Series 63	63-04	177	148		82.1	2645	h	h	a	i	s	1	1	3	1	n	1			M	
V107	new		1283	Peerless	Series 63	63-05	236	198		82.2	2760	h	h	a	i	s	1	1	3	1	n	1			M	
V107	new		1284	Peerless	Series 63	63-06	287	241		82.3	3660	h	h	a	i	s	1	1	3	1	n	1			M	
V107	new		1285	Peerless	Series 64	64-07	345	286		83.0	5120	h	h	a	i	s	1	1	3	1	n	1			M	
V107	new		1286	Peerless	Series 64	64-08	399	331		83.0	5755	h	h	a	i	s	1	1	3	1	n	1			M	
V107	new		1287	Peerless	Series 64	64-09	460	382		83.0	5755	h	h	a	i	s	1	1	3	1	n	1			M	
V107	new		1288	Peerless	Series 64	64-10	517.5	430		83.1	6270	h	h	a	i	s	1	1	3	1	n	1			M	
V107	new		1289	Peerless	Series 64	64-11	575	477		83.0	6780	h	h	a	i	s	1	1	3	1	n	1			M	
V107	new		1290	Peerless	Series 64	64-12	632.5	525		83.0	8020	h	h	a	i	s	1	1	3	1	n	1			M	
			1291	Peerless	Series GM	GM-05	228	187	82.02	82.1		h	h	a	i	s	1	1	3	1	n	1				
			1292	Peerless	Series GM	GM-06	285	231		81.1	3085	h	h	a	i	s	1	1	3	1	n	1				
			1293	Peerless	Series GM	GM-07	342	280		81.8		h	h	a	i	s	1	1	3	1	n	1				
			1294	Peerless	Series GM	GM-08	399	327		81.95		h	h	a	i	s	1	1	3	1	n	1				
			1295	Peerless	Series 211A	211A-04	630	504		80	8755	h	h	a	i	s	1	1	1	1	n	1				
			1296	Peerless	Series 211A	211A-05	840	672		80	10295	h	h	a	i	s	1	1	1	1	n	1				
			1297	Peerless	Series 211A	211A-06	1050	840		80	11870	h	h	a	i	s	1	1	1	1	n	1				
			1298	Peerless	Series 211A	211A-07	1260	1008		80	13105	h	h	a	i	s	1	1	1	1	n	1				
			1299	Peerless	Series 211A	211A-08	1470	1176		80	14700	h	h	a	i	s	1	1	1	1	n	1				
			1300	Peerless	Series 211A	211A-09	1680	1344		80	16120	h	h	a	i	s	1	1	1	1	n	1				
			1301	Peerless	Series 211A	211A-10	1890	1512		80	17465	h	h	a	i	s	1	1	1	1	n	1				
			1302	Peerless	Series 211A	211A-11	2100	1680		80	19120	h	h	a	i	s	1	1	1	1	n	1				
			1303	Peerless	Series 211A	211A-12	2310	1848		80	20760	h	h	a	i	s	1	1	1	1	n	1				
			1304	Peerless	Series 211A	211A-13	2520	2016		80	22580	h	h	a	i	s	1	1	1	1	n	1				
			1305	Peerless	Series 211A	211A-14	2730	2184		80	24400	h	h	a	i	s	1	1	1	1	n	1				
			1306	Peerless	Series 211A	211A-15	2940	2352		80	25825	h	h	a	i	s	1	1	1	1	n	1				
			1307	Peerless	Series 211A	211A-16	3150	2520		80	27575	h	h	a	i	s	1	1	1	1	n	1				
			1308	Peerless	Series 211A	211A-17	3360	2688		80	29320	h	h	a	i	s	1	1	1	1	n	1				
			1309	Peerless	Series 211A	211A-18	3570	2856		80	30645	h	h	a	i	s	1	1	1	1	n	1				
			1310	Peerless	Series 211A	211A-19	3780	3024		80	32070	h	h	a	i	s	1	1	1	1	n	1				
			1311	PVI	Maxim	20P 90A-MX	199	165.17		83		d	d	p	s	f	1	1	2	3	n	1				
			1312	PVI	Maxim	27P 90A-MX	270	224.1		83		d	d	p	s	f	1	1	2	3	n	1				
			1313	PVI	Maxim	40P 90A-MX	399	331.17		83		d	d	p	s	f	1	1	2	3	n	3				
			1314	PVI	Maxim	54P 90A-MX	540	448.2		83		d	d	p	s	f	1	1	2	3	n	3				
			1315	PVI	Maxim	14P 125A-MX	140	116.2		83		d	d	p	s	f	1	1	2	3	n	3				
			1316	PVI	Maxim	20P 125A-MX	199	165.17		83		d	d	p	s	f	1	1	2	3	n	3				
			1317	PVI	Maxim	27P 125A-MX	270	224.1		83		d	d	p	s	f	1	1	2	3	n	3				
			1318	PVI	Maxim	27P 250A-MX	270	224.1		83		d	d	p	s	f	1	1	2	3	n	3				
			1319	PVI	Maxim	40P 250A-MX	399	331.17		83		d	d	p	s	f	1	1	2	3	n	3				
			1320	PVI	Maxim	40P 125A-MX	399	331.17		83		d	d	p	s	f	1	1	2	3	n	3				
			1321	PVI	Maxim	54P 125A-MX	540	448.2		83		d	d	p	s	f	1	1	2	3	n	3				
			1322	PVI	Maxim	54P 250A-MX	540	448.2		83		d	d	p	s	f	1	1	2	3	n	3				
			1323	PVI	Maxim	72P 125A-MX	720	597.6		83		d	d	p	s	f	1	1	2	3	n	3			f,s	
			1324	PVI	Maxim	72P 250A-MX	720	597.6		83		d	d	p	s	f	1	1	2	3	n	3				f,s
			1325	PVI	Maxim	80P 125A-MX	800	664		83		d	d	p	s	f	1	1	2	3	n	3				f,s
			1326	PVI	Maxim	80P 250A-MX	800	664		83		d	d	p	s	f	1	1	2	3	n	3				f,s
			1327	PVI	Maxim	100P 250A-MX	1000	830		83		d	d	p	s	f	1	1	2	3	n	3				f,s
			1328	PVI	Maxim	120P 250A-MX	1200	996		83		d	d	p	s	f	1	1	2	3	n	3				f,s
			1329	PVI	Maxim	140P 250A-MX	1400	1162		83		d	d	p	s	f	1	1	2	3	n	3				f,s
			1330	PVI	Power VT	11WB 125A-PV	399	371		92.98		h	h	p	s	f	1	2	2	3	n	1				f,s
			1331	PVI	Power VT	16WB 125A-PV	565																			

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Justification Effici	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sourc	Date
			1356 PVI	Turbopower 99		1485ND125A-TP	1.000	999	99.9	\$40,750	d	c	s	f	f	1	2	2	3	1	1				
			1357 PVI	Turbopower 99		1485ND200A-TP	1.000	999	99.9	\$44,000	d	c	s	s	f	1	2	2	3	1	1				
			1358 PVI	Turbopower 99		1485ND330A-TP	1.000	999	99.9	\$48,000	d	c	s	s	f	1	2	2	3	1	1				
			1359 PVI	Turbopower 99		2228ND1200A-TP	1.500	1,485	99.9	\$65,850	d	c	s	s	f	1	2	2	3	1	1				
			1360 PVI	Turbopower 99		2228ND150A-TP	1.500	1,485	99	\$49,750	d	c	s	s	f	1	2	2	3	1	1				
			1361 PVI	Turbopower 99		2228ND200A-TP	1.500	1,485	99	\$48,750	d	c	s	s	f	1	2	2	3	n	n				
			1362 PVI	Turbopower 99		2228ND300A-TP	1.500	1,485	99	\$53,000	d	c	s	s	f	1	2	2	3	n	n				
			1363 PVI	Turbopower 99		297IND1200A-TP	2.000	1,986	99.9	\$67,500	d	c	s	s	f	1	2	2	3	n	n				
			1364 PVI	Turbopower 99		297IND150A-TP	2.000	1,986	99.9	\$51,500	d	c	s	s	f	1	2	2	3	n	n				
			1365 PVI	Turbopower 99		297IND200A-TP	2.000	1,988	99.9	\$50,500	d	c	s	s	f	1	2	2	3	n	n				
			1366 PVI	Turbopower 99		297IND300A-TP	2.000	1,988	99.9	\$54,750	d	c	s	s	f	1	2	2	3	n	n				
			1367 Raypak	Series 3		H4 105	107	85.6	80	2038	h	a	c	c	w	1	1	3	1	n	n				
			1368 Raypak	Series 3		H4 135	136	109	80.2	2072	h	a	c	c	w	1	1	3	1	n	n				
			1369 Raypak	Series 3		H4 165	163	130	79.8	2215	h	a	c	c	w	1	1	3	1	n	n				
			1370 Raypak	Series 3		H4 205	204	163	79.9	2345	h	a	c	c	w	1	1	3	1	n	n				
			1371 Raypak	Series 3		H4 255	268	206	79.9	2466	h	a	c	c	w	1	1	3	1	n	n				
			1372 Raypak	Series 3		H4 305	312	250		2676	h	a	c	c	w	1	1	3	1	n	n				
			1373 Raypak	Series 3		H4 385	380	304	80	3239	h	a	c	c	w	1	1	3	1	n	n				
			1374 Raypak	H Series		H4 0042	42	35	83.3	1894	h	a	c	c	w	1	1	3	1	n	n				
			1375 Raypak	H Series		H4 0066	66	54	81.9	1992	h	a	c	c	w	1	1	3	1	n	n				
			1376 Raypak	H Series		H3 0090	90	74	82.2	2138	h	a	c	c	w	2	1	3	1	n	n				
			1377 Raypak	H Series		H3 0135	135	109	80.7	2240	h	a	c	c	w	2	1	3	1	n	n				
			1378 Raypak	H Series		H3 0180	180	148	82.2	2623	h	a	c	c	w	2	1	3	1	n	n				
			1379 Raypak	Series 3		WH1 105	107	85.6	80	2282	h	a	c	c	w	1	1	3	1	n	n				
			1380 Raypak	Series 3		WH1 135	136	109	80.2	2322	d	a	c	c	w	1	1	3	1	n	n				
			1381 Raypak	Series 3		WH1 165	163	130	79.8	2476	d	a	c	c	w	1	1	3	1	n	n				
			1382 Raypak	Series 3		WH1 205	204	163	79.9	2602	d	a	c	c	w	1	1	3	1	n	n				
			1383 Raypak	Series 3		WH1 255	258	206	79.8	2725	d	a	c	c	w	1	1	3	1	n	n				
			1384 Raypak	Series 3		WH1 305	312	250		3137	d	a	c	c	w	1	1	3	1	n	n				
			1385 Raypak	Series 3		WH1 385	380	304	80	3504	d	a	c	c	w	1	1	3	1	n	n				
			1386 Raypak	Raythem WH1 Series		334-WH1	330	275.5	83.5	4496	d	a	c	c	w	1	1	3	1	n	n				
			1387 Raypak	Raythem WH1 Series		404-WH1	396	330.7	83.5	4699	d	a	c	c	w	1	1	3	1	n	n				
			1388 Raypak	Raythem WH1 Series		514WH1	511.5	427.1	83.5	5227	d	a	c	c	w	1	1	3	1	n	n				
			1389 Raypak	Raythem WH1 Series		624-WH1	627	606.2	83.5	5615	d	a	c	c	w	1	1	3	1	n	n				
			1390 Raypak	Raythem WH1 Series		724-WH1	726	689.9	83.5	6390	d	a	c	c	w	1	1	3	1	n	n				
			1391 Raypak	Raythem WH1 Series		824WH1	825	869.9	83.6	6619	d	a	c	c	w	1	1	3	1	n	n				
			1392 Raypak	Raythem WH1 Series		962-WH1	961.7	798.2	83	7487	d	a	c	c	w	1	1	3	1	n	n				
			1393 Raypak	Raythem WH1 Series		1125-WH1	1124.5	933.5	83.02	8041	d	a	c	c	w	1	1	3	1	n	n				
			1394 Raypak	Raythem WH1 Series		1223-WH1	1222.5	1015	83.03	8353	d	a	c	c	w	1	1	3	1	n	n				
			1395 Raypak	Raythem WH1 Series		1336-WH1	1335.6	1109.4	83.1	8878	d	a	c	c	w	1	1	3	1	n	n				
			1396 Raypak	Raythem WH1 Series		1468-WH1	1467	1217.6	83	9415	d	a	c	c	w	1	1	3	1	n	n				
			1397 Raypak	Raythem WH1 Series		1631-WH1	1630	1352.9	83	9728	d	a	c	c	w	1	1	3	1	n	n				
			1398 Raypak	Raythem WH1 Series		1826-WH1	1825.6	1515.2	83	10995	d	a	c	c	w	1	1	3	1	n	n				
			1399 Raypak	Raythem WH1 Series		2100-WH1	2100	1743	83	15502	d	a	c	c	w	1	1	3	1	n	n				
			1400 Raypak	Raythem WH1 Series		2500-WH1	2499	2074.1	83	16628	d	a	c	c	w	1	1	3	1	n	n				
			1401 Raypak	Raythem WH1 Series		3001-WH1	3000	2490	83	20862	d	a	c	c	w	1	1	3	1	n	n				
			1402 Raypak	Raythem WH1 Series		3500-WH1	3500	2905	83	22249	d	a	c	c	w	1	1	3	1	n	s				
			1403 Raypak	Raythem WH1 Series		4001-WH1	4000	3320	83	24484	d	a	c	c	w	1	1	3	1	n	s				
			1404 Raypak	ADB Series		H4 or WH-500	500	420	84	14638	d,h	p	c	c	w	1	2	2	3	s	1				
			1405 Raypak	ADB Series		H4 or WH-750	750	630	84	16667	d,h	p	c	c	w	1	2	2	3	s	1				
			1406 Raypak	ADB Series		H4 or WH-1000	999	840	84.1	20702	d,h	p	c	c	w	1	2	2	3	n	1				
			1407 Raypak	ADB Series		H4 or WH-1500	1499	1260	84.1	25421	d,h	p	c	c	w	1	2	2	3	n	1				
			1408 Raypak	ADB/CHX Series		ADB/CHX 500	500	485	97	22786	d,h	p	c	c	w	1	2	2	3	n	1				
			1409 Raypak	ADB/CHX Series		ADB/CHX 750	750	728	97.1	26441	d,h	p	c	c	w	1	2	2	3	n	1				
			1410 Raypak	ADB/CHX Series		ADB/CHX 1000	999	970	97.1	32102	d,h	p	c	c	w	1	2	2	3	n	1				
			1411 Raypak	ADB/CHX Series		ADB/CHX 1500	1499	1455	97.1	40081	d,h	p	c	c	w	1	2	2	3	n	1				
			1412 Raypak	Raythem H4 Series		334-H4	330	275.5	83.1	4073	h	a	c	c	w	1	1	1	1	n	n				
			1413 Raypak	Raythem H4 Series		404-H4	396	330.7	83.5	4274	h	a	c	c	w	1	1	1	1	n	n				
			1414 Raypak	Raythem H4 Series		514-H4	511.5	427.1	83.5	4561	h	a	c	c	w	1	1	1	1	n	n				
			1415 Raypak	Raythem H4 Series		624-H4	627	523.5	83.5	5148	h	a	c	c	w	1	1	1	1	n	n				
			1416 Raypak	Raythem H4 Series		724-H4	726	606.2	83.5	6086	h	a	c	c	w	1	1	1	1	n	n				
			1417 Raypak	Raythem H4 Series		824-H4	825	699.9	83.6	6558	h	a	c	c	w	1	1	1	1	n	n				
			1418 Raypak	Raythem H4 Series		962-H4	961.7	798.2	83	7504	h	a	c	c	w	1	1	1	1	n	n				
			1419 Raypak	Raythem H4 Series		1125-H4	1124.5	933.5	83	7739	h	a	c	c	w	1	1	1	1	n	n				
			1420 Raypak	Raythem H4 Series		1223-H4	1222.5	1015	83	8050	h	a	c	c	w	1	1	1	1	n	n				
			1421 Raypak	Raythem H4 Series		1336-H4	1335.6	1109.4	83	8675	h	a	c	c	w	1	1	1	1	n	n				
			1422 Raypak	Raythem H4 Series		1468-H4	1467	1217.6	83	9148	h	a	c	c	w	1	1	1	1	n	n				
			1423 Raypak	Raythem H4 Series		1631-H4	1630	1352.9	83	9668	h	a	c	c	w	1	1	1	1	n	n				
			1424 Raypak	Raythem H4 Series		1826-H4	1825.6	1515.2	83	10292	h	a	c	c	w	1	1	1	1	n	n				
			1425 Raypak	Raythem H4 Series		2100-H4	2100	1743	83	15017	h	a	c	c	w	1	1	1	1	n	n				
			1426 Raypak	Raythem H4 Series		2500-H4	2499	2074.1	83	16144	h	a	c	c	w	1	1	1	1	n	n				
			1427 Raypak	Raythem H4 Series		3001-H4	3000	2490	83	20377	h	a	c	c	w	1	1	1	1	n	n				
			1428 Raypak	Raythem H4 Series		3500-H4	3500	2905	83	21764	h	a	c	c	w	1	1	1	1	n	n				
V104	new		1429 Raypak	Raythem H4 Series		4001-H4	4000	3																	

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Personal Efficiency	Fusion Effici	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sour	Date
V104	review		1453 Raypak		Hi Delta Series	WH-302A	300	255	85		7009	d	p	p	c	w	2	2	2	2	f	1		L		
V104	review		1454 Raypak		Hi Delta Series	WH3-402A	399	339	85		9539	d	p	p	c	w	2	2	2	2	f	1		L		
V104	review		1455 Raypak		Hi Delta Series	WH3-502A	500	500	85		10906	d	p	p	c	w	2	2	2	2	f	1		L		
V104	review		1456 Raypak		Hi Delta Series	WH3-652A	650	553	85		11480	d	p	p	c	w	2	2	2	2	f	1		L		
V104	review		1457 Raypak		Hi Delta Series	WH3-752A	750	638	85		11851	d	p	p	c	w	2	2	2	2	f	1		L		
V104	review		1458 Raypak		Hi Delta Series	WH3-902A	900	765	85		13234	d	p	p	c	w	2	2	2	2	f	1		L		
V104	review		1459 Raypak		Hi Delta Series	WH8-992A	990	842	85		14764	d	p	p	c	w	3	2	2	2	f	1		L		
V104	review		1460 Raypak		Hi Delta Series	WH9-1262A	1260	1071	85		17513	d	p	p	c	w	4	2	2	2	f	1		L		
V104	review		1461 Raypak		Hi Delta Series	WH9-1532A	1530	1301	85		19720	d	p	p	c	w	4	2	2	2	f	1		L		
V104	review		1462 Raypak		Hi Delta Series	WH9-1802A	1800	1530	85		20545	d	p	p	c	w	4	2	2	2	f	1		L		
V104	review		1463 Raypak		Hi Delta Series	WH9-2002A	1999	1699	85		20545	d	p	p	c	w	4	2	2	2	f	1		L		
V104	review		1464 Raypak		Hi Delta Series	WH9-2072A	2070	1760	85		24438	d	p	p	c	w	4	2	2	2	f	1		L		
V104	review		1465 Raypak		Hi Delta Series	WH9-2342A	2340	1989	85		29224	d	p	p	c	w	4	2	2	2	f	1		L		
V106	new		1466 Raypak		MVB	MVB-H7-503	500	435				h	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1467 Raypak		MVB	MVB-H7-753	750	653				h	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1468 Raypak		MVB	MVB-H7-1003	1003	869				h	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1469 Raypak		MVB	MVB-H7-1253	1253	1088				h	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1470 Raypak		MVB	MVB-H7-1503	1503	1305				h	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1471 Raypak		MVB	MVB-H7-1753	1753	1523				h	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1472 Raypak		MVB	MVB-H7-2003	2003	1739				h	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1473 Raypak		MVB	MVB-WH7-503	500	435				d	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1474 Raypak		MVB	MVB-WH7-753	750	653				d	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1475 Raypak		MVB	MVB-WH7-1003	1003	869				d	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1476 Raypak		MVB	MVB-WH7-1253	1253	1088				d	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1477 Raypak		MVB	MVB-WH7-1503	1503	1305				d	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1478 Raypak		MVB	MVB-WH7-1753	1753	1523				d	p	p	c	w	M	3	2	3	d	1.3		L		
V106	new		1479 Raypak		MVB	MVB-WH7-2003	2003	1739				d	p	p	c	w	M	3	2	3	d	1.3		L		
			1480 RBI		8800 Series	8800S-2000	2000	1640				d	a	a	c	w	1	1	1	1	n	1.3				
			1481 RBI		8800 Series	8800S-2400	2400	1968				d	a	a	c	w	1	1	1	1	n	1.3				
			1482 RBI		8800 Series	8800S-2800	2800	2296				d	a	a	c	w	1	1	1	1	n	1.3				
			1483 RBI		8800 Series	8800S-3200	3200	2624				d	a	a	c	w	1	1	1	1	n	1.3				
			1484 RBI		8800 Series	8800S-3600	3600	2952				d	a	a	c	w	1	1	1	1	n	1.3				
			1485 RBI		8800 Series	8800S-4000	4000	3280				d	a	a	c	w	1	1	1	1	n	1.3				
			1486 RBI		8800 Series	8800S-420	420	340				d	a	a	c	w	1	1	1	1	n	1.3				
			1487 RBI		8800 Series	8800S-530	530	429				d	a	a	c	w	1	1	1	1	n	1.3				
			1488 RBI		8800 Series	8800S-630	630	510				d	a	a	c	w	1	1	1	1	n	1.3				
			1489 RBI		8800 Series	8800S-735	735	595				d	a	a	c	w	1	1	1	1	n	1.3				
			1490 RBI		8800 Series	8800S-840	840	680				d	a	a	c	w	1	1	1	1	n	1.3				
			1491 RBI		8800 Series	8800S-950	950	770				d	a	a	c	w	1	1	1	1	n	1.3				
			1492 RBI		8800 Series	8800S-1050	1050	851				d	a	a	c	w	1	1	1	1	n	1				
			1493 RBI		8800 Series	8800S-1160	1160	940				d	a	a	c	w	1	1	1	1	n	1				
			1494 RBI		8800 Series	8800S-1260	1260	1021				d	a	a	c	w	1	1	1	1	n	1				
			1495 RBI		8800 Series	8800S-1370	1370	1110				d	a	a	c	w	1	1	1	1	n	f.n.s				
			1496 RBI		8800 Series	8800S-1470	1470	1191				d	a	a	c	w	1	1	1	1	f.n.s	1				
			1497 RBI		8800 Series	8800S-1560	1560	1280				d	a	a	c	w	1	1	1	1	f.n.s	1				
			1498 RBI		8800 Series	8800S-1685	1685	1365				d	a	a	c	w	1	1	1	1	f.n.s	1				
			1499 RBI		8800 Series	8800S-1790	1790	1450				d	a	a	c	w	1	1	1	1	f.n.s	1				
			1500 RBI		8800 Series	8800S-1900	1900	1539				d	a	a	c	w	1	1	1	1	f.n.s	1				
V107	revised	85.1% efficient from 84%	1501 RBI		Dominator	DOM-300	300	255				d,h	p	p	c	w	4	2	2	2	s	1.3		L		
V107	revised	85.1% efficient from 84%	1502 RBI		Dominator	DOM-400	399	339				d,h	p	p	c	w	4	2	2	2	s	1.3		L		
V107	revised	85.1% efficient from 84%	1503 RBI		Dominator	DOM-600	600	511				d,h	p	p	c	w	4	2	2	2	s	1.3		L		
V107	revised	85.1% efficient from 84%	1504 RBI		Dominator	DOM-750	750	638				d,h	p	p	c	w	4	2	2	2	s	1.3		L		
V107	revised	85.1% efficient from 84%	1505 RBI		Dominator	DOM-900	900	766				d,h	p	p	c	w	4	2	2	2	s	1.3		L		
V107	revised	85.1% efficient from 84%	1506 RBI		Dominator	DOM-1050	1050	894				d,h	p	p	c	w	4	2	2	2	s	1.3		L		
V107	revised	85.1% efficient from 84%	1507 RBI		Dominator	DOM-1350	1350	1149				d,h	p	p	c	w	4	2	2	2	s	1.3		L		
V107	revised	85.1% efficient from 84%	1508 RBI		Dominator	DOM-1500	1500	1277				d,h	p	p	c	w	4	2	2	2	s	1.3		L		
V107	revised	85.1% efficient from 84%	1509 RBI		Dominator	DOM-1950	1950	1659				d,h	p	p	c	w	4	2	2	2	s	1.3		L		
V107	revised	85.1% efficient from 84%	1510 RBI		Dominator	DOM-2100	2100	1787				d,h	p	p	c	w	4	2	2	2	s	1.3		L		
V107	revised	thermal efficiency removed	1511 RBI		Fuera II	FI-500	500	425				d,h	p	p	c	w	2	2	2	2	d.s	1.3		L		
V107	revised	thermal efficiency removed	1512 RBI		Fuera II	FI-750	750	638				d,h	p	p	c	w	2	2	2	2	d.s	1.3		L		
V107	revised	thermal efficiency removed	1513 RBI		Fuera II	FI-1000	1000	850				d,h	p	p	c	w	2	2	2	2	d.s	1.3		L		
V107	revised	thermal efficiency removed	1514 RBI		Fuera II	FI-1250	1250	1063				d,h	p	p	c	w	2	2	2	2	d.s	1.3		L		
V107	revised	thermal efficiency removed	1515 RBI		Fuera II	FI-1500	1500	1275				d,h	p	p	c	w	2	2	2	2	d.s	1.3		L		
V107	revised	thermal efficiency removed	1516 RBI		Fuera II	FI-1750	1750	1468				d,h	p	p	c	w	2	2	2	2	d.s	1.3		L		
V107	revised	thermal efficiency removed	1517 RBI		Fuera II	FI-1950	1950	1658				d,h	p	p	c	w	2	2	2	2	d.s	1.3		L		
V2.01	revised	435 not 425 OP	1518 RBI		Fuera III Modulating	FI-M-500	500	435				d,h	p	p	c	w	M	3	2	2	d.s	2.4		L		
V2.01	revised	653 not 638 OP	1519 RBI		Fuera III Modulating	FI-M-750	750	653				d,h	p	p	c	w	M	3	2	2	d.s	2.4		L		
V2.01	revised	870 not 850 OP	1520 RBI		Fuera III Modulating	FI-M-1000	1000	870				d,h	p	p	c	w	M	3	2	2	d.s	2.4		L		
V2.01	revised	1088 not 1063 OP	1521 RBI		Fuera III Modulating	FI-M-1250	1250	1088				d,h	p	p	c	w	M	3	2	2	d.s	2.4		L		
V2.01	revised	1306 not 1275 OP	1522 RBI		Fuera III Modulating	FI-M-1500	1500	1305				d,h	p	p	c	w	M	3	2	2	d.s	2.4		L		
V2.01	revised	1523 not 1488 OP	1523 RBI		Fuera III Modulating	FI-M-1750	1750	1523				d,h	p	p	c	w	M	3	2	2	d.s	2.4		L		
V2.01	revised	1739 not 1699 OP	1524 RBI		Fuera III Modulating	FI-M-2000	1999	1739				d,h	p	p	c	w	M	3	2	2	d.s	2.4		L		
V105	new		1525 RBI		Fuera Fusion	Fusion-500	500	490				d,h	p	p	c	w	M	3	2	2	d.s	4				

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Personal Efficiency	Justification Effici	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Tankless	Water Volume	Data Sourc	Date
			1550 RBI		Spectrum	SW200	199	166	83.4	81			d	a	c	w	1	1	3	1	n				
			1551 RBI		Spectrum	SB200	199	166	83.4	81			h	a	c	w	1	1	3	1	n				
			1552 RBI		Spectrum	SW250	250	207	82.8	81			d	a	c	w	1	1	3	1	n				
			1553 RBI		Spectrum	SB250	250	207	82.8	81			h	a	c	w	1	1	3	1	n				
			1554 RBI		Spectrum	SW300	301	249			83		d	a	c	w	1	1	3	1	d				
			1555 RBI		Spectrum	SB300	301	249			83		h	a	c	w	1	1	3	1	d				
			1556 RBI		Spectrum	SW350	350	290			83		d	a	c	w	1	1	3	1	d				
			1557 RBI		Spectrum	SB350	350	290			83		h	a	c	w	1	1	3	1	d				
			1558 RBI		Spectrum	SW400	399	331			83		d	a	c	w	1	1	3	1	d				
			1559 RBI		Spectrum	SB400	399	331			83		h	a	c	w	1	1	3	1	d				
V107	new		1560 RBI		Fuiera XLF	XLFB-MB-MW3000	3000	2610					d,h	p	c	w	M	3	2	2	2.4			L	
V107	new		1561 RBI		Rendamax	R132	2032	1687			83	\$12,195	d,h	p	c	w	M	3	2	2	2.4			L	
			1562 Rendamax		Rendamax	R154	2376	1972			83	\$12,930	h	a	c	w	10	2	2	1	d				
			1563 Rendamax		Rendamax	R180	2301	2301			83	\$13,755	h	a	c	w	10	2	2	1	d				
			1564 Rendamax		Rendamax	R2034	464	410			83	\$6,915	h	a	c	w	10	2	2	1	d				
			1565 Rendamax		Rendamax	R2041	586	495			83	\$7,070	h	a	c	w	10	2	2	1	d				
			1566 Rendamax		Rendamax	R2048	698	579			83	\$7,225	h	a	c	w	10	2	2	1	d				
			1567 Rendamax		Rendamax	R2056	814	676			83	\$7,625	h	a	c	w	10	2	2	1	d				
			1568 Rendamax		Rendamax	R2066	952	790			83	\$7,945	h	a	c	w	10	2	2	1	d				
			1569 Rendamax		Rendamax	R2077	1112	923			83	\$8,295	h	a	c	w	10	2	2	1	d				
			1570 Rendamax		Rendamax	R2090	1301	1080			83	\$8,650	h	a	c	w	10	2	2	1	d				
			1571 Rendamax		Rendamax	R210	3233	2683			83	\$16,025	h	a	c	w	10	2	2	1	d				
			1572 Rendamax		Rendamax	R2105	1519	1261			83	\$9,080	h	a	c	w	10	2	2	1	d				
			1573 Rendamax		Rendamax	R2122	1767	1467			83	\$9,375	h	a	c	w	10	2	2	1	d				
			1574 Rendamax		Rendamax	R244	3758	3119			83	\$16,975	h	a	c	w	10	2	2	1	d				
			1575 Rendamax		Rendamax	R280	4313	3580			83	\$17,650	h	a	c	w	10	2	2	1	d				
			1576 Rendamax		Continuum	2424WC	180	148	82				d,h	p	c	w	M	3	2	1	d				
			1577 Rmai		Residential Tankless	2532FFUC	180	166	82				d,h	p	c	w	M	3	2	1	d				
V106	new	TanMess	1579 Rmai		Residential Tankless	R531	180	149.4	83			80.4	d	p	c	w	M	3	2	1	d				
V106	new	TanMess	1580 Rmai		Residential Tankless	R851	180	149.4	83				d	p	c	w	M	3	2	1	d				
V106	new	TanMess	1581 Rmai		Residential Tankless	R851 Plus	180	149.4	83				d	p	c	w	M	3	2	1	d				
			1582 Rmai		Residential Tankless	R981	237	199.1	84				d	p	c	w	M	3	2	1	d				
			1583 Start Fin		Caravan GGT Series	GGT-400ED	400	320			80	6700	a	a	i	s	2	1	3	1	n				
			1584 Start Fin		Caravan GGT Series	GGT-450ED	450	360			80	6798	h	a	i	s	2	1	3	1	n				
			1585 Start Fin		Caravan GGT Series	GGT-500ED	500	402			80.4	7646	h	a	i	s	2	1	3	1	n				
			1586 Start Fin		Caravan GGT Series	GGT-500ED	550	440			80	7769	h	a	i	s	2	1	3	1	n				
			1587 Start Fin		Caravan GGT Series	GGT-600ED	600	480			80	8503	h	a	i	s	2	1	3	1	n				
			1588 Start Fin		Caravan GGT Series	GGT-750ED	750	600			80	11470	h	a	i	s	3	1	3	1	n				
			1589 Start Fin		Caravan GGT Series	GGT-825ED	825	660			80	11662	h	a	i	s	3	1	3	1	n				
			1590 Start Fin		Caravan GGT Series	GGT-900ED	900	720			80	12755	h	a	i	s	3	1	3	1	n				
			1591 Start Fin		Caravan GGT Series	GGT-1000ED	1000	800			80	15294	h	a	i	s	4	1	3	1	n				
			1592 Start Fin		Caravan GGT Series	GGT-1125ED	1125	900			80	14612	h	a	i	s	4	1	3	1	n				
			1593 Start Fin		Caravan GGT Series	GGT-1200ED	1200	960			80	17006	h	a	i	s	4	1	3	1	n				
			1594 Start Fin		Caravan GGT Series	GGT-1500ED	1500	1200			80	21258	h	a	i	s	5	1	3	1	n				
			1595 Start Fin		Caravan GGT Series	GGT-1875ED	1875	1500			80	24353	h	a	i	s	5	1	3	1	n				
			1596 Start Fin		Caravan GGT Series	GGT-2250ED	2250	1800			80	29225	h	a	i	s	6	1	3	1	n				
			1597 Start Fin		Caravan GGT Series	GGT-2625ED	2625	2100			80	34094	h	a	i	s	7	1	3	1	n				
			1598 Start Fin		Caravan GGT Series	GGT-3000ED	3000	2400			80	38965	h	a	i	s	8	1	3	1	n				
			1599 Start Fin		Caravan GGT Series	GGT-3375ED	3375	2700			80	43836	h	a	i	s	9	1	3	1	n				
			1600 Start Fin		Caravan GGT Series	GGT-3750ED	3750	3000			80	48707	h	a	i	s	10	1	3	1	n				
			1601 Start Fin		Caravan GGH Series	GGHT-800ED	788	654			81.96	10166	h	a	i	s	2	1	3	1	n				
			1602 Start Fin		Caravan GGH Series	GGHT-1200ED	1197	981			81.96	15251	h	a	i	s	3	1	3	1	n				
			1603 Start Fin		Caravan GGH Series	GGHT-1600ED	1596	1308			81.96	20334	h	a	i	s	4	1	3	1	n				
			1604 Start Fin		Caravan GGH Series	GGHT-2000ED	1995	1635			81.96	25418	h	a	i	s	5	1	3	1	n				
			1605 Start Fin		Caravan GGH Series	GGHT-2400ED	2394	1962			81.96	30500	h	a	i	s	6	1	3	1	n				
			1606 Start Fin		Caravan GGH Series	GGHT-2800ED	2793	2289			81.96	35595	h	a	i	s	7	1	3	1	n				
			1607 Start Fin		Caravan GGH Series	GGHT-3200ED	3192	2616			81.96	40668	h	a	i	s	8	1	3	1	n				
V107	new		1608 Start Fin		TRG Series	TRG 50	329	264	80.2				h	p	i	s	1	2	2	2	n			M	
V107	new		1609 Start Fin		TRG Series	TRG 60	364	292	80.2				h	p	i	s	1	2	2	2	n			M	
			1610 Start Fin		TRG Series	TRG 60	399	320	80.2				h	p	i	s	1	2	2	2	n			M	
			1611 Start Fin		TRG Series	TRG 70	434	348	80.2				h	p	i	s	1	2	2	2	n			M	
			1612 Start Fin		TRG Series	TRG 70	469	376	80.2				h	p	i	s	1	2	2	2	n			M	
			1613 Smith		Series 19A	G-19A-W-3	375	297	79.2			81.6	h	p	i	s	1	2	2	2	n				
			1614 Smith		Series 19A	G-19A-W-4	320	413	79.4			82.7	h	p	i	s	1	2	2	2	n				
			1615 Smith		Series 19A	G-19A-W-5	725	575	79.3			82.1	h	p	i	s	1	2	2	2	n				
			1616 Smith		Series 19A	G-19A-W-6	931	738	79.3			81.7	h	p	i	s	1	2	2	2	n				
			1617 Smith		Series 19A	G-19A-W-7	1137	901	79.2			81.4	h	p	i	s	1	2	2	2	n				
			1618 Smith		Series 19A	G-19A-W-8	1342	1063	79.2			81.3	h	p	i	s	1	2	2	2	n				
			1619 Smith		Series 19A	G-19A-W-9	1548	1226	79.2			81.2	h	p	i	s	1	2	2	2	n				
			1620 Smith		Series 19A	G-19A-W-10	1754	1388	79.1			81.1	h	p	i	s	1	2	2	2	n				
			1621 Smith		Series 19A	G-19A-W-11	1959	1551	79.2			81.1	h	p	i	s	1	2	2	2	n				
			1622 Smith		Series 19A	G-19A-W-12	2165	1713	79.1			81	h	p	i	s	1	2	2	2	n				
			1623 Smith		Series 28A	G-28A-W-4	1154	900	77.99			81	h	p	i	s	1	2	2	2	n				
			1624 Smith		Series 28A	G-28A-W-5	1491	1166	78.2			81	h	p	i	s	1	2	2	2	n				
			1625 Smith		Series 28A	G-28A-W-6	1827	1433	78.4			81	h	p	i	s	1	2	2	2	n				
			1626 Smith		Series 28A	G-28A-W-7	2163	1699	78.6			81	h	p	i	s	1	2	2	2	n				
			1627 Smith		Series 28A	G-28A-W-8	2499	1965	78.6			81	h	p	i	s	1	2	2	2	n				
			1628 Smith		Series 28A	G-28A-W-9	2836	2232	78.7																

