SOLAR THERMAL '11
National Solar Heating & Cooling Conference

BTU METERS and the MEASUREMENT

SOLAR CONFERENCE 2011

DEC 1-2,2011 MILWAUKEE , WI

PRESENTED BY :

LOUIS FRIAS

-IMC INSTRUMENTS – PRESIDENT

BACKROUND

SCHOOLASTIC
AERONAUTICAL, MECHANICAL, ELECTRONICS

WORK EXPERIENCE
HVAC DESIGNER-CONSULTANT, HEATRANSFER, ENERGETICS
SR PRODUCT ENGINEER PNEUMATIC-ELECTRONIC CONTROLS
INSTRUMENTATION ENGINEER, FLUID FLOW, HUMIDITY, TEMPERATURE
MICROPROCESSOR EMBEDED CONTROLS AND MONITORS

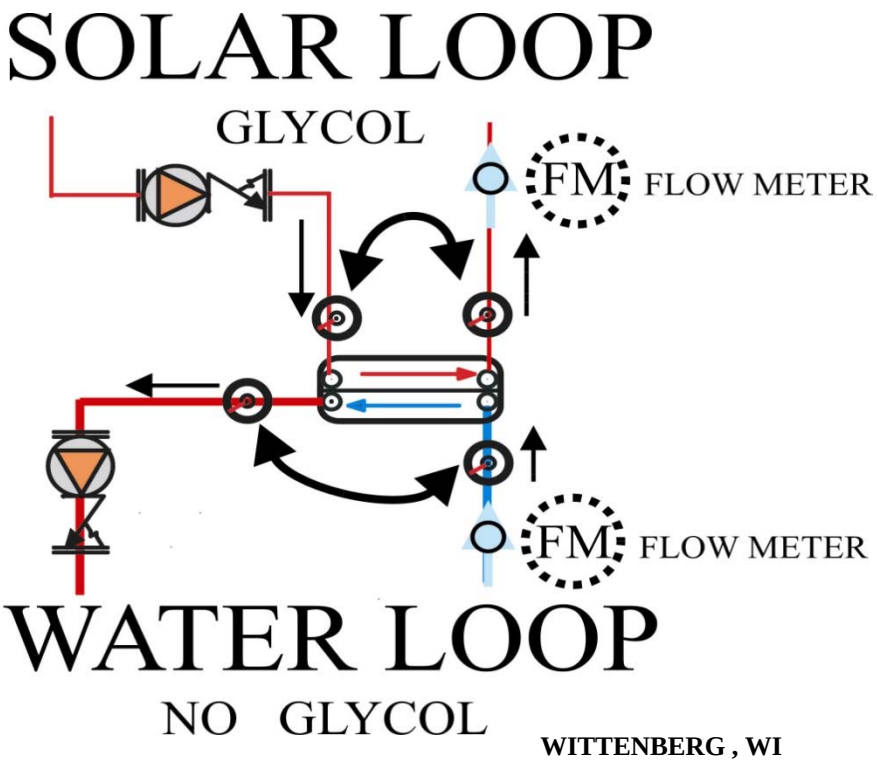
THE MEASUREMENT

INSTRUMENTATION NEEDED

FLOW METER

PRECISION TEMPERATURE SENSORS

ENERGY COMPUTER
and SOLAR CONTROLLER



WITTENBERG , WI

REFERENCE EUROPEAN STANDARD

Heat meters

Part 1: General requirements

OIML R 75-1 **..... ACCURACY REQUIREMENTS**

Edition 2002 (E)

INTERNATIONAL

RECOMMENDATION

Heat meters

Part 2: Type approval tests and initial verification tests

OIML R 75-2 **.....ACCURACY TESTS**

Edition 2002 (E)

INTERNATIONAL

RECOMMENDATION

Heat meters

Part 3: Test Report Format

OIML R 75-3 **.....TEST REPORTS**

Edition 2006 (E)

INTERNATIONAL

RECOMMENDATION

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SAMPLE CALCULATIONS.....

INTERNATIONAL RECOMMENDATION - > PG16

OIML R 75-1 Edition 2002 (E)

Annex A - Heat coefficient equations (Mandatory)

For the determination of heat exchanged in an exchange circuit, heat meters shall take the type of heat conveying liquid (generally water) into account by means of the heat coefficient $k(p, Q_f, Q_r)$. The heat coefficient is a function of the measurable physical quantities pressure p, flow temperature Q_f and return temperature Q_r, and satisfies equation A.1.

Heat coefficient for water (A.1)

$k(p, Q_f, Q_r) = 1/\nu\ (h_f - h_r / (Q_f - Q_r)$ (A.1)

where ν is the specific volume, h_f, h_r are the specific enthalpies (f-flow; r-return). The quantities ν, h_f and h_r can be calculated according to *The Industrial Standard for the Thermodynamic Properties of Water and Steam* (IAPWS-IF 97) using the International Temperature Scale of 1990 (ITS-90).

Specific volume $\nu = (dg / dp)_T$ $\nu(p, t) = p/RT = \pi g_\pi$ (A.2)

where g is the specific Gibbs free energy and

$\pi = p / p^*$ with $p^* = 16.53$ MPa

$$g_\pi = \sum_{i=1}^{34} n_i I_i (7.1 - \pi)^{I_i - 1} (\tau - 1.222)^{J_i} \quad \text{(A.3)}$$

For the figures of n_i, I_i and J_i see Table 1.

Specific enthalpy $h = g - T(dg / dT)_p$; $= \tau g_\tau$ (A.4)

where $\tau = T^* / T$ and $T^* = 1386$ K

$$g_\tau = \sum_{i=1}^{34} n_i (7.1 - \pi)^{I_i} J_i (\tau - 1.222)^{J_i - 1} \quad \text{(A.5)}$$

with 273.15 K £ T £ 623.15 K; $p_s(T)$ £ p £ 100 MPa and $R = 461.526$ J×kg^{-1}×K^{-1}

with $p_s(T)$: saturation pressure

For the figures of n_i, I_i and J_i see Table 1.

Table 1 Coefficients and exponents of equations (A.3) and (A.5)

i	Ii	Ji	ni	i	Ii	Ji	ni
1	0	−2	0.146 329 712 131 67	18	2	3	−0.441 418 453 308 46x10−5
2	0	−1	−0.845 481 871 691 14	19	2	17	−0.726 949 962 975 94x10−15
3	0	0	−0.375 636 036 720 40x101	20	3	−4	−0.316 796 448 450 54x10−4
4	0	1	0.338 551 691 683 85x101	21	3	0	−0.282 707 979 853 12x10−5
5	0	2	−0.957 919 633 878 72x	22	3	6	−0.852 051 281 201 03x10−9
6	0	3	0.157 720 385 132 28	23	4	−5	−0.224 252 819 080 00x10−5
7	0	4	−0.166 164 171 995 01x10−1	24	4	−2	−0.651 712 228 956 01x10−6
8	0	5	0.812 146 299 835 68x10−3	25	4	10	−0.143 417 299 379 24x10−12
9	1	−9	0.283 190 801 238 04x10−3	26	5	−8	−0.405 169 968 601 17x10−6
10	1	−7	−0.607 063 015 658 74x10−3	27	8	−11	−0.127 343 017 416 41x10−8
11	1	−1	−0.189 900 682 184 19x10−1	28	8	−6	−0.174 248 712 306 34x10−9
12	1	0	−0.325 297 487 705 05x10−1	29	21	−29	−0.687 621 312 955 31x10−18
13	1	1	−0.218 417 171 754 14x10−1	30	23	−31	0.144 783 078 285 21x10−19
14	1	3	−0.528 383 579 699 30x10−4	31	29	−38	0.263 357 816 627 95x10−22
15	2	−3	−0.471 843 210 732 67x10−3	32	30	−39	−0.119 476 226 400 71x10−22
16	2	0	−0.300 017 807 930 26x10−3	33	31	−40	0.182 280 945 814 04x10−23
17	2	1	0.476 613 939 069 87x10−4	34	32	−41	−0.935 370 872 924 58x10−25

	Flow position	Return position
Specific volume in (m3/kg)	0.102204×10-2	0.100370×10-2
Specific enthalpyflow in (kJ/kg)	0.294301×103	0.294301×103
Specific enthalpyreturn in (kJ/kg)	0.127200×103	0.127200×103

Heat coefficient in (MJ/(m3 K)) 4.0874 4.1621 or analogous to

BTU/(FT^3-F)

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ENTHALPY

BASIC definition

ENTHALPY= PV(FLOW WORK) +Ui (INTERNAL ENERGY)

For this analysis the PV term is considered to be ZERO because water and Glycol are basically incompressible and their DENSITIES and SPECIFIC HEATS exhibit extremely small changes as a function of PRESSURE..... Thus the term that remains is U(internals energy) as follows:

$$U = C_p \times M \times (T2-T1)$$

Where M =mass, T =temperature and
C_p is specific Heat (at constant pressure)

expressed in BTU/LB-F

Because most flow meters are of the VOLUMETRIC TYPE the following formula is suggested for ease of use

=> **Q = K x Delta-T x GPM**

Btu/Hr = (E/GPM-F) x (Temp Rise) x Gals/min

K thus is a function "SpHt" and "Density" which in turn are a function of TEMPERATURE, and GLYCOL concentration. They must be evaluated at FILM TEMPERATURS for the given concentration and type of GLYCOL each time the calculation is performed.

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THE BASIC EQUATION

Published Properties of Water at 68F > SPHt =.999 Btu/Lbm-F ,

Dens =62.32 Lbm/Ft^3 .....

Product = **62.26Btu/Ft^3 –F** known as Heat / Unit volume/ Deg F

Thus E/GPM-F =.13368 Ft^3/G x 62.26 Btu/Ft^3 x 60 G/Hr / G/Min =

K= 499.38 Btu/Hr-GPM-F

The Final Equation

E/Hr => **BTU_HR = K x Del-T x GPM**

Btu/Hr = (E/GPM-F) x (Temp Rise) x GPM

DEALING WITH CHANGING DENSITY AND SPECIFIC HEAT

For WATER...

Temp F	density Lbm/Ft^3	specific HT Btu/Lbm-F	product Btu/Ft^3-F	
68F	62.32	.999	62.26	<< Standard Conditions NIST
100F	61.99	.997	61.80	
150F	61.20	.999	60.14	
200F	60.13	1.004	60.37	.... change is 3.1 % from NIST

For PROP GLY Dow Frost-HD

Temp F	density Lbm/Ft^3	specific HT Btu/Lbm-F	product Btu/Ft^3-F	
70F	66.14	.812	53.70	<< *** Standard Conditions
100F	65.52	.830	54.38	
150F	64.32	.860	55.32	
200F	62.91	.890	55.99	.... change is 4.2 % from ST

OR .... 15.94% lower than for a WATER only system !!!!!

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Some additional information on PROPYLENE GLYCOL ...

Propylene Glycol is available in bulk form from major suppliers such as Dow Corning and so on in near pure form at 99.6% purity. In order to enhance its properties for use in HIGH TEMPERATURE SOLAR applications it is formulated with additives and reduced in concentration down to roughly 94% -96 %. The additives normally consists of a proprietary formulation that alters considerably all the mechanical and thermal properties of the new mixture such as its Density and Specific Heat. The new properties allow some P. Glycols to operate safely at temperatures up the 325F continuously which has been mandated by many state agencies such as in Wisconsin.

The two P. Glycols that we have characterized for use with Energy meters are :

DOW FROST – HD by the DOW Chemical Co.

