

Field Experiences with V-Cone Technology

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Abstract :

The V-Cone differential pressure meter was introduced in the early 80's.

Initial customer review of the technology at that time was skeptical due to the radical change in emphasis of the flow regime from a central portion of a closed conduit (orifice plate) to fluid velocity profile around a centrally mounted cone at that time unheard of.

Today much of the skepticism has passed due to the acceptance of large number of in field units > 40,000

This paper describes the principles and field use of the V-cone D.P. flow meter used in the role of wellhead metering, injection measurement allocation metering / custody transfer both topside and sub-sea in on-off-shore oil and gas production applications.

Introduction :

The V-Cone meter is a differential pressure device which, allows the fluid to be measured to pass around the exterior of a central dual cone the larger cone apex being upstream of a beta edge, and an acute angled smaller transition cone being on the downstream side of this edge.

Flow velocities in the up-stream core of the pipe are then forced to mingle with pipe wall boundary layer velocities by radial expansion across the larger cone.

After passing this beta edge (formed between the two cones and the pipe wall) the fluid then falls into a central region in which high frequency vortices form adjacent to the pipe wall and pipe center with a low amplitude.

This parameter is particularly beneficial if trash laden fluids are to be measured which will be mentioned later in the paper.

A significant flow conditioning/profiling affect is obtained by the geometry of the larger cone which cause an averaging of the fluid velocities directly up-stream of the cone beta edge.

Independent testing has show this affect to occur with close coupled out of plane elbows, and single elbows at Reynolds numbers to 8,000-10,000 and above.

Consideration must be given to any installation that employs an upstream disturbance producer other than an elbow, such as a gate valve or device which can produce jetting or high velocity fluid distortion past the cone. Practical experience, has shown that a 3-4 diameter upstream section will suffice to allow the sufficient fluid expansion needed to allow the cone to regenerate the velocity profile. (Fig 1)

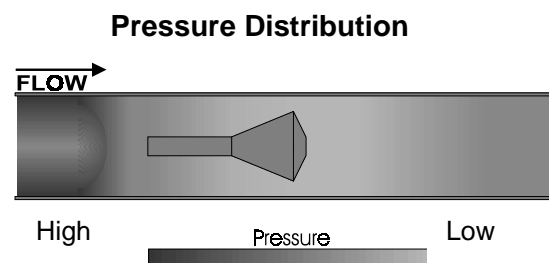


Fig 1

Standard design concepts

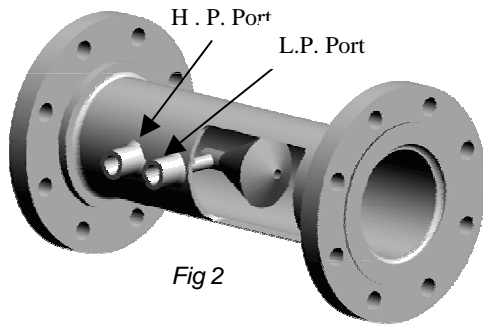
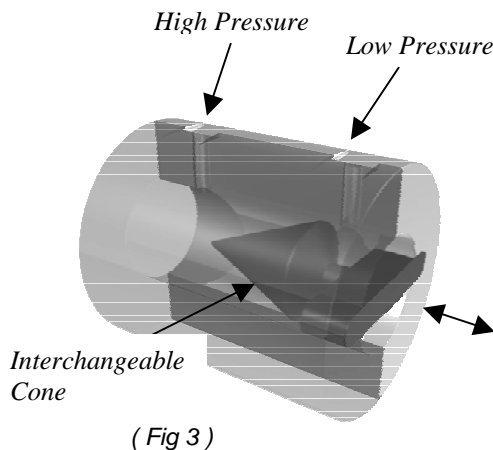


Fig 2

V-Cone with Welded Construction :

This type of construction uses a support tube which acts as both a support and low pressure conduit connected to the large cone a horizontal low pressure tube passes through the center of the cone assembly and is attached to the support tube (Fig 2).

Machined Construction :



(Fig 3)

A machined mono-block in stainless steel or other material is manufactured to allow a cone to be supported by a cross piece which can be removed allowing different cone diameters to be implemented. This allows flexibility of the metering system in respect to large turndowns. The meter is flangeless and sits between pipe flanges. see : fig 3

Installation Effects

Pipe flow velocity profiles are rarely ideal, there are many installations where flow-meters exist in which the flow is not well developed.

Trying to measure disturbed flow can create some problems in certain types of DP device. The V-Cone overcomes this problem by re shaping and distributing the up-stream velocity profile. (Fig 4).

