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"The Economic and Technical Justification for changing from a Nozzle Flow Meter to a V-Cone Flow Meter on the outlet of a Steam Recovery Boiler in a Paper Plant"

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Synopsis: ***A very large integrated Paper Plant desired to improve productivity of paper production utilizing the existing equipment.***
The technical paper describes the reasons why the Paper Plant considered the replacement of a flow meter on the steam outlet of a Recovery Boiler. In order to understand the decision this paper describes: elements of the Paper Process; the Recovery Boiler; and the factors resulting in a change of meter.
It provides the financial justification and the technical reasons for the choice of a V-Cone meter.
The influence of head loss in the choice of Flow meters is developed.

1. Introduction

At Escanaba, in Michigan, there is a very large integrated Paper Mill belonging to MeadWestvaco. This facility desired to improve productivity without significantly changing the existing equipment.
This technical paper describes the Manufacturing Plant, the Paper Process and the influence of the Recovery Boiler on the Paper Production. From this understanding, the paper then describes why it was necessary to change the Nozzle flow meter being utilized to measure the steam flow from the Recovery Boiler and the resulting choice of a V-Cone Meter.

2. Paper Manufacturing Plant at Escanaba

The Plant is a very large fully integrated Paper Mill producing 2,000 tons/day of high quality paper on a site in Michigan. The raw timber is harvested from a wide area including the company owned forests. MeadWestvaco currently owns and manages more than 700,000 acres in Michigan.

2.1 **Production Process**

2.1.1 From the incoming trees, 8-foot long logs are taken and debarked. The bark goes to the Wood Waste Boiler
2.1.2 The debarked 8-ft logs now go to a Chipper
2.1.3 The chips from the Chipper are fed into a Digester along with "White Liquor" (see 2.1.5) and 175 psi steam at 400 ^{0}F
2.1.4 The Pulp Output from the Digester goes to the Paper Making Machine and the byproduct is called "Black Liquor", which is used as fuel in the Recovery Boiler
2.1.5 The "Black Liquor" in the Recovery Boiler is fired and in the process produces "Green Liquor" which is taken from the boiler and has lime added to it and this forms " White Liquor" which is part of the feed for the Pulping Process.

From the above it is apparent that the process is highly integrated. Because of the high degree of integration, it is necessary to maximize the conversion of black liquor into white liquor. This is necessary to achieve the facility's maximum production rate.

In this operation, it can be seen that there is a requirement for Boilers to produce steam for the process and for the generators producing electrical power. However, it is also clear that the "byproduct" from the Recovery Boiler is an essential feed stock for the Pulping Process.

The Boilers will now be detailed to assist in the understanding of the plant operation

2.2 Boilers

2.2.1 A Multi-fuel Boiler produces 750 Klbs/hr at 1500 psi and 920 ^{0}F of superheated steam
The multi-fuel is wood/coal/natural gas.

2.2.2 A Gas/Oil Fired Boiler produces 400 Klbs/hr at 1500psi and 920 ^{0}F of superheated steam.

2.2.3 A Wood Waste/Gas Boiler produces 250 Klbs/hr at 1500psi and 920 ^{0}F of superheated steam
This boiler is normally fired with the bark residuals removed from the logs. It is also fired with gas when an inadequate bark supply exists.
2.2.4 A Recovery Boiler produces 550 Klbs/hr at 1500psi and 920 ^{0}F of superheated steam.
This boiler is fired with "Black Liquor" from the pulping process and the byproduct from the boiler is "Green Liquor". Green liquor is later converted to "White Liquor" which is required for the pulping process.

All the boilers produce the steam, which is fed into a common header, and then distributed around the plant to:
Drive the Generators
Feed the Process Plant
Provide the General Utilities

2.3 Generators

Three turbine generators produce 105 MWatt electricity.
The details are given in Fig 5.

3. Plant Problem to increase Productivity

3.1 The Recovery Boiler

This boiler is a key element in the total integration of the process as this entails the utilization of "Black Liquor" which comes from the initial processing of the wood to produce the Wood Pulp (see 2.1.5)

3.2 Specification and Operation of the Recovery Boiler

The boiler was originally built in the 1970's.