NOBURST- HD by the NOBLE Co.

IMPORTANT REQUIREMENTS for TRACEABLE ACCURACY

1) The physical constants of the fluid including Propylene Glycol mixtures must be known and obtained by a certified LABORATORY using traceable methology .. ASTM, ASHRAE, ASME, NIST.
2) The temperature measurement must be done with certified temperature sensors of known accuracy NIST TRACEABLE
3) The Flow measurement must be done with certified FLOW METERS of know accuracy and traceable to ASTM, ASHRAE, ASME, NIST.
4) The Energy computations must all be done using all the above recommendations and .... in often intervals with newly acquired data and newly evaluated physical fluid constants.

Focus on Energy Solar Hot Water Program - Glycol Comparative Overview — Updated 4/2/09

Note: If the recipe shows a 50/50 mix (1 part water: 1 part glycol) you actually need to add another pint of glycol per gallon of water to achieve the 53% mix for -28 no slush

Manufacturer	Product Name	Concentration	Inhibitors	pH	Temp. Rating	100% Vol Frz Prot	Color	Recipe to meet Focus -28°F Freeze Protection	Remarks
Chemical Specialties	Enviro-Frost	75%	Note 1	9.0 - 10.0	370° F	-50° F	Red	1 part water : 3 parts glycol	
Chemical Specialties	Enviro-Frost Plus	98%	Note 2	9.0 - 10.0	370° F	-50° F	Purple	1 part water : 1 part glycol	
Chemical Specialties	PGI	95%	Note 1	9.5 - 10.0	370° F	<-60° F	Clear	1 part water : 1 part glycol	
Chemical Specialties	PGI-Heavy Duty	94%	Note 1	9.5 - 10.0	350° F	<-60° F	Brt Yellow	1 part water : 1 part glycol	
Chemical Specialties	PG Aluminum Safe	40.0%	-	-	-	-7° F		too dilute - DO NOT USE	
Dow Chemical	DOWFROST	94%	Note 1	9.0 - 10.0	250° F	<-60° F	Clear	Temp rating - DO NOT USE	
Dow Chemical	DOWFROST HD	94%	Note 1	9.5 - 10.5	320° F	<-60° F	Yellow	1 part water : 1 part glycol	pH and freeze point of 50/50 solution
Dow Chemical	DOWTHERM	ETHYLENE	-	-	-	-		ETHYLENE - DO NOT USE	
Hercules Chemical Co	Cryo-tek-AG	96%	Note 1	9.5 - 9.5	370° F	-70° F	Blue	1 part water : 1 part glycol	Not recommended for evacuated Tube collectors
Hercules Chemical Co	***Cryo-tek 100***	70%	Note 1	9.5 - 10.0	230° F	-70° F	Pink	Temp rating - DO NOT USE	Not recommended for evacuated Tube collectors
Hercules Chemical Co	***Cryo-tek-AL (Note 4)***		Note 1	7 - 8.5	230° F	-60° F	Orange	Temp rating - DO NOT USE	Not recommended for evacuated Tube collectors
Hercules Chemical Co	Cryo-tek Original	45% (approx)	-	-	-	-22° F	Blue	too dilute - DO NOT USE	
Noble Company	NOBURST -100	70%	Note 1	9	370° F	-50° F	Pink	1 part water : 3 parts glycol	
Noble Company	NOBURST AL (note 4)	65-75%	Note 3	8.3	270° F	-60° F	Orange	Temp rating - DO NOT USE	
Noble Company	NOBURST HD	96%	Note 1	8-12	370° F	-60° F	Pink	1 part water : 1 part glycol	
Noble Company	Super NOBURST	96%	Note 1	9	370° F	<-60° F	Pink	1 part water : 1 part glycol	
Nu-Calgon	Freez-Kontr'l	80.0%			325° F	-60° F	Blue	1 parts water : 3 parts glycol	
Nu-Calgon	Burst-Kontr'l AP	40% premix	-	-	-	-10° F	Lt Blu	too dilute - DO NOT USE	
Nu-Calgon	Freez-Therm	ETHYLENE	-	-	-	-	-	ETHYLENE - DO NOT USE	
Nu-Calgon	Special Caleffi Glycol	40% premix	-	-	-	-	-	too dilute - DO NOT USE	
Old World Industries	Sierra	96%	not listed	10.5	Note 5	<-60° F	Green	1 part water : 1 part glycol	
Wausau Chemical	Burst Proof	70%	Note 1			<-60° F		1 part water : 3 parts glycol	
Wausau Chemical	HTF-PG	95.5%	Note 1		250° F	<-60° F	see remark	Temp rating - DO NOT USE	HTF-PG-ND (colorless) or HTF-PG-DY (green)
Wausau Chemical	HTF-PG-HD	94%	Note 1		325° F	<-60° F	Brt Yellow	1 part water : 1 part glycol	
Wausau Chemical	HTF-EG	ETHYLENE	-	-	-	-	-	ETHYLENE - DO NOT USE	

Note 1	Inhibitor generally found in glycols is Dipotassium Phosphate
Note 2	EDT A, Na Metasilicate, Methylene Phoshonic, Tolytiazole
Note 3	2-ethylhexanoic acid, Na hydroxide, Na tolytriazole, Na nitrate
Note 4	The AL designation in the name usually signifies that the product is formulated specially for Aluminum system components. MOST ARE NOT!!!
Note 5	Although the max temperature rating on this is not published, it is designed to be used in internal combustion engines, so it should be o.k. for solar

Company Contact information:

Chemical Specialties	www.chemicalspec.com	one Distributor in North Central Midwest in Edina, MN = JL Sonntag, 952-933-7768
Dow Chemical	www.dow.com	800-477-4DOW, 4520 Ashman Street, PO Box 1206, Midland, MI 48642, 3 WI Distributors
Hercules Chemical Co	www.herchem.com	800-221-9330, 111 South Street, Passaic, NJ 07055-9100, info@herchem.com
Noble Company	www.noblecompany.com	800-878-5788, PO Box 350, Grand Haven, MI 49417, sales@noblecompany.com
Nu-Calgon	www.nucalgon.com	800-554-5499, 2008 Altom Court, St. Louis, MO 63146, sales@nucalgon.com, widely distributed in WI
Old World Industries	www.sierraantifreeze.com	847-559-2000, 4065 Commercial Ave, Northbrook,IL 60062
Wausau Chemical	www.wausauchemical.com	800-950-6656, 2001 N River Dr, Wausau, WI 54403

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EXAMPLE of TABLES OF PHYSYCAL PROPERTIES FOR P. GLYCOL AT DIFFERENT CONCENTRATIONS

DENSITIES (lb/ft³) OF NOBURST SOLUTIONS

Volume percent of **Noburst-100**

TEMP. °F	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
-30										67.18	67.47
-20									66.74	67.05	67.34
-10									66.63	66.93	67.20
0							65.81	66.18	66.50	66.79	67.05
10						65.30	65.70	66.06	66.37	66.65	66.89
20				64.30	64.77	65.19	65.58	65.92	66.22	66.48	66.72
30			63.68	64.21	64.66	65.07	65.44	65.77	66.06	66.32	66.54
40	62.42	63.04	63.59	64.09	64.54	64.94	65.30	65.62	65.90	66.14	66.35
50	62.38	62.95	63.49	63.98	64.41	64.80	65.15	65.46	65.72	65.96	66.16
60	62.34	62.87	63.38	63.85	64.27	64.65	64.99	65.29	65.54	65.76	65.95
70	62.27	62.77	63.28	63.72	64.12	64.49	64.81	65.10	65.34	65.55	65.73
80	62.19	62.66	63.12	63.58	63.97	64.32	64.63	64.91	65.14	65.34	65.51
90	62.11	62.54	62.99	63.42	63.80	64.14	64.44	64.70	64.92	65.11	65.27
100	62.00	62.41	62.83	63.25	63.62	63.95	64.23	64.49	64.70	64.88	65.03
110	61.84	62.26	62.68	63.08	63.44	63.75	64.02	64.27	64.46	64.63	64.77
120	61.73	62.12	62.51	62.90	63.23	63.54	63.80	64.03	64.22	64.38	64.51
130	61.54	61.94	62.33	62.71	63.03	63.32	63.57	63.79	63.96	64.11	64.23
140	61.39	61.77	62.14	62.50	62.81	63.09	63.33	63.54	63.70	63.84	63.95
150	61.20	61.58	61.94	62.29	62.59	62.85	63.08	63.27	63.43	63.56	63.66
160	61.01	61.38	61.74	62.07	62.35	62.60	62.81	63.00	63.14	63.26	63.35
170	60.79	61.17	61.52	61.84	62.10	62.34	62.54	62.72	62.85	62.96	63.04
180	60.57	60.95	61.29	61.60	61.85	62.07	62.27	62.43	62.55	62.64	62.72
190	60.35	60.73	61.06	61.34	61.58	61.79	61.97	62.12	62.23	62.32	62.39
200	60.13	60.49	60.81	61.08	61.31	61.50	61.67	61.81	61.91	61.99	62.05
210	59.88	60.25	60.56	60.81	61.02	61.20	61.36	61.48	61.58	61.65	61.69
220	59.63	59.99	60.29	60.53	60.72	60.89	61.03	61.15	61.24	61.30	61.33
230	59.38	59.74	60.02	60.24	60.42	60.58	60.71	60.82	60.88	60.93	60.96
240	59.10	59.46	59.73	59.93	60.10	60.25	60.37	60.46	60.52	60.56	60.58
250	58.82	59.18	59.44	59.62	59.78	59.91	60.01	60.10	60.15	60.18	60.19

NBCHARTS 1/03

Noble Company
7300 Enterprise Drive
Spring Lake, MI 49456
Phone 800-878-5788 Fax 231-799-8850
www.noblecompany.com

SPECIFIC HEAT [btu/(lb·°F)] OF NOBURST SOLUTIONS

Volume percent of Noburst-100

TEMP. °F	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
-30										.723	.680
-20									.767	.728	.687
-10									.773	.734	.693
0							.846	.814	.778	.741	.700
10						.879	.850	.819	.784	.747	.707
20				.933	.909	.883	.855	.824	.790	.753	.713
30			.955	.935	.912	.887	.859	.829	.796	.759	.720
40	1.004	.979	.957	.938	.915	.891	.864	.834	.801	.765	.726
50	1.001	.979	.960	.941	.919	.895	.869	.839	.806	.771	.733
60	1.000	.980	.962	.944	.923	.899	.873	.844	.812	.777	.740
70	.999	.982	.964	.947	.926	.903	.878	.849	.817	.783	.746
80	.998	.983	.967	.950	.930	.907	.882	.854	.823	.789	.753
90	.998	.985	.970	.953	.934	.911	.886	.859	.829	.796	.760
100	.998	.986	.972	.956	.937	.915	.891	.865	.835	.802	.766
110	.998	.988	.975	.959	.940	.919	.896	.870	.840	.808	.773
120	.998	.989	.977	.962	.944	.924	.901	.875	.845	.813	.779
130	.999	.991	.979	.965	.947	.927	.905	.880	.851	.820	.786
140	.999	.992	.981	.968	.951	.931	.909	.885	.856	.826	.793
150	1.000	.994	.984	.971	.955	.936	.914	.890	.862	.832	.799
160	1.001	.995	.986	.974	.958	.939	.918	.894	.868	.838	.806
170	1.002	.997	.989	.977	.961	.943	.922	.899	.873	.844	.812
180	1.003	.998	.990	.980	.965	.948	.928	.905	.879	.851	.819
190	1.004	1.000	.993	.983	.968	.951	.932	.910	.884	.856	.826
200	1.005	1.002	.995	.986	.972	.956	.937	.915	.890	.862	.832
210	1.007	1.004	.998	.989	.975	.959	.941	.920	.895	.868	.839
220	1.008	1.005	.999	.992	.979	.963	.945	.925	.901	.874	.845
230	1.010	1.007	1.001	.994	.982	.968	.950	.930	.907	.881	.852
240	1.012	1.009	1.004	.997	.985	.971	.954	.935	.912	.887	.859
250	1.014	1.011	1.006	1.000	.989	.976	.959	.940	.918	.893	.865

