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ASSESSING HUMAN ERROR DURING COLLECTING A HYDROCARBON SAMPLE OF THE CHEMICAL PLANT USING THERP

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ABSTRACT

This paper reports the assessment method of the hydrocarbon sample collection standard operation procedure (SOP) using THERP. The Performance Shaping Factors (PSF) from THERP analyzed and assessed the human errors during collecting a hydrocarbon sample of a petrochemical refinery plant. Twenty-two scenarios and standard operating procedures (SOP) are analysed to identify the human errors. The event tree analysis is employed to quantify the human error. The finding revealed that the THERP is a feasible technique for measuring human performance errors and performance shaping factors.

Keywords: THERP, Event Tree Analysis, Human Error Probability, Hydrocarbon Sample Collection SOP.

1. INTRODUCTION

The Major Accident Reporting System indicates that human error was responsible for 90% of accidents, most of which could have been prevented by management measures; thus, the importance of human factors in industrial safety, and accident prevention is quite evident [1].

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Therefore, it is important to assess human reliability to ensure industrial safety. Human Reliability Analysis (HRA) has always been a serious concern of safety engineers and risk assessment analysts. The main reason for that is the subjectivity of the methods used to evaluate the human reliability and the uncertainty of the data concerning human factors, together with the complexity of the human behavior per se[2]. The HRA is performed not only to identify but also to measure the degree of errors of human activities while executing the tasks.

Many researchers presented the HRA methods to assists the engineers in performing the analysis of the human errors and reliability. These methods are Technique for Human Error Rate Prediction (THERP), Cognitive Reliability Error Analysis Method (CREAM), A Technique for Human Error Analysis (ATHEANA), Human Error Assessment And Reduction Technique (HEART), The Standardized Plant Analysis Risk-Human Reliability Analysis (SPAR-H), condition based human reliability assessment (CBHRA) systematic human error reduction & prediction approach (SHERPA) and so on[3-6]. These techniques vary in the form of complexities from easy to complex to use.

The THERP is the most widely used technique to date. It not only models human errors employing the probability trees and models of dependence but also, considering the Performance Shaping Factors (PSFs) affecting the operator actions. The THERP used in many strategic industries mostly in the aviation, oil, and gas, nuclear power plants and electricity power plants [7, 8].

In the sample collection activities in a chemical plant, PSFs are the key contributor to human error [9, 10]. Therefore, to reduce the human errors, attempts are made to analyze the PSFs involved in this activity. The industries have taken initiatives to improve the PSFs such as predict the potentially hazardous situation, events of the process or operation. Other measures are anticipating the routes by which each of these fatal scenarios and providing some prevention suggestions or actions to avoid dangerous events if the safeguards are not enough [11-13].

This paper presented the assessment method of the hydrocarbon sample collection standard operation procedure (SOP) using THERP. The method to assess the SOP of hydrocarbon collection sample, results, conclusions and the direction for further research are presented in this paper.

2. ASSESSMENT METHODS FOR COLLECTING A HYDROCARBON SAMPLE

We employed THERP to analyze the human errors while collecting a hydrocarbon sample. It is also aiming at assessing the failure/success rate of the attribution of human factors at each operation step of sample collection procedure (SOP) of a petrochemical refinery plant. The assessment method for the sample collection SOP is illustrated in 1. The details of the assessment are discussed in the next subsections. As illustrated in **Erreur ! Source du renvoi introuvable.**this assessment method started with gathering the information required for the event tree analysis. This information includes the SOP and the scenarios of collecting the hydrocarbon samples, starting from open the valve, collect the sample, and finally, closing the valve. In addition, at the SOP and scenario analysis stage, the performance of the operator who executing that task was observed. The event tree was developed to identify the rate of failure of the operator in performing the tasks. The PSF will be analyzed, and identified on the basis of the above-mentioned rate of failure. Then, the specific and the overall rate of error of performing the task will be identified, and analyzed. Finally, if the specific error that relate to operator is found, the alternative SOP will be proposed so that the error can be reduced.

