WIRELESS LEVEL MONITORING AND DATABASE SYSTEM FOR CHEMICAL ISOTAINER TANKS

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ABSTRACT

In the hydraulic fracturing industry, it has been a long-time problem and struggle to accurately track the usage of chemicals on fracturing site and make proper management decisions. The manual approach has measurement error and the chemical inventory information cannot be accessed by people such as directors or managers who may not be on site but need the critical information for decision-making. Obtaining chemical inventory information automatically and making it available on-line would significantly save material costs, enhancing asset management efficiency. In a designed system, a guided-wave radar level sensor is used to measure the chemical level and the chemical inventory data are updated on an internet server through the satellite internet in the control van, making the information available on-line for engineers, managers and clients. The proposed monitoring and inventory system will greatly enhance asset management efficiency and reduce cost for the oil and gas industry.

INTRODUCTION

For the chemical asset management in hydraulic fracturing, it is important to accurately track the usage of chemicals on fracturing site and send on-site asset information to decision-maker in real-time. The traditional approach to obtain chemical level is to use measuring stick to measure level manually. The asset data are recorded with a pen and paper and they are not digitally recorded, thus the asset data is processed and archived in rea-time. The manual approach has many disadvantages such as manual measurement error and a reliable level sensor is preferred for asset management purpose. Manual measurement error will result in incorrect material cost calculations, which in turn causes a long-term loss of company profit. In traditional approach, the chemical asset information is in data van and it cannot be accessed in real-time manner by managers who are not on site but need this critical information for asset management decision. Since asset information cannot be shared on line in real-time, another cost loss in traditional approach is that in order to ensure sufficient chemicals for a fracturing operation, chemical trucks must be delivered unnecessarily early with extra cost to pay drivers while they wait, or redundant chemical tanks or totes are left to ensure enough supply. Due to this inability to access real-time chemical inventory information on–site, unnecessary inventory costs have been spent for decades in this industry. Therefore, it is extremely important to obtain chemical inventory information in real-time and on-line to significantly save asset management costs and enhance management efficiency. For the oil and gas industry, there is a strong need to develop an automatic approach which has following technic features: 1. Chemical asset information is obtained without human interference. 2. Chemical asset information is real-time and shared in internet. It is also important to document usage of chemicals in fracturing jobs. On May 9, 2014, U.S. Environmental Protection Agency (EPA) released an Advanced Notice of Proposed Rulemaking. According to the proposed rules, oil and gas companies would need to submit documentation with details regarding all of the chemicals they use in hydraulic fracturing process (Weller and Palmer, 2014). It is desired that a digital detailed copy of chemicals used for fracturing jobs is saved for documentary. Due to the importance of asset management in industry, various market strategies and technologies have been developed and implemented to improve management efficiency and achieve the best resource distribution. Michalski (2009) analyses delivery risk and offers a method that uses portfolio management theory to choose suppliers. Narasimhan et al. (2007) implemented wireless sensor-actor network technology for asset management strategy. Naraharisetti et al. (2008) present a new mixed-integer linear programming model for asset management and capital budgeting, which can aid the decision-making process for supply chain redesign. Using fuzzy modeling, Arshad and Islam (2006) present asset management strategies based on transformer remnant life and rate of aging assessments. Unneland and Hauser (2005) described i-field program for Digital Oil Field. In this program, to bring innovative solutions to assets management needs, operation is transformed with real-time instrumentation delivering real-time information, allowing real-time implementation of decisions, with processes coordinated. Improved decision-making and asset reliability is achieved.