NBCHARTS 1/03

Noble Company
7300 Enterprise Drive
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DENSITIES (lb/ft³) OF NOBURST SOLUTIONS

Volume percent of **Noburst-100**

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0							65.81	66.18	66.50	66.79	67.05
10						65.30	65.70	66.06	66.37	66.65	66.89
20				64.30	64.77	65.19	65.58	65.92	66.22	66.48	66.72
30			63.68	64.21	64.66	65.07	65.44	65.77	66.06	66.32	66.54
40	62.42	63.04	63.59	64.09	64.54	64.94	65.30	65.62	65.90	66.14	66.35
50	62.38	62.95	63.49	63.98	64.41	64.80	65.15	65.46	65.72	65.96	66.16
60	62.34	62.87	63.38	63.85	64.27	64.65	64.99	65.29	65.54	65.76	65.95
70	62.27	62.77	63.28	63.72	64.12	64.49	64.81	65.10	65.34	65.55	65.73
80	62.19	62.66	63.12	63.58	63.97	64.32	64.63	64.91	65.14	65.34	65.51
90	62.11	62.54	62.99	63.42	63.80	64.14	64.44	64.70	64.92	65.11	65.27
100	62.00	62.41	62.83	63.25	63.62	63.95	64.23	64.49	64.70	64.88	65.03
110	61.84	62.26	62.68	63.08	63.44	63.75	64.02	64.27	64.46	64.63	64.77
120	61.73	62.12	62.51	62.90	63.23	63.54	63.80	64.03	64.22	64.38	64.51
130	61.54	61.94	62.33	62.71	63.03	63.32	63.57	63.79	63.96	64.11	64.23
140	61.39	61.77	62.14	62.50	62.81	63.09	63.33	63.54	63.70	63.84	63.95
150	61.20	61.58	61.94	62.29	62.59	62.85	63.08	63.27	63.43	63.56	63.66
160	61.01	61.38	61.74	62.07	62.35	62.60	62.81	63.00	63.14	63.26	63.35
170	60.79	61.17	61.52	61.84	62.10	62.34	62.54	62.72	62.85	62.96	63.04
180	60.57	60.95	61.29	61.60	61.85	62.07	62.27	62.43	62.55	62.64	62.72
190	60.35	60.73	61.06	61.34	61.58	61.79	61.97	62.12	62.23	62.32	62.39
200	60.13	60.49	60.81	61.08	61.31	61.50	61.67	61.81	61.91	61.99	62.05
210	59.88	60.25	60.56	60.81	61.02	61.20	61.36	61.48	61.58	61.65	61.69
220	59.63	59.99	60.29	60.53	60.72	60.89	61.03	61.15	61.24	61.30	61.33
230	59.38	59.74	60.02	60.24	60.42	60.58	60.71	60.82	60.88	60.93	60.96
240	59.10	59.46	59.73	59.93	60.10	60.25	60.37	60.46	60.52	60.56	60.58
250	58.82	59.18	59.44	59.62	59.78	59.91	60.01	60.10	60.15	60.18	60.19

NBCHARTS 1/03

Noble Company
7300 Enterprise Drive
Spring Lake, MI 49456
Phone 800-878-5788 Fax 231-799-8850
www.noblecompany.com

IMC INSTRUMENTS
WITTENBERG , WI

SPECIFIC HEAT [btu/(lb·ºF)] OF NOBURST SOLUTIONS

Volume percent of Noburst-100

TEMP. ºF	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
-30										.723	.680
-20									.767	.728	.687
-10									.773	.734	.693
0							.846	.814	.778	.741	.700
10						.879	.850	.819	.784	.747	.707
20				.933	.909	.883	.855	.824	.790	.753	.713
30			.955	.935	.912	.887	.859	.829	.796	.759	.720
40	1.004	.979	.957	.938	.915	.891	.864	.834	.801	.765	.726
50	1.001	.979	.960	.941	.919	.895	.869	.839	.806	.771	.733
60	1.000	.980	.962	.944	.923	.899	.873	.844	.812	.777	.740
70	.999	.982	.964	.947	.926	.903	.878	.849	.817	.783	.746
80	.998	.983	.967	.950	.930	.907	.882	.854	.823	.789	.753
90	.998	.985	.970	.953	.934	.911	.886	.859	.829	.796	.760
100	.998	.986	.972	.956	.937	.915	.891	.865	.835	.802	.766
110	.998	.988	.975	.959	.940	.919	.896	.870	.840	.808	.773
120	.998	.989	.977	.962	.944	.924	.901	.875	.845	.813	.779
130	.999	.991	.979	.965	.947	.927	.905	.880	.851	.820	.786
140	.999	.992	.981	.968	.951	.931	.909	.885	.856	.826	.793
150	1.000	.994	.984	.971	.955	.936	.914	.890	.862	.832	.799
160	1.001	.995	.986	.974	.958	.939	.918	.894	.868	.838	.806
170	1.002	.997	.989	.977	.961	.943	.922	.899	.873	.844	.812
180	1.003	.998	.990	.980	.965	.948	.928	.905	.879	.851	.819
190	1.004	1.000	.993	.983	.968	.951	.932	.910	.884	.856	.826
200	1.005	1.002	.995	.986	.972	.956	.937	.915	.890	.862	.832
210	1.007	1.004	.998	.989	.975	.959	.941	.920	.895	.868	.839
220	1.008	1.005	.999	.992	.979	.963	.945	.925	.901	.874	.845
230	1.010	1.007	1.001	.994	.982	.968	.950	.930	.907	.881	.852
240	1.012	1.009	1.004	.997	.985	.971	.954	.935	.912	.887	.859
250	1.014	1.011	1.006	1.000	.989	.976	.959	.940	.918	.893	.865

NBCHARTS 1/03

Noble Company
7300 Enterprise Drive
Spring Lake, MI 49456
Phone 800-878-5788 Fax 231-799-8850

www.noblecompany.com

EMPIRICAL SOLUTIONS to the SpHt and Dens TABLES

FOR REFERENCE ONLY (not actual polynomials)

User-Defined Model: y=a+b*(x)+c*(x)^2+e*(x)^3+d*(x-2.356)^+1.5

Coefficient Data:

a =4537.159

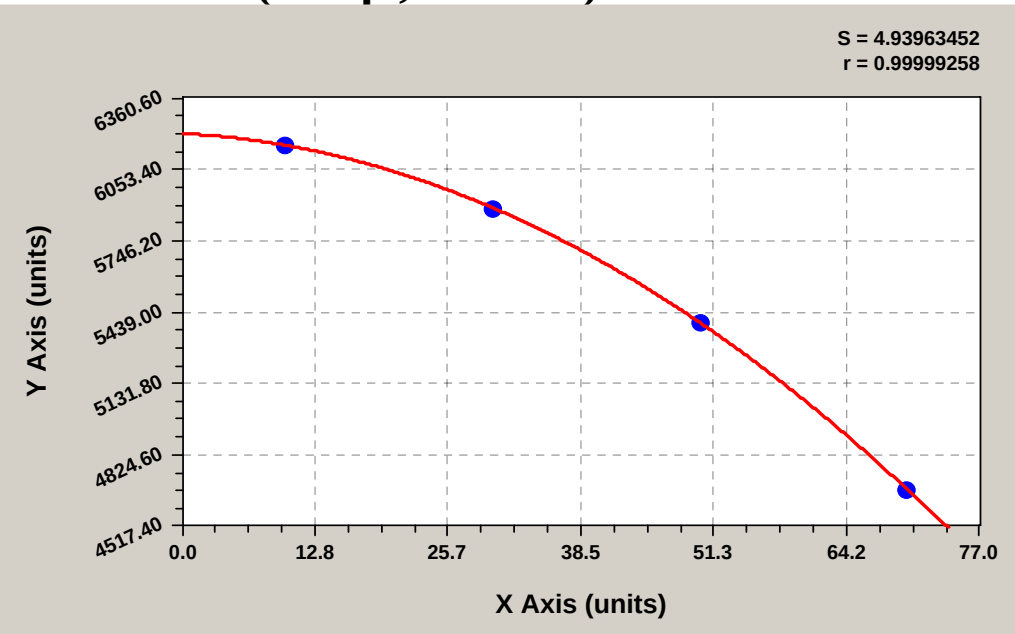
b =-0.004312

c =-140.2099

d =11911789

e=23.45E-9

Dens = f (Temp , % GLY)



User-Defined Model: y=a+b*(x)+c*(x)^2+e*(x)^3+d*(x-2.356)^+1.5

Coefficient Data:

a =4537.159

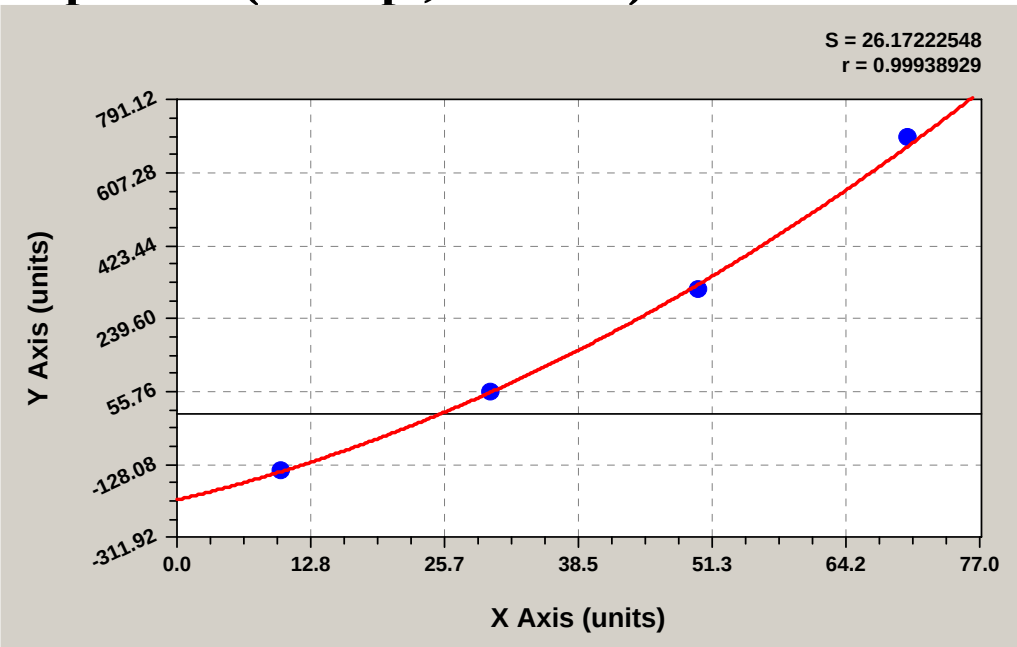
b =-0.004312

c =-140.2099

d =11911789

e=23.45E-9

SpHt = f (Ttemp , % GLY)



IMC INSTRUMENTS
WITTENBERG , WI

THE FINAL ENERGY SUMMATION

E/t => BTU/HR = K x Del-T x GPM

Btu/Hr = (E/GPM-F) x (Temp Rise) x GPM

Q=[E/Hr] t1 + [E/Hr] t2 + [E/Hr] t3 + [E/Hr] t4 + [E/Hr] t5 +

[E/Hr] t6 + [E/Hr] t7 + [E/Hr] tn + ...