Reshaping the Velocity Profile

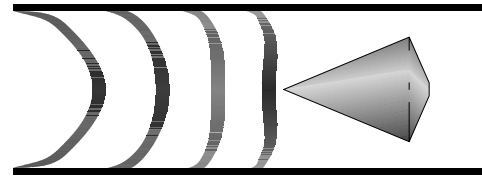


Fig 4

This feature enables the meter to be placed in a small space with minimum straight run requirement. Thus saving real estate .

Production and Test Separators

Current design of multiphase separators allow overall uncertainty (on all three phases) of about 15% - 20% according to recent API /MMS comments.

This can be due to operator control, time delay in stabilization of the vessel, incorrect design involving fluid levels, position of vessel in respect to the pressure head requirement (on liquid side) and also the main metering carry over of other product fractions.

In particular where orifice plates are used it may be necessary to perform, plate changes to facilitate turndown (otherwise the performance of the measurement system could be compromised), and to use upstream flow conditioners or velocity profile devices which add cost to a system.

Long-term vulnerability using orifice plates in production separators can be demonstrated by examining public documents in the measurement field *.

(*Examples cited in this document from Phillips Petroleum Embla-Platform NSF MW Gas Measurement for the Real World 1994)

Orifice Technology issues:

Beta Edge Degradation, Stagnation Area, and Deposition.

During the use of a velocity profile sensitive device (as an orifice) it is necessary to confirm that the beta edge of the device is both clean and has not been compromised due to trash & debris.

Current API paper standards address a clean dry and non-polluted gas, which does not take into account generally an offshore usage condition ie:-"wet gas."

This can result in high maintenance and intervention cost due to frequent plate changes.

Where paraffin's or sulphate deposition occurs in the pipe in almost all cases shift in the Cd is caused due to a re-circulatory effect at the rear of the orifice plate.

There also can be a stagnation area up-stream of the device where heavy end hydrocarbons can collect.

(see enclosed Photo examples from Marathon Oil site Appendix A and longevity issues later in the paper)

Wet Gas:

Current AGA/API paper standards do not address wet gas installation conditions, hence the use of an AGA/API standard to design a possible wet gas metering system can also end in higher intervention costs not generally assumed at the start up case.

Greater liquid injection over time to obtain more products on declining wells can result in an increase in wetness at the gas outlet. Examples of this can range from under-reading of the meter or over-reading depending on Reynolds No, Beta ratio, and liquid mass fraction seen at the meter.

Research in this field by Chevron and others indicates a Cd movement of over 2%-3% outside of the predicted API requirements due to wet gas with liquid loads of only 0.33bbl/MMscf as indicated in research.

Reference:

Dr V.C. Ting Chevron Corp :- Effect of Liquid Entrainment on Orifice Meters.

Wet Gas Lab Test CEESI Nunn C.O. :

Recent Wafer V-Cone testing at CEESI indicated a low susceptibility to Cd change with liquid load, base line values where plotted against numerous test loop instruments in a dry condition.

Flow rates from 7 –70 feet / second in a 4 inch line size where used. The liquid rate was added to a maximum of 1 and 2 Bbl per MMSCF. The liquid hydrocarbon was a Decane derivative acceptable for use in closed surroundings.

The results where plotted and the effects noted , further work is underway to see the effect of low D.P. ranges on repeatability and accuracy and Y factor changes (currently the welded version has a Y factor equation available to correct for density changes due to pressure)

(See Appendix C fig 8) - (CEESI = Colorado Experimental Engineering Station Courtesy of Chevron Inc USA).

B.P Amoco Field Test

During March 2001 BP tested a V-Cone in an upstream field condition .

A 4 inch \varnothing wafer cone was tested with a 4 inch \varnothing orifice plate 36 inches upstream and a separator downstream .

The results were very impressive.
(See Appendix C fig 7)

Longevity, Contamination, and Beta Edge Damage Lab Test

During late 98 early 99 Marathon Oil installed test meters at there on-shore hydrocarbon facility in central Wyoming. The site was producing dirty wet gas with H₂s and asphaltene contaminants. The result on the existing measurement system was not very pleasing to the client nor the local BLM (government) office whom collect royalty from these gas systems . The use of the V-cone was to see if the contamination would affect the meter the assumption that it would work was a driving force to implement the installation. 3 inch meters where fitted and the most severe well used as a test site. (See appendix A & "A-1:Orifice trash deposits")

On inspection the orifice plate units showed trash build up after only three months usage with Asphaltene / Paraffin deposition at the up-stream inlet to the meter and contaminants after the plate in the low pressure region.

