Policy Recommendations for the Treatments of ATWS Events for Standardized Nuclear Power Plants

by

Michael W. Golay

Associate Professor of Nuclear Engineering

Massachusetts Institute of Technology

Cambridge, Massachusetts 02139

9 January 1980

Prepared under Contract NRC-03-79-144

TABLE OF CONTENTS

Executive Summary

This report presents an independent analysis of ATWS licensing issues, with special attention to the question of how standardized plants should be treated. The principles underlying the current NRC policy regarding ATWS events in custom design plants are analyzed. Then, these policies are used as the precedent from which to begin consideration of the proper treatment of standardized plants.

In brief, the conclusions are the following:

1. The NRC staff's concern with ATWS is valid, and the responses of the nuclear industry to this concern have been largely irrelevant to its bases,
2. The proposed design remedies for prevention and/or mitigation of ATWS are based upon an implicit balancing of economic and public safety values,
3. The marginal benefit:cost analysis upon which the current policy rests is too imprecise to be more than a guide to the judgement of regulatory decision-makers,

The recommendations are strongly contingent upon the resolution of two questions:

1. Whether--with new information--evaluated ATWS risks become significantly greater than those presented in NUREG-0460, and
2. Whether it is desired to terminate (at least for the time being) the NRC's Standardization Program.

If the answer to either question is affirmative the following recommendations should be modified strongly in the direction of requiring Alternative 4 design changes for Reference Design plants, in a way which would be consistent with the design requirements for custom plants.

My recommendations are the following:

1. Standardized plants with CP's issued prior to 1 January 1978 should be required to have Alternative 3 design changes,
2. Other currently-docketed standardized plants should be required to have Alternative 3 design changes, if for each of them, it can be shown that they provide a level of safety which is consistent with that of standardized plants licensed before 1 January, 1978 and
3. All current reference designs should be modified to require Alternative 4 design changes for purposes of new license applications.

1. Introduction

My charge in this work is to formulate an independent opinion regarding how standardized plants should be treated with respect to Anticipated Transients Without Scram (ATWS). In doing this I have reviewed the portion of the public record which was provided to me by the NRC staff for this work, and I have discussed this question with members of the NRC staff as well as with outside persons. I also brought to this work prior relevant experience in nuclear plant design, safety system analysis, and nuclear power regulation.

My method has been to understand the history of the treatment of ATWS--leading to the current policy for custom plants, to formulate a few general decision-making principles, and to apply these principles to both current and future standardized plants in formulating a policy recommendation. This report documents that process. It is organized in two main sections:

Section 2 -- concerning the fundamental principles for the treatment of ATWS in custom plants, and

Section 3 -- concerning how standardized plants should be treated if the principles promulgated by the NRC regarding both ATWS and standardization are to be applied consistently.

Because any policy recommendation reflects one's values and experiences as well as objective facts I am writing this report in the first person--in order to emphasize that reality. There is no uniquely correct policy regarding ATWS, and the final policy (if it ever exists) will rest at least as much on the judgements and consensus of values of the decision-makers as on objective analyses. My own view is that this situation is inescapable.

Since the ATWS issue changes as new information is discovered portions of this report will be out-of-date as they are written. Similarly, in the discussion of the ATWS treatment of standardized plants the list of such plants is somewhat incorrect as a consequence of changes in utility plans after the information provided to me by the NRC staff was prepared. An important caveat of this report is that the data on which it is based are those provided to me by the staff. I have not been kept informed on the evolving status of ATWS as a generic issue (which I think is not a problem since any description of such an unsettled question will necessarily be somewhat inaccurate). Recent changes in the population of standardized plants in the licensing pipeline have been consistently downward, with the result that the population of plants upon which this report is based maximizes the severity of the ATWS issue for standardized plants. This population does not significantly affect the decision-making principles which are formulated for this issue.

2. A Discussion of ATWS as a Licensing Issue

My purpose in this section is to characterize the bases for identification of ATWS events as a class of safety problems which require a solution. The purpose is to establish the criteria by which the seriousness of ATWS events in non-standardized plants has been evaluated. This is necessary since these same criteria must be considered in deciding what is appropriate for standardized plants.

This section consists of a review of the history of ATWS as a safety problem, an examination of the criteria of ATWS safety regulation decision-making, and a characterization of the foundations of the current NRC policies regarding ATWS.

2.1 A Summary of the Evolution of Thinking Regarding ATWS Events

The purpose of reviewing the history of the treatment of ATWS as a safety issue is to identify the basis for current NRC policies regarding ATWS, since these bases have changed as the debate--principally between the NRC and the nuclear industry (consisting principally of the reactor vendor, architect-engineer, utility complex)--over ATWS has evolved.

The principal milestones in the story are summarized below:

1950's: Originally concern regarding neutronic core control resulted in the requirement for highly reliable shutdown systems for all reactors. The Naval Reactors program provided leadership in this area. Also, requirements of reactor designs having inherent power shutdown mechanisms (e.g. negative temperature and void coefficients of reactivity) were made basic licensing requirements.

1969 The possibili of common mode failures leading to ATWS events was raised with the Advisory Committee on Reactor Safeguards. Studies were requested of reactor vendors of risks of ATWS events.

