International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 16 (2017) pp. 5559-5564

Smart Pipeline Water Leakage Detection System

Gopalakrishnan P.[1], Abhishek S.[2], Ranjith R.[3], Venkatesh R.[4] and Jai Suriya V.[5]

[1]Dept. of Electrical and Electronics Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, Amrita University, India – 641112.

Orcid: 0000-0001-7785-5478

[2]Dept. of Electrical and Electronics Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, Amrita University, India – 641112.

Orcid: 0000-0003-0507-2487

[3]Dept. of Electrical and Electronics Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, Amrita University, India – 641112.

Orcid: 0000-0001-5295-2669

[4]Dept. of Electrical and Electronics Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, Amrita University, India – 641112.

Orcid: 0000-0001-5178-2282

[5]Dept. of Electrical and Electronics Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, Amrita University, India – 641112.

Orcid: 0000-0001-9401-1672

Abstract

Water is an essential natural resource required for survival. Most of the area in the planet earth is covered with water. But only less percent of water is directly consumable by living beings. Transportation of such resource is made easy by means of manmade pipeline connections. Leakage constitutes a major loss of drinking water when supplied through pipeline systems. Introducing automated leakage detection systems would save huge amount of water globally. In developed countries water leakage is found using acoustic devices which uses vibrations or sound induced by the pressurized pipes. But in developing countries major leaks are found only when it is visible on the surface, this results in considerable amount of water getting wasted. Water leak detection by means of simple embedded system aids water conservation in a cost-effective way. The flow sensors can be used for detecting the leak and solenoid valves placed in different parts of the pipeline can obstruct the water flow until the defective part of the pipeline is repaired. And further, the leak occurred shall be informed to concerned authorities wirelessly by means of cloud based data logging. GPRS module enables data logging with the existing cellular network infrastructure. A prototype of the suggested system was implemented and tested with various scenarios and the results are presented in this paper. Water resource management is one of the key goals of any country in the world as water requirement is increasing steeply; involving automation in such systems will reduce human errors and will increase efficiency and thus decreasing the supply demand gap.

Keywords: Water Leak Detection, flow rate sensor, Cloud based data logging, automatic flow cutoff

INTRODUCTION

Conservation of water is one of the major objectives for any country around the world. Water management plays a very important role in a society [1], as it is one of the basic needs for the mankind. Water supplied for human consumption must be highly efficient with minimum wastage. In a developing country like India, loss of water in domestic sector on account of leakage is approximately 30 to 40% of the total flow in the distribution. This leads to high risks in public health, money invested and on the valuable natural resource. India had an irrigation efficiency of ~36 percent in 1993-1994 and

projected that efficiency would have to increase to 60 percent by 2050 to bring a balance in the demand and supply of water [2] [3].

The existing water supply systems incorporate high range acoustic and pressure detection devices are way costlier to be implemented in developing countries. Some irrigation leak detection systems [4] use heating coils to detect the flow rate difference which has a drawback of detecting the fast change over in the system due to the uniform response of the temperature sensor. Some other systems [5] [6] use the flow sensors to measure the flow rate. This single parameter does not help in stopping leakage in the system.

In this paper, a flow sensor based system integrated with microcontroller to detect the leak due to breakage has been discussed. This system is designed to prevent the further leakage of water flowing through the pipe line. This paper is organized in the order of methodology which explains the working of the system, components used to build the system and the results which signify the efficient leakage prevention based on a prototype.

METHODOLOGY

The water leakage detection system can be deployed in the already existing plumbing with flow rate sensors attached in the path of the water flow. The sensor does not obstruct the water flow but just collects the data of flow rate. Actuators like solenoid valve is needed to control the water flow in the event of a leak.

The proposed system uses a microcontroller which constantly reads the data from multiple flow rate sensors thereby constantly monitoring the water flow. It compares the flow rate by calculating the difference in data from subsequent sensors and takes the necessary action. If the difference is greater than the set threshold, microcontroller signals the solenoid valve to stop the water flow and sends alert information to the user. This minimizes the water wastage. On the other hand, if the difference is less than the threshold, it sends the sensor data to the cloud for data logging and the process continues as shown in Fig. 1. Online data logging allows the user to keep track of the water usage and take necessary decisions to conserve the water.