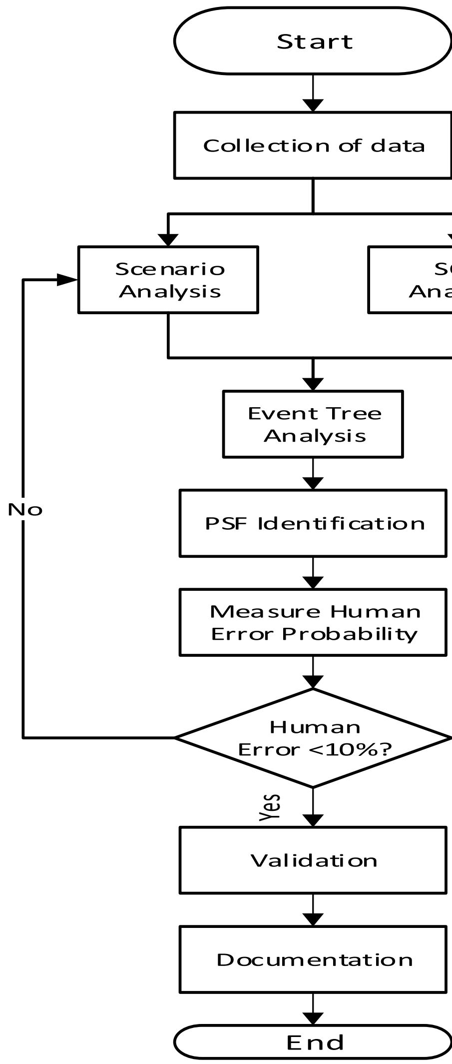

Fig.1. Method of assessing human error in the process of collecting hydrocarbon samples

2.1 Assessment Methods for Collecting a Hydrocarbon Sample

The information that related to the SOP is gathered. The data has been categorized into three stages; the open valve, collecting sample, and close valve stages. The SOPs of these activities are illustrated in **Erreur ! Source du renvoi introuvable.**1.

At this stage, the data related to the performance shaping factors (PSF) are observed and recorded. These data are the instructional length for performing the task (instructional length), the experience of the operator, the operator stress level during performing the tasks and the tagging level after collecting the hydrocarbon.

The error data was collected on the basis of the observation of the operator during performing the tasks. The observers were asked to confirm the correct SOP or the error(s) during executing the tasks. The simplified diagram of valve outlet, and the form used to record the observation is shown in Erreur ! Source du renvoi introuvable.**2** and **3**, respectively.

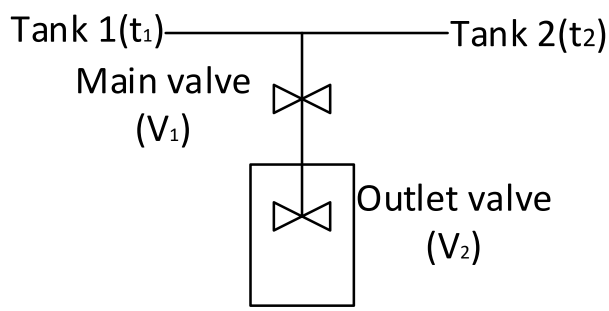

Fig.2. Simplified diagram of double valve outlet

PROBLEM SHEET							
Procedure Name							
Performance Shaping Factors :							
Instruction		Experience		Stress Level		Tagging Level	
Written :		≤ 6 months		Low		1	
	≤ 10 items	≥ 6 months		Optimum		2	
	≥ 10 items			Mod. High		3	
Oral				High		NA	
None							
Step No	Written Procedure Task Description	Dependence	Potential error	Table No.	Item No	Tabled HEP & UCBs	Stress/ Skill Factor

Fig.3. Form used to record the operator tasks during collecting the hydrocarbon sample

2.2 Scenario and SOP analysis

The scenario and SOP analysis are categorized into three; opening valve, collecting sample, and finally, closing valve. This SOP of opening valves consists of 8 steps:

1. Confirm the V_1 is closed - the operator will confirm V_1 (see Fig. 2) is closed. The Finger Point Guarantee (FPG) for re-confirmation of the visual check,

2. Choose valve opener jig - the operator will choose a suitable valve opener jig from various sizes of the opener jigs (without number/label) from a designated rack,
3. Turn V_1 opens - the operator will use jig to turn the V_1. The jig is required in turning the V_1 due to its size is small for the hand grip,
4. Confirm the V_1 is open - the operator must confirm the V_1 has been open visually. The FPG for re-confirmation of the visual check,
5. Place down jig - The operator placed the jig at the reachable safety surface or table in order to prevent the any injuries or damages,
6. Confirm the V_2 is close - The operator must confirm the V2 is closed. Reconfirmation using FPG so that it can enter into the step 7,
7. Turn the V_2 open - The operator must turn V_2 open using hand to let sample flow out, and finally,
8. Confirm sample flow out smoothly - The operator must confirm that the sample flowing out smoothly visually and do reconfirmation of the visual check using FPG.