On inspection of the V-Cone the unit (Appendix A) did not show the same severity, probably due to accelerated flow around the cone element.

This seemed to keep the cone and sensing ports clear of deposition , thus maintaining a consistent D.P. across the meter.

Entrained condensate liquid moved into slug flow condition periodically,

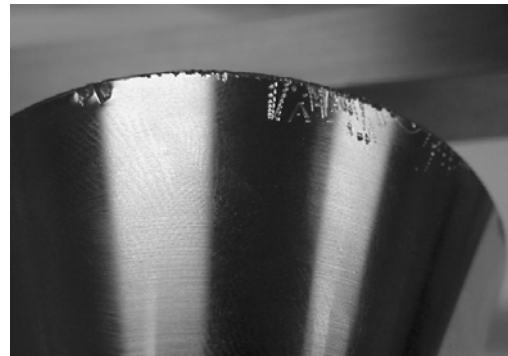
which caused liquid to enter the orifice sensing lines and also be retained after the plate. The cone meter did not show this problem due to the straight through design.

The regular "blowing" off of the plate was deemed a severe problem in man hours and traveling to the site, plus the effect on accuracy this caused. With the lack of liquid retention using the V-cone the system now runs within the BLM (us gov) guidelines.

Damage Test

Damage testing of the V-cone wafer meter was recently performed, this involved determining a base line on a calibration rig over several flow rates, after which intentional damage to the cone beta edge was performed in a somewhat severe manner.

The photographs and data * are shown in fig 5 and fig 6



*Fig 5

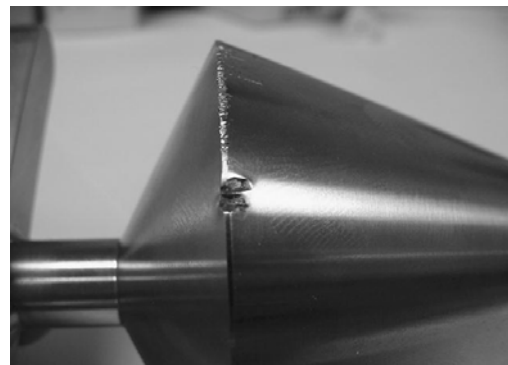


Fig 6

Test Results (damage testing)

The deviation from the test shows the Cd shifted by app. + 0.3% which is within the uncertainty of the McCrometer calibration station.

This initial test is currently being superseded by further tests with multiple damage regimes to view the effect per incident.

This work is a pre-courser to the use of the meter in a sub sea "non-intervention" environment.

(See appendix D fig 9)

Weight Penalty (platform design):

Current design of orifice systems require large up and downstream pipe lengths, this is not good if you area user since cost of real estate is premium offshore due to the large weight related cost in installing :- large pipe runs, orifice carriers, and supporting structures.

Current weight penalty costs in the Gulf of Mexico can be from app. 12\$ per pound to 25\$ per pound.

Installing a system including all piping requirements and a cast carrier can amount to high dollar amounts in the platform support requirements.

This can be compounded on deep water platforms.

Therefore using a device, which has low weight and reduced up-downstream piping needs, can reduce overall client installation costs

Installation cost relating to weight penalty :

The V-Cone can perform its own velocity profile conditioning as part of the meter design .

The installation envelope can be reduced significantly and direct coupling with elbows can be straight to the meter flange face without Cd performance degradation due to swirl or profile skewing.

Please note that the V-Cone weight is approximately only 1444 lbs for a 16inch #900 meter, 1161 lbs for 14 inch meter and only 945lbs for a 12 inch which is significantly lighter than both orifice carriers and respective up-downstream piping for these size systems ,which can weigh more than 2.5 tons, per stream.

V-Cone Technology Technical Attributes:

Real World accuracy using laboratory calibration is possible to facilitate an accurate performance over 10-1 turndown better thanthat of conventional differential producers.

Performance of +/- 0.5% at 10-1 turndown, with trash resistance, low beta edge degradation (Beta edge is after the flow on V-Cone) and no stagnation area make the unit ideal for high cost intervention areas and long-term performance.

