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Engine Control Simulator as a Tool for Preventive Maintenance

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ABSTRACT

Experience within the aircraft, ship and military sectors has shown that important benefits may be achieved through the application of computer based training systems. Simulation provides the particular benefit of enabling the response to emergency situations to be practiced within scenarios that would otherwise be too expensive or too dangerous to perform in real conditions. One of the main objects of this paper will be the establishment of techniques and processes for the minimization of dangers that emanate from the operation of engines and subsystems in a Very Large Crude Oil Carrier. With basic tool of research, the installed engine room simulator of Merchant Marine Academy of Macedonia the analysis of total behavior of ship has been examined when they are caused on this: Deteriorations in the basic sections of an engine, changes on the basic parameters of operation, damage in the auxiliary instruments and parts of networks, undesirable actions and abnormalities in the electrical network and all supporting networks. Human factors are related to crew competence in terms of decision-making, communication and operating skills. Human error is an existing parameter that often proves to be almost impossible to remove from the maritime safety formula. Thus, the human failures – errors can be avoided by different ways: firstly by improving the management and crew organisation and secondly doing preventive maintenance. The use of the simulator can indicate the ship systems which require preventive maintenance due to daily and common malfunction.

1. Introduction

It is common knowledge that both big shipping industry and shipping and offshore small medium enterprises are facing difficult but also very challenging times due to the globalization of markets and the current financial situation. The three main parameters of the production mainly maintenance, quality and safety are playing a vital role for the smooth operation of their business and the economic impacts that those three parameters could have in the industry. Unfortunately, many times they are underestimated and they cannot be realized and understood without the required training and transfer of practical skills.

Information Technology and Information Systems and Telecommunications such as the Internet could greatly improve both the maintenance techniques and the safety level in any industrial floor. The lack of innovative practices on Safety and Maintenance vocational training at a European level, combined with the need to facilitate employees' training opportunities, poses a great challenge for developing advanced learning techniques. Based on the improvements on safety and reliability reported in the other industrial fields, competitiveness of transport by ships should be increased in terms of reduction of accidents (costs and frequency); optimization of production and operation costs; by the current use of risk assessment and cost/benefit analysis techniques.

Marine engineers (IMO Model course 7.04, 1999; IMO Model course 7.02, 1999) are on board ship to ensure the safe and efficient operation of machinery. Safe and efficient operation of any individual item of machinery requires regular maintenance. Maintenance requires manpower and time and in some instances these are not always available. Many ships now operate with only three engineers on board and short periods in port provide little time to carry out maintenance. Today during the operation of ship marine engineers follow three types of maintenance: Preventive or scheduled planned maintenance, corrective-breakdown maintenance and finally the condition based maintenance.

One from the main objects of used engine room simulator (IMO Model Course 6.09, 2001; IMO Model Course 2.07, 2002) is the establishment of techniques and processes for the minimisation of dangers that emanate from the operation of engine and subsystems in a Very Large Crude Oil Carrier. The total behaviour of ship has been examined when they are caused on this: Deteriorations in the basic sections of engine, changes on the basic parameters of operation, damage in the auxiliary instruments and parts of networks, undesirable en-

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ergies and abnormalities in the electrical network and all networks that support the above. The use of the simulator can indicate the systems of ships which are requiring preventive maintenance due to daily and common malfunction.

Planned maintenance is very useful because allows maintenance schedules to be organized and to be fitted in with the ship's operating schedule. However, during the operation of ship there are components that display different rate of damage and besides a defective component can damage other components. The operating marine engineer must be aware of such issues and be willing to adjust maintenance accordingly.

These experiments form part of a larger work (Gourgoulis et al., 2004; Gourgoulis et al., 2008; Gourgoulis, 2010) concerning the use of engine simulator that simulates a dynamic real time computerized slow speed main propulsion turbocharged diesel engine incorporating a waste heat steam boiler, a turbo generator and one shaft generator.

2. List of symbols

AL	Alarm - Alarms
MF	Malfunction - Malfunctions
LO	Main Engine Lubrication
ME	Main Engine

3. Observatin plant

The engine room simulator plant at Merchant Marine Academy of Makedonia was established in 2002 and was designed, implemented and integrated by Kongsberg Nor control Simulation (Kongsberg Nor control, PPT2000-MC90-III, 1999).

