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Human Error on the Risk Reduction Actions during the NPP Maintenance

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Abstract— **This work presents an analysis about the impact of the human error on the risk reduction actions. This paper shows the dynamic in the human error within the maintenance process like is followed in the nuclear industry around the world. The conclusions show the importance of the background knowledge of the maintenance staff and the relevance of the sequence of the risk reductions actions included in the maintenance tasks.**

Index Terms—**human error, maintenance, risk reduction, nuclear power plants.**

I. Introduction

Following to Rigby [1] "the human error as any member of a set of human actions that exceeds some limit of acceptability". The tolerance may be defined clearly or not. The tolerance may be explicit or implicit in the maintenance procedures if it is possible. But in none case the human error imply a deliberated actions to damages the production, assets, personnel, public or environment [2,3].

The maintenance modelling put the focus at the beginning on the machinery [4-6]. The next stage was focused on the optimization with the modern power of calculation from the modern computer [7-10], and the last stage included the modern metaheuristics like genetic algorithm [11-12].

By on the other hand the human error raise like a necessity of show the potential of the unwanted actions on the systems. Three generations are identified on this matter. The first generation began in 1964, Swain developed THERP, Technique Human Error Rate Prediction [2] and a year after SLIM appears (Success Likelihood Index Methodology) [13]. The second generation includes in 1998 CREAM [14] (Cognitive Reliability and Error Analysis Method) introduced by Hollnagel and relevant member of this group rise in 2000 when is presented ATHEANA [15-16] (A Technique for Human Event Analysis) by the Nuclear Regulatory Commission at USA. However in 1994 the first member of the third generation is presented by Kirwan et al., NARA [17] (Nuclear Action Reliability Assessment).

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These methods are only a few, but it is a demonstration of the Human Error Analysis is a discussion still open. The considerations about human error in this work pretend to add a new perspective about the context in Nuclear Power Plants (NPP) Maintenance.

II. Human Error

The human error could be classified in Error of Omission (EOO) and Error of Commission (EOC) [3]. In the EOO one or more steps within a procedure are loss, but not intentionally by the technician. The technician does not warn the loss of the steps. The reasons include bad written procedures and stress. In the EOC the procedure is intentionally changed by the technician. The technician believes that the modified method is better than the original. He believes that the modified procedure has better performance too. [18]. But in this last case a new safety analysis for the changed procedure is not done and the modification could imply on the safety issues of the NPP.

In [18] the necessity of a supervisor is demonstrated with a model based in historical field data from US NPP. But the presence of the supervisor does not ensure that errors do not occur. K. Sasou & J. Reason in [19] showed as the error detection, error indication and the error correction is provided by a number of factors. These factors are called performance shaping factors, PSFs. The table 1 resumes some of those in [19].

TABLE I
Performance shaping factors

Detection	Indication	Correction
Deficiency in communication	Excessive authority gradient	Excessive authority gradient
Excessive authority gradient	Excessive professional courtesy	Excessive professional courtesy
Excessive belief	Deficiency in task management	Deficiency in task management
Deficiency in task management	-	-

In 1990 J. Reason [20] had submitted their "Swiss cheese model" to clarify the dynamics of the progress of faults in monitored actions leading to an accident. The Fig. 1 shows this model for 3 technicians work alone. In this figure the holes represents the EOO and EOC during a procedure. The slices represent one procedure done by the technician. Three single procedures related between them are showed. When three holes are aligned the accidental sequences is developed

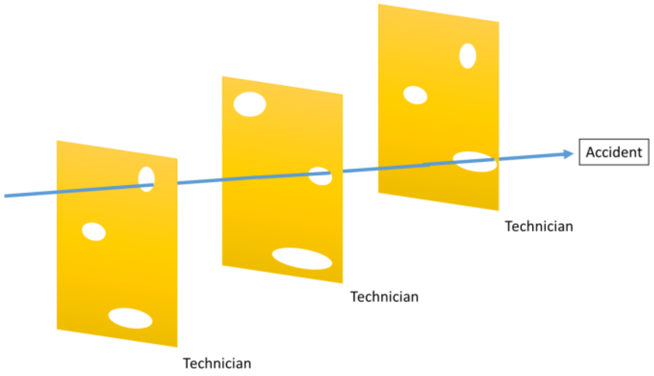

Fig. 1. Model for 3 technicians with EOO and EOC indicated as holes in the slices of cheese. The alignment of those holes facilitates an accidental sequence.

