KNOWLEDGE DEGRADATION WITHIN ROUTINE OPERATION PRACTICES IN TRR – LESSONS LEARNED

M. Gharib
Atomic Energy Organization of Iran, Iran

Email address of main author: mgharib@aeoi.org.ir

Abstract. Human factors play a major role in almost all sorts of knowledge management. Even in cases such as a nuclear incident, still the human part is prominent. It is showed that how general knowledge is eroded within routine practices and end up to disastrous consequences in abnormal conditions. Therefore relevant organizations should be aware of this natural tendency and find ways to confront it.

1.Introduction

In the shift operation of Tehran research reactor (TRR) in June 2001, a sequence of events commenced and ultimately led to the halt of operation for several months. An ad hoc committee was assigned to conduct a peer review of the events and finally presented its findings to authorities[1]. Although the causes of the failures were apparently due to hardware problems, but, nevertheless, subsequent investigations showed that human behavior and knowledge degradation of operating personnel within routine practices played a major role in initiation and propagation of malfunctions.

In this paper, human aspects of this incident would be highlighted and reviewed. Attention is paid on the role of human factors especially the effectiveness of personnel's knowledge in such abnormal occasions.

2. Brief description of the incident

2.1. Reactor

TRR is a 5 MW pool type research reactor operating since 1967. It was operating with original high-enriched Uranium (HEU) fuels till 1992. In 1993 core was converted from HEU to low enriched Uranium (LEU) fuels in order to comply with new international rules. The common policy in such occasions is to confine scope of changes to minimum. Nevertheless, upon core conversion a number of inevitable changes occurred:

2.1.1. A larger number of fuel assemblies are required in order to provide the same level of excess reactivity as before.

2.1.2. A larger number of control elements are required as a result of core larger volume.

In order to relax these constraints as much as possible, a common practice is to load as much as fuel material per fuel assembly as feasible. In this fashion LEU fuel assemblies, maintaining the same outer dimensions, contain larger number of fuel plates compared with HEU fuels. In our case, there are 19 plates per LEU fuel assembly rather than 14 in old HEU fuels. Nonetheless, vital spaces within new fuel assemblies are compromised as regard to coolant channels and, very importantly, conduits to house neutron absorbing blades in a special fuel assembly known as control fuel assembly (CFA). Regarding the problem of requiring too many neutron-absorbing elements, a remedy is to employ fork type control elements (rather than tube type as in HEU core) permitting a larger surface area exposed to neutron absorption. In this sense, we may still use the same number of control drive mechanisms by incorporating two neutron absorbing blades into a single drive and, therefore, keep the number of drive mechanisms the same as in HEU core.

In real world nothing is earned priceless, therefore here, too, one encounters a situation in which simplicity (safety) and ease of operation are sacrificed in exchange of complexity and neutron economy. Fork type control rod (from now on we may loosely use the term “rod” even if the physical shape is not really rod) is inherently unsafe and it might be stuck, in some occasions, within its guide. In a sense, this is the inception of the following incident from the hardware point of view.

2.2. Incident

A short summary of incident, which is following, is necessary in order to have a better understanding of shortcomings, especially in the area of management and human related activities. Activities are summarized based on the logbook and additional explanatory conversations with personnel during our inspection and analysis.

2.2.1. Upon check list completion, approach to criticality proceeded in the morning hours of the first day. Shim rods (high absorbing control rods) 70% out of core and still no criticality achieved. Whereas, very importantly, critical point at previous run was 62.5%.

2.2.2. A scram signal occurred, very likely due to reactivity excursion, but assumed and recorded in the logbook as water flow limit violation (scram due to underflow).

2.2.3. Later inspection and analysis showed that there were in fact a hidden dangerous excess reactivity inside the core that personnel were not aware of it. A control fuel assembly stuck to its absorber blades and suspended over the core and upon its sudden release (probably due to water suction) enough energy released to increase temperatures high enough for subsequent chain of events of stuck rod problem.

2.2.4. In further attempts to restart up reactor again, it was found that control rods were so hard in movement within their CFAs that disengagement for one was feasible only with the aid of mechanical jacks.

2.2.5. Unaware of abnormal situation and feeling no need for consultancy (such as reactor safety committee), they finally succeeded to bring reactor to 4 MW power, after replacing defective CFA with a new one, but in a very unstable and dangerous situation. At this time all control rods were 75% out of core at the time of criticality; contrary to the expected position of around 63% of the last run.