The last year was installed the new Neptune instructor application (Kongsberg Maritime Simulation and Training, E-learning system for maritime training on the Instructor Station, 2010), and is capable of controlling all simulation models installed in the system. The new instructor system allows the instructor to develop a complete exercise module from any personal computer running the application; from the simulator classroom, instructor's office or home. Through the new instructor and assessment system, the instructor has access to a unique tool that allows the assessment of students on all levels, from support to management. The assessment system allows the instructor to monitor, and use for assessment, not only alarms, but any of the 6,000 available variables in the simulation models. The instructor can give credits or penalty points depending on student's performance.

The simulated main engine '*ME*' is a B&W 5L90 MC, five cylinder in-line, low speed, two stroke engine with turbocharging and scavenging a ir cooling. The ship model is based on a VLCC (Very Large Crude Oil Carrier). Vessel's main particulars: Length 305.00 m, Breadth 47.00 m, Depth 30.40 m, Summer draught 19.07 m, CB 0.801, Dead-weight 187997 tons, Speed 14 knots. In the examined scenario the ship was running in open sea following the mode '*Slow Ahead – Loaded*'. The ambient sea water temperature was 15 ^oC, the ambient air temperature was 20 ^oC and the ambient air humidity was 50%. Sea water depth was 200 *m*, main engine fuel link position was 94.4% and the main engine speed command was 74 *rpm*.

Simulator training (Gourgoulis et al., 2004; Gourgoulis et al., 2008, Gourgoulis, 2010) or research projects of Merchant Marine Academy of Makedonia are realized by the following phases: proposal phase, data collection and implementation, simulation and data recording, analysis and reporting. The instructor system of engine room simulator comprises the facilities and features needed for the instructor to prepare, control and evaluate the simulator training courses or research studies.

The engine room simulator plant has the possibility of import of 492 malfunctions "*M*". From these, 158 have the possibility of change from 0% (normal operation) in 100% (full damage) while the rest have the possibility of progressive increase of rhythm of deterioration of damage. The corresponding likely warnings (alarms) "*AL*" are 401. Main objective of research project is to be programmed in the various individual scripts all pre selected damage – abnormalities for the best depiction of operation of ship. During the recording of warnings, it was realized that critical situation was the recording of three first alarms.

With full damage (100 %) and for an important number of *M* (166) was observed that only 3 *AL* were displayed in 3 h - 42 min - 55 sec. The particular sequence of *AL* (aft bilge well level, engine room bilge well level, hydrophore tank level) was standardized, with plenty of time for the person in charge of watch to realize - solve the damage. Thus, the more precise research of above *M* was not necessary since these malfunctions had been programmed already on 100 % (absolute damage).

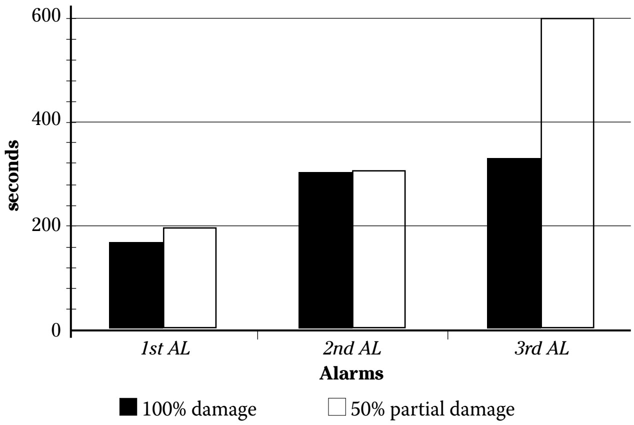
In 334 *M*, the pre mentioned standardized sequence of appearance of three alarms was not observed. Also in 142 from 288 *M*, the change the rhythm of deterioration of damage was possible. Thus, for the above *M* the further examination of *M* with lower percentages of damage (50%, partial damage) was realized.

All the essential actions have been recorded in every case; have been received reports on the presented alarms and abnormalities during the operation of engine. The most critical scripts were executed again and again increasing each time the number of pre planned malfunctions and adjusting the percentage of damage.

he behavior of machine was investigated and all trip codes were checked in processes that are related with the smooth operation of machine and rests of auxiliary subsystems. The grading of systems was done and besides the time of reaction of personnel in charge of watch was evaluated.

