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OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

The Effects of Supervisor Experience and Assistance of a Shift Technical Advisor (STA) on Crew Performance in Control Room Simulators

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This Work Performed For
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THE EFFECTS OF SUPERVISOR EXPERIENCE AND ASSISTANCE OF A SHIFT TECHNICAL ADVISOR (STA) ON CREW PERFORMANCE IN CONTROL ROOM SIMULATORS

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LIST OF ABBREVIATIONS

AFW	auxiliary feedwater
AI	analog input (continuously variable controller)
AMRL	Air Force Aerospace Medical Research Laboratory
AN	annunciator
ANOVA	analysis of variance
AO	analog output (parameter value)
BOP	balance of plant operator
BWR	boiling water reactor
CSF	critical safety function
CV	critical value
DI	digital input (control action)
ECCS	emergency core cooling system
F	test statistic for analysis of variance/covariance
gpm	gallons per minute
IRM	intermediate range monitor
KV	kilovolts
LO	lead operator; also logical output (indicator lamp) in PMS data
LOAD	turbine loading scenario
LOFW	loss of feedwater scenario
M-G	motor generator
MANOVA	multivariate analysis of variance
MSIV	main steam isolation valve
MSLB	main steam line break scenario
MWe	megawatts (electric)
n	number of individuals
NPP	nuclear power plant
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
OSO	operating sequence overview
p	probability
P/L	preconditions and limits

P-Lvl	pressurizer level
PMS	Performance Measurement System
psi	pounds per square inch
PWR	pressurized water reactor
r	Pearson product-moment correlation coefficient
R	coefficient of multiple correlation
RCS	reactor coolant system
REP	radiological emergency plan
RHR	residual heat removal system
RMS	root-mean-square
RO	reactor operator
RWST	refueling water storage tank
Rx	reactor
SCM	subcooling margin
sd.	standard deviation
SG	steam generator
SGL	steam generator level
SGTR	steam generator tube rupture scenario
SI	safety injection
SP	setpoint
SRM	source range monitor
SRO	senior reactor operator
STA	shift technical advisor
SUP	supervisor
SWAT	Subjective Workload Assessment Technique
TDF(D)	task data form (descriptive)
TOB	time-out-of-band
TPC	task performance criteria (data form)
TPIC	task performance identification checklist (data form)
TRIP	turbine trip scenario
TSC	task sequence chart (data form)
UHI	upper head injection system
VT	videotape
$\overline{X}$	mean
Z	deviation score

ABSTRACT

This report describes the second experiment in a Nuclear Regulatory Commission-sponsored program of training simulator experiments to evaluate the effects of selected performance shaping factors on the performance of nuclear power plant control room operators. The factors investigated were the experience level of the Senior Reactor Operator (SRO) in the supervisor's role and the presence of a Shift Technical Advisor (STA) to assist the operating crew.

The experiment was conducted in the plant-referenced training simulator for a 1100 MWe pressurized water reactor (PWR) plant. Data were collected from 20 three-man crews of licensed operators. The crews were split into "high" and "low" experience groups on the basis of the supervisor's years of experience as an SRO. One half of the high- and low-SRO experience groups were assisted by an STA. The crews performed four exercises, a turbine tie-on and three plant casualties which ranged in severity from an uncomplicated steam generator tube rupture to a major steam line break with loss of coolant and primary makeup water.

Two sets of content-referenced performance measures were derived from task analyses of the procedurally correct responses to the four casualties. One set of measures focused on task performance, e.g., counts of tasks initiated, task elements performed correctly, and the time taken to execute the required sequences. The second set of measures was based on control of system parameters related to maintaining plant critical safety functions. Comparative analyses of instructor subjective rating forms and the performance of license trainees were conducted to validate the performance measures.

System parameters and control manipulations were recorded by the computer controlling the simulator. Data on communications and selected verifications were obtained from checklists completed during review of videotapes of the exercises. Questionnaires were used to collect biographical information and data on the workload experienced by the participants during each exercise.

No significant differences in overall performance were found between groups led by "high" and "low" experience supervisors. The presence of the STA had no effect on overall team performance. These results were identical to the results of a similar experiment performed with BWR crews in 1983.

