NUCLEAR SAFETY AND RELIABILITY

WEEK 2

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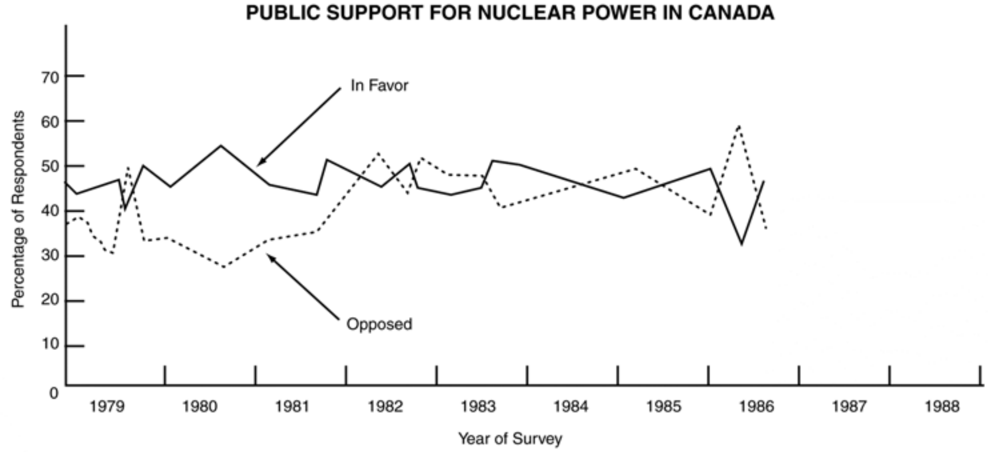
1. Public Perceptions

The nuclear utility industry operates very much in the public view. Utilities are often owned by governments, and are always regulated in a number of ways. Plant and power line location, operating policy, financial affairs, etc. are all matters for prolonged public debate. Major decisions are all strongly influenced by government agencies. These government bodies report more or less directly to the people at large. The opinion of the electorate has a demonstrable influence on elected officials, both singly and collectively. In calculating the odds on a re-election, a few percentage points in opinion polls on a major topic such as "environment" commands a great deal of attention. Figure 2.1 indicates the major reason that political support for nuclear energy in Canada is lukewarm at present. (Author's note: not much changed in recent years). Many people see power plants, environmental pollution, high costs, big business and bombs all wrapped together in a package called "nuclear". We are identified by the adjective rather than by the noun that it modifies.

FIGURE 2.1
PUBLIC SUPPORT FOR NUCLEAR POWER IN CANADA



It is this attitude that must be changed if the nuclear enterprise is to prosper; many of the current problems have this one at their base. Change must be initiated by the people who know the subject best -- the people inside the industry.

2. Opposition to Nuclear Energy, Causes

The nuclear enterprise began with the general support of the people and their governments, a generous supply of funds, and an unusually strong collection of technical talent. What has gone wrong?

Opposition to the nuclear energy enterprise is sometimes difficult to understand for professionals who work in the field. One reaction is - "I am giving my best in the cause of cheap electricity (economic benefit) at a salary which does not balance the effort I put into my job. Why don't the people support me?" The simple answer is that they are afraid of us and afraid of what we are doing. They are afraid because they do not understand the process and they are being told we are dangerous people. If you wanted to scare someone about nuclear plant operation, you might tell some stories of administrative hang-ups or less-than-perfect operation. But the listener might be hearing different sounds. If he or she is an average Canadian, the information would raise up one or more of three fears: cancer, genetic damage, or bombs. These are the three fears that have been cultivated by anti-nuclear groups over the past 30 years. A few words can bring these fears to the surface, yet it takes at least several hours to explain logically why these fears are unjustified.

The key word is "logically". To explain the reaction of many people to logical discussion, a useful model is the parent-adult-child model of psychology described by Thomas A. Harris in the book "I'm OK, You're OK". When we don't understand something in the sense of adult understanding, our minds tend to revert to the rules installed in the child's mind. This part of our memory is dominated by parents' messages of right and wrong. We accept or reject these messages depending on our own judgment of the credibility of the speaker. In the case of nuclear power there are conflicting messages. (This is not unique to our field - when you see an oil industry commercial, what credibility do you assign to the claims made?).

