DEVELOPMENT OF A STRATEGIC PLAN FOR PERFORMING ANALYSIS IN SUPPORT OF AN OPERATING STATION: A POINT LEPREAU G.S. PERSPECTIVE

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by

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ABSTRACT

Safety analysis is traditionally viewed as a design related activity that is performed in order to obtain the Construction and Operating Licenses for a new plant. Its primary function is to evaluate and demonstrate the adequacy of Special Safety Systems, and to assess the overall plant design to ensure that safety objectives are met. Such analyses require large specialized resources both in terms of people and computing facilities and must be completed in a tight time frame consistent with the project schedule.

In contrast to the design stage, the operations phase requires a significantly different kind of analytical support. Besides ensuring that the analysis reflects how the station is actually operated and maintained, there is a need to provide on-going analytical support as the station ages in a timely and cost-effective manner. The establishment of a Safety Analysis group at Point Lepreau fulfilled this need. At the same time it optimized the use of off-site consulting services for the large scale technical effort required to address on-going topical safety analysis issues.

This paper follows from an earlier one which focused on the manner in which the on-site PLGS analysis group was formed (Reference 1). The intent of the present paper is to outline the functions of the group and to explain the process which has set the overall long term direction of the analytical program. A key element in the establishment of this process is the recognition of the eight basic components of analysis and the understanding of how they relate back to plant operation and maintenance. The rationale of how much effort should be expended and how these resources are allocated are also discussed.

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1. BACKGROUND

Atomic Energy of Canada Limited (AECL) performed the original set of safety analyses required to obtain the construction and initial operating licences for the Point Lepreau Generating Station. This was done over the time period from 1974, when site approval was obtained, to 1983 when the station was granted its full power operating licence. Although each submission to the Atomic Energy Control Board (AECB) was reviewed and approved by the experienced staff of the on-site NB Power licensing group, the analysis itself was performed off-site by the design organization as part of its defined scope of work. This approach was necessary for a variety of reasons which include:

- large volume of work,
- short time scale to complete the work to the satisfaction of the AECB,
- wide variety of experienced detailed specialists required,
- proximity to the Plant designers and detailed design information,
- awareness of relevant research and development work,
- familiarity with past licensing issues and safety analysis approach.
- large computational and associated administrative resources required,

During this period, the attention of the site staff was focused on those areas in which they had primary responsibility. These areas included design review, operator training, development of the commissioning and associated quality assurance programs, coordination with construction on scheduling for testing and turnover of plant systems, preparing operational documentation and managing the overall activities necessary to obtain the Operating Licence.

As the station entered its operating phase it became apparent that the analytical program which served its purpose during the design and construction period was no longer optimum. A new approach was required to address the emerging needs in a timely and cost effective manner. The primary factors which contributed to this evolution included:

- Poor operational perspective by the design staff was forcing the analysis to quickly become more of a paper exercise and bear little resemblance to that which should support the way the station is actually operated and maintained. This in turn generated a lack of credibility and hence usefulness and applicability of the analysis (and the Safety Report) in the minds of station staff.

- Lack of long-term commitment and continued responsibility on the part of the design agency for analytical support during operation led to a situation in which there was a lack of an overall long term plan both for analysis and its supporting standards, methods developments and associated R & D. This in turn, generated an ad-hoc reactive approach in which an inordinate amount of money and effort were being expended just to prevent losing more ground to address emerging issues.

- High cost of analysis combined with the lack of understanding or other spin-off benefits being transferred from the design agency to site staff resulted in an extremely poor cost/benefit ratio for the work being performed.

2. SAFETY ANALYSIS GROUP: ON-SITE CAPABILITY

The situation which was developing was unacceptable for NB Power for which the continued good performance of Point Lepreau was and remains crucially important to the provincial economy and to meet customer commitments. In deciding how best to proceed, NB Power reviewed its mandate and responsibilities. This is summarized as follows:

> The mandate of the utility is to provide safe, economic and reliable electricity to meet both current and future provincial demands. In the context of Nuclear Power, this implies ensuring that the design, operation and maintenance of the facility poses an acceptable level of health and safety risk to the public (as judged by the rules in effect when the unit was first licensed) and in doing so protect the operating license in a manner consistent with the allowable economic resources.