To meet the chemical asset management needs and reduce management cost for fracturing industry, a level monitoring and database system is proposed in this paper. The proposed system is an interdisciplinary tool which correlates engineering with business strategies. Modern technologies such as guided wave radar level sensor, wireless communication and database server are collaborated with asset management concepts and terminologies to build up an efficient business structure to achieve long-term cost saving. In the proposed system, a guided-wave radar level sensor with stainless rod is used to measure the chemical level in a chemical isotainer tank with the advantages of high accuracy in tough industrial environment. The measured level data are transmitted from isotainer tanks to the control van on the job site through a wireless radio network. The chemical inventory data are updated on an internet server through the satellite internet in the control van, making the information available on-line for engineers, managers and clients. The detailed asset management information such as job information, tank information and material type etc. are collected and available online which builds up a business structure with feedback for different levels of managers and engineers to achieve best distribution efficiency of materials. With the help of digital database, the chemicals used for fracturing job are easily digitally archived so that time and money are saved for company in preparing disclosure report to comply with chemical tracking and safety regulation requirements.

To verify the effectiveness of the proposed level monitoring and database system, on-site experiments were performed in Brighton districts in Colorado. Experimental results verified the effectiveness of the proposed approach and promising future in practical application. The proposed level monitoring system will greatly enhance asset management efficiency and reduce cost for the oil and gas industry.

PROPOSED WIRELESS LEVEL MONITORING SYSTEM

Schematic of the proposed level monitoring system is demonstrated in Figure 1**Error! Reference source not found.**. In the developed system, chemical level is first measured by a guided wave radar level probe system and then the measured level sensor signal is transmitted through a wireless radio network by a slave box in isotainer tank to a master box in data van. The data van will send the level data to server through satellite internet. The instruments of level monitoring system in an isotainer tank are shown in Figure 2. These instruments include a slave box, level sensor assembly, solar panel and battery. Due to the tough operation environment of oil and gas industry and the needs to obtain the level data in rea-time, there are certain requirements that the proposed wireless level monitoring system need to meet: 1. A reliable level sensor needed to be chosen for the tough chemical environment; 2. The level data should be sent wirelessly to data van, since it is not convenient to deploy data cables for isotainer tank. 3. The level monitoring system should obtain power itself and it should not rely on external electric power source so that this level system can work everywhere.

The chemical liquid in the isotainer tank can be corrosive and it may be viscous. Past industry experience proves that guided wave radar is a reliable type of level sensor for tough environment and it is chosen as the level sensor for the proposed system. In guided wave radar level sensor, high frequency micro wave pulses are guided along a steel rod. The microwave pulses are reflected upon liquid level surface. The running time is evaluated by the instrument and used to estimate the distance. In the proposed system , two-wire 4-20 mA/HART is used for power supply and measured value transmission over the same cable.

A phoenix contact radio system is used in field to transmit the level data to data van. The master radio and slave radios are operated in PLC emulation mode and modbus RTU is used as the communication protocol. Master radio is installed in the data van and it sends request to slave radio to read data from certain register where the level sensor data is stored.

An isotainer tank is an isolated unit from the truck and it has no power system with itself. To power the electronics, a solar panel with a deep-cycle battery is used as the power supply of the radio and the PLC in an isotianer tank. Therefore the operation of level monitoring system independent from external power resource and this keeps maintenance effort as minimum as possible.

A computer in data van communicates with the master box using the PC application software of the proposed level monitoring system. The computer collects the data and transmits them to the SQL database server in office through the satellite-based internet in data van. Clients, managers and engineers can access the SQL database server to get the updated detailed information of chemical tanks.

The proposed level monitoring system has following advantages: real-time inventory information; maintenance free; inventory cost saving; easy access database through world-wide internet; improvement of management efficiency. By improving measuring precision and providing real-time level of chemicals, material consumption calculation will be more accurate and inventory management decisions can be made in a more efficient way.

FIELD TEST RESULTS

Field test of level monitoring system were performed in two fracturing jobs in Brighton district. Description information of these two jobs is shown in Table 1. Photo of two fracturing wells of these two jobs is shown in Figure 3**Error! Reference source not found.**. An isotainer tank is instrumented with proposed level monitoring system, as shown in Figure 4. A data van instrumented with proposed level monitoring system is the commander center of the fracturing job, as shown in Figure 5 and Figure 6. The proposed system can also be deployed in yard to monitor chemical asses in yard. Test was also performed in facility yard office in Brighton to monitor the chemical level in isotainer tanks in yard, as shown in Figure 7. Figure 8 demonstrates the data shown in office mode version of the software for proposed level monitoring and database system.

