

Internship Final Review

Fangzhou Xia Fluid Metrology Group



About Me

Fangzhou Xia

- School
 - University of Michigan, Ann Arbor (UM)
 - Shanghai Jiao Tong University, China (SJTU)
- Dual Degree
 - Mechanical Engineering, B.S.E. (UM)
 - Electrical and Computer Engineering, B.S.E. (SJTU)
- Expected Graduation Date
 - May, 2015
 - August, 2015



Project List

- Volumetric Prover Software Redesign
- Experiment Data Processing Automation
- Single Injector Tester Concept Proof
- Oil Prover Software Migration



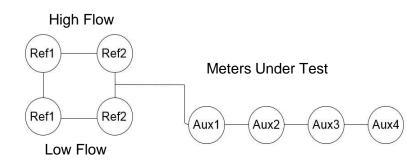
- Initial Status
 - Operational rig for calibration
 - Well-tested software
- Problem Identification
 - Software outdated (15 years)
 - Possible operational error due to user interface
 - Insufficient test capability

Solution

 Redesign Volumetric Prover software using LabVIEW

niversal Flov jle <u>E</u> dit <u>V</u> ie	w Bench: Real Time Screen w			
Channel - Check to Log Data	Description [CH0 - Flow Meter Temp	Actual Value	Units Averaged	Current Data File Current Data File Current Data File Data Loging Logito File Start Text Exection Text Inter
Ch1	CH1 - Inlet Temp	0.00	PSI 0.00	Current Data File Path
🔽 Ch2	CH2 - Supply Pressure	0.00	PSI 0.00	
🔽 Ch3	CH3 - Back Pressure	1.00	PSI 1.00	Change Data File
Ch4	CH4 - Fluid Tank Temp	0	PSI 0	Data Logging
CH5	CH5 - Meterr A		PSI 0	Log to File Start Test Eree Run
Ch6	CH6 - Meter B		L/MIN 0	Test Time 17
Ch7	CH7 - Test Item 2		PSI 0	
Max 214 "Min [0 3G [0 PPH [L/Min 0	Aux L/Mir SG PPH	killiary 1	Auxilliary 2 UMm SG PFH 0 % RowDill between MacRel 215
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Sto	p PWM Output	Target	Actual	0.001 1 1
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	Unclamped	0 10	olt 🛛	6 Intervals 7 Intervals
		Activate	0 PSI	0.3 Delta T US Delta Title Adjust Adjust Target Egit
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Original Volumetric Prover Software

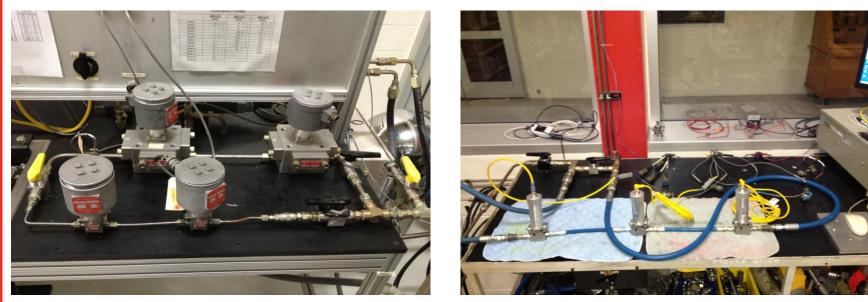


Original System Concept Diagram



4 1/2/2015

- Target Hardware Setup
 - -2 pressure sensors and 2 temperature sensors
 - 4 reference meters and up to 8 auxiliary meters



Auxiliary Meters Under Test

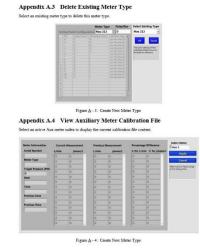


Fuel Systems

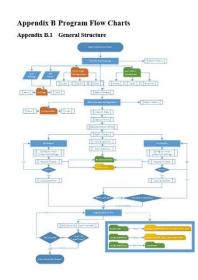
Task Completion

- Fully developed user interface for data processing
- Adapted FPGA code for standard data acquisition
- Electrically tested hardware connection
- Developer, operator documentation

iversal Flow Meter										anning FL	iel /stems
est Setti	ngs S	ensor Cont	figuration	Calibratio	on Verific	ation		Help	Exit		
Flow Flui	d Statu			Reference	e Meter 1	Reference	e Meter 2	PPH Calibra	ation Compariso	n	
Pressur	e (PSI)	Temperat	ture (F)	Type	Max 215	Type	Max 215	1.0			Avg
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,				Ref Avg	ррн 0	Ref Avg	PPH Diff(%)	D OK?	Meter Under T		All OK?
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Documentation





