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Risk Assessment in Catalytic Reforming Unit in one of the Iran's Refinery by using FTAMethod

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Abstract

Human are always looking for means to improve their lives. The human desire for a better life caused he used his talents and abilities for invention of machine and tools, explore different material and new ways to work from ancient times until now and we are already seeing some of the progress. Modern technology reduced risk of earlier, however it faced people with new risks. Thus overtime they needed a system to oversee the work safety. At present we run it as a Risk Management in the organization under HSE Management and a subset of its activities in order to eliminate or reduce the risks. Nowadays several techniques are used to analyze safety systems. Today, due to the fact that our country is based on oil industry and its important role in the economy, so pay attention to HSE issues in the oil, gas and petrochemical industries is very important. In this industries risk is high and all units in all organizations should identify all risks and are looking to reduce and if possible eliminate them. This study investigates the failure occurrence probability of a Furnace in catalytic reforming unit in one of the Iran's refinery by using Fault Tree Analysis (FTA) method for 500 h operating interval.

Key words

Refinery, Hazardous industry, FTA, Primary event, Catalyst reforming, Heater furnace, Failure rate

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1. Introduction

The petroleum industry including refineries has been identified as one of the most hazardous industries in many parts of the world and any operation handling flammable materials in considerable quantities must, or at least should, make every effort to understand as much as possible the nature and magnitude of the fire and explosion hazard posed by these materials [1].

Accidental explosion hazards are of great concern to the refining and chemical processing industry, and a number of catastrophic explosion accidents have had significant consequences in terms of death, injury, property damage, loss of profit, and environmental impact [2].

According to incomplete statistics among 1972-2011 on 30 largest property damage losses in the refineries, more than 80 percent of these losses are related to the fire and explosion [3]. Also during the investigations on nine Iranian gas refineries among 2007-2011, 1129 accidents have been recorded. The incidence of fatal accident was 1.64 per 100000 and of nonfatal accidents was 1857 per 100000 workers per years [4].

Due to the destructive nature of hydrocarbon and chemical forces when handled incorrectly, fire and explosion protection principles should be the prime feature in the risk philosophy mandated by management for a facility [5].

2. Fault Tree Analysis Introduction

Fault Tree Analysis (FTA) is a logical and diagrammatic method of evaluating the probability of an accident that results from sequences of faults and failure events. FTA is useful for understanding the mode of an accident's occurrence logically [6].

A fault tree thus depicts the logical interrelationships of primary events that lead to the undesired event which is the top event of the fault tree and generally display with rectangular. A Fault Tree is a complex of entities known as "gates" which serve to permit or inhibit the passage of fault logic up the tree. The gates show the relationships of events needed for the occurrence of a "higher" event. The "higher" event is the output of the gate; the "lower" events are the inputs of the gates. The gate symbol denotes the type of relationship of the input events required for the output event [7,8].

These involve gates such that the inputs below gates represent failures. Outputs of gates represent a propagation of failure depending on nature of the gate. The main two are: The OR gate whereby any input causes the output to occur; the AND gate whereby all inputs need to occur for the output to occur. These interrelationships are represented in a Fault tree diagrams that are logic block diagrams that display the state of system (top event) in terms of the states of its components (primary events) [8].

2.1 probabilistic and statistical analyses

As mentioned above, given the failure probabilities of system components, the probability of the final event can be calculated. The simplest way in formulating a reliability problem is to use the standard Boolean operators ANDandOR [6].

The OR-gate is equivalent to the Boolean symbol "+". For 'n' input events attached to the OR-gate, the equivalent Boolean expression is $\sum_{i=1}^{n} A_n$ and in the terms of probabilitywe have (Every two events are independent of each other):

$$P(Q) = \sum_{i=1}^{n} P(A_i) \quad (1)$$

The AND-gate is equivalent to the Boolean symbol "•". Similarly for 'n'input events attached to the AND-gate, the equivalent Boolean expression is $\prod_{i=1}^{n} A_i$ and in the term of probability we have (Every two events are independent of each other):

$$P(Q) = \prod_{i=1}^{n} P(A_i) \quad (2)$$

Which "Q" is the output and "A_i"are the inputs of the gates.

The failure probability of each primary event is obtained from Eq. 3:

$$P(A_i) = 1 - e^{-\lambda t} \quad (3)$$

Which "λ"is the componentfailure rate (1/hr) and "t" is theintended time.

