Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: MD-ENG-511 Date: 14 April 2014

Project Internal Reference: PPD docdb: 2080 Mu2e docdb:

Project: Mu2e Calibration System

Title: Preliminary Hydraulic Calculations

Author(s): Dave Pushka

Reviewer(s): n/a

Key Words: Fluid hydraulic calculations

Applicable Codes: FESHM 5031.1, ASME B31.3

Abstract Summary:

Calculations and correspondences are attached.

This is a preliminary set of hydraulic calculations to do a first pass line and pump sizing and to calculation the fluid transit time from a neutron generator to the detector.

The purpose of creating an engineering note is to capture this work as an aid to those who will perform the final design and to assist in the baseline cost estimate.

Fermilab Engineering Manual Requirements:

Chapter 1: There is no specification for this work. Experimenters are planning a radioactive calibration system based on a previously used system at BaBar. This note is to perform some preliminary hydraulic line sizing.

Chapter 2: Risk analysis has not been formally prepared. Piping engineering notes have been prepared previously and are deemed 'low risk".

Chapter 3: Requirements and specification reviews by the project have not been formally prepared.

Chapter 4: This engineering note has been specifically prepared to address chapter 4 of the engineering manual.

Chapter 5: The 'reviewed by' signature on the cover page of this document addresses Chapter 5 of engineering manual.

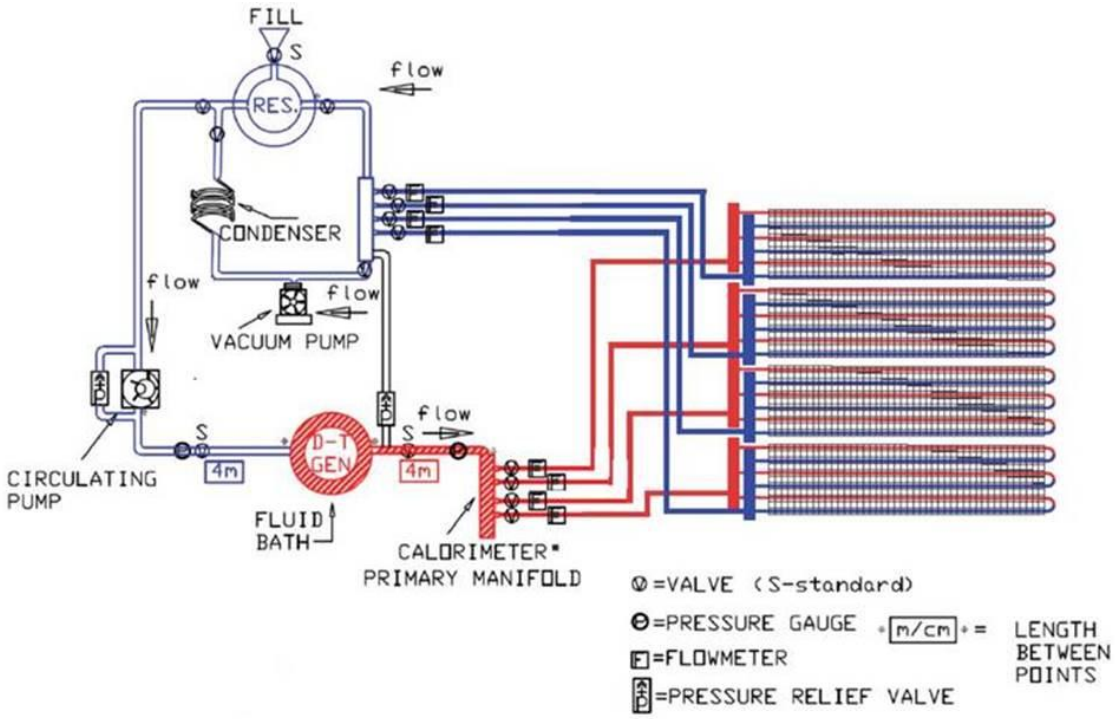
Chapter 6: No materials were purchased as part of the preparation of this document.

Chapter 7: This is a document and no testing is required.

Chapter 8: This is a document and no release to operations is required

Chapter 9: Unless there are lessons learned from this effort, this engineering note and the other material posted in PPD docdb 2080 will be considered the final written Project Report as described in Chapter 9. This note will be placed in the PPD document data base as a means of Archiving and Control.