Proponents tell the people "Don't be concerned - we will take care of everything. All is well". Opponents tell them "They are lying to you. This course of action will lead to the end of the world". Which are they to believe? The child mind judges right and wrong by results - the examples of Hiroshima, the radium dial painters, the uranium miners, Three Mile Island, and Chernobyl are powerful negative images. Probably the strongest negative image is the Indian nuclear bomb test in 1974, because it is an example that contradicts the line nuclear industry proponents presented for many years; that the IAEA non-proliferation system would prevent such occurrences. This test was a major blow to the credibility of nuclear proponents because it revealed what appeared to be their lies. Before the test the legitimate fear of being bombed out of existence had been covered by "parental" reassurance - but the test destroyed the credibility of this reassurance and released the fear. These quite primitive fears are most often covered by various rationalizations or by indifference, but they surface at times of crisis.

Immediately after the TMI accident, the job of explaining the situation to Ontario Hydro employees fell partly on myself. During the first few days the most frequent question was "Is it going to hurt us?" People were afraid. This is the child looking for reassurance from the parent. Within a week, however, the questioning changed to a much more critical tone: the anti-nuclear messages had begun to sink in, and the simplistic answers given in the first days were being examined. This was the time of the 'Taves' affair at the Bruce nuclear station. A statement "This accident could not happen here, but many similar situations might arise" was clipped at the comma by the press and read by a Bruce nuclear first operator. He knew better - and he told his MPP and the press. The MPP was a member of the opposition; the government was in a minority position. The resulting uproar took several weeks to disperse, and permanently damaged the credibility of Ontario Hydro spokespersons. The lesson is that we are dealing with some very fragile opinions without much adult judgment supporting them. A word here or there can swing the balance. In this climate the negative message is simpler and clearer, and therefore is the one more likely to be believed. In our times we receive many different messages in a given day. There is simply not sufficient time to make a carefully reasoned judgment on each of them. The power of the media is amplified, at least on matters of short-term collective judgment, because they must present the essence of complex issues in a few seconds. Their editorial judgment becomes the majority judgment.

The core of fear of the nuclear industry is understandable in view of recent opinion polls reported by Inglehart. According to Inglehart, roughly 80 percent of the people in the US and western Europe believe that nuclear plants can blow up like Hiroshima bombs. Within this group there are differences of opinion as to the probability. Only 20 percent recognize that such an event is impossible. No wonder they are scared. No wonder they oppose nuclear energy - I would be frightened too if I believed this. Something is wrong with our communication process. Most likely, the problem is that most civilian nuclear power industry people cannot speak authoritatively on the subject (or do not feel comfortable doing so) and those who do know will not talk.

The opponents of this enterprise are mostly convinced of the rightness of their cause - there are few who really manipulate the situation in a conscious manner. The case has become a truly political issue. The outcome will depend on how well we can put our case to the people in an adult form, so they have the information at hand on which to base reasoned judgment. This is the only way to overcome the childish fear reaction.

A bit of evidence that supports the above is the fact that support for nuclear power in Ontario (as measured by the regular poll) fell considerably after the Mississauga train derailment and fire. The people who changed their minds may have lost trust in all large technologies after being betrayed by the friendly choo-choo train.

One perspective on the relationship of technology to society in the US is given by Aaron Wildavsky in a timely Scientific American article which - it was published in January 1979, two months before the Three Mile Island accident. Wildavsky (who later collaborated with Mary Douglas on a book titled "Risk and Culture") discusses the social aspects of risk acceptance. It is a difficult piece to read, but contains some useful ideas.

3. Nuclear industry reaction

Much of the response by the industry in the early days of our enterprise was in the parent-to-child mode. The typical message read "I know you can't understand this complicated subject, but don't worry. We will take care of you." This type of message may have been sufficient when the industry was in the early stages of development and when it had not really come close to a large number of people. Now that nuclear energy has become part of everyday life it is necessary to settle the issue in an adult manner - through education and well-informed discussion.