During the fracturing job, GasFlo G in the isotainer tank was pumped at different stages. Using the wireless radio network, the level sensor data was successfully transmitted from the isotainer to the data van. The real-time level data was then sent to database server through the satellite internet. The chemical asset information of fracturing site can then be available in the internet in real-time. The volume pumped for GasFlo G is estimated from clean volume as a reference compared with the volume estimated from level sensor data. Test results show that the level data from the proposed monitoring system matched with the volume derived from clean volume.

Table 2 shows the GasFlo G used from stage 1 to stage 8 as estimated from clean volume. From the clean volume, the subtotal GasFlo G pumped is 660.95 gallon from stage 1 to stage 8. From level monitoring data in

Table 3 and

Table **4**, Total GasFlo G pumped = 5577-4916= 661 gallon. Table 5 shows Gasflo G derived from clean volume for stages 9, 10, 11 and 12.

Table **6** and

Table 7 show the level sensor data of stage 9 and stage 10. Table 8 shows the summary of the comparison between the clean volume derived Gasflo G data and level sensor data. It can be seen that the level sensor data obtained from the proposed level monitoring system matches well with the derived Gasflo G volume data from clean volume. In 2014, several tests were performed in Brighton district. Figure 8 shows test data demonstrated in office mode. Different color means different status such as “filling” or “draining”. Green color means the chemical is filling; yellow color means chemical is draining and blue color means chemical level is static.

CONCLUSIONS

The field tests were performed in Brighton district to verify the effectiveness of the proposed system. The proposed level monitoring and database system can deliver the chemical asset information in real-time from any location without human interference. The real-time on-line chemical information will achieve best management efficiency of chemical asset. Digital archives of chemical usage will help to track and document chemicals in fracturing jobs. Time and cost in asset management will be reduced for oil and gas companies by implementing proposed level monitoring and database system. Followings are summarized technical advantages of the proposed system.

1) Level sensor measured the chemical level precisely and automatically.
2) Proposed system collected the chemical level data through wireless network and formed the SQL server database.
3) The proposed system deployed and operated at fracturing site without human interference after installation.
4) The asset data are recorded and archived digitally.

The proposed wireless monitoring system has great potential to be implemented in oil and gas industry to greatly reduce the inventory cost and increase management efficiency.

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Table 1 - Job information

District	Job	Well Name	Date Created
Brighton	Job1	Shurview 13N-3HZ	6/11/2013
Brighton	Job2	Shurview 33C-3HZ	6/13/2013

Table 2 - GasFlo G data for stage 1-stage 8

Stage	Pump duration GasFlo G(min.)	clean volume (BBL)	Clean volume (gallon)	Pumped GasFlo G volume (gallon)	GasFlo G discharge rate (Gallon/minute)
1	33	1218	51156	51.156	1.55

2	33.7	1231	51702	51.702	1.53
3	42.65	2335	98070	98.07	2.30
4	33.93	1989	83538	83.538	2.46
5	39	2286	96012	96.012	2.46
6	38.82	2276	95592	95.592	2.46
7	39.23	2295	96390	96.39	2.46
8	35.86	2107	88494	88.494	2.47
			subtotal	**660.954**	

Table 3 - Level sensor data before stage 1

History											
ID	**Tank Serial Number**	**Tank Modbus Address**	**Inventory**	**Inventory Change**	**Date**	**Time**	**Units**	**Product**	**Job ID**	**Ma**	**Level height**
509278	TRLU8604489	4	5577	8	6/11/2013	6/11/2013 12:29:54 PM	LBS	GasFlo G	1001993721/19		

Table 4 - Level sensor data after stage 8

History											
ID	**Tank Serial Number**	**Tank Modbus Address**	**Inventory**	**Inventory Change**	**Date**	**Time**	**Units**	**Product**	**Job ID**	**Ma**	**Level height**
509334	TRLU8604489	4	4916	-653	6/12/2013	6/12/2013 12:45:03 PM	GAL	GasFlo G	1001993721/19	15.66	62.79