The reported workloads of supervisors assisted by STAs were significantly lower than the workloads reported by those who were not. The reported workload of STAs was significantly lower than the workloads of the operators (ROs and SROs) for all sequences. There were significant differences in perceived workload for the four operating sequences, corresponding to the relative severity of the events.

The results of the experiment suggested that, within the range of supervisor experience examined, years of control room experience may not be an important predictor of performance. For the sequences examined, the presence of an STA does not contribute significantly to crew performance but may reduce the workload of the supervisor.

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As Project Manager for the U. S. Nuclear Regulatory Commission, Mr. John C. Lowry defined the objectives of the project and provided insightful criticism of the experimental design.

Lee Ashton and Paul Schmidt assisted in the analysis of the operating sequences used in this study, and also contributed immeasurably to the authors' understanding of the functioning and operation of the plant. The programming expertise of Mr. Robert Utterback made it possible to automate large portions of the scoring of the operators' performance. Mr. C. Michael Lewis of the Georgia Institute of Technology created a system of programs for reducing the large volume of data collected and assisted in the statistical analysis.

The project is indebted to Mr. Gary Ried of the U. S. Air Force Aerospace Medical Research Laboratory for supplying the Subjective Workload Assessment Technique scaling materials and performing the computations required for scale development.

1. INTRODUCTION

1.1 Background

In March of 1983 Oak Ridge National Laboratory (ORNL), under the sponsorship of the U. S. Nuclear Regulatory Commission (NRC), Office of Nuclear Regulatory Research, initiated a research program entitled "Training Simulator Experiments." The primary objective of the program was to develop a data base on nuclear power plant (NPP) operator performance during abnormal/emergency events for use in addressing various issues associated with the operational safety of NPPs, including: (a) the adequacy of control room staffing requirements; (b) the effectiveness of symptom-based vs. event-based procedures; (c) the relationship between a control room operator's education level and job performance; (d) the relationship between a control room operator's acquired experience and job performance; and (e) the effectiveness of operator aids during off-normal events.

The principal source of data for the project is a set of experiments conducted in full scale, high fidelity NPP control room simulators. NRC licensees voluntarily participate in the experiments, contributing the time of their staffs (e.g., licensed operators, training specialists) and the use of their simulators. Each experiment consists of a series of predefined exercises to which operating crews respond in the simulator. Automated data recording, observation, videotaping, and self-report questionnaires are used to obtain individual and crew performance measures for each simulator exercise. As an adjunct to the simulator experiments, the project utilizes field data (e.g., plant records, operator's logs) to establish the credibility of operator response to each simulator exercise. The field data collected in conjunction with this project will be described in a separate report.

1.2 Purpose of the Experiment

The current series of simulator experiments was designed to provide information on performance shaping factors relevant to regulatory consideration of the qualifications and training of nuclear power plant control room crews.

The initial experiment performed for this project was conducted at a boiling water reactor (BWR) simulator in the fall of 1983 (Ref. 1). The purpose of the initial experiment was to investigate the effects of Senior Reactor Operator (SRO) experience, the presence or absence of a Shift Technical Advisor (STA), and practice as a crew on operating crew performance during four anticipated plant transient exercises. The basic operating crews in the 1983 experiment consisted of one Reactor Operator (RO) and one SRO (the minimum crew required by the plant's license and one man less than the normal operating crew). The specific questions addressed by the experiment were:

1. Do operating crews led by more experienced SROs perform better than operating crews led by relatively less experienced SROs?
2. Do operating crews augmented by an STA perform better and/or experience lower perceived workload than do operating crews without STAs?
3. Does operating crew performance improve as a function of the crew's practice in working with the STA?

The second experiment, which is described in this report, was planned as a partial replication and extension of the 1983 experiment, but with pressurized water reactor (PWR) operators, and was undertaken to:

1. ensure the reliability and generality of the findings of the 1983 experiment;
2. further develop and refine the performance measures employed in the first experiment;

3. extend the range of operating sequences to include true emergency conditions (where the STA's contribution may become more critical) in addition to the anticipated transients employed in the 1983 experiment; and
4. obtain data with which to validate the performance measures used in the 1983 and 1984 studies.