Translated into specifics, this means:

a) Ensuring that the plant is operated and maintained within acceptable bounds as demonstrated or judged by the analysis upon which the license is based. This requires that detailed requirements be clearly specified, and can be translated into clear and workable operating and maintenance practices and procedures through a set of measurable parameters with action levels and appropriate response times given and understood. (It should be noted that the approach, rigour and level of detail imposed on Safety Analysis by this requirement is far in excess of that which is characteristically performed in initially licensing the plant.)

b) Identifying and systematically removing deficiencies and shortcomings in past analysis (with priority on those issues affecting O & M practices) and take them to a consistent level of detail with quantified levels of uncertainties.

MISSION

To meet these objectives, NB Power decided to establish an on-site Safety Analysis group with specialized expertise in each of the key disciplines with the capability to:

- Develop and direct the long term analytical and R & D Program.
- Ensure compatibility between Design, Operation and Analysis (DOA).
- Provide support to operations on; response to questions and issues, perform impairment studies, assessment of events and design changes.
- Develop strategies and either carry out or direct analysis in response to licensing issues.
- Interact with station staff (including training and simulator groups) to enhance the importance and understanding of analysis in the effort of creating an improved safety culture at the station.

In performing these functions, the need to improve the understanding of the rationale and the basis of the overall analysis program was emphasized. Necessary steps were taken to produce supporting documentation in an easily understandable format for future reference. This helped to address operational issues on a sound technical basis and minimize potential conflicts which often arise between compliance activities and plant production.

To be cost effective, the size of the NB Power group was kept relatively small, with additional analytical effort being made available through various specialized consulting groups.

3. PROCESS TO ESTABLISH THE OVERALL PROGRAM DIRECTION

As it was recognized that a successful group must have an appropriate mix of both short and a long term plans, careful attention was given to developing and implementing a long term program. This program was put together based on the following process:

- Creation and review of the basic components of analysis (refer to next section).

- Assessment of the current state of each basic component.

- Applying the premise that the analysis is only as good as the weakest link, therefore, concentrate on the weakest components until they all reach equal strength and can progress together.

- Applying the premise that there will be a need for continued analysis until the plant is decommissioned; and therefore implement a long term program based on a review of priorities in each analysis discipline. In many instances this involves going back to basics to get an improved foundation of knowledge and using a "building block" approach.

- Seek out partners who will also benefit from the work and can contribute in sharing the cost and thereby off-set the increased cost of quality work. This is especially important in the early years where the payback from the upfront investment is still low yield compared to the later years.

- Fix up any "institutionally" related problems with analysis; based on review of past problems (see earlier section).

4. BASIC COMPONENTS OF ANALYSIS

The process described above hinges on the assessment of the basic components of analysis. These eight components are listed below and subsequently discussed.

1. Methodology & General Assumptions
   a) overall
   b) accident specific
2. Understanding of the basic physical processes that can take place during accidents in each discipline:
   a) reactor physics
   b) system thermal-hydraulics
   c) subchannel thermal-hydraulics
   d) fuel
   e) fuel channel
   f) moderator
   g) containment
   h) atmospheric dispersion

3. Computer code simulation of the physical phenomena in each discipline
   - a) development
   - b) verification
   - c) documentation
   - d) QC/archiving/ maintenance

4. Plant Representation (Model) of Process, control and safety systems
   - a) development
   - b) verification
   - c) documentation
   - d) QC/Archiving/ Maintenance

5. Assumptions pertaining to
   - a) O & M
   - b) equipment (eg. EQ/SQ)
   - c) R & D
   - d) overall plant response

6. Documentation
   - a) standard format
   - b) hierarchy
   - c) references to station documentation

7. Qualified, Knowledgable experienced Team of People and supporting resources
   - a) Training
     - basic sciences/Math
     - Design, Operation, Maintenance, Analysis, Licensing, R & D, etc.
   - b) Computers, station documentation, report production facilities, etc.

