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To : Distribution

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Subject : **Flow Meter Research for APS Beam-Lines**

Many critical APS beam-line componenets, such as the photon shutters and fixed masks, utilize porous media for heat transfer enhancement and consequently rely on steady operation at design flow rates to ensure that the proper levels of heat transfer enhancement are maintained. Due to their critical nature, these componenets can never fail and are designed with high safety factors to ensure a very high degree of mechanical reliability. However, because these components experience varying degrees of heat flux depending on the beam's location at any instant, they can not easily be interlocked on coolant temperature rise or surface temperature. It is therefore easiest and most logical to interlock the device on the coolant flow rate because the level of heat tranfer enhancement is governed by the coolant flow rate. In order to maintain high levels of component reliability it is therefore necessary to ensure that the flow metering system, which the component is interlocked on, has an equal or greater degree of reliability.

Due to the critical nature of the components which will be monitored by the flow meters, it is desirable to minimize the potential for mechanical failure by focusing on passive flow meters, i.e. those with no moving parts. Table 1 lists the salient characteristics desired for APS flow metering devices. As a first step, an in-depth literture search was performed utilizing the Thomas Register and other sources to gather information on various available passive flow meters. Flow meter types considered included differential producers such as the orifice plate, venturi, V-Cone, and averaging pitot type, stress/strain transmitting types such as the strain gage target meter and the vortex shedding meter, thermal-type meters such as the hot wire/film anemometer and thermal flow meter, ultrasonic flow meters and electro-magnetic flow meters. For each type of flow meter, vendors were contacted and encouraged to visit the APS and prepare a formal presentation on their products. In addition, vendors were encouraged to provide, on a several month trial basis, a demonstration model for testing and evaluation. In this manner, a total of 15 defferent flow meters and 8 pressure transmitters, used for differential producers, were obtained for testing purposes.

A simple yet highly accurate flow meter testing station was contructed based on the ASME flow calibration standard which employs a static weighing technique. The actual flow rate is determined by diverting the flow into a tared capture vessel and measuring the fill time and mass of the diverted fluid. Associated valving and pressure regulation was incorporated into the system to ensure constant flow rate through the system. The actual flow rate is compared to the meter readings during the test to determine the error associated with the flow meter. All signals were captured and recorded via a multi-channel high-speec data acquisition system. Figure 1 shows a schematic of the system.

From the start, it was apparent that differential producers held the highest promise for reliability due to the fact that the differential pressure transmitter, the device which measures the differential pressure across the flow meter, can be remotely located away from the flow meter and any high levels of radiation present in the APS front end area. There are no moving parts or electornics at the site of the flow meter this eliminating the possibility for a local failure. The pressure transmitter can be located in an area where maintenance can be performed without breaching the radiation environment which would require a beam-line shut-down. Due to the above advantages, a large portion of the flow meter research facused on differential producers and associated pressure transmitters.

A means to evaluate the performance of pressure transmitters was also incorporated into the flow meter testing station. An 11 foot tall water manometer was used to characterize each pressure transmitter prior to testing. The transmitter output versus the actual differential pressure was determined over the usable range and a characterization curve was determined. A Fortran program was written to perform the data analysis, and utilized the characterization vurves to isolate the flow meter error from the transmitter error. This procedure provides information on transmitter repeatability as well as accuracy. In this manner, the cumulative error for any combination of differential producer and differential pressure transmitter could be analyzed. A typical output for a V-Cone differential producer is provided in Figure 2.

Figure 3 shows the accuracy as a function of flow rate for several types of meters tested. The turbine flow meter is included as it is a popular choice for flow metering. The results of the V-Cone differential producer are impressive, yielding less than 0.5% error in most cases. Typical differential producers such as orifice plates tend to have 5% error under normal operation. It was also shown that the V-Cone performance is independent of entrance and exit effects which is not typical. Most flow meters are sensitive to entrance and exit effects and generally require 15 hydraulic diameters of straight pipe upstream and 10 downstream to ensure no introduction of additional error. This means that the V-Cone can be mounted in any plumbing configuration without needing to worrry about errors associated with entrance and exit effects. Figure 4 shows data taken on three different V-Cone meters; on 1/2” size and two 3/4” size with different flow ranges.