SUMMARY OF DATA ACQUISITION and FINAL SUMMATION

1) Temperatures obtained every 2 seconds

2) Flow is totalized every 17 seconds

3) All film parameters are evaluated at film conditions according to the given tables every 17 seconds and the above equation is executed and added to the on going ENERGY sum total .

4) The sum total is stored in the PERMANENT ENERGY METER MEMORIES

The TEMPERATURE DIFFERENCE

The SENSORS used for this measurement play a key roll in the overall ENERGY METER accuracy. Their operating temperatures range is from 50F to 225 F with the most active ENERGY MEASUREMENT occurring from 80F to 200F. Because of the wide range of operation there are normally supplied as MATCHED temperature DIFFERENCE sensors with a high degree of accuracy as TEMPERATURE DIFFERENCE sensors.

The following will give you an idea of accuracies required for a ONE PERCENT ERROR at different operating temperature differences....

DELTA- T	1% match requirement
30F	0.30 F
20F	0.20F
10F	0.10F
5F	0.005F
4F	0.004F
2F	0.002F

The requirement is over the Entire temperature measuring range of 70 F to 225F !!!!!

As you can see from the above the lower the active DELTA T the more difficult the measurement becomes.

Next we will see what the active temperature rise across a collector is when exposed to maximum insolation of ONE SUN **279.8 btu/hr-sqft**
south USA...= 882 watts/sq mtr

IMC INSTRUMENTS
WITTENBERG , WI

COLLECTED ENERGY

ASHRAE HNDBK OF FUNDAMENTALS … SOLAR RADIATION

----------analysis - ONE SUN ----------

-Analysis for July 21 worst-case design Direct Normal Solar intensity is 345 bty/hr-sqft. This is at an atmospheric Air mass of ZERO. The actual levels that reach the surface at air mass B=.205 are as follows:

@ 48 deg N.Latitude(North-USA) Solar noon altitude is 62.6 deg

@ 32 deg N. Latitude (South-USA Solar noon altitude is 78.6 deg

IDN=A/e^(B/Sin(b)) 345/e^(0.205/Sin(78.6 deg)=…….. **279.8 btu/hr-sqft** south USA…= 882 watts/sq mtr

IDN=A/e^(B/Sin(b)) 345/e^(0.205/Sin(62.6 deg)=…….. 273.8 btu/hr-sqft North USA…= 863.7 watts/sq mtr

I realize that with so many variables in each individual solar collector system the actual instantaneous energy collection will be dependant on variables such as fluid temperatures and outside air temperatures deviation to NORMAL orientation, atmospheric absorption (i.e. water vapor and dust) and so forth. However, with the described initial conditions it will be reasonable to assume that we can collect 75% of the above-calculated NORMAL energy falling on the SOLAR PANEL. The "INITIAL" temperature rise will occur as follows:

FOR FLAT PANELS ONLY !! **..... At (Ti-Tair)=0**

Assume the following.. Panel AREA=**40 SqFt**, Efficiency of **0.75%** , Insolation level of **279.8 btu/hr-sqft**

Thus at **ONE SUN** the Energy collected by a 40SQFT collector .. south USA >> 279.8 btu/hr-sqft x Eff(75% at 90F) = 209.8 Btu/hr-Ft^2 x 40 Ft^2 =

= 8394 Btu/Hr

IMC INSTRUMENTS
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THE TEMPERATURE RISE

Published Properties of Water at 68F > SPHt =.999 Btu/Lbm-F , Dens =62.32 Lbm/Ft^3, thus the Product =62.26 Btu/Ftt^3

Thus E/GPM-F =.13368 Ft^3/G x 62.26 Btu/Ft^3 x 60 G/Hr / G/Min = **499.38 Btu/Hr-GPM-F**

Final Equation for water at NIST conditions

BTU_HR = K x Del -T x GPM

E/Hr = **Btu/Hr = (E/GPM-F) x (Temp Rise) x GPM**

Energy collected by a 40SQFT collector .. south USA >> 279.8 btu/hr-sqft x Eff(75% at 90F) = 209.8 Btu/hr-Ft^2 x 40 Ft^2 = **8394 Btu/Hr**

Del -T = BTU_HR / (K x GPM)

Temperature rise across the 40Ft^2 collector = **8394 / (499.4 x 1.2GPM)** =

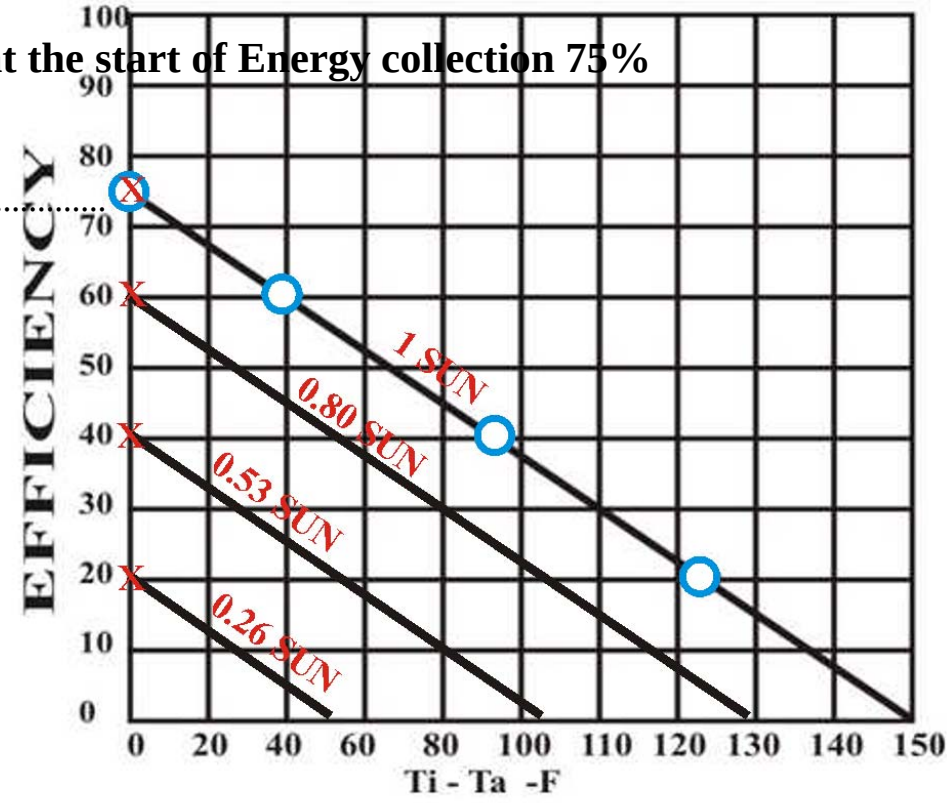
14.0 F temperature rise at the start of Energy collection 75%

X **1 SUN 14.0 F at 75% ➔** .....

X **0.8 SUN 11.2-F at 60% ➔**

X **0.53 SUN 7.5-F at 40% ➔**

X **0.26 SUN 3.7-F at 20%➔**



FOR REFERENCE

ONE SUN in this analysis .... 279.8 btu/hr-sqft or 882 watts/sq mtr

IMC INSTRUMENTS
WITTENBERG , WI

ALLOWABLE TEMPERATURE MEASUREMENT ERROR

Temperature rise across the 40Ft^2 collector =

8394 / (499.4 x 1.2GPM) = as follows:

at 1.0 SUN and 0F (Ti-Ta)

===➔ 14.0 F at 75% ERROR ===> 0.2F / 14.0F = 1.4%

at 1.0 SUN and 40F (Ti-Ta)

===➔ 11.2-F at 60% ERROR ===> 0.2F / 11.2F = 1.8%

at 1.0 SUN and 90F (Ti-Ta)

===➔ 7.5-F at 40% ERROR ===> 0.2F / 7.5F = 2.7%

at 1.0 SUN and 125F (Ti-Ta)

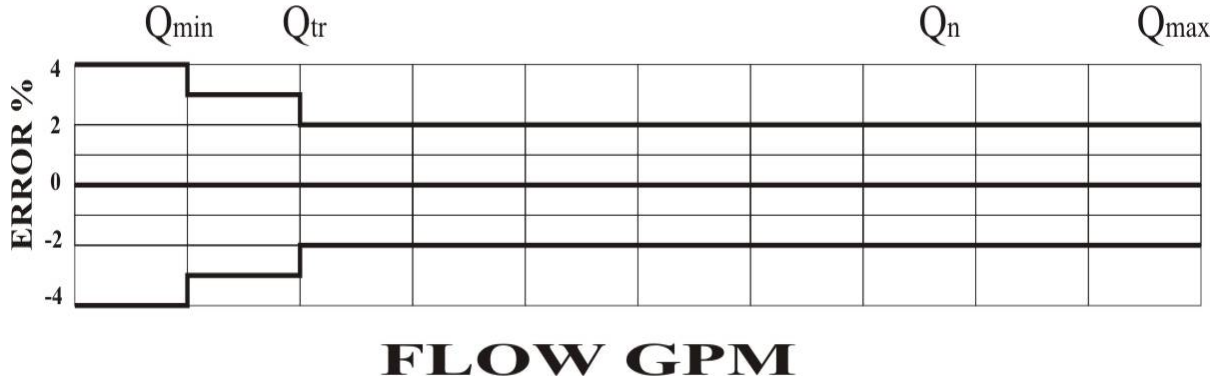
===➔ 3.7-F at 20% ERROR ===> 0.2F / 3.7F = 5.4%

This is why there is an absolute need for PRECISION MATCHED SENSORS with a MAX 0.2 F ERROR !!!

IMC INSTRUMENTS
WITTENBERG , WI

- **<u>THE FLOW METER and its RATED ACCURACY</u>**
- Most NIST TRACEABLE flow meter tests are done by the GRAVIMETRIC method. They pass water at a constant rate thru the meter under test and after a given sample of time the flow stops. They weigh the sample (gravimetric) and calculate the total volume of water metered by the device under test. The totalized displayed volume on the meter under test is then compared to the actual volume and the error is recorded. This is done at a very SPECIFIC flow rate. There are 4 flow rates that are normally recognized as defining the overall performance of a flow meter as follows.....