Table 5 - GasFlo G data for stage 9-12

Stage	**Pump duration GasFlo G G(min.)**	**Clean volume (BBL)**	**Clean volume (Gallon)**	**Pumped GasFlo G volume (gallon)**	**Gasflo G discharge rate (Gallon/minute)**
9	133	1732	72744	72.744	0.55
10	51.68	3043	127806	127.806	2.47
11	56.73	2581	108402	108.402	1.91
12	47	2288	96096	96.096	2.04

Table 6 - Level sensor data in stage 9

History											
ID	Tank Serial Number	Tank Modbus Address	Inventory	Inventory Change	Date	Time	Units	Product	Job ID	Ma	Level height
509335	TRLU8604489	4	4903	-13	6/12/2013	6/12/2013 3:00:56 PM	GAL	GasFlo G	1001993721/19	15.63	62.64
509342	TRLU8604489	4	4836	-9	6/12/2013	6/12/2013 8:06:27 PM	GAL	GasFlo G	1001993721/19	15.48	61.84

Table 7 - Level sensor data in stage 10

History											
ID	Tank Serial Number	Tank Modbus Address	Inventory	Inventory Change	Date	Time	Units	Product	Job ID	Ma	Level height
509343	TRLU8604489	4	4823	-13	6/12/2013	6/12/2013 8:35:20 PM	GAL	GasFlo G	1001993721/19	15.45	61.68
509352	TRLU8604489	4	4688	-4	6/12/2013	6/12/2013 10:20:49 PM	GAL	GasFlo G	1001993721/19	15.15	60.08

Table 8 - Summary of field test results for Job ID 100199719

Stage	Chemical data derived from clean volume (gallon)	Level sensor data(gallon)	Difference (gallon)	Error rate (%)	Remarks
Stage 1-stage 8	660.95	661	0.05	0.007565	
Stage 9	72.744	67	-5.744	-7.89618	Last for 2 hours
Stage 10	127.806	135	7.194	5.628844	
Stage11	108.402	103.67	-4.732	-4.36523	
Stage 12	96.096	93.08	-3.016	-3.13853	
Stage 13-stage 20	691.698	662.58	-29.118	-4.20964	