8. Funding

The first component (Methodology and general assumptions) comprises both general and accident specific items. It is based on a combination of Licensing rules and practices, knowledge of the expected plant response(including all the various operating modes and configurations), the physical processes which we expect to occur during the accident, and the ability of the current codes and models to capture the appropriate behaviour. This area received a lot of attention during the late 1970s and early 1980s, but has evolved only marginally since that time.

The second component refers to the knowledge provided by the R & D program. Information generated from this program feeds into a number of other areas; notably Methodology (Component 1), code development and verification (Component 3 a & b) and detailed specific assumptions pertaining to R & D (Component 5c). The R & D program has received a lot of attention over the years and has generated a vast amount of fundamental understanding and data which supports our current analysis. As work in this area tends to be very expensive, it is very important to know what R & D should be performed in order to support future analysis.

The third component refers to the computer codes used to simulate the extremely complex physical processes that are expected to occur during an accident. These codes simulate somewhat simplified phenomena and the uncertainty resulting in this approach must be reflected back in the methodology (Component 1). Code simulation uncertainty is one of the three ingredients (plant model and methodology being the other two) which make up the "simulation uncertainty". This must be determined in order to accurately specify instrument and process control uncertainty allowances in the plant. Although most codes have been "compared" or verified against R & D results, in most instances the R & D program has not provided enough detailed information upon which code simulation uncertainties can be rigorously determined. Note this imposes an additional demand (quantitative versus qualitative R & D) on Component #2.

As the codes are the analytical workhorse, it is imperative that they be maintained in excellent order and that their evolution and documentation keep pace in an auditable fashion, otherwise it will not be possible to know precisely what version of the code was used in a given piece of analysis.

The fourth component is subtly different from the third, but is used together with the code to simulate the response of a plant to an accident. These are referred to as plant specific models of the process, control and safety systems. Without an accurate reflection of the plant design in the models, the results simply bear no relationship to the actual plant. An over-simplified model also makes the tie into O & M requirements very complex. As these models are used in conjunction with the codes, they too must be documented, verified (to a stated accuracy), maintained and controlled. Again this is a big money sink if not approached and managed properly.

The fifth component relates to the specific assumptions that are made in conducting the analysis. One of the most important are those pertaining to O & M as they effectively set the limits to operation. Care must be taken to explicitly indicate and justify (relative to station documentation and practice) the O & M assumptions and the implications arising from them from the System Engineer/Operator/Maintainer perspective, as these effectively become requirements they must enforce. An operational perspective is useful here as it is difficult for a designer and theoretical analyst to think and hence document (at least without a guide) in a form that station staff find useful. The importance of making, justifying and documenting these assumptions cannot be over-emphasized, as it is unreasonable to penalize plant operation in terms of not meeting availability requirements when a crucial assumption is either buried implicitly in the generation of a model or methodology and hence is either outright unreported, or put in a non-comprehensible manner.

The sixth component is the manner by which the analysis is documented. With the exception of the archived code and model versions and critical output, the only historical account of actually performing an analysis is in the detailed analysis report and a summary contained in the Safety Report. As most analyses are complex and intricate, it is important to develop a format which will convey the detailed information necessary for others to understand what was done, why it was done, how it was done and what was found. The report must stand the test of time and allow other analysts (both internal and external) to reproduce the work, and to understand the assumptions and the results. A hierarchy of documentation such as that shown in Figure 1, helps bring most of the station related documentation together and ensures consistency with a minimum of duplication so that documentation configuration control is possible. By ensuring that all the documents in the hierarchy are kept up to date (i.e. through a process of either partial or complete revisions), the state of knowledge is documented and passed on with confidence in the technical content of all the references. This is an essential training component.

The seventh component is the existence of a team of qualified knowledgable experienced people which are supported by the necessary resources in the computational and report production areas. A team approach to analysis is considered necessary due to the complex interdisciplinary nature of the type of problem being solved. A complete team requires a mix of both generalists and specialists who collectively can cover all the following areas: the higher sciences and maths, plant design, operation, maintenance, licensing, analytical techniques, R & D, etc. It is not only important to set up a good winning team, but since people move around, it is imperative to manage this critical resource well and to establish training programs and material to produce qualified analysts in as short as time as possible so that a balanced stable work force is maintained. This team also clearly requires the necessary computational and report production resources which can smoothly evolve and keep pace with the natural evolution of the other components. Inadequate resources or team isolation (both internal and external) will quickly undermine the group.