3.2.1 The boiler is a Babcock and Wilson unit, originally built in the 1970's. It consists of:
A firing chamber where the "Black Liquor" is burned with air. Initially oil is used to commence the firing.
A Large Drum containing the boiler tubes where the heat generated in the firing chamber heats the water to produce steam
2 Super heaters, get the 1475 psi steam to 920 ^{0}F, which is required to remove any moisture from the steam. The superheated steam is used in the turbine generators for producing electricity. The steam rating is 550,000 lbs/hr.

3.3 Problems with running at maximum rates within the Recovery Boiler

3.3.1 The superheated steam from this boiler leaves through a non-return valve, a flow meter and an isolation valve to the generator. The output from this pipe must be at 1475 psi and 920 ^{0}F. If it is below that value there is a risk of liquid separation, which would destroy the Turbine due to the momentum of liquid particles.

3.3.2 At the boiler drum, there is a safety relief valve, which will activate if the pressure exceeds 1625 psi. **These restraints have serious implications on the pressure drop from the Recovery Boiler to the Turbine.**

3.3.3 The maximum pressure drop in this section of pipe should not exceed 100 psi.

When the throughput of the Recovery Boiler reaches it's steam rating it was apparent that there was danger of lifting the safety relief valve.

3.4 Research to determine the Critical Parts in the Process

It was decided to install 7 Pressure transmitters in the process to determine where the major head losses occurred.
There is a 12 psi drop through the Non-Return-Valve (NRV), and the existing Nozzle Flow Meter had a pressure drop of 15 psi. Along with the other valve and the pipework the process operated at very close to the 100 psi and there were times when the safety relief valve would be activated. I.e. the 1475psi to 1625psi with a safety margin.

3.5 Solution and implications when solving the Pressure Loss Problem

Note: All the piping within the Boiler House must meet the ASME P Stamp Power Piping Standards. These are extremely stringent, and have purchasing, manufacturing and inspection implications for the manufacturing supplier. This results in very careful consideration when piping components have to be changed.

3.5.1The Company examined the possibility of replacing the 2 Super Heaters to reduce the pressure drop. The cost associated with replacing the super heaters is between $0.5 M and $0.75 M. The labor cost to remove of the existing units and the install the new units would have also been very high.

3.5.2 It became clear that the 15psi drop through the Nozzle Flow meter was a key element in the decision-making process. If this could be reduced dramatically, it would not be necessary to buy new Super heaters.

3.6 Choice of the V-Cone Meter

Different types of Flow meters were considered, including, ultrasonic meters, averaging Pitot tubes, orifice, Venturi but they were all dismissed on the basis of head loss, accuracy, reliability or installation possibilities. The only meter, which met all the requirements, was a V-Cone meter.
The V-Cone had the attraction of reducing the head loss to 5 psi. (See Fig 9) It was accurate and reliable and could be fitted into the existing space occupied by the Nozzle. A 12" Schedule 150 V-Cone in P 22 CrMoly material was purchased. (See Fig 6)

3.6.1 Details of the V-Cone Meter

3.6.1.1 The V-Cone meter is a differential pressure meter, which has the significant technical advantage of working on the fluid in the center of the pipe by supporting a cone in that position. The additional benefit of the V-Cone technology is that the downstream pressure tap is taken from the center of the fluid in the downstream side of the cone. These 2 technical developments give the V-Cone a very significant advantage over any other differential pressure meter. These points are illustrated in Fig. 6, which is a drawing of the meter provided for this project.

3.6.1.2 This figure also illustrates why the pressure drop is reduced with this device. It can be seen that the fluid flow does not meet a bluff body but a carefully selected body shape, which directs the fluid around it and reduces the loss when vortices are shed.

3.6.1.3 In steam applications or wet gas instances, the V-Cone allows the liquid to flow along the pipe wall, thus bypass the differential producer, and consequently reduce erratic effects.

3.6.1.4 Fig 7 gives the sizing calculations for this particular meter and it can be seen that it was a 12" sch. 120 meter with a 0.85 Area Ratio

3.6.1.5 The V-cone meter requires to be calibrated and Fig. 8 gives the results of the calibration from the McCrometer Water Laboratory. The Average Cd value produced was 0.7566 and this figure was used for the calculation algorithms in the MeadWestvaco facility

3.7 Effect of Changing to the V-Cone

The replacement of the Nozzle flow meter with the V-Cone has resulted in a 10% drop in pressure drop and since it has been installed it has performed as specified and there was not been any danger of lifting the safety relief valve. This has allowed the plant to run at maximum loads more often.
The performance of the V-Cone has had the additional implication that there is a reduction in the energy required to drive the steam to the Turbine and an increased efficiency in the Generator since the steam is supplied in the most efficient form.
The plant engineers have carried out mathematical Case studies on the effect of increasing the pressure by 10psi through their boilers (or any mechanical device, which has a pressure drop) and Fig 10 shows the results of these studies. In Case #1 where there is a high pressure the savings are $2,652/year; in Case #2 where there is an intermediate pressure the savings are $10,412/year and in Case #3 at low pressure there is a saving of $32,900/year.

