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DARLINGTON NEW BUILD PROJECT JOINT REVIEW PANEL

UNDERTAKING NUMBER #77

Approved by: Barclay Howden, Director General - DRIMPM

Date: Wednesday, April 13, 2011

An intervenor referred to 33 accidents occurring over 59 years as outlined on the IAEA website. Please compile, at a high level, the number of events that were caused by human errors.

General Conclusions:

CNSC recognizes that in large and complex interactive systems, human error can contribute substantially to system failures. At nuclear power plants, operational experience demonstrates that human error accounts for a considerable proportion of safety-related incidents. However, experience also shows that human intervention can be very effective if there is a thorough understanding of the situation in the plant. Thus, an efficient interface of human and plant systems is important not only to prevent human errors but also to assist the licensee in coping with unforeseen events. In addition, the licensee's management systems are key in ensuring that human errors and their precursors can be identified early so as to prevent or mitigate events.

Because of the above, a significant part of the licensing and compliance effort by both CNSC and licensees is focused on the measures that the licensee has in place to detect, prevent and mitigate human errors that can emerge in their licensed activities. Management system elements such as design and analysis, quality assurance, maintenance, operation, training, and plant documentation need to take human errors into account. Human factors analysis is a discipline that spans and integrates, in varying ways, with all activities associated with a nuclear power plant. Much of what has been learned and applied in this discipline stems from events of the past, not only in the nuclear industry, but also in other complex fields such as aeronautics.

Specific to this undertaking, it appears that intervenor was referring to a list of events posted at http://www.guardian.co.uk/news/datablog/2011/mar/14/nuclear-power-plant-accidents-list-rank . This list appears, in the same form, in a large number of other websites.

CNSC staff could find no evidence of the existence of this list on the IAEA website; however, CNSC staff researched each of the events in the list and found the following:

a) Number of events with human error as the clear and primary cause: 13 out of 33 (39%)

b) Number of events where direct human error can be ruled out: 9 out of 33 (27%) - however, human errors may have contributed to accident precursors (such as design errors)

c) Number of events with unknown cause (lack of information): 6 out of 33 (18%)

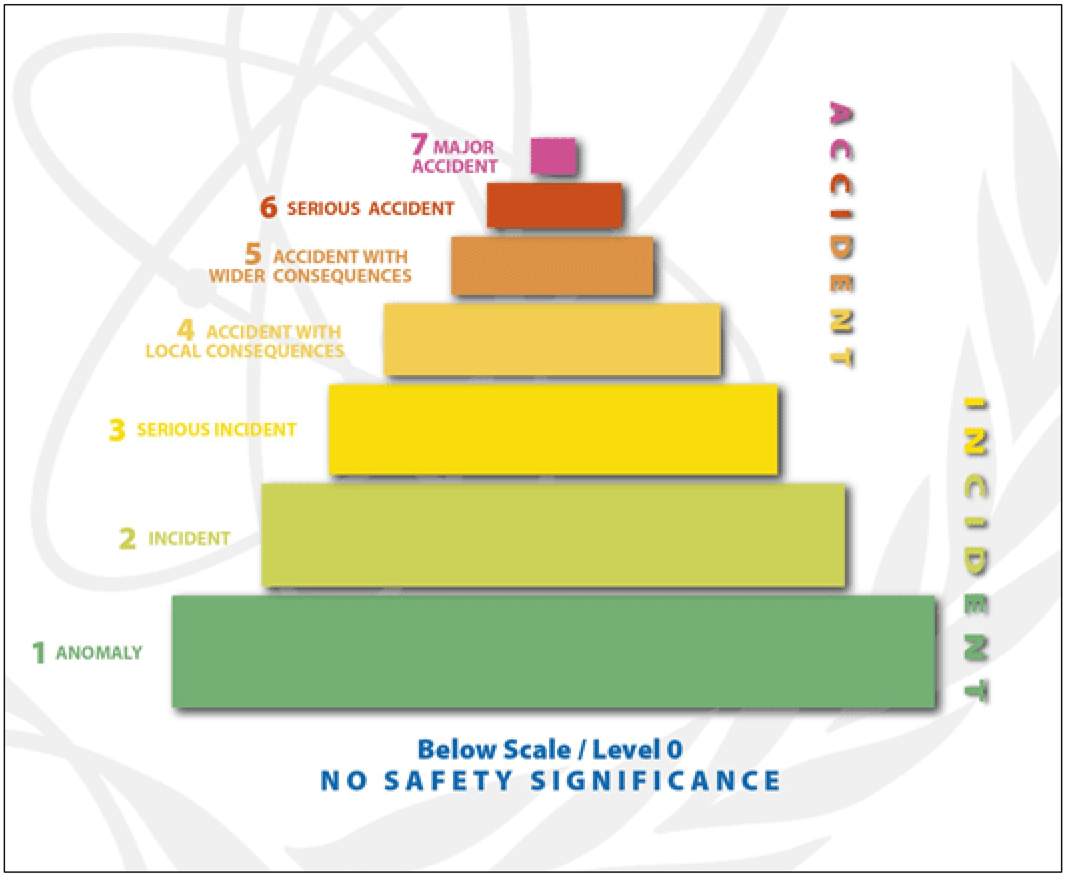
If one assumes, for conclusion b) that a human error contributed to an accident precursor that contributed to the event, one can conclude that, from this list, human error may have played a role 66% of the time.