1973 The Atomic Energy Commission released the report WASH-1270 (Technical Report on Anticipated Transients Without Scram for Water-Cooled Power Reactors). The report concluded that ATWS events constitute a sufficient public safety hazard and that future plants (i.e. those docketed for Construction Permit licensing after 1 October 1976) would be required to provide safety systems to deal with such events. A design goal of limiting ATWS events having serious consequences to a frequency less than 10^{-7} per reactor year was set. The development of detailed design methods and vendor studies of ATWS events was begun. The NRC staff after review of industry analyses of ATWS for plants by the various vendors specified desired ATWS design changes. The various industry segments formed a fairly united front maintaining that ATWS were much less likely than the NRC staff evaluations would indicate, and that no new safety systems were required (or at least not in the form proposed by the NRC staff).

1975 The NRC released the report WASH-1400 (The Reactor Safety Study). Considering only independent random failures in the scram system--given that a transient requiring a scram had occurred--the study concluded that serious ATWS event probabilities are low (typically 10^{-5} to 10^{-7} per reactor year), that ATWS events are not important contributors to the overall level of public risk due to power reactors, and that the consequences of some ATWS events could be significant.

1976 The Electric Power Research Institute issued a series of reports (EPRI NP-251, Part I; ATWS: A Reapprasial Part I), and EPRI NP-265, Part II, vols. 1-4 (ATWS: A Reappraisal, Part II). which generally supported the contentions of industrial critics of the NRC staff positions regarding ATWS. Two major points were made:

1. Common mode failures will not contribute significantly to risks from ATWS events since after discovery of such a failure mode (in the worst case via a failure at an inconvenient moment) the mode will be "rectified" and thereby eliminated,
2. The expected frequency of ATWS events due to independent random scram system component failures is evaluated (using a different data base) to be much lower (by one or two orders of magnitude per independent failure) than the previous NRC staff estimates.

1978 The NRC issued the report NUREG-0460 v. 1 & v. 2 (Anticipated Transients Without Scram for Light Water Reactors) evaluating the results of ATWS studies to-date and presenting the revised NRC position. It concluded that current design LWR's have a probability of approximately 2 x10^{-4} per reactor year of encountering an ATWS event having significant consequences It set a revised safety design goal of

10^{-6} per reactor year for ATWS events having serious consequences.

The NRC's Lewis Committee review of WASH-1400 criticized the study in several areas including a rejection of the levels of precision implied by the risk analyses of the study. A warning to the NRC against using stochastic risk analysis as a basis for detailed licensing decision-making was also issued.

The NRC issued the report NUREG- 460, v. 3 which stated the current policies regarding ATWS events. The prior quantitative probabilistic ATWS design goals and random probability analyses have been abandoned, but the need for ATWS protection is maintained--being justified in any event by the unacceptably upper-estimate of likelihood of common-mode failures leading to ATWS events. Two levels of design changes are required depending on the vintage of the power station.

1979 The NRC endorsed the Lewis Committee recommendations as Commission policy.

The timetable of establishing a final ATWS policy is upset by the accident at the Three Mile Island-2 power station. It is likely that final ATWS positions will be among the NRC policies influenced by that accident.

2.2 Common-Mode Failures

Because of the high reliability of individual scram system components it has generally become recognized that overall scram system failures due to multiple independent random component failures are relatively unlikely. Rather, the consensus is that the most likely path leading to an ATWS is that of a common mode failure.

Based on experience to-date with common-mode failures it has been stated that the frequency of such failures is probably no greater than the range of 10^{-4} to 10^{-5} per year (e.g. see NUREG-0460, v. 3, p. 10-1).

A problem arises at this stage in that there is a temptation to treat common mode failures in the same way as random events, the likelihood of which can be analyzed using probabilistic methods. This would be an incorrect procedure since common mode failures are--by definition--excluded from the event tree. EPRI (in EPRI NP-251) stated this argument indirectly in presenting the concept of "rectifyability"--i.e. a common mode failure is outside the set of possible failure pathways because this failure mode will have been "rectified." The former part of the argument is correct, but experience has shown that the latter part is not.

When an unknown common failure mode exists one is generally unable to estimate the likelihood that it will be exercised--initially because one is necessarily ignorant of its existence. However, it is usually also incorrect to treat a common mode failure as a random event. For some such failure modes a deterministic (i.e. p=1) analysis is more realistic (e.g. the case of the defective Kahl circuit breakers). In such cases the common mode failure occurs when the required set of conditions to activate the failure mode arise (e.g. the Brown's Ferry starts, the Kahl circuit breakers are called upon to operate). The unavoidable possibility of the existence of such unknown failure modes is an inherent limitation of event-tree analysis, which has come to be widely recognized.

The main way in which it seems reasonable to me to treat common mode failures as random events is if they are viewed as human failures, in that the power station design/construction team would have made an undetected mistake. However, we currently have only low-quality data regarding the behavior of such teams, and their numbers are small enough that one can question whether random behavior is an appropriate model. However, this treatment is suggested as a way by which experience regarding the frequency of common mode failures that can be thought-of using current methodologies for risk analysis.

The significance of recognition of common mode failures as the most likely set of paths to an ATWS event is that it makes moot the fault-tree (synthesis) arguments regarding whether such events constitute a significant public safety problem. Effectively the ATWS argument--in terms of likelihood--that a problem exists becomes one that there are few reliable ways which are not currently in use, to reduce common mode failures and the upper estimate for common-mode failure frequencies which one could make from the sparse experience to-date is relatively large. Since the consequences of an unmitigated ATWS could be very serious the evaluated upper estimate of risk is judged to be unacceptably large.