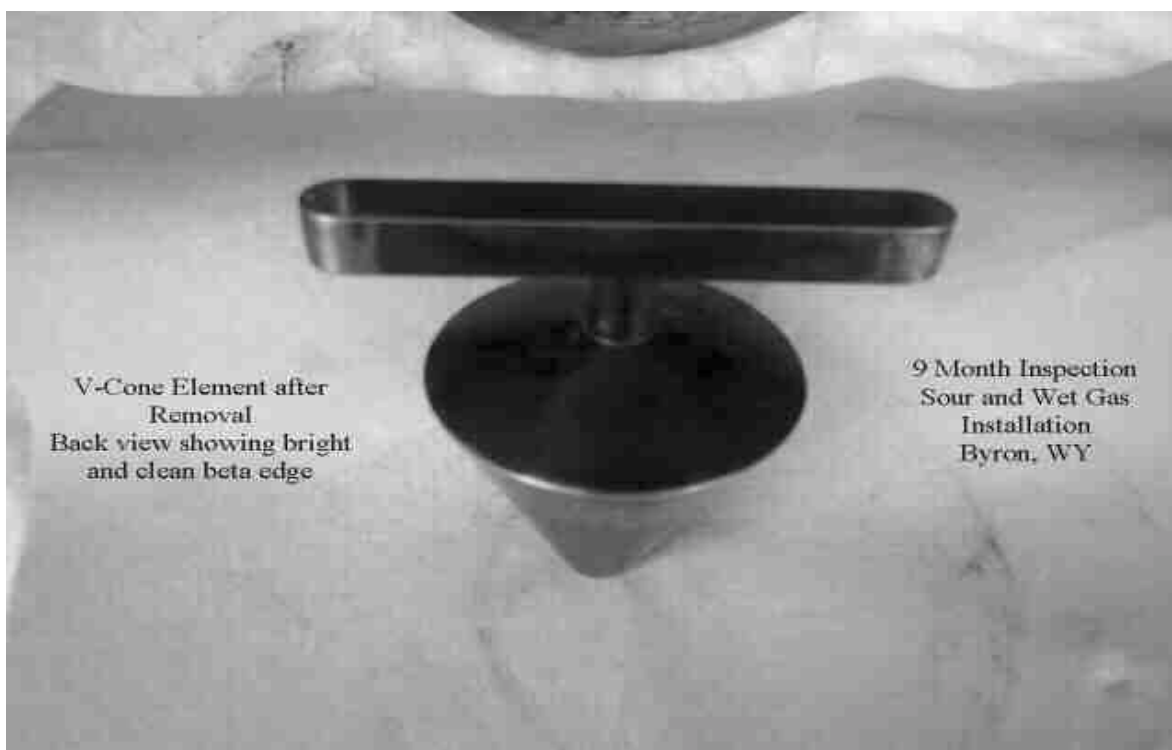
The low weight of the device will ensure economy of installation without having to purchase long piping lengths and high dollar flow conditioners/profilers (certain 12 inch diameter flow profile generator units can cost over \$8-10,000 dollars).

Sub Sea Implementation and Design

Currently 35 precision tube units are in service in a sub-sea wellhead marine environment, in Norway, Angola, and South China Seas . The main usage has been water injection metering , however, allocation gas metering has been a recently accepted philosophy with the device. Implementation to >12000 feet is acceptable with a new configuration and special sensor housing. *(See Appendix D fig 10)*