The analysis results, including assumptions and sources, are presented on the following pages.

Background Information:

Detailed information about the International Nuclear and Radiological Event Scale (INES) is available from http://www.iaea.org/Publications/Factsheets/English/ines.pdf

Figure 1: The International Nuclear and Radiological Event Scale[1]



[1] reference http://www-ns.iaea.org/tech-areas/emergency/ines.asp

Results of Research:

It appears that the April 7 intervenor was referring to a list of events posted at http://www.guardian.co.uk/news/datablog/2011/mar/14/nuclear-power-plant-accidents-list-rank . This list appears, in the same form, in a large number of other websites.

> **Note**: It is important to note that the list did not, in fact come from the IAEA website, but rather was compiled by staff of the Guardian. This is stated in the article as
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> "*We have identified 33 serious incidents and accidents at nuclear power stations since the first recorded one in 1952 at Chalk River in Ontario, Canada. The information is partially from the International Atomic Energy Authority* (sic) - *which, astonishingly, fails to keep a complete historical database - and partially from reports. Of those we have identified, six happened in the US and five in Japan. The UK and Russia have had three apiece*"

CNSC staff could find no evidence of the existence of this list on the IAEA website however much of the information in the table can be found from Google searches of IAEA information, via Wikipedia or information sources such as http://www.climatesceptics.org . In all cases where information could not be directly confirmed via the IAEA website, the source information could not be confirmed to be accurate.

The list is given on the next page with a column added on the right showing, based on CNSC review of the events, whether human error was a clear and primary cause of the accident. Sources are listed in footnotes.

Year	Incident	INES level	Country	IAEA description	CNSC Analysis: Human Error Clear and Primary Cause?
2011	Fukushima	5	Japan	Reactor shutdown after the 2011 Sendai earthquake and tsunami; failure of emergency cooling caused an explosion	No
2011	Onagawa		Japan	Reactor shutdown after the 2011 Sendai earthquake and tsunami caused a fire	No
2006	Fleurus	4	Belgium	Severe health effects for a worker at a commercial irradiation facility as a result of high doses of radiation	No, but worker received radiological dose because radiation protection procedures were not followed
2006	Forsmark	2	Sweden	Degraded safety functions for common cause failure in the emergency power supply system at nuclear power plant	No
2006	Erwin		US	Thirty-five litres of a highly enriched uranium solution leaked during transfer	Yes – design error[2]
2005	Sellafield	3	UK	Release of large quantity of radioactive material, contained within the installation	Yes – design error[3]
2005	Atucha	2	Argentina	Overexposure of a worker at a power reactor exceeding the annual limit	Possibly – root cause analysis not yet completed[4]
2005	Braidwood		US	Nuclear material leak	No (plant aging issue)
2003	Paks	3	Hungary	Partially spent fuel rods undergoing cleaning in a tank of heavy water ruptured and spilled fuel pellets	Yes[5]
1999	Tokaimura	4	Japan	Fatal overexposures of workers following a criticality event at a nuclear facility	Yes[6]
1999	Yanangio	3	Peru	Incident with radiography source resulting in severe radiation burns	Yes[7] - radiation protection procedures were not followed
1999	Ikitelli	3	Turkey	Loss of a highly radioactive Co-60 source	Yes[8]
1999	Ishikawa	2	Japan	Control rod malfunction	Yes[9] - error in execution of procedure
1993	Tomsk	4	Russia	Pressure buildup led to an explosive mechanical failure	Possibly[10] (investigation not conclusive)
1993	Cadarache	2	France	Spread of contamination to an area not expected by design	Unknown – information could not be located
1989	Vandellos	3	Spain	Near accident caused by fire resulting in	No[11] – mechanical