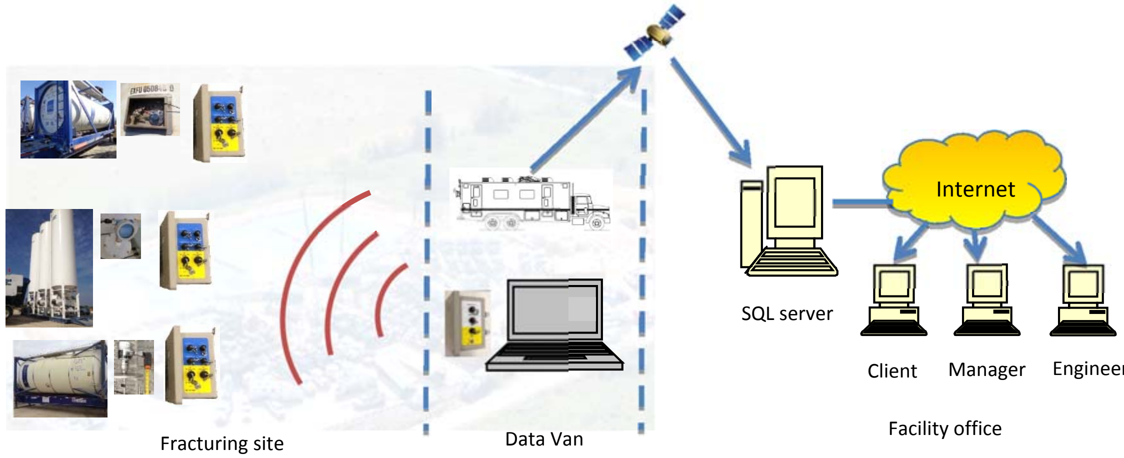

Figure 1 - Schematic of wireless- level monitoring system

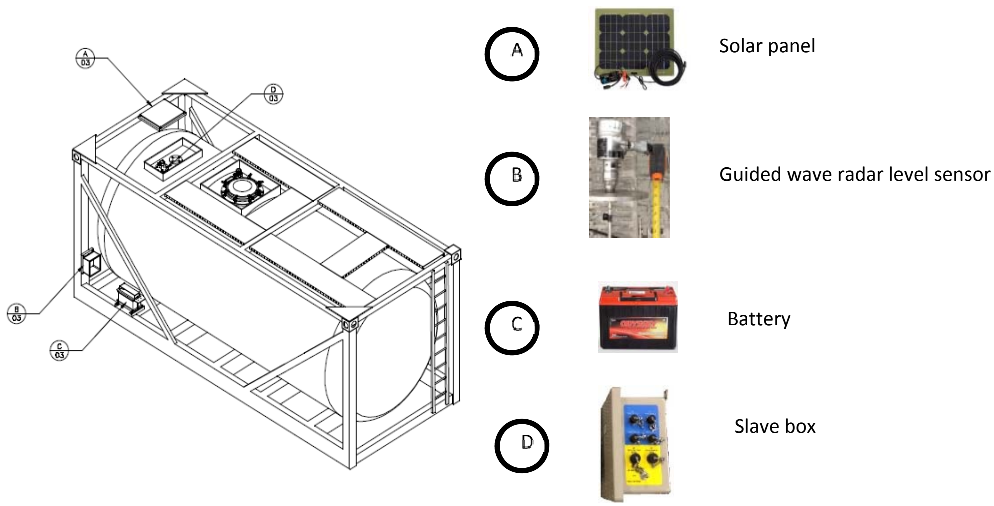

Figure 2 - Wireless level monitoring system in isotainer tank

Figure 3 - Fracturing site

Figure 4 - The isotainer tank used to test proposed level monitoring system

Figure 5 - TMV3H45 and master box of the level monitoring system

Figure 6 - Level monitoring system installed in data van 5H78

(a) Master box installed in yard (b) Computer in yard office

Figure 7 - proposed level monitoring system instrumented in yard office

Tanks | History inventory | Jobs

Job ID	Tank Serial Number	Product	Volume	Volume Change	Units	Time	Status
11001921122	EXFU0599199	NE-945	1597.08	-11.17	GAL	11/19/2014 1:48...	Draining
11001921122	EXFU0599199	NE-945	1317.84	-279.24	GAL	11/19/2014 5:11...	Static
11001921122	EXFU0599199	NE-945	1306.45	-11.39	GAL	11/19/2014 7:21...	Draining
11001921122	EXFU0599199	NE-945	1242.5	-63.95	GAL	11/19/2014 7:28...	Static
11001921122	EXFU0599199	NE-945	1219.93	-22.57	GAL	11/19/2014 9:36...	Draining
11001921122	EXFU0599199	NE-945	1164.91	-55.02	GAL	11/19/2014 9:41...	Static
11001921122	EXFU0599199	NE-945	1185.8	20.89	GAL	11/19/2014 10:3...	Filling
11001921122	EXFU0599199	NE-945	4166.57	2,980.77	GAL	11/19/2014 11:5...	Static
11001921122	EXFU0599199	NE-945	4005.4	-161.17	GAL	11/20/2014 3:28...	Draining
11001921122	EXFU0599199	NE-945	3924.28	-81.12	GAL	11/20/2014 3:35...	Static
11001921122	EXFU0599199	NE-945	3832.06	-92.22	GAL	11/20/2014 8:40...	Draining
11001921122	EXFU0599199	NE-945	3766.46	-65.60	GAL	11/20/2014 8:44...	Static
11001921122	EXFU0599199	NE-945	3395.76	-370.70	GAL	11/21/2014 9:50...	Static

Figure 8 - Data shown as in office mode of proposed level monitoring system from data van 5H78 in fracturing location.