1.3 Report Organization

The remainder of this document is divided into seven sections:

Section 2. Objectives, hypotheses, and experimental design;
Section 3. Method;
Section 4. Performance evaluation;
Section 5. The effects of supervisor experience and the presence of an STA on crew performance;
Section 6. Subjective workload;
Section 7. Summary and conclusions; and
Section 8. References

Supporting materials are presented in seven appendices.

2. OBJECTIVES

Within the range of issues enumerated in Section 1.1, priority emphasis was placed on issues regarding the training and qualifications of NPP control room personnel. Two issues of immediate interest were the amount of plant operating experience required for an operator to perform effectively as a SRO and the desirability of a requirement that a crew member have degree-level engineering expertise, a requirement currently filled by the STA. The experiments performed in 1983 and 1984 were designed to address these issues by collecting performance data using a plant-referenced training simulator and currently available operations personnel.

2.1 Planned Analyses

In structuring the design of the current experiment, specific analyses were planned to address the issues of supervisor experience and the contribution of the STA. These analyses were similar to those performed for the 1983 experiment but were modified to overcome some of the limitations of the earlier study.

2.1.1 Supervisor Experience

The analysis was developed to focus on the effect of supervisor experience on overall team performance. The supervisor has primary responsibility for the direction and integration of control room crew activities. Therefore, of all crew members, the supervisors' prior experience and training were expected to have the greatest effect on overall crew performance.

The results of the 1983 experiment (Ref. 1) indicated that, with the exception that crews led by less experienced SROs responded more rapidly than crews led by more experienced SROs, there were no differences in overall performance due to the experience level of the SRO leading the crew. However, in that study even the least experienced SRO had 40 months experience as a licensed operator. The absence of significant

performance differences as a function of SRO experience may have been an artifact of the population available for the experiment: proficiency may reach near-asymptotic levels for licensed operators beyond a given level of experience.

The approach taken in the 1983 study was essentially conservative, in that all operators were fully qualified for the roles they assumed in the experiment. This was done to insure that the results of the experiment could be generalized with some confidence to the population of interest, licensed operators at commercial plants. As it happened, even the less experienced SROs had considerably more operating experience than the minimum required for the SRO license. If the question of "the minimum level of experience" required for SROs is to be examined empirically, it is desirable to include the range of experience from newly licensed operators through the levels represented in the 1983 experiment. The 1984 experiment therefore employed operators having a wider range of experience levels (as measured by months since the first NRC operator license was awarded) in the supervisor's position.

2.1.2 STA Addition

In the 1983 experiment, the effect of the addition of an STA to the control room crew on crew performance was examined for four anticipated transients. The scenarios employed in that experiment were not expected to require the engineering expertise of the STA, as detailed procedures were available for dealing with each transient. However, there was a need to test an assumption that the primary contribution of the STA to crew performance involves events which challenge the STA's engineering expertise. By examining events which presumably did not involve extensive engineering expertise, the study provided a baseline for comparison with crew performance in emergency events designed to challenge the STA's engineering expertise. Although there was a tendency for the STA-assisted crews to achieve slightly higher scores on the task performance measures, the differences obtained were not large enough to achieve statistical significance.

The present experiment employed a wider range of exercise difficulty*, including a routine evolution, a more severe analysed transient, and a severe accident sequence, so as to better test the contribution of the STA.

2.1.3 Validation

In addition to the data necessary to perform the analyses described above, supplementary data were collected for the purpose of validating the system of performance measures employed in the experiment.

2.2 Hypotheses

The present experiment was structured to yield data on the three questions stated below. The specific hypotheses derived from these questions are simply testable propositions that may be supported or not supported by the data. Failure to support a hypothesis, particularly the finding of no difference between experimental groups, also may provide meaningful information regarding the larger question from which the hypothesis was derived (see Reference 2).

(1) Do 3-man control room crews led by more experienced supervisors perform better than crews with relatively less experienced supervisors? It is hypothesized that crews led by high-experience supervisors will exhibit better performance than crews led by low-experience supervisors (H-1).

(2) Do crews augmented by an STA perform better than crews without such assistance? It is hypothesized that the presence of an STA contributes to the effectiveness of the crew, *i.e.*, that crews assisted by an STA will perform better than similar crews without an STA (H-2).

*There is no agreed-upon metric of scenario difficulty. In these experiments we have used perceived workload as a rough measure of relative difficulty.