HARDWARE COMPONENTS

This section deals with the explanation about the hardware components used in the implementation of smart water leakage detection system.

Flow sensor

The main input to the microcontroller is the flow sensor (as shown in Fig. 2) which is used to find the flow rate of a liquid. There are various kinds of flow sensors, and the one which is deployed in the proposed system is based on the principle of Hall Effect. Electric potential is generated perpendicular to both electric current flowing along a conducting material and an external magnetic field applied at right angles to the current upon application of the external disturbance. This principle is directly used to measure the flow rate [6]. When the liquid moves through the pipe it rotates a small turbine attached to the hall sensor which produces pulses whenever the blade is rotated and the analog signal produced is sent to the microcontroller for calculations and the same is transmitted to the cloud GPRS module. The flow sensor is capable of detecting up to 30L/Min and a pressure of 2.0MPa.

Solenoid Valve

The control action is taken by means of solenoid valve during the event of water leak by stopping the water flow.

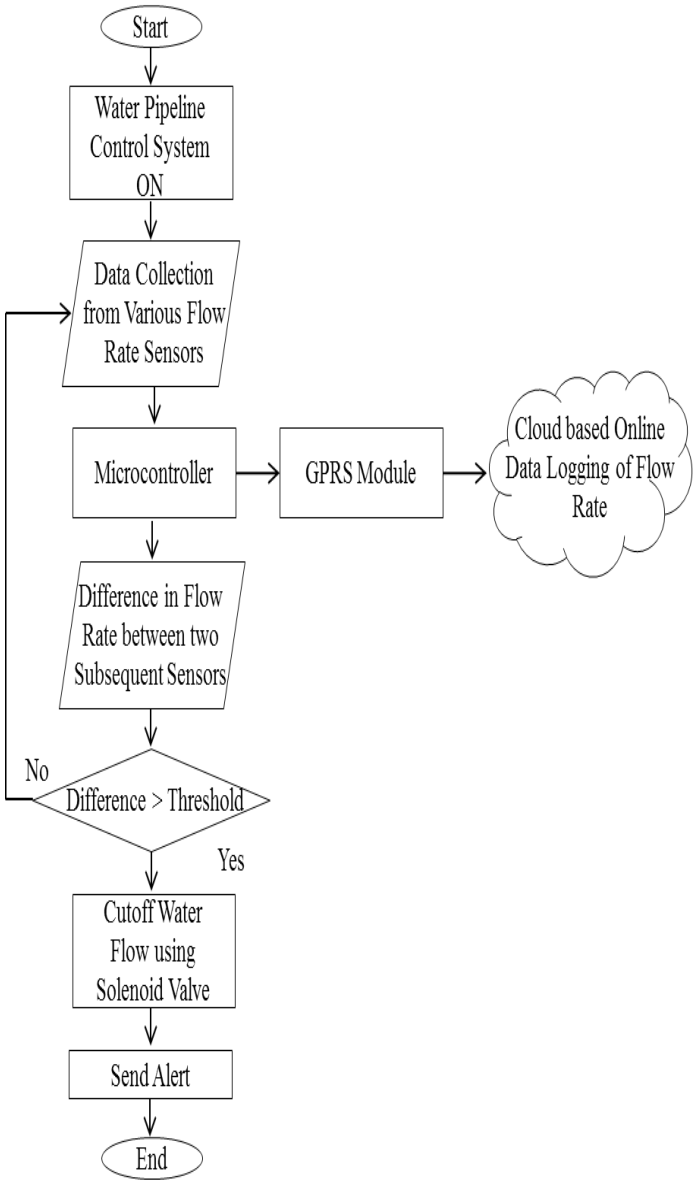


Figure 1: Flow Chart describing the Control Action to minimize Water Wastage

Figure 2: Water Flow Rate Sensor

The solenoid valve (as shown in Fig. 3) is an electromechanical device which is used to regulate the flow of the liquid. Internally the valve has a ferromagnetic rod type material blocking the flow of the fluid. When the coil is energized the rod gets attracted and clears the area for the flow of the fluid. The solenoid valve used here requires 12V DC.