The eighth component (funding) is of course essential. This is discussed at the end of this paper.

5. PROGRAM IMPLEMENTATION

Having identified and studied the basic components of analysis, work got underway to re-enforce the weak areas. As programs began to take effect, the list was again reviewed and the process repeated. Some of the major areas where changes were introduced are summarized below.

i) The team concept was introduced into analysis. Individuals were selected crossing many disciplines. Although this team works mostly on one project, care is taken to avoid isolationism. By holding frequent review meetings the evolving approach and viewpoint can be effectively communicated. "Brainstorm" sessions encourage people to participate and contribute to a pride of ownership as well as an improved product. Centralized control ensures well needed consistency across the disciplines but allows for evolution.

ii) An upfront step in the analysis, referred to as the AMAD, was introduced whereby the Analysis Methods, Assumptions and Data (including the precise code and model versions to be used) are produced, documented and approved prior to the start of what used to be classically viewed as the "analysis". This AMAD section (appropriately revised if needed during the course of analysis if unforseen problems are encountered) becomes a part of the standardized report. Other sections of the report include: behaviour (which outlines how the plant is expected to respond and what physical processes are taking place in each discipline at various times during the accident), the AMAD (which in addition to the above, outlines the various simplifications in the methodology which must be made in order to make the analysis tractable) the results, which can differ from that discussed in the behaviour section due to the simplifications outlined in the AMAD section. Sections providing the archive file locations, as well as a final summary are also included. The format for the detailed analysis report is also followed in the Safety Report which summarizes the analysis. As much of the early analysis was not reported separately, the Safety Report became very detailed. In the future as these analysis are superseded and documented in separate detailed reports, the level of detail in the Safety Report can gradually be reduced, and more emphasis placed on O & M requirements.

iii) Development of Standards for Codes and Models

It was clear that the utility in conjunction with the developer must share the responsibility for the maintenance and upkeep of certain critical codes. It was therefore necessary to create an up-to-date list of critical codes and to develop rules for their application. The key features are summarized below:

Each code and model version must be uniquely identified using a format common throughout all analysis disciplines and one which facilitates multi-users, different sites and different computer systems; for example, NUCIRC Mod. 1.504 PL3 VAX.

Each new version must be accompanied by a release form to update all the affected parties and users. The collection of release forms provides a summary of the evolution of the code/model and links together the formal documentation of the base versions which are updated only periodically.

The analysis report must clearly specify which precise versions were used. All versions used in analysis must be archived for an indefinite period of time.

- Code and model changes are to be approved by the code boss.
- Anyone finding an error must report it promptly to the code boss who will then initiate a fan-out of this information.

In addition to the requirements, NB Power also outlines a philosophy for guiding development. The central concept involves a modular approach to allow for the ease of documentation and control as well as encouraging transportability from one code to another to avoid reinventing the wheel. A building block versus an ad-hoc approach allows the modelling to evolve forward over time and to have less "stand alone" models which are costly to maintain and generally must be upgraded before they can be used again. This concept eventually leads to more flexible and robust codes and models and minimizes the overall cost.

Each major code should have a long term development plan (unless it has reached true maturity) which is prioritized and fits logically into the R & D strategic plan and future needs of analysis. Such plans exist for the CATHENA, PRESCON and PHOENICS codes.

Finally, efforts should be made to consolidate codes down to a small number of well written, documented and verified versatile general purpose codes, which run specific plant models. This again is cost effective in the long run since not only is code maintenance expensive, but each code has its own idiosyncracies and widely used general purpose codes have an inherent advantage in a wide base of user support and familiarity than a highly specialized code to which consideration must be given to keeping select individuals on the regular payroll or risk effectively loosing the technology over time. These factors often sway the balance in decision making away from what superficially appears to be a quick, and simple way to go, since the utility will be carrying, and hence paying for, that decision and its implications, long into the future.