III. Model Human Error with THERP

THERP [3] uses conventional reliability technology with adaptations to the uncertainties and interdependencies of human performance. THERP model the human behavior in a Boolean graphic. The right branches represent the erroneous actions and the left branches the successful action. And the actions indicated with dash lines are for the recovery actions. In general area associated to control actions by supervisors. All probabilities, except those in the first branching, are conditional probabilities. Fig. 2 shows an example of this Boolean graphics.

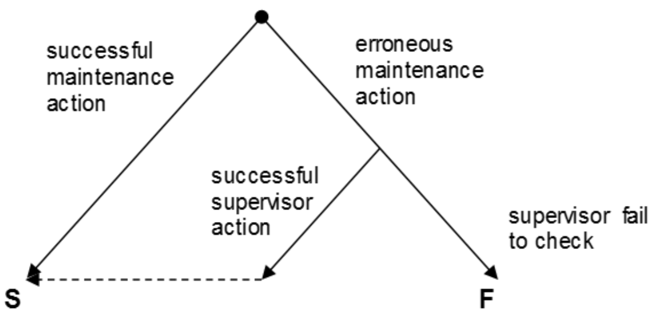

Fig 2. Model human error using THERP. A bold dot and the arrows were included to clarify the sequences.

In order to develop an analysis must define the system failure, list and analyze the related human operation, estimate the error probabilities for each one and finally estimate the effects of human errors on the system.

IV. Conceptual Modeling I

Our problems are three procedures that require the intervention of mechanical, electronic and, instrumentation and control maintenance task force. The three procedures are done sequentially and in a disjoint way each other. The order at first is not relevant.

We will use the Swiss cheese model to model our problem in a conceptual way. The Fig. 3 shows the model with a right design of the controls (barriers).

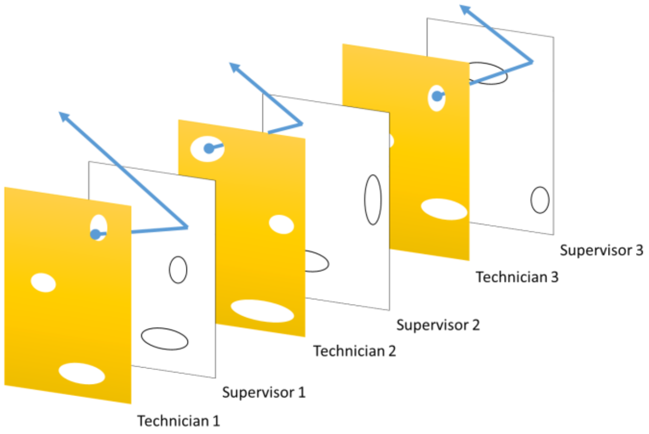

Fig. 3. Model for 3 technicians and 3 supervisors. The design works right.

The design of the tasks include the probabilistic safety assessment to design a low risk tasks, well writing procedures, training for the technicians and the supervisors and adequate maintenance management at least [21-23].

One of the primary objectives of a probabilistic risk, or safety, assessment is identify and evaluate risk reduction actions (e.g. training, inspection program, check redundancy, diversity in checklists for selfcontrol, work hour limits, better coordination, quality assurance management, etc.). This actions must be included as part of a normal maintenance or operation of the NPP. So the EOO and EOC must be discovered and analyzed before that the procedures are released.

The EOO is more aligned with the poor writing procedures or checklist off. The EOC depend strongly with the management and the degree of improvisation of the technicians and supervisors within the policy of the organization. So, the Fig. 3 is dynamically changed when the supervisor 1 is replaced with the supervisor 1 for the second shift due to an illness. See Fig. 4.

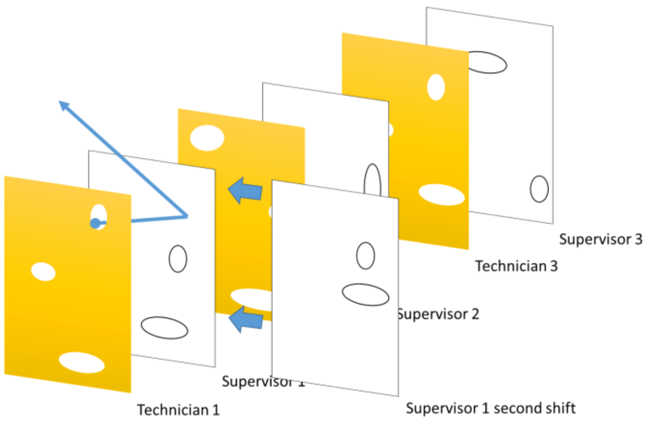

Fig. 4. The graphic shows the replace of the supervisor 1.