2.3 Benefit-Cost Analysis

A justification which is presented for the NRC requirement that the perceived ATWS problem be fixed is that the technology for the remedy is available and can be installed at relatively modest cost. This is important since it is not merely recognition that ATWS consequences would be unacceptably large which motivates the requirement for a design change. It is also motivated by the expectation that the design changes can be implemented at low cost.

This situation is contrasted sharply with that of Class 9 events, which would also have unacceptably large consequences, but for which comprehensive design remedies are not required--in view of the prohibitively large costs of the latter.

Both positions rest on a balancing of public safety benefits against economic costs. With regard to the requirement for an ATWS design change it is important to note that it implies that the two benefit: cost ratios, R_1 and R_2, are both positive, where

$$R_1 = \left[\frac{\text{benefits of avoiding the costs of unmitigated ATWS event consequences (given that the event has occurred)}}{\text{costs of ATWS design changes}} \right],$$

and

$$R_2 = \left[\frac{\text{benefits of marginal reduction in expected costs of ATWS events}}{\text{costs of ATWS design changes.}} \right].$$

Because of ignorance regarding the likelihood of [illegible] possible pathways for an ATWS event it is impossible to defend either statement with a high degree of precision. In effect, it is the judgement of the NRC staff that these propositions are true which justifies the status of ATWS as a safety problem (see NUREG-0460, v. 2, section 1.4). No sector of the nuclear vendor architect-engineer utility complex appears to agree with this position, especially that $R_2 > 1$.

With regard to the balancing of safety and economic costs and benefits, one sometimes encounters the following syllogism

1. The NRC is charged with protection of public health and safety in nuclear matters.
2. The NRC is not charged with protection of the economic vitality of nuclear power.
3. Therefore, the NRC may not use economic criteria in evaluating the adequacy of a particular safety system.

In this case the conclusion does not follow from the previous two statements, and would be valid only if the second statement said 'prohibited from' rather than 'not charged with'. Thus, the current NRC mandate can be interpreted as allowing, but not requiring, a balance of economic and safety costs. In reality, such a balancing is inescapably required--and allowable--for several reasons.

A. Logic requires it,

B. In effect, the political mandate of the NRC requires it,

C. Its use has been validated in previous NRC decisions, which have been found to be socially acceptable, and

D. The Calvert Cliffs decision requires it explicitly in the Environmental Review for reactor licensing.

Logic and Political Mandates--The Congress has not provided explicit guidance regarding an acceptable set of criteria for public safety protection decision-making. In the absence of such guidance, if no countervailing values are introduced to balance the requirement to provide for adequate public safety protection one is led to a requirement for allowing no nuclear risks. This follows because of the existence of an irreducible minority of citizens for whom no level of nuclear power risk is acceptable. The wishes of this group can be ignored only if either

(a) Nuclear power risks can be reduced to zero (an impossibility), or

(b) A more important value than avoidance of existing risks can be introduced as a decision-making criterion (in this case, the economic benefit provided by nuclear power to the much larger majority which is willing to bear some level of risk).

Economic benefit is the major alternative value which arises in public safety protection decision problems. That the Congress does not wish nuclear power to be suppressed (and by implication, that economic values are acceptable criteria) has been affirmed by the Supreme Court in its decisions regarding Vermont Yankee Nuclear Power Corp. vs. National Resources Defense Council, and Aschelman vs. Consumer Power Co. in 1978.

Precedent - A body of precedent exists which also affirms the acceptability of the use of economic criteria. This is in the form of prior NRC decisions which have become the standard of guidance in safety licensing decisions. Among the decisions which have utilized economic criteria are the following:

1. The decision setting the marginal cost criterion for satisfaction of the As Low As Reasonably Achievable (ALARA) goal of minimizing low-level radiation exposures to the general population. The criterion which was determined permits dose-reducing design changes to be omitted if the cost:benefit ratio exceeds $1000 per man-rem.

2. The practice of excluding Class Nine accidents from consideration in determining the Design Basis Accident in licensing actions.

Environmental Review - The Calvert Cliffs Decision in 1971 (Calvert Cliffs Coordinating Committee vs. U.S. Atomic Energy Commission, Second U.S. Circuit Court of Appeals), which provides a judicial interpretation of the National Environmental Policy Act of 1969, also establishes the requirement for a cost:benefit justification for Environmental Review-licensing decisions.

The Primacy of Safety Protection - Among the NRC staff (and elsewhere) one sometimes encounters the view that the Commission's primary mission is the promotion of public safety. Often such statements are used as parts of arguments advocating safer, but more expensive, nuclear plant designs. I think that this characterization of the NRC mandate is deceptively simple. In effect, the Congress has given the NRC the mandate of providing a socially acceptable level of public safety and environmental protection. This implies a requirement for maintaining nuclear risk levels low enough that the consensus preference for avoiding them is balanced by additional preferences for other competing values--notably economic benefits. The historical practice of nuclear power regulation has affirmed this as an accurate operational model of the NRC's mission. Thus, there exist two regions of risk regulation:

1. That in which risks are so great that the preference for their reduction clearly exceeds any competing preferences (the desire for elimination of the perceived hydrogen bubble during the early days of the Three Mile Island-2 incident provides a striking example), and

2. That in which preferences for risk avoidance and other values are of similar magnitudes.

I think that the ATWS issue falls into the former class, but it is very unclear to what degree safety in this area must be improved in order to provide acceptable public protection.