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Efficiency Effic	Justion Effic	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sourc	Date
V107	revised	Improved ThermEff	1649	Smith	Series 28HE	G28HE-W-15	4608	3831	83.1	83.4	p	h	h	p	i	s	M	2	2	3	f	3				
V107	revised	Improved ThermEff	1650	Smith	Series 28HE	G28HE-W-16	4923	4095	83.2	83.4	p	h	h	p	i	s	M	2	2	3	f	3				
V107	revised	Improved ThermEff	1651	Smith	Series 28HE	G28HE-W-17	5238	4358	83.2	83.4	p	h	h	p	i	s	M	2	2	3	f	3				
V107	revised	Improved ThermEff	1652	Smith	Series 28HE	G28HE-W-18	5553	4622	83.2	83.4	p	h	h	p	i	s	M	2	2	3	f	3				
V106	new	Tankless	1653	Takagi	Flash	T-KJr	140	116.2	83.0		p	d	d	p	c	W	M	3	2	1	ds	3	Y			
V106	new	Tankless	1654	Takagi	Flash	T-KD20	185	151.7	82.0		p	d	d	p	c	W	M	3	2	1	ds	3	Y			
V106	new	Tankless	1655	Takagi	Flash	T-H1	199	183	92.0		p	d	d	p	c	W	M	3	2	1	ds	3	Y			
V106	new	Tankless	1656	Takagi	Flash	T-K1S	190	161.5	85.0		p	d	d	p	c	W	M	3	2	1	ds	3	Y			
V106	new	Tankless	1657	Takagi	Flash	T-M1	235	193.4	82.3		p	d	d	p	c	W	M	3	2	1	ds	3	Y			
V106	new	Tankless	1658	Takagi	Mobius	T-M199	189	164	82.3		p	d	d	p	c	W	M	3	2	1	ds	3	Y			
V104	feratne		1659	Thermal Solutions	Evolution Series	EVA-250	250	220		88	p	d,h	p	c	W	1	1	2	3	f	3					
V104	feratne		1660	Thermal Solutions	Evolution Series	EVA-500	500	440		88	p	d,h	p	c	W	1	1	2	3	f	3					
V104	feratne		1661	Thermal Solutions	Evolution Series	EVA-750	750	660		88	p	d,h	p	c	W	1	1	2	3	f	3					
V104	feratne		1662	Thermal Solutions	Evolution Series	EVA-1000	1000	880		88	p	d,h	p	c	W	1	1	2	3	f	3					
V104	feratne		1663	Thermal Solutions	Evolution Series	EVA-1500	1500	1320		88	p	d,h	p	c	W	1	1	2	3	f	3					
V104	feratne		1664	Thermal Solutions	Evolution Series	EVA-2000	2000	1760		88	p	d,h	p	c	W	1	1	2	3	f	3					
V104	new		1665	Thermal Solutions	Evolution Series	EVA-500	500	440		88	p	d,h	p	c	W	2	2	2	3	f	3					
V104	new		1666	Thermal Solutions	Evolution Series	EVA-750	750	660		88	p	d,h	p	c	W	2	2	2	3	f	3					
V104	new		1667	Thermal Solutions	Evolution Series	EVA-1000	1000	880		88	p	d,h	p	c	W	2	2	2	3	f	3					
V104	new		1668	Thermal Solutions	Evolution Series	EVA-1500	1500	1320		88	p	d,h	p	c	W	2	2	2	3	f	3					
V104	new		1669	Thermal Solutions	Evolution Series	EVA-2000	2000	1760		88	p	d,h	p	c	W	2	2	2	3	f	3					
V104	new		1670	Thermal Solutions	Evolution Series	EVA-500	500	440		88	p	d,h	p	c	W	2	2	2	3	f	3					
V104	new		1671	Thermal Solutions	Evolution Series	EVA-750	750	660		88	p	d,h	p	c	W	3	3	2	3	f	3					
V104	new		1672	Thermal Solutions	Evolution Series	EVA-1000	1000	880		88	p	d,h	p	c	W	3	3	2	3	f	3					
V104	new		1673	Thermal Solutions	Evolution Series	EVA-1500	1500	1320		88	p	d,h	p	c	W	3	3	2	3	f	3					
V104	new		1674	Thermal Solutions	Evolution Series	EVA-2000	2000	1760		88	p	d,h	p	c	W	3	3	2	3	f	3					
V104	new		1675	Thermal Solutions	Evolution Series	EV2500	2500	2200		88	p	d,h	p	c	W	3	3	2	3	d.s.f	3					
V104	new		1676	Thermal Solutions	Evolution Series	EV3000	3000	2640		88	p	d,h	p	c	W	3	3	2	3	d.s.f	3					
V106	new		1677	Thermal Solutions	Evolution Series	EVC-750	750	705		94	p	h	h	p	c	W	3	2	3	d.s.f	4					
V106	new		1678	Thermal Solutions	Evolution Series	EVC-1000	1000	940		94	p	h	h	p	c	W	3	2	3	d.s.f	4					
V106	new		1679	Thermal Solutions	Evolution Series	EVC-1500	1500	1410		94	p	h	h	p	c	W	3	2	3	d.s.f	4					
V106	new		1680	Thermal Solutions	Evolution Series	EVC-2000	2000	1880		94	p	h	h	p	c	W	3	2	3	d.s.f	4					
V106	new		1681	Thermal Solutions	Evolution Series	EVA-500	500	420		84	p	d,h	i	c	W	3	3	1	3	d.s.f	2,4					
V104	new		1682	Thermal Solutions	Solaris	SOL-1000	1000	840		84	p	d,h	i	c	W	3	3	1	3	d.s.f	2,4					
V104	new		1683	Triad Boiler Systems	Series 300	210-ATM	210	171.99	80.6		a	h	a	s	f	1	1	1	1	1	n					
V106	new		1684	Triad Boiler Systems	Series 300	300-ATM	300	240.4	79.2		a	h	a	s	f	1	1	1	1	1	n					
V106	new		1685	Triad Boiler Systems	Series 900	600	600	504.8	84.3		p	h	p	s	f	1	1	1	2	3	s					
V106	new		1686	Triad Boiler Systems	Series 900	700	700	589.4	83.8		p	h	p	s	f	1	1	1	2	3	s					
V106	new		1687	Triad Boiler Systems	Series 900	800	800	664.8	83		p	h	p	s	f	1	1	1	2	3	s					
V106	new		1688	Triad Boiler Systems	Series 900	900	900	746.1	82.5		p	h	p	s	f	1	1	1	2	3	s					
V107	new		1689	Triad Boiler Systems	Series 900	1000	1000	829	82.2		p	h	p	s	f	1	1	1	2	3	s					
V107	new		1690	Ulrica Boilers	UB90-100 Series	UB90-90	150	45	90		i	h	i	o	s	1	2	2	3	3	n					
V107	new		1691	Ulrica Boilers	UB90-100 Series	UB90-75	75	68	90		i	h	i	o	s	1	2	2	3	3	s	4		M		
V107	new		1692	Ulrica Boilers	UB90-100 Series	UB90-100	100	90	90		i	h	i	o	s	1	2	2	3	3	s	4		M		
V107	new		1693	Ulrica Boilers	UB90-200 Series	UB90-125	125	112.5	90		p	h	p	o	s	1	2	2	3	3	s	4		M		
V107	new		1694	Ulrica Boilers	UB90-200 Series	UB90-150	150	135	90		p	h	p	o	s	1	2	2	3	3	s	4		M		
V107	new		1695	Ulrica Boilers	UB90-200 Series	UB90-175	175	157.5	90		p	h	p	o	s	1	2	2	3	3	s	4		M		
V107	new		1696	Ulrica Boilers	UB90-200 Series	UB90-200	200	180	90		p	h	p	o	s	1	2	2	3	3	s	4		M		
V107	new		1697	Ulrica Boilers	USC Series	USC 3	50	44	87		2	h	2	i	2	1	2	2	3	3	s	3		M		
V107	new		1698	Ulrica Boilers	USC Series	USC 4	100	87	87		2	h	2	i	2	1	2	2	3	3	s	3		M		
V107	new		1699	Ulrica Boilers	USC Series	USC 5	140	122	87		2	h	2	i	2	1	2	2	3	3	s	3		M		
V107	new		1700	Ulrica Boilers	DV-B Series	DV-100B	100	82	83		h	h	a	i	2	1	2	2	3	3	f	1,3		M		
V107	new		1701	Ulrica Boilers	DV-B Series	DV-108B	108	82	83		h	h	a	i	2	1	2	2	3	3	f	1,3		M		
V107	new		1702	Ulrica Boilers	DV-B Series	DV-125B	125	103	82		h	h	a	i	2	1	2	2	3	3	f	1,3		M		
V107	new		1703	Ulrica Boilers	DV-B Series	DV-150B	150	122	80		h	h	a	i	2	1	2	2	3	3	f	1,3		M		
V107	new		1704	Ulrica Boilers	DV-B Series	DV-200B	199	160	80		h	h	a	i	2	1	2	2	3	3	f	1,3		M		
V107	new		1705	Ulrica Boilers	MG8 Series	MG8-50	50	42	84.1		a	h	a	i	a	1	2	1	3	1	n	1		M		
V107	new		1706	Ulrica Boilers	MG8 Series	MG8-75	75	63	83.1		a	h	a	i	a	1	2	1	3	1	n	1		M		
V107	new		1707	Ulrica Boilers	MG8 Series	MG8-100	100	83	82		a	h	a	i	a	1	2	1	3	1	n	1		M		
V107	new		1708	Ulrica Boilers	MG8-125	MG8-125	125	104	82		a	h	a	i	a	1	2	1	3	1	n	1		M		
V107	new		1709	Ulrica Boilers	MG8 Series	MG8-150	150	124	83		a	h	a	i	a	1	2	1	3	1	n	1		M		
V107	new		1710	Ulrica Boilers	MG8 Series	MG8-175	175	143	81		a	h	a	i	a	1	2	1	3	1	n	1		M		
V107	new		1711	Ulrica Boilers	MG8 Series	MG8-200	200	165	80.5		a	h	a	i	a	1	2	1	3	1	n	1		M		
V107	new		1712	Ulrica Boilers	MG8 Series	MG8-250	250	205	81.9		a	h	a	i	a	1	2	1	3	1	n	1		M		
V107	new		1713	Ulrica Boilers	MG8 Series	MG8-300	299.99	243	80		a	h	a	i	a	1	2	1	3	1	n	1		M		
V421	new AHRI		1714	Viessmann	Vitocrossal 200 CM2	CM2-186	643	643	97.0		h	h	h	Forced Draft	Stainless Steel	p	1	3	2	3	f	4			AHRI	7-Oct-13
V421	new AHRI		1715	Viessmann	Vitocrossal 200 CM2	CM2-246	851	878.0	95.0		h	h	h	Forced Draft	Stainless Steel	p	1	3	2	3	f	4			AHRI	7-Oct-13
V421	new AHRI		1716	Viessmann	Vitocrossal 200 CM2	CM2-311	1112.0	1078	97.0		h	h	h	Forced Draft	Stainless Steel	p	1	3	2	3	f	4			AHRI	7-Oct-13
V421	new AHRI		1717	Viessmann	Vitocrossal 200 CM2	CM2-400	1445.0	1372	95.0		h	h	h	Forced Draft	Stainless Steel	p	1	3	2	3	f	4			AHRI	7-Oct-13
V421	new AHRI		1718	Viessmann	Vitocrossal 200 CM2	CM2-500	1710	1600.0	95.0		h	h	h	Forced Draft	Stainless Steel	p	1	3	2	3	f	4	</			

Version	Change	Comment	Record	Manufacturer	Product Name	Model Number	Input MBH	Output MBH	Annual Efficiency	Seasonal Efficiency	Austion Effici	MSRP	Application	Combustion	Construction	Heat Exch	Stages	AF Control	Damping	Purge Cycles	Vent Class	Vent Category	Tankless	Water Volume	Data Sourc	Date
			1749 Viessmann	Atola Renox Series	AR-185	185	158		85.41	\$3,385	h		a	i	s	1	1	1	1	1	1	1				
			1750 Viessmann	Atola Renox Series	AR-210	179			85.43	\$3,645	h		a	i	s	1	1	1	1	1	1	1				
			1751 Viessmann	Atola Renox Series	AR-250	213			85.24	\$4,260	h		a	i	s	1	1	1	1	1	1	1				
			1752 Viessmann	Atola Renox Series	AR-270	230			85.11	\$4,511	h		a	i	s	1	1	1	1	1	1	1				
			1753 Viessmann	Atola Series	RS-8-A	550			83	\$6,866	h		a	i	w	1	1	1	1	1	1	1				
			1754 Viessmann	Atola Series	RS-11-A	800			83	\$10,166	h		a	i	w	1	1	1	1	1	1	d				
			1755 Viessmann	Atola Series	RS-14-A	1050			83	\$12,242	h		a	i	w	1	1	1	1	1	1	1	1			
			1756 Viessmann	Vitodens 200	WB2-6-24	91	81		89.01	94.2	h		p	ss	s	M	3	2	2	3	3	f				
			1757 Viessmann	Vitodens 200	WB2-8-32	124	112		88.95	94	h		p	ss	s	M	3	2	2	3	3	f				
			1758 Viessmann	Vitodens 200	WB2-11-44	172	153		89.1	94	h		p	ss	s	M	3	2	2	3	3	f				
			1759 Viessmann	Vitodens 200	WB2-15-60	230	205		89.1	94	h		p	ss	s	M	3	2	2	3	3	f				
			1760 Viessmann	Vitogas 100 GS1 Series	GS1-22	90	76		84.4	85.6	h		a	i	s	1	1	1	1	1	1	n				
			1761 Viessmann	Vitogas 100 GS1 Series	GS1-29	115	96		85.2	85.5	h		a	i	s	1	1	1	1	1	1	n				
			1762 Viessmann	Vitogas 100 GS1 Series	GS1-35	123			84.8	85.5	h		a	i	s	1	1	1	1	1	1	n				
			1763 Viessmann	Vitogas 100 GS1 Series	GS1-42	165	140		84.9	85.5	h		a	i	s	1	1	1	1	1	1	n				
			1764 Viessmann	Vitogas 100 GS1 Series	GS1-48	190	161		84.7	85.5	h		a	i	s	1	1	1	1	1	1	n				
			1765 Viessmann	Vitogas 100 GS1 Series	GS1-60	240	203		84.6	85.4	h		a	i	s	1	1	1	1	1	1	n				
			1766 Viessmann	Vitogas 100 GS10 Series	GS10-72	300	257		85.7	70.86	h		a	i	s	2	1	1	1	1	1	n				
			1767 Viessmann	Vitogas 100 GS10 Series	GS10-84	291			85.6	70.06	h		a	i	s	2	1	1	1	1	1	n				
			1768 Viessmann	Vitogas 100 GS10 Series	GS10-96	380	325		85.5	81.66	h		a	i	s	2	1	1	1	1	1	n				
			1769 Viessmann	Vitogas 50 ECV Series	ECV-65	65	54		83	83.1	h		a	i	s	1	1	1	2	2	3	n				
			1770 Viessmann	Vitogas 50 ECV Series	ECV-80	80	67		83	83.1	h		a	i	s	1	1	1	2	2	3	n				
			1771 Viessmann	Vitogas 50 ECV Series	ECV-100	100	84		83	83.1	h		a	i	s	1	1	1	2	2	3	n				
			1772 Viessmann	Vitogas 50 ECV Series	ECV-115	115	97		84	83.1	h		a	i	s	1	1	1	2	2	3	n				
			1773 Viessmann	Vitogas 50 ECV Series	ECV-140	140	118		84	83.1	h		a	i	s	1	1	1	2	2	3	n				
			1774 Viessmann	Vitogas 50 ECV Series	ECV-155	155	131		84	83.1	h		a	i	s	1	1	1	2	2	3	n				
			1775 Viessmann	Vitogas 50 ECV Series	ECV-180	180	151		84	83.1	h		a	i	s	1	1	1	2	2	3	n				
			1776 Viessmann	Vitogas 50 ECV Series	ECV-200	200	168		84	83.1	h		a	i	s	1	1	1	2	2	3	n				
V107	new		1777 Viessmann	Vitogas 50 ECD Series	ECD-65	65	54		83.7	83.5	h		a	i	s	1	1	1	3	1	1	n				
V107	new		1778 Viessmann	Vitogas 50 ECD Series	ECD-80	80	66		83.5	83.5	h		a	i	s	1	1	1	3	1	1	n				
V107	new		1779 Viessmann	Vitogas 50 ECD Series	ECD-100	100	83		83.5	83.5	h		a	i	s	1	1	1	3	1	1	n				
V107	new		1780 Viessmann	Vitogas 50 ECD Series	ECD-115	115	95		83.5	31.90	h		a	i	s	1	1	1	3	1	1	n				
V107	new		1781 Viessmann	Vitogas 50 ECD Series	ECD-140	140	116		83.4	34.75	h		a	i	s	1	1	1	3	1	1	n				
V107	new		1782 Viessmann	Vitogas 50 ECD Series	ECD-155	155	129		83.5	34.75	h		a	i	s	1	1	1	3	1	1	n				
V107	new		1783 Viessmann	Vitogas 50 ECD Series	ECD-180	180	149		83.2	37.50	h		a	i	s	1	1	1	3	1	1	n				
V107	new		1784 Viessmann	Vitogas 50 ECD Series	ECD-200	200	166		83	37.50	h		a	i	s	1	1	1	3	1	1	n				
V104	update		1785 Viessmann	Vitogas 50 RS Series	RS-8-V50	550	468		85	12.336	h		a	i	s	1	1	1	1	1	1	n				
V104	update		1786 Viessmann	Vitogas 50 RS Series	RS-11-V50	800	680		85	14.146	h		a	i	s	1	1	1	1	1	1	n				
V104	update		1787 Viessmann	Vitogas 50 RS Series	RS-14-V50	1050	897		85	17.040	h		a	i	s	1	1	1	1	1	1	n				
			1788 Viessmann	Rondomat	RMT-125	508	426.72		84		h		p	i	s	1	1	2	2	2	3	f				
			1789 Viessmann	Rondomat	RMT-160	650	546		84		h		p	i	s	1	1	2	2	2	3	f				
			1790 Viessmann	Rondomat	RMT-195	792	665.28		84		h		p	i	s	1	1	2	2	2	3	f				
			1791 Viessmann	Rondomat	RMT-230	934	784.56		84		h		p	i	s	1	1	2	2	2	3	f				
			1792 Viessmann	Rondomat	RMT-270	1096	920.64		84		h		p	i	s	1	1	2	2	2	3	f				
			1793 Viessmann	Rondomat	RMT-320	1300	1092		84		h		p	i	s	1	1	2	2	2	3	f				
			1794 Viessmann	Rondomat	RMT-380	1544	1296.96		84		h		p	i	s	1	1	2	2	2	3	f				
			1795 Viessmann	Rondomat	RMT-440	1787	1501.08		84		h		p	i	s	1	1	2	2	2	3	f				
			1796 Viessmann	Rondomat	RMT-500	2031	1706		84		h		p	i	s	1	1	2	2	2	3	f				
			1797 Viessmann	Rondomat	RMT-560	2275	1911		84		h		p	i	s	1	1	2	2	2	3	n				
			1798 Viessmann	Rondomat	RMT-700	2843	2388		84		h		p	i	s	1	1	2	2	2	3	n				
			1799 Viessmann	Rondomat	RMT-780	3168	2661		84		h		p	i	s	1	1	2	2	2	3	n				
			1800 Viessmann	Rondomat	RMT-860	3493	2934		84		h		p	i	s	1	1	2	2	2	3	n				
			1801 Viessmann	Rondomat	RMT-910	3696	3104.64		84		h		p	i	s	1	1	2	2	2	3	n				
			1802 Viessmann	Rondomat	RMT-1080	4387	3685.08		84		h		p	i	s	1	1	2	2	2	3	n				
			1803 Viessmann	Veromat	VS8-05	191	174		91.1	\$11,729	h		p	i	s	10	1	2	2	2	3	1				
			1804 Viessmann	Veromat	VS8-08	300	270.2		90.1		h		p	i	ss	w	3	2	2	2	3	d				
			1805 Viessmann	Veromat	VS8-10	396	356.2		89.95		h		p	i	ss	p	3	2	2	2	3	d				
			1806 Viessmann	Veromat	VS8-13	488	439.1		89.98		h		p	i	ss	p	3	2	2	2	3	d				
			1807 Viessmann	Veromat	VS8-17	638	575.6		90.2		h		p	i	ss	p	3	2	2	2	3	d				
			1808 Viessmann	Veromat	VS8-22	846	763.3		90.2		h		p	i	ss	p	3	2	2	2	3	d				
			1809 Viessmann	Veromat	VS8-28	1071	966.3		90.2		h		p	i	ss	p	3	2	2	2	3	d				
			1810 Viessmann	Veromat	VS8-37	1389	1252.5		90.2		h		p	i	ss	p	3	2	2	2	3	d				
			1811 Viessmann	Veromat	VS8-46	1726	1557.2		90.2		h		p	i	ss	p	3	2	2	2	3	d				
			1812 Viessmann	Veromat	VS8-57	2160	1948.8		90.2		h		p	i	ss	p	3	2	2	2	3	d				
			1813 Viessmann	Veromat	VS8-72	2702	2437.7		90.2		h		p	i	ss	p	3	2	2	2	3	d				
			1814 Viessmann	Veromat	VS8-89	3361	3032.3		90.2		h		p	i	ss	p	3	2	2	2	3	d				
			1815 Viessmann	Vitola 200 Series	VB2-18	90	75		83.3	84.5	h		p	i	s	1	1	2	2	2	2	n				
			1816 Viessmann	Vitola 200 Series	VB2-22	116	97		83.6	84	h		p	i	s	1	1	2	2	2	2	n				
			1817 Viessmann	Vitola 200 Series	VB2-33	146	122		83.6	84	h		p	i	s	1	1	2	2	2	2	n				
			1818 Viessmann	Vitola 200 Series	VB2-40	185	185		83.2	84	h		p	i	s	1	1	2	2	2	2	n				
			1819 Viessmann	Vitola 200 Series	VB2-50	238	198		83.9		h		p	i	s	1	1	2	2	2	2	n				
			1820 Viessmann	Vitola 200 Series	VB2-63	299.9	249		83.03	83.9	h		p	i												

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			1849	Wei-McLain	LGB Series 2	LGB-14	1690	1368.9	79.5	81	2295.7	h	a	i	s	1	1	1	1	1	n				
			1850	Wei-McLain	LGB Series 2	LGB-15	1820	1474.2	79.6	81	2402.8	h	a	i	s	1	1	1	1	1	n				
			1851	Wei-McLain	LGB Series 2	LGB-16	1980	1579.5	79.6	81	2505.8	h	a	i	s	1	1	1	1	1	n				
			1852	Wei-McLain	LGB Series 2	LGB-17	2050	1684.8	79.7	81	2627.3	h	a	i	s	1	1	1	1	1	n				
			1853	Wei-McLain	LGB Series 2	LGB-18	2210	1790.1	79.8	81	2746.6	h	a	i	s	1	1	1	1	1	n				
			1854	Wei-McLain	LGB Series 2	LGB-19	2340	1895.4	79.8	81	2863.9	h	a	i	s	1	1	1	1	1	n				
			1855	Wei-McLain	LGB Series 2	LGB-20	2470	2000.7	79.9	81	2979.0	h	a	i	s	1	1	1	1	1	n				
			1856	Wei-McLain	LGB Series 2	LGB-21	2600	2106	79.9	81	3097.1	h	a	i	s	1	1	1	1	1	n				
			1857	Wei-McLain	LGB Series 2	LGB-22	2730	2211.3	80	81	3270.6	h	a	i	s	1	1	1	1	1	n				
			1858	Wei-McLain	LGB Series 2	LGB-23	2860	2316.6	80	81	3543.8	h	a	i	s	1	1	1	1	1	n				
			1859	Wei-McLain	PGF Series 6	PGF-5-PIDN	244	199	81.6	81	3694	h	a	i	s	1	1	3	1	1	n.f				
			1860	Wei-McLain	PGF Series 6	PGF-6-SPN	3247	247	76.8	80.98	3631	h	a	i	s	1	1	1	1	1	n.f				
			1861	Wei-McLain	PGF Series 6	PGF-7-SPN	3565	296	78.2	80.8	4593	h	a	i	s	1	1	1	1	1	n.f				
			1862	Wei-McLain	PGF Series 6	PGF-8-PIN	427	346	79.1	81.03	5312	h	i	i	s	1	1	3	1	1	n.f				
			1863	Wei-McLain	GV Series 3	GV-3	70	61	87.1	87.5	3718	h	i	i	s	1	2	2	3	1	n.f				
			1864	Wei-McLain	GV Series 3	GV-4	105	92	87.6	87.3	3993	h	i	i	s	1	2	2	3	1	n.f				
			1865	Wei-McLain	GV Series 3	GV-5	140	122	87.1	87.2	4274	h	i	i	s	1	2	2	3	1	n.f				
			1866	Wei-McLain	GV Series 3	GV-6	175	153	87.4	87	4591	h	i	i	s	1	2	2	3	1	n.f				
			1867	Wei-McLain	CGS Series	CGS-3-PIN	67	57	85.1	85.3	2791	h	i	i	s	1	1	2	3	1	n.f				
			1868	Wei-McLain	CGS Series	CGS-4-PIN	100	85	85	3013	h	i	i	i	s	1	1	2	3	1	n.f				
			1869	Wei-McLain	CGS Series	CGS-5-PIN	133	112	84.2	84	3306	h	i	i	s	1	1	2	3	1	n.f				
			1870	Wei-McLain	CGS Series	CGS-6-PIN	167	140	83.8	83.4	3594	h	i	i	s	1	1	2	3	1	n.f				
			1871	Wei-McLain	CGI Series 2	CGI-25-PIN	42	84	84	1748	h	i	i	i	s	1	1	2	3	1	n.f				
			1872	Wei-McLain	CGI Series 2	CGI-3-PIN	67	57	85.1	84.3	1980	h	i	i	s	1	1	2	3	1	n.f				
			1873	Wei-McLain	CGI Series 2	CGI-4-PIN	100	85	84	2082	h	i	i	i	s	1	1	2	3	1	n.f				
			1874	Wei-McLain	CGI Series 2	CGI-5-PIN	133	112	84.2	83.7	2286	h	i	i	s	1	1	2	3	1	n.f				
			1875	Wei-McLain	CGI Series 2	CGI-6-PIN	167	140	83.8	83.3	2500	h	i	i	s	1	1	2	3	1	n.f				
			1876	Wei-McLain	CGI Series 2	CGI-7-PIN	200	167	83.5	83	3232	h	i	i	s	1	1	2	3	1	n.f				
			1877	Wei-McLain	CGI Series 2	CGI-8-PIN	233	194	83.3	82.7	3259	h	i	i	s	1	1	2	3	1	n.f				
			1878	Wei-McLain	Model 80 Boiler-Burner	380	346	278	80.2	82.7	3259	h	i	i	s	1	1	1	1	1	n.f				
			1879	Wei-McLain	Model 80 Boiler-Burner	480	491	396	80.7	82.9	3613	h	i	i	s	1	1	1	1	1	n.f				
			1880	Wei-McLain	Model 80 Boiler-Burner	580	639	515	80.6	82.6	4029	h	i	i	s	1	1	1	1	1	n.f				
			1881	Wei-McLain	Model 80 Boiler-Burner	680	787	634	80.6	82.3	4441	h	i	i	s	1	1	1	1	1	n.f				
			1882	Wei-McLain	Model 80 Boiler-Burner	780	935	753	80.6	82.2	4853	h	i	i	s	1	1	1	1	1	n.f				
			1883	Wei-McLain	Model 80 Boiler-Burner	880	1082	872	80.6	82	5265	h	i	i	s	1	1	1	1	1	n.f				
			1884	Wei-McLain	Model 80 Boiler-Burner	980	1230	991	80.5	82	5677	h	i	i	s	1	1	1	1	1	n.f				
			1885	Wei-McLain	Model 80 Boiler-Burner	1080	1378	1110	80.5	81.9	6089	h	i	i	s	1	1	1	1	1	n.f				
			1886	Wei-McLain	Model 80 Boiler-Burner	1180	1526	1229	80.5	81.8	6501	h	i	i	s	1	1	1	1	1	n.f				
			1887	Wei-McLain	Model 80 Boiler-Burner	1280	1674	1348	80.5	81.8	6913	h	i	i	s	1	1	1	1	1	n.f				
			1888	Wei-McLain	Model 88 Boiler-Burner	488	1010	810	79.7	81.9	2166.2	h	p	i	s	1	1	1	1	1	n.f				
			1889	Wei-McLain	Model 88 Boiler-Burner	588	1357	1064	79.8	81.9	2395.2	h	p	i	s	1	1	1	1	1	n.f				
			1890	Wei-McLain	Model 88 Boiler-Burner	688	1703	1358	79.8	81.6	2788.4	h	p	i	s	1	1	1	1	1	n.f				
			1891	Wei-McLain	Model 88 Boiler-Burner	788	2049	1632	79.8	81.4	3102.4	h	p	i	s	1	1	1	1	1	n.f				
			1892	Wei-McLain	Model 88 Boiler-Burner	888	2396	1904	79.8	81.3	3371.8	h	p	i	s	1	1	1	1	1	f.s				
			1893	Wei-McLain	Model 88 Boiler-Burner	988	2713	2176	79.8	81.2	3754.9	h	p	i	s	1	1	1	1	1	f.s				
			1894	Wei-McLain	Model 88 Boiler-Burner	1088	3103	2452	79.8	81.1	4037.6	h	p	i	s	1	1	1	1	1	f.s				
			1895	Wei-McLain	Model 88 Boiler-Burner	1188	3392	2724	79.8	81.1	4392.8	h	p	i	s	1	1	1	1	1	f.s				
			1896	Wei-McLain	Model 88 Boiler-Burner	1288	3753	3000	79.8	81.1	4713.2	h	p	i	s	1	1	1	1	1	f.s				
			1897	Wei-McLain	Model 88 Boiler-Burner	1388	4113	3270	79.9	81	5125.8	h	p	i	s	1	1	1	1	1	f.s				
			1898	Wei-McLain	Model 88 Boiler-Burner	1488	4474	3550	79.9	81	5427.0	h	p	i	s	1	1	1	1	1	f.s				
			1899	Wei-McLain	Model 88 Boiler-Burner	1588	4763	3820	79.9	81	5661.8	h	p	i	s	1	1	1	1	1	f.s				
			1900	Wei-McLain	Model 88 Boiler-Burner	1688	5124	4090	79.9	81	5946.6	h	p	i	s	1	1	1	1	1	f.s				
			1901	Wei-McLain	Model 88 Boiler-Burner	1788	5485	4370	79.9	80.9	6300.7	h	p	i	s	1	1	1	1	1					
			1902	Wei-McLain	Model 88 Boiler-Burner	1888	5845	4640	79.9	80.9	6615.4	h	p	i	s	1	1	1	1	1					
			1903	Wei-McLain	Model 94 Series 3	894	2327	2028	80.3	81.2	5616.7	h	p	i	s	1	1	1	1	1					
			1904	Wei-McLain	Model 94 Series 3	994	2687	2320	80.3	81.2	6007.2	h	p	i	s	1	1	1	1	1					
			1905	Wei-McLain	Model 94 Series 3	1094	3247	2612	80.3	81.3	6512.2	h	p	i	s	1	1	1	1	1	n				
			1906	Wei-McLain	Model 94 Series 3	1194	3608	2904	80.3	81.4	6903.6	h	p	i	s	1	1	1	1	1					
			1907	Wei-McLain	Model 94 Series 3	1294	3969	3190	80.3	81.4	7468.4	h	p	i	s	1	1	1	1	1					
			1908	Wei-McLain	Model 94 Series 3	1394	4330	3480	80.4	81.4	7949.5	h	p	i	s	1	1	1	1	1					
			1909	Wei-McLain	Model 94 Series 3	1494	4691	3770	80.4	81.4	8557.6	h	p	i	s	1	1	1	1	1					
			1910	Wei-McLain	Model 94 Series 3	1594	5052	4070	80.4	81.5	8932.8	h	p	i	s	1	1	1	1	1					
			1911	Wei-McLain	Model 94 Series 3	1694	5412	4360	80.4	81.5	9317.5	h	p	i	s	1	1	1	1	1					
			1912	Wei-McLain	Model 94 Series 3	1794	5773	4650	80.4	81.5	9695.5	h	p	i	s	1	1	1	1	1					
			1913	Wei-McLain	Model 94 Series 3	1894	6134	4940	80.5	81.5	10068.1	h	p	i	s	1	1	1	1	1					
			1914	Wei-McLain	Model 94 Series 3	1994	6495	5230	80.5	81.5	11264.2	h	p	i	s	1	1	1	1	1	f				
			1915	Wei-McLain	Model 94 Series 3	2094	6856	5520	80.5	81.5	11649.7	h	p	i	s	1	1	1	1	1	f				
			1916	Wei-McLain	Model 94 Series 3	2194	7216	5810	80.5	81.5	12431.2	h	p	i	s	1	1	1	1	1	d				
			1917	Wei-McLain	Model 94 Series 3	2294	7577	6100	80.5	81.5	12846.2	h	p	i	s	1	1	1	1	1	d				
			1918	Wei-McLain	Model 94 Series 3	2394	7938	6390	80.5	81.5</															

E-Tools Reference Documentation



REFERENCE DOCUMENTATION

AHU & MUA PROGRAMS, V1.07

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1.0 INTRODUCTION

The Air Handling Unit (AHU) and Make-Up Air (MUA) Programs estimate the annual gas consumption and gas cost associated with the operation of these ventilation systems. The programs are nearly identical and calculate the energy required to maintain a design room temperature for a range of ambient temperatures given a predefined ventilation rate. The user may also analyze the benefit of installing a heat recovery unit in the existing and/or new AHU system. For both the MUA and AHU, the user may evaluate the effect of a reduction in the number of hours and the operating temperature of the ventilation system per 24-hour period. Two programs allow a facility to have both a make-up air unit and a separate air-handling unit.