2.2.6. Although very surprising to the operators of such nonconformity (in all nuclear reactors, as a safety measure they always check and compare criticality points of subsequent runs), but nonetheless they added even 3 more extra fuel assemblies during the two day shifts as a result of lack of reactivity due to Xenon poisoning.

2.2.7. After 33 hours of operation, one of operators suspected of abnormality, discovered a CFA to be hovering on core top. This happened as a result of a lingering friction effect of neutron absorber blade with its CFA. Therefore, the missing reactivity very soon revealed. This CFA could have easily fallen into the core and could have produced a surge of power and thus disastrous consequences.

2.2.8. Reactor was shut down and problem was fixed, but instead of keeping it closed for further investigation, it continued its scheduled run for the rest of week.

3. Probable causes

In this section probable causes are summarized. They are classified into two categories as instrumental, and human related. Although we are more concerned about the second category but deep probing into instrument related failures revealed that still human factors are the underlining fabric.

3.1. Instrument related factors

A short review of this category is required in order to have a full insight on the whole problem

3.1.1.Control rod drop time and magnetic current measurement

Operators must observe two factors of control rods routinely. One is to measure magnet current (out of water magnet to be switched ON and OFF in order to hold or release control rod) and do not let it exceed certain limits. This limit is chosen such that high enough to grab the rod and withstands its weight and low enough to release the rod in case of too much friction. The other is to measure drop time of control rod, free falling within the aqueous environment of core. This is to check how freely absorber blades move within its guide. Drop times too long is an indication of friction or other problems. Close investigation showed that there have been some irregularities on both matters. Values of drop time were suspiciously long and magnet currents were mostly violated.

3.1.2. Drop time display

There is a display on main console inside control room to show drop time of each control rods in the core. Since this value should not normally exceed 700 ms, there are only three 7-segment LEDs to show three digits. If by any chance it takes more than a second (due to extra friction) there is no way to know the true value unless being smart enough and just guess.

3.1.3. Drop time calibration instrument

Since fork type control rods are very sensitive to mishandling and mismanagement, therefore a calibration instrument is provided in a clean room adjacent to control room. Each drive mechanism is to be checked there either for necessary electric current for magnetization and also drop time measurement in free fall. The whole thing is worked in the air. Very soon it was realized, during our inspection, that the whole thing is out of order and we ended up with drop times less than 200 ms while the course of free fall was 63 cm. It is quite obvious, from Newton's second law, this should be 358 ms or higher. Higher values might be even more reasonable because of any extra friction or delay time in the system. Very surprised of how this faulty machine were used for so long for this sensitive matter and hoping to find the source of malpractice, we conferred with old records and especially commissioning documents. Quite embarrassingly these records showed the same wrong values (less than 360 ms) with large and unacceptable variance. Probably not only experimenters but also the contractor were negligent to the philosophy of such instrument (a non-calibrated calibrator!). It all seems that as if there were some duties for people to fill out the forms and just leave them as records.

3.1.4. Lack of quality control

Non-existence of a sound quality control is another instrumental deficiency. Inspecting unused control rods in fresh storage room showed faulty rods, which should have been rejected right from the beginning. It is unclear whether similar flaws exist in other parts, which have not gone through our inspection. Lack of quality control stretches well in the realm of bookkeeping with a sloppy documentation and logbook recording.

3.2. Human factors

Even within the factors classified as instrumental, we observed human factors at the bottom line. Here we deal with more direct human factors which categorized into general factors (dealing with cultural and other general aspects) and factors specific to TRR environment.

3.2.1. General factors

3.2.1.1. Economic incentives

Reactor personnel are extra paid for being in shift operation. There is an obvious economic incentive to keep the system running even while undermining the true safety of the system. The situation is worse when the general economic condition of people is bad.

3.2.1.2. Carelessness

A lot of problems could have been prevented with more carefulness. This really depends on individuals but environmental conditions may worsen this (such as attending too many night shifts). Being careful in handling control rods or filling out documentations could have played a positive role in incident prevention and improving the general safety standards.