The SOP of collecting the hydrocarbon sample. This SOP consist of seven steps:

1. Flush the hydrocarbon sample for 30 seconds – The operator must flush the sample for about 30 seconds to remove all clogging or contaminant at sample line,
2. Rinse sampling bottle with a liquid sample - The sampling bottle must be rinsed thoroughly using the liquid sample from V_2 to remove all the contaminants, If the operator fails to rinse the sampling bottle, it will invalidate this SOP and has to repeat from step 1,
3. Flush rinsed liquid to the vent - The liquid used during rinsing must be flushed through designated vent beneath the V_2 in order to prevent the liquid from contaminate the air and may cause sparks,
4. Re-rinse the sampling bottle with a liquid sample - To ensure the sampling bottle is rinsed thoroughly before filling the sample,
5. Re-flush the rinsed liquid to the vent - To ensure the liquid used for rinsing is properly flushed,
6. Collect 250ml of samples - The sampling bottle must fill with 250ml of a liquid sample, and

7. Place bottle on safety table - The sampling bottle must be placed on a sturdy table that reachable by the operator to ensure the bottle safety before entering to valve closing SOP.

The SOP of closing valves consist of the following steps:

1. Confirm liquid sample flow smooth - The smooth flow of a liquid sample must be confirmed visually, and reconfirmation using FPG,
2. Confirm the V_1 is open - The operator must check the loose condition of the V_1 by hand,
3. Close V_2 - The V_2 must be closed tightly until liquid sample stop flows
4. Close V_1 - The V_1 must be closed using valve opener jig until tight,
5. Give allowance to the valve - The valve must be turned 90 degrees opposite to give allowance to the valve, which is about a quarter turn from the fully closed position,
6. Confirm the V_2 is closed - The V_2 must be confirmed closed visually and reconfirmation using FPG, and
7. Confirm liquid sample stop flowing - The operator must open the V_2 again to confirm the liquid sample has stop flowing and reconfirmation using FPG.

2.3 Event Tree Analysis

The event tree is aiming at identifying the operator errors during executing the task. The sample of develop in an even tree is shown in Fig.4.

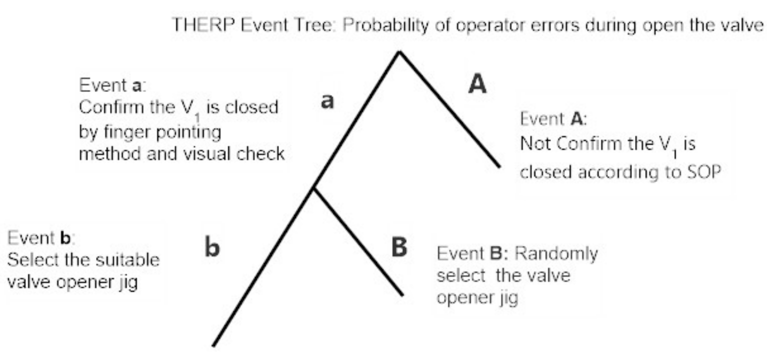

Fig.4. Example of event tree analysis

The THERP employed the event tree to model all the possible errors before estimate the human error probability. The small letters e.g. the ‘**a**’, and ‘**b**’ indicate that the operators did the task exactly as in the SOP. On the other hand, the capital letters e.g. '**A'** and '**B**' represent the tasks that are not followed the SOP. At this stage, the probability of success in performing task **a** is:

$$P(a) = 1 - P(A) \tag{1}$$

From the Eq. (1), the following relationship can be established:

$$P(a)P(b|a) + P(a)P(B|a) + P(A)P(b|A) + P(A)P(B|A) = 1 \tag{2}$$

The probability that the operator will unsuccessfully complete the task is can be calculated as in Eq. (3):

$$\begin{aligned} P(F) &= P(a)P(B|a) + P(a)P(b|a) + P(A)P(b|A) + P(A)P(B|A) \\ &= P(a)P(B) + P(A)P(b) + P(A)P(B) \end{aligned} \tag{3}$$