Electrical savings are calculated with use of a VFD on the fan motor and are included within the Ventilation MUA/AHU ETool. The calculations for these savings are documented in the VFD ETool Reference Documentation and have not been included in this document to avoid duplication.

2.0 PROGRAM METHOD

The program calculates the amount of heat required (in btu's) to make up for heat lost through the ventilation system. These values are converted to an equivalent gas consumption and cost based on the calorific value of gas and the average cost of gas respectively. All calculations are performed using Imperial equations.

2.1 Inputs

The user must provide the following values (or the values are determined and imported from other programs such as the Boiler Selection Toolbox)

Existing System: Air Flow Rate (cfm)
 Supply Air Temperature (°F)
 Existing Equipment Efficiency (%) (from Boiler Selection Toolbox)
 Actual Hours of Operation (hrs/24 hour period)

New System: New Air Flow Rate (Percentage of Existing Flow Rate) (%)
 New Air Supply Temperature (°F)
 New Equipment Efficiency (%) (from Boiler Selection Toolbox)

For the new system, the day is divided into three 8-hour periods – midnight to 8:00 am, 8:00 am to 4:00 pm and 4:00 pm to midnight. For each period, the user inputs:

Start and End Time for Peak Air Supply (time of day)
 Air Flow Reduction Rate for Non-Peak Times (%)
 Air Supply Temperature for Non-Peak Times (°F)

For an AHU with Heat Recovery: Amount of Fresh Air (%) for existing system and/or new system

2.2 Calculations

2.2.1 Heat Required

Heat required to maintain the supply air temperature is determined by the following formula:

$$q_{Vent} = \sum_{-5}^{T_i} q_{BIN} = \sum_{-5}^{T_i} 1.08 QH (T_i - T_o) \quad [\text{Ref 1}]$$

Where: q = Annual Heat Requirement (BTU)

Q = ventilation rate (cfm)

1.08 = energy required to raise temperature of 1 cu.ft. of air 1 F° (in BTU/°F/hour)

T_i = desired supply air temperature (°F)

T_o = outside temperature (°F)

H = 30 year average of total hours that occur inside a specified temperature range (BIN number).

2.2.2 Heat Recovery

If the Air Handling Unit is equipped so that some or all of the fresh air can be replaced with recirculated room air, the heat required to maintain the desired supply air temperature is calculated as follows:

$$T_{mc} = \frac{Q_f T_o + Q_r T_r}{Q}$$

$$q_{Vent} = \sum_{-5}^{T_i} q_{BIN} = \sum_{-5}^{T_i} 1.08 QH (T_i - T_{mc})$$

Where: q = annual heat requirement (BTU)

Q = ventilation rate (cfm)

1.08 = energy required to raise temperature of 1 ft³ of air 1 F° (in BTU/°F/hour)

Q_f = fresh air ventilation rate (cfm)

Q_r = recirculated air ventilation rate (cfm)

H = 30 year average BIN number (hours)

T_i = desired supply air temperature (°F)

T_o = outside temperature (°F)

T_r = room temperature (°F)

T_{mc} = AHU mixing chamber temperature (°F)

2.2.3 Gas Consumption

$$NG_E = \frac{q_{vent}}{NG_{cal} Eff / 100}$$

Where: NG_E = Annual Gas Consumption (in M^3)
 q_{vent} = Annual Heat Loss from ventilation system (in BTU)
 NG_{cal} = Calorific value of Natural Gas (35,300 Btu/ m^3)
 Eff = Equipment Efficiency (in %)

2.2.4 Gas Consumption for Actual Hours of Operation of Existing System

$$NG_A = \frac{t}{24} NG_E$$

Where: NG_A = Annual Gas Consumption for actual hours of operation (M^3)
 t = Actual Hours of Operation per 24 hour period (hrs)

2.2.5 Peak Period Operation

The day is divided into three 8 hour periods (0:00 to 8:00, 8:00 to 16:00 and 16:00 to 24:00). For each period, the user selects the start of peak use and the end of peak use. The heat required is calculated as follows:

$$q_{Vent_p} = \frac{t_p}{8} \sum_{-5}^{T_i} q_{BIN\ 0-8} = \frac{t_p}{8} \sum_{-5}^{T_i} 1.08 QH_{0-8} (T_i - T_o)$$

Where: q_{Ventp} = Ventilation Heat Loss for peak usage period (Btu)
 t_p = Number of Hours of Peak Operation (hrs)
 q_{BIN0-8} = Heat Loss during the hours of 0:00 to 8:00 (BTU)
 H_{0-8} = 30 year average of total hours that occur inside a specified temperature range (BIN number) during the hours 0:00 to 8:00.
 T_i = Supply Air Temperature ($^{\circ}F$)
 T_o = Ambient Temperature ($^{\circ}F$)

Equivalent calculations are performed for the 8:00 to 16:00 hour period and 16:00 to 24:00 hour period.

2.2.6 Off-Peak Reduced Operation

For non-peak hours of operation, in the three time periods, the user may reduce both the room temperature and the ventilation rate. The calculations are based on the following equation:

$$q_{Vent_{np}} = \frac{t_{np}}{8} \sum_{-5}^{T_i} q_{BIN\ 0-8} = \frac{t_{np}}{8} \sum_{-5}^{T_i} 1.08 Q_{red} H_{0-8} (T_{ired} - T_o)$$

Where: $q_{Vent_{np}}$ = Annual Heat Loss during reduced operations (Btu)

t_{np} = Number of non-peak hours of operation (hrs)

q_{BIN0-8} = Heat Loss during the hours of 0:00 to 8:00 (Btu)

Q_{red} = Reduced Ventilation Rate (cfm)

T_{ired} = Reduced Temperature during off-peak hours (°F)

T_o = Ambient Temperature (°F)

Equivalent calculations are performed for the other two time periods.

2.2.7 Gas Consumption by New System

For each 8 hour period of the day:

$$q_{Vent_{tot}} = q_{Vent_p} + q_{Vent_{np}}$$

$$NG_N = \frac{q_{Vent_{tot}}}{NG_{cal} \times Eff}$$

Where: NG_N = Annual Gas Consumption (in M^3)

$q_{Vent_{tot}}$ = Annual Heat Loss from ventilation system (in BTU)

NG_{cal} = Calorific value of Natural Gas (35,300 Btu/ m^3)

Eff = Equipment Efficiency (in %)

2.3 Ambient Temperature from BIN Numbers

BIN numbers are used to determine the ambient temperature. BIN numbers represent the 30-year average of the total number of hours per year that occur within specified temperature ranges. Table 3 shows the BIN numbers for Toronto. For other locations, the calculated values for gas consumption are modified by a factor based on the relative Heating Degree Days compared to Toronto as follows:

Location	Factor
Niagara	0.904
Ottawa	1.112
Moncton	1.128
Fredericton	1.142

Table 3: BIN Numbers (IP units) for Toronto [Ref. 2]

Temperature Range (°F)	Hours			
	0:00 to 8:00	8:00 to 16:00	16:00 to 24:00	Total
90 to 95	0	10	2	12
85 to 90	0	45	12	57
80 to 85	1	122	45	168
75 to 80	19	238	95	352
70 to 75	98	277	231	606
65 to 70	184	217	217	618
60 to 65	219	201	249	669
55 to 60	310	180	259	749
50 to 55	286	202	236	724
45 to 50	226	212	186	624
40 to 45	202	185	242	629
35 to 40	247	234	260	741
30 to 35	330	213	246	789
25 to 30	257	224	226	707
20 to 25	177	151	135	463
15 to 20	151	84	131	366
10 to 15	110	83	81	274
5 to 10	57	29	52	138
0 to 5	39	13	15	67
-5 to 0	6	0	0	6

2.4 Energy Use Summary

The program's Energy Use Summary is calculated by the following equations. The summary is shown in SI units since gas is sold by the m³.

Total Estimate Annual Gas Savings

The following equation is used for each AHU or MUA that is entered. The *total* estimate annual gas savings is the addition of savings from all units.

$$NG_S = NG_A - NG_N$$

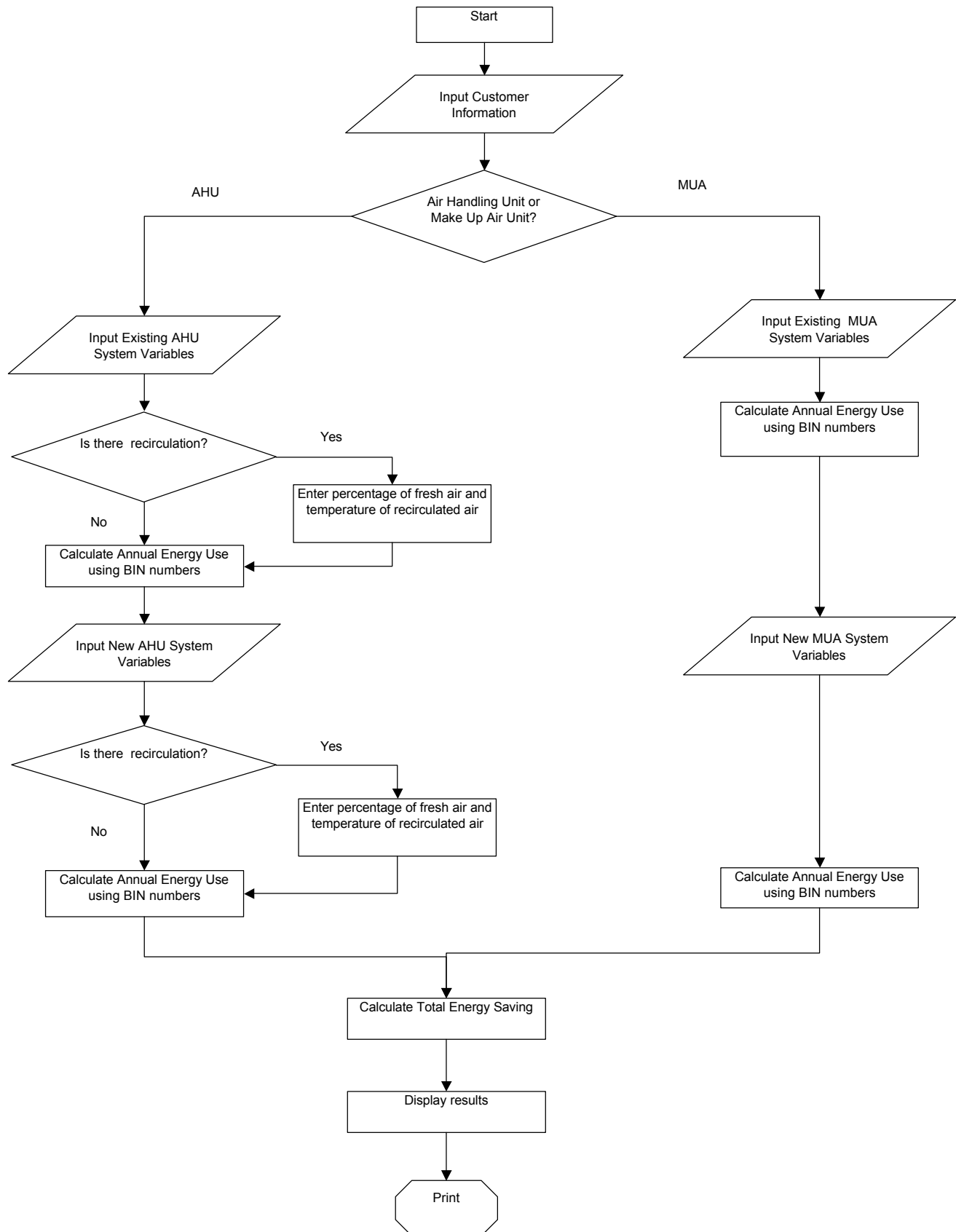
Where: NG_S = Estimated Annual Gas Saving (M³)

NG_A = Actual Gas Use by Existing System (M³)

NG_N = Estimated Annual Gas Used by New System (M³)

FLOW CHART

Air Handling Unit/Make Up Air Flow Chart



REFERENCES

Enbridge – Etool

AHU and MUA Programs

Reference Documentation

References:

1. ASHRAE 2001 Fundamentals Chapter 26: Thermal Loads Equation 26.
2. Environment Canada, Atmospheric Weather Service 1968-1992



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REFERENCE DOCUMENTATION

CLIMATIC DATA, V1.07

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Enbridge – Etool

Climatic Data

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1.0 INTRODUCTION

Climatic Data is used in the calculation of heat losses from building components, sizing of heating and ventilating equipment and the estimation of gas consumption and cost savings by upgrading systems. The two main charts of data are BIN numbers and Heating Degree Days.

2.0 BIN NUMBERS

BIN Numbers refer to the annual number of hours, on average for a 30 year period, that the ambient temperature falls within a defined temperature range (usually 5 F°). In some cases there is hourly data for different time period during the day (midnight to 8:00 am, 8:00 am to 4:00 pm, and 4:00 pm to midnight). No BIN numbers are available for Niagara Falls. For the purposes of these E-Tools, they have been estimated as 0.903 times the Toronto numbers, based on the relationship between HDD for the two cities.

Annual BIN Numbers for Selected Canadian Locations [Ref. 1]

Temperature Intervals		Hours			
Temp (*F)	Range	TORONTO	OTTAWA	MONCTON	FREDERICTON
-60	-55				
-55	-50				
-50	-45				
-45	-40				
-40	-35				
-35	-30				
-30	-25				1
-25	-20		7	1	4
-20	-15		16	7	12
-15	-10		38	27	32
-10	-5	1	88	68	82
-5	0	6	161	123	135
0	5	67	207	191	190
6	10	138	252	256	256
11	15	274	322	315	333
16	20	366	382	407	386
21	25	463	441	504	478
26	30	707	487	712	640
31	35	789	766	904	840
36	40	741	706	718	707
41	45	629	594	658	644
46	50	624	613	683	657

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Climatic Data

Reference Documentation

51	55	724	626	736	716
56	60	749	728	781	761
61	65	669	732	685	697
66	70	618	661	472	512
71	75	606	476	311	360
76	80	352	287	147	191
81	85	168	138	50	94
86	90	57	48	10	30
91	95	12	12		4
96	100		3		
101	105				
106	110				

Table 2: BIN Numbers by Daily Time Period for Toronto (IP units) [Ref. 1]

Temperature Range (°F)	Hours			
	0:00 to 8:00	8:00 to 16:00	16:00 to 24:00	Total
90 to 95	0	10	2	12
85 to 90	0	45	12	57
80 to 85	1	122	45	168
75 to 80	19	238	95	352
70 to 75	98	277	231	606
65 to 70	184	217	217	618
60 to 65	219	201	249	669
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10 to 15	110	83	81	274
5 to 10	57	29	52	138
0 to 5	39	13	15	67
-5 to 0	6	0	0	6

3.0 HEATING DEGREE DAYS

The quantity “Heating Degree Days” (HDD) refers to the product of the amount of time the ambient temperature is below a selected reference temperature (usually room temperature of 18°C) multiplied by the difference in temperature between the reference temperature and ambient temperature. If the ambient temperature is at or above the reference temperature, there is no HDD number. The higher the reference temperature, the greater the number of HDD is any given period (month, year).

Heating Degree Days for Selected Canadian Locations (Below 18°C) [Ref. 2]

	Location				
	Toronto Airport	Niagara Falls NPCSH	Ottawa Airport	Moncton Airport	Fredericton Airport
January	752.9	697.1	883.1	816.3	853.0
February	662.1	623.7	751.0	717.1	732.6
March	571.6	528.1	633.2	625.7	627.4
April	353.3	322.4	360.8	421.9	406.2
May	171.8	143.0	150.3	230.7	212.5
June	49.4	31.8	37.8	84.8	72.5
July	8.9	3.1	7.2	18.9	17.1
August	17.8	7.6	20.0	30.5	29.3
September	102.5	70.7	115.4	136.8	137.2
October	282.6	233.1	304.6	316.0	322.9
November	445.5	399.7	494.1	478.1	493.8
December	647.4	600.8	763.4	709.1	738.6
Total	4065.8	3661.1	4520.9	4585.9	4643.1

Heating Degree Days for Selected Canadian Locations (Below 15°C) [Ref. 2]

	Location				
	Toronto Airport	Niagara Falls NPCSH	Ottawa Airport	Moncton Airport	Fredericton Airport
January	659.9	604.1	790.1	723.3	760.0
February	577.3	538.9	666.2	632.3	647.8
March	478.9	435.7	540.2	532.7	534.4
April	265.9	237.6	273.7	332.1	316.5
May	98.9	77.4	81.6	147.1	128.9
June	15.0	9.1	11.0	35.4	25.5
July	0.6	0.1	0.5	2.6	1.7
August	2.8	0.9	3.0	6.1	5.2
September	47.3	27.5	55.3	68.8	67.7
October	194.0	150.2	214.5	225.5	231.6
November	355.6	310.5	388.4	388.4	404.0

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Climatic Data

Reference Documentation

December	554.4	507.9	616.1	616.1	645.6
Total	3250.6	2899.9	3710.4	3710.4	3768.9

4.0 CALCULATION OF BOILER OVERSIZE FACTOR

The boiler oversize factor (BOF) determines by what value the Existing Boilers are oversized versus the Seasonal Load of the building. This factor is used to calculate the Estimated Heat Loss in the boiler Lead-Lag ETool as shown in Equation 1.

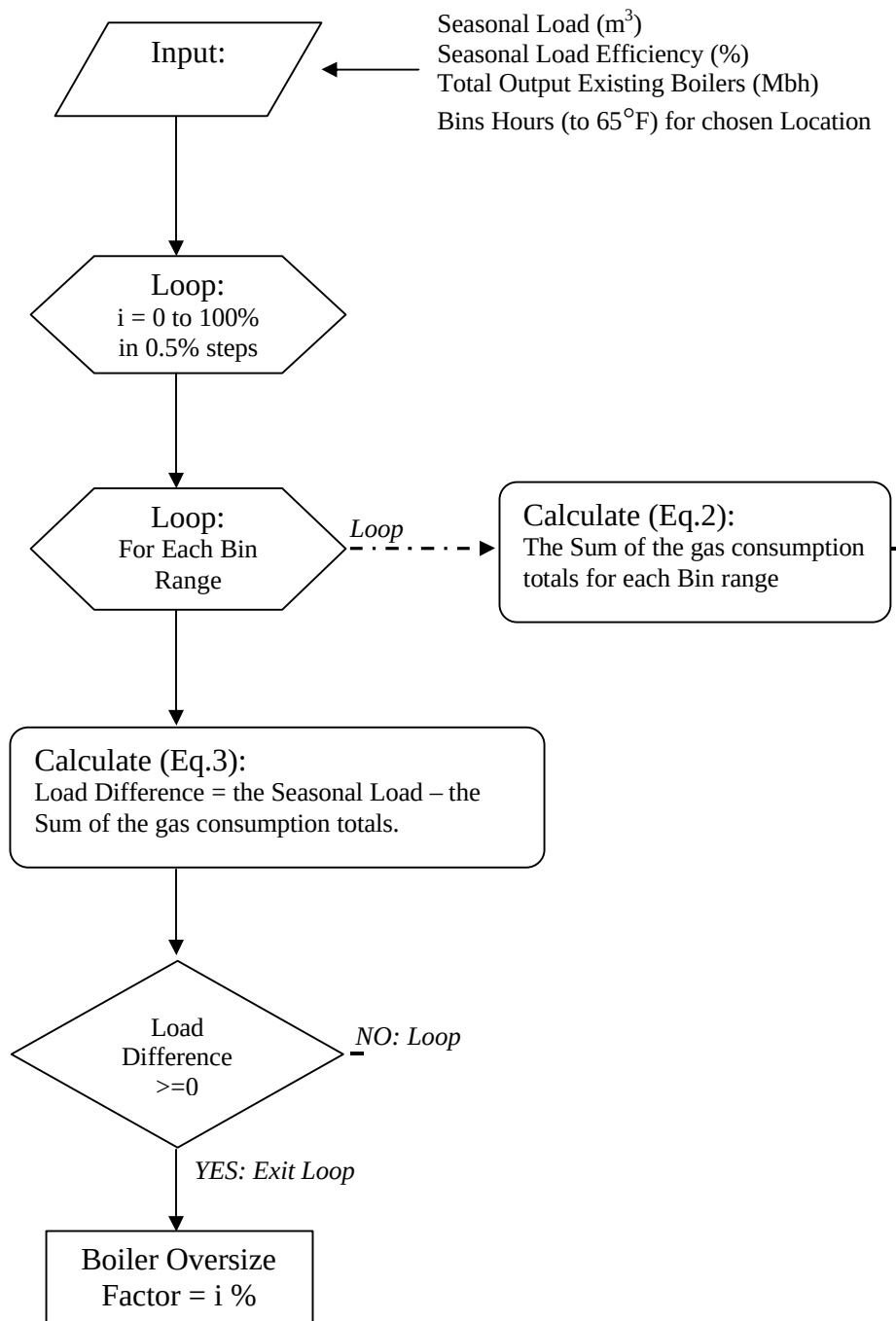
$$Est. Heat Loss = ExistBoilTotalOutput - (ExistBoilTotalOutput \times BOF) \quad (Eq.1)$$

where,

Est. Heat Loss	= Estimated Building Heat Loss (Mbh)
ExistBoilTotalOutput	= Total Output of the Existing Boilers (Mbh)
BOF	= Boiler Oversize Factor (%)

The BOF is determined from an algorithm dependent on the building Seasonal Load, the Seasonal Load Efficiency, the total output of the Existing Boilers, and Bin numbers for the site.

A flowchart of the BOF algorithm is shown.



Equations used in the algorithm include:

$$SumBinGas = \frac{1}{calorific\ NG / 1000} \times \frac{1}{Seasonal\ Eff} \times (ExistingOutput - (ExistingOutput \times i)) \times \%HeatLoss + SumBinGas \quad (Eq.2)$$

where,

SumBinGas	= sum of the gas consumption for each Bin range (m ³).
calorific NG	= calorific value of natural gas = 35,310 Btu/m ³ .
Seasonal Eff	= seasonal load efficiency of the existing boilers (%).
Existing Output	= total output of existing boilers (Mbh)
% Heat Loss	= % of Heat Loss from 100% @ Design to 0% @ 65°F
i	= Boiler Oversize Factor (%)

$$LoadDifference = Seasonal\ Load - SumBinGas$$

(Eq.3)

where,

LoadDifference	= difference calculated (m ³).
Seasonal Load	= seasonal load of the building (m ³).
SumBinGas	= as calculated in Eq.2 (m ³).

5.0 MEAN DAILY TEMPERATURES

The program contains the daily mean temperatures from January 1, 2000 to July 31, 2004 for Toronto, Niagara Falls, Ottawa, Moncton and Fredericton. These are used to calculate HDD for these locations. Because of the length of the tables of data, they are not included in this document.

6.0 REFERENCES

1. Environment Canada, Atmospheric Weather Service 1968-1992
2. Environment Canada, Meteorological Service of Canada – Canadian Climate Normals 1971-2000 www.climate.weatheroffice.ec.gc.ca/climate_normals/



REFERENCE DOCUMENTATION

DESTRATIFICATION SAVINGS CALCULATOR, V1.07

September 23, 2008



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1.0 INTRODUCTION

Destratification of large commercial heated spaces is generally done through the use of large diameter or other types of ceiling fans or air movement equipment. Heating utility energy savings are available due to more uniform temperature profiles along the building height and a reduction of ceiling temperatures.

This document provides referenced documentation for calculating space heating energy savings due to temperature destratification.

Calculations are done based on user inputs. A flow chart outlining the program methodology is included in the Appendices.

2.0 USER INPUTS

2.1 Customer Information

The customer information area is to provide reference for the particular project. This information is not used in the calculations.

2.2 Building Dimensions

Enter the building dimensions for:

- Length (ft)
- Width (ft)
- Height (ft)
- % of Destrat Coverage: This is the percentage of the building coverage that is being destratified. Monitoring of a warehouse facility indicated the destratification coverage was approximately 100' diameter per fan using 20' diameter fans at low speeds (20Hz). This would be considered the minimum coverage as larger fans or higher speeds would increase this area.

2.3 Heating System

2.3.1 Efficiency

Enter the efficiency of the heating system:

- Operational Efficiency [Default = 80%]: This would typically be the combustion efficiency of a unit heater.
- Seasonal Reduction [Default = 15%]: The seasonal reduction is the difference between combustion efficiency and seasonal efficiency.

2.3.2 Method of Heat Delivery

Enter the method of heat delivery from the available options:

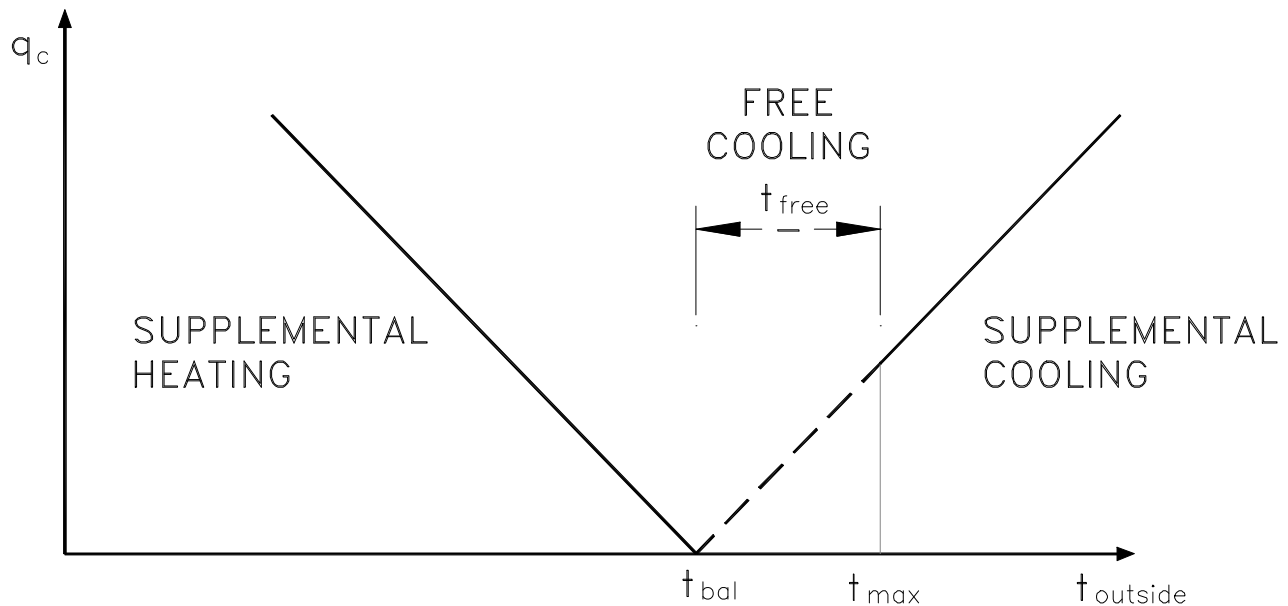
- Forced Air Unit
- Infrared
- Floor
- MUA/AHU

2.4 HVAC System

Enter the HVAC system parameters:

- Thermostat Setpoint (F): This is the setpoint of the local heating system or unit heater thermostat in degrees F.
- Thermostat Reduction [After Destrat] (F): This is the amount that the thermostat can be reduced as a result of having a destratified temperature profile.
- Outdoor Balance Temperature [Heating]: The Balance Temperature t_{bal} of a building is defined as that value of the outdoor temperature $t_{outside}$ at which, for the specified value of the interior temperature, the total heat loss is equal to the heat gain from sun, occupants, lights, etc. (Fundamentals 2005, 32.18). Fundamentals 2005, 32.18 also states that there is a period in which cooling can be supplied by opening windows or increasing ventilation and mechanical ventilation is only required when the outside temperature exceeds a threshold value t_{max} . This period can be supplied during the economizer mode (if available) on the ventilation system and is commonly referred to as 'free cooling' and shown as t_{free} . The figure below shows a schematic of the balance temperature as referenced from Fundamentals 2005, Fig.12, 32.19.

Figure 1: Balance Temperature Schematic



An extensive literature review produced little referenced documentation relating actual balance temperature to building type. HVAC Systems and Equipment 2004, 3.7 suggests that mechanical cooling is seldom required at outside temperatures below 55F. Fundamentals 2005, 32.19 suggest that the balance temperature varies widely between buildings and has been reduced with the introduction and use of energy savings appliances.

Balance temperatures have been estimated by the author with an available references shown for building types available in the calculator.

Table 1: Balance Temperature

Site Type	Balance Temperature (C)		Supplemental Cooling (C) [t _{free} = 2.8C]		Reference
	(C)	(F)	(C)	(F)	
Hospitals	12.8	55	15.6	60.1	ASHRAE S3.7 F32.18
Hotel	12.8	55	15.6	60.1	ASHRAE S3.7
Long Term Care	12.8	55	15.6	60.1	ASHRAE S3.7
Multi-Residential Nonprofit	15	59	17.8	64.0	Boiler Selection Tool
Multi-Residential Private	15	59	17.8	64.0	Boiler Selection Tool
Municipalities	12.8	55	15.6	60.1	ASHRAE S3.7
New Construction	12.8	55	15.6	60.1	ASHRAE S3.7
Office	14	55	16.8	62.2	Boiler Selection Tool
Other Sectors	12.8	57.2	15.6	60.1	ASHRAE S3.7
Retail	12.8	55	15.6	60.1	ASHRAE S3.7
Schools	12.8	55	15.6	60.1	ASHRAE S3.7
Universities	14	57.2	16.8	62.2	Boiler Selection Tool
Warehouse	12.8	55	15.6	60.1	ASHRAE S3.7

The Balance Temperature for the existing tool is currently a user input value.