User Interface

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- Major Improvements
 - User friendly interface with drop down list for test configurations reducing operational error
 - Increased test capability with 8 channels
 - Real time measurement display for monitoring purpose

Edit Operate Icols Window Help ersai Flow Bench: w Meter Prover Rig st Settings Sensor Configurati	ion Calibration Verification	1	Help Exit	Curtome	Fuel Systems	Elle Edt Operate Tools Window Universal Flow Bench: Flow Meter Prover Rig Test Settings Sensor C		tion Verification	Help	Exit	Fuel System
ser Settings	Auxiliary Meter Settings					Flow Fluid Status	Refere	nce Meter 1 Referer	ce Meter 2 PPH Calil	bration Comparison	1
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come to Universal Flow Bench	Archive Folder	Save a	Reload Dera	Арр		Progress User settings OK.			0	Record All Dat	

Test Configurations



Experiment Data Processing Automation

Problem Identification

- Experiment data for different meters are mixed together
- Manually generating multiple graphs in Excel is inefficient

Solution

- Write VBA code to select data from multiple files
- Automate graph generation process using VBA

12	Δ	В	С	D	E	F
1	SERIAL	TIME	Tempera	Fuel Supply	Fuel Count	Fuel Flow
2	FF132215027	18.09.2013 06:46:46	103.55	1200.368	600.1087	493.0101
3	FF132215027	18.09.2013 06:46:46	104.11	1199.902	600.0997	505.6552
4	FF132215027	18.09.2013 06:46:46	103.89	1199.327	600.0472	508.5698
5	FF132215027	18.09.2013 06:46:46	103.5	1199.948	600.0226	512.652
6	FF132205372	18.09.2013 06:48:20	103.76	1199.606	600.0124	493.0101
7	FF132215049	18.09.2013 06:49:59	103.1	1200.062	600.0209	505.6552
8	FF132215052	18.09.2013 06:51:18	103.89	1199.622	600.0226	508.5698
9	FF132215056	18.09.2013 06:52:59	103.4	1199.7	599.8313	512.652
10	FF132215062	18.09.2013 06:54:22	103.91	1199.997	600.1307	508.2286
11	FF132215074	18.09.2013 06:56:13	101.69	1200.368	599. 7 836	528.4424
12	FF132215086	18.09.2013 06:57:41	103.54	1199.902	600.1587	521.3388
13	FL132215027	18.09.2013 07:04:32	101.45	1199.327	599.9922	503.3595
14	FL132205372	18.09.2013 07:05:55	104.04	1199.948	599.9715	494.5811
15	FL132215049	18.09.2013 07:07:22	103.89	1199.606	600.1087	507.1052
16	FL132215052	18.09.2013 07:08:49	104.42	1200.062	600.0997	509.2353
17	FL132215056	18.09.2013 07:10:19	103.62	1199.622	600.0472	514.0179
18	FL132215062	18.09.2013 07:11:25	104.45	1199.7	600.0257	509.9074
19	FL132215074	18.09.2013 07:12:39	103.71	1199.922	600.349	531.7236
20	FL132215086	18.09.2013 07:14:03	103.66	1199.318	599.9357	524.2227
21	FB132215027	18.09.2013 07:15:40	103.83	1199.441	599.9428	502.165
22	FB132205372	18.09.2013 07:17:07	104.08	1199.653	599.8557	492.903
23	FB132215049	18.09.2013 07:18:26	103.64	1199.816	599.9995	505.8741
24	FB132215052	18.09.2013 07:19:45	103.9	1199.572	599.8618	509.2022
25	FB132215056	18.09.2013 07:21:09	103.97	1199.256	599.9675	513.0915
26	FB132215062	18.09.2013 07:22:35	103.55	1199.761	599.9193	508.1359
27	FB132215074	18.09.2013 07:23:57	104.11	1199.648	599.9395	529.2034
28	FB132215086	18.09.2013 07:25:10	103.89	1200.175	599.8613	522.4238
29	FR132215027	18.09.2013 07:27:10	103.5	1199.687	600.001	502.548
30	FR132205372	18.09.2013 07:28:55	103.76	1200.115	599.9236	495.2854
31	FR132215049	18.09.2013 07:30:38	103.1	1199.658	599.9529	507.8246