Marginal Benefit-Cost Judgements--

The upper limit estimated costs of implementing the various proposed ATWS design changes are of the order of 10 million dollars per plant for PWR's and 100 million dollars per plant for BWR's according to the NRC (in NUREG-0460, v. 1.)

I am usually suspicious of the precision of benefit:cost analyses. This is because expected-cost engineering estimates have a way of growing faster than the general economic inflation rate as projects progress. It is also because of lack of empirical data and consensus, regarding factors which appear in an ATWS risk calculation--e.g. the probability of an ATWS event, mechanisms for health and property damage, and how such damage should be valued in economic terms. However, the precision of engineering cost estimates is generally much greater than that of risk estimates.

The point of this general imprecision is especially important regarding the issue of how standardized plants should be treated since the current NRC policy regarding what level of ATWS remedy should be required for custom plants (and by implication also for standard plants) rests on an imprecisely stated marginal benefit:cost judgement. Considering the uncertainty inherent in any benefit:cost analysis it seems to me to be difficult to defend the use of any particular marginal benefit:cost analyses in selecting safety policy options. A decision-maker is logically required to use such an analysis in the intuitive process of formulating policy judgements, so the point which I am attempting to make is not that such analyses should be avoided. Rather it is that their use should be accompanied by a frank admission of the degree to which any such judgements are subjective and liable to error. I think that any judgements regarding ATWS solutions will necessarily have this flavor.

Safety as a Bargain --

Experience since the Three Mile Island-2 (TMI-2) accident has indicated that the costs of reactor accidents have tended to be significantly under-estimated in the past in several ways:

- o in terms of the effects on the financial health of the utility company owning thepower station,
- o in terms of economic disruption in the region near the accident site,
- o in terms of psychological trauma among the nearby public,
- o in terms of the direct costs and potential judgement costs of liability litigation.

I suspect that the actual values of R_1 and R_2 are significantly greater than existing estimates, and they are very likely greater than unity. Thus, it could be argued that the frequently-expressed nuclear industry view that funds spent in improving safety in current design reactors are largely wasted is usually wrong, and that in the instance of proposed ATWS remedies the industry is wrong.

The TMI-2 accident also has important cost implications for the standardization program. As a direct consequence of the accident at TMI-2 the reactor at TMI-I has been required to shutdown indefinitely--thereby greatly increasing the economic costs of the accident. If the two TMI units were not identical, it is less certain that TMI-1 would have been shut down.

2.4 Measures for Dealing with ATWS Events

In order to assess the implications of various standardization policy options with respect to ATWS events it is necessary to describe the proposed remedies for plants by the various vendors. The alternative ATWS remedies are described in NUREG-0460, v.3 and my concise summary of them is presented in Table 1. It is seen that Westinghouse plants would not be greatly affected by any of the proposed design change alternatives. Plants by both Babcock and Wilcox and by Combustion Engineering would be substantially affected by Alternatives 2 thorugh 4. The plants most affected by Alternatives 2 through 4 would be those by General Electric.

The NRC staff recommendation has been to require Alternative 3 for plants with Construction Permits (CP's) granted before 1 January 1978 and to require Alternative 4 for all other plants. This policy was formulated principally with custom plants in mind. In considering the question of the treatment which should be applied to standard plants I am accepting--without making a statement regarding the merits of the case--that the staff recommendation will be implemented and are well-founded. The question to be resolved regarding standard plants then becomes that of how the latter plants should be treated in order to be consistent with the treatment of custom plants and with assurances given previously, via NRC policy statements, to applicants for standard plant licenses. and in order to maintain a healthy standardization program.

Table 1. Staff-Recommended ATWS Design Changes According to Reactor Vendor*

	Alternative ATWS Remedies			
Reactor Vendor	Alternative 1 Do Nothing	Alternative 2 Increase ATWS Prevention Capability	Alternative 3 Increase ATWS Prevention Capability as in Alternative 2, and Increase Mitigation Capability	Alternative 4 Increase ATWS Prevention Capability (but less than in Alternative 2), and Mitigation Capability (more than in Alternative 3)
Westinghouse	1	2-currently is in-place for some plants	2 3a-substantially accomplished for current plants	2 3b
Babcock & Wilcox	1	2 4	2 3a 4	2 3b 5
Combustion Engineering	1	2 6	2 3a 6	2 3b 5
General Electric	1	7 8 9 10	7 8 9 10 11 12	12 13 14

*Legend for Table 1 on next page.

Legend for Table 1

Possible ATWS Design Changes

1. No Change
2. Provision of additional activation circuitry for diverse means of activation of ATWS-mitigation systems.

3a. Demonstration of primary coolant system integrity and ability of needed valves to function during long-term cooling portion of an ATWS event.

3b. Same as 3a, except that core neutronic conditions are more stressful.