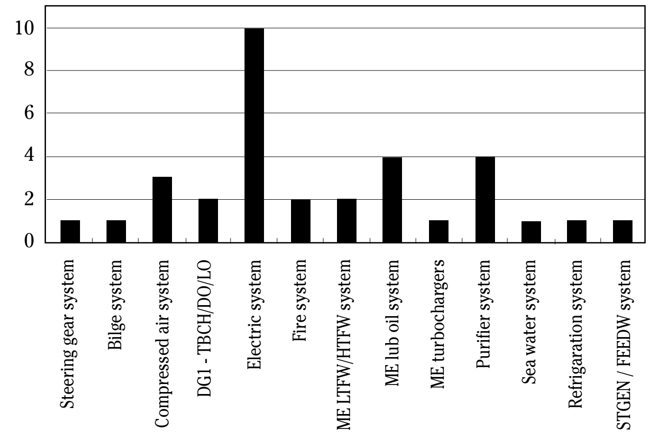
Taking into account that data follow regular distribution and excluding the pre mentioned appearance standardized sequence of three *AL* the average time of appearance of *AL* for 100% and 50% damage are shown in Fig. 1. From this figure it can be seen, that even for non-standard sequences *AL* the average time of appearance of first *AL*, irrespective of percentage of damage, is extremely enough for the personnel in charge of watch to scan all subsystems of the ship before the final completion of the damage. Examining the number of 1st *AL* that occur in relation with the observation time, it can be deduced that that the larger and steeper concentration of *AL* observed for times > 20 sec in case of full damage (100%) and for times > 30 sec in case of partial damage (50%).

Figure 1: Average time of appearance time of AL



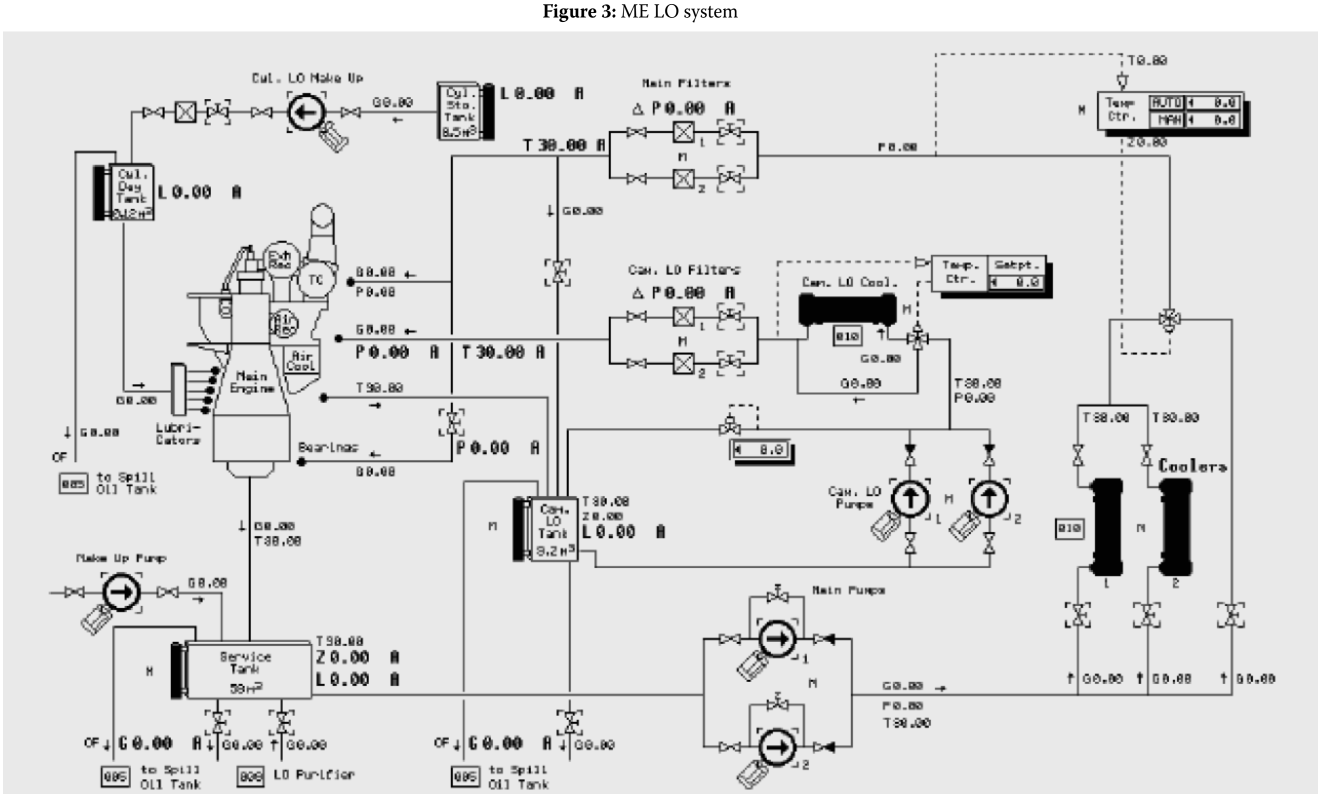
At full damage (100%), 36 first alarms were displayed in very short periods and more specific in first 10 seconds. Since the time of 10 seconds is a time in which the reactions of personnel are clearly limited, it can be seen form figure 2 that the most affected subsystems that require proper periodic maintenance is the Electric system, *ME* lubrication system "*LO*" of ship (Figure 3) and Purifier system. At partial damage (50%), in first 10 seconds the total number of alarms is reduced to 2 alarms. Figure 2 shows the number of alarms in accordance with the affected sub systems for full damage (100%) in 10 seconds.