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2 http://www.climatesceptics.org/event/805
3 http://www.neimagazine.com/story.asp?sectionCode=132&storyCode=2029958
4 http://www.climatesceptics.org/location/south-america
5 http://www.haea.gov.hu/web/v2/portal.nsf/news_en/67341D92B1B0D3B1C125711A00434331?OpenDocument
6 See report at http://www-bcf.usc.edu/~meshkati/tefall99/NSC.pdf
7 See report at http://www-pub.iaea.org/MTCD/publications/PDF/Pub1101_web.pdf
8 See report at http://www-pub.iaea.org/MTCD/publications/PDF/Pub1102_web.pdf
9 http://www-ns.iaea.org/downloads/coordination/snr-reg-meeting-2007/SRM2007-Fukushima3.pdf
10 See Report http://www-pub.iaea.org/mtcd/publications/pdf/p060_scr.pdf

Year	Incident	INES level	Country	IAEA description	CNSC Analysis: Human Error Clear and Primary Cause?
				loss of safety systems at the nuclear power station	failure on conventional side of plant (turbine)
1989	Greifswald		Germany	Excessive heating which damaged ten fuel rods	Yes[12]
1986	Chernobyl	7	Ukraine (USSR)	Widespread health and environmental effects. External release of a significant fraction of reactor core inventory	Yes
1986	Hamm-Uentrop		Germany	Spherical fuel pebble became lodged in the pipe used to deliver fuel elements to the reactor	No – design issue – however fuel pebble was damaged when operator tried to dislodge pebble.
1981	Tsuruga	2	Japan	More than 100 workers were exposed to doses of up to 155 millirem per day radiation	Likely[13] – minimal information available on web
1980	Saint Laurent des Eaux	4	France	Melting of one channel of fuel in the reactor with no release outside the site	Unknown – minimal information available on web
1979	Three Mile Island	5	US	Severe damage to the reactor core	Yes
1977	Jaslovské Bohunice	4	Czechoslovakia	Damaged fuel integrity, extensive corrosion damage of fuel cladding and release of radioactivity	Unknown[14] - on-power refueling accident (Vertical fueling machine) – details of accident progression are minimal on web
1969	Lucens		Switzerland	Total loss of coolant led to a power excursion and explosion of experimental reactor	No[15] – design issue
1967	Chapelcross		UK	Graphite debris partially blocked a fuel channel causing a fuel element to melt and catch fire	Unknown – Mechanical failure likely - details of accident progression are minimal on web
1966	Monroe		US	Sodium cooling system malfunction	Unknown[16] – Mechanical failure likely - details of accident progression are minimal on web
1964	Charlestown		US	Error by a worker at a United Nuclear Corporation fuel facility led to an accidental criticality	Yes[17] – accidental transfer of uranium solution to tank containing 93% U-235

[11] http://www.csn.es/descarga/Primerinformeingles.pdf

[12] http://en.wikipedia.org/wiki/Greifswald_Nuclear_Power_Plant
[13] Radiation exposures of this type can be generally attributed due to inadequate radiation protection precautions
[14] See report http://www.omegainfo.sk/kuruc_30th_anniversary_of_reactor_accident_in_A-1_NPP.pdf
[15] http://en.wikipedia.org/wiki/Lucens_reactor and http://www.nucleartourist.com/events/part-melt.htm
[16] http://www.wattpad.com/26415-wiki-list-of-civilian-nuclear-accidents
[17] http://www.rionline.org/ri-nuclear-accident.htm

Year	Incident	INES level	Country	IAEA description	CNSC Analysis: Human Error Clear and Primary Cause?
					- fatality
1959	Santa Susana Field Laboratory		US	Partial core meltdown	No[18] - design flaw in coolant pumps
1958	Chalk River		Canada	Due to inadequate cooling a damaged uranium fuel rod caught fire and was torn in two	Possibly[19] - details of accident progression are minimal on web
1958	Vinča		Yugoslavia	During a subcritical counting experiment a power buildup went undetected - six scientists received high doses	Possibly[20]- details of accident progression are minimal on web
1957	Kyshtym	6	Russia	Significant release of radioactive material to the environment from explosion of a high activity waste tank.	Likely[21] - details of accident progression are minimal on web, but accident was attributed to equipment not being maintained
1957	Windscale Pile	5	UK	Release of radioactive material to the environment following a fire in a reactor core	Yes[22] - poor temperature instrumentation led to operator decision to increase reactor power
1952	Chalk River	5	Canada	A reactor shutoff rod failure, combined with several operator errors, led to a major power excursion of more than double the reactor's rated output at AECL's NRX reactor	Yes[23]