2.4 Performance Shaping Factor

Performance shaping factor (PSF) is defined as any factor that influences human performance. In this context, the PSFs are (see Fig.3):

1. External PSF: Instructional length for performing the task (instructional length) – refer to the manual of SOP to perform the collecting sample. It has been divided into *Written*, *Oral* instruction and *None* (the SOP is not available). The instructional length that less than or equal to 10 steps to perform the task is considered as *Low*. If the number of steps bigger than 10 steps, the instructional length is set as *High*,
2. Internal PSF: Experience of the operator – the operator that assigned to perform the task that less than or equal to 6 months is consider as inexperience worker,
3. Stressors PSF: Operator stress level during performing the tasks – the stress level is categorized into low, optimum/normal, moderate, and high, and
4. Internal PSF: Tagging level after collecting the hydrocarbon sample – divide to four; level 1, 2, 3, and no available (N/A).

3. RESULTS AND DISCUSSION

The results of the THERP are shown in the sections. We divide into 3; before, during, and after sample collection. These results are shown in Table 1 to 3, respectively. The event tree analysis diagrams are shown in Fig. 4 to 6 for each SOP activity.

Table 1. Errors during opening valve

Steps	Tasks	Error Description	Consequences
1	Confirm open V_1 is close	Omit confirmation	Unable to confirm initial condition
2	Choose valve opener jig	Choose wrong size jig	Unable to open valve
3	Turn the V_1 open	Omit turning Turn wrong valve	Sample unable to flow
4	Confirm V_1 Open	Omit confirmation	Unable to confirm step execution
5	Place down jig	Hold on jig	Difficult to execute another step
		Place jig at unsafe location	Jig fell injuring operator Jig fell damaging jig or other equipment
6	Confirm V_2 is closed	Omit confirmation	Unable to confirm initial condition
7	Turn V_2 open	Omit turning	Sample unable to flow
8	Confirm sample flow out smooth	Omit confirmation	Difficult to collect sample