4. Provision of a diverse four-channel back-up scram system.
5. Provision of increased pressure relief capacity via additional pressurizer safety relief valves; and possibly increased pressurizer size and/or feedwater flowrate.
6. Provision of a diverse, four-channel supplementary ATWS protection system.
7. Provision of separate, redundant ATWS control rod injection system.
8. Provision of independent, diverse water level trip sensing systems for drain line failures.
9. Provision of an approved recirculation pump trip system.
10. Changes in control system logic to reduce frequency of vessel isolation transients and to permit feedwater runback.
11. Double injection rate of liquid reactivity poison.
12. Making the liquid injection signal system automatic and independent and diverse from scram system.
13. Provision of liquid reactivity poison injection system of sufficient capacity that long-term core cooling is assured.
14. Provision of higher quality recirculation pump trip system than under Item 9.

2.5 Analogy with the LOCA Decisions

In practice the ATWS problem is very similar in the following ways to that which faced the AEC in setting performance criteria for emergency core cooling systems under loss of coolant accident (LOCA) conditions. Thus, it could be useful in formulating the appropriate resolution of ATWS issues to consider prior experience in resolution of LOCA issues. The similarities are the following:

1. It is recognized that the consequences of such an accident could be very serious.
2. Designs for safety systems which could mitigate the effects of the accident exist, which indicate that the costs of the remedy would be relatively small.
3. It is recognized that relatively little can be done, in addition to current efforts, to make the accident less likely.
4. It is not known very well how likely the accident is, but it is thought that the accident is the unprotected event which currently presents the greatest marginal-risk, and
5. It is also thought that the benefit which consists of avoiding the costs of unmitigated accidents would greatly exceed the costs of mitigation.

In essence, a decision to require or not to require an ATWS "fix" cannot be defended in precise technical terms since the required data for such an argument do not exist, and--in some instances--cannot be generated. In the end, the decision regarding the need for and requirements of an ATWS design modification is based upon the judgements of the safety regulatory decision-makers.

3. Standardized Plants and ATWS

The purpose of this section is to examine the past NRC treatment of ATWS for both standardized and non-standardized plants, and my evaluations of these issues in the context of past actions and current policies.

In this section I characterize the attitude of the NRC regarding power station design standardization, the status of current standardized plants, the future prospects regarding use of standardized plants, the NRC staff recommendations regarding standardized plants, and my own recommendations.

3.1 NRC Policies Regarding Standardized Plants

In the past the NRC has promulgated policies promoting the use of standardized plant designs as a means of reducing the duration and effort of the licensing review for new plants. There are several classes of plants and sub-plant units for which reference design licenses are available (ie duplicate, replicate, and standardized plants; also standard plant nuclear steam supply systems, balance of plant and turbine island). For purposes of this discussion all such plants are treated as a single group.

Without attempting to reproduce the details of the various standard plant options the consistent features of these licenses, design approvals, and of NRC policy statements regarding them are the following:

1. An approval for a reference-design concerning a standard plant or system will have a fixed duration during which an applicant for a new plant or system license can use this design (providing that his site and balance-of-plant are suitable)

with the understanding that a full-scale NRC staff licensing review specifically for his license would be unnecessary, by virtue of the previous approval of the design.

2. The widely perceived spirit of standardization has been that during the period of the design approval it would not be required that the reference design or the designs of plants using it be modified as changes in custom plant safety system design requirements arise. Such design changes would be incorporated in reference plant designs at the next subsequent design approval stage, afger expiration of the current design approval duration. Literally this understanding is incorrect since official NRC pronouncements in this area (e.g. the NRC Statement on Standardization of Nuclear Power Plants, Federal Register, 31 August 1978) reserve the right for the Commission to require changes in reference designs whenever such changes are judged to be necessary. This has been interpreted through a policy of classification by the Regulatory Requirements Review Committee (RRRC) of possible safety system design change requirements into three classes for which the following conditions apply:

Category I -- Concerning safety issues sufficiently minor that no design changes are justified for currently-approved reference designs,

Category II - Concerning safety issues for which design changes may be required during the period of the current reference design approval, and

Category III - Concerning safety issues for which design changes will be required during the period of current reference design approval. (See

Review of the Commission Program for Standardization of Nuclear Power Plants and Recommendations to Improve Standardization Concepts, NUREG-0427 (May, 1978) p. III-9).

Despite the decision-making freedom which the NRC has reserved to itself it is necessary--in effect--that the number of Class III and Class II design change requirements be kept small if the standardization program is to have any substance, and if it is to be attractive to nuclear license applicants.

The current list of issues before the RRRC which could reasonably be placed into Categories II and III is so large that I am very uncertain that a stable standardization program can be maintained. In addition the cont nuing regulatory turmoil arising from the TMI-2 accident is almost certain to make such stabilization even more difficult.

3. Despite all of this the spirit of the standardization program has been that the major exception to the principle of "freezing" reference designs for a specified interval would arise if the previously-granted design approval were "disqualified for good cause." It is obvious that what constitutes good cause is open to interpretation. In this case no new applications utilizing the previous reference design would be approved, and a policy decision regarding the treatment of plants which had at least begun licensing would need to be formulated. The spirit of past NRC policy statements regarding standardization has been to encourage use of reference designs. This is done by

means of discouraging the later disapproval of previously-approved reference designs, even when the design requirements for similar custom plants may have changed.