Analysis of the above events:

Number of events with human error as the clear and primary cause: 13 out of 33 (39%)

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Number of events with unknown cause (lack of information): 6 out of 33 (18%)

[18] http://en.wikipedia.org/wiki/Sodium_Reactor_Experiment
[19] http://www.nuclearfaq.ca/cnf_sectionD.htm#nru1958
[20] http://www.johnstonsarchive.net/nuclear/radevents/1958YUG1.html
[21] http://en.wikipedia.org/wiki/Kyshtym_disaster and http://www.hubberts-arms.org/index.php?topic=5764.0
[22] http://www.lakestay.co.uk/1957.htm
[23] http://www.nuclearfaq.ca/cnf_sectionD.htm#x

What are "precursors" that contribute to human error?

Task Demands

- Time pressure (in a hurry)
- Simultaneous, multiple tasks
- Unclear goals, roles, or responsibilities
- Lack of or unclear standards
- Interdisciplinary work
- Complex / High information flow

Work Environment

- Distractions / Interruptions
- Changes / Departure from routine
- Confusing displays / control
- Work - around
- Unexpected equipment conditions
- Back shift or recent shift change

Individual Capabilities

- Unfamiliarity with task
- Lack of knowledge (faulty mental model)
- Lack of proficiency; inexperience
- Overzealousness for safety critical task
- Illness or fatigue
- Lack of big picture

Human Nature

- Stress
- Habit patterns
- Assumptions
- Complacency / over confidence
- Inaccurate risk perception
- Communication shortcuts

How can the Effects of Human Errors be Mitigated?

Below is a sample of only a few of many tools used to mitigate against human errors not only in the nuclear industry, but also in other industrial sectors:

A strong safety culture[24]:

> Safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.

CNSC expects the licensee (from individuals to the organization) to demonstrate the ongoing presence of a strong safety culture in all of the licensee's activities. Some examples of where safety culture can be found:

- Employees have a questioning attitude and processes exist to answer those questions in a timely manner.
- The licensee encourages all events to be reported in an open, learning and non-punitive manner such that lessons can be learned to reduce or prevent events from happening in the future.
- Employees show that safety comes before production by using event free tools when performing their duties.
- Robust pre-job and post job briefings are conducted to predict where things can go wrong and use lessons learned from the past and the use of Operational Experience (OPEX)
- Rigorous approach to ensuring safety such as:
  - Training programs
  - Quality assurance
  - Use of operational feedback to improve processes and procedures
  - Procedural compliance
  - Practice a communicative approach

Integrating human factors thinking into all activities such as:

- Safety Analysis (understanding the role humans can play in events)
- Design of structures, systems and components that humans will interface with.
- Training (e.g. using a simulator to test operator responses)
- Procedures
- Work Planning (e.g. allow sufficient time and resources to accomplish jobs)
- Job briefings and rehearsals
- Supervision

[24] For more information, please refer to IAEA – INSAG-4, *Safety Culture*, a report by the International Nuclear Safety Advisory Group, Austria, 1996. http://www-pub.iaea.org/MTCD/publications/PDF/Pub882_web.pdf

A strong defence in depth[25] philosophy.

> Defence in depth is the establishment of several levels of protection, including successive barriers preventing the release of radioactive material to the environment. The objectives are as follows:
>
> - to compensate for potential human and component failures;
> - to maintain the effectiveness of the barriers by averting damage to the plant and to the barriers themselves; and
> - to protect the public and the environment from harm in the event that these barriers are not fully effective.

This philosophy is not just restricted to the plant design itself, but also applies to activities and methodologies such as:

- the performance and checking of engineering calculations (cross checking or confirming work done by others)
- human factors studies (observing how humans interface with plant systems)
- research and development (to better understand how the plant systems will 'behave')
- organizational structures (to allow independent audits, cross-checking, arms length oversight

[25] For more information, please refer to IAEA – INSAG-10, *Defence in Depth in Nuclear Safety*, a report by the International Nuclear Safety Advisory Group, Austria, 1996. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1013e_web.pdf