Even up to the present time, the industry often has reacted to criticism with a defensive "the only news worth printing is good news" attitude. This is not effective. It is difficult, but essential, to react with a balanced, reasonable opinion when dealing with the public. We are in this business for the long term and must have the support of most of the population in order to continue it in an orderly manner. We do not have it now.

4. A non-hazard: Power reactors can't blow up like bombs

This is one of the few absolute statements in the nuclear safety area. A reasonable question is "Why not?" If and when this question is asked we must have some kind of sensible answer. In fact it might be wiser to raise the point directly rather than let our opponents carry the argument by innuendo. The question can be answered at a number of levels, three of which are discussed here.

Level 1, the quickie: any one of the following is a sufficient reason.

1. CANDU uses natural uranium as fuel. With natural uranium, the chain reaction can continue only if the neutrons are slowed down before they collide with uranium to cause the next round of fission events. This is too slow to make a bomb.

2. No device exists to push the uranium fuel together so as to produce large amounts of fission energy quickly, in any power reactor. This is a necessary step in making a bang. Even if the fuel were pushed together quickly, it is too weak to make a bomb.

3. There is too much water next to the fuel. Steam pressure would force the fuel apart and shut down the reactor before high energy density was reached - therefore, no bang. The system is too wet to make a bomb.

(The Chernobyl explosion was a steam explosion of moderately high energy, made possible by the lack of effective shutdown systems and made worse by the particular design of that reactor type. Even then, the physical damage produced was minuscule compared with that produced by even a modest nuclear weapon.)

Level 2 - high school physics:

This level attempts to teach some facts about explosions as well as the qualitative and quantitative differences between them. The argument is rather long, so has been included in a separate reference document (see "A REACTOR CANNOT EXPLODE LIKE A NUCLEAR BOMB"). The article describes various thought-experiments to illustrate the essential features of explosions of various types.

Level 3 - reactor and weapon dynamics:

This level describes the time-dependence of a real nuclear explosion compared with a "CANDU Bomb Test". Explosion kinetics: the data on a nuclear explosion are taken from an open publication. The data on CANDU disassembly are taken from a study done on Pickering A.

A nuclear weapon: The nuclear S-device has a pure plutonium core surrounded by shaped-charge high explosive (HE). The core, initially sub-critical, is rapidly compressed to a highly supercritical state by firing of the HE. The reaction starts from a single neutron and grows according to the equation:

$$\frac{dN}{dt} = \alpha(t)N$$

where: N = neutron density
$\alpha(t)$= Rossi alpha at time t

At the first generation: $\alpha(0) = \frac{a}{\ell}$

Where: a = excess neutrons per generation, $\rho - \beta$
ℓ= prompt-neutron generation time

Figure 2.2 shows the time dependence of the Rossi alpha and the power generation rate. It can be seen from the small graph at the bottom that almost all of the energy input is complete in about 70 nanoseconds, and is terminated by rapid expansion of the core due to the extremely high energy density. At t=700 ns the core is about the size of a softball. (**The energy input to this softball is roughly equivalent to the thermal output of Point Lepreau in 16 hours at full power. Little wonder it goes bang**.) At this time the extremely high vapor pressure (at a temperature of ~50 million degrees) overcomes the external pressure of the HE and forces all material outward.

The CANDU Bomb Test: An attempt has been made to devise the worst possible power burst in CANDU, in order to compare this with the performance of the S-device. The following preparations are necessary: (a) disable SDS1, SDS2, reactor regulating system, and (b) place high explosive on all reactor headers. The reactor is slightly subcritical before the test. The burst is initiated by firing the explosive and is terminated by moderator boiling due to molten fuel injection. Figure 2.3 shows the resulting transient. Note that the time scale is in seconds rather than nanoseconds.