(3) Does the performance advantage of crews augmented by the STA vary as a function of the difficulty of the operating sequence? It is hypothesized that the contribution of the STA will have a greater effect on performance during the more difficult sequences, i.e., the difference in performance between the STA and No-STA groups will be larger for the more difficult exercises than for the less difficult exercises (H-3).

(4) It is also hypothesized that the benefit afforded by the STA will be greater for crews led by relatively less experienced supervisors than for crews led by more experienced supervisors (H-4).

2.3 Design of the Experiment

The experiment was of a three factor design, with two between-subjects factors: 1) the supervisor's months of experience as a supervisor and 2) the assistance or absence of an STA, and one within-subjects factor, "scenarios," as shown in the diagram below. The subscripts indicate the number of crews in each cell of the design.

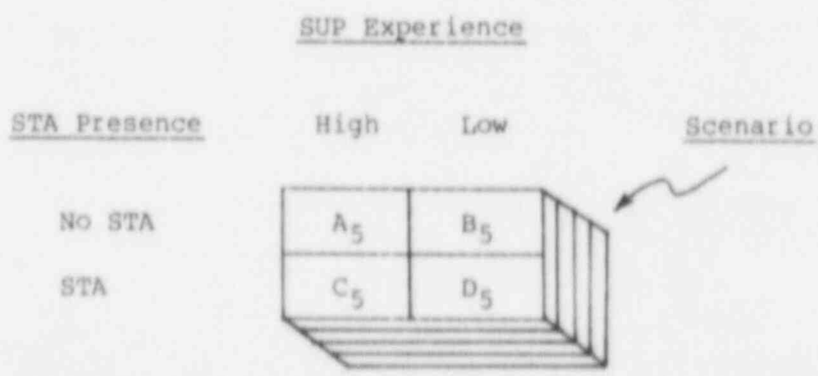

Figure 2-1 Diagram of experimental design.

In the above design, comparison of groups A and C with groups B and D allows a test of hypothesis H-1, that crews led by high-experience supervisors will exhibit better performance than crews led by low-experience supervisors. Similarly, comparison of groups A and B with groups C and D allows a test of hypothesis H-2, that crews augmented by an STA will perform better than similar crews without an STA.

Comparing the performance of the STA and No-STA groups across the range of scenarios employed provides a test of hypothesis H-3 that the differences in performance between the STA and No-STA groups will be larger for the more difficult exercises than for the less difficult exercises, which would be indicated by the "presence of STA" by "scenario" interaction. The interaction of "supervisor experience level" with "presence of STA" provides a test of hypothesis H-4 that the benefit afforded by the STA will be greater for crews led by relatively less experienced supervisors than for crews led by more experienced supervisors.

3. METHOD

The experiment was conducted in the plant-referenced training simulator located at the site of one of the two participating plants, which were both two-unit Westinghouse PWRs. This section describes the subjects, scenarios, simulator, and data collection instruments and procedures.

3.1 Subjects

The subjects for this experiment were licensed operators and STAs undergoing requalification training. The participating utility provided operators from two PWR plants of similar design. Plant "A" was currently operational; Plant "B" was sufficiently near completion for the issuance of "cold" licenses to the operators. Operators from both plants trained in the plant-referenced simulator for Plant A, which was used for the experiment. The engineering design of both plants is similar with very few variations in control panel layout between the two plants. These operators participate in four 5-day sessions of refresher training over the course of a year. A training group usually consisted of four to six men, one or two ROs, two SROs, and one or two STAs, who were selected for assignment to training on the basis of the plant's operational schedule.

Since crews from two plants participated in the experiment, it was important that the design minimize the potential effects of this extraneous factor. The experiment employed 20 3-man teams made up of one SRO supervisor (SUP) and two ROs. Twelve of the crews, numbered 1 through 12, were from Plant A, and the remaining eight, crews 13 through 20, were from Plant B. The "plant" factor was controlled (balanced-out) simply by having equal numbers of crews from each plant in each experimental condition, i.e., three of the five crews in each cell of Figure 2-1 were from Plant A, and two from Plant B.