This makes it very clear that a Flow Meter with a low-pressure drop results in an ongoing cost saving as well as a capital cost saving.

4. Conclusions

4.1 The MeadWestvaco plant was able to run at maximum loads without a major capital investment in plant.
4.2 This was achieved by a careful study of the key parameters affecting throughput.
4.3 A detailed pressure drop study in the area of the Recovery Boiler highlighted the Nozzle flow meter as the limiting element.
4.4 Replacement of the existing flow meter with a V-Cone solved the problem.
4.5 The paper highlights the cost savings, which can be achieved when there is a reduction in the pressure loss through such a plant.

Fig.1 Photograph of the Escanaba Mill in Michigan

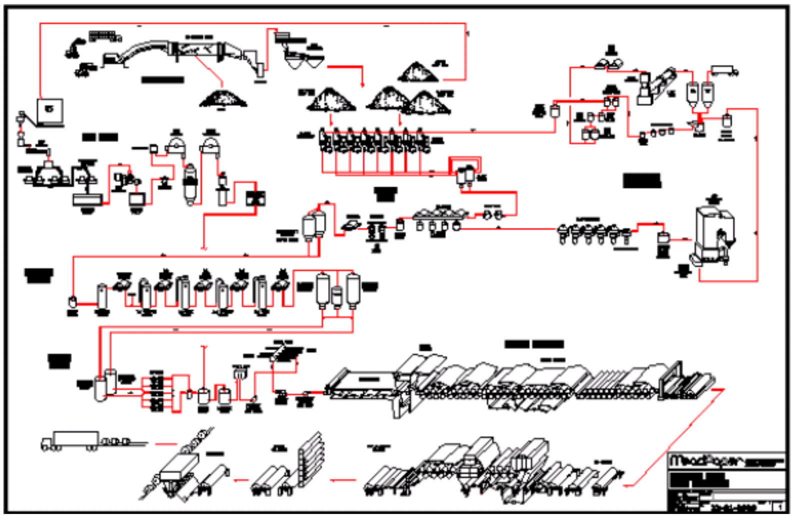

Fig 2 Process Flow – Mill Overview

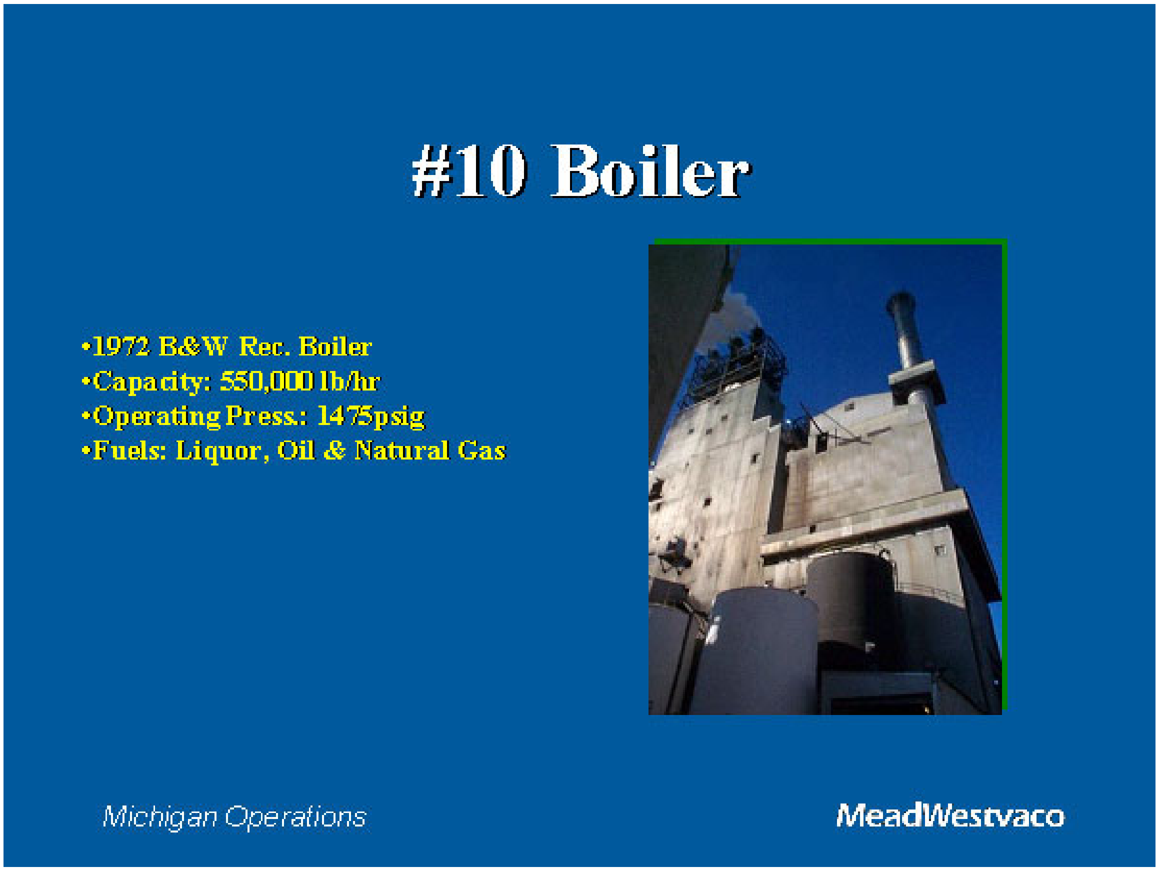

Fig 3 Recovery Boiler

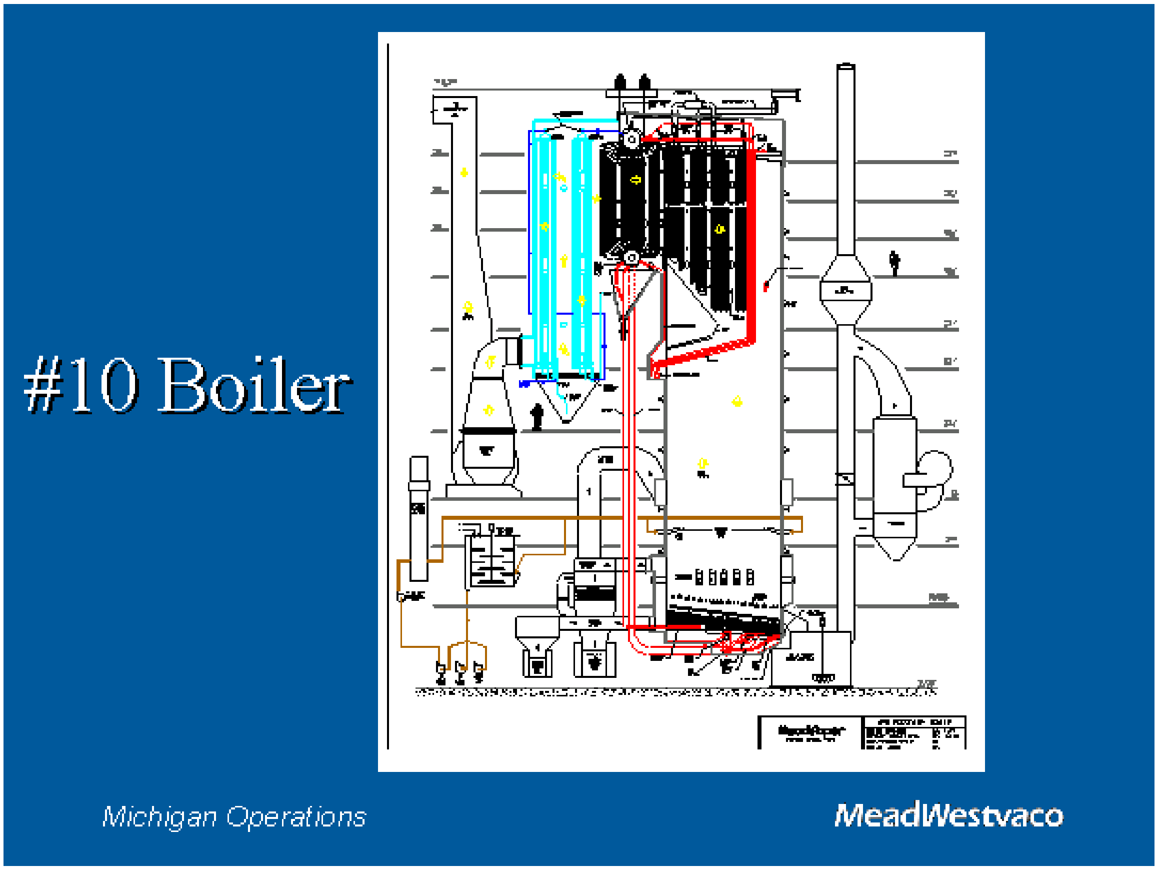