Note that the supervisor 1 for the second shift has different EOO or EOC with him. These may be due to a different training, background, historical events in his professional life and/or experiences in the facility and so on.

The Fig. 5 shows the graphic with the change and its consequences.

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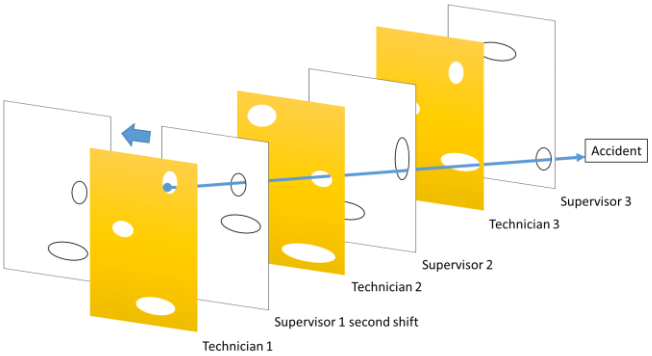

Fig. 5. The graphic shows the consequences of the supervisor change.

V. CONCEPTUAL MODELING II

One more time there are three procedures that require the intervention of mechanical, electronic and, instrumentation and control maintenance task force. The three procedures are done sequentially and in a disjoint way each other. The order at first is not relevant but in this case the problem now is focusing on supervises a maintenance task to avoid the EOO and/or EOC from the mechanical technician.

The Fig. 6 shows a conceptual graphic where in the middle is the machine, subsystem or system, around the machine are located the different task forces (mechanical, electrical and, instrumentation and control). The precedence between them is showed by arrows in a clockwise. The mechanical task is the first task of maintenance. In Fig. 6 the maintenance is done without supervision due to this the EOO and/or EOC impact straightly to the machine.

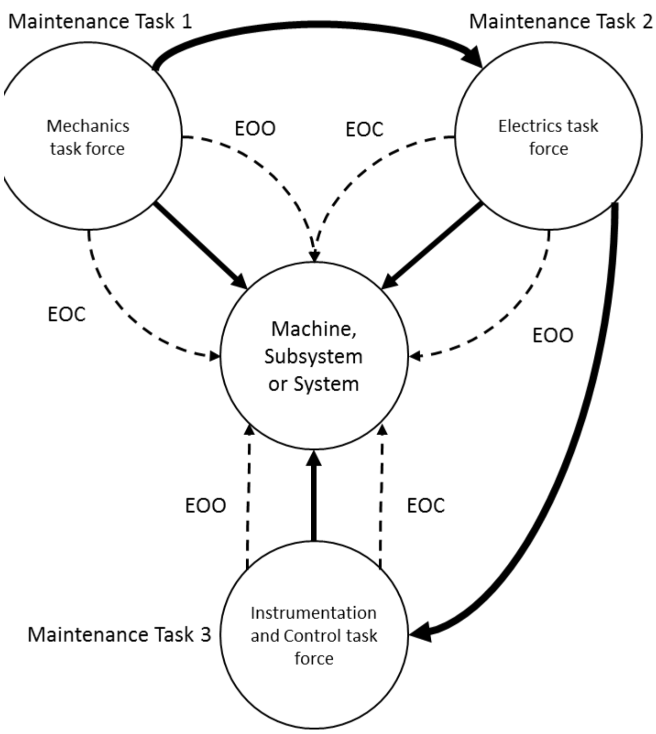

Fig. 6. Maintenance on a machine without supervision.

The Fig. 7 shows the same intervention, but now with supervision. In this case the EOO and/or EOC are limited to the previous intervention tasks. The supervisor plays a relevant role in the containment of the propagation of the error over the machine.