The normal operating crew for each unit consists of one SRO-licensed unit supervisor and two RO-licensed operators. One of the ROs is responsible for the operation of the reactor and associated safety systems and

is designated the lead operator (LO). The second RO is responsible for the operation of the secondary side of the plant and is called the balance-of-plant (BOP) operator. When a unit is operating, a second SRO, the shift supervisor, is on duty in the control room, and an STA is on duty in an office nearby. In the experiment, the unit crew was left to deal with each exercise on their own, without the assistance or direction of the shift supervisor.

The experimental groups were formed on the basis of the supervisors' experience. The SROs leading the crews were split into "high" and "low" experience groups on the basis of their months of experience as an SRO. The dividing point in the operator population of Plant A was 18 months experience as an SRO, as determined from a listing of operator experience supplied by the training center. All SROs in the SUP-low groups from Plant A had at least two years of experience as an RO, and many had much more. For operators from Plant B, the range of experience was very different: all of the participating operators had been licensed in the eight months preceding the beginning of data collection. However, 7 of the SROs had earlier held RO and/or SRO licenses at Plant A. For the Plant B SUP, the distinction between more and less experienced was based on the possession of prior licensed experience at Plant A, and thus represented a fairly clean dichotomy between experienced and truly inexperienced supervisors.

One half of the high- and low-SUP experience groups were assisted by an STA. The experimental design (diagramed in Figure 2-1) divided the 20 operating crews into four groups of five teams* each:

A. "SUP-high, No-STA": High-experience SRO + 2 ROs (crews 1-3, and 13 & 14)

*The terms "crew" and "team" are used interchangeably throughout this report. The term "group" refers to a set of crews. For example, "the STA group" refers to the 10 crews in groups C and D who were assisted by an STA.

B. "SUP-low, No-STA": Low-experience SRO + 2 ROs (crews 4-6, 15 & 16)

C. "SUP-high, STA": High-experience SRO + 2 ROs + STA (crews 7-9, 17 & 18)

D. "SUP-low, STA": Low-experience SRO + 2 ROs + STA (crews 10-12, 19 & 20)

Table 3-1 shows the average number of months of experience as a licensed operator for all groups in the experiment. A detailed tabulation of the experience and education of the individual participants is presented in Appendix A.

Table 3-1 Months since license for SUPs and "ROs"

PLANT A		First License			SRO License		
Position	Group	$\overline{X}$	sd.	Range	$\overline{X}$	sd.	Range
SUP	HIGH	48[a]	9	36-57	41	17	23-57
SUP	LOW	42	8	35-56	11	6	3-18
"RO"[b]	HIGH	26	22	3-56			
"RO"[b]	LOW	29	22	3-58			
PLANT B		**First License**			**SRO License (Plant B)**		
Position	Group	$\overline{X}$	sd.	Range	$\overline{X}$	sd.	Range
SUP	HIGH	53	7	45-60	10	2	7-12
SUP	LOW	4	1	3-5	4	1	3-5
"RO"[c]	HIGH	10	17	1-52			
"RO"[c]	LOW	15	32	1-94			

a. Tabled figures are rounded to the nearest whole month. The data in this table are derived from the biographical data presented in Appendix A.

b. "RO" groups include individuals licensed as SROs who filled RO roles in the experiment.

c. Plant B "ROs" include individuals with prior licensed experience at Plant A.

Because of the relative scarcity of ROs in the requalification groups, one of the positions normally filled by an RO was filled by an SRO in 15 of the 20 crews. When it became evident that a large proportion of the RO positions would be filled by SROs, an attempt was made to balance the four treatment groups with respect to this potentially important factor.* The "ROs" were selected from the other operators available in the training group so that the average level of experience for the two operators in non-supervisory roles was an similar as possible for all groups. Since we could not control the assignment of operators to training groups, it was not possible to completely balance the RO-SRO mix in all treatment groups. However, over the 20 crews, the number of SROs in RO positions were nearly equal in the high- and low-SUP experience groups (7 and 8, respectively) and in the STA- No-STA groups (8 and 7). Further, 7 of the SRO "ROs" were in the LO position, and 8 in the BOP position. The proportions of SROs in these positions were nearly equal in the STA and No-STA groups, but <u>not</u> in the high- and low-SUP experience groups.

In addition to the 20 teams of licensed operators, two teams of prelicense trainees performed three of the experimental scenarios. The data from these groups were used in the validation analysis described in Section 5.