2.5 Motor Specifications

The number of motors and horsepower of each motor on the air curtain is input. The total HP is calculated and shown. There is a wide range of motor sizes used depending on the size of the size of fan or air movement equipment. A typical large diameter fan has a motor size of either 1, 1.5, or 2 hp.

Other inputs of motor specifications include:

- Motor Loading (Default = 85%)
- Motor Efficiency (Default = 80%)

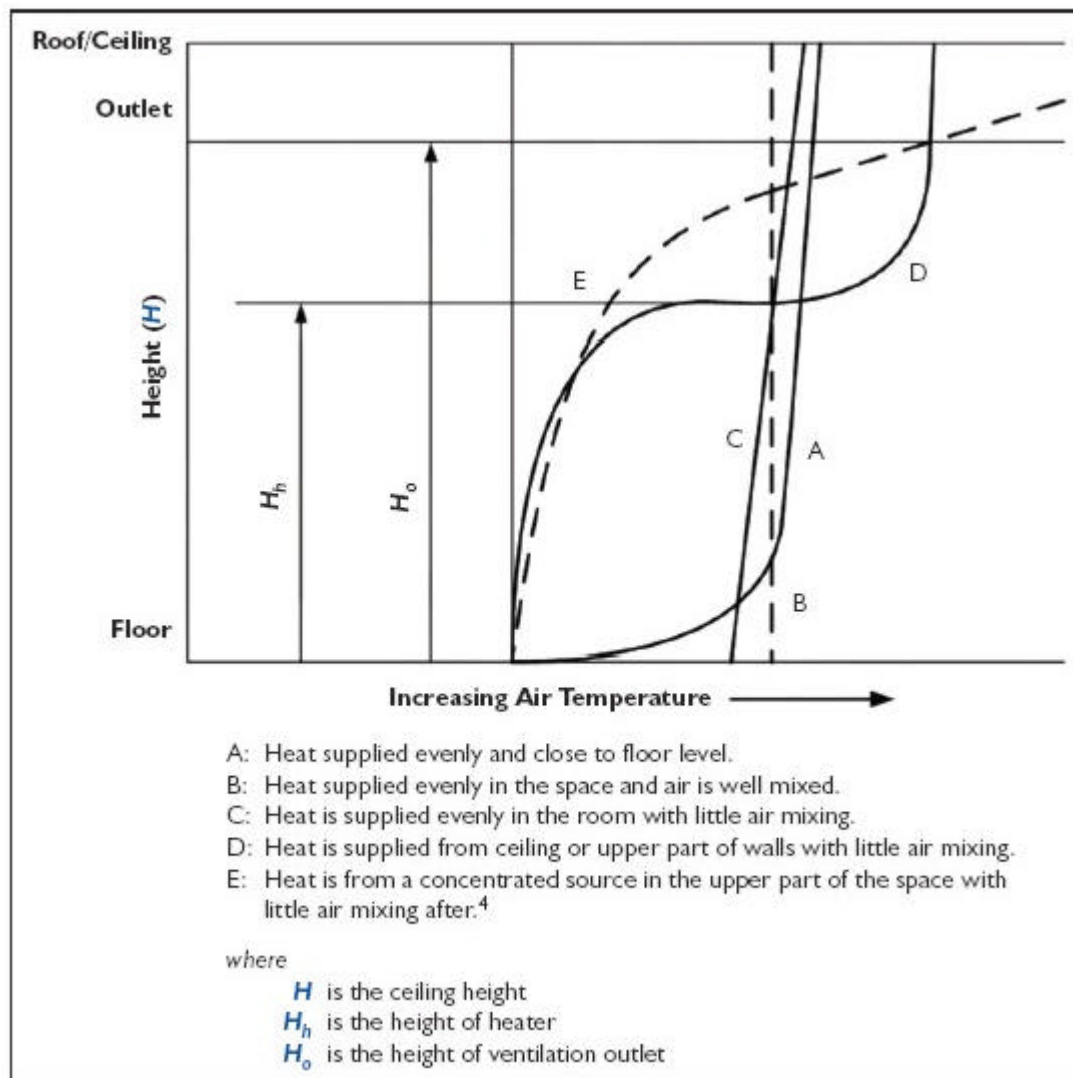
2.6 Temperature Profile

A table is supplied for input of the existing temperature profile of the heated space. Temperatures and heights of the locations are input for 5 different locations including:

- Ceiling
- Exhaust
- Heater
- Stat Level
- Floor

A chart is shown of the both the existing and destratified temperature profiles. A difference of 2°F from ceiling to stat level is used to define the destratified temperature profile. The temperature profile may vary depending on the method of heating or other factors. The figure below shows sample heating profiles and the respective methods of heating.

Figure 2: Sample Vertical Profiles Of Indoor Air Temperature Determined By Heat Supply Location (Andersen, 1998).



2.7 Shell Construction

The shell construction of the heated space is defined.

2.7.1 Construction Details

A separate form is included for defining the R-Value of the ceiling, three types of walls (defined as Type A, B, C) and the floor. If only one type of wall is used then a value of “0” or blank should be entered for two of the wall types.

A message is shown saying “Total Height does not match Building Height” if the sum of the wall heights does not match the building height entered above.

There is a limitation of having a maximum ceiling height of 100’.

2.7.2 Windows

The area (ft²) and R-Value of any windows in the ceiling or respective wall types is input into the table.

2.7.3 Doors

The area (ft²) and R-Value of any doors in the ceiling or respective wall types is input into the table.

2.8 Cold Weather Ventilation

Enter the ventilation rates for:

- Mechanical Ventilation (cfm): the air exchange provided by mechanical means such as exhaust fans or air handlers in cubic feet per minute.
- Passive Ventilation (ACH): the air exchange provided by natural means such as infiltration through open windows, doorways, or building leakage. A default value of 0.2 is used.

2.9 Utility Cost

Enter the utility cost for:

Natural Gas (\$/m³)

Electricity (\$/kWh)

3.0 ENERGY SAVINGS CALCULATIONS

All calculations are done in IP units. Any SI values input by the user are first converted to the required IP unit prior to calculation. The conversions are not shown.

3.1 Methodology – Energy Savings Due To Destratification

Stratification is occurrence of an increasing air temperature gradient between the floor and ceiling, usually due to uncirculated or stagnant air near the ceiling (Pignet and Saxena, 2002). Pignet and Saxena also state if stratification is present, the heating requirements of the facility are increased due to increased average wall and ceiling temperatures. If the air is destratified, the temperature at the ceiling level as well as the heat loss rates will be considerably reduced.

Richard Aynsley (Aynsley, 2005) presents three different methods of calculating energy savings due to destratification in warehouses. [*Note, methods have been named by this author.*]

1. **Simplified Ceiling Heat Loss Analysis:** This involves calculating the change in heat loss through the roof from a corresponding reduction of ceiling temperatures due to destratification versus average outdoor temperatures. The roof surface for large single-story buildings such as warehouses typically offers the largest surface for heat loss. This method does not account for ventilation heat losses or indoor heat gains.
2. **Total Building Energy Analysis:** This method as originally suggested by Pignet and Saxena 2002 involves the analysis of actual building energy consumption as well as an estimation of other internal heat loads such as lighting and occupants. The energy savings is a proportional reduction of energy consumption from a reduced average indoor temperature due to destratification versus an average outdoor air temperature.
3. **Building Energy With Temperature Profile Analysis:** Aynsley presents an enhancement to the Pignet and Saxena method above by suggesting the use of measuring vertical temperature profiles as suggested by Andersen, K.T. 1998. The vertical temperature profile is used to provide a more accurate analysis of the heat loss of walls and ceiling.

The Destratification Savings Calculator methodology involves the following:

- **Annual Heating Hours:** Typical outdoor weather data is used in determining the annual hours of operation of heating equipment. The annual usage also accounts for internal building loads.
- **Shell Construction:** The building area and R-Value shell construction is input by the user. This information is combined with the temperature profile analysis below.
- **Temperature Profile Analysis:** An existing temperature profile of the facility as input by the user is used to calculate the heat loss reduction versus a destratified temperature profile for the varying segments of the facility's shell construction.
- **Ventilation Savings:** Savings are calculated for both mechanical and passive ventilation airflows.
- **Motor Loading:** Energy requirements of the motor loads are also accounted for in the analysis.

The building energy is not used in this analysis for several reasons:

- a) It may be difficult to determine the building energy requirements for a building if there are additional building functions or structures other than just open warehousing (ie., offices or supporting facilities) included on the same utility meter.
- b) It may not be practical or necessary to destratify the entire warehouse or facility. This Calculator will allow analysis of only a portion of the building.
- c) Internal heating loads may be difficult if not impossible to accurately calculate for facilities with supporting structures or for only portions of the building as mentioned above.

3.2 Outside Environmental Data

The calculations use environmental time-series data from the ASHRAE WYEC2 (Weather Year for Energy Calculations 2) for the Toronto location. The WYEC2 file represents typical year hourly weather data based on environmental data from 1961-1990. These values include the outside hourly Dry-Bulb temperature (F).

3.3 Calculations

3.3.1 Annual Hours of Heater Operation

The annual hours of heater operation is calculated from:

Equation 1: Annual Hours of Heater Operation

$$AnnualHoursHtrOp = \sum_0^{8760} DryBulb_{WYEC2} \leq OutdoorBalanceTemp$$

where:

AnnualHoursHtrOp = the total annual hours of heater operation, hrs/yr

DryBulb_{WYEC2} = the annual hourly ASHRAE WYEC2 dry-bulb temperatures, °F

OutdoorBalanceTemp = the outdoor temperature when heating starts in the facility, °F

3.3.2 Temperature Profile

The height and respective existing temperature profile is input by the user.

The floor temperatures for the destratified profile is set equal to the existing floor temperature.

The destratified ceiling temperature is calculated as 2°F above the stat level temperature.

Aynsley, 2005 suggests a destratified floor to ceiling temperature difference of 1°F is possible.

The value of 2°F from stat level to ceiling will provide a conservative energy savings estimate.

The destratified temperatures for the remaining locations are averaged to provide a straight-line profile between the floor and ceiling.

3.3.3 Shell Construction

The shell construction area and R-Value is input for the ceiling and several wall types as outlined in the user inputs. Areas and R-Values for windows and doors are also input.

3.3.3.1 EQUIVALENT R-VALUE

The equivalent R-Value for the ceiling and respective wall types is calculated as:

Equation 2: Equivalent R-Value

$$R_{Eq} = A_T / \left(\frac{A_{Wall}}{R_{Wall}} + \frac{A_{Windows}}{R_{Windows}} + \frac{A_{Doors}}{R_{Doors}} \right)$$

[Ref: ASHRAE 2005, F23.4, eqn11]

where:

R_{Eq} = the equivalent R-Value of the shell segment, (hr-ft²-°F)/Btu

A_T = the total area of the shell segment, ft²

A_{Wall} = the total area of the wall segment not including areas of the windows or doors, ft²

$A_{Windows}$ = the total area of the windows in the respective shell segment, ft²

A_{Doors} = the total area of the doors in the respective shell segment, ft²

3.3.3.2 HEAT LOSS SAVINGS

3.3.3.2.1 Ceiling

The heat loss savings for the ceiling is calculated as:

Equation 3: Heat Loss Savings; Ceiling

$$q_{\text{Ceiling}} = \frac{A_{\text{Ceiling}}}{R_{\text{EqCeiling}}} \times (\text{Temp}_{\text{ExistingCeiling}} - \text{Temp}_{\text{Destrat}}) \times \% \text{Destrat}$$

[Ref: ASHRAE 2005, F30.23, eqn33]

where:

q_{Ceiling} = the heat loss savings of the ceiling, Btu/hr

A_{Ceiling} = the total area of the ceiling, ft²

$R_{\text{EqCeiling}}$ = the equivalent R-Value of the ceiling, (hr-ft²-°F)/Btu

$\text{Temp}_{\text{ExistingCeiling}}$ = the ceiling temperature of the existing profile, °F

$\text{Temp}_{\text{Destrat}}$ = the ceiling temperature of the destratified profile, °F

%Destrat = the % of Destrat Coverage

3.3.3.2.2 Walls

The heat loss savings for each of the selected wall types is calculated as:

Equation 4: Heat Loss Savings; Wall

$$q_{\text{Wall}} = \frac{A_{\text{Wall}}}{R_{\text{EqWall}}} \times (\text{Temp}_{\text{ExistingWall}} - \text{Temp}_{\text{Destrat}}) \times \% \text{Destrat}$$

[Ref: ASHRAE 2005, F30.23, eqn33]

where:

q_{Wall} = the heat loss savings of the wall, Btu/hr

A_{Wall} = the total area of the wall, ft²

R_{EqWall} = the equivalent R-Value of the wall, (hr-ft²-°F)/Btu

$\text{Temp}_{\text{ExistingWall}}$ = the average temperature of the existing profile, °F

$\text{Temp}_{\text{Destrat}}$ = the average temperature of the destratified profile, °F

%Destrat = the % of Destrat Coverage

3.3.4 Cold Weather Ventilation

3.3.4.1 MECHANICAL

The mechanical ventilation is input directly as a rate of airflow in cubic feet per minute (CFM).

3.3.4.2 PASSIVE

Passive ventilation is the air exchange provided by natural means such as infiltration through open windows, doorways, or building leakage and is input as air changes per hour (ACH). This is converted to an airflow rate in CFM as follows:

Equation 5: Passive Ventilation; Airflow Rate

$$CFM_{Pass} = ACH \times BldgVol / 60$$

where:

CFM_{Pass} = the passive ventilation airflow rate, CFM

ACH = the passive ventilation air changes per hour rate input by the user, ACH

BldgVol = the building volume being the product of the building dimensions (length, width and height), ft³

3.3.5 Motor Energy Use

The Shaft (or Brake) HP for the motor is calculated as:

Equation 6: Motor Shaft HP

$$\text{ShaftHP} = \# \text{Motors} \times \text{NameplateHP} \times \text{Motor Loading\%}$$

where:

#Motors = the number of motors

NameplateHP = the motor Nameplate HP (horsepower)

Motor Loading% = the % of motor loading [default 85%].

The electrical kW (kilowatt) demand for the motor is calculated from the Shaft HP.

Equation 7: Motor kW Demand

$$kW = \frac{\text{ShaftHP} \times 0.746}{\text{Motor Efficiency(\%)}}$$

[Ref: Ontario Hydro, 1990]

where:

ShaftHP = the calculated value for Shaft HP

Motor Efficiency (%) = the value input in the System Description.

The annual motor energy use is calculated from a combination of the annual hours of heating operation and the kW demand.

Equation 8: Motor Annual kWh Usage

$$kWh = \text{AnnualHoursHtrOp} \times kW$$

where:

kWh = the annual kilowatt-hour usage of the motors used for the destratification equipment

AnnualHoursHtrOp = the total annual hours of heater operation, hrs/yr

kW = the kW demand of the destratification equipment

4.0 ANNUAL SAVINGS

The annual savings are shown on an energy, utility, and dollar basis for the system shown.

4.1 Energy

4.1.1 Building Shell

The building shell annual energy savings is calculated below.

Equation 9: Annual Energy Savings: Building Shell

$$q_{\text{SaveShell}} = \left(\sum_{\text{Walls}}^{\text{Ceiling}} \text{HeatLossSavings} \right) \times \text{AnnualHoursHtrOp} / 1000$$

where:

$q_{\text{SaveShell}}$ = total annual energy savings of the building shell due to the destratification equipment, MBtu/yr

HeatLossSavings = the Heat Loss Savings of the walls and ceiling, Btu/hr

AnnualHoursHtrOp = the total annual hours of heater operation, hrs/yr

4.1.2 Mechanical Ventilation

The mechanical ventilation annual energy savings is calculated below.

Equation 10: Annual Energy Savings: Mechanical Ventilation

$$q_{\text{SaveMech}} = 1.08 \times \text{CFM}_{\text{Mech}} \times (\Delta T_{\text{Existing-Destrat Exhaust}}) \times \text{AnnHrsHtrOp} / 1000 \times \% \text{Destrat}$$

[Ref: ASHRAE 2005, F30.13, eqn10]

where:

q_{SaveMech} = total annual energy savings of the mechanical ventilation due to the destratification equipment, MBtu/yr

CFM_{Mech} = the mechanical ventilation airflow, CFM

$\Delta T_{\text{Existing-Destrat Exhaust}}$ = the temperature difference between the existing minus the destratified temperature profile at the exhaust, °F

AnnHrsHtrOp = the total annual hours of heater operation, hrs/yr

%Destrat = the % of Destrat Coverage

4.1.3 Passive Ventilation

The passive ventilation annual energy savings is calculated below.

Equation 11: Annual Energy Savings: Passive Ventilation

$$q_{\text{SaveMech}} = 1.08 \times \text{CFM}_{\text{Pass}} \times (\Delta T_{\text{Existing-Destrat Exhaust}}) \times \text{AnnHrsHtrOp} / 1000 \times \% \text{Destrat}$$

[Ref: ASHRAE 2005, F30.13, eqn10]

where:

q_{SaveMech} = total annual energy savings of the mechanical ventilation due to the destratification equipment, MBtu/yr

CFM_{Mech} = the mechanical ventilation airflow, CFM

$\Delta T_{\text{Existing-Destrat Average}}$ = the temperature difference between the existing minus the destratified temperature profile at the exhaust, °F

AnnualHoursHtrOp = the total annual hours of heater operation, hrs/yr

%Destrat = the % of Destrat Coverage

4.2 Utility Savings

4.2.1 [kWh/yr]

The kWh/yr utility savings is generated by the destratification electrical motor. The annual utility use is calculated above. This is shown as a negative value.

4.2.2 [m³/yr]

The natural gas savings is available from the energy savings of the building shell, as well as mechanical and passive ventilation if applicable. This utility savings is calculated as:

Equation 12: [m³/yr] Utility Savings

$$M3_{\text{AnnSave}} = \frac{q_{\text{save}}}{35,300 \times \text{NetSeaEff}} \times 1,000$$

where:

$M3_{\text{AnnSave}}$ = total annual natural gas savings for the destratification equipment, m³/yr

q_{save} = total annual energy savings of the destratification equipment, MBtu/yr

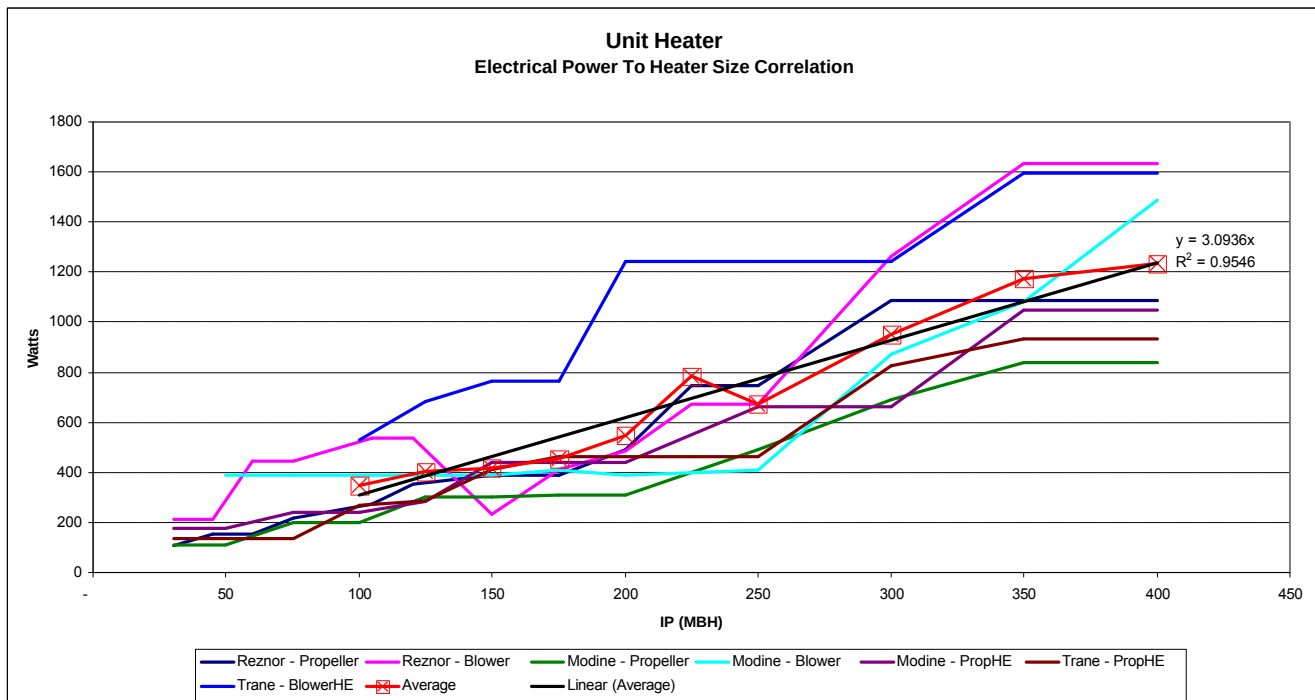
NetSeaEff = the Net Seasonal Efficiency of the heating system, %. Calculated as the Operational minus the Seasonal Reduction Efficiency.

4.3 Auxiliary Electrical Savings

The auxiliary savings represents electrical savings through the reduced use of auxiliary heating equipment. This includes items such as blower motors on unit heaters. ASHRAE, 2008 S9.13-9.15 terms this value as the Auxiliary Energy Ratio (electrical energy input per fuel energy input) and provides benchmark values for residential blowers on non-condensing and condensing furnaces of 0.028 and 0.034 respectively. These values are referenced from Phillips, 1998 which found that average blower motor power consumption has risen from 13 W/kW (0.013) of rated furnace output for furnaces installed in the 1960s to 28 W/kW (0.028) for furnaces installed between 1990 and 1994. Neither documents provide values for commercial/industrial unit heaters.

The specifications for commercial/industrial unit heaters from several commonly used unit heater manufacturers were analyzed and an equation was developed to correlate electrical power to unit heater input size. A figure and equation of this correlation is shown below.

Figure 3: Unit Heater Electrical Power



Equation 13: [kWh/yr] Auxiliary Savings

$$AuxkWh_{AnnSave} = 3.0936 \times \frac{q_{save}}{1,000}$$

where:

$AuxkWh_{AnnSave}$ = total annual electrical savings for the auxiliary heating equipment, kWh/yr

3.0936 = correlation of electrical power (Watts) to fuel energy input (MBH)

1,000 = conversion from Watts to kW

q_{save} = total annual energy savings of the destratification equipment, MBtu/yr

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Converting the equation to compare on a similar unit basis (ie., Watt electrical input per Watt fuel energy input) provides an Auxiliary Energy Ratio value of 0.011. It is reasonable to assume this type of heater will have a lesser value versus residential furnaces due to the fact that residential furnaces are designed to move heated air through duct work and thus require larger and more powerful blowers.

4.4 Dollar Savings

The dollar savings for the mechanical systems is a product of the utility use and the utility cost for the respective system.

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FLOW CHART

Destratification Input & Calculations: Flowchart

**PART A)
CUSTOMER INFO.**

Customer Info.

**PART B)
BUILDING INFORMATION**

Building Dimensions
- L, W, H

Efficiency
- Operational
- Seasonal

Forced Air	
Infrared	
Floor	
MUA/AHU	

Heating System
(Net Seasonal
Efficiency)

Method of Heat
Delivery

HVAC System
- Thermostat Setpt
- Outdoor Balance Temp

HVAC System
(Annual Hours of
Heater Op.
(hrs/yr)

WYEC2 Weather	
Year 2 Hourly	
Annual Data	

Motor Specs
- #, HP
- Loading
- Efficiency

Motor Specs
(Total HP)

Temperature
Profile

Destratification
Temperature

Show Temperature
Profile Chart

Shell
Construction
Details

Windows/Doors
- Area
- R-Value

Equivalent
R-Value

Heat Loss
Savings

Cold Weather
Ventilation

Utility Cost

**PART C:
ANNUAL SAVINGS**

Calculate Annual
Savings
- Building Shell
- Ventilation
- Motor

Motor Energy Use
Energy Savings
Utility Savings
\$ Savings

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INFRARED SAVINGS, V1.07

August 01, 2008



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Appendices

Flow Chart

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1.0 INTRODUCTION

The Infrared Savings Tool is used to evaluate energy savings for low and high intensity infrared heating systems versus non-infrared heating. The calculates are done to determine the non-infrared system annual gas use, the infrared annual gas use, the savings for the infrared system, the incentive amount, and the payback of the infrared system.

2.0 PROGRAM METHOD

The user must enter facility and heating system information into the program. Calculations are done based the user inputs. A flow chart outlining the program methodology is included in the Appendices.

All calculations are done using Imperial equations.

2.1 Facility Type

The facility type; New or Retrofit, is just used to change visual labels in the program as shown in Table 1.

Table 1: Facitily Type Adjustment

Label	New Facility	Retrofit Facility
System Efficiency	Forced Air Efficiency	Old System Efficiency
Installed System Cost	Installed I.R. Premium Cost	Installed Retrofit System Cost

2.2 Location

The selected facility location determines the BIN numbers to be used in the calculations. BIN numbers are shown in the Appendices. Due to the lack of BIN numbers for the Niagara region, a percentage value of 90.04% for the annual energy requirement is used versus the Toronto values since this is the difference in 18C heating degree hour values.

2.3 Design Heat Loss (Btu/h)

The user enters the rate of Design Heat Loss of the facility.

$$q' = \text{Design Heat Loss (Btu / h)}$$

2.4 Forced Air / Old System Efficiency (%)

The users enters the combustion efficiency of the forced air or existing system that will be used to compare to the infrared system.

$$Eff_{FA} = \text{Combustion Efficiency of Forced Air System}$$

2.5 Outside Temperature When Heating Starts (F)

Many buildings have internal sources of heat that maintain building temperatures during moderate cold outdoor temperatures. The calculations only use BIN values below the temperature when the heating system is required.

2.6 Heat Application

Space heating assumes heat is required 24 hrs per day during the heating season. Spot heating uses a proportion of the total annual energy requirement depending on the amount of time out of 24 hours used.

$$TOU = \frac{HrsPerDay}{24}$$

where,

TOU = Time of Use

HrsPerDay = 24 (space heating); user input (spot heating)

2.7 Infrared Design Heat Loss

The Infrared Design Heat Loss is 85% of a standard heat loss calculation ^[Ref1].

$$q'_{IR} = q' \times 0.85$$

where,

q'_{IR} = the Infrared Design Heat Loss (Btu/h)

This becomes the new combustion output requirement for the infrared system.

2.8 Intensity – Energy Savings Option

The selected Intensity – Energy Savings Option determines the value of the Energy Savings Option (ESO) as shown in Table 2.

Table 2: ESO Values

Intensity – Energy Savings Option	ESO Value (%)
None	0
Low – 2 Stage	10 ^[Ref2]
Low – Condensing	10 ^[Ref3]
High – Energy Efficient	10 ^[Ref.4]

Note that High Intensity – Energy Efficient heaters to have 65% or higher infrared efficiency.

2.9 Infrared ESO Heat Loss

The ESO value further reduces the infrared design combustion output requirement.

$$q'_{ESO} = q'_{IR} \times (1 - ESO_{Val})$$

where,

q'_{ESO} = the Design Heat Loss for the Infrared System including ESO Value (Btu/h)

ESO_{Val} = the ESO value (%)

This becomes the new combustion output requirement for the infrared system with an ESO and is shown as the Net Required IR System Output (Btu/h).

2.10 Total System Output (Btu/hr)

The sum of the individual infrared heating systems combustion outputs.

2.11 I.R. Reduction (Btu/h)

The reduction of combustion output for an infrared heating system is calculated as:

$$q'_{REDUCT} = q' - q'_{ESO}$$

2.12 Annual Energy Requirement

The annual energy calculation for both the Infrared and Non-IR systems involves use of BIN numbers^[Ref.5] for the respective facility locations. The calculation involves several steps.

2.12.1 Unit BIN Range: Rate of Heat Loss

$$q'_{UBIN} = \frac{\text{HeatSystemOutput}}{\# \text{BIN Ranges}}$$

where,

q'_{UBIN}	= the unit rate of heat loss per BIN temperature range (Btu/h)
HeatSystemOutput	= the required rate of output of the heating system (Btu/h)
	= q' for forced air or existing heating systems.
	= q'_{REDUCT} for infrared heating systems.
$\# \text{BIN Ranges}$	= the number of BIN temperature ranges (in 5°F increments) between “Outside Temperature When Heating Starts” and the minimum BIN temperature (unitless).

2.12.2 BIN Range: Rate of Heat Loss

$$q'_{BIN} = q'_{UBIN} \times \text{BINrangePosition}$$

where,

q'_{BIN}	= the rate of heat loss per BIN temperature range (Btu/h)
q'_{UBIN}	= the unit rate of heat loss per BIN temperature range (Btu/h)
BINrangePosition	= the number of incremental BIN ranges starting with #1 at “Outside Temperature When Heating Starts” (unitless)

2.12.3 BIN Range: Heat Loss

The rate of heat loss for each BIN temperature range is multiplied by the respective number of hours for that range. This provides the total annual heat loss of each BIN temperature range.

$$q_{BIN} = q'_{BIN} \times \text{BIN Hours}$$

where,

q_{BIN}	= Heat Loss for a given BIN temperature range (Btu)
q'_{BIN}	= Rate of Heat Loss for a given BIN temperature range (Btu/hr)
BIN Hours	= The number of hours in the BIN range (hr)

2.12.4 Total Annual Energy Requirement

A sum of the heat loss for each BIN range is calculated. This provides the total annual energy requirement.

$$q_{ANNUAL} = \sum_{LowTemp}^{StartTemp} q_{BIN}$$

where,

$$q_{ANNUAL} = \text{Annual Energy Requirement (Btu)}$$

2.13 Total Annual Gas Use

The total annual energy savings is converted to an annual volume of natural gas for each system.

$$NG_{TotalAnn} = \frac{q_{ANNUAL}}{NG_{cal} \times Eff}$$

where,

$$NG_{TotalAnn} = \text{Total annual volume of natural gas use (m}^3\text{)}$$

$$q_{ANNUAL} = \text{Total annual energy requirement for either the infrared or the non-ir (Btu)}$$

$$NG_{cal} = \text{Calorific value of natural gas (35,300 Btu/m}^3\text{)}$$

$$Eff = \text{Heat system combustion efficiency for either the infrared or the non-ir system (\%)}$$

The annual gas use calculation for the infrared and non-ir systems use q_{ANNUAL} and Eff values for the respective system.

The Annual Gas Savings for the Infrared system is the annual gas use for the non-ir system minus the annual gas use for the infrared system.

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Infrared Savings

Reference Documentation

2.14 Annual Dollar Savings for IR System

The Average Gas Cost is multiplied by the Total Annual Gas Use of the infrared system.

2.15 Calculated Incentive

The calculated incentive is the Incentive Rate multiplied by the Annual Gas Savings for the Infrared system.

2.16 Payback

Payback is calculated as the Installed New or Retrofit System Cost divided by the Annual Dollar Savings for the IR System.