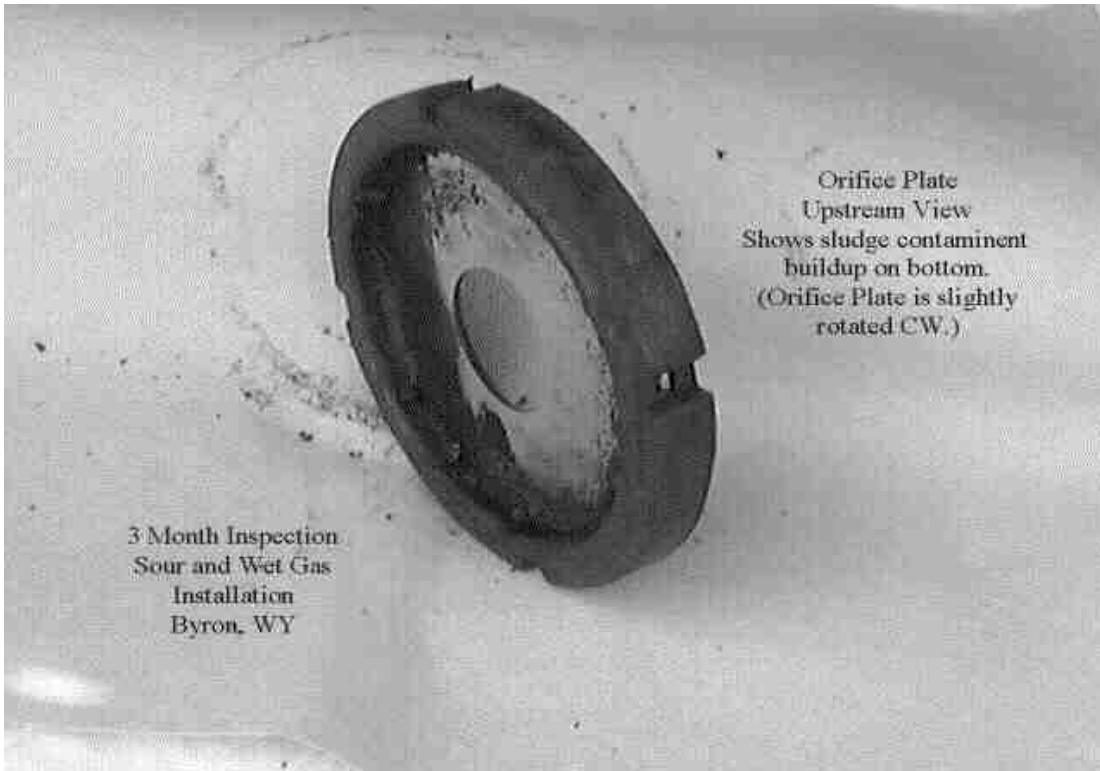
Appendix A

Wet Gas Photographs Wellhead Metering



Appendix A-1

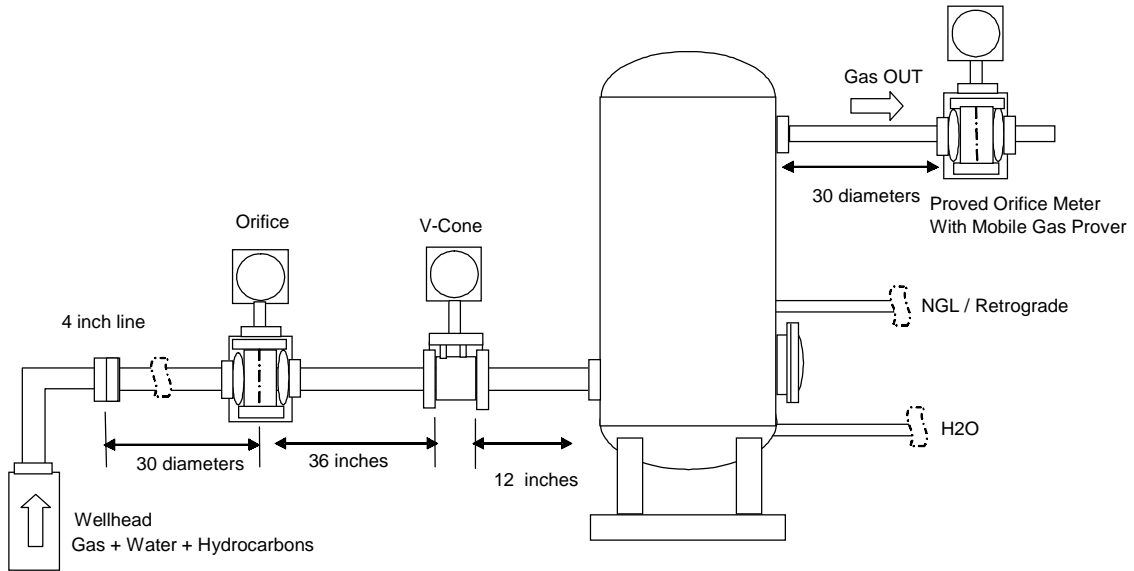