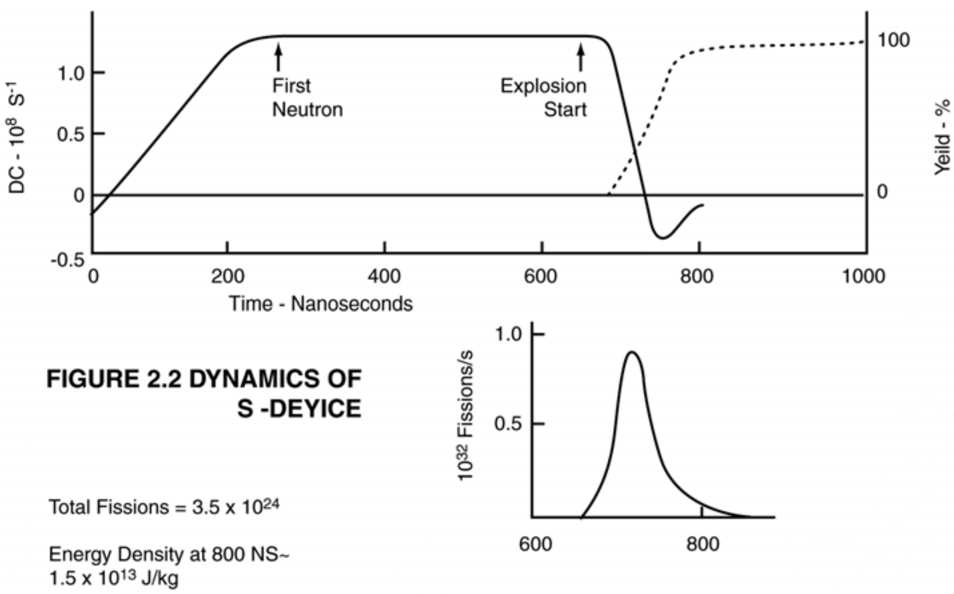


FIGURE 2.2 DYNAMICS OF S -DEYICE

The effects of the S - device are well known. The power burst in CANDU, by comparison, is a very mild affair. Peak instantaneous pressure is in the range of 1 MPa instead of about 106 MPa in case of the S - device. Shielding stops essentially all direct radiation in the CANDU case; the shielding and containment walls easily stop the expanding shock wave produced by the steam explosion. Some leakage may occur during the over-pressure period. The CANDU burst is trivial compared with that of the S - device. The combination of simultaneous total system failures required to produce an effect even near to this magnitude in CANDU makes the event frequency essentially zero.