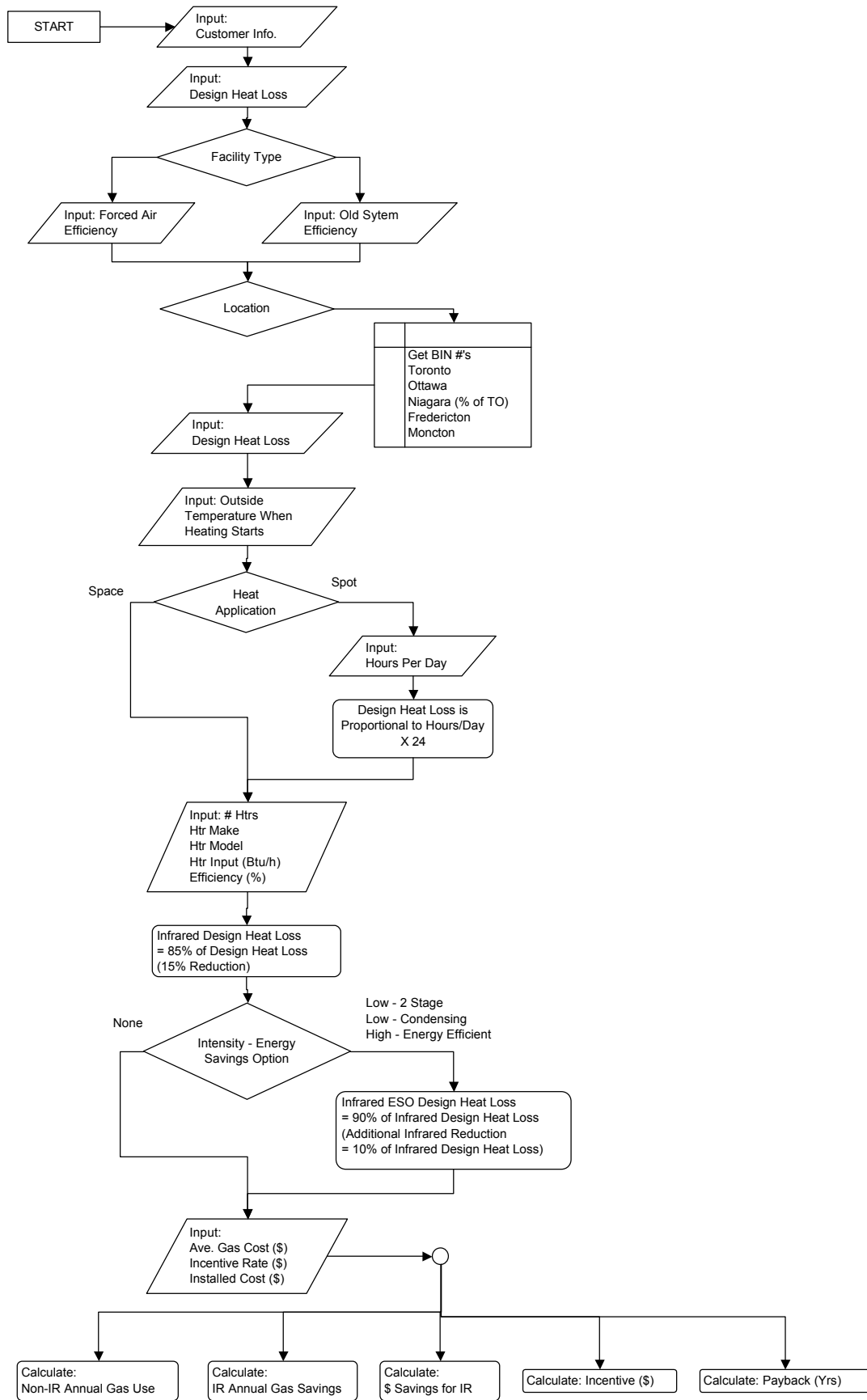
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INFRARED SAVINGS TOOL



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E-TOOL PROGRAMS

REFERENCE DOCUMENTATION

PIPE / SURFACE INSULATION, V1.07

August 01, 2008



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1.0 INTRODUCTION

The Pipe & Surface Insulation Savings Tool estimates a potential savings of insulating or re-insulating in a new or retrofit heating system. The program calculates the heat loss that would occur with new insulation and with existing or no insulation applied. These heat loss values are converted into a gas loss which are compared to estimate the potential savings and payback

2.0 PROGRAM METHOD

The program is based on finding the difference in heat loss from a pipe/surface with new insulation to that with no/existing insulation. The difference in heat loss can be transformed into a natural gas volume and related cost savings.

All calculations are done using Imperial equations. If ‘Metric’ is selected, all SI values are converted into IP units before being used in the equations and the result converted back to IP units.

2.1 Pipe Heat Loss Calculation

Heat loss (Btu/h) for a pipe is calculated by the following equations [Ref. 1]:

Uninsulated Pipe (Eq.1)

$$q' = L \times \frac{T_s - T_\infty}{\frac{\ln\left(\frac{r_2}{r_1}\right)}{2pk_{pipe}} + \frac{1}{2pr_2\overline{h_c}}}$$

Insulated Pipe (Eq.2)

$$q' = L \times \frac{T_s - T_\infty}{\frac{\ln\left(\frac{r_2}{r_1}\right)}{2pk_{pipe}} + \frac{\ln\left(\frac{r_3}{r_2}\right)}{2pk_{insul}} + \frac{1}{2pr_3\overline{h_c}}}$$

where, q' = Rate of Heat Loss (btu/h)
 L = length of pipe (ft)
 T_s = inside pipe temperature (°F)
 T_∞ = room or ambient temperature (°F)
 r_1 = inside pipe radius (ft)
 r_2 = outside pipe radius (ft)
 r_3 = outside insulation radius (ft)
 k_{pipe} = thermal conductivity of pipe (Btu.in/hr.ft².°F)
 k_{insul} = thermal conductivity of insulation (Btu.in/hr.ft².°F)
 $\overline{h_c}$ = convective heat transfer coefficient (Btu/hr.ft².°F)

2.1.1 Pipe Radius

The pipe radius for both inside (r_1) and outside (r_2) are derived from the nominal diameter entered. Table 1 shows inside and outside diameters in IP units for each size and type of piping used. The outside insulation radius (r_3) is calculated by adding the thickness of insulation to r_2 .

Table 1: Dimensional Data for Size and Type of Piping (IP units)

Nominal Dia. (in)	Inside Dia. (in)	Outside Dia. (in)	Nominal Dia. (in)	Inside Dia. (in)	Outside Dia. (in)
Schedule 40 Steel Pipe [Ref. 2]			Type L Copper Tubing [Ref. 3]		
0.75	0.824	1.05	0.25	0.315	0.375
1	1.049	1.315	0.375	0.43	0.5
1.25	1.38	1.66	0.5	0.545	0.625
1.5	1.61	1.9	0.625	0.666	0.75
2	2.067	2.375	0.75	0.785	0.875
2.5	2.469	2.875	1	1.025	1.125
3	3.068	3.5	1.25	1.265	1.375
3.5	3.548	4	1.5	1.505	1.625
4	4.026	4.5	2	1.985	2.125
5	5.047	5.563	2.5	2.465	2.625
6	6.065	6.625	3	2.945	3.125
8	8.071	8.625	3.5	3.425	3.625
10	10.192	10.75	4	3.905	4.125
12	12.09	12.75	5	4.875	5.125
14	13.25	14	6	5.845	6.125
16	15.25	16	8	7.725	8.125
18	17.25	18	10	9.625	10.125
20	19.25	20	12	11.565	12.125
22	21.25	22			
24	23.25	24			
26	25.25	26			
30	29.25	30			
34	33.25	34			
36	35.25	36			
42	41.25	42			
160 PSI PVC Pipe [Ref. 5]			SDR 15 Flex. Polyethylene Pipe [Ref.4]		
1.5	1.754	1.9	0.5	0.622	0.742
2	2.193	2.375	0.75	0.824	0.944
2.5	2.655	2.875	1	1.049	1.169
3	3.23	3.5	1.25	1.38	1.564
4	4.154	4.5	1.5	1.61	1.824
6	6.115	6.625	2	2.067	2.353
			2.5	2.469	2.799

2.1.2 Pipe Fittings

Heat loss for pipe fittings are calculated by the same equations (1) & (2). However, an *equivalent* length of pipe for heat loss is used instead of the actual length of pipe (L) in order to account for increased heat loss due to pipe fittings. Table 2 indicates the equivalent area (from ASHRAE Handbook) and calculated equivalent length of pipe for a specific nominal pipe diameter in IP units.

The following sample calculation demonstrates how equivalent length of pipe is calculated for a 6in Flanged Coupling.

$$\begin{aligned} \text{Cross Sect. Area of a 6" nom. dia. Pipe} &= p \times \text{nom. diameter} \\ &= p \times 6" \\ &= 18.85 \text{ in}^2 \text{ or } 1.571 \text{ ft}^2 \end{aligned}$$

$$\text{Equiv. Length of Pipe (ft)} = \frac{\text{Equiv. Area}}{\text{Area of Pipe}} = \frac{1.820 \text{ ft}^2}{1.571 \text{ ft}^2} = 1.159$$

Table 2: Heat Loss Equivalent Length of Pipe for Fittings (IP units) [Ref. 6]

Nominal Pipe Dia. (in)	Flanged Couplings		90 Degree Elbows		Long Radius Elbows		Tees		Crosses	
	Equiv. Area (ft ²)	Equiv. ft of Pipe	Equiv. Area (ft ²)	Equiv. ft of Pipe	Equiv. Area (ft ²)	Equiv. ft of Pipe	Equiv. Area (ft ²)	Equiv. ft of Pipe	Equiv. Area (ft ²)	Equiv. ft of Pipe
1	0.320	1.222	0.795	3.037	0.892	3.407	1.235	4.717	1.622	6.196
1.25	0.383	1.170	0.957	2.924	1.084	3.312	1.481	4.526	1.943	5.937
1.5	0.477	1.215	1.174	2.990	1.337	3.405	1.815	4.622	2.380	6.061
2	0.672	1.283	1.650	3.151	1.840	3.514	2.540	4.851	3.320	6.341
2.5	0.841	1.285	2.090	3.193	2.320	3.545	3.210	4.905	4.190	6.402
3	0.945	1.203	2.380	3.030	2.680	3.412	3.660	4.660	4.770	6.073
3.5	1.122	1.224	2.980	3.252	3.280	3.580	4.480	4.889	5.830	6.363
4	1.344	1.283	3.530	3.371	3.960	3.782	5.410	5.166	7.030	6.713
4.5	1.474	1.251	3.950	3.353	4.430	3.760	6.070	5.152	7.870	6.680
5	1.622	1.239	4.440	3.392	5.000	3.820	6.810	5.202	8.820	6.738
6	1.820	1.159	5.130	3.266	5.990	3.813	7.840	4.991	10.080	6.417
8	2.410	1.151	6.980	3.333	8.560	4.087	10.550	5.037	13.440	6.417
10	3.430	1.310	10.180	3.888	12.350	4.717	15.410	5.886	19.580	7.479
12	4.410	1.404	13.080	4.163	16.350	5.204	19.670	6.261	24.870	7.916

2.2 Flat Surface Heat Loss Calculation

Heat loss (Btuh) for a flat surface is calculated by the following equations [Ref 1]:

Uninsulated Flat Surface (Eq.3)

$$q' = A \times \frac{T_1 - T_2}{\frac{L_1}{k_{Surface}} + \frac{1}{h_c}}$$

Insulated Flat Surface (Eq.4)

$$q' = A \times \frac{T_1 - T_2}{\frac{L_1}{k_{Surface}} + \frac{L_2}{k_{Insul}} + \frac{1}{h_c}}$$

where, q' = Rate of Heat Loss (btu/h)
 A = area of flat surface (ft²)
 T_1 = warm side temperature (°F)
 T_2 = cold side temperature (°F)
 L_1 = thickness of surface (ft)
 L_2 = thickness of insulation (ft)
 $k_{surface}$ = thermal conductivity of flat surface (Btu.in/hr.ft².°F)
 k_{insul} = thermal conductivity of insulation (Btu.in/hr.ft².°F)
 $\overline{h_c}$ = convective heat transfer coefficient (Btu/hr.ft².°F)

2.3 Ambient Temperature from BIN Numbers

For piping/flat surfaces that are located outside, BIN numbers are used to determine the ambient temperature. BIN numbers represent the total number of hours per year that occur within specified temperature ranges. Table 3 shows the BIN numbers for each location. No BIN numbers were available for Niagara Falls. These have been estimated as 0.903 times Toronto numbers, based on the relationship between the HDD for the two cities.

Table 3: BIN Numbers (IP units) [Ref. 7]

Temperature Range (°F)	Hours			
	Toronto	Ottawa	Moncton	Fredericton
-30 to -25				1
-25 to -20		7	1	4
-20 to -15		16	7	12
-15 to -10		38	27	32
-10 to -5	1	88	68	82
-5 to 0	6	161	123	135
0 to 5	67	207	191	190
6 to 10	138	252	256	256
11 to 15	274	322	315	333
16 to 20	366	382	407	386
21 to 25	463	441	504	478
26 to 30	707	487	712	640
31 to 35	789	766	904	840
36 to 40	741	706	718	707
41 to 45	629	594	658	644
46 to 50	624	613	683	657
51 to 55	724	626	736	716
56 to 60	749	728	781	761
61 to 65	669	732	685	697
66 to 70	618	661	472	512
71 to 75	606	476	311	360
76 to 80	352	287	147	191
81 to 85	168	138	50	94
86 to 90	57	48	10	30
91 to 95	12	12		4
96 to 100		3		

2.4 Thermal Conductivity (k-value)

2.4.1 Pipe Material

The program uses the following thermal conductivity (k-values) for the pipe material selected:

Steel.....27 Btu.in/hr.ft².°F

Copper.....227 Btu.in/hr.ft².°F

Polyethylene.....20 Btu.in/hr.ft².°F

PVC.....20 Btu.in/hr.ft².°F

2.4.2 Insulation

The k-values are temperature dependent and based on equations derived from ASTM material specifications. The equations are shown in Table 4. For an existing insulation, the program increases the k-value by the condition of the insulation (excellent, good, fair, or poor).

Table 4: Thermal Conductivity Equations [Ref. 8]

Insulation Material	ASTM No.	Equation for Thermal Conductivity (k-value)	Maximum Temp. (°F)
Fiberglass Pipe Wrap	N/A	0.25	N/A
850F Mineral Fiber Pipe	C547-95	$0.208 + 2.94 \times 10^{-4} T_s + 1.143 \times 10^{-6} T_s^2$	850
1200F Mineral Fiber Pipe	C547-95	$0.2143 + 3.179 \times 10^{-4} T_s + 6.786 \times 10^{-6} T_s^2$	1200
1800F Mineral Fiber Board	C612-93	$0.193 + 7.17 \times 10^{-4} T_s + 2.6196 \times 10^{-7} T_s^2$	1800
1200F Mineral Fiber Board	C612-93	$0.2114 + 3.184 \times 10^{-4} T_s + 6.855 \times 10^{-7} T_s^2$	1200
850F Mineral Fiber Board	C612-93	$0.215 + 4.293 \times 10^{-4} T_s + 1.065 \times 10^{-6} T_s^2$	850
450F Mineral Fiber Board	C612-93	$0.214 + 5.565 \times 10^{-4} T_s + 8.734 \times 10^{-7} T_s^2$	450
Elastomeric Tube & Sheet	C534-94	$0.280 + 1.556 \times 10^{-4} T_s + 1.482 \times 10^{-6} T_s^2$	200
Polystyrene 1.6 PCF	C578-92	$0.174 + 2.779 \times 10^{-4} T_s + 1.1234 \times 10^{-6} T_s^2$	165
Calcium Silicate Pipe & Block	C533-95	$0.355 + 4.586 \times 10^{-4} T_s + 7.142 \times 10^{-8} T_s^2$	1200
Cellular Glass Block	C552-91	$0.302 + 5.24 \times 10^{-4} T_s + 8.692 \times 10^{-7} T_s^2$	800
Perlite Pipe & Block	C610-95	$0.452 + 4.246 \times 10^{-4} T_s + 2.679 \times 10^{-7} T_s^2$	1200
Insulating & Finishing Cement	C449-95	$1.413 + 1.203 \times 10^{-3} T_s + 1.825 \times 10^{-6} T_s^2$	1200

2.5 Convective Heat Transfer Coefficient

The convective heat transfer coefficient is calculated by the equation,

$$\overline{h_c} = 0.3 \times \text{Wind Speed (mph)} + 1.63 \quad (\text{Eq.5})$$

2.6 Heat Loss Conversion to Gas Use

To convert heat loss into an amount of natural gas used per year, the following equation is used,

$$\text{Gas Use (m}^3 \text{ / yr)} = \frac{\text{Heat Loss (Btu / h)}}{\text{calorific value of natural gas} \times \text{SystemEfficiency}} \times \text{Annual hrs of Use (h / yr)} \quad (\text{Eq.6})$$

where,

calorific value of natural gas = 35,310 Btu/m³

SystemEfficiency = the boiler system efficiency as entered by the user

2.7 Economic Summary

The program's Economic Summary is calculated by the following equations. The Economic Summary is shown in SI units since gas is sold by the m³.

Total Estimate Annual Gas Savings

The following equation is used for each pipe and flat surface that is entered. The *total* estimate annual gas savings is the addition of savings from all pipes and flat surfaces.

$$\text{Est. Annual Gas Savings (m}^3\text{)} = \text{Existing / NonInsulated Gas Use} - \text{New Insulated Gas Use} \quad (\text{Eq.7})$$

Total Estimate Annual Savings

$$\text{Total Est. Annual Savings} = \text{Total Est. Annual Gas Savings (m}^3\text{)} \times \text{Average Gas Cost / m}^3 \quad (\text{Eq.8})$$

Total Estimated Incentive

$$\text{Total Est. Incentive} = \text{Total Est. Annual Gas Savings (m}^3\text{)} \times \text{Incentive Rate / m}^3 \quad (\text{Eq.9})$$

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Total Capital Cost Estimate

The following equation is used for each pipe length and flat surface area that is entered, except when a “Lump Sum Capital Cost” is entered in the Site & System Input section of the program. The *total* capital cost estimate is the addition of capital costs from all pipes and flat surfaces.

$$\text{Capital Cost Est.} = \left(\frac{\text{Material Cost} + \text{Labour Cost}}{\text{Unit Length or Unit Area}} \right) \times \text{Unit Length or Unit Area} \quad (\text{Eq.10})$$

Payback Period without Incentive

$$\text{Payback Period without Incentive} = \frac{\text{Total Insulating Cost}}{\text{Total Est. Annual Savings}} \quad (\text{Eq.11})$$

Payback Period with Incentive

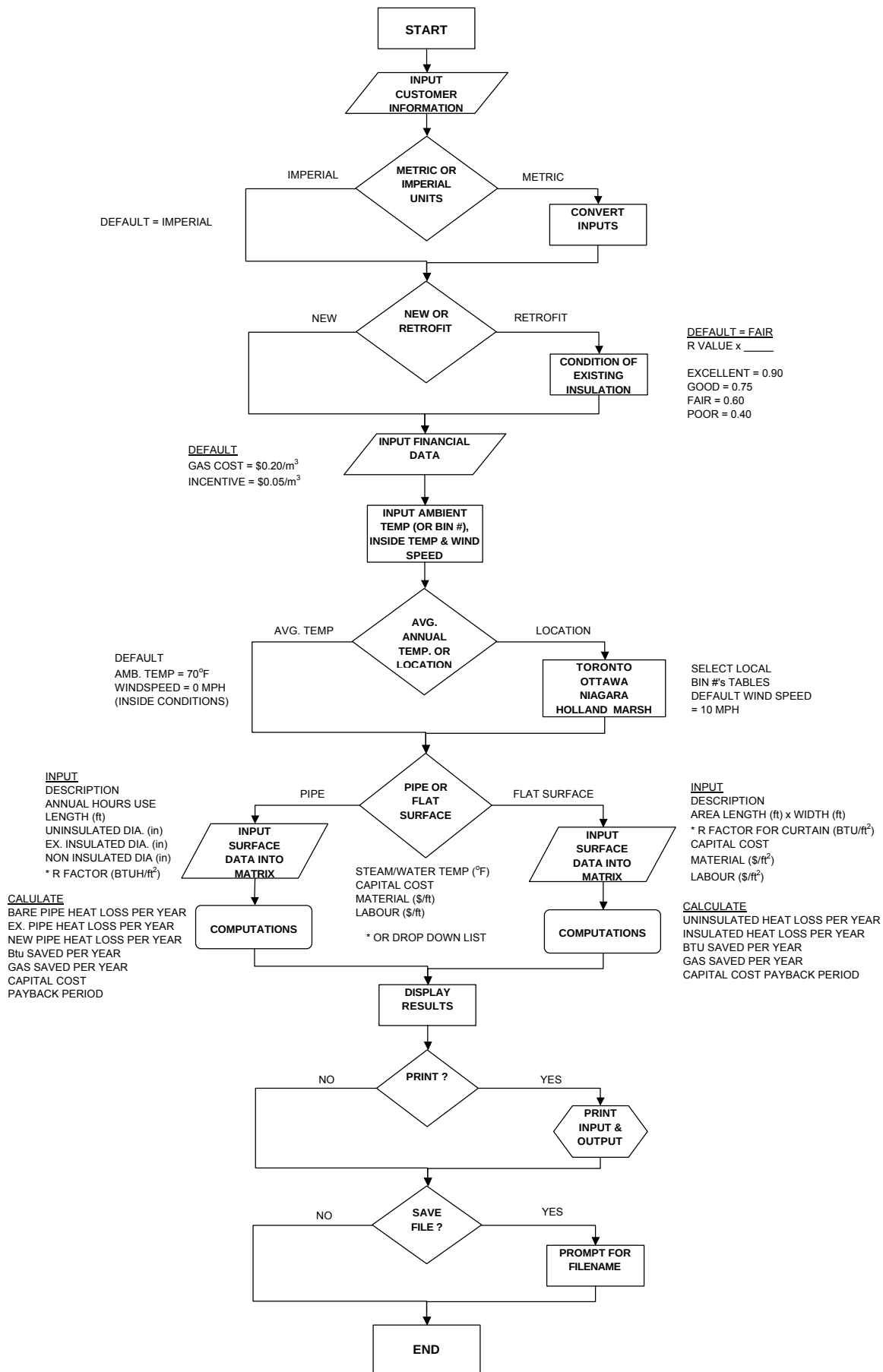
$$\text{Payback Period with Incentive} = \frac{\text{Total Insulating Cost} - \text{Total Est. Incentive}}{\text{Total Est. Annual Savings}} \quad (\text{Eq.12})$$

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REFERENCE DOCUMENTATION

AIR CURTAIN SAVINGS, V1.07

September 23, 2008



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1.0 INTRODUCTION

Air curtains are used in commercial applications to provide energy savings through the reduction of heated or conditioned air loss from open doorways. Additional benefits also include the reduction of dust or insect entry through open doors as well as allowing fast, smooth traffic flow.

This document provides referenced documentation for calculating energy savings from reduced airflow through an air curtain versus an open doorway.

Several manufacturers of air curtains were contacted to discuss energy savings analysis being used in the industry. These include:

- Bill Powlesland P.Eng., IAQ, Daltec
- Michael Launer, President, Enershield
- Berner International
- Kingman Industries

Calculations are done based the user inputs. A flow chart outlining the program methodology is included in the Appendices. Estimated annual savings assumes air curtain equipment is installed and operated within manufacturers' recommendations. Certain limitations may exist due to building pressure differentials or other application issues.

2.0 USER INPUTS

2.1 Utility

2.1.1 Cost

Enter the utility cost for:

Natural Gas (m3)

Electricity (\$/kWh)

2.1.2 Heating/Cooling

Checkboxes are available to indicate whether the air curtain will be used with:

- Heating system
- Cooling system.
- Heating Humidification: If humidification is used during heating then the latent heat is used in the calculation of total heat.

2.2 Air Curtain Operation

2.2.1 % Of Coverage

The % of Coverage indicates the amount of door coverage by a truck or other obstacles. This is indicated by the selections:

- Wide Open [0% Coverage]. This is the case for a door completely open to flow-thru traffic.
- Partially Covered [40% Coverage]. This includes doors that may be partially covered by multiple sized trailers or other obstacles.
- Full Coverage [90% Coverage]. This includes doors that are typically entirely covered by trailers or other items and are relatively well sealed with bumper pads, etc..

2.2.2 Season of Operation

Checkboxes are available to indicate the season of operation in which the air curtain will be used:

Spring [March, April, May]
 Summer [June, July, August]
 Fall [September, October, November]
 December [December, January, February]

2.2.3 Schedule of Operation

The time of use for the air curtain is input for three separate periods:

Morning [12:00AM to 8:00AM]
 Day [8:00AM to 6:00PM]
 Evening [6:00PM to 12:00AM]

These time periods are adjustable. There are also inputs to define the Minutes Per Opening of the door during the respective time period as well as the Openings Per Hour.

2.2.4 Door Specifications

2.2.4.1 SIZE

The length(ft) and height(ft) of the door that the air curtain is being used is input. The area is calculated and is shown.

2.2.4.2 LOCATION

The user selects the location of the door as:

- Interior: the door is located between interior zones of different temperatures of a building (ie., a walk-in cooler)
- Exterior: the door is located on an exterior location separating the interior conditions from the outside environment.

2.2.4.3 FACING DIRECTION

The user selects the facing direction of the door as North, South, East, or West.

2.2.4.4 MOTOR SPECIFICATIONS

The number of motors and horsepower of each motor on the air curtain is input. The total HP is calculated and shown. There is a wide range of motor sizes used depending on the size of the door. For example, Enershield manufacturers air curtains that have motor sizes from ½ HP up to 25 HP.

Other inputs of motor specifications include:

- Motor Loading (Default = 85%)
- Motor Efficiency (Default = 80%)

The defaults for motor loading and motor efficiency are referenced from the Enbridge Report: Reference Documentation / VFD Airflow Default Parameters, 31-Jan-2007.

2.2.4.5 CURTAIN EFFECTIVENESS

A value for the air curtain effectiveness is input. ASHRAE 2004, S17.9 suggests values of air curtain effectiveness at preventing infiltration through an entrance generally range from 60 to 80%.

A default of 70% is used.

2.2.4.6 OUTDOOR BALANCE TEMPERATURE

The Balance Temperature t_{bal} of a building is defined as that value of the outdoor temperature $t_{outside}$ at which, for the specified value of the interior temperature, the total heat loss is equal to the heat gain from sun, occupants, lights, etc. (Fundamentals 2005, 32.18).

HVAC Systems and Equipment 2004, 3.7 states for all systems using a primary-air system for outside air, there is an outside temperature (balance temperature) at which secondary cooling is no longer required.

An input value is available for both the Heating and Cooling Outdoor Balance Point temperatures.

2.2.5 HVAC System

2.2.5.1 SETPOINT

HVAC setpoints are input for:

- Heating Dry-Bulb Temperature (C)
- Cooling Dry-Bulb Temperature (C)
- Humidity (%)

2.2.5.2 INTERIOR (OPPOSITE DOOR)

Setpoints for the environmental conditions on the opposite side of the interior door (ie., inside a cold storage) are input for:

- Temperature (C)
- Humidity (%)

The savings when using an interior door are calculated for the HVAC space only. It is not calculated for the space opposite the HVAC space (ie., cold storage).

2.2.6 Equipment Efficiency

Inputs for heating and cooling system efficiency are available:

- Heating (Default = 80%)
- Cooling (Default = 3.0 COP)

3.0 HEATING/COOLING LOAD CALCULATIONS

All calculations are done in IP units. Any SI values input by the user are first converted to the required IP unit prior to calculation. The conversions are not shown.

3.1 Methodology -Energy Transfer Through Doorways

ASHRAE 2004, S17.9 states that the effectiveness of an air curtain is the comparison of infiltration rate or heat flux through an opening when using an air curtain versus the transmission that would take place through a simple opening with no restriction. There are several methods of calculating air transfer through openings such as doorways in commercial buildings.

Air Density Difference

This is the primary method of calculation that ASHRAE (2006, R13.4) uses for calculating the energy transfer of infiltration air. It is based on the air exchange resulting from a difference in air density between the zones as developed by Gosney and Olama (1975).

Lawton and Howell (1995) showed the theoretical energy savings using air curtains installed in high-traffic doorways using this method.

Nitin Magoo (2003) used this same method for calculating energy transfer through open dock doors.

Flow Caused By Wind

Air curtain manufacturers tend to use the ASHRAE 2005, F27.10 eqn 29 for calculating the energy savings for exterior doors. This method calculates the airflow rate through a door based on a specified wind speed. This can be a relatively site specific method of calculation as the direction of wind, effectiveness of wind shelter, proximity to other buildings, etc. have a large effect on the calculation.

Stack Effect (Thermal Forces)

Stack effect is caused by thermal stratification in a building and can cause low pressure at the base of the building. This low pressure results in outdoor air being sucked in through openings at the base of the building and exhausted out the top of the building. The calculations for the flow caused by thermal forces is both building construction and height specific and therefore difficult to determine without on-site monitoring.

Mechanical Pressure

Some buildings have a mechanical ventilation system that cause the building to operate under a positive or negative pressure versus the exterior or within zones of the building itself. This pressure difference results in airflow through exterior or zone openings and is generally specific to the site and difficult to determine without on-site monitoring.

Both Enershield and IAQ air curtain manufacturers suggest they install equipment with consideration for pressure differential and thermal forces. For example, the air curtain blowers will be installed with

a slight tilt in order to counteract these forces as well as multi-speed or VFD may be used to adjust airspeed to counteract pressure differences.

Using solely the Air Density Difference method of calculating the energy transfer through doorways is considered conservative. It is realistic to consider the Air Density Difference as the minimum energy transfer while the using the gross Flow Caused By Wind method is the maximum. The actual is somewhere in-between depending on the site specifications. It is not uncommon for manufacturers to use the Air Density Difference for interior doorways and the Flow Caused By Wind for exterior doorways.

These calculations use the Air Density Difference for interior doorways and the maximum of either Air Density Difference or 80% of the Flow Caused By Wind for exterior doorways. Using 80% of the Flow Caused by Wind provides a conservative estimate for exterior doorways and helps to account for sheltered areas.

3.1.1 Current Limitations

3.1.1.1 ENERGY TRANSFER THROUGH DOORWAYS

There is a lack of published research for exterior located air curtains. Current research generally uses computer analysis or other means to estimate the effectiveness of the air curtain rather than actual monitoring of energy transfer through the doorway. The research has also primarily been focused on interior doorways of cold storage or refrigerated areas and the Air Density Difference of calculation. Manufacturers contacted are very interested in participating in any research projects that would involve developing a more realistic model for calculating energy savings that accounts for the various methods of air exchange through an exterior doorway.

3.2 Outside Environmental Data

The calculations use environmental time-series data from the ASHRAE WYEC2 (Weather Year for Energy Calculations 2) for the Toronto location. The WYEC2 file represents typical year hourly weather data based on environmental data from 1961-1990.

These values include the outside hourly Dry-Bulb temperature (F), coincident Relative Humidity (%), wind direction (0 to 359 degrees), and the wind speed (mph).

The hourly enthalpy (Btu/lbda) and air density (lb/ft³da) were calculated using the PsycExcel software add-in for Excel© by Raiza Engineering Software. Both were corrected for an altitude of 578 ft (Toronto). The enthalpy and density values were checked using ASHRAE 2005, F6.0.

3.3 Interior Design Conditions

The indoor enthalpy and density are calculated from an algorithm developed from the publication: "Procedure for determining heating and cooling loads for computerizing energy calculations, Algorithms for Building Heat Transfer Subroutines, ASHRAE, 1976 as referenced.

3.4 Calculation – Air Density Difference

Energy transfer through doorways from air exchange due to air density differences is developed from:

Equation 1: Total Annual Energy Load

$$q_t = q_{inf} D_t D_f$$

[Ref: ASHRAE 2006, R13.4, eqn11]*See Note

where:

q_t = total annual sensible and latent infiltration load due to air density difference, Btu

q_{inf} = sensible and latent infiltration hourly load due to air density difference, Btu/h

D_t = doorway open-time factor, hrs/yr

D_f = doorway flow factor, %

* Note the effectiveness of air curtain [1-E] was removed from the equation since the calculation is intended to show the airflow through an open door without an air curtain. The savings are shown as the difference between a wide open door and a doorway with an air curtain rather than the total load through an air curtain as is the intent of the ASHRAE equation. The effectiveness factor accounted for in the savings section.

3.4.1 Hourly Energy Transfer

The hourly energy transferred is determined from the following equation:

Equation 2: Total Hourly Energy Load

$$q_{inf} = 795 .6 A (h_o - h_i) r_i \left(1 - \frac{r_o}{r_i}\right)^{0.5} (gH)^{0.5} F_m$$

[Ref: ASHRAE 2006, R13.4, eqn12]

where:

q_{inf} = sensible and latent infiltration hourly load due to air density difference, Btu/h

A = doorway area, ft²

h_i = enthalpy of interior air, Btu/lbda

h_o = enthalpy of exterior air, Btu/lbda

ρ_i = density of interior air, lb/ft³

ρ_o = density of exterior air, lb/ft³

g = gravitational constant, 32.174 ft/s²

H = doorway height, ft

F_m = density factor (shown below)

3.4.1.1 DENSITY FACTOR

The Density Factor is determined from the equation below having the variables as described above.

Equation 3: Density Factor

$$F_m = \left[\frac{2}{1 + \left(\frac{r_i}{r_o} \right)^{1/3}} \right]^{1.5}$$

[Ref: ASHRAE 2006, R13.4, eqn13]

3.4.2 Doorway Open-Time Factor

3.4.2.1 SEASON OF OPERATION

The airflow through the door caused by wind is only considered in the calculations for the WYEC2 hours of the year for the selected season of air curtain operation. This is done by use of an algorithm comparing the month of the year with the selected seasons. The selected season determines the calendar month as discussed in the inputs.

3.4.2.2 SCHEDULE OF OPERATION

The user input schedule further limits the airflow values that are used by only selecting the hours that the air curtain is operational.

3.4.2.3 PERCENTAGE OF TIME OPEN

The percentage of time that the door is open for each hour is determined in the Schedule of Operation by the Minutes Per Opening and the Openings Per Hour in the following formula.

Equation 4: Percentage of Time Open

$$\%TimeOpen = 100 \times \text{Minimum of} \left(\frac{MinutesPerOpening \times OpeningsPerHour}{60} \right) \text{ or } 1$$

3.4.2.4 DOORWAY OPEN-TIME FACTOR

The doorway open-time factor is a sum of the combination of both the seasonal and scheduled operation along with the percentage of time open during the respective hourly periods over the entire year.

Equation 5: Doorway Open-Time Factor

$$D_t = \sum_0^{8760} \text{Hours}_{\text{Season\&Schedule}} \times \% \text{TimeOpen}$$

3.4.3 Doorway Flow Factor

The doorway flow factor is the ratio of actual air exchange to fully established flow (ASHRAE, 2006, R13.5). This factor is based on the dry-bulb temperature difference across the doorway whereas:

$$\begin{aligned} D_f &= 1.1, \text{deltaT} < 20\text{F} \\ D_f &= 0.8, \text{deltaT} \geq 20\text{F} \end{aligned}$$

3.4.4 Door Location

3.4.4.1 INTERIOR DOOR

An interior door location uses design data including temperature, relative humidity, enthalpy and density of the HVAC System Setpoint versus the Interior (Opposite Door) conditions.

3.4.4.2 EXTERIOR DOOR

An exterior door locations uses design data including temperature, relative humidity, enthalpy and density of the HVAC System Setpoint versus outdoor annual hourly WYEC2 conditions.