Fig 4 Schematic of the Recovery Boiler

Fig 5 Turbine Meter Room

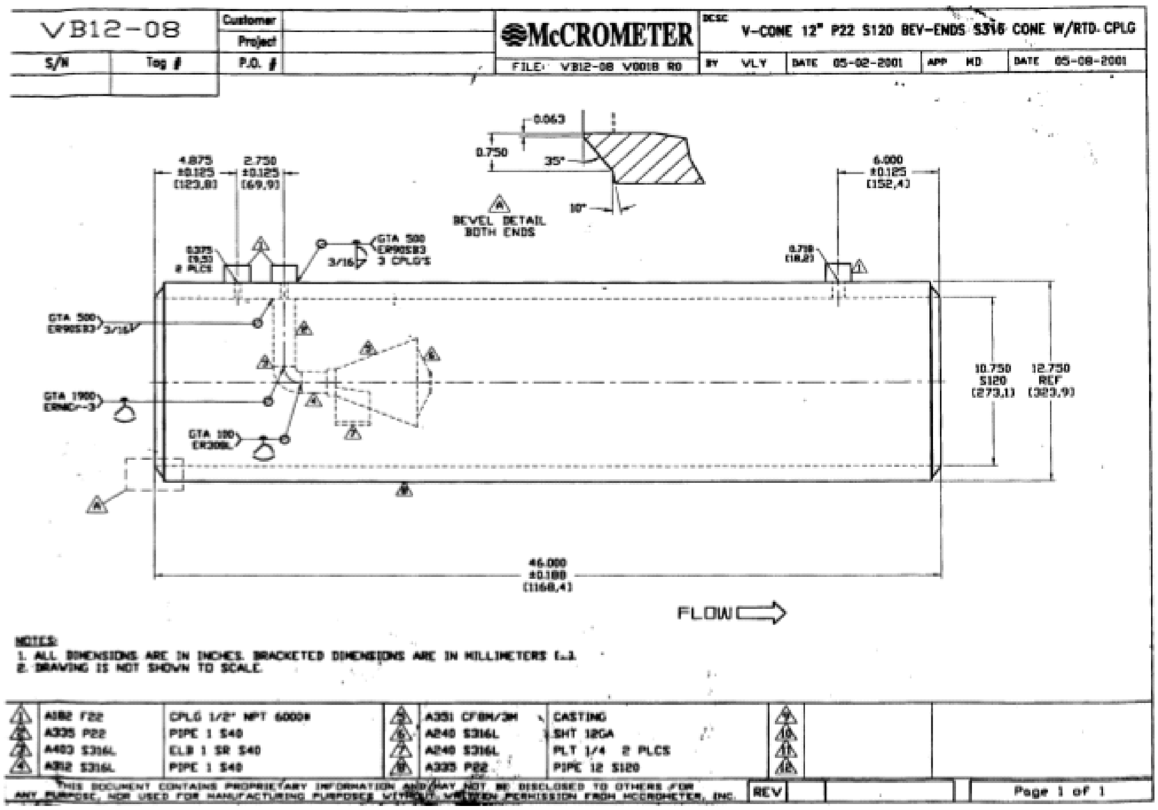

Fig 6 Drawing of the 12” V-Cone Meter

V-Cone Application Sizing

Serial #	01-1388	Fluid State	GAS
Tag	15-FE-0122	Fluid	Steam , WATER
Model	VB12-08	End User	Crane Engineering - Mead Paper
Job Ref.	JB7567		

Description	V-Cone 12" Sch 120 Beveled End Chrome Moly P22 Material with a 316 SS Cone.	Mktg. Code	8 4 058
Note			