Figure 2: Number of AL in 10 seconds (100% damage) in different sub systems



The *LO* system of main engine [Fig.3, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] and more specific all filters must be cleaned regularly to avoid pressure/flow reduction. For example, the introduction of malfunction '*ME* camshaft lubrication oil filter dirty' shows in 8 seconds the alarm 'Camshaft lubrication oil press inlet *ME*'. The level service tank oil is unstable in poor weather and if the level is low, there may be false. If the purifier is operated with 'broken' water seal, much oil is continuously discharged to the sludge tank and there is a risk of emptying the *LO* well completely. Also low oil temperature gives reduced pressure at main engine. The cylinder *LO* tank must be refilled periodically. At low cylinder *LO* tank level there will be *ME* slow down/shut down.

Figure 3: ME LO system



Source: Kongsberg Nor control, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual

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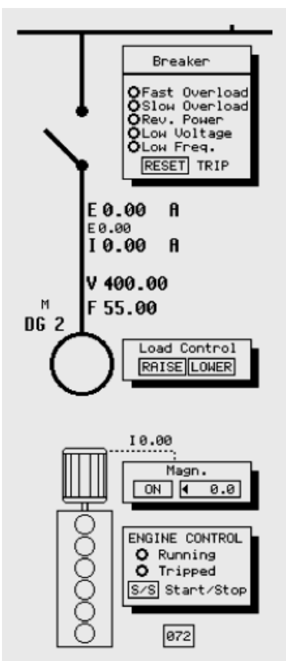
Shutdown of *ME* occurs if Main *LO* inlet pressure is lower than 1,0 bar and Cam shaft *LO* pressure is lower than 1,5 bar. Slowdown of *ME* occurs if main *LO* inlet pressure is lower than 1,2 bar, Cam shaft *LO* pressure is lower than 2.0 bar, Piston cooling oil flow is lower than 84.4 t/h Main *LO* inlet temperature is greater than 60 °C, Cam shaft *LO* temperature is greater than 70 °C and Piston *LO* outlet temperature is greater than 70 °C. One of the most difficult situations for the marine engineers during the work on board is the appearance of shutdown alarm in short period. It was deduced that we had 7 times 'shutdown' (5 times due to *LO* and 2 times due to electric system) in 20 seconds. The critical malfunctions of *LO* were the next: Main *LO* pump wear, Main *LO* filter dirty, Main engine camshaft *LO* pump wear and failure and Main engine camshaft filter dirty.