3.2 Status and Recommendations Regarding Current Standardized Plants (i.e. Those for Which Applications Have Been Docketed)

The problem of the ATWS treatment of standard plants is that of how to treat plants which have at least been docketed for construction permit (CP) licensing, and how to treat new applications. Currently-docketed license applications are discussed in this section and new applications in Section 3.3. The NRC staff recommendations for ATWS remedies would require Alternative 3 design changes for plants with CP's presented before 1 January 1978, and Alternative 4 changes for all other plants. The status of the current population of docketed standard plants is summarized, according to vendor, in Table 2. If the staff's recommendations were applied to all standard plants it would require that some plants using the same reference designs would be required to implement different design changes.

This would cause a serious problem since for standardized plants this policy would be arbitrary and inconsistent. It is inconsistent since it would require otherwise identical plants to implement design changes which would result in two different levels of improvement in public safety protection. An implicit goal of safety regulation is to maintain--for plants of the same vintage--

Table 2

Current Standardized Plants

Reactor Vendor	Construction Permit Before 1/1/78	Construction Permit After 1/1/78	No Construction Permit To-Date
Westinghouse	South Texas 1&2	Marble Hill 1&2	Jamesport 1&2
	Byron 1&2		New England 1&2
	Braidwood 1&2		
	Callaway 1&2		
	Wolf Creek		
	Sterling		
	Tyrone		
	Millstone 3		
	Seabrook 1&2		
Babcock & Wilcox			Erie 1&2
Combustion Engineering	Palo Verde 1,2&3	WPPSS 3&5	Perkins 1,2&3
	Cherokee 1,2&3	Yellow Creek 1&2	Palo Verde 4
			New Haven 1&2
General Electric	Hartsville 1,2,3&4	Phipps Bend 1&2	Black Fox 1&2

the allowed level of risk at an approximately uniform value from one facility to another. I recognize that this goal is an idealization which is very difficult to achieve in practice. However, it imposes a decision-making principle which should not be violated if possible. Since the staff's recommendations would result in such a violation it seems reasonable to me that they should be modified for the treatment of current standard plants. Consistency would require that current identical standard plants be treated uniformly.

An additional principle arises, that the overall level of risk to society due to all nuclear installations should be held below some maximum value. This implies that the allowed risk due to individual plants should be decreased as time progresses, and as the total population of plants grows. I think that this principle is important mainly in deciding how ATWS issues should be resolved for new applications (either custom or standardized). All of the standardized plant applications which have been docketed were submitted within an interval of less than six years, which permits them to be considered reasonably to be all of the same vintage.

In deciding whether Alternative 3 or 4 should be imposed, on current standardized plants a question of fairness arises. If Alternative 3 remedies are to be required for custom plants given CP's before 1 January 1978 then it would be both inconsistent and inequitable to require Alternative 4 remedies (because of the greater costs of the latter) for standard plants of the same vintage. This would argue that the early standard plants should be required to implement Alternative 3, as with the custom plants. Then, uniform treatment of all current standardized plants would require use of Alternative 3 for all such plants.

In addition to being consistent this policy would have the virtues of improving the stability of the standardization program (with some attendant safety and economic benefits), at the price of a reduced level of safety for currently-docketed standard plants for which applications were submitted after 1 January 1978.

The status of current standardized plants is summarized in Table 2. It is seen that 22 standard plants being licensed after 1 January 1978, would be affected by the proposed treatment. The 24 plants with CPs prior to 1 January 1978 would be required to have Alternative 3 ATWS remedies as would custom plants of the same vintage. The 22 plants which did not have their CP's on that date would also be required to implement Alternative 3 design changes.

Of this group six plants are Westinghouse units, for which the required design changes under Alternatives 3 or 4 are relatively minor. Thus, the safety implications of the differences between the two ATWS alternatives for the Westinghouse plants appear to be fairly small.

Babcock and Wilcox has only two plants in the entire standardized plant population. The systems to be affected by the Alternative 3 or 4 ATWS remedies are those which participated in the Three Mile Island - 2 accident. It is conceivable that the generally hostile political atmosphere prevailing currently (as part of the legacy of the TMI-2 accident) regarding anything nuclear having to do with Babcock and Wilcox could result in a requirement for an Alternative 4 requirement for the Babcock and Wilcox plants.

I think that this would be an incorrect decision for the following reasons (in addition to those cited previously):

1. Consistency in treatment of standardized plants requires that a single--currently unpopular--vendor not be singled-out for unusually harsh treatment.
2. The number of Babcock and Wilcox plants is small. Thus, the marginal public safety effects of choosing between the two alternatives would also be expected to be small.

The bulk of the non-Westinghouse plants are Combustion Engineering units (10). The ATWS modifications under Alternative 3 and 4 for Combustion Engineering plants are similar to those required for the Babcock and Wilcox plants. Also, according to some of the persons interviewed in this work the differential levels of risk from Alternative 3 to Alternative 4 for both vendors are similar.

All of the PWR systems have generally longer characteristic response times (typically of the order of tens-of-seconds) than do BWR systems (typically of the order of seconds) during ATWS transients. This arises because of the less direct coupling of the reactor neutronic behavior to events occurring in the nuclear steam supply-turbine system in the former reactors. Consequently, BWR's (i.e. General Electric plants) require the most extensive ATWS safety systems. There are four General Electric standard plants which did not have CP's prior to 1 January 1978.