C_f	0.7566	
P_f	1500	psiG
T_f	950	°F
ρ	1.963	lb/ft3
μ	2.885e-02	cP
G	0.6223	
Z	0.9191	
Y	0.99112	
k	1.275	
C_p	9.205	
Mw	18.015	
P_b		
T_b		
Z_b		
P_{baro}	14.696	psiA
P_c	3198.8	psiA
T_c	1164.8	°R
F_a	1.012	
aPE	D 6.7e-06	d 6.7e-06
P_v		

⇐ Entered value.

q	max. Flowrate	750000	lb/H
Re	max. Reynolds	1.517e+07	
V	max. Velocity	166.0	fps
ΔP	max. Dp	263.99	inWC
ΔP	min. Dp	2.5937	inWC
D	Meter I.D.	10.827	in
d	Cone O.D.	5.7500	in
β	Beta Ratio	0.8473	
	Turn Down	10	

McCrometer Cal.	
Third Party Cal.	
Dye. Pen. Exam.	
Hydro. Test	
X-Ray Exam.	
Mag. Part.	
PMI	
CMTR Copies	✓
McCrometer Eng.	KTL

	Re	Velocity fps	Gas. Exp. Y	ΔP inWC	Flowrate lb/H
1	1.517e+07	165.99	0.9911	263.99	7.5000e+05
2	1.365e+07	149.40	0.9928	213.10	6.7500e+05
3	1.213e+07	132.80	0.9943	167.87	6.0000e+05
4	1.062e+07	116.20	0.9957	128.18	5.2500e+05
5	9.099e+06	99.597	0.9968	93.955	4.5000e+05
6	7.583e+06	82.997	0.9978	65.118	3.7500e+05
7	6.066e+06	66.398	0.9986	41.609	3.0000e+05
8	4.550e+06	49.798	0.9992	23.376	2.2500e+05
9	3.033e+06	33.199	0.9997	10.380	1.5000e+05
10	1.517e+06	16.599	0.9999	2.5937	75000

Table based on one flow condition (P, T ...)

Record Start Date	04-25-2001
Print Date	05-31-2001

McCROMETER

Fig 7 Final –Cone Sizing Calculation

McCrometer, Inc.
V-Cone - Calibration Report

Serial Number:	01-1388	Meter Inside Diameter(inch):	10.827
Calibration Date:	05-31-2001	Cone Outside Diameter(inch):	5.750
Report Date:	05-31-2001	Beta Ratio:	0.8473
Model Number:	VB12-08	Average Cd:	0.7566

Description:	V-Cone 12" Sch 120 Beveled End Chrome Moly P22 Material with a 316 SS Cone.
Sold To:	Crane Engineering - Mead Paper

	Temp °F	Time sec	Weight LBS	Actual Rate GPM	ΔP inWC	Reynolds /1000	Cd
1	82.0	31.648	9441.00	2153.69	17.195	728.53	0.7563
2	82.0	31.688	9422.00	2146.65	17.060	726.14	0.7568
3	82.0	31.713	9410.00	2142.22	16.997	724.65	0.7566
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

Certified By:	P. Hobbs	Certification Date:	5-31-01
Calibration Fluid:	WATER	Record Filename:	01-1388

This calibration was performed on a gravimetric flow stand, traceable to the National Institute of Standards and Technology, USA. The flow measurement uncertainty of the facility is estimated to be +/-0.15% of reading based on the cumulative uncertainties of time, weight and temperature measurements combined with other systematic uncertainties.

McCrometer, Inc.
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e-mail: info@mccrometer.com Web Site: http://www.mccrometer.com
Hours: 8 a.m. - 4:30 p.m. PST Monday-Friday

Fig 8 Water Calibration Certificate in the McCrometer Water Lab.