Wet Gas Photographs Wellhead



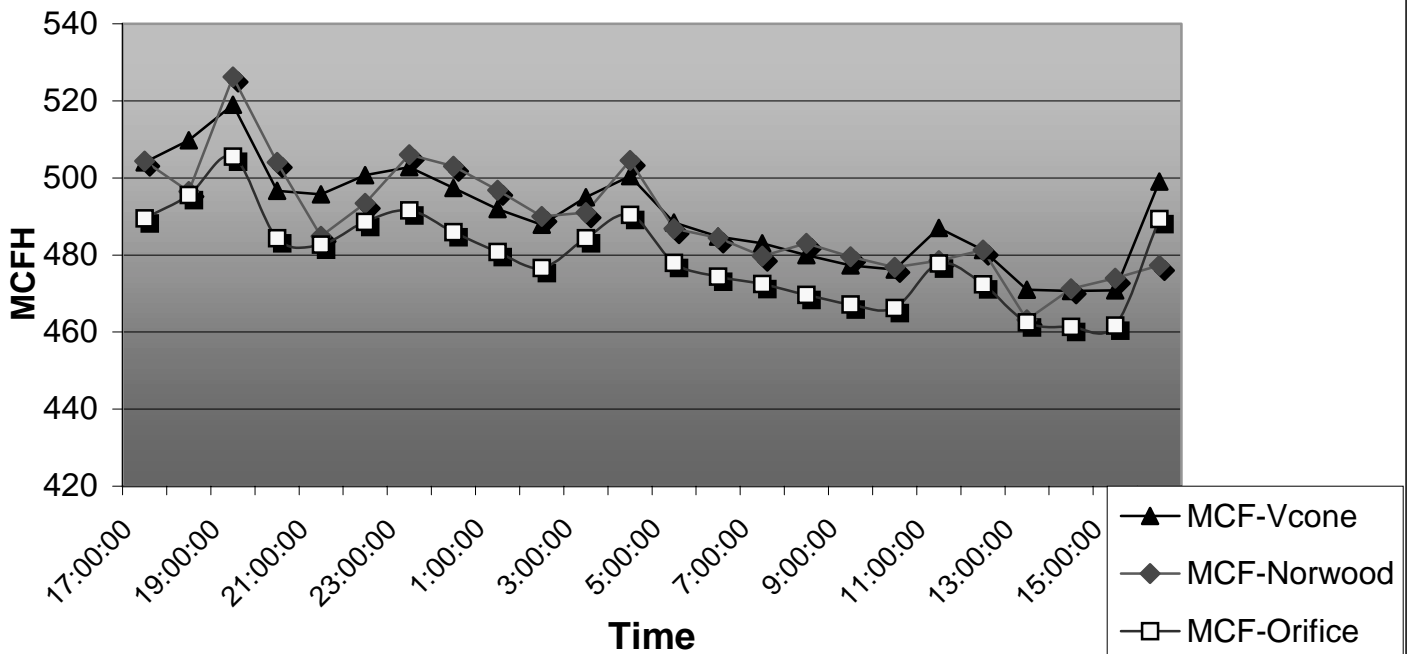
Appendix B

Gas Production Separator

(Typical Arrangement)
 (BP Norwood Separator Site Wy.USA.)