- **1- Qmin.... Minimum flow at which there will be a consistent measurable signal output but with considerable error**
- **2-Qtr.....Transitional flow at which the error will increase considerably if the flow falls below**
- **3- Qn.....Nominal flow which is the maximum "continuous flow" the meter should be exposed because of durability considerations.**
- **4- Qmax...Maximun flow that the meter should never exceed.**



FLOW METERS

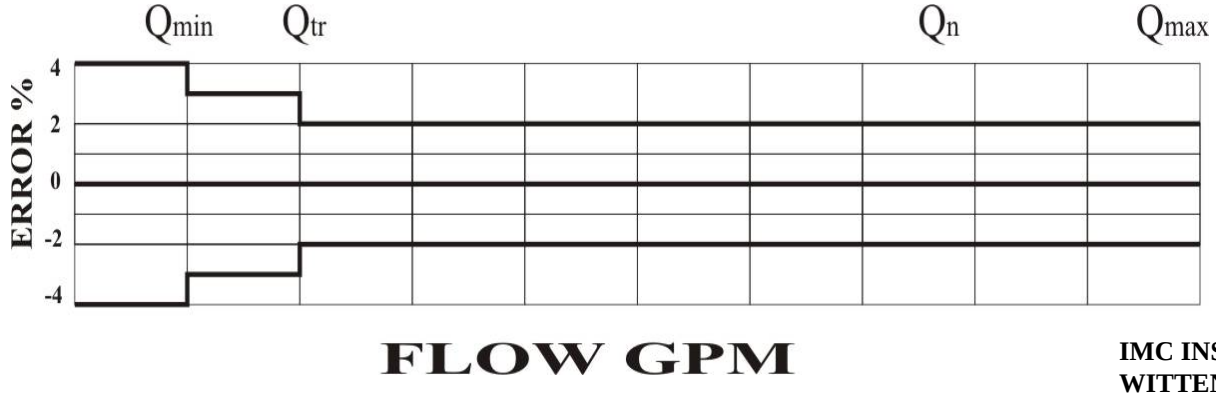
The most important factors in selecting flow meters are:

- TEMPERATURE - PRESSURE
- MAXIMUM CONTINUOUS FLOW RATE
- MAXIMUM ERROR and
- its ABILITY to METER IMPROPERLY DISTRIBUTED FLOW in the pipe cross sections

TYPICAL SPECS:
-Temperature 125F, 200F, 250F
-Pressure 135Psig, 230psig
-FLOW :
Varies with the application-- 0.15gpm to 1500gpm

SIZE	CONT FLOW	SIZE	CONT FLOW
1/2”	2 GPM	3”	130 GPM
3/4”	4.5	4”	270
1”	8.0	6”	700
1 1/2“	25	8”	1500
2”	50		

Maximum Error
For Solar work it is 2% maximum allowed,
====➔ " 1% preferred "



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PRACTICAL FLOW CONSIDERATIONS

Example of REAL FLOW PROFILES in the cross section of pipes. The RED profile is after an ELBOW

The PADLE WHEEL FLOW METER is an example of a very poor choice of measuring device for this application. VORTEX FLOW METERS do not sample the flow over the entire cross section.

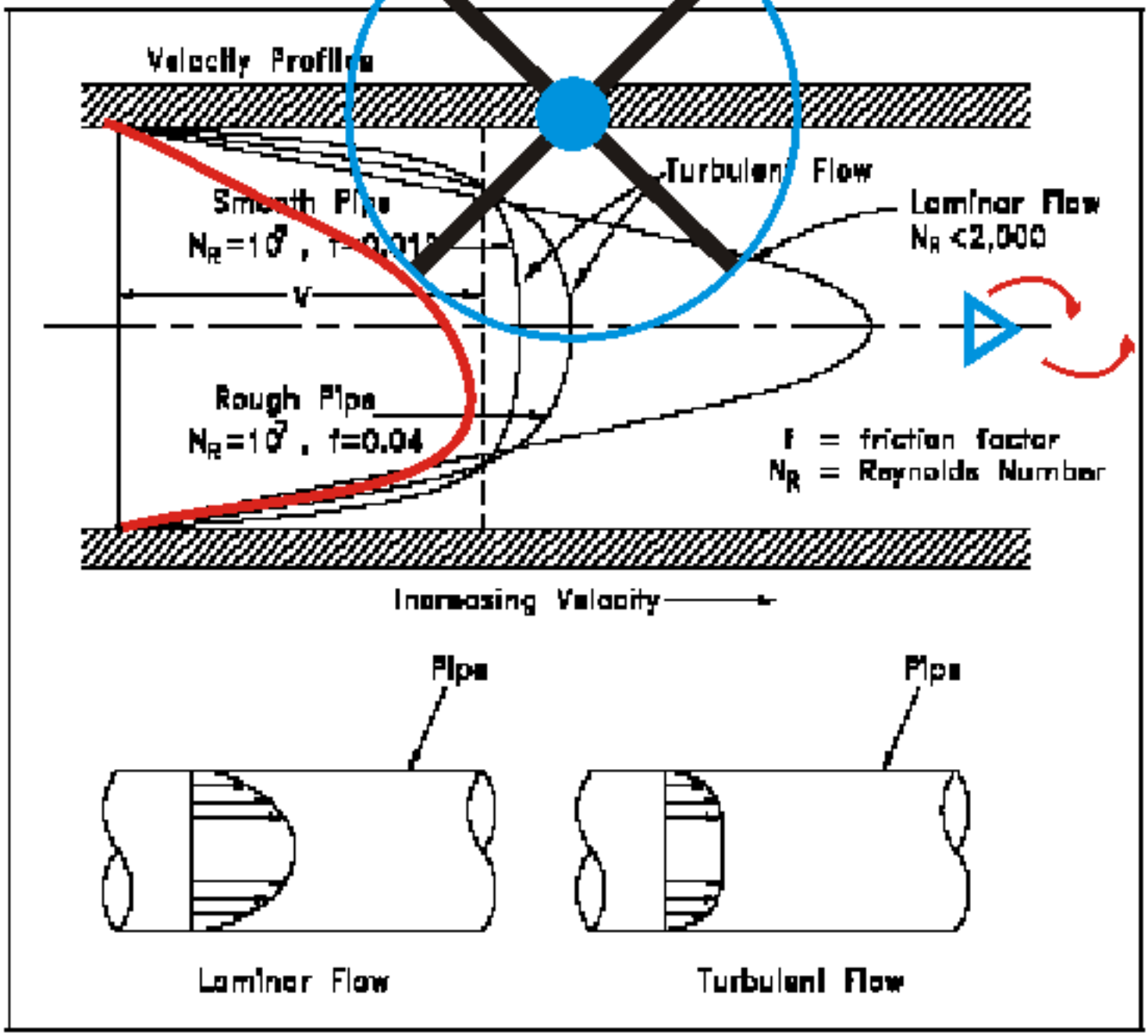
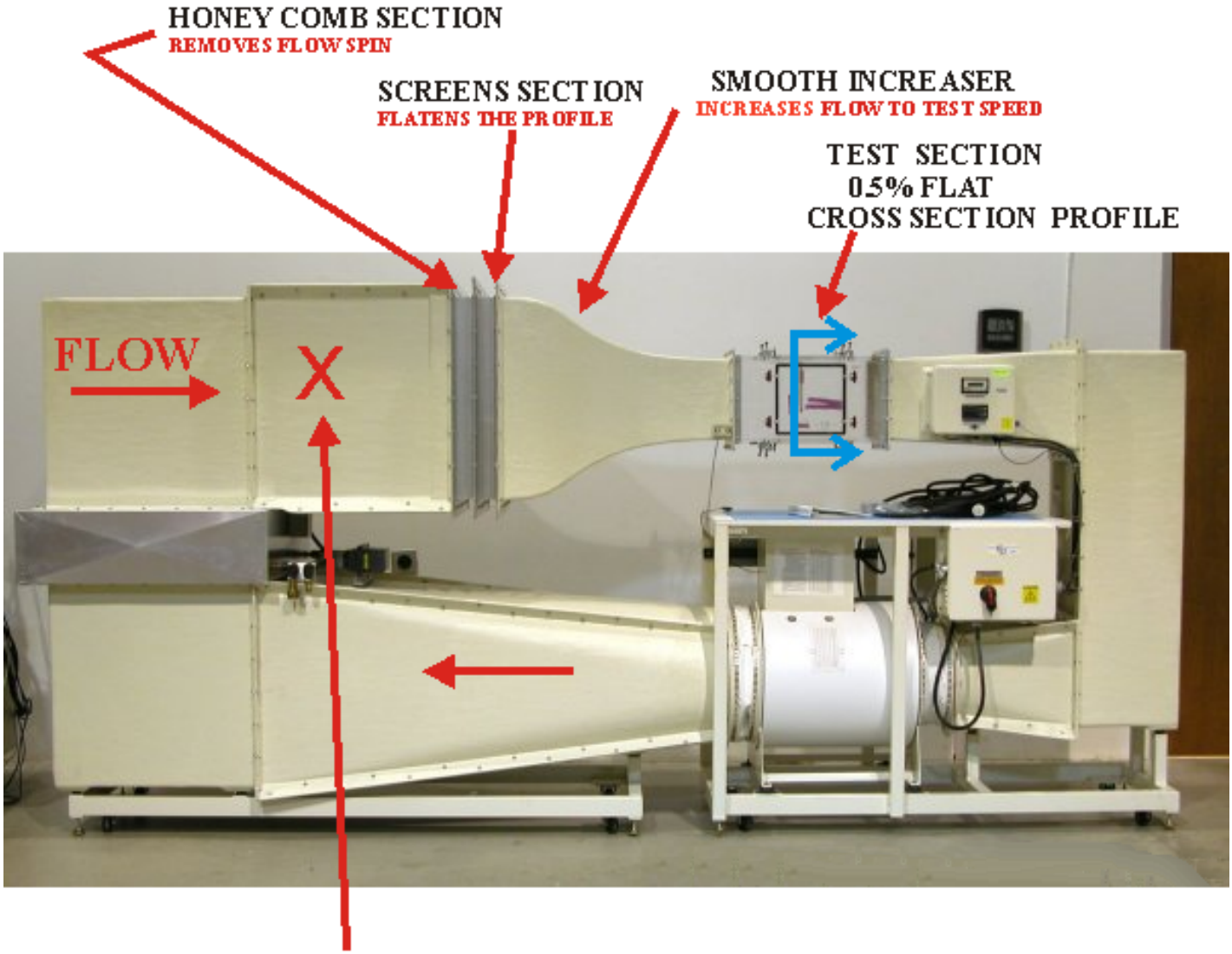


Figure 5 Laminar and Turbulent Flow Velocity Profiles

To appreciate what it takes for the flow PROFILE to be STRAIGHTENED OUT, the following is an example of what is required !!!!!

To appreciate what it takes for the flow PROFILE to be STRAIGHTENED OUT, the following is an example of what is required !!!!!