3.4.5 Sensible Heat Ratio – Heating Humidification

The Sensible Heat Ratio (ASHRAE 2004, S46.2) or Sensible Heat Factor (Kahoe, 1993) is the ratio of sensible heat to total heat. This equates to:

Equation 6: Sensible Heat Ratio

$$SHR = 0.24 \left(\frac{t_o - t_i}{h_o - h_i} \right)$$

[Ref: ASHRAE 2004, S46.2]

where:

SHR = sensible heat ratio

0.24 = specific heat of air, Btu/lbda/F

t_o = outdoor dry-bulb temperature, F

t_i = indoor dry-bulb temperature, F

h_o = outdoor enthalpy, Btu/lbda

h_i = indoor enthalpy, Btu/lbda

The SHR is used to determine the energy transfer for a heating load if Heating Humidification is not used. The total heat energy transfer is multiplied by the SHR to get the total sensible heating load as follows:

Equation 7: Sensible Heat Load

$$q_s = q_t \times SHR$$

where:

q_t = total annual sensible and latent infiltration load due to air density difference, Btu

q_s = total annual sensible infiltration load due to air density difference, Btu

SHR = sensible heat ratio

3.5 Calculation - Flow Caused By Wind

The Flow Caused By Wind is determined using the following equation:

Equation 8: Flow Caused By Wind

$$Q_{Hour} = 0.88 \times C_v \times A \times U \times \%TimeOpen$$

[Ref: ASHRAE 2005, F27.10, eqn29]

where:

Q_{Hour} = airflow rate per hour, cfm/hr

C_v = effectiveness of opening (see below)

A = area of opening, ft² (input by the user)

U = wind speed, mph (from the WYEC2 data)

%TimeOpen = the percentage of time the door is open (see above)

3.5.1 Effectiveness of Opening

The effectiveness of opening is assumed to be 0.5 to 0.6 for perpendicular winds and 0.25 and 0.35 for diagonal winds (ASHRAE 2005, F27.10). Values of 0.5 and 0.25 respectively are used in the calculations as conservative values.

An equation was developed to determine the effectiveness of opening value based on the direction of door opening (as input by the user) and the annual hourly wind direction from the WYEC2 data. This equation is based on the table below.

Table 1: Effectiveness Value versus Door Direction

Wind Direction	Degrees	Effectiveness Value			
		North Facing	East Facing	South Facing	West Facing
North	0	0.5	0.25	0	0.25
[Proportion effectiveness vs degrees]					
East	90	0.25	0.5	0.25	0
[Proportion effectiveness vs degrees]					
South	180	0	0.25	0.5	0.25
[Proportion effectiveness vs degrees]					
West	270	0.25	0	0.25	0.5
[Proportion effectiveness vs degrees]					

The effectiveness value along with the other inputs provide an airflow value for each typical hour of the year.

3.5.2 % Cover

The % of Coverage indicates the amount of door coverage by a truck or other obstacles. This is selected by the user as:

- Wide Open [0% Coverage]. This is the case for a door completely open to flow-thru traffic.
- Partially Covered [40% Coverage]. This includes doors that may be partially covered by multiple sized trailers or other obstacles.
- Full Coverage [90% Coverage]. This includes doors that are typically entirely covered by trailers or other items and are relatively well sealed with bumper pads, etc..

3.5.3 Heating Load

3.5.3.1 SENSIBLE HEATING

The Sensible Heating Load is then calculated as a change in sensible heat as:

Equation 9: Wind – Sensible Heat Load

$$q_{SHwind} = \sum_{1}^{8760} (1.08 \times Q_{Hour} \times (Heating\ Setpt - Outside\ DryBulb))$$

[Ref: ASHRAE 2005, F30.13, eqn10]

where:

q_{SHwind} = annual sensible heat load (Btu)

1.08 = energy required to raise temperature of 1 cu.ft. of air 1 °F (in BTU/hr-cfm-°F)

Q_{Hour} = airflow rate per hour, cfm/hr

Heating Setpt = the heating setpoint as input by the user (°F)

Outside DryBulb = the outside dry bulb temperature from the WYEC2 data (°F)

Several conditions are placed on the hourly summation of the annual sensible heat load including:

- Out DryBulb must be less than the balance temperature, t_{bal} (see Balance Temperature below).
- Season of Operation must be selected.

3.5.3.2 LATENT HEATING LOAD

If Heating Humidification is used then the Latent Heating Load is also calculated as:

Equation 10: Wind – Latent Heat Load

$$q_{LHwind} = \sum_{1}^{8760} (4840 \times Q_{Hour} \times (W_{HVAC} - W_{Outside}))$$

[Ref: ASHRAE 2005, F30.13, eqn11]

where:

q_{LHwind} = annual latent heat load (Btu)

4840 = conversion factor

Q_{Hour} = airflow rate per hour, cfm/hr

W_{HVAC} = the humidity ratio of the HVAC heating setpoint

$W_{Outside}$ = the humidity ratio of the outside conditions

The same conditions as the Sensible Heat Load above must be satisfied for the hourly summation of the latent heating load.

3.5.3.3 TOTAL HEATING LOAD

The total heating load $\{q_{THwind}\}$ is the algebraic sum of the sensible and latent heat load. An additional condition has been placed on the total heating load according to the Balance Temperature of the building.

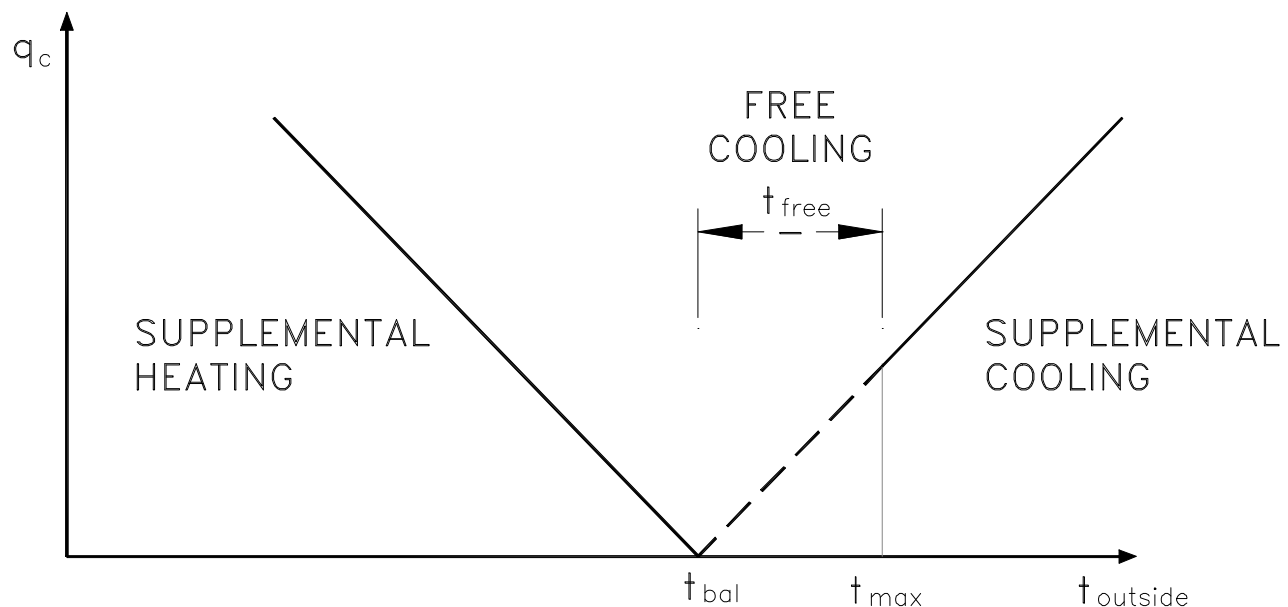
3.5.3.3.1 Balance Temperature

The Balance Temperature t_{bal} of a building is defined as that value of the outdoor temperature $t_{outside}$ at which, for the specified value of the interior temperature, the total heat loss is equal to the heat gain from sun, occupants, lights, etc. (Fundamentals 2005, 32.18).

HVAC Systems and Equipment 2004, 3.7 states for all systems using a primary-air system for outside air, there is an outside temperature (balance temperature) at which secondary cooling is no longer required.

Fundamentals 2005, 32.18 also states that there is a period in which cooling can be supplied by opening windows or increasing ventilation and mechanical ventilation is only required when the outside temperature exceeds a threshold value t_{max} . This period can be supplied during the economizer mode (if available) on the ventilation system and is commonly referred to as 'free cooling' and shown as t_{free} . The figure below shows a schematic of the balance temperature as referenced from Fundamentals 2005, Fig.12, 32.19.

Figure 1: Balance Temperature Schematic



An extensive literature review produced little referenced documentation relating actual balance temperature to building type. HVAC Systems and Equipment 2004, 3.7 suggests that mechanical cooling is seldom required at outside temperatures below 55F. Fundamentals 2005, 32.19 suggest that the balance temperature varies widely between buildings and has been reduced with the introduction and use of energy savings appliances.

Balance temperatures have been estimated by the author with an available references shown for building types available in the calculator.

Table 2: Balance Temperature

Site Type	Balance Temperature (C)		Supplemental Cooling (C) [t _{free} = 2.8C]		Reference
	(C)	(F)	(C)	(F)	
Hospitals	12.8	55	15.6	60.1	ASHRAE S3.7 F32.18
Hotel	12.8	55	15.6	60.1	ASHRAE S3.7
Long Term Care	12.8	55	15.6	60.1	ASHRAE S3.7
Multi-Residential Nonprofit	15	59	17.8	64.0	Boiler Selection Tool
Multi-Residential Private	15	59	17.8	64.0	Boiler Selection Tool
Municipalities	12.8	55	15.6	60.1	ASHRAE S3.7
New Construction	12.8	55	15.6	60.1	ASHRAE S3.7
Office	14	55	16.8	62.2	Boiler Selection Tool
Other Sectors	12.8	57.2	15.6	60.1	ASHRAE S3.7
Retail	12.8	55	15.6	60.1	ASHRAE S3.7
Schools	12.8	55	15.6	60.1	ASHRAE S3.7
Universities	14	57.2	16.8	62.2	Boiler Selection Tool
Warehouse	12.8	55	15.6	60.1	ASHRAE S3.7

The Balance Temperature for the existing tool is currently a user input value.

3.5.4 Cooling Load

The Cooling Load is calculated from the change in enthalpy as:

Equation 11: Wind – Total Cooling Load

$$q_{TCwind} = \sum_{1}^{8760 \text{ Condition}} (4.5 \times Q_{Hour} \times (Enthalpy_{Out} - Enthalpy_{InsideCool}))$$

[Ref: ASHRAE 2005, F30.13, eqn8]

where:

q_{TCwind} = annual total cooling load (Btu)

4.5 = air total heat factor (Btu/hr-cfm per Btu/lb enthalpy)

Q_{Hour} = airflow rate per hour, cfm/hr

$Enthalpy_{Out}$ = the outdoor enthalpy as calculated from the WYEC2 data (Btu/lb_{da})

$Enthalpy_{InCool}$ = the indoor enthalpy calculated from the Cooling Setpoint (F) and the Humidity (%). The indoor enthalpy is calculated from an algorithm developed from the publication: "Procedure for determining heating and cooling loads for computerizing energy calculations, Algorithms for Building Heat Transfer Subroutines, ASHRAE, 1976 as referenced.

Several conditions are placed on the hourly summation of the annual sensible heat load including:

- Out DryBulb must be greater than the balance temperature, $t_{bal} + \text{free cooling, } t_{free}$ (see Balance Temperature above).
- Season of Operation must be selected.

4.0 MOTOR ENERGY USE

The Shaft (or Brake) HP for the motor is calculated as:

Equation 12: Motor Shaft HP

$$ShaftHP = \# Motors \times NameplateHP \times Motor Loading\%$$

where:

#Motors = the number of motors

NameplateHP = the motor Nameplate HP (horsepower)

Motor Loading% = the % of motor loading [default 85%].

The electrical kW (kilowatt) demand for the motor is calculated from the Shaft HP.

Equation 13: Motor kW Demand

$$kW = \frac{ShaftHP \times 0.746}{Motor Efficiency(\%)}$$

[Ref: Ontario Hydro, 1990]

where:

ShaftHP = the calculated value for Shaft HP

Motor Efficiency (%) = the value input in the System Description.

The annual motor energy use is calculated from a combination of the time of operation and the kW demand. The time of operation is determined similar to the air curtain seasonal and scheduled operation.

Equation 14: Motor Annual kWh Usage

$$kWh = \sum_{0}^{8760} Hours_{Season\&Schedule} \times kW$$

where:

kWh = the annual kilowatt-hour usage of the motors used for the air curtain

kW = the kW demand of the air curtain motors above

5.0 ANNUAL SAVINGS

The annual savings is shown on an energy, utility, and dollar basis for the mechanical system shown.

5.1 Energy Savings

The air curtain energy savings are calculated for the heating and cooling mechanical systems as:

Equation 15: Air Curtain Energy Savings

$$q_{save} = \frac{q_t \times E \times (1 - \%Cover)}{1,000} \times Factor_{Location}$$

[Ref: ASHRAE 2004, S17.9, eqn2]

where:

- q_t = total annual sensible and latent infiltration load (see below), [Btu]
- q_{save} = total annual savings of the heating or cooling load due to the air curtain, (MBtu)
- E = the effectiveness of the air curtain (see below)
- $\%Cover$ = the selected percentage of door coverage
- $Factor_{Location}$ = the Heating or Cooling Location adjustment factor

5.1.1 Total Annual Load

The total annual load is dependent on the location of the doorway as described in the Methodology and as shown below:

- Interior Doorway: $q_t = q_{inf}$
- Exterior Doorway: $q_t = \text{maximum of } q_{inf} \text{ or } q_{wind}$

5.1.2 Effectiveness of Air Curtain

The effectiveness of air curtains range from very poor to more than 0.7 (ASHRAE 2006, R13.6). ASHRAE 2004, S17.9 suggests values of air curtain effectiveness at preventing infiltration through an entrance generally range from 60 to 80%.

A default value of 70% is used for E .

5.2 Utility Savings

5.2.1 Cooling

The cooling utility savings is calculated as:

Equation 16: Cooling Utility Savings

$$\text{CoolingKWHsave} = \frac{q_{\text{save}}}{3,413 \times \text{COP}} \times 1,000$$

where:

CoolingKWHsave = total annual electrical savings for the cooling system, kWh

q_{save} = total annual energy savings of the heating or cooling load due to the air curtain,
MBtu/yr

3,414 = the conversion of kWh to Btu

COP = the coefficient of performance of the cooling system

5.2.2 Heating

The heating utility savings is calculated as:

Equation 17: Heating Utility Savings

$$\text{HeatingM3save} = \frac{q_{\text{save}}}{35,300 \times \text{HtgSysEff}} \times 1,000$$

where:

HeatingM3save = total annual natural gas savings for the heating system, m³

q_{save} = total annual energy savings of the heating or cooling load due to the air curtain,
MBtu/yr

HtgSysEff = the heating system combustion efficiency, %

5.2.3 Motor

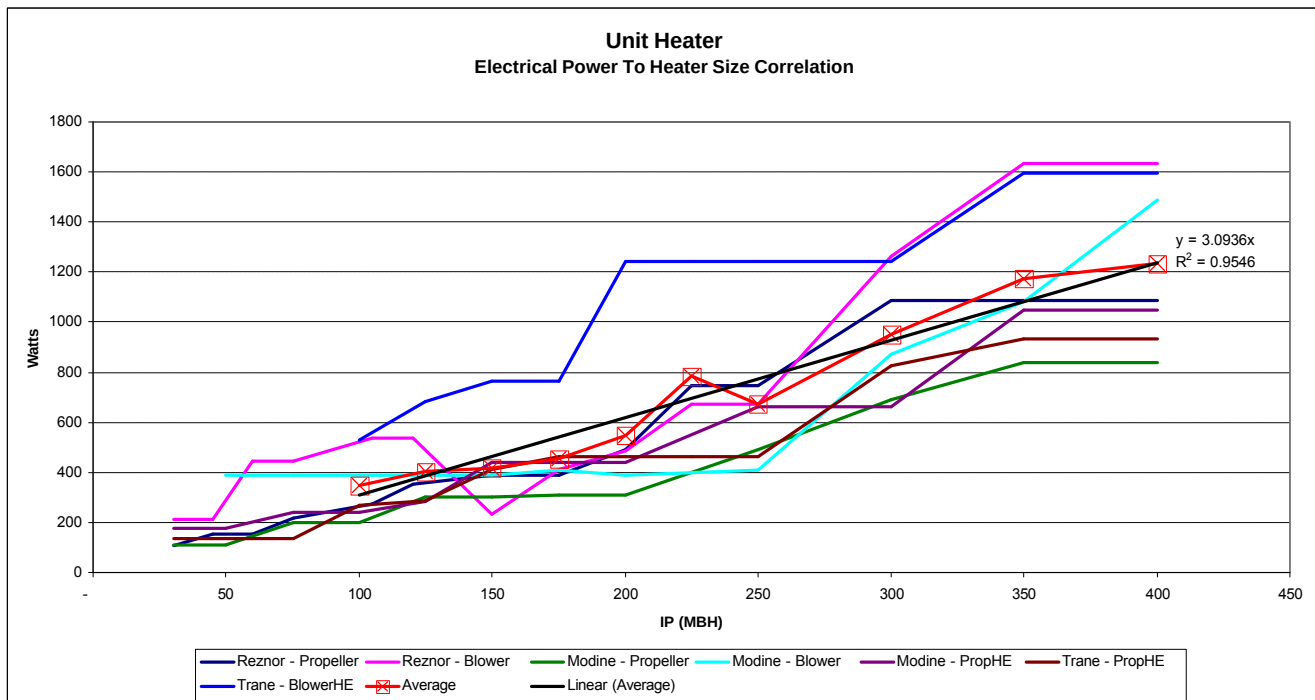
The motor annual utility use is the annual kWh usage as calculated above. This is shown as a negative value.

5.3 Auxiliary Electrical Savings

The auxiliary savings represents electrical savings through the reduced use of auxiliary heating equipment. This includes items such as blower motors on unit heaters. ASHRAE, 2008 S9.13-9.15 terms this value as the Auxiliary Energy Ratio (electrical energy input per fuel energy input) and provides benchmark values for residential blowers on non-condensing and condensing furnaces of 0.028 and 0.034 respectively. These values are referenced from Phillips, 1998 which found that average blower motor power consumption has risen from 13 W/kW (0.013) of rated furnace output for furnaces installed in the 1960s to 28 W/kW (0.028) for furnaces installed between 1990 and 1994. Neither documents provide values for commercial/industrial unit heaters.

The specifications for commercial/industrial unit heaters from several commonly used unit heater manufacturers were analyzed and an equation was developed to correlate electrical power to unit heater input size. A figure and equation of this correlation is shown below.

Figure 2: Unit Heater Electrical Power



Equation 18: [kWh/yr] Auxiliary Savings

$$AuxkWh_{AnnSave} = 3.0936 \times \frac{q_{save}}{1,000}$$

where:

$AuxkWh_{AnnSave}$ = total annual electrical savings for the auxiliary heating equipment, kWh/yr

3.0936 = correlation of electrical power (Watts) to fuel energy input (MBH)

1,000 = conversion from Watts to kW

q_{save} = total annual energy savings of the destratification equipment, MBtu/yr

Enbridge

Air Curtain Savings - Reference Documentation

23-Sep-08

Converting the equation to compare on a similar unit basis (ie., Watt electrical input per Watt fuel energy input) provides an Auxiliary Energy Ratio value of 0.011. It is reasonable to assume this type of heater will have a lesser value versus residential furnaces due to the fact that residential furnaces are designed to move heated air through duct work and thus require larger and more powerful blowers.

5.4 Dollar Savings

The dollar savings for the mechanical systems is a product of the utility use and the utility cost for the respective system.

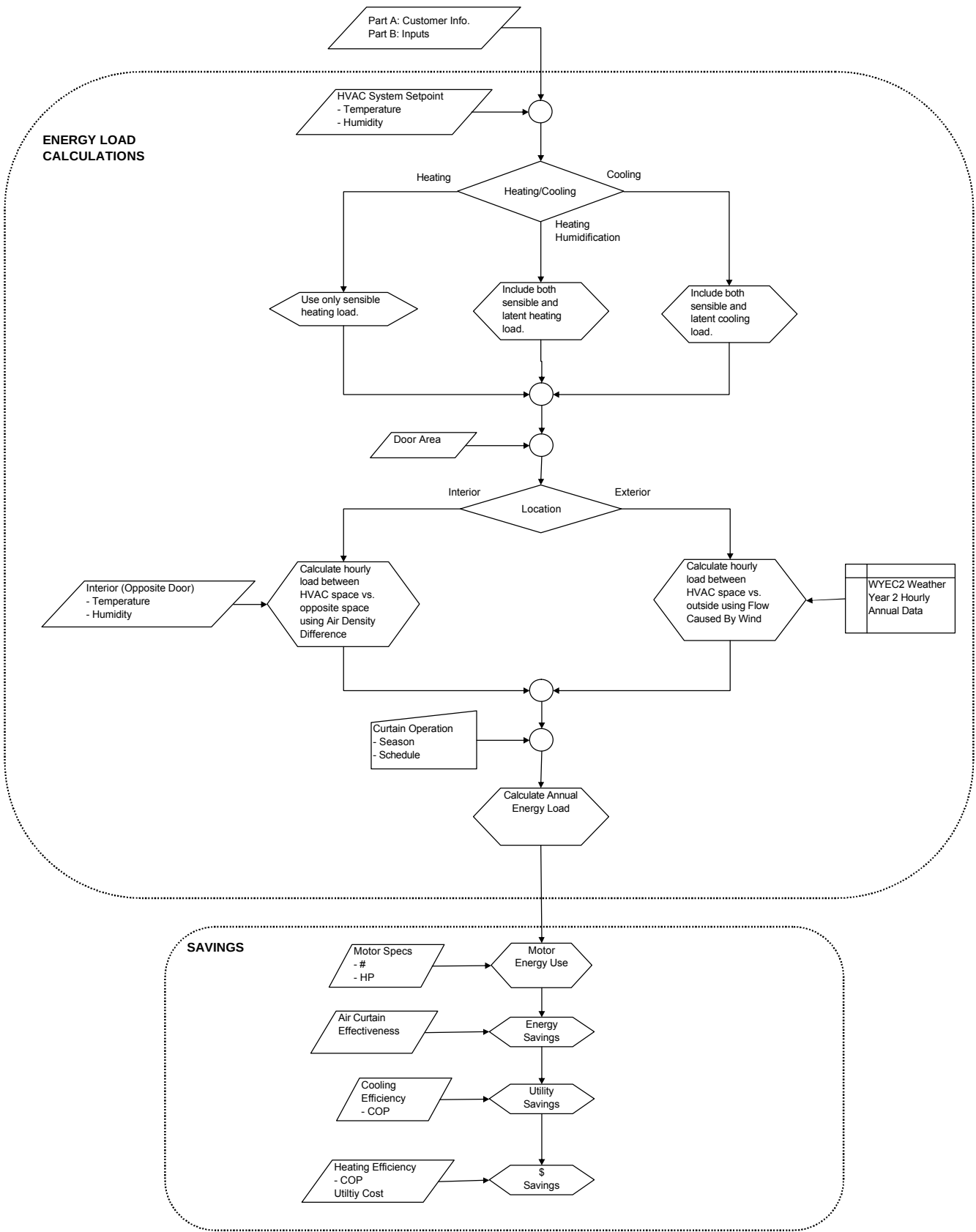
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FLOW CHART

Air Curtain Input & Calculations: Flowchart



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1.0 INTRODUCTION

The VFD Calculations Tool is used in both the VFD ETool as well as the Ventilation ETool program. The calculations are done to determine the electrical savings by use of a VFD controlled motor or pump versus a non-VFD motor with possible use of an inlet or outlet method of control. The background calculations are identical for both the Standalone and Ventilation Tool, however, the interface is slightly different.

The main differences are that the Ventilation Tool:

- does not include an application for pumps.
- the user enters input variables by selecting the 'Electrical Variables' button.
- the Duty Cycle is determined through the Peak and Partial supply scheduling rather than distinctly through a Duty Cycle %.

Other notable differences are indicated throughout this document.

2.0 PROGRAM METHOD

Calculations are done based the user inputs. A flow chart outlining the program methodology is included in the Appendices. All calculations are done using Imperial equations.

2.1 Project Information

The user must manually enter project information into the standalone program. The Ventilation ETool has this information automatically generated from the Main ETool client system information.

2.2 System Description

2.2.1 Application

The application; Fan or Pump is selected.

2.2.2 Existing

The existing system control method is selected for either a fan or pump system. These include:

- No Control
- Outlet Damper (fan)
- Inlet Vane (fan)
- Throttling Valve (pump)

The selection is only available for the respective motor application.

The existing control factors used for the selected options are shown in the table below. Minimum flow values of 20% are used throughout the calculations.

Table 1: Existing Control Factors

Flow	None	[Fan Application]		[Pump]
		Outlet Damper	Inlet Vane	Throttling Valve
100%	1	1.00	1.00	0.999
90%	1	0.96	0.76	0.972
80%	1	0.91	0.64	0.940
70%	1	0.86	0.56	0.905
60%	1	0.79	0.50	0.866
50%	1	0.72	0.47	0.823
40%	1	0.66	0.42	0.777
30%	1	0.58	0.40	0.726
20%	1	0.51	0.39	0.672

[Ref: Hydro Quebec 1993]

2.2.3 Proposed

The proposed system control method of VFD is selected. If 'No Control' is selected then 0 savings are calculated.

2.2.3.1 FAN APPLICATION

The VFD control factors for a Fan Application are based on the Motor Load (or % Flow), the Motor Efficiency Load Factor, and the VFD Efficiency whereas:

Equation 1: Fan VFD Control Factor

$$\text{FanVFDControl Factor} = \frac{\text{Flow}^2}{\text{Motor Efficiency Load Factor} \times \text{VFDEfficiency}}$$

[Ref: Hydro Quebec 1993]

where:

Flow = % of fan airflow or pump flow. These have been allocated to 10% increments from 100% to 20%.

Motor Efficiency Load Factor = the motor efficiency load factor as specified in the table below. *VFDEfficiency* = the VFD efficiency as specified in the table below.

Table 2: Motor Load Efficiency & VFD Efficiency

Flow %	Motor Eff Load Factor	VFD Efficiency
100%	1	0.96
90%	1	0.94
80%	1	0.91
70%	1	0.89
60%	0.99	0.858
50%	0.97	0.826
40%	0.93	0.791
30%	0.86	0.748
20%	0.76	0.7

[Ref: Hydro Quebec 1993.]

The calculated Fan VFD Control Factors are shown in the table below.

Table 3: Fan VFD Control Factors

Flow %	Fan VFD Control Factor
100%	1.042
90%	0.862
80%	0.703
70%	0.551
60%	0.424
50%	0.312
40%	0.218
30%	0.140
20%	0.075

[Ref: EPRI, 1992.]

2.2.3.2 PUMP APPLICATION

The VFD control factors for a Pump Application are included in the table below.

Table 4: Pump VFD Control Factors

Flow %	Pump VFD Control Factor
100%	1.028
90%	0.794
80%	0.595
70%	0.432
60%	0.303
50%	0.210
40%	0.153
30%	0.130
20%	0.143

[Ref: EPRI, 1992.]

2.2.4 Efficiency

The efficiency of the VFD [default 97%] and Motor [default 85%] can be input by the user or chose the default efficiencies.

2.2.5 Electrical & Project Cost

Enter the electrical & project cost of the project. The Ventilation ETool has this information automatically generated from the Main ETool client system information.

2.3 Power/Flow Parameters

2.3.1 Select Calculation Option

Select either Motor / Airflow / Pump. Only Motor or Airflow may be selected if a Fan Application is chosen and only Motor or Pump may be selected if a Pump Application is chosen.

2.3.1.1 MOTOR

Use this option if the airflow or pump flow is unknown. Enter the Nameplate HP and Motor Loading % of the motor. The Shaft (or Brake) HP for the motor is calculated as:

Equation 2: Motor Shaft HP

$$\text{ShaftHP} = \text{NameplateHP} \times \text{MotorLoading\%}$$

where:

NameplateHP = the motor Nameplate HP (horsepower)

MotorLoading% = the % of motor loading [default 85%].

2.3.1.2 AIRFLOW

Use this option for a fan if the required airflow parameters are known. The Shaft (or Brake) HP for the motor is calculated as:

Equation 3: Airflow/Motor Shaft HP

$$\text{ShaftHP} = \frac{\text{Airflow}(\text{cfm}) \times \text{Pressure Increase}(\text{"w.c.})}{6356 \times \text{FanEfficiency}(\%)}$$

[Ref: Gladstone 1981]

where:

Airflow(cfm) = the airflow of the fan in cfm.

Pressure Increase ("w.c.) = the pressure increase across the fan in inches of water column.

Fan Efficiency (%) = the fan efficiency [default 70%].

2.3.1.3 PUMP

Use this option for a pump if the required fluid flow parameters are known. The Shaft (or Brake) HP for the motor is calculated as:

Equation 4: Pump/Motor Shaft HP

$$\text{ShaftHP} = \frac{\text{Pumpflow(gpm)} \times \text{Head (ft)} \times \text{Spec.Gravity}}{3960 \times \text{PumpEfficiency(\%)}}$$

[Ref: HVAC Systems and Equipment Handbook, 2000]

where:

Pumpflow(gpm) = the fluid flow of the pump in gpm.

Head (ft) = the working pressure of the pump in feet.

Spec.Gravity = the specific gravity of the fluid.

PumpEfficiency = the pump efficiency [default 70%].

2.3.1.4 BASELINE BRAKE HORSEPOWER

Use this option for a fan if motor nameplate HP or fan information is unavailable. This procedure is defined in ASHRAE Standard 90.1-2004, Table G3.1.2.9 and is the Baseline Fan Brake Horsepower to be used for defining improved performance. A selection is available to allow calculation for either Constant Volume or Variable Volume systems. A filtration credit for HEPA filters has also been included. The Shaft (or Brake) HP for the motor is calculated depending on the airflow and system volume according to the equations referenced below.

Equation 5: Constant Volume Baseline Brake HP {Airflow < 20,000cfm}

$$\text{Baseline Brake HP} = 17.25 + [\text{Airflow(cfm)} - 20,000] \times 0.0008625$$

[Ref: ASHRAE 90.1, 2004]

Equation 6: Constant Volume Baseline Brake HP {Airflow >= 20,000cfm}

$$\text{Baseline Brake HP} = 17.25 + [\text{Airflow(cfm)} - 20,000] \times 0.000825$$

[Ref: ASHRAE 90.1, 2004]

Equation 7: Variable Volume Baseline Brake HP {Airflow < 20,000cfm}

$$\text{Baseline Brake HP} = 24 + [\text{Airflow(cfm)} - 20,000] \times 0.0012$$

[Ref: ASHRAE 90.1, 2004]

Equation 8: Variable Volume Baseline Brake HP {Airflow >= 20,000cfm}

$$\text{Baseline Brake HP} = 24 + [\text{Airflow(cfm)} - 20,000] \times 0.001125$$

[Ref: ASHRAE 90.1, 2004]

An additional pressure credit is given for system having clean filtration with pressure drops in excess of 1" w.c.. This credit is calculated if HEPA filtration is selected by the user and is added to the Baseline Brake HP calculated above.

Equation 9: Pressure Credit (BHP) of HEPA Filtration

$$\text{Pressure Credit (BHP)} = \text{Airflow}(\text{cfm}_{\text{Filter}}) \times (\text{SP}_{\text{Filter}} - 1) / (4.984 \times 746)$$

[Ref: ASHRAE 90.1, 2004]

where:

Airflow(cfm_{Filter}) = the pressure drop across a clean HEPA filter. A value of 1.37" w.c. is used for this value [Ref: Trane literature for HEPA 99.97 DOP, clean, 500 fpm face velocity]

2.4 Duty Cycle

Enter the 'Annual Hours of Operation' as well as the percentage of 'Time' that the application is operating at each respective flow.

The operating hours per year are calculated for each flow from the Annual Hours of Operation times the % Time.

This develops the Duty Cycle profile of the application. Duty Cycles can be saved. Pre-saved Duty Cycles can be imported.

2.5 Electrical Calculations

The electrical kW (kilowatt) demand at 100% flow is calculated from the Shaft HP for Motor, Airflow and Pump as shown. This calculation is done separately for both the Existing and Proposed application.

Equation 10: kW Demand @ 100% Flow For Motor, Airflow, Pump

$$kW@100\%Flow = \frac{ShaftHP \times 0.746}{Motor\ Efficiency(\%)}$$

[Ref: Ontario Hydro, 1990]

where:

ShaftHP = the calculated value from Eqn's 2, 3, or 4.

Motor Efficiency (%) = the value input in the System Description.

The electrical kW (kilowatt) demand at 100% flow for Baseline BHP is calculated according to ASHRAE 90.1-2004, G3.1.2.9.

Equation 11: kW Demand @ 100% Flow For Baseline Brake HP

$$kW@100\%Flow = \frac{bhp \times 0.746}{(1 - e^{[-0.2437839 \times \ln(bhp) - 1.685541]})}$$

[Ref: ASHRAE 90.1-2004]

where:

bhp = the Baseline Brake HP without filtration

The pressure credit of the HEPA filtration in kW is added to the kW for Baseline Brake HP according to the equation below to give a total kW demand when using the Baseline Brake HP calculation option.