Figure 4: Circuit breaker of DG2



Source: Kongsberg Nor control, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual

The electric system of ship is protected by the main circuit breakers. The most common alarms of electric system are 'Earth leakage current – 440V' and 'Diesel generator breaker trip'. The average time of appearance of above alarms is about 7 seconds. The main circuit breakers [Fig. 4, Circuit breaker of DG2, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] connecting each generator to the electric bus bar are disconnected automatically for the following reasons: connection shock, overload current, reverse current, low voltage, low frequency and bus bar shock. The reverse current protection takes place if the generator's prime mover (diesel engine or steam turbine) is shut down. The generator will then function as an electric motor driving the steam turbine or diesel engine, if it is not disconnected. 'Bus bar shock' is most likely caused by a very rough connection to one of the other generators.

It is important to know the systems with less strain during the engineering of watch. The last could be found checking the sub systems that have the fewest *AL*. In case of full damage (100%) and controlling the database it was realized that almost 70% of the *AL* (281/401) are not presented as 1st alarm. This percentage is increased still more in the case of 2nd alarm (81.5%, 327/401) and touches upon almost the 86.5% (347/401) in the case of 3rd alarm.

Table 1 shows various subsystems that *AL* are not displayed very common due to applied malfunctions. Zero '0' means that all possible alarms have been displayed in relevant sub systems. For example in the first system, fuel oil supply system the number of possible alarms is 8. After the execution of possible malfunctions (100% damage), it can be observed that as 2nd or 3rd alarm the appearance of 2 alarms is possible.

Sub systems such as, Fuel oil service tanks, Heavy fuel oil settling tanks, Spill oil and bunker tanks and *ME* crank casing oil mist system, *ME* piston cooling, *ME* turbochargers, Steam Condenser, Exhaust boiler, Air condition system, Sea water system, Waste heat recovery system, Bilge separator, Fresh water generator and Start – Service air system are not affected by applied typical malfunctions in serious grade. From Table 1 it can be seen that planned and preventive maintenance are required the next sub systems: *ME* cylinder oil lubrication, *ME* bearing system (Crosshead/Crankshaft), *ME* bearing system (Main/Thrust) and Fire detection system.

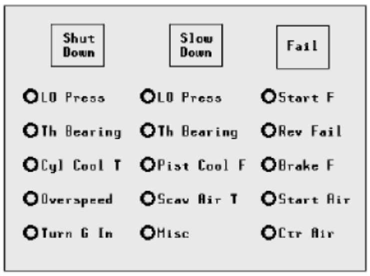
It is known that if the engine is operated without cylinder oil lubrication, the mechanical friction between liner and piston increases, and the piston may finally seizure in the liner. Reduced lubrication oil flow to the piston (cooling) may result in piston seizure/damage. Loss of sufficient oil flow to the bearings will finally result in damaged bearings. Long operation at extreme high exhaust temperatures will cause damage to the exhaust valves.

Table 1: *AL* that are not displayed due to applied *M* (100%).

Sub systems	*AL*	1st *AL*	2nd *AL*	3rd *AL*
Fuel Oil Supply System	**8**	4	6	6
ME LO System	**12**	8	10	8
ME Cyl Oil Lubrication	**10**	2	3	4
Me Control System	**8**	6	4	5
ME Cylinder Liner Cooling	**10**	4	9	9
ME Cylinder Metal Temps	**10**	5	0	10
Ltfw / Htfw System	**10**	5	8	6
ME Exhaust System	**12**	7	6	7
ME Scavenging Air System	**6**	2	1	6
ME Bearing System (Crossh/Cranc)	**10**	0	10	10
ME Bearing System (Main/Thrust)	**7**	0	7	7
Fire Detection System	**2**	0	2	2
Stern Tube System	**10**	8	8	8
Bilge Wells / Sludge Tank	**5**	2	3	3
Purifier System	**17**	11	15	17
Electric Power System	**27**	24	21	23
Dieselgenerator 1	**27**	21	23	22
Dieselgenerator 2	**27**	21	22	21
Oil Fired Boiler	**11**	5	5	8
Steam Generator	**8**	5	6	3
Refrigeration System	**20**	12	13	16
Steering Gear System	**8**	6	7	8
Fresh Water Sanitary	**6**	4	4	4