Pressure transmitters were also sutdied in depth on a cost versus functionality basis keeping in mind the required high degree of reliability. In general, it seems that pressure transmitters can be divided into two catagories: industrial transmitters and laboratory transmitters. Industrial transmitters tend to be rangeable, temperature and humidity compensated, and very heavy duty as they are expected to operate in harsh environments. Laboratory transmitters tend to be fixed in range and not compensated. Laboratory grade transmitters, however, are usually half the price of an industrial transmitter. In the case of the APS, all transmitters shall monitor one flow meter only and shall be located in a constant temperature and humidity environment. The laboratory grade transmitter is more than adequate for APS flow meters.

In conclusion, the selection of flow metering devices for the APS beam-lines has been studied in depth to ensure an extremely high degree of reliability for the safety interlocking of critical components. Differential producers, in particular the V-Cone, in conjunction with laboratory grade pressure transmitters offer an optimized solution for the selection of flow metering devices for APS critical components. The total cost for a V-Cone and transmitter is approximately &850 which is similar to a typical flow meter such as the turbine meter.

Salient Characteristics of Front End/Beamline Flow Meters

- No moving parts
- Preferably no contact between the sensors and the fluid
- High reliability (in particular at the site of the flow meter)
- Minimal maintainence
- Low flow rate measuring capabilities
- Low pressure drop
- Remote readout capabilities
- Compact
- Must work with deionized water
- Must be able to operate in a radiation environment

Table 1

INPUT FILE: 10289205.DAT BTB 10/28/92

BRAIDED HOSE INPUT

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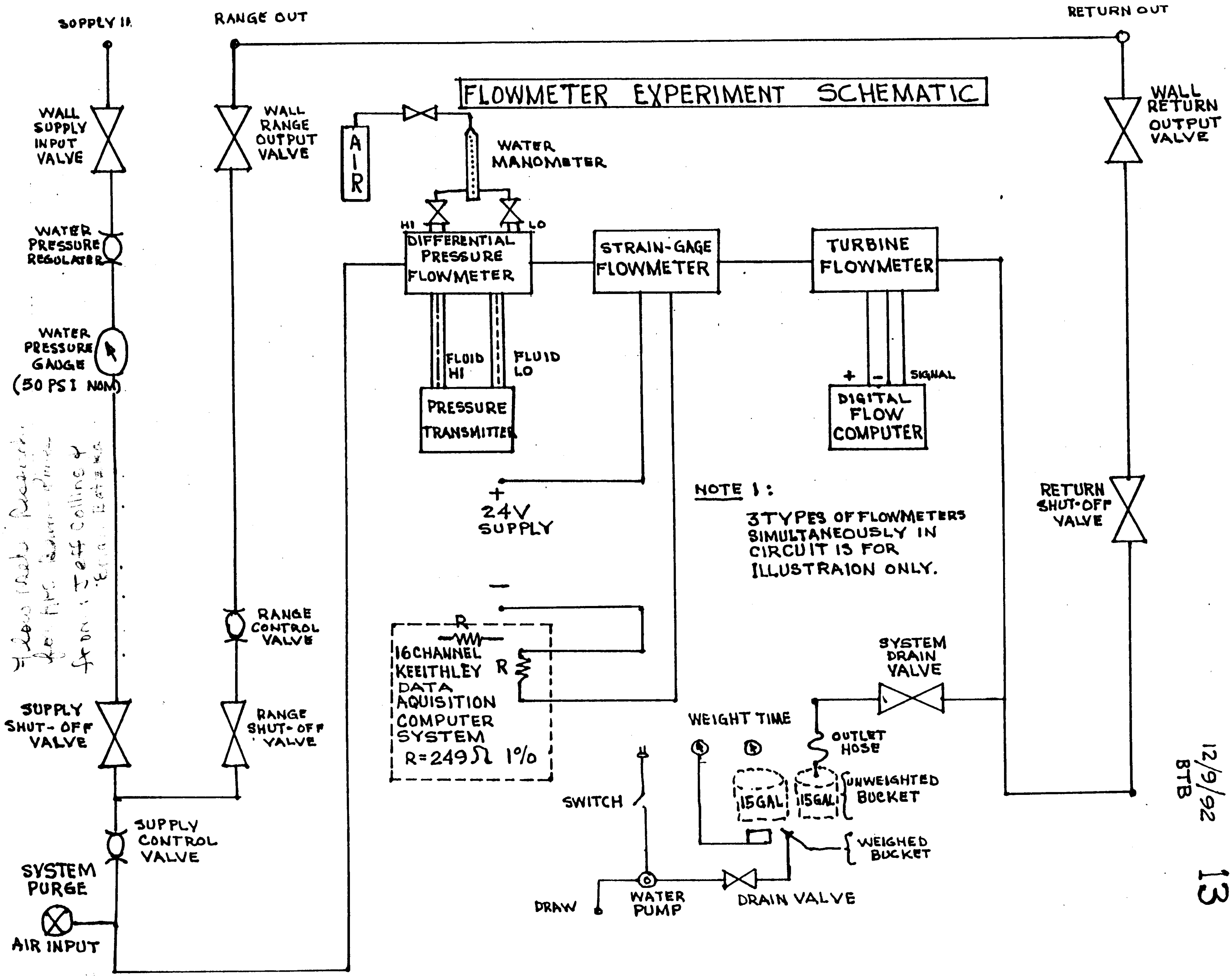
FLOWMETER TYPE : V-CONE
LINE SIZE : 0.750”
APPROACH I.D. : 0.8250”
BETA RATIO : 0.4518
MAX. FLOWRATE : 5.00 gpm
MAX. DIFFERENTIAL : 45.400 “ WATER
TURNDOWN RATIO : 10:1