WIND TUNNEL WITH 0.5% FLAT CROSS SECTION TEST SECTION



LOW VELOCITY SETTLING CHAMBER V= ONE THENTH OF TEST CHAMBER

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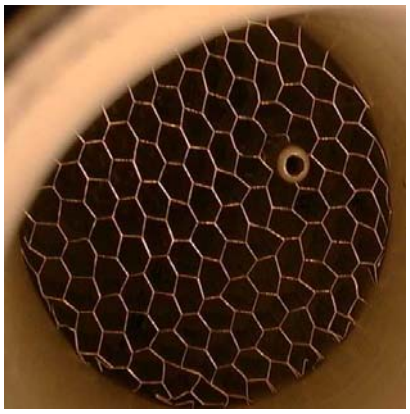
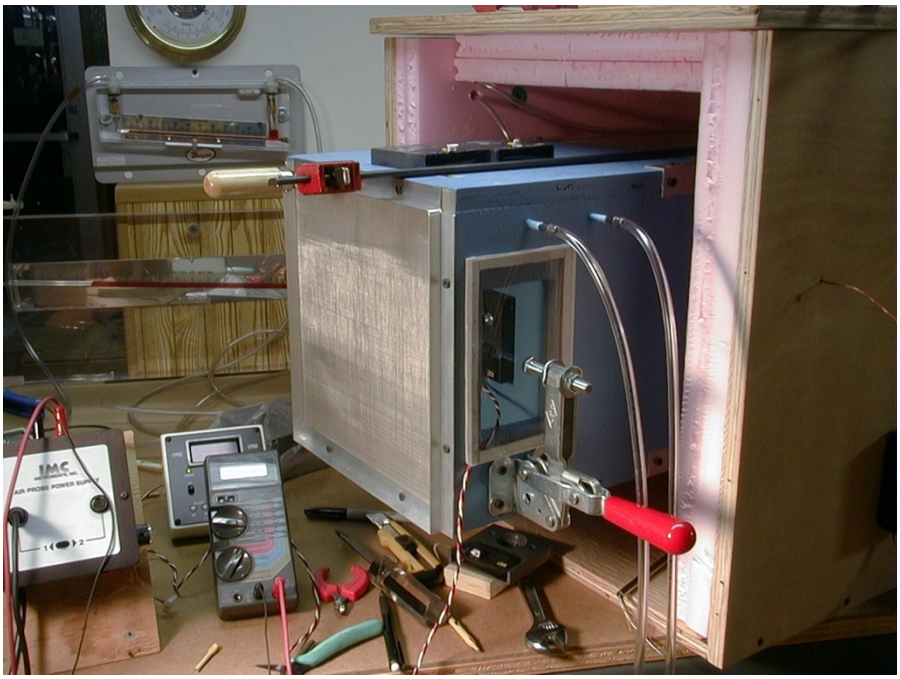
WITTENBERG , WI

CONSTRUCTION OF FLOW TEST SECTIONS



HONEY COMB SECTION



HONEY COMB SECTION

SCREEN SECTION

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Examples of flow meters with a good degree of FLOW Correction built in to their METERING PERFORMANCE.

SINGLE JET FLOW METER

MULTI JET FLOW METER

WOLTMAN FLOW METER

IMC INSTRUMENTS
WITTENBERG , WI

MAGNETIC FLOW METERS

Are almost insensitive to poor flow profiles and are unaffected by impurities. Measuring accuracies range from 0.1 % of reading to 0.5% of reading. Their dynamic flow range is from 100 :1 to 300:1

FLOW TUBE COMPLETELY FREE OF OBSTRUCTIONS

MOUNT –IT- ANYWHERE
Even in front of elbows

IMC INSTRUMENTS
WITTENBERG , WI

INSTALLATION PRECAUTIONS

IMC FLOW METERS MODELS FLPM & FLPH

INSTALLATION AND OPERATING INSTRUCTION Rev. 11-08-2009

1) Prior to installation please confirm that the system TEMPERATURE and PRESSURE DO NOT EXCEED the **NAME PLATE RATING**. The maximum flow specified for the meter should also never be exceed as excessive wear may occur.

2) It is recommended that **UNIONS and SHUT OFF VALVES** be installed upstream and downstream of the flow meter to allow for **service and removal of the flow meter**. IF the meter is to be temporarily removed a piece of straight pipe can be installed in its place until the meter is serviced and returned back into operation.

3) To insure that only clean liquid enters the flow meter it is HIGHLY recommended that a **FILTER-STRAINER** be installed upstream of the meter inlet. In addition to the above it is also recommended that the system be flushed thoroughly after any plumbing changes. The use of Pipe tape is discouraged in lieu of TFE plumbers compound thread paste to avoid loose tape from entering the fluid stream.

4) When installing the flow meter pay careful attention that the **direction of flow matches** the arrow on the body of the flow meter. The flow meter body is to be mounted with the name plate facing UP. The only exception to this is when vertical mount is permitted and is clearly shown on the name plate of the flow meter.

5) For the 1/2" and 3/4" flow meters there is a requirement to have at least **5 to 7 pipe diameters of STRAIGHT pipe** in order to achieve rated accuracy. Meters 1" and larger require at least **3 pipe diameters.**

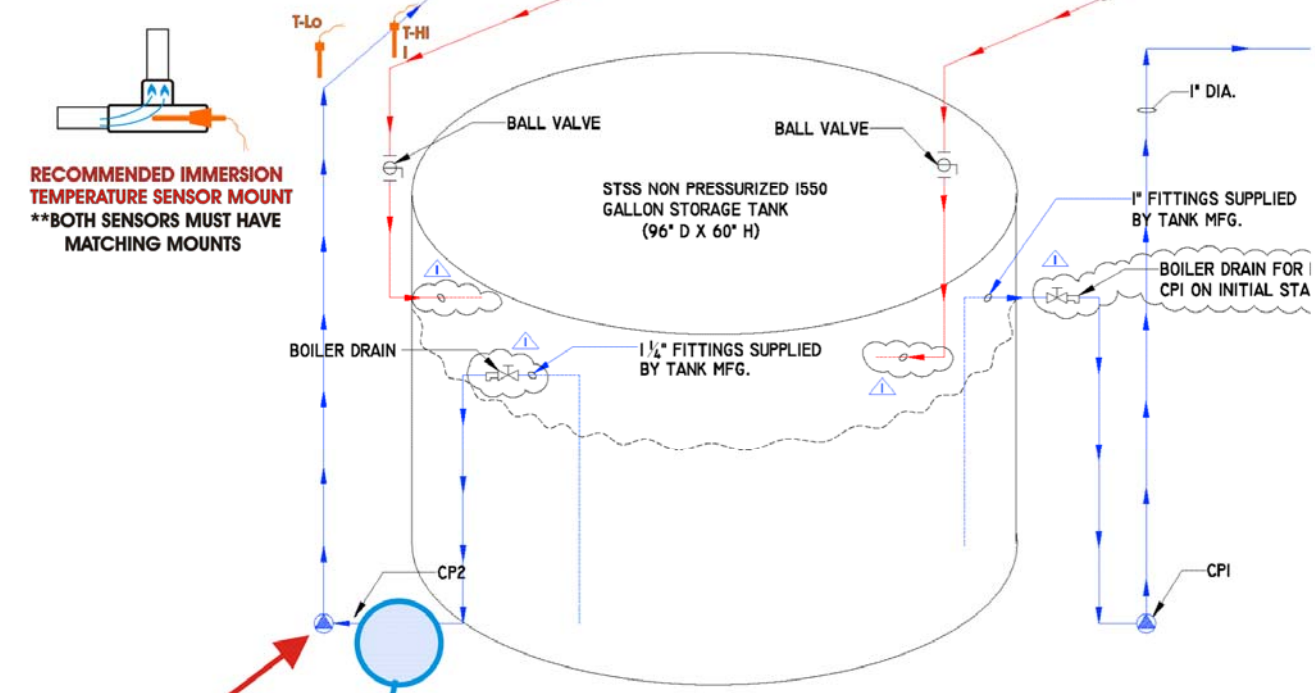
6) EXTRA SPECIAL ATTENTION should be paid in PREVENTING the flow meter from being exposed to **WATER HAMMER as well as FREEZING fluids.** Damage will occur

Any questions should be directed to:
Attn. Flow meter dept.
IMC Instruments, Inc.

FOR: **SAMPLE PROJECT** 3-15-2011

Long Island City, NY

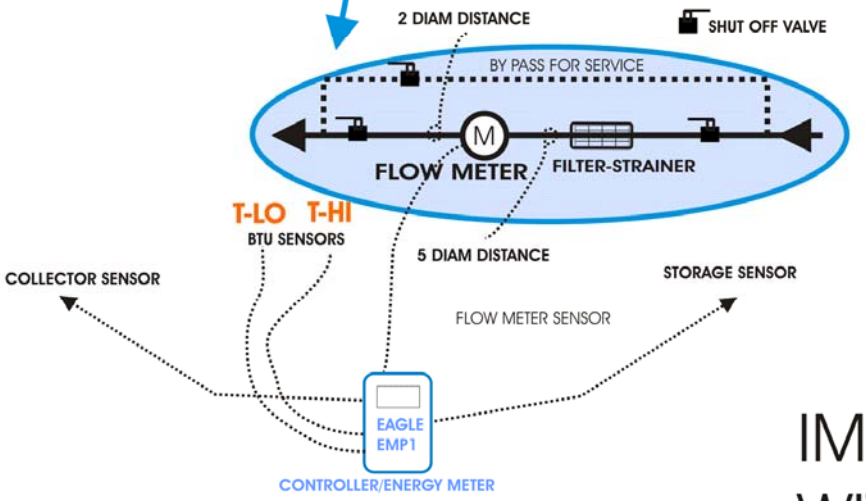
Project: **SAMPLE PROJECT**



RECOMMENDED IMMERSION TEMPERATURE SENSOR MOUNT
**BOTH SENSORS MUST HAVE MATCHING MOUNTS

COLLECTOR TO STORAGE PIPING DIAGRAM

TO MINIMIZE TURBULENCE
PLEASE NOTE.....
THAT THE PUMP IS UPSTREAM
OF THE FLOW METER

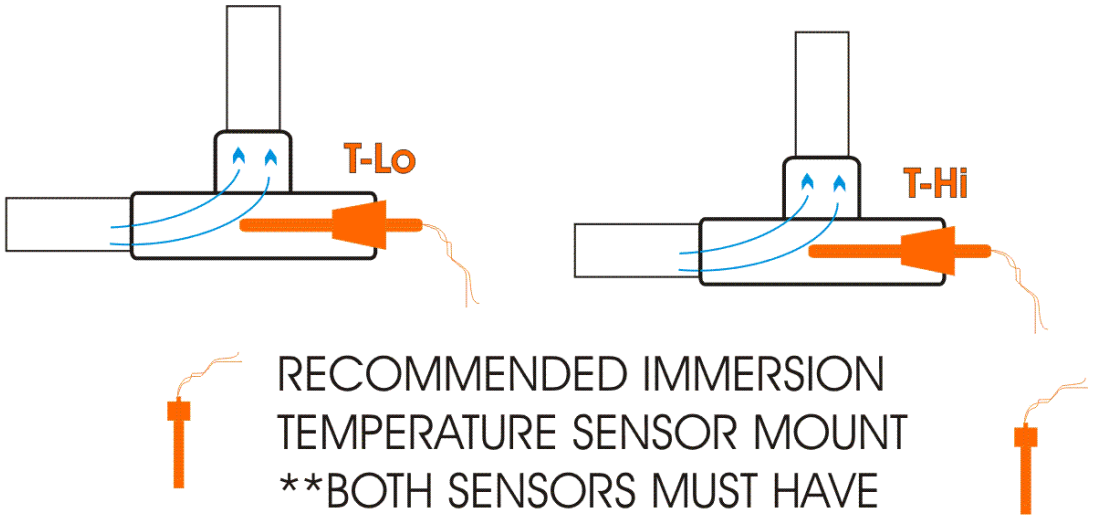


IMPORTANT NOTE
FLOW METER
TEMPERATURES AND FLOW RATES
MUST NEVER BE EXCEEDED AT ANY TIME.