Based on this discussion, my evaluation of differences between Alternatives 3 and 4 for the various vendors is the following (going from least to greatest difference):

Vendor	No. of Plants Without CP's on 1/1/78
1. Westinghouse	6
2. Combustion Engineering	10
3. Babcock and Wilcox	2
4. General Electric	6

Thus the population of post-1/1/78 standardized plants contributing significantly increased risks would be not greater than 18 (i.e., all but the Westinghouse plants) if Alternative 3 rather than Alternative 4 remedies were required.

It has been argued--in effect--(in NUREG-0460 v. 3) that requiring an Alternative 3 remedy for custom plants not having CP's by 1 January 1978 is justified because the marginal safety decrement caused by this decision is small enough that it is outweighed by the benefits of avoiding costly backfits and design modifications to plants which are all past the initial design stage. This is also an allowable principle because it applies only to a fixed number of plants, and is not open-ended in the sense that it could be applied to future plants. By extension it would be argued that a similar treatment for all current standard plants is justified because the small fixed population limits the safety degradation inherent in using Alternative 3 rather than Alternative 4. And, this reduction is more than balanced by the benefits of (a) avoiding costly design changes and (b) encouraging the use of reference-design plants.

It has been suggested by some members of the NRC staff that ATWS risks have been shown by more recent analyses to be much greater than indicated in NUREG-0460. If this turns out to be the case then my previous statement could easily be unjustified.

Then, based on currently-available information, it seems reasonable to me that Alternative 3 is a preferable requirement to Alternative 4 for currently docketed standardized plants because it appears that the marginal safety costs of this decision would be small, and would be likely to be exceeded by the benefits of encouraging standardization and avoiding backfits. If the standardization program is not to continue, however, the justification for this recommendation would be substantially reduced. Because of the arguments that consistency and fairness would be satisfied by permitting Alternative 3 for post-1/1/78 standard plants I would still recommend this policy option in such a case, but it would not be a strong recommendation.

These recommendations could also be criticized on the basis that this treatment of standardized plants licensed after 1 January 1978 would not be consistent with requiring an Alternative 4 remedy for custom plants licensed after that date. The justification for the inconsistency is that prior NRC policy statements have implied that standard plants would be significantly less liable to required design changes than would custom plants. This is an assurance which was given by the NRC to license applicants at the time of application, while custom plant applicants were fully aware at the time of application of their liability to design change requirements.

3.3 Recommendations Regarding the Treatment of Future Standardized Plants

In my view the risk reductions associated with the design changes which would be required for all vendors under Alternative 4 are important enough to constitute Category III safety issues, and "good cause" for revocation of any existing standard plant design approvlas with regard to new license applications. The significance of the design change is so great, except perhaps with the Westinghouse plants, that the new safety system would represent a quantum improvement over the old system. Thus, if new custom plants were required to have Alternative 4 ATWS remedies, then consistency and effective enforcement of the requirements for ATWS designs demands that the same rules apply to new reference-design plants. Otherwise the new license applicants could continue to evade the requirement for ATWS safety systems by continuing to build reference-design plants of the pre-ATWS type with an Alternative 3 ATWS.

In any event, this point is probably moot since there appears to be little interest among electric utility companies in building new plants of any type. During the past five years a net decline has been observed in the total capacity of nuclear plants at all phases of life beyond the Construction Permit docket date. In addition, the current situation of nuclear power in the United States makes it virtually inconceivable that new plants will be ordered during the next few years. I think that this is so because the current political climate regarding nuclear power generally is so suspicious and unstable that utility executives will be unable to commit their companies to new nuclear projects (because of the accompanying risks of large uncontrolled costs once the project is underway).

A related question is that of whether the standardization program should be maintained during the near future. My opinion is that it should not. The reasons for this are the following:

1. The essential element of a standardization program--regulatory stability--is impossible to provide at this time. Such stability requires the existence of a social consensus regarding the need for nuclear power and that current technology can provide an acceptable level of safety. I see no hope that a sufficiently strong consensus can be formed in the reasonably near future. Thus, I believe that maintenance of an effective standardization program is an impossible goal.
2. The number of currently-identified, but unresolved, major safety issues within the NRC is too great for maintenance of a stable standardization program, and
3. There is currently no need for a standardization program since there is no prospect that many new standardized plant orders will be placed within the next few years.

As I have discussed in the previous section, if the standardization program were eliminated the justification for permitting an Alternative III remedy for the post-1/1/78 standardized plants would become much more tenuous than it is currently.

3.4 NRC Standardization Branch Position

The NRC Standardization Branch (in memorandum of Jan. 11, 1979 from C. J. Heltemes to W. P. Gammill) has recommended (in Option 6 of that memo) that of the standardized plants without CP's on 1 January 1978, only those which are mated to a plant (i.e. duplicate or replicate) having a CP on that date should be allowed to have an Alternative 3 ATWS design. It also recommends that all future standard plants docketed for licensing be required to use an Alternative 4 ATWS design. If the former recommendation were imposed, four standard plants would remain for which license applications had been docketed but for which no CP's had been issued for themselves, replicate or duplicate plants by 1 January 1978:

Plant Name	Vendor	Reference Design
Black Fox, 1&2	General Electric	GESSAR-238 NSSS
Erie 1&2	Babcock & Wilcox	BSAR-25 .

The Preliminary Design Approval (PDA) for GESSAR-238 NSS was issued before 1/1/78 and that for BSAR-25 in May, 1978.