(iv) IMPROVEMENT TO PLANT MODELS

The oversimplification of the plant representation in the original analysis led to many difficulties which were not easily rectified. The least of which was that the lack of detail resulted in not only poor simulations, but of forcing many important assumptions pertaining to plant systems not being stated since portions of the systems were not explicitly modelled. In response, a model improvement program was introduced to all major systems considered in the analysis. In addition to following the philosophy and code requirements outlined in the previous section, improved codes and models were tuned against site data and the simulation uncertainty of the plant models derived from relevant commissioning and special tests, as well as plant transients. To facilitate future development, a standard format (Reference 2) was derived whereby each system would be characterized onto a database from which the analyst draws upon to develop the required level of detail in the model. In addition to more conventional means, the database is checked for errors by utilizing a cad-graphics program and seeing if critical piping endpoints are correctly placed in the 3-D space. Use of a data base implies that apart from upkeep to keep abreast of design changes; that the activity is performed only once. Previous methods required a review of the drawings each time a model was developed.

New developments in file management show promising signs of being able to couple separate system models together easily. With the use of this approach both a detailed and simplified representation of a given plant system can be developed. The analyst can then choose between a variety of models depending on the nature of the problem he is solving. In this fashion run time and storage space can be minimized. Even though computers are steadily becoming more powerful and faster, these factors are still major considerations as they force many otherwise unnecessary simplifications.

IMPLEMENTATION OF PROJECT DOA

In order to systematically ensure consistency between Design, Operation and Analysis, NBPC implemented project DOA. The approach (discussed in detail in Ref. 3), involves a careful review of a given systems components (by following the operational flowsheets) to identify, discuss and document the requirements arising from either design, analysis, or licensing points of view. This review encompasses both the process as well as control functions and is designed to improve related documentation such as Design and Operating Manuals, Test Procedures, Impairments Manual, Maintenance Manuals, Training Manuals, and Emergency Operating Procedures.

The DOA process produces a data sheet on each component. This sheet identifies the component, outlines its function, provides a description of the component (including explicit drawing references for future quick access), states location (for use by analysts involving EQ global and local (jet impingent/pipe whip) issues. A list of parameters, that can vary day to day or season to season, are then listed (even passive components such as tanks have contents that vary). A discussion is then provided as to whether the given variable can adversely effect system performance, and if so, specify its allowable range. If a parameter is considered critical, then its associated indication is also considered critical. A similar list and discussion is also provided for "non-variant" parameters as these are important to modellers and might change if the component ages significantly or is replaced, yet they should normally occupy a position of secondary importance with the site staff since they do not routinely vary. Other considerations such as environmental and seismic qualification requirements, as well as periodic inspection and testing requirements are also provided. Where other documents exist giving detailed requirements, the DOA document references these "basis documents" and hence acts like a road map to where all the critical information can be found.

The DOA process has shown the importance of more detailed and explicit plant models and AMADs. These have/are being incorporated accordingly. For instance, if a parameter associated with a given component is considered critical (say level in a tank) then the model should explicitly input both the indicated (unsafe fault) value as well as the instrument uncertainty (under both normal and upset conditions). If necessary the model must contain a pre and post processor to convert the measured parameter (in this instance level) into one used in the code (volume). In this fashion the relationship (both geometric and tap reference) between level and volume are established once and properly documented (as part of the model) allowing analyst and system engineer to speak the same language. In a similar context, O & M staff do not want to know what enthalpy was assumed if their instrumentation is based on temperature. Although these examples are relatively simple, they eliminate a source of confusion between analyst and site staff that could, from a human factors perspective, possibly lead to unnecessary errors. DOA feeds back into the analysis, operational perspective of what can be controlled, and what is measured along with what is important. It also ensures the appropriate operating envelope and allowances are taken into account based on how the plant is actually Operated & Maintained.