The valve will be equivalent to a closed switch when it is energized. A total flow of up to 3L/Min with a maximum pressure of 3 psi can be achieved. This valve is connected to the output of microcontroller by the means of a relay circuit. This valve will be activated by means of a trigger pulse from the microcontroller whenever leakage is being detected in the pipe line sensor system.

Figure 3: Solenoid Valve

GPRS Module

The primary objective of GPRS Module (SIM900A) is to transmit the obtained flow rate sensor data from the microcontroller to the Cloud based Server wirelessly. In the proposed system GPRS Module is used as a data transmitting device where there is no access point available to the Internet after certain range. The GPRS module uses the mobile network radio waves for easy access to the internet.

With the aid of SIM Card and external power supply, the module will be ready to communicate to the internet. Several AT commands are used to connect to the Internet via GPRS which has a TCP/IP protocol (Inbuilt). A Baud rate of 9600 is maintained for communication between the microcontroller and GPRS module. The serial Monitor of the Arduino IDE is turned on to monitor the activity going in between the two devices like Connection Status, Data Transfer status etc. whenever necessary.

Microcontroller

The microcontroller takes input from the sensors and based on the user's algorithm, it takes decisions and signals the actuator. The proposed system involves reading of a simple analog data and turning on/off a relay. Since there are no complex calculations involved, a simple 8-bit microcontroller like ATmega328 will be sufficient. Since it is a RISC based controller, it requires low power for operation.

CONSTRUCTION AND WORKING

This section describes the construction and working of the smart water leakage detection system.

Flow sensor placement

This system starts to work when the water is allowed by the water board authorities for various industrial uses and domestic purposes. The water flow measurement sensors are placed at regular intervals in main pipeline as well as in the branches (as depicted in Fig. 4 & 5). This kind of setup ensures that the leak can be located at a particular branch. The water enters through all the pipelines and reaches the desired location flowing through various flows rate measurement sensors.

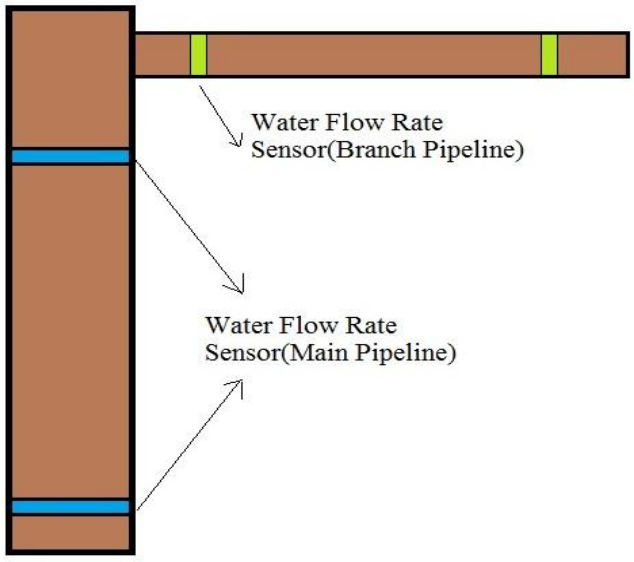


Figure 4: Water flow sensor placement

(a) (b)

Figure 5: Hardware Setup, (a) Sensor-Actuator Placement in the pipeline; (b) Flow sensor Placed in the path of water flow

Flow rate monitoring system

All the flow rate measurement sensors pertaining to a particular area are connected to microcontroller for as show in Fig. 6. Couple of microcontrollers is connected to the Network such that we can monitor and control water supply for the whole region. Each Flow rate sensor sends the amount of water passing through it to microcontroller. The microcontroller collects the data from flow sensors and sends the values to the Cloud using GPRS [7] connected to the internet. The flow rate measurements are logged into a sensor cloud which can be utilized for later use. This method is commonly known as data logging.

Leak Detection Algorithm

The Microcontroller constantly monitors the flow rate when the system is in On State. The Leak detection algorithm works in such a way that, whenever the Flow rate difference between two consecutive sensors is greater than a calibrated threshold value, a leakage is detected by the microcontroller. Fig. 7 shows the leakage scenario in the system. The Flow rate difference is also logged into the Cloud through GPRS module as in Fig. 8. Whenever a Leakage is detected an alert or notification is triggered and message is sent to the concerned authorities.