The reason for which these four plants are treated differently from other standard plants is that they are neither duplicate nor replicate plants. There is an effective, but unwritten, NRC Standardization Branch policy that a reference design having a PDA does not truly become "frozen" until a CP has been issued for a plant utilizing that design. It is inescapable that this policy greatly dilutes the value of a PDA, and undermines the stability of the standardization program. (It also provides an incentive to minimize the number of standardized designs, since new applicants will tend to prefer use of PDA's which have been used in obtaining prior CP's).

This policy seems somewhat arbitrary, and it is presumably justified on the basis that a reference design which has survived the CP review is better-understood (and therefore safer) than one which has undergone only the PDA review. On the basis of arguments presented previously (consistency, fairness, and protection of the standardization program) it seems to me that these four plants should be allowed an Alternative 3 design change, along with the other standardized plants.

However, this should be done only if it can be shown that each of these plants utilizing Alternative 3 would provide a level of safety similar to that available from other standardized plants employing Alternative 3 design changes. For the Black Fox units this would amount to showing that they would impose no more risk than the Hartsville 1-4 units, which use the GESSAR-238 Nuclear Island Reference Design. The Black Fox units use the GESSAR-238 NSSS Reference Design which is substantially the same as the NSSS portion of the GESSAR-238-NI design. This demonstration should be relatively easy, since ATWS design changes are concerned mainly with the NSSS.

For the Erie units this demonstration is much more difficult since the vendor, Babcock and Wilcox, has no other standardized designs. Thus, the comparison would presumably be made to the Palo Verde or Cherokee units, all of which reference CESSAR. Considering that the Babcock and Wilcox plants are considerably different in their designs than the Combustion Engineering plants I suspect that the required demonstration (which would be the burden of the applicant) is impossible. However, if it can be done an Alternative 3 design should be permitted for the Erie units also.

Thus, my recommendation is identical to that of the standardization Branch staff with the exception that I would require an Alternative 3 design for these four plants. My recommendation is a modified version as Option 5 of the Heltemes-to-Gammil memo: I think Option 5 is preferable to Option 6 because it is more clearly based on a simple decision-principle --that of minimizing required design changes for standard plants. The justification for Option 6 seems to me to be more arbitrary and possibly also motivated by a desire to avoid the embarrassment which would be caused by the inconsistency of requiring substantially different safety system design changes for plants which are otherwise identical.

4. Summary and Conclusions

Regarding the treatment of ATWS as a general problem, the following points are important:

1. More currently unexploited opportunities are available for ATWS mitigation than prevention. This motivates the staff's emphasis on design remedies which enhance mitigation capabilities.

2. From the initial appearance of ATWS as a safety issue to the present day the basic justification for concern has been the inability to ensure that common mode failures will not make ATWS events unacceptably likely. Most of the argument about the probability of ATWS events has focussed upon such events arising from independent-random failures of scram system components, and does not address the likelihood of an ATWS event due to a common mode failure.
3. Common mode failures are not random events (except in the sense of being failures of human judgement), and their likelihood is inherently unknowable in a precise fashion.
4. The preceding point coupled with recognition that some ATWS events could have significant consequences justifies treatment of ATWS as a safety problem.
5. The general requirement for an ATWS design remedy is founded on a balancing of public safety benefits against economic costs.
6. It is proposed to require one class of design changes for plants licensed before 1 January 1978, and a second (more stringent) class of changes for newer plants.

Regarding NRC policies on nuclear plant standardization the following points are important:

1. Since the inception of the reference design concept the NRC has consistently promoted use of the various forms of standardized plants.
2. An assurance has been consistently imbedded in the NRC standardization policy that plants utilizing previously approved reference designs would be immunized from the minor required improvements in safety system designs (ratchets) which are more routinely imposed on custom plants during licensing. This assurance would only be revoked for "good cause."
3. There are currently 22 standard plants which either received their CP's after 1 January 1978 or are still in CP licensing:

My major conclusions, recommendations and comments are the following:

1. Requiring either Alternative 3 or 4 ATWS design changes on all nuclear plants would result in a major change in the safety of nuclear plnats; and would constitute "good cause" for requiring design changes in all standardized plants.
2. Given that Alternative 3 ATWS remedies will be required for old plants and Alternative 4 remedies for new plants, consistency between custom and standardized plants before 1 January 1978 should also be required to implement Alternative 3 design changes.
3. Given that future custom plants will be required to implement Alternative 4 ATWS designs consistency requires that future standardized plants meet the same requirement.

4. Respect for previous NRC standardization policy, assurances that design change requirements would be minimized for standardized plants--not having CP's by 1 January 1978--be required to implement Alternative 3 design changes. This position is also supported by concern for the goal of achieving an approximately uniform level of safety among different nuclear facilities (i.e. among otherwise identical plants which lie on opposite sides of the 1 January 1978 ATWS policy boundary), and for protection of the standardization program.
5. The current standardized plant ATWS recommendations of the Standardization Branch agree with my recommendations with the exception that the Erie 1&2 and Black Fox 1&2 plants would be required by the NRC staff to implement Alternative 4 designs. These plants are among the current standardized plants which were without CP's on 1 January 1978. The reason for treating them differently from their contemporaries is that their reference designs had not been used by any plants licensed before 1 January 1978. My recommendation is that these plants be permitted to use Alternative 3 ATWS remedies, contingent upon showing that for each plant the achieved level of safety will be consistent with that achieved by other standardized plants when Alternative 3 is used.