3.2 Operating Sequences

In consultation with the utility, five operating sequences (exercises) were selected for the 1984 experiment:

(1) the turbine-loading segment of a unit startup (LOAD);

(2) turbine trip during startup (TRIP);

*Unfortunately, this did not become evident until data collection was more than half completed. The number of ROs who did not appear for requalification training as scheduled was much higher than the number of SROs who did not.

(4) total loss of feedwater/loss of 6.9 KV shutdown board (LOFW); and

(5) main steam line break (MSLB) outside containment with a steam generator tube rupture and puncture of the refueling water storage tank.

These five sequences were chosen to represent a range of difficulty from the routine (LOAD and TRIP) to the MSLB, which was a severe accident precursor sequence developed by the utility's instructors to challenge the crew and invite increased participation by the STA. The events are described briefly in the Operating Sequence Overviews (OSOs) and Task Sequence Charts (TSCs) attached as Appendix B, which follow the format of the NRC Crew Task Analysis (Ref. 3).

It was planned that each of the 20 crews of licensed operators would complete all five scenarios. The three trainee groups were to perform the turbine loading and the three analysed transients, but not the MSLB sequence. The first data collection was on a trainee group from Plant B. During this session it became evident that a) it would not be possible to perform all five sequences in the time available, and b) the trainees (and presumably the licensed operators as well) were well-drilled in the responses to the SGTR. The SGTR and TRIP sequences were the most routine, and the TRIP sequence was of interest because a number of such routine trips had occurred at the Plant A, so there were records of actual performance to compare with the simulator data. Accordingly, it was decided to drop the SGTR sequence. However, after data had been collected from five teams of licensed operators, it was decided that the SGTR sequence should be used in place of the TRIP, because the TRIP sequence was not challenging the crew's ability to maintain critical safety functions. The SGTR represented a far more serious threat to the safe operation of the plant, and was judged far more likely to occur in real life than the LOFW and MSLB scenarios.

The operators were <u>not</u> informed in advance what exercises would be used in the experiment. Many appeared to be surprised by the LOFW and the loss of the RWST in the MSLB sequence, which suggests that operators were not told by earlier participants what exercises would be employed. The order of presentation of the first three exercises was balanced across teams by the use of randomized 3x3 Latin squares, and the MSLB scenario was always presented last.

The simulated casualties were programmed by the instructor, who followed a protocol supplied by the experimenters. Each sequence was initiated from identical conditions, and each subsequent malfunction was inserted according to a detailed protocol. In general, each exercise was terminated when the end-state specified in the protocol had been achieved, or after 45 minutes. One SGTR sequence was terminated when the simulation program malfunctioned.*

3.3 Simulator

The training simulator used in this study is shown schematically in Figure 3-1. The simulator is a reproduction of the control room for an 1100 megawatt (MWe) PWR plant. The simulator duplicates the Unit II section of the two-unit control room for Plant A. One or a combination of up to 12 of approximately 120 programmed malfunctions may be selected from the instructor's console. Figure 3-1 shows the general location of controls for major plant systems, which are listed in Table 3-2.