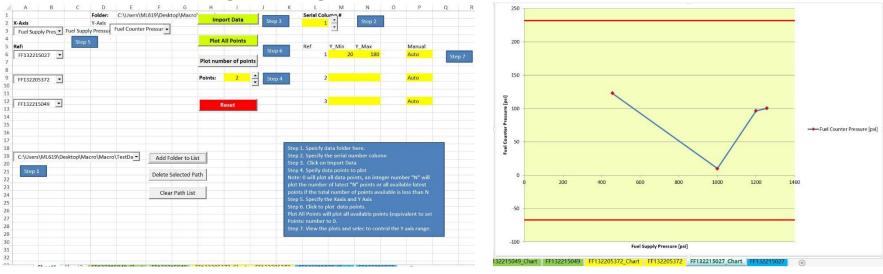
.csv File with Multiple Meters



Experiment Data Processing Automation

Task Completion

- Data selection based on user input with step-by-step instructions and configuration memory
- Automated graph generation with control limits shown



Data Selection User Interface

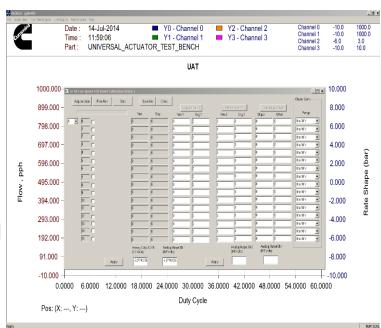
Data Plotting with Control Limits



Single Injector Tester Concept Proof

Initial Status

- Widely-used UHSDA software
- Hardware available at FSP
- Problem Identification
 - Inefficient brought-back testing
 - No available cheap tester
- Solution
 - Design a single injector tester
- My Role
 - Conduct concept proof using parts of UHSDA



UHSDA Software

Single Injector Tester Concept Proof

- Task Completion
 - User interface with all parameters on the same screen
 - PWM output, RS 232 serial communication for injector driver, and analog sensor reading input
 - PLCs investigation for cost efficient implementation

Period (s) 30			0						
	Measured	Point 1	Capture	Point 2	Capture	Parameters	Calculate	Take Data	
Calibration Reading	Raw	Eng Raw	Eng	Raw	Eng	Slope	Offset	Free Run	
emperature 0	0 0	1	1	2	2	0	0	Stop	
essure 🔽 0	0	1	1	2	2	0	0	Save Calib	
BD 🔽 0	0 0	1	1	2	2	0	0	Reload Calib	
	ation (uSec) 0 namic Command Va	riables Units = Amps	<u> </u>	Flow M	leter 2 0	0	0 Flow Meter Calibrat		0
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nou carrent comment.	vic Command Variah	les Units = Microseco	inds						
The carrent comments.		iles Units = Microsecc VBoost 1				5			
Pull-in Time: 18	7	VBoost 1 c Commands	ime: 0			5	0		
Dynar	7	VBoost 1	ime: 0				0	load Calib	

User Interface



Injector Driver Hardware



Single Injector Tester Concept Proof

- Concept Proof Result
 - Feasibility confirmation of PC based single injector tester with current low level data acquisition mechanism
 - Significant price drop with PLC implementation can lower the cost for production

	2080 Micro820	1763 <u>MicroLogix</u> 1100	PicoGFX Controllers
Digital I/O	20	Up to 128	Up to 272
Analog Input	4	Up to 16	Up to 40
Analog Output	1	Up to 16	Up to 40
RS-232	1	1	None
EtherNet/IP	1	1	None
LCD Screen	1	1	1
I/O Expansion	None	Up to 4 1762 MicroLogix I/O	1760 Pico Expansion I/O

Rockwell Micro PLC Comparison



Proposed PLC Module



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Oil Prover Migration

Initial Status

- Developed Volumetric Prover
- Working viscor and oil rig
- Problem Identification
 - Lack analog flow meter inputs
 - Acquire data for both rigs
- Solution
 - Migrate the Oil Prover additional requirements to the Volumetric Prover software