V-Cone vs. Orifice Plate & Separator



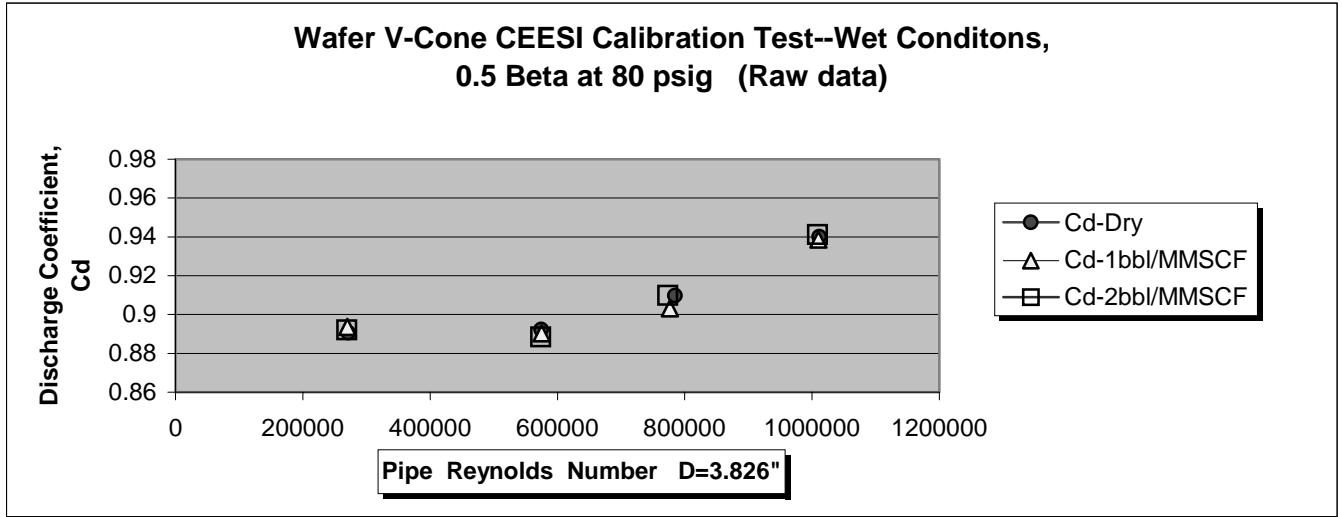
Appendix C

Fig 7

Data from BP/ Norwood Seperator Site Wy

--TIME--	MCF- Vcone	MCF- Norwood	MCF- Orifice	DP- Norwood	DP-Orifice	-PSIA-	-DEGF-	--MMBTU--
17:00:00	504.053	504.41	489.526	153	51.5	373.5	119.9	479.708
18:00:00	509.756	496.5	495.586	148	52.5	375.6	119.9	485.135
19:00:00	519.024	526.25	505.496	165	54.7	374.9	119.6	493.955
20:00:00	496.692	504.04	484.337	152	50.6	371.7	119.5	472.702
21:00:00	495.705	484.87	482.686	141	50.3	371.9	119.4	471.762
22:00:00	500.691	493.45	488.556	145	51.3	373.2	119.4	476.507
23:00:00	502.829	506.04	491.551	152	51.9	373.8	119.4	478.543
0:00:00	497.401	503.08	485.979	152	51.2	369.8	119.3	473.376
1:00:00	491.94	496.79	480.75	150	50.2	369.4	119.3	468.18
2:00:00	487.84	490.04	476.625	145	49.1	371.2	119.3	464.277
3:00:00	495.004	491.04	484.341	144	50.6	371.5	119.2	471.096
4:00:00	500.487	504.5	490.445	152	51.8	372.3	119.2	476.314
5:00:00	488.422	486.87	477.947	142	49.4	370.7	119	464.831
6:00:00	484.779	484.45	474.372	142	48.9	369	119	461.364
7:00:00	483.022	479.67	472.455	138	48.6	368.4	119	459.692
8:00:00	479.931	483	469.689	142	48.3	366.5	118.9	456.75
9:00:00	477.279	479.58	467.129	140	47.6	367.8	118.9	454.226
10:00:00	476.231	476.83	466.232	138	46.9	370.9	118.8	453.228
11:00:00	486.98	478.54	477.817	139	50.7	361.3	118.6	463.46
12:00:00	481.302	481.29	472.392	145	49.4	362.8	118.6	458.055
13:00:00	470.997	463.2	462.513	128	45.4	376.7	118.7	448.248
14:00:00	470.623	471.2	461.351	131	0	373.2	118.7	447.891
15:00:00	470.861	474	461.711	134	45.7	373	118.7	448.119
16:00:00	499.061	477.33	489.357	136	54.2	355.3	118.6	474.957
Totals	11770.91	11736.97	11508.843					