Equation 12: Pressure Credit (kW) of HEPA Filtration

$$\text{Pressure Credit (kW)} = \text{Airflow}(\text{cfm}_{\text{Filter}}) \times (\text{SP}_{\text{Filter}} - 1) / (4.984)$$

[Ref: ASHRAE 90.1, 2004]

where:

Airflow(cfm_{Filter}) = the pressure drop across a clean HEPA filter. A value of 1.37" w.c. is used for this value [Ref: Trane literature for HEPA 99.97 DOP, clean, 500 fpm face velocity]

2.5.1 Total Electrical Consumption

The total electrical consumption

2.5.1.1 EXISTING CONTROL (BEFORE RETROFIT)

The sum of the electrical consumption for the existing control is calculated as:

Equation 13: Existing Control Electrical Consumption

$$\text{Existing kWh} = \sum_{\text{Flow}=20}^{\text{Flow}=100} [\text{Existing Control Factor}_{\text{Flow}\%} \times \text{kW @100\%} \times \text{Operation}(\text{hrs / yr})]$$

where:

$\text{Existing Control Factor}_{\text{Flow}\%}$ = the existing control factor at each respective flow of the duty cycle from Table 1.

$\text{kW @100\%}$ = the electrical demand from Eqn. #5.

$\text{Operation}(\text{hrs / yr})$ = the operating hours at each respective flow from the duty cycle.

2.5.1.2 PROPOSED CONTROL (AFTER RETROFIT)

The sum of the electrical consumption for the VFD control is calculated as:

Equation 14: VFD Control Electrical Consumption

$$\text{VFD kWh} = \sum_{\text{Flow}=20}^{\text{Flow}=100} \left[\frac{\text{VFD Control Factor}_{\text{Flow}\%} \times \text{kW @100\%}_{\text{Proposed}} \times \text{Operation}(\text{hrs / yr})}{\text{VFDEfficiency}\%} \right]$$

where:

$\text{VFD Control Factor}_{\text{Flow}\%}$ = the VFD control factor at each respective flow of the duty cycle from Table 3 for fan applications and Table 4 for pumps.

$\text{kW @100\%}$ = the electrical demand from Eqn. 5.

$\text{Operation}(\text{hrs / yr})$ = the operating hours at each respective flow from the duty cycle.

$\text{VFDEfficiency}\%$ = the VFD Efficiency % as input in the System Description.

2.5.2 Electrical Savings

2.5.2.1 ENERGY (KWH)

The electrical energy savings results from Eqn. #6 minus Eqn. #7.

The electrical energy savings for the Ventilation ETool calculates the savings the same as above with the following exceptions:

- a) the minimum airflow for the duty cycle is 20% even if the Peak or Partial Supply is lowered more than 20% with the exception of part b) below.
- b) if the Peak or Partial Supply is set at 0% than the electrical energy savings for that period is the difference between the control system operating at 100% and being turned off. This provides electrical energy savings the same as if the motor was turned off for that period (schedule savings).

2.5.2.2 DEMAND (KW)

The kW savings is the product of the electrical demand @ 100% (Eqn. #5) and the differences of the control factors of the existing and proposed systems.

Equation 15: Electrical Demand Savings

$$kW \text{ Savings} = \left\langle \left[\text{Existing Control Factor}_{Flow=100\%} \right] - \left[\frac{\text{VFD Control Factor}_{Flow=100\%}}{\text{VFDEfficiency}\%} \right] \right\rangle \times kW @ 100\%$$

2.5.2.3 SAVINGS (\$)

The electrical energy savings in dollars is the product of the electrical energy savings from above and the Electrical Cost as input in the System Description.

2.5.3 Simple Payback (yrs)

The Simple Payback is the Project Cost as input in the System Description divided by the Electrical \$ Savings from above.

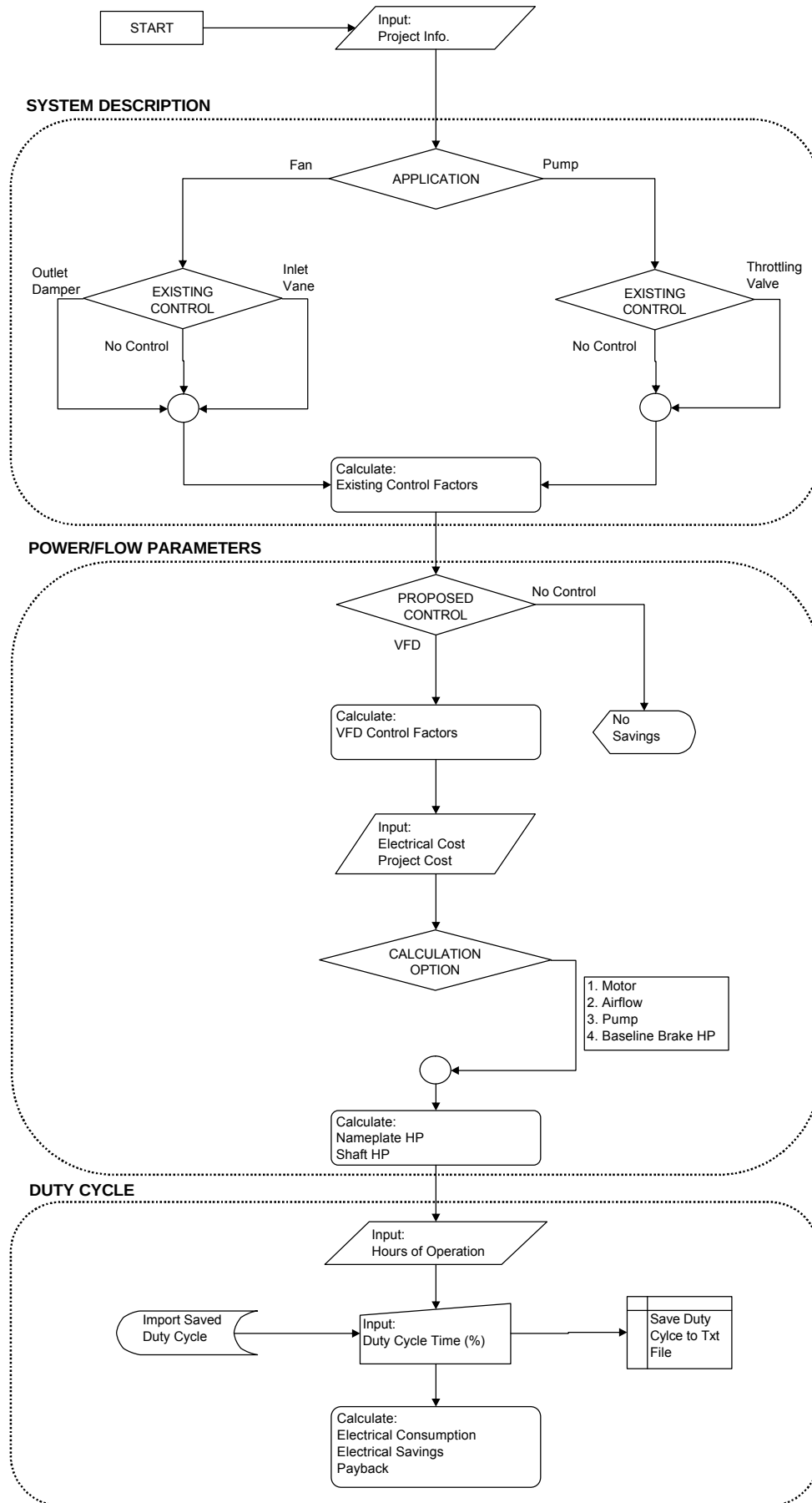
Enbridge – Etool

VFD Calculations

Reference Documentation

FLOW CHART

VFD Input & Calculations: Flowchart



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E-TOOLS USER MANUALS



USER MANUAL

AHU & MUA PROGRAMS, V1.07

August 01, 2008



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1.0 INTRODUCTION

The Air Handling Unit (AHU) and Make-Up Air (MUA) Programs estimate the annual gas consumption and gas cost associated with the operation of these ventilation systems. The programs are nearly identical and calculate the energy required to maintain a design room temperature for a range of ambient temperatures given a predefined ventilation rate. The user may also analyze the benefit of an air recirculation unit in the existing and/or new AHU ventilation system. For both the AHU and MUA the user may evaluate the effect of a reduction in the number of hours and/or operating temperature that the ventilation system is operated per 24-hour period. Two programs are required so that a facility may incorporate both a make-up air unit and a separate air-handling unit.

Electrical savings are calculated with use of the VFD Calculations Tool. This is used in both the VFD ETool as well as the Ventilation ETool program. The calculations are done to determine the electrical savings by use of a VFD controlled motor or pump versus a non-VFD motor with possible use of an inlet or outlet method of control. The background calculations are identical for both the Standalone and Ventilation Tool, however, the interface is slightly different.

The main differences are that the Ventilation Tool:

- does not include an application for pumps.
- the user enters input variables by selecting the ‘Electrical Variables’ button.
- the Duty Cycle is determined through the Peak and Partial supply scheduling rather than distinctly through a Duty Cycle %.

A complete user manual is available separately for the VFD ETool portion of the Ventilation ETool.

Calculations have been developed that quantify the electrical cooling load savings with the reduction of airflow from a buildings air handler or makeup air unit through the use of VFD controls. These have been added to the existing Ventilation MUA & AHU ETools.

The Ventilation ETool has previously calculated the heating load savings due to a reduction of ventilation airflow during heating requirements. The addition of the cooling load savings calculations provides the electrical energy savings during building cooling requirements.

2.0 USING THE PROGRAM

The program inputs are separated into 3 categories:

- 1) Existing System Inputs
- 2) New System Inputs

2.1 Entering Existing System Data

2.1.1 Air Flow Rate

The initial air flow rate (in cfm) is populated from the input data file. However, it can be adjusted by the user from this value using a spinner button.

2.1.2 Supply Air Temperature

The supply air temperature (°F) is selected by the user, using a spinner button.

2.1.3 Existing Equipment Efficiency

Select the efficiency of the existing equipment using a spinner button.

2.1.4 Type of Facility

This cell is populated from the input data file and indicates the number of people in the facility or whether it is an apartment in order to determine which ASHRAE rules apply.

2.1.5 Percentage of Fresh Air (for AHU systems with recirculation)

User inputs the percentage of the fresh air.

2.1.6 Actual Hour of Operation

If the system is on for only part of the day, input the average number of hours of operation during a 24 hour period. Enter the value 24 if the system is always on.

2.1.7 Electrical Variables

VFD Calculation Parameters - MUA

Enter the VFD parameters for

Select A Calculation Method

1. Motor Rated Power

☒ Motor Rated Power

Electric Motor Rated Power (HP)

Motor Loading (%)

2. Airflow

☐ Airflow

3. Baseline Brake HP

☐ Baseline Brake HP

Notes:
A) Only use Baseline Brake HP if the Motor Rated Power or Airflow Parameters are not available.

Other Parameters

Motor Efficiency (%) Frequency Converter Efficiency (%)

Set Defaults OK Cancel

In determining the electrical savings opportunities for an air handler in either the MUA or AHU, the ESC should use the following procedure prioritized as shown:

1. Motor Horsepower: If the nameplate horsepower is available for the unit then the ESC should input this value.
2. Airflow & Pressure: If the motor horsepower is unknown or unavailable then the ESC should input the Total External Static Pressure of the unit. This is available either from the original specifications of the unit or through an air balance of the unit. When using the VFD ETool then the air handler airflow in CFM is also required.
3. Baseline Brake Horsepower: This procedure is defined in ASHRAE Standard 90.1-2004, Table G3.1.2.9 and is the Baseline Fan Brake Horsepower to be used for defining improved performance. This method is only to be used if information for #1 or #2 are unavailable. A selection has been added to allow calculation for either Constant Volume or Variable Volume systems. A filtration credit for HEPA filters (using a static pressure drop of 1.37" w.c.) has also been included (Ref: Trane literature for HEPA 99.97 DOP, clean, 500 fpm face velocity).

2.1.8 Cooling Load

Cooling Calculation Parameters - MUA

Enter the Cooling Load

Month of Operation

☒ May
☒ Jun
☒ Jul
☒ Aug
☒ Sep

Cooling System Setpoint

RH (%)
 Dry Bulb Temperature (F)

Cooling Unit Efficiency

☒ Age ☐ Rating

☐ New
☐ 5-10yrs
☒ 10yrs_plus

COP

The Cooling Unit Efficiency value is defaulted depending on the Age of Equipment. If the Rating is known, then the COP value can be entered directly to override the default. The unit efficiency is considered conservative versus the system efficiency.

Notes:
 1) Enter values for:
 - Month of Operation
 - Cooling System Setpoint
 - Cooling System Efficiency
 2) Select Set Defaults to reset default values.

Set Defaults **OK** **Cancel**

Enter information for the cooling load operation:

1. Month of Operation: Enter which months of operation the cooling unit is being used [default = 50%]
2. Cooling System Setpoint: Enter the % Relative Humidity and Dry-Bulb Temperature (F) cooling system setpoints [default = 75F].
3. Cooling Unit Efficiency: Select either the Age or Rating of the Cooling Unit. Calculations use the Cooling Unit efficiency and not the Cooling System Seasonal efficiency.
 - a. Age: The default COP efficiency values are based on age as shown below:
 - i. New: COP=5.0
 - ii. 5-10yrs: COP=4.5
 - iii. 10yrs_plus: COP=4.0
 - b. Rating: If the rating of the Cooling Unit is know then select this and enter the COP value.

2.2 Entering New System Data

2.2.1 New Equipment Efficiency

If the proposed MUA system is either:

- Schedule
- Replace with New MUA (Schedule Optional)
- No Changes

then the new equipment efficiency is the same as the MUA existing efficiency.

If the proposed MUA system is:

- Convert to AHU from Heating (VFD Optional)

then the new efficiency is taken from either the selected New System or Lead-Lag Space Heating Seasonal Efficiency in the Boiler Selection Tool.

If the proposed MUA system is:

- Convert to AHU from DHW (VFD Optional)

then the new efficiency is taken from either the selected New System or Lead-Lag DHW Seasonal Efficiency in the Boiler Selection Tool.

The new system efficiency reads “0” if additional values must be entered into the Boiler Selection Tool.

2.2.2 Percentage of Fresh Air (for AHU systems with recirculation)

User inputs the percentage of the fresh air.

2.2.3 Actual Hour of Operation

If the system is on for only part of the day, input the average number of hours of operation during a 24 hour period. Enter the value 24 if the system is always on.

2.2.4 Peak Hours of Use

The day is divided into three 8 hour periods – 0:00 to 8:00, 8:00 to 16:00 and 16:00 to 24:00. For each 8 hour period the user selects the start time for peak use and the end time. For instance, if there were two work shifts starting at 6:00 and ending at 22:00, the user would choose 6:00 for the start time in the first 8 hour period, 8:00 for the end time followed by 8:00 for the start time in the second period and 16:00 for the end time, followed by 16:00 start time and 22:00 end time in the third period.

2.2.5 New Supply Air Temperature

Enter the temperature of the air for the new system during peak use, using the spinner button.

2.2.6 New Air Flow Rate

The new air flow rate is input as a percentage of the existing system ventilation rate. If they are the same, enter 100%. The program will indicate immediately if the selected airflow rate falls below ASHRAE minimums

2.2.7 Partial Supply for Non-Peak Times

The user has the option of reducing both the airflow rate and the supply air temperature during off peak hours, such as, in the example above, non-peak hours would be from 22:00 hours to 06:00 hours. The day is divided into the same three 8 hour periods and the program calculates the reduced amount of energy required for each time period based on the number of non-peak hours available. The user inputs the reduced ventilation rate and reduced supply air temperature, using spinner buttons, in each time period. The program will notify the user if selected values fall below ASHRAE minimums.

3.0 OUTPUTS

3.1.1 Annual Gas Consumption – Existing Equipment, 24 hr per day Operation (with or without recirculation)

The program calculates the estimated gas consumption for the existing system as follows

- based on a 24 hour per day operation
- using BIN numbers of the annual hours at each range of ambient outdoor temperatures
- heat the incoming ventilation air up to design supply air temperature (with or without mixing).

3.1.2 Annual Gas Consumption – Actual Hours of Operation (with or without recirculation)

If the operating schedule is less than 24 hours per day, the annual gas consumption is estimated as a percentage of 24 hour operation. The user can use this feature to assess the amount of gas that could be saved if a reduced number of hours of operation were implemented (e.g. not operating the ventilation system during periods when the facility was vacant.)

3.1.3 Annual Gas Consumption – New System (with or without recirculation)

The user can implement a number of potential gas saving measures with the new equipment.

- The supply air temperature can be changed
- The ventilation air flow rate can be changed
- Peak hours of usage can be defined
- Reduced temperatures and air flow rates can be defined for non-peak times

The program calculates the net energy saved by the new system over the existing system.

3.1.4 Electricity Savings For VFD

The electricity savings in kWh and kW is shown if the VFD option is selected.

3.1.5 Electricity Savings For Cooling Load

The electricity savings in kWh is shown if the Cooling Load option is selected.



USER MANUAL

AIR CURTAIN CALCULATOR, V1.07

August 01, 2008



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Introduction

Air curtains are used in commercial applications to provide energy savings through the reduction of heated or conditioned air loss from open doorways. Additional benefits also include the reduction of dust or insect entry through open doors as well as allowing fast, smooth traffic flow.

The Air Curtain Tool calculates energy savings from reduced airflow through an air curtain versus an open doorway.

Estimated annual savings assumes air curtain equipment is installed and operated within manufacturers' recommendations. Certain limitations may exist due to building pressure differentials or other application issues.

Customer Information

Enter the customer information to define the project location and contact information.

Inputs

A number of inputs are required to define the operation and specifications of the location in which the air curtain is being used.

Utility

Cost

The natural gas and electricity unit costs for the facility must be entered.

Heating/Cooling

Checkboxes are available to indicate whether the air curtain will be used with:

- Heating system
- Cooling system.
- Heating Humidification: If humidification is used during heating then the latent heat is used in the calculation of total heat.

Air Curtain Operation

% of Coverage

The % of Coverage indicates the amount of door coverage by truck or other obstacles. This is indicated by the selections:

- Wide Open [0% Coverage]. This is the case for a door completely open to flow-thru traffic.
- Partially Covered [40% Coverage]. This includes doors that may be partially covered by multiple sized trailers or other obstacles.
- Full Coverage [90% Coverage]. This includes doors that are typically entirely covered by trailers and are well sealed with bumper pads or other obstacles.

Season of Operation

Checkboxes are available to indicate the season of operation in which the air curtain will be used:

- Spring [March, April, May]
- Summer [June, July, August]
- Fall [September, October, November]
- December [December, January, February]

Schedule of Operation

The time of use for the air curtain is input for three separate periods:

- Morning [12:00AM to 8:00AM]
- Day [8:00AM to 6:00PM]
- Evening [6:00PM to 12:00AM]

These time periods are adjustable. There are also inputs to define the Minutes Per Opening of the door during the respective time period as well as the Openings Per Hour.

Door Specifications

Size

The length(ft) and height(ft) of the door that the air curtain is being used is input. The area is calculated and is shown.

Location

The user selects the location of the door as:

- Interior: the door is located between interior zones of different temperatures of a building (ie., a walk-in cooler)
- Exterior: the door is located on an exterior location separating the interior conditions from the outside environment.

Facing Direction

The user selects the facing direction of the door as North, South, East, or West.

Motor Specifications

The number of motors and horsepower of each motor on the air curtain is input. The total HP is calculated and shown. There is a wide range of motor sizes used depending on the size of the door. For example, Enershield manufactures air curtains that have motor sizes from ½ HP up to 25 HP.

Other inputs of motor specifications include:

- Motor Loading (Default = 85%)
- Motor Efficiency (Default = 80%)

The defaults for motor loading and motor efficiency are referenced from the Enbridge Report: Reference Documentation / VFD Airflow Default Parameters, 31-Jan-2007.

Curtain Effectiveness

A value for the air curtain effectiveness is input. ASHRAE 2004, S17.9 suggests values of air curtain effectiveness at preventing infiltration through an entrance generally range from 60 to 80%.

A default of 70% is used.

HVAC

HVAC Setpoint

HVAC setpoints are input for:

- Heating Dry-Bulb Temperature (C)
- Cooling Dry-Bulb Temperature (C)
- Humidity (%)

Interior (Opposite Door)

Setpoints for the environmental conditions on the opposite side of the interior door (ie., inside a cold storage) are input for:

- Temperature (C)
- Humidity (%)

The savings when using an interior door are calculated for the HVAC space only. It is not calculated for the space opposite the HVAC space (ie., cold storage).

Balance Point

The Balance Point is the outdoor temperature when supplemental space heating or cooling is no longer required. This is the value at which the internal heating or cooling sources of the facility equal the heat loss or gain.

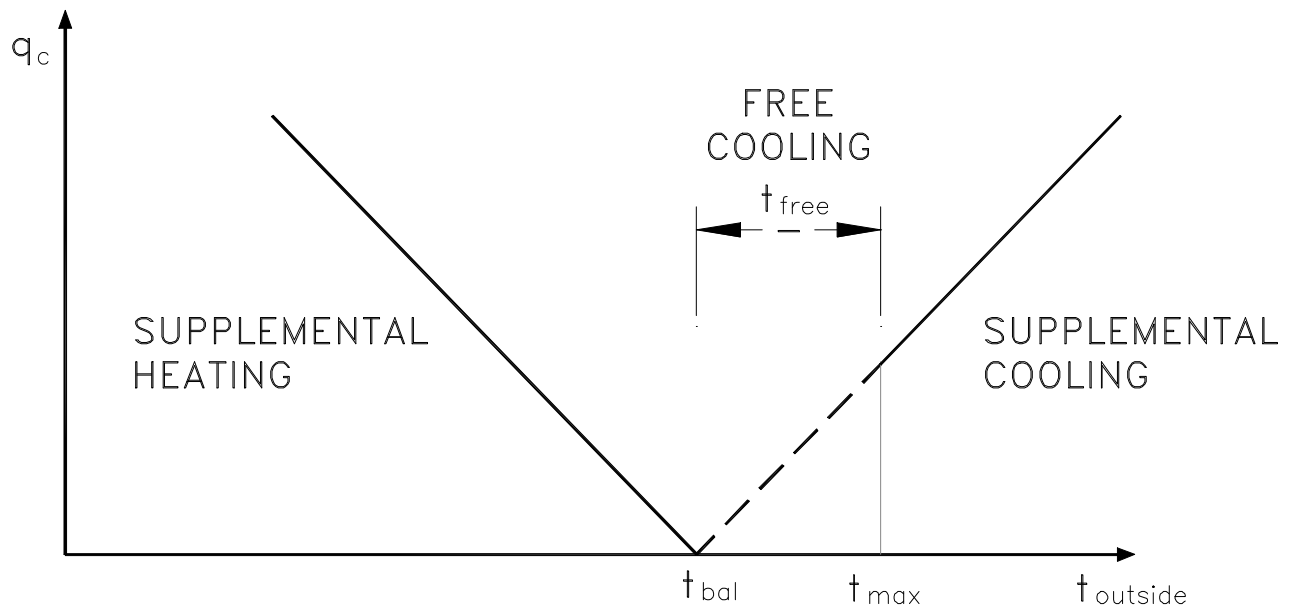
Heating (Default = 18C)

Cooling (Default = 25C)

The Balance Temperature t_{bal} of a building is defined as that value of the outdoor temperature $t_{outside}$ at which, for the specified value of the interior temperature, the total heat loss is equal to the heat gain from sun, occupants, lights, etc. (Fundamentals 2005, 32.18).

HVAC Systems and Equipment 2004, 3.7 states for all systems using a primary-air system for outside air, there is an outside temperature (balance temperature) at which secondary cooling is no longer required.

Fundamentals 2005, 32.18 also states that there is a period in which cooling can be supplied by opening windows or increasing ventilation and mechanical ventilation is only required when the outside temperature exceeds a threshold value t_{max} . This period can be supplied during the economizer mode (if available) on the ventilation system and is commonly referred to as ‘free cooling’ and shown as t_{free} . The figure below shows a schematic of the balance temperature as referenced from Fundamentals 2005, Fig.12, 32.19.

Figure 1: Balance Temperature Schematic

An extensive literature review produced little referenced documentation relating actual balance temperature to building type. HVAC Systems and Equipment 2004, 3.7 suggests that mechanical cooling is seldom required at outside temperatures below 55F. Fundamentals 2005, 32.19 suggest that the balance temperature varies widely between buildings, it has been reduced with the introduction and use of energy savings appliances, and that in general the traditional base of 65F not be used.

Balance temperatures have been estimated by the author with an available references shown for building types available in the calculator.

Table 1: Balance Temperature

Site Type	Balance Temperature (C)		Supplemental Cooling (C) [t _{free} = 2.8C]		Reference
	(C)	(F)	(C)	(F)	
Hospitals	12.8	55	15.6	60.1	ASHRAE S3.7 F32.18
Hotel	12.8	55	15.6	60.1	ASHRAE S3.7
Long Term Care	12.8	55	15.6	60.1	ASHRAE S3.7
Multi-Residential Nonprofit	15	59	17.8	64.0	Boiler Selection Tool
Multi-Residential Private	15	59	17.8	64.0	Boiler Selection Tool
Municipalities	12.8	55	15.6	60.1	ASHRAE S3.7
New Construction	12.8	55	15.6	60.1	ASHRAE S3.7
Office	14	55	16.8	62.2	Boiler Selection Tool
Other Sectors	12.8	57.2	15.6	60.1	ASHRAE S3.7
Retail	12.8	55	15.6	60.1	ASHRAE S3.7
Schools	12.8	55	15.6	60.1	ASHRAE S3.7
Universities	14	57.2	16.8	62.2	Boiler Selection Tool
Warehouse	12.8	55	15.6	60.1	ASHRAE S3.7

The Balance Temperature for the existing tool is currently a user input value.

Equipment Efficiency

Inputs for heating and cooling system efficiency are available:

- Heating (Default = 80%)
- Cooling (Default = 3.0 COP)

Annual Savings

The annual energy and utility savings are shown. The savings result from the reduction of heated or conditioned air loss from open doorways. Calculations are included in the Air Curtain Calculations / Reference Documentation.



USER MANUAL

Boiler Selection, V2.00

MARCH 16, 2009



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1.0 Introduction

The Boiler Selection Tool is used to evaluate energy efficient commercial boiler and water heater alternatives.

The tool predicts existing and new seasonal efficiencies from basic data on boiler type, age, application, etc. Energy savings for two new system alternatives can be compared. The tool includes analysis capability for a Lead-Lag boiler system that uses a new boiler plant as the Lead and the existing plant as the Lag.

2.0 Boiler Selection

The Boiler Selection screen allows the user to define several boiler systems for analysis of either Space Heating or Domestic Hot Water (DHW):

- Existing System
- New System A
- New System B
- Lead – Lag

BR: If the building has DHW included with the Space Heating then the analysis will only include systems entered for Space Heating.

Each system can have up to 2 boiler plants specified. These are labeled as “#1” and “#2”. These labels are for plant identification only, there is no difference in analysis between the two plants.

A database of boiler manufacturers and models has been developed for this tool and is representative of the major products being sold in Ontario, but is not necessarily complete.

BR: If a boiler is not listed, then select “other boiler” from the drop-down list and enter the boiler information.

2.1 Existing System

This section is where you enter existing information for space heating and/or DHW boiler systems.

Manufacturer: Select the manufacturer of the existing boiler system. You only have two different boiler manufacturers to choose from. Enter the one manufacturer as #1 and the other as #2 respectively. If the desired boiler manu/model is not available in the drop down lists then select “Other Boiler” and enter the Manufacturer and Model information in the text boxes below the drop downs. Do not try to type information in the drop downs.

Model: Select the model of for each manufacturer. A drop down list will appear based on the manufacturer selected. Choose the appropriate model.

BR: If a boiler manufacturer or model is not on the selected list you can use “other boiler”. This choice allows the user the ability to manually type in the make, model and boiler characteristics of the existing plant.

Qty: Select the quantity of boilers for the each of the loads.

Boiler Characteristic Fields (Automated)

The characteristics below are automatically selected when the make and model are chosen from above.

BR: When “other boiler” is selected in manufacturer the user will be able to manually insert unit input, combustion efficiency.

Unit Input ('000 Btu/h): The boiler input will be selected from the manufacturer database.

Combustion Efficiency (%): Shows the combustion efficiency of the selected boilers as read from the boiler database.

Boiler Characteristic Fields (Calculated)

Total Input ('000 Btu/h): Shows the total input for each plant with a sub-total also included.

Heating Output ('000 Btu/h): Shows the combustion (or thermal) output of the boiler plants.

Seasonal Efficiency (%): Select the Seasonal Efficiency button to go to the Seasonal Efficiency calculations.

Estimated Annual Gas Use (m³): Shows the normalized estimated annual gas use for the existing system.

2.2 New System A (Control Upgrade Only)

This is where you enter information for a proposed new boiler system. Same process as above select make, model and qty for proposed system.

Only this section can be used if 'Control Upgrade Only' has been selected for the respective boiler system. For instance, if Heating Boiler is 'Control Upgrade Only' then the Space Heating section is used for analyzing the control savings. Section B or Lead-Lag Space Heating Sections will not show savings on the Summary. Section B or Lead-Lag can be used however for the DHW Boiler analysis if Boiler Retrofit or Lead-Lag are selected for DHW.

Estimated Annual Gas Savings (m³): Shows the gas savings versus the existing system.

2.3 New System B

This is where you enter information for a proposed new boiler system. Same process as above select make, model and qty for proposed system.

Estimated Annual Gas Savings (m³): Shows the gas savings versus the existing system.

2.4 Lead - Lag

Enter information for a Lead boiler system. This process is similar to “New System A”. The tool assumes the Lag system is the Existing system. As with New System A, two different types of boilers can be selected.

BR: The Lead-Lag Button must be selected in the main page for this worksheet to work.

Estimated Annual Gas Savings (m³): Shows the gas savings versus the existing system.

BR: The tool allows visual analysis of either New System A or New System B on the screen, however only one of the option is transferred to the summary page for claiming DSM Savings. Please select the best system by clicking on the DSM Program button . System selected should be the one the customer or business partner elect to use. Print the summary page once for each of New System A, New System B or lead-lag when the business partner or customer wish to see all options.

3.0 Seasonal Efficiency

Enter specific details for the Space Heating and/or DHW to determine the seasonal efficiency of the required systems:

- Existing
- New System A
- New System B
- Lead-Lag

Details are considered for the entire boiler system and do not differentiate between the loads.

3.1 Space Heating or Combined Space/Domestic

The following settings below are default values based on the make and model of boiler selected. If you choose “Other Boiler” as a make and model for system A or B the settings below will need to be made manually. Boiler pumping, maximum supply water temperature, jacket average temperature, I/O control and quality of maintenance are not default values. They are user determined values regardless of boiler selection. Flue damping, air/fuel control and purge cycles are default and are only user adjustable when “Other Boiler” is selected.

Boiler Pumping: Select the type of system pumping as either:

- Continuous
- Intermittent

This value is used for determining the Control portion of the Seasonal Efficiency.

BR: *This detail is a portion of the details used for determining the Maximum Supply Water Temperature “Loss %” value.*

Flue Damping*: The flue damping of the system is read from the boiler database. If “other boiler” is selected then the flue damping method can be selected as necessary as either:

- None
- Burner Fan
- Mechanical

BR: *This detail is a portion of the details used for determining the Maximum Supply Water Temperature “Loss %” value.*

Oversizing Ratio: Is an automated calculation, the user cannot adjust this value. This is the ration of boiler system load versus the total building maximum demand. This ration will be used for determining the Maximum Supply Water Temperature “Loss %” value.

Total # Heating Stages: The number of stages is needed for determining the Maximum Supply Water Temperature “Loss %” value. This value is read from the boiler database and is set from the combination of quantity of boilers with the database values for the number of stages for the selected boilers

Maximum Supply Water Temperature: Select the boiler system maximum supply water temperature. This value is used for determining the Control portion of the Seasonal Efficiency.

Jacket Average Temp: Select the average temperature of the boiler jacket.

I/O Control: Select the type of boiler system control as either:

- None/Non-Functional
- Old
- New

This value is used for determining the Control portion of the Seasonal Efficiency.

A/F Control: The air/fuel control of the system is read from the boiler database. If “other boiler” is selected then the A/F Control method can be selected as necessary as either:

- None
- Staged
- Modulating

Purge Cycles: The method of system purge is read from the boiler database. If “other boiler” is selected then the Purge Cycles method can be selected as necessary as either:

- None
- Pre or Post
- Pre & Post

Total Losses: A value for the total system losses is shown.

Estimated Seasonal Efficiency: The calculated seasonal efficiency is shown.

3.2 Domestic Hot Water

Entry of details for the DHW systems is identical to the Space Heating or Combined Space/Domestic.



USER MANUAL

DESTRATIFICATION SAVINGS CALCULATOR, V1.07

August 01, 2008



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1.0 INTRODUCTION

Destratification of large commercial heated spaces is generally done through the use of large diameter or other types of ceiling fans or air movement equipment. Heating utility energy savings are available due to more uniform temperature profiles along the building height and a reduction of ceiling temperatures.

This document provides referenced documentation for calculating space heating energy savings due to temperature destratification.

2.0 USER INPUTS

2.1 Customer Information

The customer information area is to provide reference for the particular project. This information is not used in the calculations.

2.2 Building Dimensions

Enter the building dimensions for:

- Length (ft)
- Width (ft)
- Height (ft)
- % of Destrat Coverage: This is the percentage of the building coverage that is being destratified. Monitoring of a warehouse facility indicated the destratification coverage was approximately 100' diameter per fan using 20' diameter fans at low speeds (20Hz). This would be considered the minimum coverage as larger fans or higher speeds would increase this area. Enter dimensions only for the area in which the destratification equipment will be used.