Not Critical

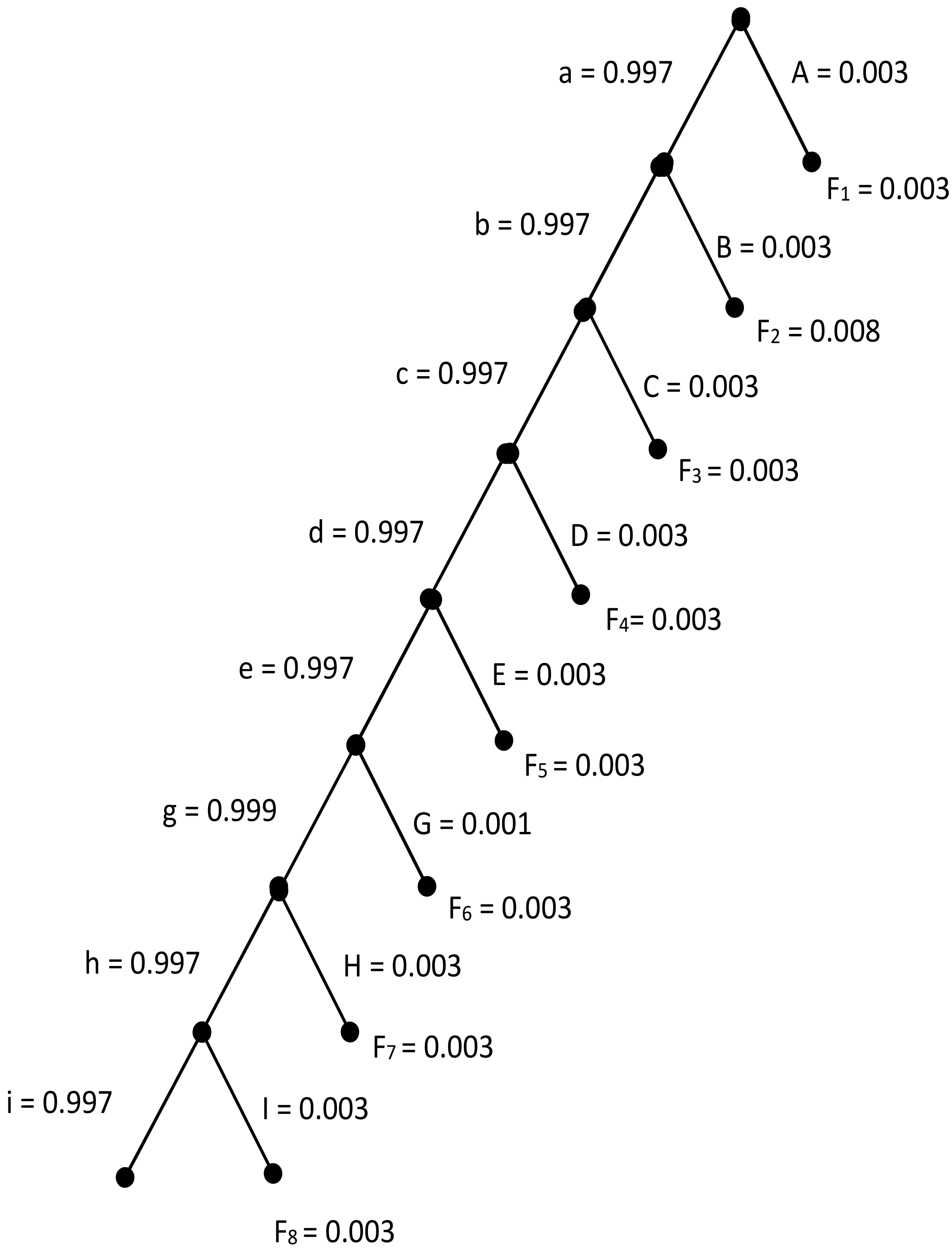

Fig.5. Event tree analysis at the open valve step

Fig. 4 shows the event tree analysis of the opening valve step.The small letters of "**a**" to "**h**" presents the success rates of step 1 to 8. The capital letters of "**A**" to "**H**" present the probability of steps 1 to 8 . The rate of failure and success at the open valve SOP are as in Eq (1) and Eq (2):

$P_r[F_{OPEN\ VALVE}]$= 0.003 + 0.003 + 0.003 + 0.003 + 0.003 + 0.001 + 0.003 + 0.003=0.022,

$P_r[S_{OPEN\ VALVE}]$=1-0.022=0.978

Table 2. Errors during collecting sample

Steps	Tasks	Error Description	Consequences
1	Flush samples for 30 seconds	Omit flushing Flushng less than 30 seconds	Excessive cloggings and contaminant could affect sampling result
2	Rinse sampling bottle with sample liquid	Omit rinsing	Sampling bottled could be contaminated
3	Flush rinse liquid through vent	Operator flush the rinsed liquid at other places then designated vent	Flush liquids could contaminate the air and cause spark
4	Re-rinse the sampling bottle with sample liquid	Omit re-rinsing	Contaminants could still exists in the sampling bottle
5	Re-flush the rinsed liquid to the vent	Omit re-flushing	Flush liquids could contaminate the air and cause spark
6	Collect 250 ml of samples	Operator collect less than 250ml of sample	Sampling testing could not be executed
7	Place bottle on safety table	The operator did not place bottle on safety table	the bottle could fell causing damage to bottle and injuries to the operator and

	peripheral equipment.