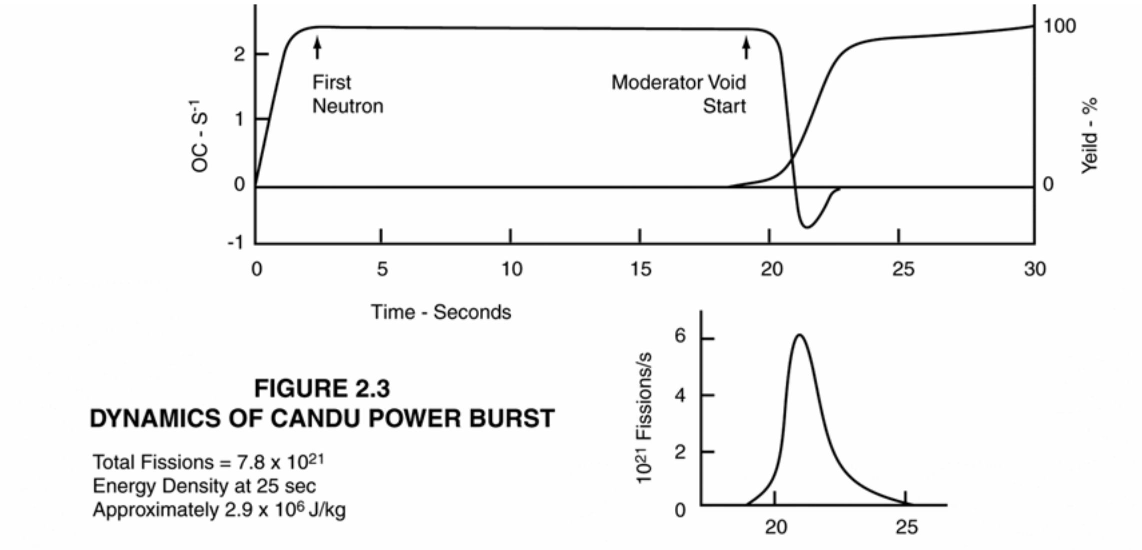


FIGURE 2.3
DYNAMICS OF CANDU POWER BURST

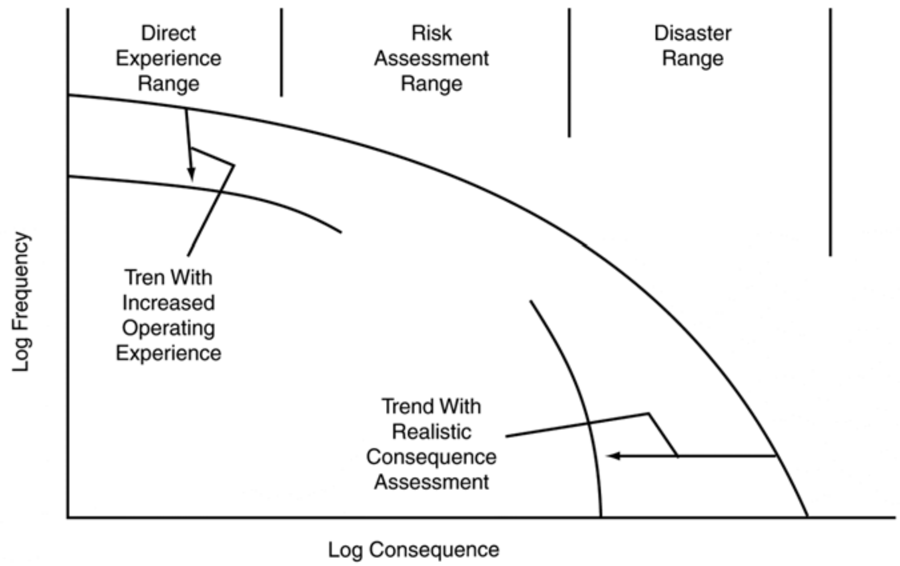
Total Fissions = 7.8×10^{21}
Energy Density at 25 sec
Approximately 2.9×10^{6} J/kg

5. <u>The question of probabilities</u>

Many people strongly discount the probability term of the risk equation, particularly for potentially disastrous events that have not happened recently. The causes that lead to death on a regular basis seem to have a higher acceptance level. People seem to be completely unimpressed with numbers like "there is only one chance in a billion per year that a large meteorite will strike the earth and kill fifty million people" even though this number is roughly correct. They look only at the potential consequences. They equate nuclear reactors with bombs and measure them by the known potential consequences. One of the few positive aspects of the Chernobyl accident is that it was nearly the maximum achievable disaster that can be produced by a large power reactor. Eventual long-term health effects, including deaths and injuries, will be much smaller than those we have (unfortunately) become used to in our industrial world.

Figure 2.4 is a sketch of a typical nuclear plant risk spectrum and today's trends. As operating experience is accumulated and plant equipment is improved, the frequency of minor accidents already has decreased significantly. Along with this trend it is reasonable to assume that the frequency of events that could develop into major accidents if combined with other failures also has decreased. At the low frequency, high consequence end of the accident spectrum, experimental work has improved modeling of sequences of events, so that major conservatisms that were necessary in earlier analyses now can be removed. The Chernobyl accident will likely, when fully analyzed, show further areas in which the consequence estimates can be reduced.

FIGURE 2.4 THE RISK SPECTRUM



Most of the effective work in accident analysis can be done in the mid-frequency range just beyond the area of direct experience. Probabilistic safety evaluation offers an orderly structure for reduction of the frequency of occurrence in this range. One way out of the industry's present state of being suspiciously tolerated is to have lots of big accidents so as to demonstrate that the disaster scenarios do not exist. This likely is not a realistic course of action. About the only remaining method is to operate the plants economically and safely for many years, and to work toward a more realistic description of the supposed "disaster" situations. Steady communication, accurate description of the risk spectrum, and demonstration of the careful attention being paid to safety constitute the best available strategies for reaching broad public acceptance.