2.3 Heating System

2.3.1 Efficiency

Enter the efficiency of the heating system:

- Operational Efficiency [Default = 80%]: This would typically be the combustion efficiency of a unit heater.
- Seasonal Reduction [Default = 15%]: The seasonal reduction is the difference between combustion efficiency and seasonal efficiency.

2.3.2 Method of Heat Delivery

Enter the method of heat delivery from the available options:

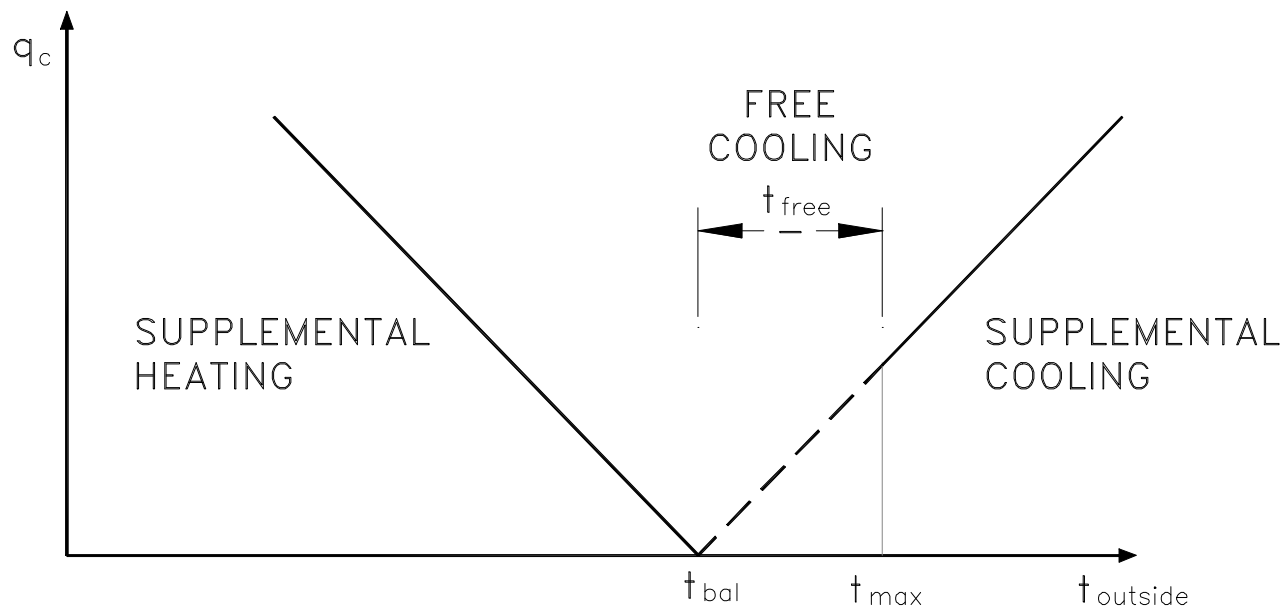
- Forced Air Unit
- Infrared
- Floor
- MUA/AHU

2.4 HVAC System

Enter the HVAC system parameters:

- Thermostat Setpoint (F): This is the setpoint of the local heating system or unit heater thermostat in degrees F.
- Thermostat Reduction [After Destrat] (F): This is the amount that the thermostat can be reduced as a result of having a destratified temperature profile.
- Outdoor Temperature When Heating Starts (F): The outdoor temperature when the heating system operates. This is dependent on the heat loss of the building and the amount of heat being generated by processes or equipment other than the heating system.
- Outdoor Balance Temperature [Heating]: The Balance Temperature t_{bal} of a building is defined as that value of the outdoor temperature $t_{outside}$ at which, for the specified value of the interior temperature, the total heat loss is equal to the heat gain from sun, occupants, lights, etc. (Fundamentals 2005, 32.18). Fundamentals 2005, 32.18 also states that there is a period in which cooling can be supplied by opening windows or increasing ventilation and mechanical ventilation is only required when the outside temperature exceeds a threshold value t_{max} . This period can be supplied during the economizer mode (if available) on the ventilation system and is commonly referred to as 'free cooling' and shown as t_{free} . The figure below shows a schematic of the balance temperature as referenced from Fundamentals 2005, Fig.12, 32.19.

Figure 1: Balance Temperature Schematic



An extensive literature review produced little referenced documentation relating actual balance temperature to building type. HVAC Systems and Equipment 2004, 3.7 suggests that mechanical cooling is seldom required at outside temperatures below 55F. Fundamentals 2005, 32.19 suggest that the balance temperature varies widely between buildings, it has been reduced with the introduction and use of energy savings appliances, and that in general the traditional base of 65F not be used.

Balance temperatures have been estimated by the author with an available references shown for building types available in the calculator.

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Schools	12.8	55	15.6	60.1	ASHRAE S3.7
Universities	14	57.2	16.8	62.2	Boiler Selection Tool
Warehouse	12.8	55	15.6	60.1	ASHRAE S3.7

The Balance Temperature for the existing tool is currently a user input value.

2.5 Motor Specifications

The number of motors and horsepower of each motor on the air curtain is input. The total HP is calculated and shown. There is a wide range of motor sizes used depending on the size of the size of fan or air movement equipment. A typical large diameter fan has a motor size of either 1, 1.5, or 2 hp.

Other inputs of motor specifications include:

- Motor Loading (Default = 85%)
- Motor Efficiency (Default = 80%)

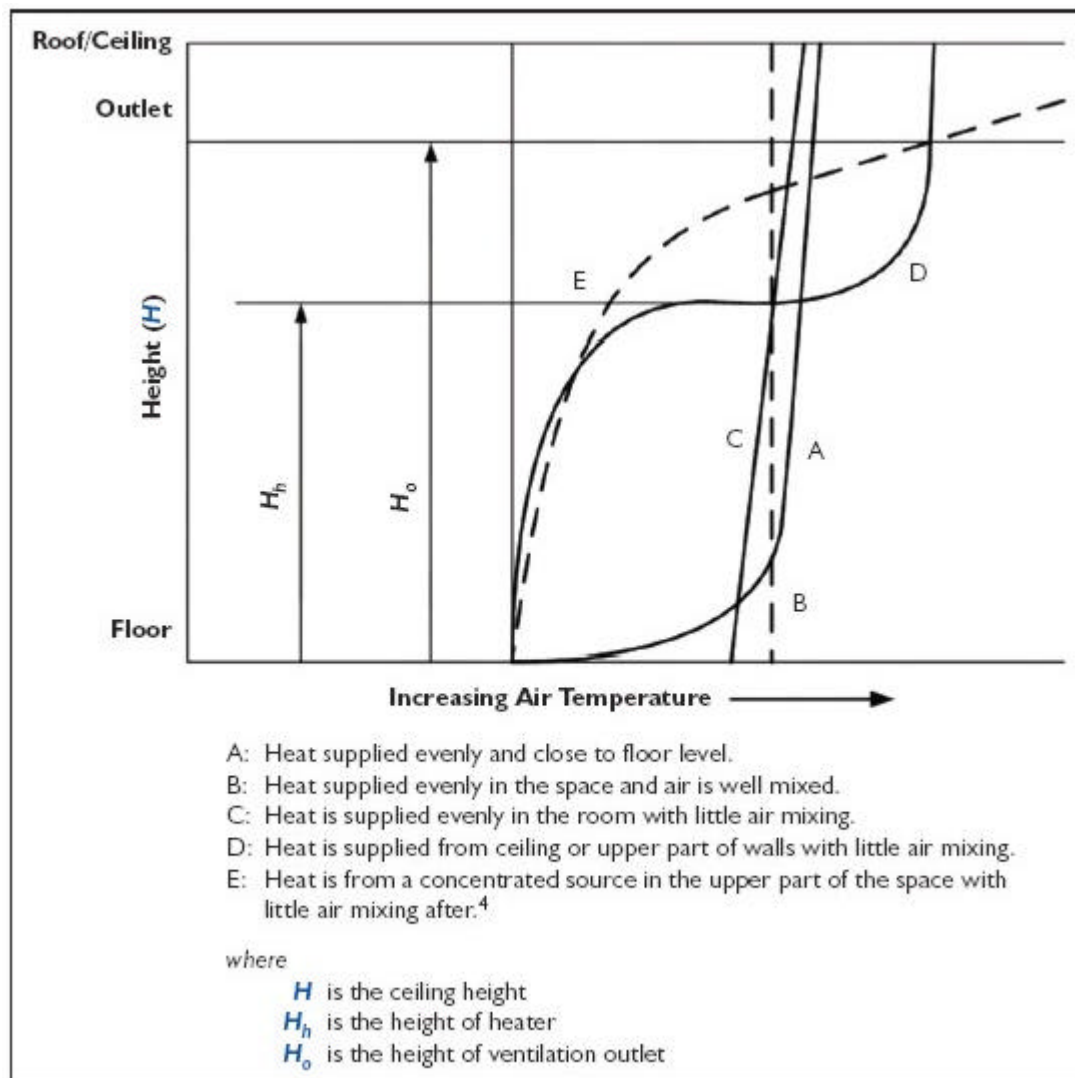
2.6 Temperature Profile

A table is supplied for input of the existing temperature profile of the heated space. Temperatures and heights of the locations are input for 5 different locations including:

- Ceiling
- Exhaust
- Heater
- Stat Level
- Floor

Non-applicable values can be set to zero. The height of the ceiling is set equal to the building height. A chart is shown of the both the existing and destratified temperature profiles. A difference of 2°F from ceiling to stat level is used to define the destratified temperature profile. The temperature profile may vary depending on the method of heating or other factors. The figure below shows sample heating profiles and the respective methods of heating.

Figure 2: Sample Vertical Profiles Of Indoor Air Temperature Determined By Heat Supply Location (Andersen, 1998).



2.7 Shell Construction

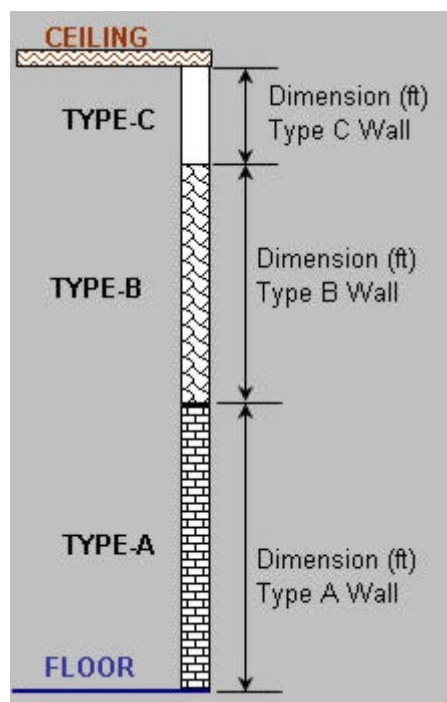
The shell construction of the heated space is defined.

2.7.1 Construction Details

A separate form is included for defining the R-Value of the ceiling, three types of walls (defined as Type A, B, C) and the floor. If only one type of wall is used then a value of “0” or blank should be entered for two of the wall types.

A message is shown saying “Total Height does not match Building Height” if the sum of the wall heights does not match the building height entered above.

There is a limitation of having a maximum ceiling height of 100’.



2.7.2 Windows

The area (ft²) and R-Value of any windows in the ceiling or respective wall types is input into the table.

2.7.3 Doors

The area (ft²) and R-Value of any doors in the ceiling or respective wall types is input into the table.

2.8 Cold Weather Ventilation

Enter the ventilation rates for:

- Mechanical Ventilation (cfm): the air exchange provided by mechanical means such as exhaust fans or air handlers in cubic feet per minute.
- Passive Ventilation (ACH): the air exchange provided by natural means such as infiltration through open windows, doorways, or building leakage. A default value of 0.2 is used.

2.9 Utility Cost

The natural gas and electricity unit costs are pre-populated from the ETools project file. These values must be entered if using the standalone version.

3.0 ANNUAL SAVINGS

The annual savings are shown on an energy, utility, and dollar basis for the system shown. Heating utility energy savings are available due to more uniform temperature profiles along the building height and a reduction of ceiling temperatures. Calculations are included in the Destratification / Reference Documentation.



USER MANUAL

INFRARED SAVINGS, V1.07

August 01, 2008



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1.0 INTRODUCTION

The Infrared Savings Tool is used to evaluate energy savings for low and high intensity infrared heating systems versus non-infrared heating. The calculated savings are estimates only. Actual savings will vary depending on a multiple of factors including: insulation values, building leakage, ceiling height, building air volume, system design/layout, control strategy, building usage, etc.. The user can opt to conduct separate independent studies on actual savings.

Low intensity source temperatures range from 300 to 1200F.

High intensity source temperatures range from 1800 to 5000F.

2.0 HEAT SYSTEM DATA

2.1 Facility Type

Enter whether the heating system in the facility is New or Retrofit

2.2 Location

Select the location of the facility from one of:

- Toronto
- Ottawa
- Niagara
- Fredericton
- Moncton

The design heat loss must be changed respective to the location.

2.3 Design Heat Loss (Btu/h)

Enter the design heat loss of the facility in Btu/hr. It is the responsibility of the user to ensure the Design Heat Loss corresponds reasonably with the heater sizing and location.

Calculations involving the heat loss values use BIN numbers for the respective locations. Due to the lack of BIN numbers for the Niagara region, a percentage value of 90.04% is used versus the Toronto values since this is the difference in 18C heating degree hour values.

2.4 Forced Air / Old System Efficiency

If a New facility is being analyzed then select the Forced Air system combustion efficiency that will be used for comparing the infrared system.

If an Existing facility is being analyzed then select the existing or old system combustion efficiency.

2.5 Outside Temperature When Heating Starts (F)

Many buildings have internal sources of heat that maintain building temperatures during moderate cold outdoor temperatures. Enter the outside temperature when the heating system generally starts.

2.6 Heat Application

Select whether the heating system is a “Space” or “Spot” type heating application. Space heating refers to continuous 24 hours per day heating. This would be generally thermostatically controlled. Spot heat refers to heat directed to specific areas. Heaters are usually manually controlled on/off. Examples include: ice rink stands, horse riding arenas, other non-essential areas or zones for temporary heat. A Spot application allows input for the number of hours per day that the heating system is required and calculations are prorated depending on this time of use.

2.7 Heater Information

Up to 5 types of heating systems can be included in the analysis. Inputs are identical for each system.

Htrs: Enter the numbers of heaters.

Make: Select a manufacturer from the list. Note that the list of heat manufacturers may not be complete. The user is to verify heater specifications.

Model: Select a model from the list. Note that the list of heat models may not be complete. The user is to verify heater specifications.

Input Btu/h: Enter the Input in Btu/h for each selected heating system.

Efficiency %: Enter the Combustion Efficiency in % for each selected infrared heating system.

Output (Btu/hr): This is a calculated value of the selected heating system output.

Intensity – Energy Savings Option: Select the Intensity – Energy Savings Option for each selected heating system from the dropdown list of:

- ☐ None
- ☐ Low – 2 Stage
- ☐ Low - Condensing
- ☐ High – Energy Efficient

High intensity – Energy Efficient heaters to have a minimum of 65% infrared efficiency.

Total Output (Btu/h): Shows the total output of the selected heating system. A combined Total System Output is also shown.

I.R. Reduction (Btu/h): Shows the calculated rate of energy reduction for all selected infrared heating systems.

Net Required IR System Output (Btu/hr): Shows the calculated rate of output for all selected infrared heating systems.

2.8 Average Gas Cost (\$/m3):

Enter the cost of natural gas. This includes all commodity, transportation, and delivery charges.

2.9 Incentive Rate (\$/m3):

Enter the incentive rate for the customer.

2.10 Installed New/Retrofit System Cost (\$):

Enter the new or retrofit system cost. This is used to determine system payback.

3.0 PROGRAM OUTPUTS

3.1 Total Estimated Annual Gas Use for Non-IR System:

Shows the total calculated annual gas use for a non-infrared system in m³.

3.2 Total Estimated Annual Gas Savings for IR System:

Shows the total calculated annual gas savings for the selected infrared heating systems in m³.

3.3 Total Estimated Annual Dollar Savings for IR System:

Shows the total calculated annual savings for the infrared system in dollars.

3.4 Calculated Incentive (\$):

Shows the calculated incentive for the selected infrared heating systems.

3.5 Payback (Years):

Shows the calculated payback of the selected infrared heating systems versus a non-infrared system.



USER MANUAL

NORMALIZE DATA, V1.07

Jan 01, 2008



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1.0 INTRODUCTION

The Normalize Data Tool takes the actual billing data and normalizes the non-seasonal load portion versus 30 yr average heating degree days.

2.0 BALANCE POINT

The balance point adjusts the temperature for calculating heating degree-days (HDD). This temperature is compared to daily outdoor temperature data during the billing period. Heating degree-days equal the sum of all outdoor temperatures below the balance point during the billing period.

BR: Balance Point guidelines are as follows:

▪ MultiRes	18 Deg. C
▪ Schools	18 Deg. C
▪ Office & Commercial	18 Deg. C
▪ Warehouses	10 - 17 Deg. C
▪ All others	18 Deg. C

3.0 MONTHLY DATA

A maximum of 48 months of customer consumption data will be loaded from ESM

**BR: A minimum of 12 months of customer consumption data is required to run E-Tools.
The 12 months selection should be the most recent.**

3.1 DHW (CheckBoxes)

Select which months have only Domestic Hot Water (or Base Load). If all boxes are unchecked, then the gas consumption readings for July, August, and September are used to determine the average daily base load. Otherwise, only the selected months are used to determine the average daily base load.

If the Bill Date for the first month is prior to the 15th of the month then the previous month is shown for the DHW selector as well as for the Normalized graph. The following 11 months are the sequential months after the first month. They are not based on the billing month.

All values including HDD for Normalization are based of the month shown rather than the Bill Date month.

3.2 Reading Date (MM/DD/YYYY)

Using the spinner buttons the user can select the 12 months of consumption that satisfies all of the conditions itemized below and where the r-squared is the highest. Only 12 months of data can be viewed and normalized at one time.

There are several conditions that must be satisfied when selecting the reading date:

1. The Number of Days in the 12 months of billing period must be equal or higher than 355 days.
2. The Number of Days in the 12 months of billing period must be equal or lower than 375 days.
3. The r-squared value of the straight line correlation of actual gas bill consumption versus HDD/day (shown in the Baseline Consumption graph) must be equal or greater than 0.80 .
4. There must be 12 separate months shown for the Reading Dates. For example: a 12 month period having reading dates of 11/02/2000 and 11/29/2000 cannot be used. This condition also determines if any month does not include gas consumption data.

If any of the conditions are not satisfied then the message “CHANGE DATE” is shown above Reading Date.

The condition that is not satisfied is shown in the “Date Selection Criteria [Value]” box on the right. For example: if the number of days in the 12 month billing periods is 351 then the message “Billing Days < 355 [351]” is shown.

3.3 Billing Period

The numbers of days covered in the current billing period are found on the gas bill.

3.4 HDD (Heating Degree Days)

Do not rely on the HDD as seen on the gas bill, these numbers are based on 18°C. If the balance point temperature selected is different, *the program will* make the necessary adjustments.

3.5 Gas Consumption (m3)

The volume of gas is found on the gas bill.

3.6 Base Load (m3)

The average daily base load as calculated from the DHW Checkboxes for the selected months is used to determine the flat line average monthly base load for the entire year.

BR: Flat line base load consumption will be used.

3.7 Actual Seasonal Load (m3)

The actual seasonal load is the calculated difference between actual gas consumption and baseload.

4.0 TOTAL ANNUAL CONSUMPTION

4.1 Seasonal

The calculated annual 30-year average gas use of the total, seasonal and non-seasonal loads. This is calculated using the percentages as shown in the reference documentation.

4.2 Non-Seasonal

DHW:

If loads are input by the user for cooking and other uses, the DHW value is adjusted accordingly.

Cooking:

The user can specify an average monthly gas-cooking load

Other:

The user may input an average monthly consumption value for other significant loads.

5.0 BASELINE CONSUMPTION (GRAPH)

The baseline consumption graph compares actual consumption by Heating Degree-Days and selects the straight line of best fit. If the r^2 is less than 0.80, the user should select another time period that is closer to a 'normal' year.

6.0 NORMALIZED NATURAL GAS CONSUMPTION (GRAPH)

A graph comparing actual gas consumption, baseload and normalized 30-year average load are plotted for the selected time period.



E-TOOL PROGRAMS

USER MANUAL

PIPE / SURFACE INSULATION, V1.07

August 01, 2008



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1.0 INTRODUCTION

The Pipe & Surface Insulation Savings Tool estimates a potential savings of insulating or re-insulating in a new or retrofit heating system. The program calculates the heat loss that would occur with new insulation and with existing or no insulation applied. These heat loss values are converted into a gas loss which are compared to estimate the potential savings and payback

2.0 USING THE PROGRAM

The program inputs are separated into 3 categories:

- 1) Site & System Inputs
- 2) Heating Pipes Table
- 3) Flat Surfaces Table

2.1 Entering Site & System Data

Imperial or Metric Units

Choose from the drop-down list which units (Imperial or Metric) you prefer to use for entering the piping and flat surface information.

Facility

Choose from the drop-down list which type of facility (Retrofit or New) you are modeling.

Location

Choose from the drop-down list which location applies (Toronto, Ottawa, Moncton, Fredericton). The program uses ambient temperature data called BIN numbers, for the location selected where outdoor piping and/or flat surfaces exist. BIN numbers represent an average number of hours each year within a temperature range, which were recorded from the past 25-years. Choose the location which is closest if none of the locations apply,.

Boiler Type

Choose from the drop-down list which boiler type applies (Hot Water or Steam).

Boiler System Efficiency

Enter the system efficiency of the boiler and heating system.

Existing Insulation Condition

Choose from the drop-down the condition of the existing insulation for a retrofit facility. The program arbitrarily reduces the effectiveness of existing insulation by 10% for excellent condition, 25% for good condition, 40% for fair condition and 60% for poor condition.

Average Months Annual Use

Enter the average number of months the system is in use. A value is necessary only where the analysis involves outdoor piping.

Annual Gas Usage (m³)

Enter the estimated total annual gas use in m³. One m³ of natural gas is approximately 35,310 Btu.

Average Gas Cost/m³

Enter the average price of natural (\$/m³).

Incentive Rate/m³

Enter the incentive rate (\$/m³), if an incentive will be applied.

Lump Sum Capital Cost

You may enter a single lump sum capital cost for the upgrade in the space provided or enter unit costs of materials and labour in the Heating Pipes and Flat Surface tables below.

2.2 Heating Pipes Table

Piping with the same properties can be entered in one of the 9 rows provided. Row #10 is used only for pipe fittings. If any of the properties are different (eg. pipe diameter, type of existing insulation, insulation thickness), you must enter that pipe information into a new row.

Enter in the following information for each pipe:

Description

Use a suitable description for each pipe. This is for your own reference.

Annual Hours of Use

Estimate the number of hours the pipe is used per year. There are 168 h/wk, 8760 h/yr.

Avg Steam/Water Temp

Estimate the temperature of the steam/water that flows inside the pipe.

Avg Amb. Temp

For indoor piping, use an average air temperature for that zone. If the pipe is outdoors, this can be left blank since BIN numbers will then be applied.

Wind Speed

Enter a wind speed in mph. For indoor piping, enter a value of 0. If the pipe is outdoors, a value greater than 0 must be entered for wind speed. A reminder is shown if you click on the blue Wind Speed button that says “Enter a Wind Speed of 0 for Indoor Piping”. The typical range in annual average wind speeds for these locations is 5 to 15 mph. A value of 10 mph is common.

Length of Pipe

Measure and enter the total length of pipe.

Pipe Material

To enter a pipe material select the *Pipe Material* button. If the cursor is not located in a cell under the *Pipe Material* column a message will pop up that says “Your Selection Is Outside Of Required Range”. A menu is shown displaying piping materials (steel, copper, polyethylene, and PVC). Select the pipe material that applies and close the menu by clicking on the “X” in the top-right corner of the form.

Nominal Dia.

Measure and enter the nominal outside diameter of pipe. If existing insulation is in place, estimate to the best of your ability the diameter.

Exist Insulation Thickness

Estimate the thickness of the existing insulation that is used. If no insulation is used enter “0”.

k-value Existing

To enter thermal conductivity (k-value) for the existing insulation, select the *k-Value Existing* button. If the cursor is not located in a cell under the *k-Value* column a message will pop up that says “Your Selection Is Outside Of Required Range”. A menu is shown displaying types of insulation (Fiberglass Pipe Wrap, 850F Mineral Fiber Pipe, etc...). Select the insulation that applies and close the menu by clicking on the “X” in the top-right corner of the form. The k-value for the insulation chosen will be shown in the cell.

New Insulation Thickness

Enter the thickness of the new insulation.

k-value New

To enter a k-value for the new insulation, select the *k-Value New* button. If the cursor is not located in a cell under the *k-Value* column a message will pop up that says “Your Selection Is Outside Of Required Range”. A menu is shown displaying types of insulation (Fiberglass Pipe Wrap, 850F Mineral Fiber Pipe, etc...). Select the insulation that applies and close the menu by clicking on the “X” in the top-right corner. A k-value for the insulation chosen will be shown in the cell.

Capital Cost per Unit Length

Estimate the capital costs for material and labour per unit length new insulated pipe. These columns can be ignored, if you entered a lump sum capital cost above.

Fittings

To enter pipe fitting information into the program, go to row #10 in the Heating Pipes Table and follow these steps:

- 1) Enter the diameter of the pipe where the arrow is pointing.
- 2) Click on the Fittings button located in row #10 under the description column.
- 3) Enter the number of each fitting that exists in the system.
- 4) Click on the red “Return to Program” button in top-right corner. The program calculates the equivalent length of pipe and enters it into the Length of Pipe column.
- 5) Continue to enter the other information in that row.
- 6) If more fittings with different properties (eg. diameter or pipe material) need to be entered, the current fitting information in row #10 must be manually cut and paste into an above row. Repeat steps 1-5.

2.3 Flat Surfaces Table

Flat Surfaces with the same properties can be entered in one of the 5 rows provided. If any of the properties are different (eg. surface material, type of existing insulation, insulation thickness), you must enter that flat surface information into a new row. The calculations assume the existing surface is uninsulated.

Enter in the following information for each flat surface:

Description

Use a suitable description for each flat surface. This is for your own reference.

Annual Hours of Use

Estimate the number of hours the flat surface is used per year. There are 168 h/wk, 8760 h/yr.

Length and Width

Measure the dimensions of the flat surface and enter Length and Width.

Cold and Warm Side Temp

Estimate the average temperature of each side of the flat surface. If the cold side is outdoor, it can be left blank since the BIN numbers will be applied.

Wind Speed

For indoor flat surfaces, enter a value of 0. If the flat surface is outdoor, a value greater than 0 must be entered for wind speed. A reminder is shown if you click on the green Wind Speed button that says “Enter a Wind Speed of 0 for Indoor Piping”. The typical range in annual average wind speeds for these locations is 5 to 15 mph. A value of 10 mph is common.

Surface Material

To enter a surface material select the green surface material button. If you are not located in a cell under the Surface Material column a message will pop up that says “Your Selection Is Outside Of Required Range”. A menu pops up displaying the following materials: steel, copper, polyethylene, and PVC. Select the surface material that applies and close the menu by clicking on the “X” in the top-right corner.

Thickness of Surface

Measure or estimate the thickness of the hot surface.

Insulation Thickness

Enter the thickness of the new insulation.

k-value New

To enter a k-value for the new insulation, select the *k-Value New* button. If the cursor is not located in a cell under the *k-Value* column a message will pop up that says “Your Selection Is Outside Of Required Range”. A menu is shown displaying types of insulation (Fiberglass Pipe Wrap, 850F Mineral Fiber Pipe, etc...). Select the insulation that applies and close the menu by clicking on the “X” in the top-right corner. A k-value for the insulation chosen will be shown in the cell.

Capital Cost per Unit Length

Estimate the capital costs for material and labour per square foot or square metre of new insulated surface. These columns can be ignored, if you entered a lump sum capital cost above.



USER MANUAL

VFD ETool V1.07

August 01, 2008



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1.0 INTRODUCTION

The VFD Calculations Tool is used in both the VFD ETools as well as the Ventilation ETools program. The calculations are done to determine the electrical savings by use of a VFD controlled motor or pump versus a non-VFD motor with possible use of an inlet or outlet method of control. The background calculations are identical for both the Standalone and Ventilation Tool, however, the interface is slightly different.

The main differences are that the Ventilation Tool:

- does not include an application for pumps.
- the user enters input variables by selecting the ‘Electrical Variables’ button.
- the Duty Cycle is determined through the Peak and Partial supply scheduling rather than distinctly through a Duty Cycle %.

Other notable differences are indicated throughout this document.

2.0 PROGRAM METHOD

Calculations are done based the user inputs. A flow chart outlining the program methodology is included in the Appendices. All calculations and inputs are done using Imperial equations.

2.1 Project Information

The user must manually enter project information into the standalone program. The Ventilation ETool has this information automatically generated from the Main ETool.

2.2 System Description

2.2.1 Application

The application; Fan or Pump is selected.

2.2.2 Existing

The existing system control method is selected for either a fan or pump system. These include:

- No Control
- Outlet Damper (fan)
- Inlet Vane (fan)
- Throttling Valve (pump)

The selection is only available for the respective motor application.

2.2.3 Proposed

The proposed system control method of VFD is selected. If 'No Control' is selected then 0 savings are calculated.

2.2.4 Efficiency

The efficiency of the VFD [default 97%] and Motor [default 85%] can be input by the user or choose the default efficiencies.

2.2.5 Electrical & Project Cost

Enter the electrical & project cost of the project. The Ventilation ETool has this information automatically generated from the Main ETool.

2.3 Power/Flow Parameters

In determining the electrical savings opportunities for an air handler in either the Ventilation/MUA/AHU or VFD ETools, the ESC should use the following procedure prioritized as shown:

1. Motor Horsepower: If the nameplate horsepower is available for the unit then the ESC should input this value.
2. Airflow & Pressure: If the motor horsepower is unknown or unavailable then the ESC should input the Total External Static Pressure of the unit. This is available either from the original specifications of the unit or through an air balance of the unit. When using the VFD ETool then the air handler airflow in CFM is also required.
3. Baseline Brake Horsepower: This procedure is defined in ASHRAE Standard 90.1-2004, Table G3.1.2.9 and is the Baseline Fan Brake Horsepower to be used for defining improved performance. This method is only to be used if information for #1 or #2 are unavailable. A selection has been added to allow calculation for either Constant Volume or Variable Volume systems. A filtration credit for HEPA filters (using a static pressure drop of 1.37" w.c.) has also been included (Ref: Trane literature for HEPA 99.97 DOP, clean, 500 fpm face velocity).

2.3.1 Select Calculation Option

Select either Motor / Airflow / Pump / Baseline Brake Horsepower. Only Motor, Airflow or Brake Horsepower may be selected if a Fan Application is chosen and only Motor or Pump may be selected if a Pump Application is chosen.

2.3.1.1 MOTOR

Use this option if the airflow or pump flow is unknown. Enter the Nameplate HP and Motor Loading (default 85%) of the motor. The Shaft (or Brake) HP for the motor is calculated.

2.3.1.2 AIRFLOW

Use this option for a fan if the required airflow parameters are known; airflow (cfm), total external pressure increase, and fan efficiency (default 70%). The Shaft (or Brake) HP for the motor is calculated.

2.3.1.3 PUMP

Use this option for a pump if the required fluid flow parameters are known; flow (gpm), head (ft.), specific gravity (default = 1), pump efficiency (default 70%). The Shaft (or Brake) HP for the motor is calculated.

2.3.1.4 BASELINE BRAKE HORSEPOWER

Use this option for a fan if the motor hp or fan total external pressure drop is unknown and as prioritized above. Input the airflow (cfm), HEPA filtration is used, and the system volume (constant or variable). The Shaft (or Brake) HP for the motor is calculated.

2.4 Duty Cycle

Enter the ‘Annual Hours of Operation’ as well as the percentage of ‘Time’ that the application is operating at each respective flow. A Duty Cycle name can be entered beside “Duty Cycle:”.

The operating hours per year are calculated for each flow from the Annual Hours of Operation times the % Time. The shaft HP as well as the operating cost at the respective airflows or pump flows are shown.

This develops the Duty Cycle profile of the application. Duty Cycles can be saved. Pre-saved Duty Cycles can be imported.

2.4.1 Total Electrical Consumption

The total electrical consumption is calculated and shown for both the existing control (before retrofit) and the proposed VFD control (after retrofit).

2.4.1.1 EXISTING CONTROL (BEFORE RETROFIT)

The sum of the electrical consumption for the existing control is shown.

2.4.1.2 PROPOSED CONTROL (AFTER RETROFIT)

The sum of the electrical consumption for the VFD control is shown.

2.4.2 Electrical Savings

2.4.2.1 ENERGY (KWH)

The electrical energy savings results from the difference of energy before and after retrofit. The electrical energy savings for the Ventilation ETool calculates the savings the same as above with the following exceptions:

- a) the minimum airflow for the duty cycle is 20% even if the Peak or Partial Supply is lowered more than 20% with the exception of part b) below.
- b) if the Peak or Partial Supply is set at 0% than the electrical energy savings for that period is the difference between the control system operating at 100% and being turned off. This provides electrical energy savings the same as if the motor was turned off for that period (schedule savings).

2.4.2.2 DEMAND (KW)

The kW savings is the product of the electrical demand @ 100% and the differences of the control factors of the existing and proposed systems.

2.4.2.3 SAVINGS (\$)

The electrical energy savings in dollars is the product of the electrical energy savings from above and the Electrical Cost as input in the System Description.

2.4.3 Simple Payback (yrs)

The Simple Payback is the Project Cost as input in the System Description divided by the Electrical \$ Savings from above.