The subjects discussed above are all in place and proceeding smoothly. Attention is now being focused on producing the NBPC version of the R & D strategic plan to ensure that the R & D reflects the users end needs (Component 2). The process which is currently being undertaken is aimed at producing an end result from the R & D program, of a well defended value for simulation uncertainty for the various aspects of safety analysis. This in essence leads to a program of quantifying the current level of uncertainty for the various accidents in the matrix. This is necessary in order to both rigorously specify accuracy requirements on station instrumentation and to have a strong defense of trip coverage and dose preditions. The process which is being followed in each analysis discipline; is to compare the actual plant geometry and operating modes and conditions in conjunction with the actual physical processes that are expected to occur in response to an accident (viewed across the entire accident analysis matrix) and identify, analyze and prioritize the simplifying assumptions arising from the use of the current generation of methodology, codes and models. This process will generate a long term list which will guide NBPC input to COG, based on the users needs.

In addition to work on the strategic plan, attention will soon be focused on a review of methodology to ensure the various modes of plant operation and the desired operating envelopes (Component 1) are properly reflected and that EQ is properly integrated into analysis methodology, and finally to develop a strategy for analyst training (Component 7).

CONSTRAINTS

This paper would be incomplete if it did not discuss the issue of how much money should be funnelled into this type of activity (Component 8). This of course is a difficult philosophical issue. The answer to the question of how does a utility balance what they feel must be done and what they would like to do against what they have available and feel is justifiably right and proper, does not come easy. This issue is made even more nebulous when one looks outside the nuclear industry and observes the disproportionate amount of money being spent on reactor safety and licensing. In many instances, not only is risk reduced, but also lives can be demonstrably saved by channelling these funds into such items as critical road improvement or establishment of cancer clinics, etc. Nonetheless, one cannot deny the **perception** of uniqueness of our industry, and the long lead time required to develop the analytical technology required to address the questions and issues of tomorrow. Failure to adequately invest in such activities, while showing short term financial gains, will however manifest itself later on down the road.

The bottom line is that the safety objectives discussed earlier in this paper must be met and demonstrated convincingly with quality analysis that is both firmly supported and will survive external scrutiny; and that the cost of the Safety & Licensing program for a unit is supported as follows: The cost of acquiring the construction and initial operating license be included in the capital cost of the unit, and the ongoing Safety and Compliance program (including R & D) be fully supported through the units O & M budget. This is therefore directly reflected in the provincial power rates and hence subject to review through processes like the Public Utility Review Board. Unrealistic escalation of expectations on either the part of the designer, marketer, utility or regulator simply must be held in check if the nuclear option is to remain viable (for existing as well as new plants).

NB Power currently spends about $5.3 million per year on its Safety & Licensing related activities (this includes about $1 million on Safety & Licensing R & D but excludes the $1.7 million/year AECB "Licensing fee".) This represents about 8% of the yearly O & M budget,* which we feel is an appropriate balance. As about $3 million per year are set aside for Safety Studies, and some studies now cost upwards of $1 million to complete, there is strong incentive to both spread the work out over time, and to find partners for the work. NB Power has been relatively successful on both accounts. Given a 30 year outlook on analysis has allowed us to "pace" ourselves. In addition, close co-operation with Hydro Quebec and AECL projects such as the CANDU-3 has provided not only shared costs but additional technical resources and much valued additional perspectives.

RATIONALE FOR DISPLAYING RESOURCES

NB Power uses the following rationale in allocating manpower and money on analysis issues:

1) Divide items between short and long term issues. A holistic view of the universe can often turn many short term fire fighting issues into a component of a long term project; and

2) Once all the basic analysis components are at equal strength, try to spread the long term funding equally across these components and disciplines.

*** includes fuel costs and cost of PT replacement but excludes capital costs and depreciation.**

BENEFITS OF THIS APPROACH

The approach described in this paper is essentially a living process geared to making response to on-going and future issues quicker, easier and more technically sound, as a result of investing in the technology and by the pursuit of understanding. It is heavily slanted towards a pro-active versus reactive approach and hence avoids the problems associated with an ad-hoc approach to issues which can consume far too much time and effort. Although this method involves upfront planning time and effort, it is expected to produce significant long term savings due to improved efficiency and stability of key resources. Finally, by taking a limited but progressive approach to the issue of analysis, the utility clearly shows that it takes its responsibility for safety seriously. This concept of course lies at the heart of our industries philosophy and that which makes the domestic CANDU industry unique.