Image 1: Schematic diagram of System courtesy of Kevin Flood and Frank Porter:



Pump Info Emails:

Date: Fri, 11 Apr 2014 00:35:39 +0200
From: "Racine, Mike" <racine@slac.stanford.edu>
To: "kflood@caltech.edu" <kflood@caltech.edu>
Subject: RE: Babar Source Calibration system circulation pump info?

Hi Kevin,

Here's the info on the pump;

Magnatex Pump
Mod# MP421-N40
SIZE 1.5X1X6
MAT. 316SS
CAP. 55GPM
TDH 70FT
IMP. DIA 4.35
MOTOR 5HP@3550RPM
S/N M-10729

Hope this helps. I do remember that we changed impellers early on after the installation and I have that impeller in my office. I do not know what the impeller is that is inside the pump right now.

Mike

From: christi prust [mailto:cprust@magnatexpumps.com]
Sent: Monday, April 14, 2014 11:45 AM
To: David R. Pushka
Cc: afry@magnatexpumps.com; 'Neal Gunn'; radams@magnatexpumps.com; porr@magnatexpumps.com
Subject: Curve for M-10729

Dave,

Please find the attached performance curve for your service. It looks like you have an existing 4.3" impeller, but the new curve is showing a 4.5" impeller. Please let me know if you have any questions or if there is anything else we can do to help.

Your existing pump was purchased in 1998.

Best regards,

Christi Prust
Magnatex Pumps, Inc.
719-329-0777 (v)
719-329-0888 (f)
cprust@magnatexpumps.com
www.magnatexpumps.com

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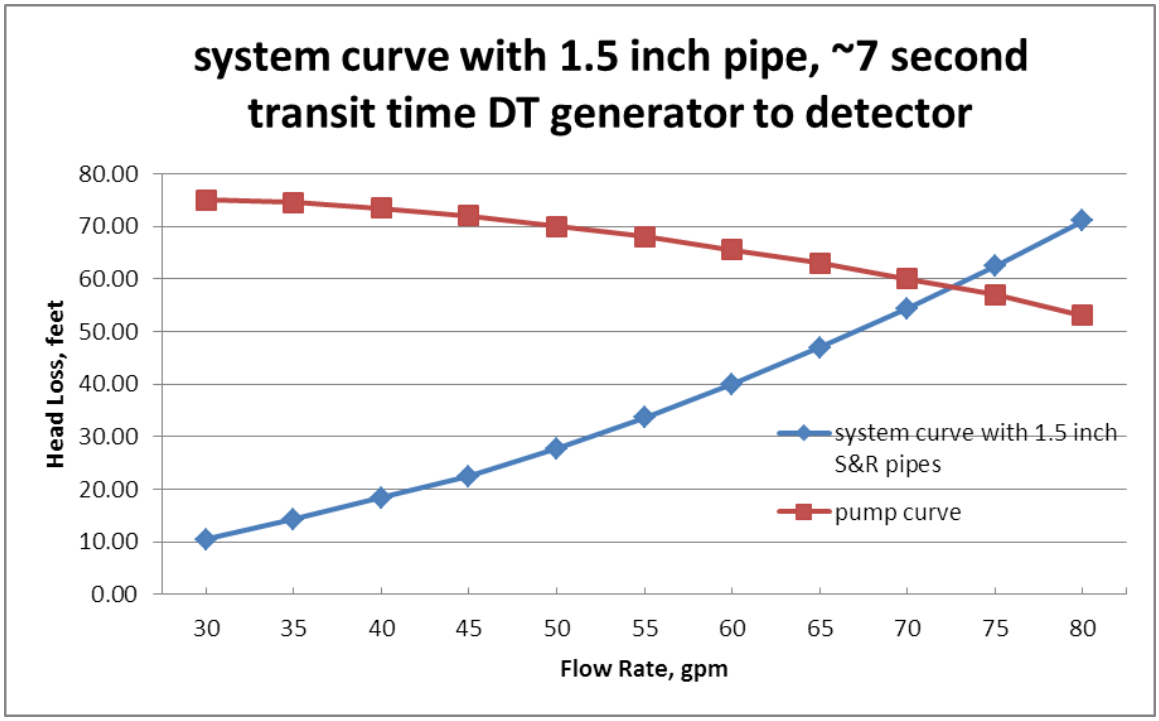
System and Pump Curves (Summary of the Hydraulic Calculations):



Discussion:

System will operate where the pump and system curves cross. This is at approximately 70 GPM and a pressure of just under 60 feet of head.