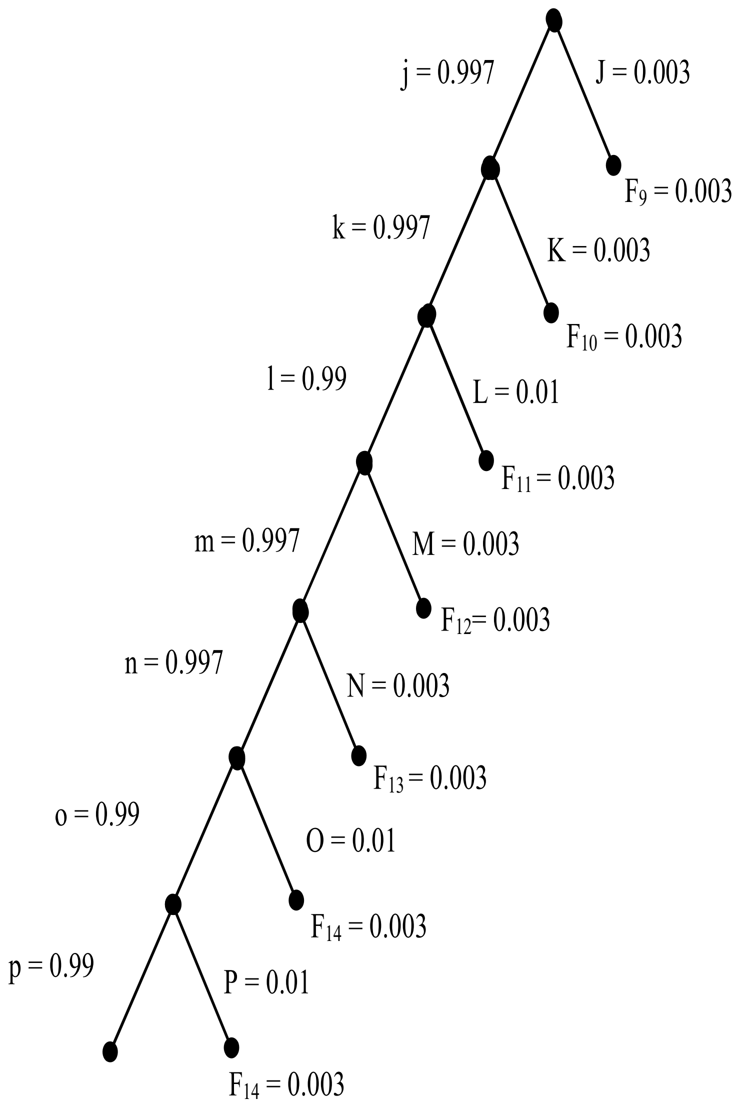

Fig.6. Event tree analysis during collecting sample

Fig. 5 shows the event tree analysis during collecting hydrocarbon sample.The small letters of "**j**" to "**p**" presents the success rates of step 1 to 8. The capital letters of "**J**" to "**P**" present the probability of steps 1 to 7. The rate of failure and success at the collecting sample are as follows:

$P_r[F_{COLLECT\ SAMPLE}] = 0.003 + 0.003 + 0.003 + 0.003 + 0.003 + 0.003 + 0.003 = 0.021$,

$P_r[S_{COLLECT\ SAMPLE}]=1-0.021=0.979$

Table 3. Errors during closing valve

Steps	Tasks	Error Description	Consequences
1	Confirm sample flow smooth	Omit conformation	Current flowing condition cannot be determined
2	Confirm V_1 is opened	Omit conformation	Current V_1 condition cannot be determined
3	Close V_2	Omit closing Valve	Could not sample flowing
4	Close V_1	Omit closing Valve	Could not sample flowing
5	Give allowance to V_1	Omit giving allowance	V_1 could stuck
6	Confirm V_2 is closed	Omit conformation	Current V_2 condition cannot be determined
7	Confirm sample liquid stop flowing	Omit conformation	Could not sample flowing
Not Critical			

Fig. 6 shows the event tree analysis of the closing valve step. The small letters of “**q**” to “**w**” presents the success rates of step 1 to 8. The capital letters of “**Q**” to “**W**” present the probability of steps 1 to 7. The rate of failure and success at the close valve SOP are as follows:

$P_r[F_{CLOSE\ VALVE}]= 0.003 + 0.003 + 0.003 + 0.003 + 0.003 + 0.003 + 0.003=0.021$,

Using the Eq.(3) the total failure rate is:

$$P_r[F_{Total}]= P_r[F_{OPEN\ VALVE}]+P_r[F_{COLLECT\ SAMPLE}]+ P_r[F_{CLOSE\ VALVE}]$$
$$=0.022+0.021+0.021=0.064$$

$P_r[S_{Total}]=1-0.064=0.936$

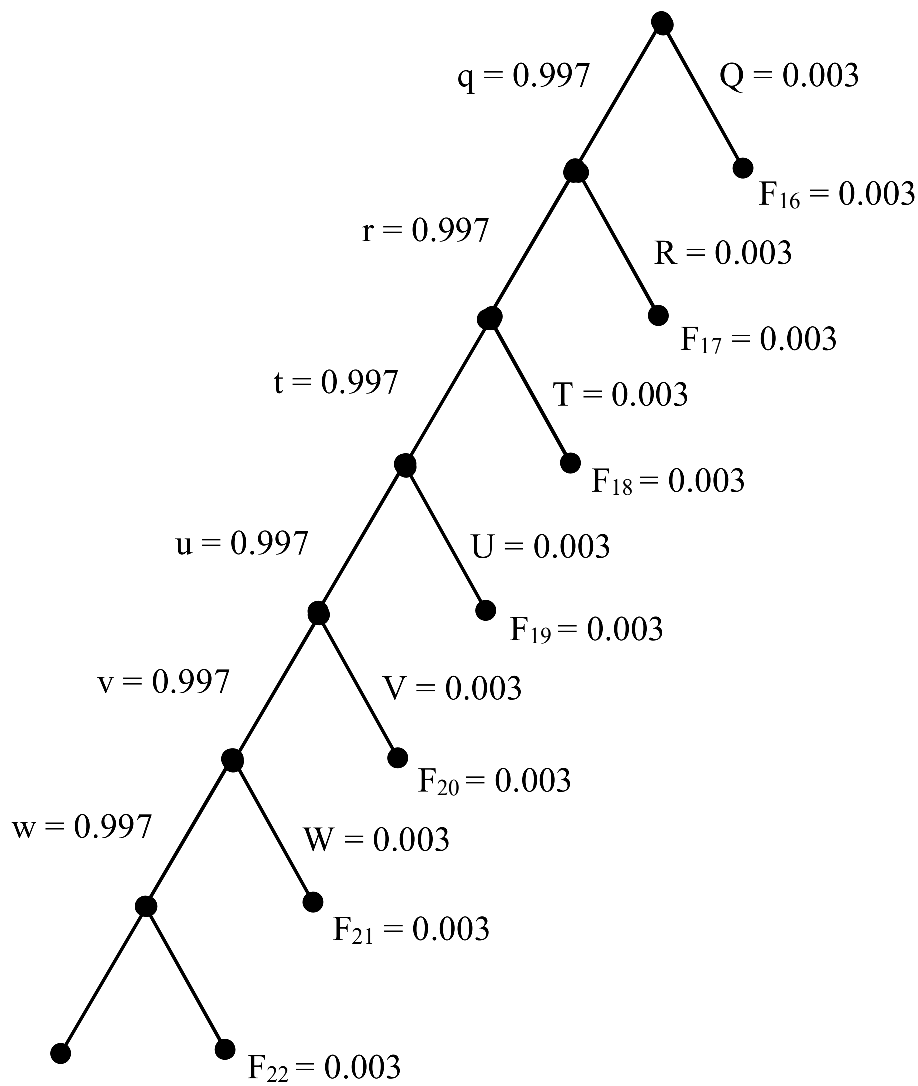

Fig.7. Event tree analysis during closing valve

In summary, Tables 1 up to 3 identified the critical human errors. The event tree analysis in Fig. 4 up to 6 provide a quantitatvive measures of failure and success at the stages of opening valve, collecting samples, and closing valve. This result highlights the fact that when performing THERP assessment at the opening valve stage, the human errors scenarios can present more pessimistic results [14].

4. CONCLUSION

THERP is an effective technique for measuring human performance liability measure and the given scenarios and SOP is measured with the help of this technique. The THERP analysis was done separately at the stages of the SOPs of opening the valve, collecting sample and closing the valve. The error descriptions for first stage are omit confirmation, choosing wrong jig, place the jig on wrong place and omit turning. While the consequences that occur are in step one, four and six in which they were unable to confirm the initial condition but these consequences were not critical. The error descriptions for second stage are omit flushing, omit rising, flushing for less than 30 seconds, safety of bottle placement and operator did not collect the 250 ml sample. The event tree analysis is used to measure the failure of operator while performing the given tasks. It shows that the rate of failure for opening the valve was 0.022 whereas the success rate was 0.978 and it is indicating that the task was performed efficiently, the rate of failure for collecting the sample was 0.021whereas the rate of success was 0.979 again depicting that this scenario was also handled smoothly. And rate of failure for closing the valve was 0.064 whereas the rate of success for this stage was 0.936 indicating that the operator did well. This means that the activity of collecting hydrocarbon sample was performed well and there was no sign of any dangerous event to take place. The SOP and scenarios which is design to measure this ask of collecting hydrocarbon is effective because no error is being done by the operator and he handled the task well. The operators followed the SOP at every stage so that the human error were minimized.

5. ACKNOWLEDGEMENTS

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