And For $\lambda t<0.1$ we have: $P \approx \lambda t$

The main steps used to develop a fault tree analysis:

1. Definition of the system, the TOP event (the potential accident), and the boundary conditions
2. Construction of the fault tree
3. Identification of the minimal cut sets
4. Qualitative analysis of the fault tree
5. Quantitative analysis of the fault tree
6. Reporting of results and recommending appropriate corrective actions [9,10].

3. Case Study

Catalyst reforming is one of the key processes in refineries by which gasoline is made with high quality and process that increases the octane of the hydrocarbons with the slow burning (low octane) by creating new structures without changing the number of carbon atoms.

This unit can be divided to two stages: unifier and platformer. Feed of catalytic reforming unit, to achieve specific properties of platformer unit, primarily enters into the unifier unit.Feed is sent directly from distillation unit. If you could not provide the feed from distillation unit, it can be used from the emergency reservoir.

Crude naphtha enters heater furnace by H.P-2A pump (or H.P.2B auxiliary pump). The fuel of the heater furnace is provided from stripper and debutanizer towers.

Fig.1 shows a part of a catalytic reforming unit including a heater furnace, pump motor devices, the reservoirs, heat exchanger, fuel gas drum and its associated system.

Based on the mechanism of process and critical condition of temperature, flow and pressure, "Explosion in H-H-1 heater furnace" is considered as a top event.

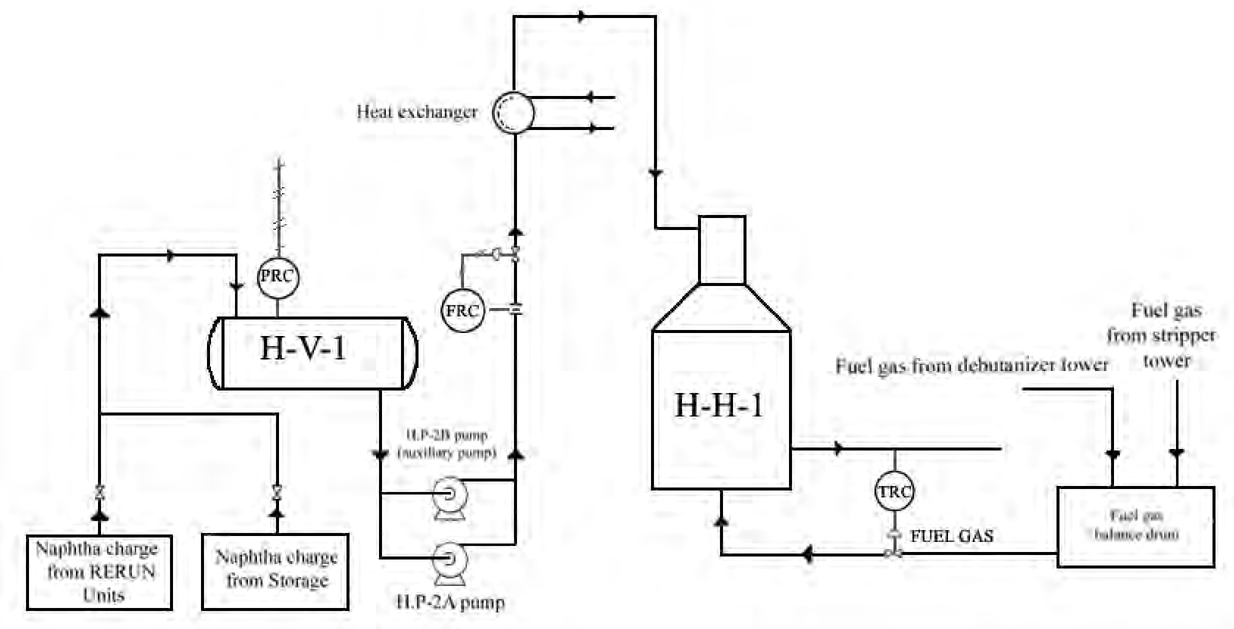

Figure1. Heater Furnace system

3.1 Fault tree analysis for Heater furnace system

In this study, according to Hazard and Operability (HAZOP) information which is done in refinery, check list of heater furnace's hazard performed and its fault tree illustrate. Fig.2 and 3 show fault tree of heater furnace system. At the first level, 3 immediate causes are considered for the top event. In addition at the next levels, several immediate causes are identified for each event.

The last immediate cause for each event is known as primary event and display with circle (signifies that the appropriate limit of resolution has been reached) and diamond (describes a specific fault event that is not further developed, either because the event is of insufficient consequence or because information relevant to the event is unavailable) [6].