3.2.1.3. Lack of curiosity

It is believed that for sensitive technical activities curios people have priority in employment. Our work showed a widespread lack of curiosity within our ensemble. In fact, to some extent, curios workers are regarded as meddler and therefore very soon he realized not to bother about his environment. A curios person would try to uncover facts and he or she would play a positive role for solving problems during abnormal conditions. As we inspected, a curios operator tried to uncover the problem of extra reactivity right at the first day of incident asking relevant questions but very soon realized silence is healthier.

3.2.1.4. Lack of questioning

Shyness and feeling ashamed prevents one from questioning from others. Unhealthy environment makes the situation worse and invites people to keep silent feeling ashamed if it turns out being negligent. In many occasions bringing a simple question to others may prevent difficult situations. It was turned out that many operators were opt to discuss their opinion but fearing from boss and afraid of humiliation within their coworkers prevented them from questioning. A sound and open environment permits everybody to express himself no matter how much trivial his opinion is. In such cases managers and senior operators encourage their personnel to question and criticize existing system in order to prepare a friendly atmosphere for such colloquium. When asked why not questioning while aware of chain of flaws, almost all responded with the same answer: fear of making their manager discontent.

3.2.1.5. Burden of administrative rule over scientific views

A common problem in developing countries is superiority of administrative section over scientists in research centers. Director of research center does not have much power to allocate money for important tasks and being allowed to spend in certain places where he believes it should. The way of shift payment is a problem of this sort.

3.2.1.6. Cover-ups

A systematic struggle to hide unpleasant subjects under the carpet was prevailed. Personnel widely felt compelled to recount things in a way to minimize undesired (as they thought) consequences. Probably this may be expected to some extent in other establishments too. But the matter of fact is that cover-up is one of the most damaging agents in nuclear industry.

3.2.2. Factors specific to TRR

3.2.2.1. Lack of independent supervision

An independent supervisory body to control and supervise reactor activity is crucial. Nuclear safety department has long ago established for this purpose but its role confined to more bureaucratic formalities. A stronger role of a “safety committee” or “advisory committee” is recommended. There have been such committees but they used to be overshadowed by administrative rules.

3.2.2.2. Poor systematic training

It turned out that general and technical knowledge of reactor personnel were diluted in the course of time. More importantly, basic scientific principles were forgotten as a result of every day chores and routine tasks. Although formal short term retraining programs may help a lot, but, in fact, their deficiencies are laid somewhere else.

It turned out that the most weakness is in comprehension of the most basic and simple principles of physics and mathematics. For example, preliminary understanding of statistics (mean, variance, etc.) is poor. Also basics of physics such as Newton’s laws (free fall in air, water, etc.), electricity and magnetism should be improved a lot. It is also highly recommended for all of them at all levels to have a better understanding of physical numbers, significant digits, instrumental precision, errors and its estimation and similar topics. This list would not end unless we add our recommendation to add a passion for logic and reasoning into their program. We may equally recommend implementing sophisticated simulator training; that would be just fine, but we feel priority is with a training course in philosophy of science, resources of knowledge, skepticism and exercising reason and rationality in pursuing every day business. Probably this is the most important course for them. We are all subjected to commit mistakes. Learning to be prepared to acknowledge our mistakes and willing to go into dialogue for follow up corrections is quite important and not available in current curriculums.

3.2.2.3. Misinterpretation of checklists

Existence of checklists is a tool in hands of reactor personnel to perform their tasks fast and accurate. Unfortunately, they were inaccurate and erroneous and, as a matter of habit, every body got it signed and confirmed. As an example, there were many misinterpretations on magnet current and drop time values. The problem is that as if checklist completion is a task by itself and upon completion the task is fulfilled. As an example, there were many accounts of drop time and magnet current measurements, all beyond acceptable limits, but without any corrective actions. Checklists should thoroughly be checked for discrepancies and not go further unless to have a solid reason for that.

3.2.2.4. Lack of access to all necessary documents

A good QA/QC program dictates an easy access of personnel to all technical information. While in practice they did not have access to some required information on the matter of control elements. Most of crucial information and documents were closely kept by reactor manager while operators should have hands on them. This means if by any chance manager gets sick, the rest are potentially in trouble.