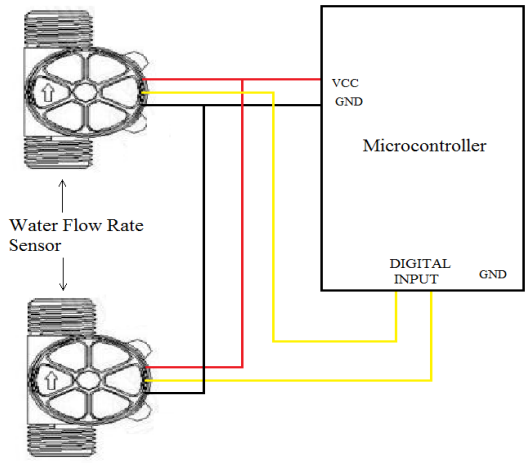


Figure 6: Microcontroller connected to flow sensors

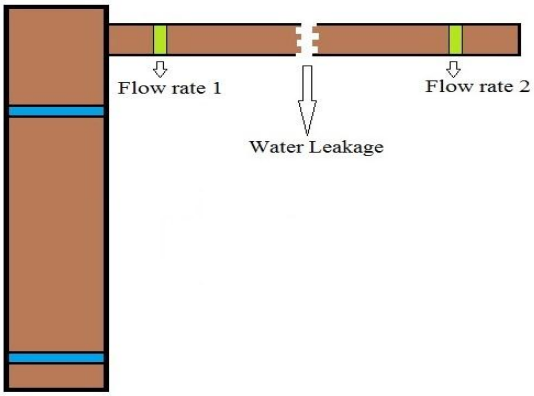


Figure 7: Leakage Scenario

Integrated Water Cut-off System

The automatic water cut-off system is very useful to stop the leakage of water at various points if a leakage is detected. The Monitoring system detects the leakage of water and sends an alert signal. In addition to this the water supply is stopped with the help of solenoid value connected to the water pipelines [8].

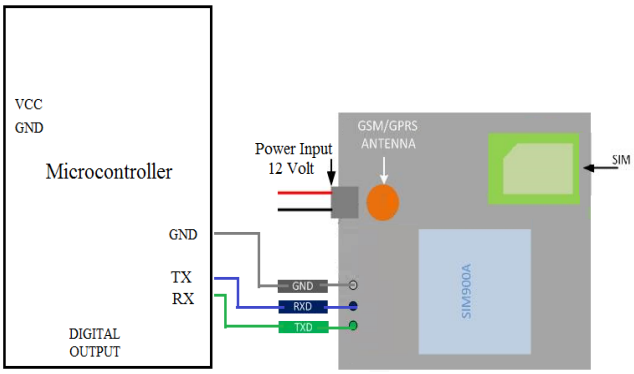


Figure 8: GSM/GPRS module setup

The solenoid valve is connected in series with a transistor such that the transistor works as a switch. Fig. 9 shows the circuitry involved in the solenoid valve set up. The Solenoid valve is normally closed type. Whenever the base signal is applied to the transistor, makes the solenoid value normally open allowing the flow of water. But in case of water leakage, the solenoid value should have normally closed configuration for blockage of water supply. Hence the base signal to the transistor is removed which stops the water flow thus saving wastage of water at initial stage itself.

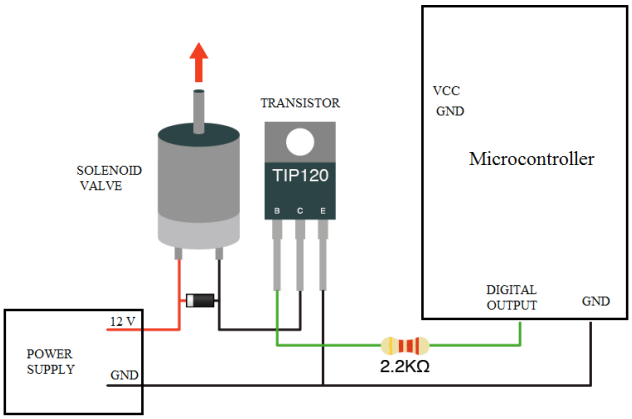


Figure 9: Solenoid Circuit

Fig. 10 (a) and (b) show the condition of the leakage in the beginning of the leak and after the action of the solenoid valve. The leak is completely prevented and a notification is sent to the authority.