TRANSMITTER TYPE :HONEYWELL STD 924
TRANSMITTER RANGE :0-50”
CHARACTERIZATION INTERCEPT : -.026924
CHARACTERIZATION SLOPE : 1.007500

MEASURED FLOWRATE (gpm)	TRANSMITTER READING (“ H2O)	MANOMETER READING (“ H2O)	TRANSMITTER FLOWRATE (gpm)	MANOMETER FLOWRATE (gpm)	TRANSMITTER DEVIATION (%)	MANOMETER DEVIATION (%)
1.063	2.099	2.087	1.067	1.064	0.356	0.088
1.497	4.077	4.081	1.488	1.489	-0.600	-0.556
2.030	7.619	7.649	2.035	2.039	0.255	0.454
2.372	10.397	10.448	2.378	2.384	0.240	0.486
3.055	17.186	17.288	3.059	3.068	0.134	0.431
3.477	22.344	22.484	3.489	3.500	0.363	0.680
3.924	28.161	28.345	3.919	3.932	-0.131	0.197
4.349	34.306	34.536	4.327	4.341	-0.510	-0.175
4.832	42.408	42.699	4.813	4.829	-0.398	-0.056
5.061	46.583	46.905	5.045	5.063	-0.314	0.032

Figure 2


FLOWMETER EXPERIMENT SCHEMATIC
SUPPLY IN
RANGE OUT
RETURN OUT
WALL SUPPLY INPUT VALVE
WALL RANGE OUTPUT VALVE
WALL RETURN OUTPUT VALVE
AIR
WATER MANOMETER
HI
LO
DIFFERENTIAL PRESSURE FLOWMETER
STRAIN-GAGE FLOWMETER
TURBINE FLOWMETER
WATER PRESSURE REGULATOR
WATER PRESSURE GAUGE (50 PSI NOM)
FLUID HI
FLUID LO
PRESSURE TRANSMITTER
+
-
SIGNAL
DIGITAL FLOW COMPUTER
+ 24V SUPPLY
-
NOTE 1:
3 TYPES OF FLOWMETERS SIMULTANEOUSLY IN CIRCUIT IS FOR ILLUSTRAION ONLY.
RETURN SHUT-OFF VALVE
RANGE CONTROL VALVE
R
16 CHANNEL KEEITHLEY DATA AQUISITION COMPUTER SYSTEM
R=249Ω 1%
SYSTEM DRAIN VALVE
SUPPLY SHUT-OFF VALVE
RANGE SHUT-OFF VALVE
WEIGHT TIME
OUTLET HOSE
15GAL
15GAL
UNWEIGHTED BUCKET
SWITCH
WEIGHED BUCKET
SUPPLY CONTROL VALVE
SYSTEM PURGE
AIR INPUT
DRAW
WATER PUMP
DRAIN VALVE
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BTB
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