3.2.2.5. Persisting to continue a shift while there is a malfunction

One of surprises is on this matter. Even though everybody thought that they should have stopped the run, but in reality a push to complete 7-day shift was persistent. The first occasion of this matter was right at the beginning with a scram due to an extraordinary excess reactivity before full criticality. At this point the matter should have communicated with safety committee. But, instead, in the next round of start up they wrestled with all control rods to push them up against abnormal entanglement and reach criticality with all means. Finally it was critical at 4 MW but at a very different control rod position. Not disturbed by all these alarms, more fuel assemblies were added to keep it running. Even after discovery of suspended fuel, instead of stopping the shift, reactor continued its operation way on to the end, after rectifying the problem. There is no obvious justification for this much persistence.

3.2.2.6. Poor bookkeeping

Logbook is provided to record important occasions. Operator should feel free to write his observations accompanied with date and time. It is a prevailing weakness on the matter of recording occurrences in the logbook. For example a misconception amongst them is as though not important to record activities while reactor not critical. It was very hard for fact-finding committee to get along with those written accounts (and lack of data) in the logbook.

3.2.2.7. Lack of clarity on job descriptions

Another deficiency was lack of clarity about their duties. For example the philosophy behind checklist completion is not clear for them. Similar matter is calibration instrument for drop time measurement. They are not quite aware of how these results should be handled and interpreted. In effect senior operators should promote a correct mentality and they should try to transfer this mentality to others.

3.2.2.8. Lack of proper maintenance

As mentioned previously, lack of systematic QC program is a chronic disease of this system. This deficiency has also affected repair and maintenance works, which interferes with safe operation of reactor. In most cases, as a minimum, it brings confusion to operators.

3.2.2.9. Lack of incentive to attract professionals

As our investigation showed, most problems are human related at their roots. If professionals and well-trained people are on control, then the risk of problematic incidents is less and we are confronted with such accidents rarely. The prerequisite of attracting such professionals is to prepare a sound environment and this in itself relies on the presence of sound people. Therefore somehow the system should gets itself out of this circle and equip itself with such professionals especially at managerial and higher levels

4. Conclusion

In short, in the realm of nuclear knowledge management, in addition to the well-established criteria generally discussed in well-known references, quality and ability of a nuclear establishment as a whole should be considered. This quality deals with not only all professional skills of individuals (technicians, engineers, managers, etc.) but also takes into account the ability and capacity of the "system" as a whole. This includes a diverse spectrum from quality of instruments and hardware, to managerial qualifications. Loading personnel with so much information is not a big deal, but rather, it is very crucial to know whether this information is accessible in proper time and place. Moreover, it is also of prime importance to know whether this information is scientifically viable and not diluted or distorted under subjective misinterpretations.

Under normal conditions, one may not get a good knowledge about system quality. But it is under abnormal conditions and emergency situations that system would reveal its true quality unmasked. In a nuclear reactor working at normal condition, everything appears perfectly neat. Whilst, at the same time, there are probably many shortcomings within the system and many pitfalls of ignorance within human resources. Only it is during abnormal situations that deficiencies are observable and so powerful to push the whole system towards aggravation and easily end up with catastrophic accidents. It is only in such conditions that efficiency of classical learning and transfer of knowledge (nuclear and conventional) are truly tested and being evaluated. In other words, system quality is most realistically evaluated under accident conditions.

A lesson learned that, the main component of a system quality comes, in practice, from the part of human resources. This in turn is subjected to a complicated interaction between academic training and personal belief system. It seems that improper habits may have as equally contribution in producing accidents as other faulty hardware. These habits, usually under repetitive work conditions, transform themselves into, as though, harmless forms very difficult to detect and therefore required corrective actions. Another lesson learned here is that with a set of old and imperfect instruments one can still manage his work as long as a minimum degree of reason and skepticism is exercised.

An important lesson is that, presence of shortsighted managers assigned to fixed jobs for a prolonged time could be potentially dangerous in itself. This is especially important when these managers are unable to comprehend their environment and the need to bring about a change in their environment and prevailing habits around. With undeveloped managers, knowledge degradation of affiliated personnel is far more accelerated. Thus the risk factor of such system is higher and very prone to develop a self-destructive system indeed. Therefore, it is concluded that a periodic change in managerial levels may be the minimum chance if the degraded system is to be saved in future against probable accidents. These actions are not automatic in itself and assistance under international cooperation provided by outsiders such as IAEA and alike is very much appreciated.

REFERENCES

[1] Gharib, morteza, et al., Risk analysis of stuck-rod accident in Tehran research reactor, NRC internal technical report, October 2001