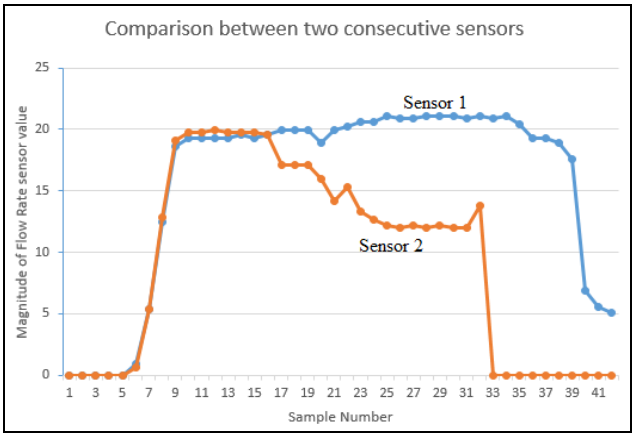
(a) (b)

Figure 10: (a) Few Cycles after beginning of the leak; **(b)** Supply cut off after Leak Detection

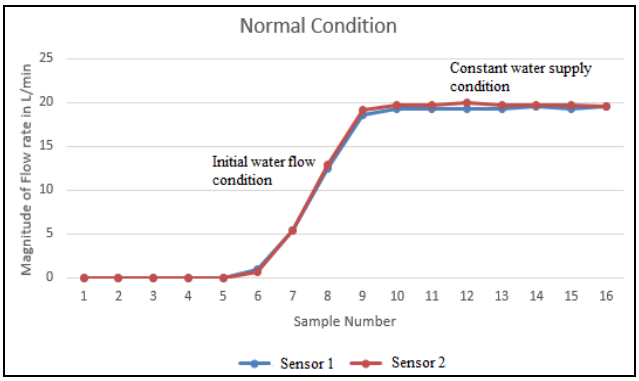
RESULTS AND DISCUSSION

A prototype was developed with help of two flow rate sensors and solenoid value (12V) connected in series in the water pipeline. The prototype is tested at various conditions of water flow. Positive results were obtained using the prototype built.

Water Flow controller is turned ON initially such that water flows through the water pipelines. The Flow rate data of both the sensors is obtained by the microcontroller periodically. The Microcontroller also uses water leakage detection algorithm to calculate the flow rate difference between two consecutive sensors. The difference is also logged into the Cloud for triggering the leakage detection. Once the leak is detected notification is sent to authorities for fixing of damaged pipelines. In addition to Water flow is stopped when leak is detected.



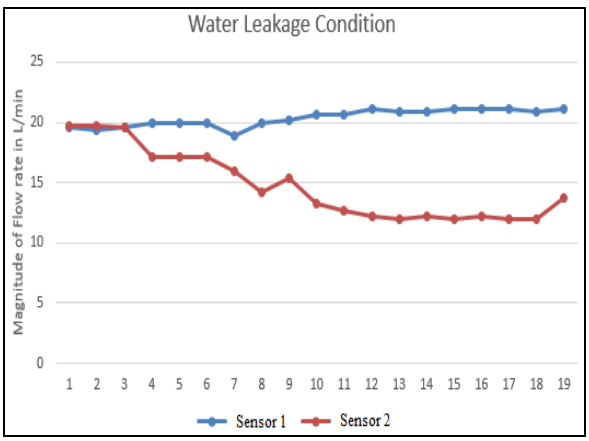
(a)



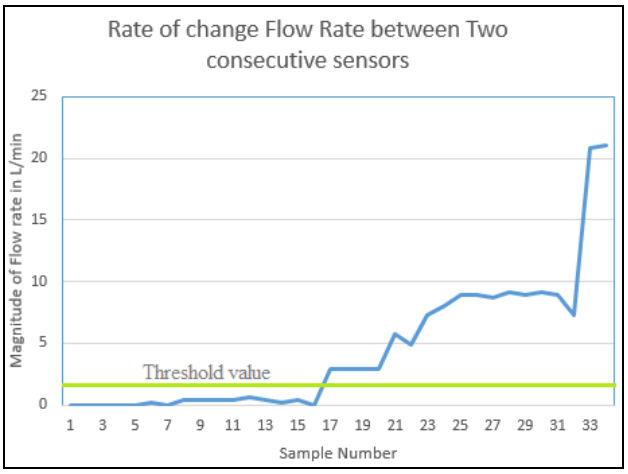
(b)