IMC INSTRUMENTS INC
WITTENBERG WI
DESG BY L.F . 715 445 4946
loui@tds.net

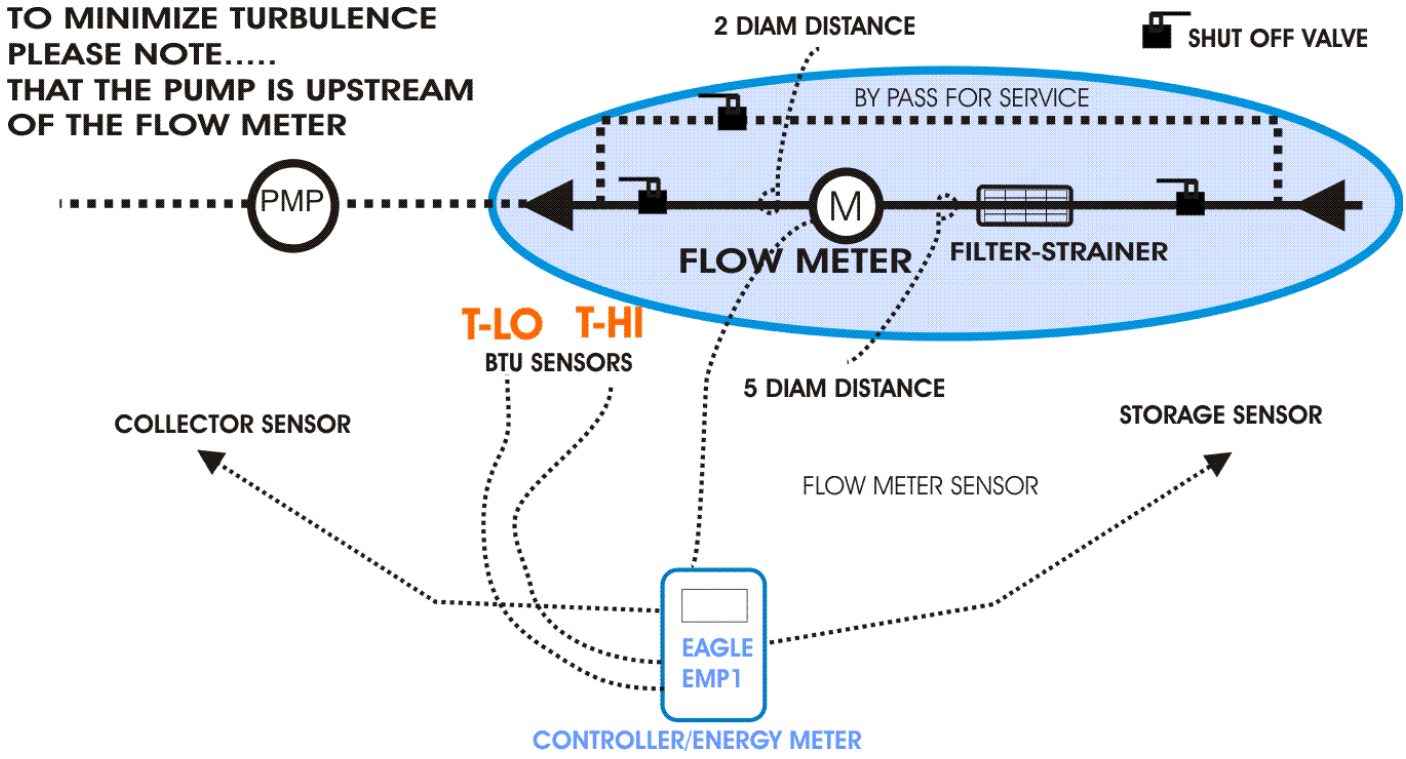
TEMPERATURE SENSORS

ALL PIPING MUST BE WELL INSULATED



RECOMMENDED IMMERSION
TEMPERATURE SENSOR MOUNT
**BOTH SENSORS MUST HAVE
MATCHING MOUNTS

FLOW METER INSTALLATION



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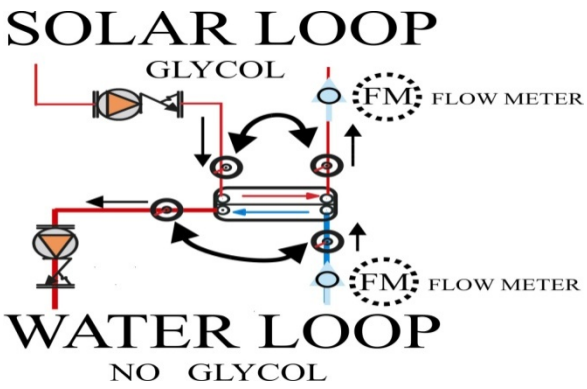
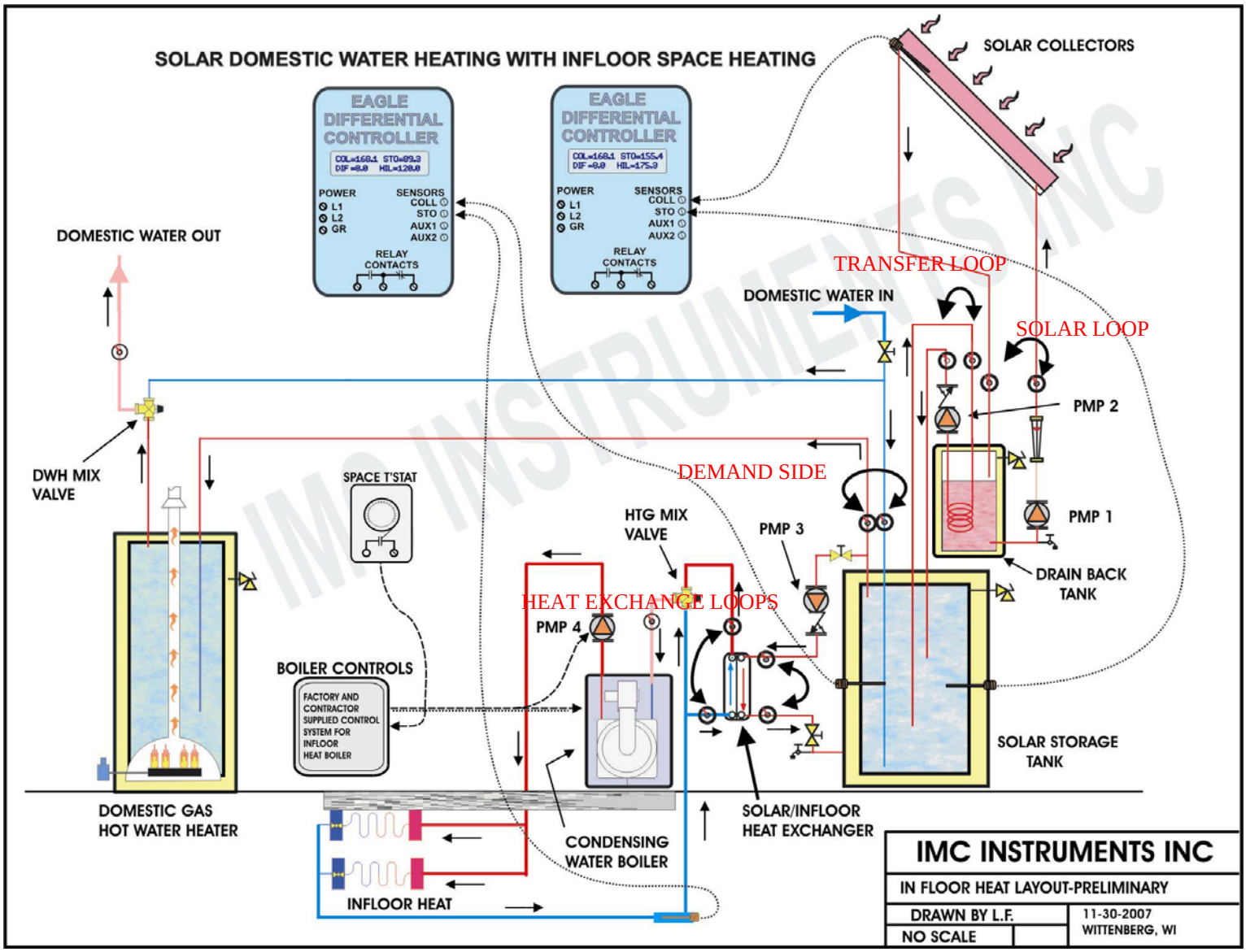
WITTENBERG , WI

WERE DO WE METER??





IMC INSTRUMENTS
WITTENBERG , WI

What can we expect for measuring accuracy?

PERFORMANCE SPECIFICATIONS cont

b) The over all accuracy of the Thermal Energy meter is dependant on the magnitude of the heat transfer fluid temperature increase thru the solar collection as follows:

Temp Diff	Flow Mtr Error	Sensor error	Calculator error	MAX. TOTAL error
50.0 F **	+/- 2.0% Max	+/-0.2F/50.0 = 0 .4%	+/- 0.4%	2.8%**
14.0 F	+/- 2.0% Max	+/-0.2F/14.0 = 1.4%	+/- 0.4%	3.8%
11.2 F	+/- 2.0% Max	+/-0.2F/11.2 = 1.8%	+/- 0.4%	4.2%
7.5 F	+/- 2.0% Max	+/-0.2/F7.5 = 2.6%	+/- 0.4%	5.0%
5.4 F**	+/- 2.0% Max	+/-0.2/F5.4 = 3.7%	+/- 0.4%	6.1%**
3.5 F	+/- 2.0% Max	+/-0.2F/3.5 = 5.7%	+/- 0.4%	8.1%

-- Currently The following PROPYLENE GLYCOLS are approved and stored in our computers for use with IMC ENERGY METERS …

Dow Frost-HD -The Dow Chemical

No Burst-HD - The Noble Company

As other Glycols are approved they will be characterized and entered into the IMC Energy METERS.

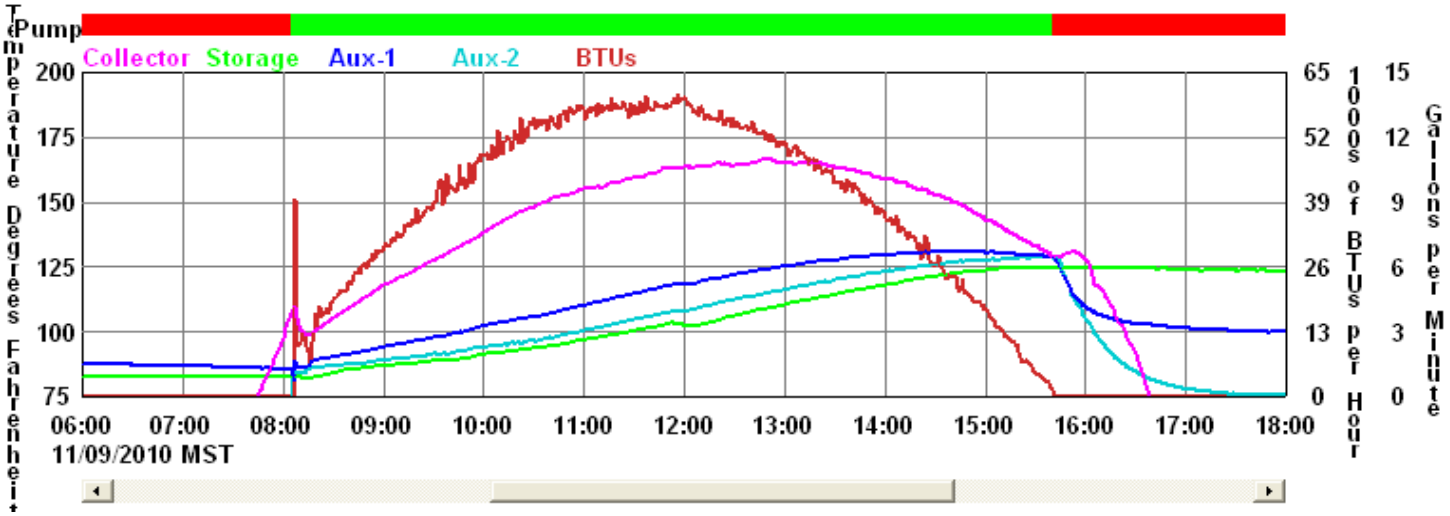
**Note values used to show OIML compliance

IMC INSTRUMENTS
WITTENBERG , WI

Job by CAPITOL SOLAR in DENVER CO.
300 SqFt FLAT PANELS 2 arrays VERY INFORMATIVE !!