During the execution of scenarios, both in the cases of full damage (100%) and partial damage (50%), it was deduced that if first alarm can be avoided quickly the rest alarms do not follow immediately. Because some of the alarms are associated with trip codes of main engine (Auto chief: Shutdown - Slowdown, *ME* serious damage, Fire detection engine – deck area) it was checked the percentage of damage that cannot cause serious problem on the operation of main engine. Finding the critical rate of damage, where we do not have trip of *ME* [Fig. 5, (Kongsberg Nor control, PPT2000-MC90-III, 1999)], we

Figure 5: Control panel of trip codes of ME

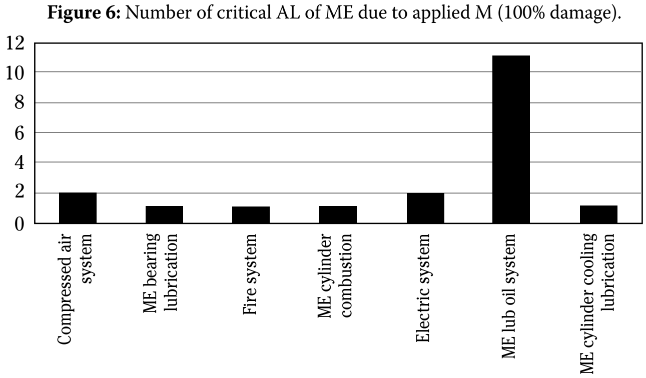


Source: Kongsberg Nor control, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual

could take information of limits of each system, helping us in better organization of maintenance.

Figure 6 shows the number of alarms (1st, 2nd, 3rd) that are associated with trip codes of *ME*. It was observed the appearance of trip codes as 1st *AL* 7 times, as 2nd *AL* 17 times and as 3rd *AL* 5 times. From fig. 6 it can be deduced that *ME LO* system is the most dangerous system for the avoidance of trip codes of *ME*. In case of 50% partial damage the number of trips of *ME* is significant lower and more specific it was not observed trip of *ME* as 1st *AL*. Trying to find the critical rate of damage, where we do not have trip of *ME* it was observed that reducing the percentage of damage from 100% to 94% the disappearance of trip of ME was obvious.

Figure 6: Number of critical AL of ME due to applied M (100% damage).



4. Conclusions

The lack of innovative practices on maintenance at a European level is today more than ever a challenge to be met. Engine room simulator could transfer state of the art knowledge on maintenance. Engine room simulation solutions are focusing directly at the a better workload for the operator by 'intelligently' improving at the same time the safety of navigation and upgrading the professional skills of the officer in duty - in other words, building the *'virtual'* link between the shore based jobs and the seagoing ones, attracting the young ones to the profession and recovering the 'Maritime Know How' that we are in risk of loosing.

Casualties are generally never a result of one particular incident but made up of a number of occurrences that come together to form a sequence of events that can ultimately lead to an unmanageable situation. The safe operation of ships requires a high level of onboard management, maneuvering and control, navigation and good knowledge of craft handling characteristics. Human errors and misjudgments can occur on a daily basis. Any formal safety assessment approach should apply to operational procedures and systems that provide redundancy, guidance and/or reduces the risk of unsafe practices. Besides, failure loss prevention is fundamental to the maintenance function. It is very critical to be well known the consequence of failure 'what happened?' the technical cause of failure 'why did it happen?' and the design improvements/lessons learned 'how can it be prevented?'

Examining the number of first alarms that occur in relation with the observation time it can be deduced that that the larger and steeper concentration of alarms is observed for times > 20 sec in case of full damage (100%) and for times > 30 sec in case of partial damage (50%). Three most are the most affected subsystems that require proper periodic maintenance: Electric system, Main engine lubrication system of ship and Purifier system. Besides, it was observed that planned and preventive maintenance are required the next sub systems: Main engine cylinder oil lubrication, Main engine bearing system (Crosshead/Crankshaft), Main engine bearing system (Main/Thrust) and Fire detection system.

Trying to find the critical rate of damage, where we do not have trip of *ME* it was observed that reducing the percentage of damage from 100% to 94% the disappearance of trip of ME was obvious.

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