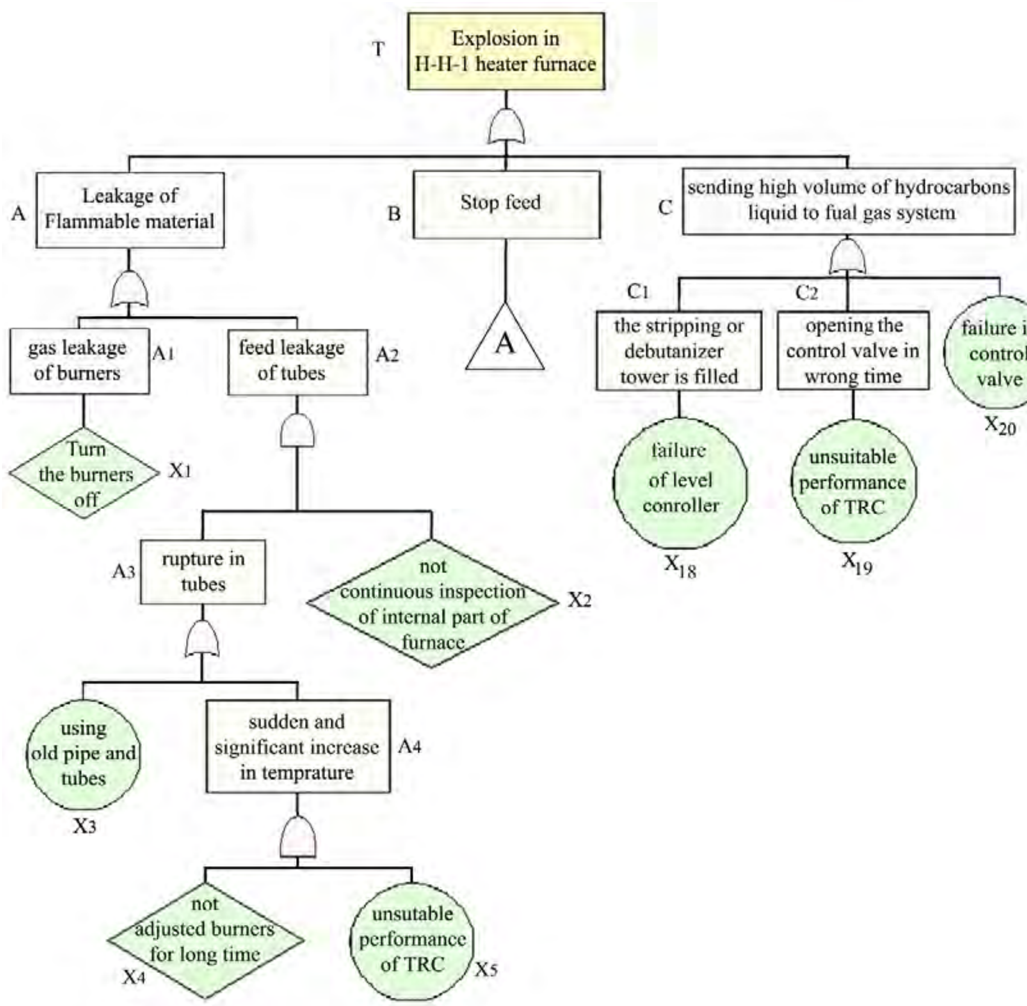

Figure 2. Fault Tree Diagram for" heater furnace H-H-1"

According to the Eq. 1 and 2 we can explain the fault tree in terms of the primary event.

$T = A + B + C$

We perform the top-down substitution and expand it until the primary event expression for the top event obtained.

$$T = X_1 + X_2X_3 + X_2X_4X_5 + X_{11}X_{12} + X_{11}X_{13} + X_{11}X_{16} + X_{11}X_{17} + X_{14}X_{12} + X_{14}X_{13} + X_{14}X_{16} + X_{14}X_{17} + X_{15}X_{12} + X_{15}X_{13} + X_{15}X_{16} + X_{15}X_{17} + X_8X_9 + X_8X_{10} + X_6 + X_7 + X_{18} + X_{19} + X_{20}$$

It can be seen that there are 22 portable path of top event occurrence.

The minimal cut sets can be obtained by using the Boolean algebra's laws. Every minimal cut set is a "smallest" combination in that all the failures are needed for the top event to occur.