21:40:21 ET=29:19:59 Communication Port Active, timeouts=0 Flux=0.00
Last Data Received: 29:33 21.6 106.9 23.9 165.3 99.4 74.8 OFF OFF GPM=0.00 FPL=000 AX3=000 KWH=00
High Limit 165.3 Differential 23.9
Pump is OFF On_Hours= 7.60 Duty_Cycle= 0.26 Cycles=1
Samples=52745 Samples saved=1819 Samples Logged=528 Open_Sensors=0 Data_Errors=0

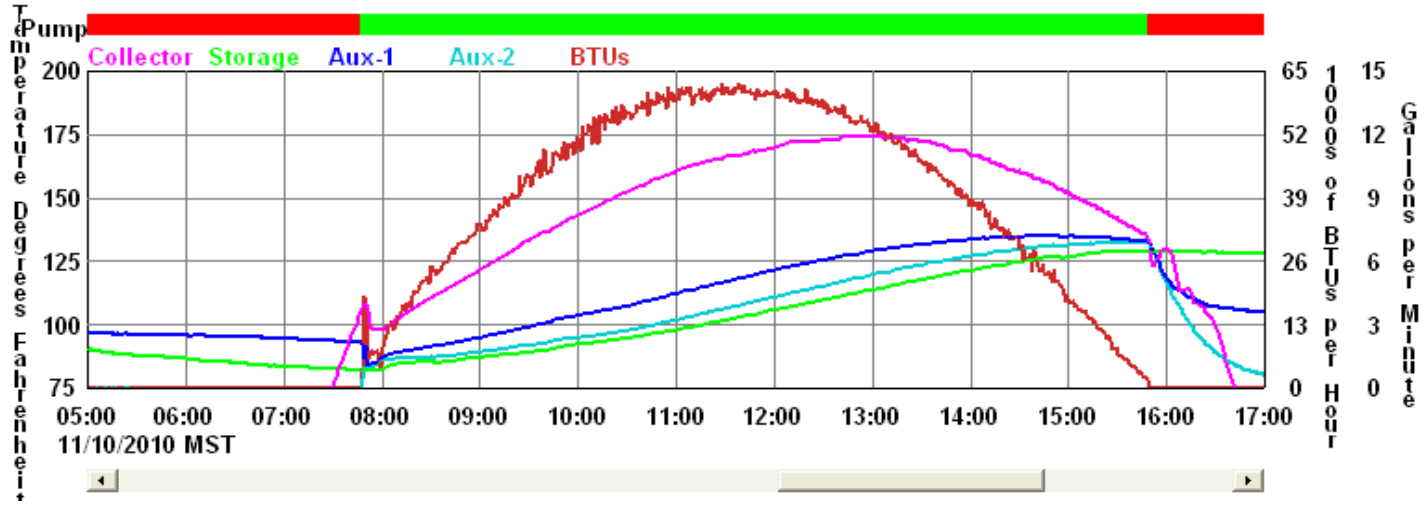
Quantity	Current	Maximum	Minimum	Day Max	Day Min
Collector	21.6	167.1	13.4	167.1	13.4
Storage	106.9	125.2	81.9	125.2	81.9
Aux-1	99.4	131.4	75.4	131.4	75.4
Aux-2	74.8	129.6	72.4	129.6	72.4
BTUs Captured	301205.9			301205.9	
KWHs Captured	88.3			88.3	
BTU/hour	0.0	61339.1		61339.1	



EXAMPLE of IMC CHARTING SOFTWARE

18:10:57 ET=49:50:34 Communication Port Active, timeouts=0 Flux=0.00
Last Data Received: 50:02 34.0 127.9 23.9 165.3 103.6 76.5 OFF OFF GPM=0.00 FPL=000 AX3=000 KWH=0(
High Limit 165.3 Differential 23.9
Pump is OFF On_Hours=15.62 Duty_Cycle= 0.31 Cycles=2
Samples=89624 Samples saved=3091 Samples Logged=897 Open_Sensors=0 Data_Errors=0

Quantity	Current	Maximum	Minimum	Day Max	Day Min
Collector	34.0	174.8	13.4	174.8	20.8
Storage	127.9	129.2	81.9	129.2	82.1
Aux-1	103.6	135.5	75.4	135.5	76.5
Aux-2	76.5	132.8	72.4	132.8	73.4
BTUs Captured	627079.2			325873.3	
KWHs Captured	183.7			95.5	
BTU/hour	0.0	63065.7		63065.7	



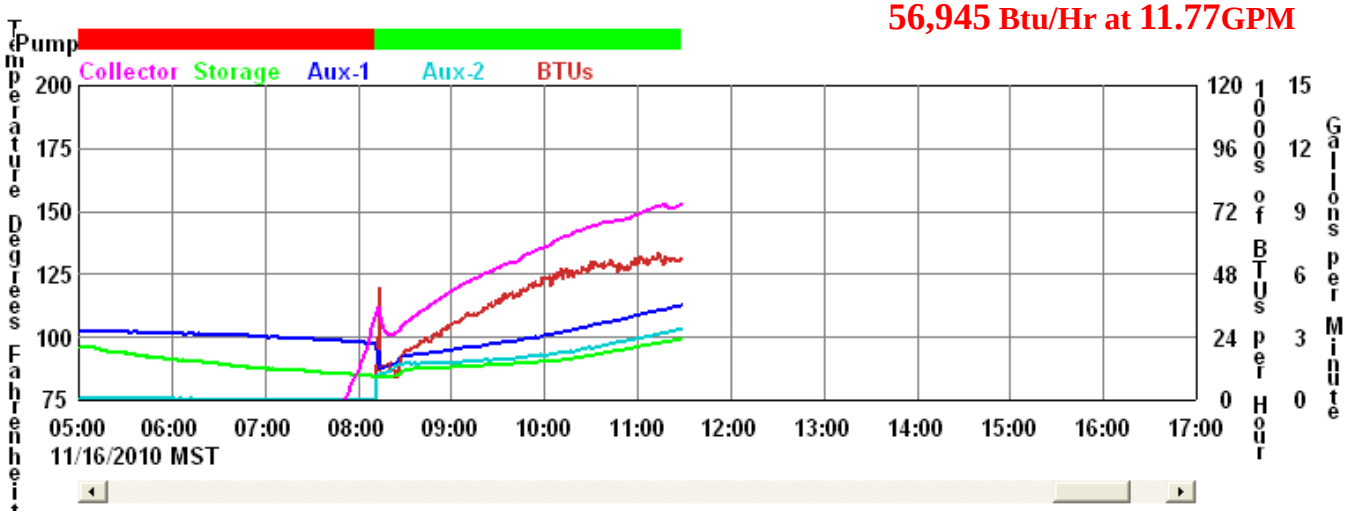
Job by CAPITOL SOLAR in DENVER CO.
300 SqFt FLAT PANELS 2 arrays VERY INFORMATIVE !!

Below: Cold winter day, 36-40F high, only 29F by 4:40 PM. Flux = .60 means only 60% on suns energy available due to orientation of the array and the time of year.

11:28:54 ET=187:08:30 Communication Port Active, timeouts=0 Flux=0.60
Last Data Received: 187:11 153.1 99.8 23.9 165.3 113.0 103.6 ON OFF GPM=11.77 FPL=129 AX3=000 KWH=(
High Limit 165.3 Differential 23.9
Pump is ON GPM=11.77 BTU Factor=0.9893 On_Hours=51.50 Duty_Cycle= 0.28 Cycles=17
Samples=336502 Samples saved=10000 Samples Logged=3366 Open_Sensors=0 Data_Errors=0

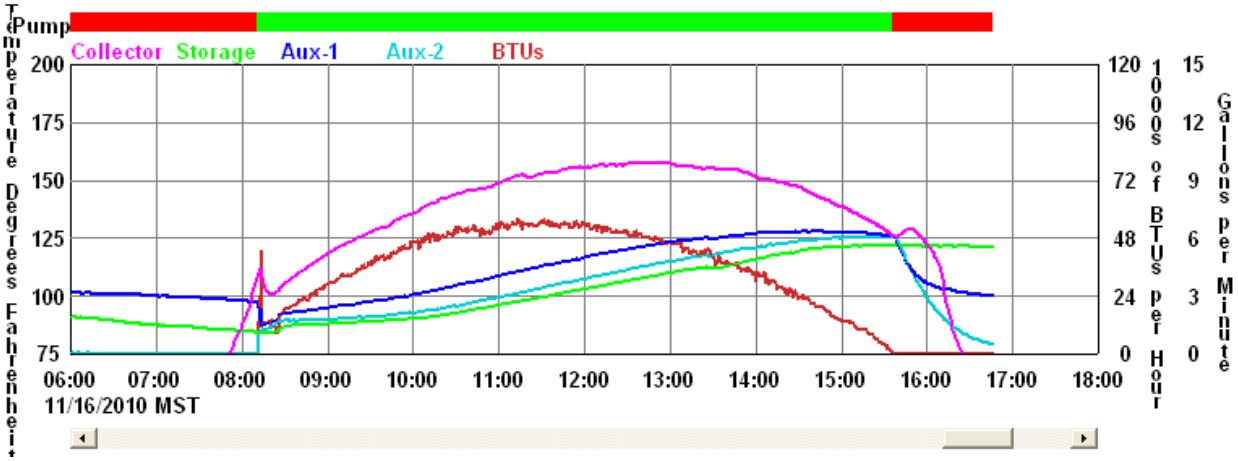
Quantity	Current	Maximum	Minimum	Day Max	Day Min
Collector	153.1	178.9	8.3	153.1	8.3
Storage	99.8	132.5	81.9	112.1	84.3
Aux-1	113.0	153.2	75.4	113.3	79.7
Aux-2	103.6	136.6	72.4	103.8	74.3
BTUs Captured	1825140.8			130358.5	
KWHs Captured	534.8			38.2	
BTU/hour	56945.9	115576.2		57077.7	

Note ....
MID DAY PERFORMANCE
56,945 Btu/Hr at 11.77GPM



16:46:53 ET=192:26:30 Communication Port Active, timeouts=0 Flux=0.00
Last Data Received: 192:29 41.8 121.7 23.9 165.3 100.3 79.2 OFF OFF GPM=0.00 FPL=000 AX3=000 KWH=0
High Limit 165.3 Differential 23.9
Pump is OFF On_Hours=55.63 Duty_Cycle= 0.29 Cycles=17
Samples=346032 Samples saved=10000 Samples Logged=3461 Open_Sensors=0 Data_Errors=0

Quantity	Current	Maximum	Minimum	Day Max	Day Min
Collector	41.8	178.9	8.3	158.4	8.3
Storage	121.7	132.5	81.9	122.2	84.3
Aux-1	100.3	153.2	75.4	128.4	79.7
Aux-2	79.2	136.6	72.4	126.5	74.3
BTUs Captured	1973830.8			279048.4	
KWHs Captured	578.3			81.8	
BTU/hour	0.0	115576.2		57077.7	



THE END

------THANKS for COMING !!!------

IMC INSTRUMENTS
WITTENBERG , WI