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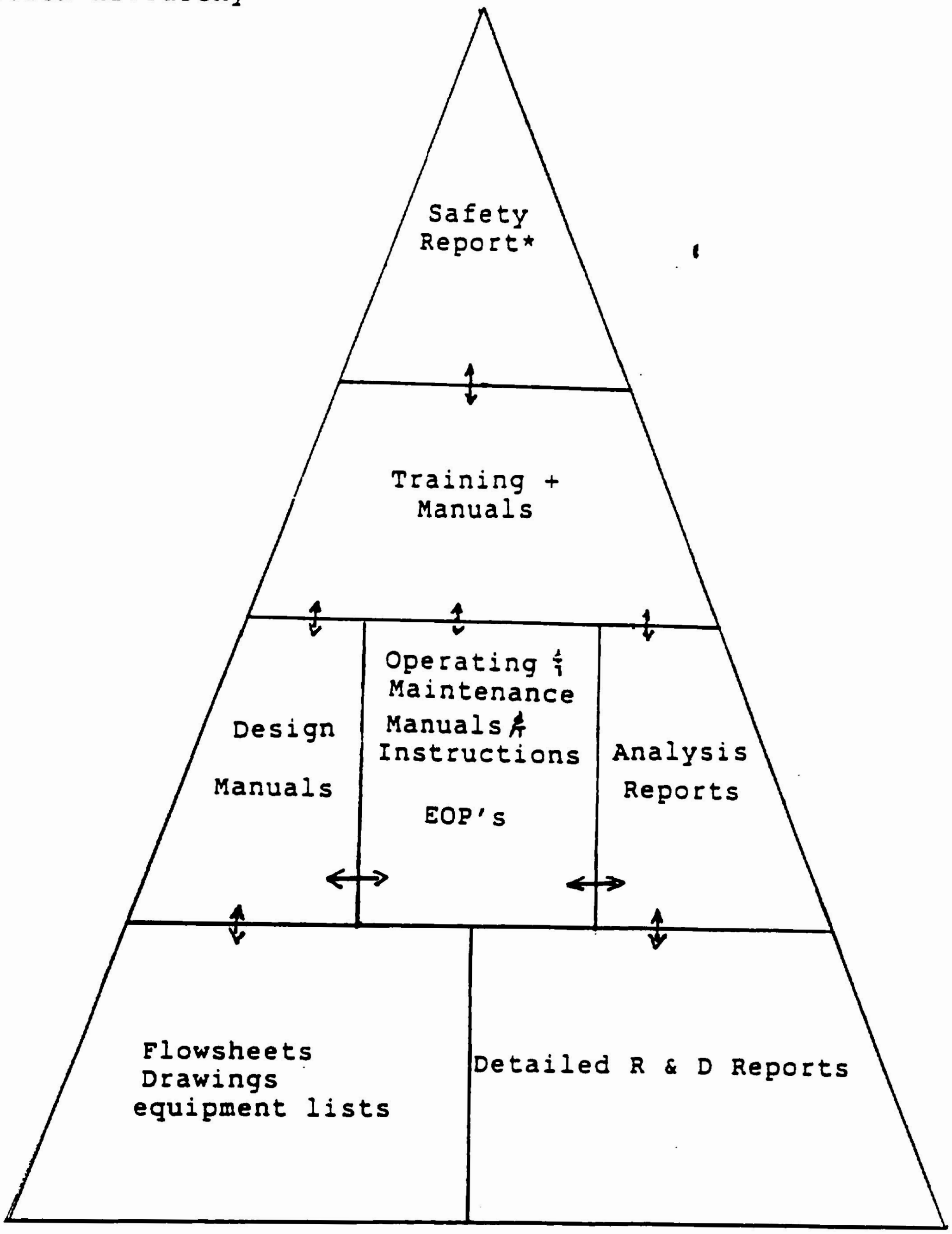
FIGURE 1

Documentation Hierarchy



+ dedicated for Training
* includes summary of R & D