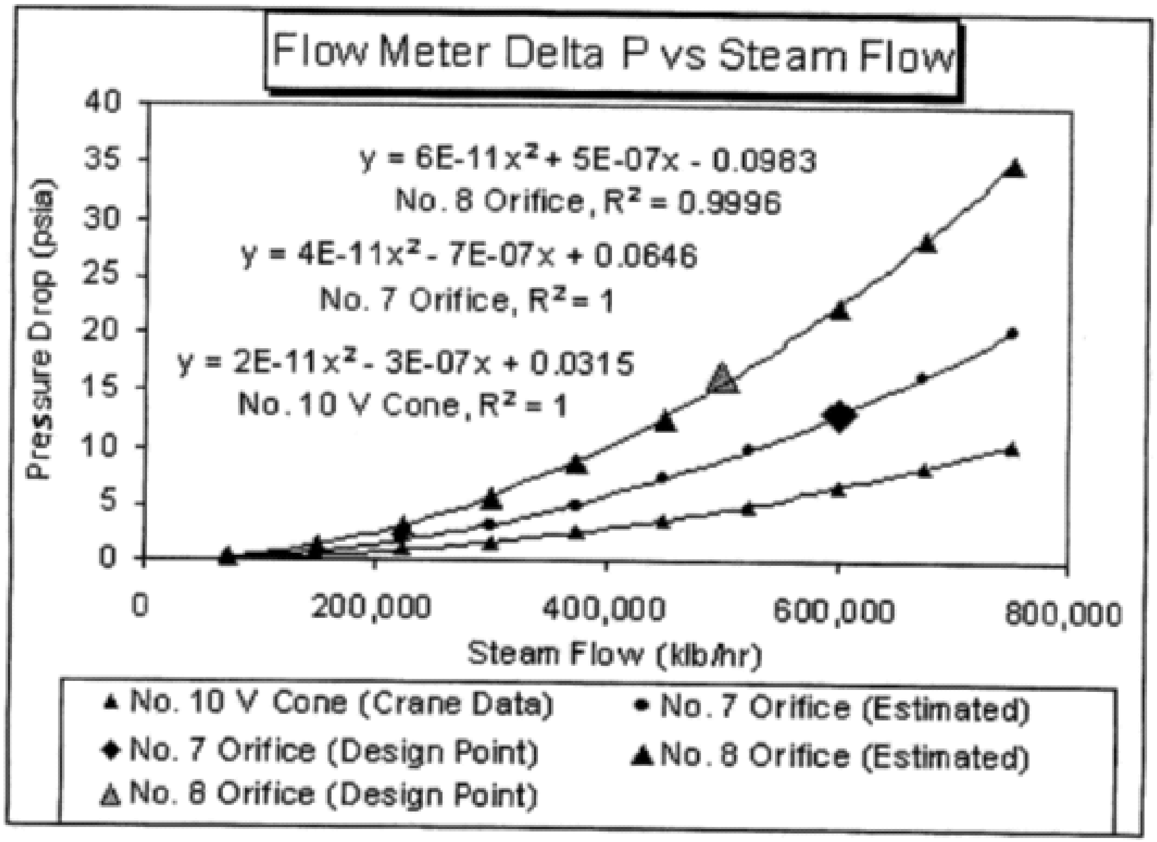

Fig 9 Graph of Pressure Drop in Steam for Orifice Plates and V-Cones

	CASE #1 1514 PSIA boiler pressure with 290 DEGF superheat 400 KPPH		CASE #2 400 PSIA boiler pressure with 150 DEGF superheat 400 KPPH		CASE #3 60 PSIA boiler pressure with 100 DEGF superheat 200 KPPH	
Boiler PSIA	1514	1524	400	410	60	70
Saturation Temp	597.5072538	598.3874597	444.6268321	447.0512928	292.6927648	302.9163015
SuperHeat Temp	290	290	150	150	100	100
Steam Enthalpy/Lb	1420.597633	1420.74669	1303.825839	1304.41094	1230.056839	1233.753203
Steam Flow KPPH	400	400	400	400	200	200
BTU/H of steam	568239053.2	568298676.1	521530335.5	521764376.2	246011367.9	246750640.6
BTU's input to Boiler	659157301.7	659226464.2	604975189.2	605246676.4	285373186.8	286230743.1
Gas Eff	0.84	0.84	0.84	0.84	0.84	0.84
Gas $/KSCF	4.26	4.26	4.26	4.26	4.26	4.26
Gas BTU/KSCF	973000	973000	973000	973000	973000	973000
Gas in Boiler KSCF/Hr	677.4484087	677.5194905	621.7627844	622.0418051	293.2920727	294.1734255
$ in Boiler/Hr	2885.930221	2886.233029	2648.709462	2649.89809	1249.42423	1253.178793
$ in Boiler/Day	69262.32531	69269.59271	63569.02708	63597.55415	29986.18151	30076.29103
$ in Boiler/Year	25280748.74	25283401.34	23202694.88	23213107.27	10944956.25	10977846.23
$/Yr Saved with 10 PSI gain		**2652.600044**		**10412.38265**		**32889.97237**

Fig 10 Cost Savings with 10 psi rise in Pressure.