According to this point that $X_5=X_{19}$, $X_{12}=X_{11}$ and $X_{15}=X_{17}$ and substituting them we have:

$$T = X_1 + X_{11} + X_{15} + X_6 + X_7 + X_{18} + X_{19} + X_{20} + X_2X_3 + X_8X_9 + X_8X_{10} + X_{16}X_{14} + X_{14}X_{13}$$

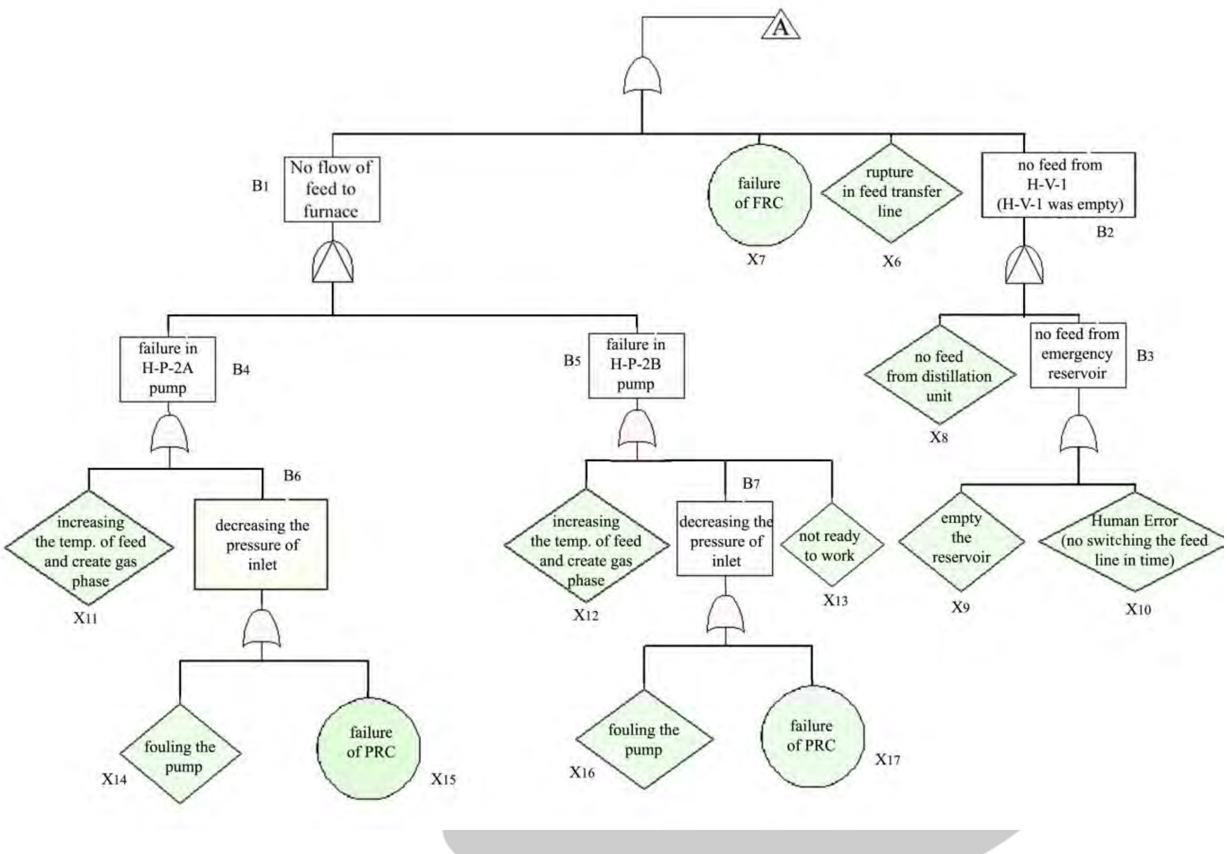

Figure 3. Fault Tree Diagram for "stop feed"

Top event appear as the union of various combinations (intersections) of basic events and it's the minimal cut sets 8 singles and 5 doubles.

Observing that the top event is obtained by summing the minimal cut sets. With according to the rare event Approximation the probability of the top event is equal to the probabilities of the union of the minimal cut sets:

$$T = P(X_1) + P(X_{11}) + P(X_{15}) + P(X_6) + P(X_7) + P(X_{18}) + P(X_{19}) + P(X_{20})$$

Note that the probabilities of the double minimal cut sets are neglected.

The required data for this case study were collected from three sources including mechanical unit's report, data collected from previous and IAEA-TECDOC-478.

Primary events	Symbol	**Failure Rate** × 10^{-5} (1/hr)
Turn the burners off	X_1	46
Increasing the temperature of the feed and create gas phase	X_{11}	11.4
Failure of PRC	X_{15}	0.022
rupture in feed transfer line	X_6	1.14
Failure of FRC	X_7	0.022
Failure of LC	X_{18}	0.022
Failure of TRC	X_{19}	3.8
Failure of Control valve (remain to open)	X_{20}	1.14

Table 1.Failure rate of the primary events

The last step in the qualitative and quantitative parts of the analysis is to describe the different event sequences arising from the initiating event.