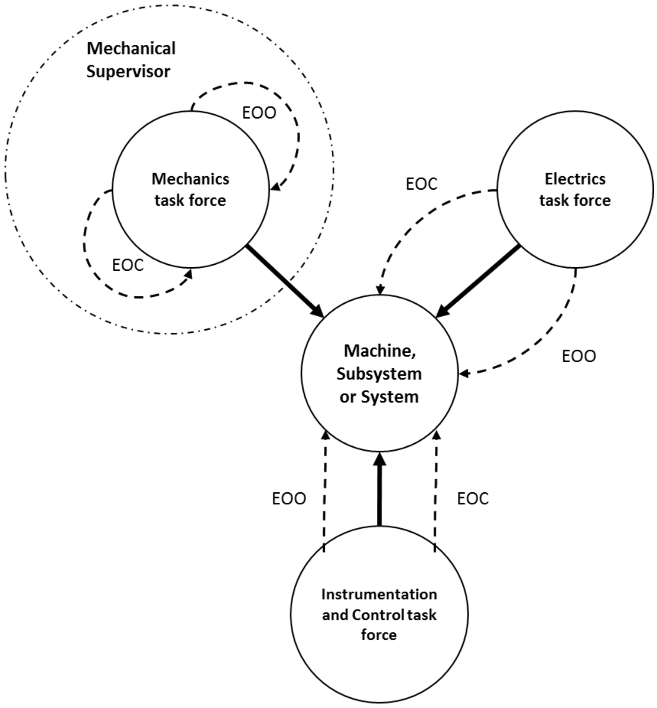

Fig. 7 Maintenance on a machine with supervision in the mechanical maintenance. The precedencies were hidden for clear the graphic.

Finally the Fig. 8 shows the intervention the supervisor when the maintenance tasks were finished.

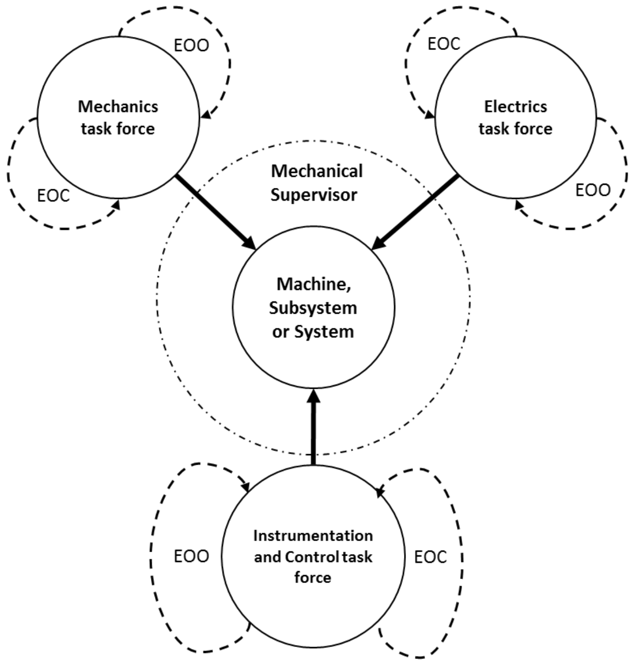

Fig. 8 Maintenance on a machine with supervision in the mechanical maintenance when the supervisor arrives when the maintenance tasks were finished.

In this last case the supervisor arrived late to control the technicians maintenance tasks and the situation may be how is showed in the Fig. 8 or the technician was a behavior similar to Fig. 6. The supervisor will require additional information from independent sources different that the communication from the technician to assure the rightful of the mechanical maintenance tasks (e.g. supplies warehouse can provide to the supervisor with the parts carried out by

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the technician). These other sources are not available for all cases (e.g. manual calibration of inner parts).

VI. Modeling

Model with THERP the first step in the procedure of a mechanical maintenance task and the final task when the machinery setup previous to run it. Fig. 9 shows the THERP model without supervision.

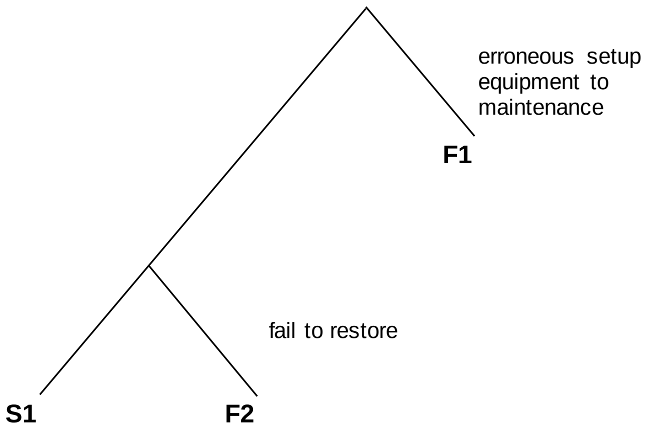

Fig. 9. The THERP model shows the Boolean model from the technician without supervision.