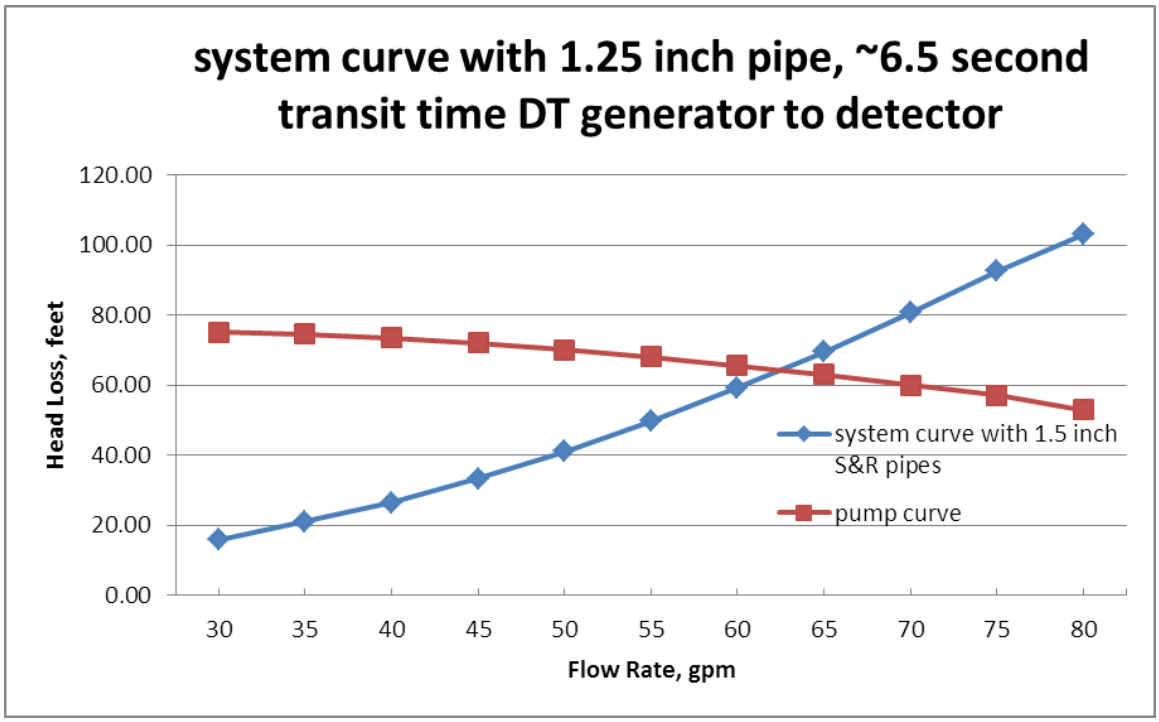
This was calculated for 1 ½ inch iron pipe size (ips) schedule 10 S stainless steel piping for both the supply and the return. Both the supply and the return were each assumed to be 22 meters long. The piping inside the detector was assumed to be 0.375 inch outside diameter, 0.020 inch thick wall aluminum tubing. An average length of 1.6 meters was assumed for each of the 24 parrallel passes of detector tubing.

Fluid is Fluorinert FC 77with properties as shown below in the calculation section.

An assumption was made to include ten (10) 90 degree, long radius elbows on both the supply and return piping.

Note that this operating point causes the pump to run out on its curve, slightly exceeding the motor horsepower and requiring about 9 feet of net positive suction head. Actual availble suction head (NPSHA) should be at least 15 feet. Presumeably, this partially explains why the pump needed to have the impeller changed at BaBar.