1	er						Help	Exit		ystems
Test Settings	Sensor Con	figuration	Calibratio	Verifica	tion					
Flow Fluid Sta	tus		Referenc	e Meter 1	Reference	e Meter 2	PPH Calibr	ation Compariso	n	
Pressure (PS	I) Tempera	ture (F)	Туре	Max 215	Туре	Max 215	1.0			Avg 📈
Supply 0	Supply	0	L/min	0	L/min	0	Hdd		Au	x Avg 📈
Inlet 0	Inlet	0	g/cc	0	g/cc	0	8		110	elect Meter
Avg 0	Avg	-	РРН	0.0144	РРН	0.0144	0.0			Aux 1
Target 0	Target		pulse/L	0	pulse/L	0	0.0	Time (s)	30.0 T	ime Out 🥚
Diff(%) 1000	Diff(%)	0					-		_	Period 🥮
, 14			Ref Avg	РРНО	Ket Avg	PPH Diff(%)		Meter Under T	est Settinas	All 🥚
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	x 215	Type N			Max 213		Max 213	Target PPH	Overide PPI	Override
Type Ma		L/min c	. I	L/min	0	L/min	0	30	0	0
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L/min 0 g/cc 0)	PPH	0	PPH	0	Sample	Max Waitin	S and a second
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L/min 0 g/cc 0	19782	PPH o	1	pulse/L	0					
L/min 0 g/cc 0 PPH 0.0					0 ne? 🌒	Dor	ne? 🕥	Record	All Data	

Volumetric Prover Software



Oil Prover Migration

- Task Completion
 - Additional sensor input channels specified
 - Low level data acquisition test complete
 - User interface updating in progress
 - Software implementation and validation in progress

A	A	В	C	D	E	F	G	н	1	1	К	L	M	N	0	P	Q	R	S
					onnection	Instructio	on (Last Updated: Fang						-			-			
		Digital Inp		nection				nalog Inp		ection			Shared ch	annel, nee	d hardwa	are rewiring	g for differe	nt test if cl	hannel u
Board		NI PCI-78					Board	NI PCI-62											
Cable		SHC68-61					Cable	SHC68-6											
Pin Shiel	ld	SCB-68	#1				Pin Shield	SCB-68	#1										
Software			Pin#	Negative			Software Channel		Pin#	Negative									
Max 213		DIO0		35 DGND			Supply Pressure	AI 0		68 AI GND	67								
Max 213		DIO1		36 DGND		2	Inlet Pressure	AI 1		33 AI GND	32								
Max 215		DIO2		37 DGND		3	Supply Temperature			65 AI GND	64								
Max 215		DIO3		38 DGND	- 9	1	Inlet Temperature			30 AI GND	29	9							
Auxiliary		DI04		39 DGND		5	Analog Auxiliary 1			28 AI GND	21	7							
Auxiliary		DIOS		40 DGND		5	Analog Auxiliary 2			60 AI GND	59	9							
Auxillary	3	DIO6		41 DGND		7	Analog Auxiliary 3			25 AI GND	24	4							
Auxiliary	4	DI07		42 DGND	1	8	Analog Auxiliary 4	AI 7		57 AI GND	56	5							
Auxiliary	5	DIO8		43 DGND		9													
Auxiliary	6	D109		44 DGND	14	0													
Auxiliary	7	DIO10		45 DGND	18	1													
Auxiliary	8	DIO11		46 DGND	15	2													
					C	il Prover	Cable Connection Sug	esstion (I	ast Up:	lated: Fangzhi	u Xia 7/9/	(2014)							
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Board		NI PCI-78	13 R				Board	NI PCI-62	159				Board	NI PCI-62	59				
Cable		SHC68-61	B-RDIO				Cable	SHC68-6	B-EPM				Cable	SHC68-6	B-EPM				
Pin Shiel	Id	SCB-68	#1				Pin Shield	SCB-68	#1				Pin Shiel	c SCB-68	#2				
Software	e Channe	Positive	Pin#	Negative	Pin#		Software Channel	Positive	Pin#	Negative	Pin#		Software	Positive	Pin#	Negati	ve Pin#		
													Supply Pr	e Al O		68 AI GND	6	7	
													Inlet Pres	51 AI 1		33 AI GND	3	2	
													Auxillary	FAI 2		65 AI GND	6	4	
													Back Pre	5: AI 3		30 AI GND	2	9	
Auxiliary	4	DIO4		39 DGND	3		Analog Auxiliary 1	AL4		28 ALGND	27	7	Supply Te	ei Al 4		28 AI GND	2	7	
Auxiliary	2	DIOS		40 DGND		5	Analog Auxiliary 2			60 AI GND			Inlet Terr			60 AI GND	5	9	
Auxiliary	3	DID6		41 DGND		7	Analog Auxiliary 3			25 ALGND	24	1	Auxiliary	1AI 6		25 AI GND	2	4	
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LabVIEW Code in Modification



Sensor Input Channel Specification

Lessons Learned

Team Work

- Importance of following standards
- Effective communication skill
- Efficient learning
- Individual Work
 - On-time delivery
 - Embracing challenges
 - Enhanced technical skills

Cummins

- Great culture, numerous events, nice place to work



Q&A



Thank you!