The probability of failure for primary events at the end of each time intervals can be obtained according to the Table 1 and Eq.3. The results are shown in Table 2 and Fig.4.

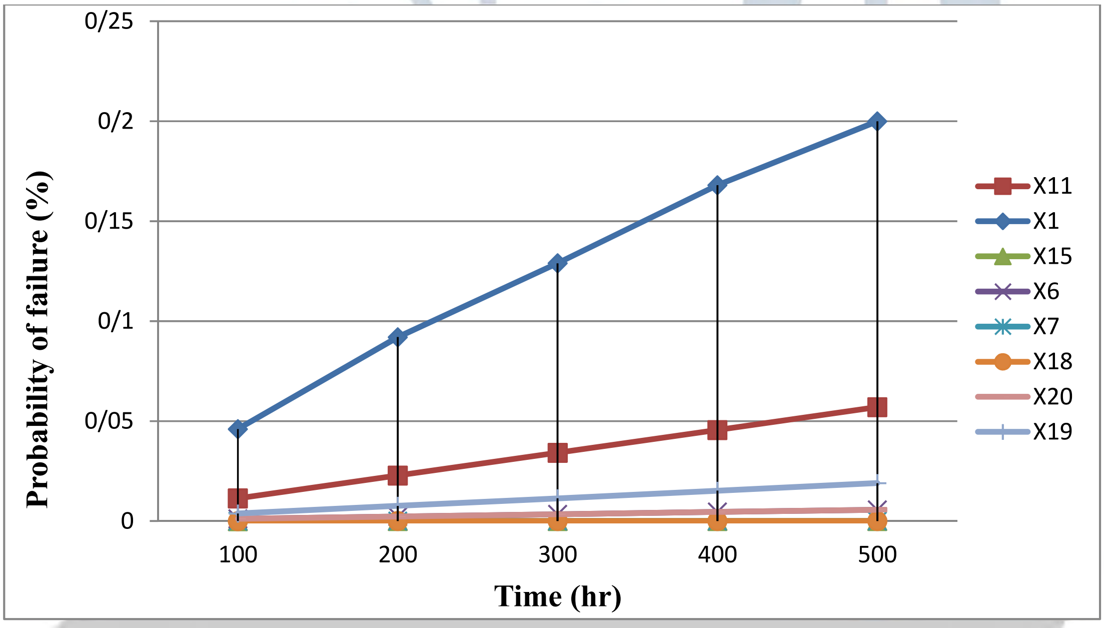

Figure 4.probability of failure for the primary events

Primary event	Probability of failure at the end of the time intervals (%)					Importance at the end of 500 hrs(%)
	100 (hr)	200 (hr)	300 (hr)	400 (hr)	500 (hr)	
X_1	0.046	0.092	0.129	0.168	0.2	69.51
X_{11}	0.0114	0.0228	0.0342	0.0456	0.057	19.81
X_{15}	2.2E-5	4.4E-5	6.6E-5	8.8E-5	1.1E-4	0.038
X_6	1.14E-3	2.28E-3	3.42E-3	4.56E-3	5.7E-3	1.98
X_7	2.2E-5	4.4E-5	6.6E-5	8.8E-5	1.1E-4	0.038
X_{18}	2.2E-5	4.4E-5	6.6E-5	8.8E-5	1.1E-4	0.038
X_{19}	3.8E-3	7.6E-3	0.0114	0.0152	0.019	6.6
X_{20}	1.14E-3	2.28E-3	3.42E-3	4.56E-3	5.7E-3	1.98

Table 2.The quantitative result for primary event

As shown in Table 2 the primary events can be ranked according to their criticality or importance.

This ranking clearly shows the progression of the accident and helps in specifying where additional procedure or safety system will be most effective in protecting against these accidents.

4. Conclusion

Generally, risk assessment and risk management are not easy to perform in a refinery unit, due to the complex process, the large number of equipment and dependencyunittoanother. In this regard, the equipment (heater furnace) from a catalytic reforming unit is selected and as a case study, FTA is done.

This analysis indicated the highest probability of failure for the primary event “failure in the burners”. If the burners are turned off by self, the gas leakage and due to the high temperature in the furnace the probability of the explosion can be exist.

Therefore, maintenance activities and continuous inspection of burners are recommended. The lighter of the burners must be inspectedandrepairedthedamage.Also the old and rusty burners should be replaced.

This simple modification reduces the probability in risk equation and therefore the risk of failure in the whole system is reduced.

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