Design of Automated Fire and Safety System in Tanks and Vessels

AfaqAhmed Jamadar[1], Rawoot Altaf Adam[2], Shaikh Ateef Shabbir[3], Isaf Danish[4], Mulla Saahil[5]

[1]Professor, Dept. of Mechanical Engineering, A.I. Kalsekar Technical Campus, New Panvel, Maharashtra, India
[2,3,4,5] Pursuing BE final year, Mechanical Engineering, A.I. Kalsekar Technical Campus, New Panvel, Maharashtra, India

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Abstract: *A literature review was performed and information related to extinguishment of actual tank fire and incidents corresponding to tank fires were gathered. Our aim was to come to a conclusion to at least lower the number of such vast losses that occur due to tank fires. Almost all the incidents had great destruction due to lately actuation of fire safety system. A system which could be automatically initiated at detection of fire and be fast and economical. A small scale prototype on such a system was planned and successfully made to demonstrate the system that was concluded.*

Key Words: **AFFF- Aqueous Film Forming Foam, PIC-Peripheral Interface Controller**

1. INTRODUCTION

In total, 480 tank fire incidents have been identified worldwide since 1950. Looking to this history it was very necessary to timely trigger the fire system so that it is never too late and the situations are not out of control. Keeping this in mind a project was undertaken on this particular topic of fire and safety automation in tanks and vessels. This report consists a brief about the system using PIC controller as the brain of the system. An overview of which type of foam is to be used is explained. The system is designed to detect a fire inside the tank as well as in the vicinity of the vessel and activate the respective valve so that the system starts to function. This entire system is designed keeping in mind the overall cost of the system so that automation is economical. This makes the application of this system feasible and economical in large as well as small tanks. Further exclusion of human intervention ensures the safety of human life and also ensures the safety from human errors. The system consists of thermocouple, solenoid operated flow control valves, foam proportionate, and Peripheral Interface Controller in addition to basic fire extinguishing components like pump and nozzles.

2. LITERATURE REVIEW

Literature review is carried out to acquire knowledge about all the incidents from 1950 to 2003. And other sources are the internet wherein we referred various international journals.

Information about various reference papers have been used as a reference, which is as discussed below

In [1] The Technica Report: As a consequence of a major tank fire in 1988 in Singapore, which started in a floating roof tank that escalated to two nearby tanks, a study escalation mechanisms were made by Technica Ltd [1]. The study was made on behalf of a number of oil companies located in Singapore and one aim was to develop an engineering model in order to predict fire spread from one tank to another. The model allowed Technica to study the influence of a variety of parameters such as the effect of wind, cooling water sprays, type of floating roof, tank diameter, tank spacing, etc. As a part of this study, a literature review was made, both regarding full surface tank fires and large spill/bund fires and some brief information is given for about 120 fires.

In [2] The API Report: In 1995, Loss Control Associates, Inc prepared a report for the American Petroleum Industry (API), "Prevention and suppression of fires in large aboveground storage tanks" [2]. The study applied to storage of flammable and combustible liquids in vertical atmospheric tanks having a diameter of 30,5 m (100 feet) or larger and/or storage capacities of 80 000 barrels or greater. In this particular study, an analysis was made of past fires and a brief summary of case histories is given for 128 fires. In [3] The Sedwick Report: On behalf of the LASTFIRE project group, a search for tank fires was made 1996 by the company Sedgwick Energy & Marine Limited in their database [3]. This study identified 141 incidents and contributed with many new tank fires, especially outside the USA. As the information in the report is very limited it did not contribute to the collection of detailed information.

In [4] The NFPA Special Data Information Package: On request, NFPA provides various forms of statistics and a specific search was made of tank fire incidents [7]. Parts of the report provide statistical data from 1980 to 1998. However, the statistics cover fires in flammable or combustible liquid storage tank facilities in general and not only tank fires specifically. The statistics are therefore presented in various forms, e.g. related to incident type, by year, ignition factor, etc. This does not provide specific information but in an annex to the report, some technical information was given specifically related to some few tank fires.

In [5] Tank Fires Review of fire incidents 1951–2003 BRANDFORSK Project 513-021: In total, 480 fire incidents have been identified dated from 1951 to 2003. However, only limited data has been obtained concerning fires during

2003. The total number of tank fire incidents during this 50 years period is probably considerably higher, which is evident when studying the increasing numbers of identified fires for each decade as shown in Figure 1.

Number of identified tank fire incidents per decade from the 1950s.

Decade	1950s	1960s	1970s	1980s	1990s	2000s
No. of fires	13	28	80	135	161	62*

*) Last fire identified 2003-09-28

Figure-1: Number of identified tank fire incidents per decade from 1950

3. METHODOLOGY

Scientifically fire is an outcome of reaction between fuel and oxygen. There are numerous ways to extinguish the fire. The general methods are Cooling the burning material, excluding oxygen from the fire, removing fuel from the fire, and Using flame inhibitors. Out of these we decided to use flame inhibitor i.e. AFFF foam. The reason for using foam was that tank fire are many a times oil based and water cannot extinguish it.