The task begins with the setup the equipment to the mechanical maintenance tasks. These tasks may be at least one or more, the complexity depends on the machinery, subsystem or system. The specific procedure of mechanical maintenance is not included here for clarity. After the mechanical maintenance tasks were done the last step is the restoration the machine previous to run it.

In the model exists two possible sequences for failure and only one to successful.

Note that the model does not include any recovery actions, due to these require the presence of the supervisor or special reevaluation of the situation by the technician that in this case was not taken into account.

Fig. 10 shows the same procedure but now with supervision. Note that rise a recovery action due to the presence of the supervisor and additional check for the restoration tasks.

In this model, persist two sequences of failure; but the first incorporates a recovery action and the second additional control. Due to this, the model has two successful sequences. Similar sequences were calculated in [26] where the human error probabilities without supervision was equal to $5.05x10^{-1}$ and the human error probabilities with supervision was equal to $1.009x10^{-1}$. Improvement in the probability of error is a factor 5.

The EOO and EOC are hidden in the model associated with real data from the NPPs. It is not a clear way to present the analysis. But not in all cases data help to expose the EOO or EOC.

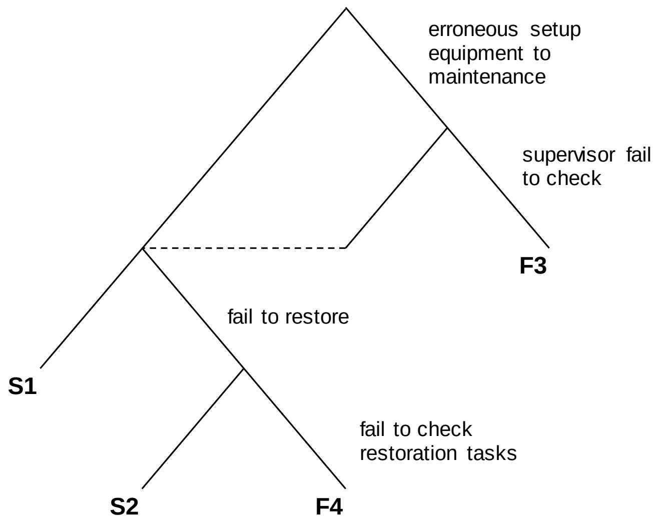

Fig. 10 THERP model with a technician supervised.

VII. Discussion

Comparing the exposed results of conceptual models with the THERP models it is clear the difficult of translate to a quantifiable model the complexity of the possible interactions in the maintenance areas.

The dynamic of the interactions between the technician and the supervisor is not simple to model in a one model. Several models are necessary for accomplish a fulfill vision of the maintenance EOO and EOC.

Risk reductions actions from probabilistic safety assessments represents a right guide to reduce the risk in the maintenance tasks. But due to the model may not include the whole picture of the maintenance staff interactions is not a simple way to accomplish the fulfill vision.

Human error reevaluated in this work is an effort to extend the knowledge around the concept of Human Error Hotspots (HEH) [27]. The HEH results in a clear and relevant concept for itself and from the Human Error in general. So, the HEH results every time as a trigger of an accidental sequence like the examples shown.

Several accidents in nuclear industry [28-32] and others in the chemical industry [33-34] includes several examples of HEHs, these historical events give to HEH their relevance.

VIII. Conclusions

On the basis of exposed models and its correlation with daily activities on the maintenance tasks it is concluded that:

1. Collecting and analyzing events and take decision in accidental situations and retrain with this knowledge to all the staff.

2. All maintenance staff should possess the same theoretical and practical knowledge of the plant.

3. An analysis must be made of decisions taken and show items theoretical and practical that endorse the decisions taken.

4. The previous point should see the scope and limits of

those decisions, by clarifying cases in which would not be valid them.

5. Groups of technicians and supervisors must rotate its members as well as rotate the shift, in such a way of standardize the knowledge and standardize the management of each shift independently of its members

IX. Further Works

Human Error Hotpots, require works for a systematic way to approach the HEH analysis.

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