A sensible alternative design is to use 1 ¼ ips pipe for the supply line and 1 ½ ips pipe for the return. This slightly reduces the transit time by about ½ second, raises the system curve, and causes the pump to run back on the operating curve:


system curve with 1.25 inch pipe, ~6.5 second transit time DT generator to detector
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Head Loss, feet
30
35
40
45
50
55
60
65
70
75
80
Flow Rate, gpm
system curve with 1.5 inch S&R pipes
pump curve

Calculations:

Hydraulic flow Calculations:

Formulas:

Pipe Delta P = 0.000216*(f*L*ρ* Q^2)/(d^5)

Fitting Delta P = 0.0001078*(K*ρ* v^2)

K = f*(L/D)

Q = flow rate in gallons per minute	75	
ρ = fluid density in pound per cubic foot		
d = pipe inner diameter in inches		
f = friction factor calculated based on pipe roughness and Reynold's number		
L = pipe length, feet		
D = pipe inner diameter in feet		
K = Resistance coefficient		

Total pressure drop, psi	48.14	psi
Total Head loss, ft	62.44	feet
Transit time from D-T generator to center of detector	6.89	seconds

Fluid Properties:

Fluid:	FC77	
Density, kg/m3	1780	kg/m^3
Density, pound/cubic foot	111.12184	#/ft3
kinematic viscosity, v (cSt)	0.8	cSt
kinematic viscosity, v' (m^2/sec)	0.0000008	m^2/s
specific gravity of fluid	1.780798718	

Pipe Data:

Supply:

Supply Pipe Diameter, nominal	1.5 sch 10S		
Supply Pipe inner diameter, in		1.682	in
Supply Pipe inner x-section area, in^2		2.222	in^2
Supply Pipe absolute roughness, e		0.00015	
Supply Pipe relative roughness, e/D		0.001070155	
Supply Pipe length from DT gen to DS vac vsl		18	m
Supply Pipe length from outside of DS vac vsl to detector		4	m
Supply Pipe Total Length, meters		22	m
Supply Pipe Length, feet		72.16	ft
Supply Pipe number of 90 degree elbows		10	
Supply Pipe 90 elbow K factor		14 * f_{turb}	
Supply Pipe f_{turb}		0.021	

Sum of K factors for supply piping		2.94	
Supply Pipe fluid Velocity, (ft/s)		10.83	feet/sec
Reynolds's number, Re		1.69E+05	
transit time for supply piping		6.66	seconds
Friction factor, f		0.0230	
Supply Piping Delta P = 0.000216*(f*L*ρ* Q^2)/(d^5)		16.64	psi
Supply Piping Fitting Delta P = 0.0001078*(K*ρ* v^2)		4.13	psi

Return:

Return Pipe Diameter, nominal	1.5 sch 10S		
Return Pipe inner diameter, in		1.682	
Supply Pipe inner x-section area, in^2		2.222	in^2
Return Pipe absolute roughness, e		0.00015	
Return Pipe relative roughness, e/D		0.001070155	
Return Pipe length from DT gen to DS vac vsl		18	m
Return Pipe length from outside of DS vac vsl to detector		4	m
Return Pipe Total Length, meters		18	
Return Pipe Length, feet		59.04	
Return Pipe number of 90 degree elbows		10	
Return Pipe 90 elbow K factor		14 * f_{turb}	
Return Pipe f_{turb}		0.021	
Sum of K factors for return piping		2.94	
Return Pipe Fluid Velocity, (ft/s)		10.83	feet/sec
Reynolds's number, Re		1.69E+05	
transit time for return piping		5.45	seconds
Friction factor, f		0.0220	
Return Piping Delta P = 0.000216*(f*L*ρ* Q^2)/(d^5)		13.03	psi
Return Piping Fitting Delta P = 0.0001078*(K*ρ* v^2)		4.13	psi

Detector Tubing:

number of passes of detector tubing		24	
Detector tubing outside diameter, in		0.375	in
Detector tubing wall, in		0.02	in
Detector tubing inside diameter, in		0.335	in
Detector tubing inner x-section area, in^2		0.088	in^2
Detector tubing absolute roughness, e		0.000005	
Detector tubing relative roughness, e/D		0.0002	
Detector tubing length, m		1.5996	m

Detector tubing length, ft	5.2481	ft
Velocity, (ft/s)	11.37	feet/sec
Reynolds's number, Re	3.54E+04	
transit time for detector tubing	0.46	seconds
Friction factor, f	0.0350	
Delta P = 0.000216*(f*L*ρ* Q^2)/(d^5)	10.20	psi