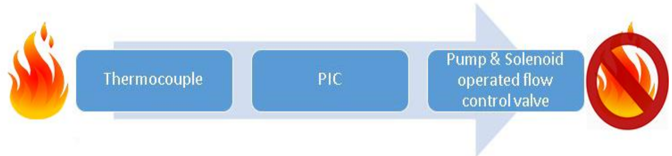


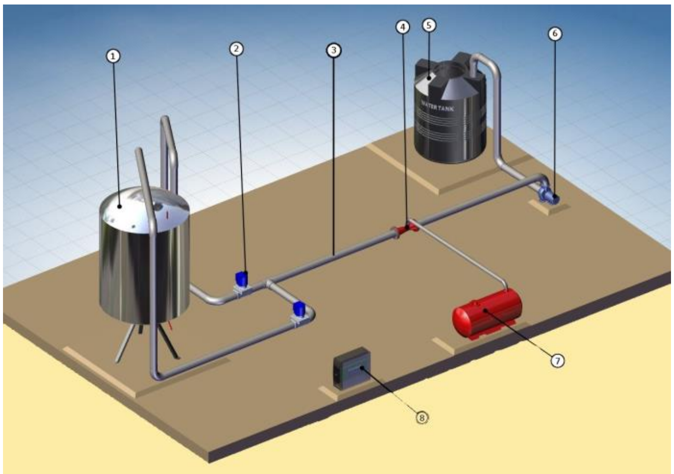
Figure-2: Simplified Block Diagram

Fire means flames and flames means temperature. In this method, we are using a thermocouple to detect the elevated temperature of the flames as an input and give an equivalent electrical output, which is then interpreted by PIC. PIC then control the switching of pump and solenoid operated flow control valve as per the electrical input. When the pump is switched ON, the water flows from the water storage and mixed with the AFFF concentrate in Foam proportioner to form a foam. This foam is then admitted into the vessel, where the fire is to be extinguished via solenoid operated flow control valve, which is in ON position.

3.1. Advantages of Our Method

- Human error is eliminated
- Quick response
- Economical when compared to other automatic systems
- This method is impeccable for fire safety in small tanks and vessels.

3.2. Design of System Intended



No.	Part Name
1.	Vessel
2.	Solenoid Operated Flow Control Valve
3.	GI Pipe (3/4")
4.	Foam Proportionator
5.	Water Storage Tank
6.	Pump
7.	Foam storage Tank
8.	Programmable Intelligent Computer (PIC)

Figure-3: System Desgin

4. COMPONENTS USED IN OUR SYSTEM

Below are the details of the components that we are using and the reason why we are choosing those components over large number of other components available in market to perform a similar task.

4.1. K-type thermocouple

There are many types of thermocouples available in the market which have their own unique characteristics of temperature, durability, chemical resistance, and application compatibility like Type J, K, T, E, R, S, and B thermocouples. Over these we are using K type thermocouple. Its temperature range of is -200 to 2300°C, and its limit of error is +/- 1.1C or 0.4%. The high temperature range of the thermocouple makes it suitable to be used to detect the temperature of fire. Other thermocouples like the N-type thermocouple have similarly high temperature range but the k-type thermocouple is less costly and readily available.

4.2. PIC (Peripheral Interface Controller)

We could have used microcontroller like Arduino microcontroller and logic controllers PLC (Programmable Logic Controllers). But, PLC is an entire system and more expensive whereas PIC is a single chip computer, very small, and very cheap. Moreover, the PLC require ladder logic which is more difficult than the limited 37 instruction code in PIC. On the other hand, PIC boards have higher clock speed than Arduino and its code is extremely efficient which allows the PIC to run with typically less program memory.

4.3. Foam Proportioner

Foam proportioner mixes the foam properly with water so that a suitable foam solution is formed in a proper foam to water ratio. We are using the foam proportioner as an inline inductor. It eliminates the need of a separate metering device for the foam concentrate. It saves unnecessary excess mixing of foam with water.

4.4. AFFF Foam

AFFF foam provides better flow and spreading over the surface compared to other types of foams. This allows faster extinguishing of flames. Foam is the only factor that is capable of withholding the flame vapours and put an end to them.