Figure 11: (a) Flow rate data obtained from cloud; **(b)** Flow rate during normal Condition

The graph in Fig. 11(a) shows the data logged from two consecutive sensors during a given interval. The graph in Fig. 11(b)) shows the condition of flow rate during normal condition. When there is no water flow, the flow rate is zero and when the water is allowed to flow, the flow rate gradually increases and is remains constant.



(a)



(b)

Figure 12: (a) Flow rate during water leakage; **(b)** Flow rate difference in a node during water leakage

When there is a leak in a particular node, the flow rate in that node changes as show in Fig. 12(a). As the flow rate change between the two sensors in that node increases, the water supply is shutdown (as shown in Fig. 12(b)) after a given threshold value.

CONCLUSION

Water for domestic purposes is always very essential and it is mandatory to prevent it from getting wasted due to any pipeline leaks. Hence the designed prototype is an effective solution for monitoring the flow of water as well as detecting for leaks in the pipelines. The smart water leakage detection system can help in water distribution process by remote activation of solenoid valves. Usage of cloud logging technique enables the data acquisition and analysis in any point of the pipeline. This makes the system cost efficient and simple.

The system is capable of detecting leaks between any sensor nodes rather than the exact location of the leak. The sensors require lengthy wiring for power supply and data transmission. This reduces the area under observation. The sensors and actuators can be powered by batteries or solar panel. Wireless transceivers can be fitted to acquire the data from the sensor and send command signals to actuator. This sensor network based system may increase the system cost, but it adds the advantage of monitoring a huge area with minimal human power.

REFERENCES

[1] Mukul Kulshrestha, Efficiency Evaluation of Urban Water Supply Utilities in India, Environmental Engineering Division, Department of Civil Engineering, National Institute of Technology, MANIT-Bhopal, India.

[2] Water sector in India: Overview and focus areas for the future, PanIIT Conclave 2010, Available from: https://www.kpmg.de/docs/Water_sector_in_India.pdf

[3] Guidelines For Improving Water Use Efficiency in Irrigation, Domestic & Industrial Sectors, Central water commission, Ministry of water resources, Government of India, November 2014, Available from: http://wrmin.nic.in/writereaddata/Guidelines_for_improving_water_use_efficiency.pdf

[4] Adam Openshaw, Kalvin Vu, Irrigation Leak Detection-Using Flow Rate Sensors to Detect Breaks in an Irrigation System, Available from: http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1010&context=cpesp

[5] Teddy Ariyatham, water leak detection, california state university, northridge, Available from: http://scholarworks.calstate.edu/bitstream/handle/10211.3/132789/Ariyatham-Teddy-thesis-2015.pdf?sequence=1

[6] Ria Sood, Manjit Kaur, Hemant Lenka, DESIGN AND DEVELOPMENT OF AUTOMATIC WATER FLOW METER, International Journal of Computer Science, Engineering and Applications (IJCSEA) Vol.3, No.3, June 2013

[7] T.Deepiga, A.Sivasankari"Smart Water Monitoring System Using Wireless Sensor Network at Home/Office," International Research Journal of Engineering and Technology, Vol. 2, No.4, pp. 1305-1314, July 2015.

[8] N.Suresh, E.Balaji, K.Jeffry Anto, J.Jenith," Raspberry Pi based Liquid Flow Monitoring and Control," International Journal of Research in Engineering and Technology, Vol.03, pp. 122-125, Jul. 2014.

[9] Ali M. Sadeghioon, Nicole Metje, David N. Chapman and Carl J. Anthony, "Smart Pipes: Smart Wireless Sensor Networks for Leak Detection in Water Pipelines," Journal of Sensor and Actuator Networks, Vol. 3, pp. 64-78, 2014.