Fig 8



Appendix D

Fig 9

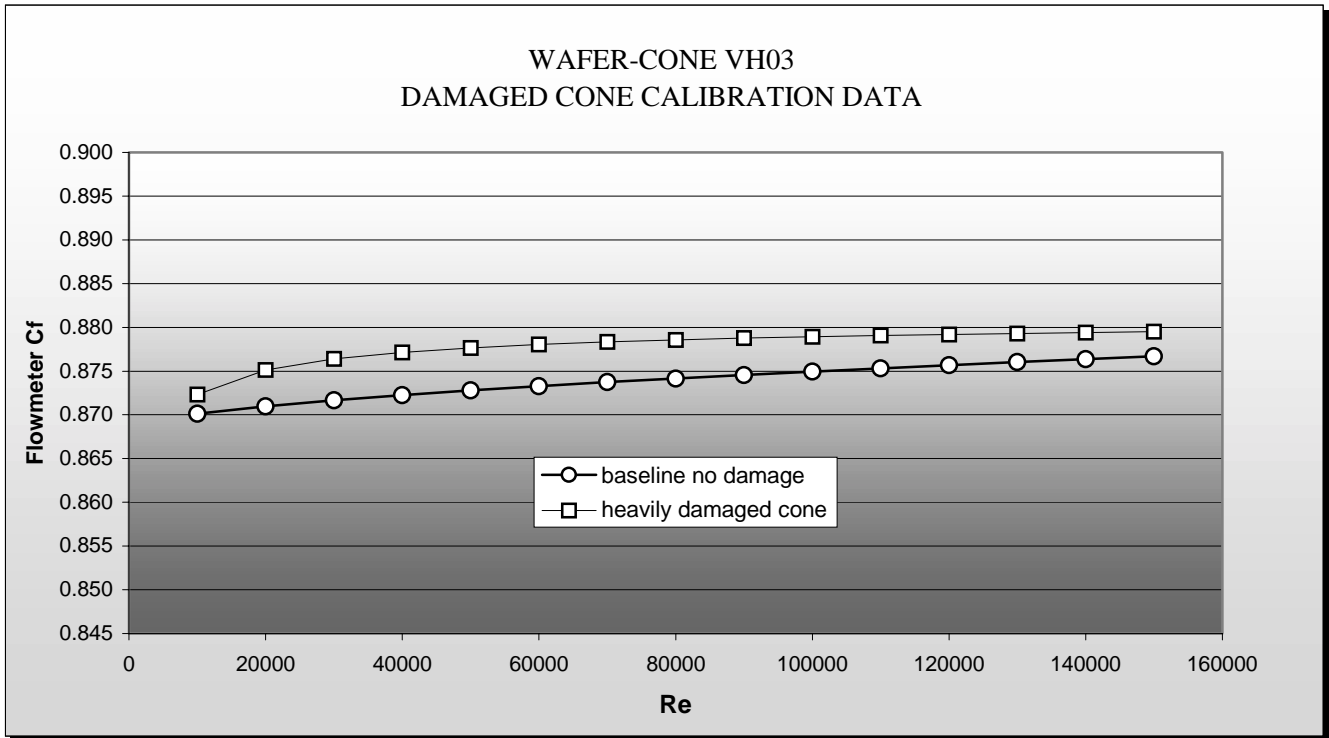
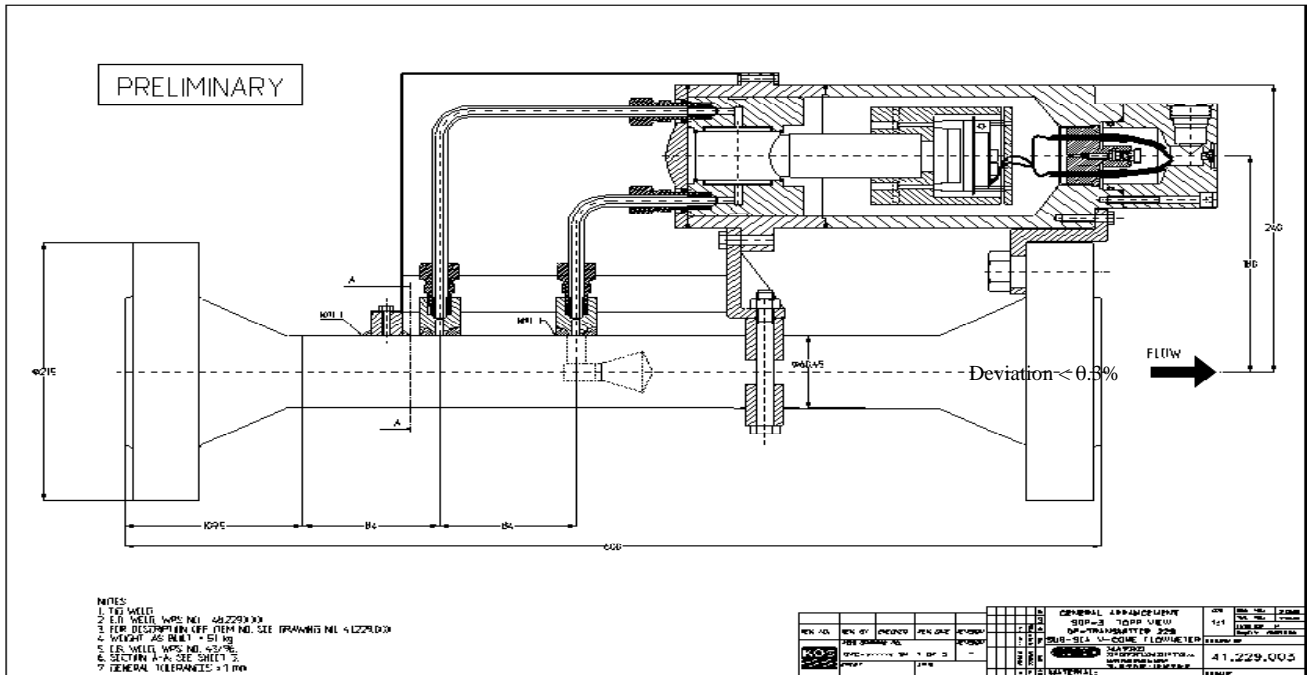


fig 10



Reference Documents / Data :

Hayward	A Basic Guide and Source Book for Users	1973.
Szabo / Winarski Hypnar	V-Cone Meter for Natural Gas Flows	1992.
Miller	Flow Measurement Handbook	(Latest Edition)
GRI	Wet Gas Research V-Cone 4 inch Diameter	1997
Lawrence	V - Cone Technology (Old Wine in a new Bottle)	1998
Lawrence	D.P. Metering for the New Millennium	1999
Lawrence	Wellhead metering using V-Cone Technology NSFMMW	2000
Bright	BP Amoco Wy test separator data	2001