5.CALCULATIONS

5.1. Pipe Dimensions

Diameter= ¾ inch ......(Available Standards)
Length = 3 metre ....(Constraint)

5.2. Vessel Dimensions

Diameter = 12 inches = 0.304 metre
Height = 14 inches= 0.355 metre
Area of Vessel = $\frac{\pi}{4} \times 0.304^2 = 0.072\ m^2$
Volume of vessel = $0.072 \times 0.355 = 0.025\ m^3$
Available time to completely fill the vessel (t) = 60 seconds

5.3. Pump calculation

Required Discharge (Q) = $\frac{Volume}{t}$

$= \frac{0.025}{60}$

$= 4.166 \times 10^{-4}\ m^3/sec$

$= 24.996$ lit/min

Head (H) = 1 metre
Density of water (ρ) = 1000 kg/m^3
Acceleration due to gravity (g) = 9.81 m/s
Water Power = $\frac{\rho \times g \times Q \times H}{6000} = \frac{1000 \times 9.81 \times 0.0004166 \times 1}{60000}$
$= 11.352 \times 10^{-6}$ KW
Water Power = 1.52×10^{-5} Horsepower

Since Pumping Power and Discharge is too low. Hence, we selected small capacity DC pump.

6.WORKING EXPLAINED

6.1. Case I

When the fire breaks out inside the vessel due to lightning, human error or some other external reason. Thermocouple 1 fabricated inside the vessel detects the rise is in temperature, this rise in temperature is taken as an input. Thermocouple 1 then produces an electrical signal equivalent to the rise in temperature as an output. This output electrical signal is then sent to the PIC.

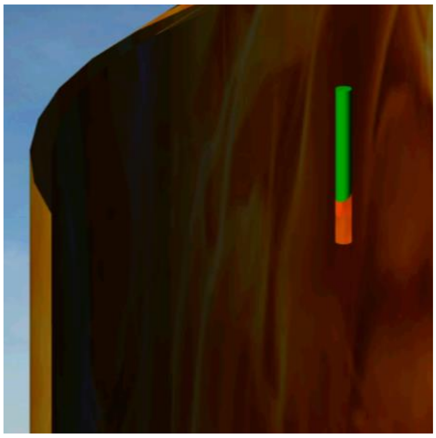


Figure-4: Thermocouple response to flame

As soon as PIC receive an electrical signal from the thermocouple, it starts processing and generates another electrical signal, which is then sent to the solenoid operated flow control valve and pump and they are switched ON.

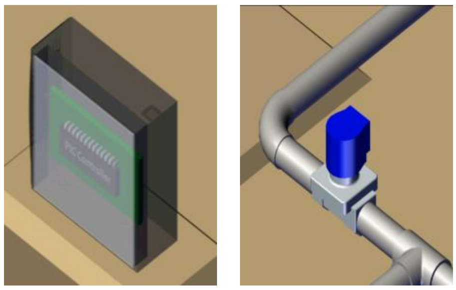


Figure-5: PIC controller(Left), solenoid operated flow control valve (Right).

Water from the storage tank is pumped in the pipelines. Water flows into the foam proportioner. Inside foam proportioner, water enter from convergence section and foam concentrate enter from throat section and get mixed. Resultant Foam having appropriate properties is then come out from the divergence section. This foam is admitted inside the vessel through the solenoid operated flow control valve.

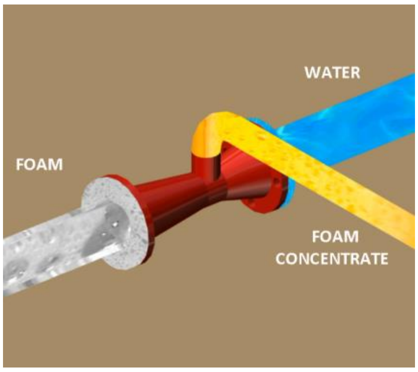


Figure-6: Foam proportioner mixing shown

Foam after admitting into the vessel get settle at the bottom of the vessel and create a blanket over the burning substance, preventing oxygen supply to it and cools down the burning substance. This act of forming blanket extinguishes the fire.

6.2. Case II

When the fire breaks out in the vicinity of a vessel due to lightning, human error or some other external reason. Thermocouple 2 fabricated outside the vessel detects the rise is in temperature, this rise in temperature is taken as an input and the output electrical signal is then sent to the peripheral interface controller. As soon as PIC receive an electrical signal from the thermocouple 2, it starts processing and generates another electrical signal, which is then sent to the second solenoid operated flow control valve and pump. This electrical signal is used to switch ON the pump and triggers the second solenoid operated flow control valve.

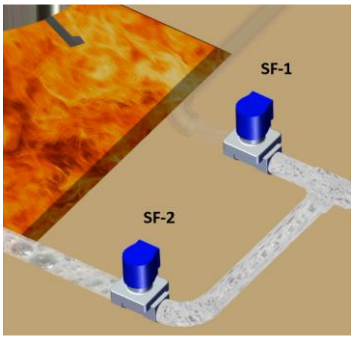


Figure-7: SF2- The second solenoid operated flow control valve.

7. CONCLUSION

From the above details we conclude that many losses due to tank fires can be avoided by the proposed automated system. This system can be used in both small tanks as well as large tanks.

REFRENCES

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