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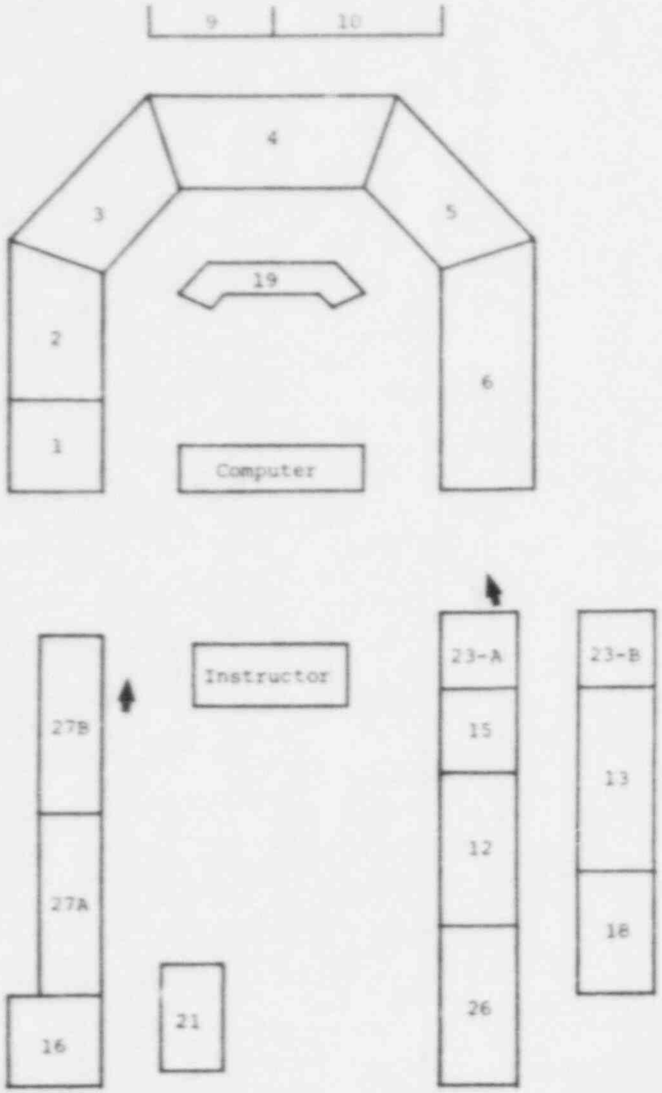
*For this exercise, only those tasks which were initiated before the simulator froze were scored. The way in which performance was evaluated for exercises which did not evolve in the way postulated by the task analysis is discussed in Section 4.3.2.



Location of plant systems shown in schematic

Location[a]	System
1	Generator, Auxiliary Power
2	Turbine Control
3	Feedwater and Condensate
4	Reactor Control
5	Reactor Coolant System
6	Engineered Safeguards and Auxiliary Systems
9	Vent and Ice Condenser
10	Temperature Monitor
12	Radiation Monitoring
13	Neutron Monitoring
15	Water Service Systems
16	161 KV Switchboard
18	In-Core Probe
19	Operator's Desk
21	Electrical Console
23-A, B	Upper Head Injection
26	Diesel Generators
27-A	Essential Raw Cooling Water
27-B	Component Cooling Water
▲	Cameras (arrow shows direction aimed)

a. The numbers given in the location column correspond to the numbered locations in Figure 3-1.

Figure 3-1 Schematic of the 1100 MWe PWR training simulator.

3.4 Data Collection Instruments

Data from an automated recording system, checklists completed by observers, and questionnaires completed by the participating operators and STAs were used in the analysis of the experiment.

3.4.1 Performance Measurement System

Records of control actions and system parameters produced by the simulator's performance measurement system (PMS) were the primary source of performance data. The occurrence, timing, and sequencing of operator control actions and the times from the appearance of cues (annunciated alarms or critical values of system parameters) requiring or enabling task initation until the satisfaction of task success criteria were determined from these records, as was time-out-of-band and RMS error for subcooling, pressurizer level, and steam generator level.

The PMS is a computer software system developed by General Physics Corporation for the Electric Power Research Institute (EPRI) (Ref. 4). The PMS is designed to record simulator status and operator actions and provide an easily understandable output. The system consists of an on-line data collection segment and a series of off-line data interpretation programs. The on-line assembly language data collection program is executed with the simulation program in the simulator's computer. This program collects all control room data (gauge readings, annunciator actuation, switch positions, etc.) during simulator operation. Simulator status is scanned at approximately 1-second intervals, but to avoid missing rapid operator actions, switch positions are scanned at a shorter interval. To extend the data collection capacity, a dynamic compression technique is used. This technique basically collects data only when successive scans of simulator status indicate changes in the value of a parameter or the operation of a control. When a change occurs, all simulator conditions at that time are recorded. The resulting data tape is, in effect, a sequence of "snapshots," each containing the status of every light, meter, switch, and knob in the simulator.

The simulator data consist of four types of inputs and outputs:

- Digital Inputs (DIs) - discrete inputs from the control room to the simulation programs. An example is the position of a two-position switch on one of the control panels.
- Digital Outputs - discrete outputs from the simulation programs to the control room. These outputs are of two types: 1) signals to annunciator tiles (ANs) turning these "on" or "off", and 2) "logical outputs" (LOs) signals to other indicator lamps such as status lights.
- Analog Inputs (AIs) - continuous inputs from the control room to the simulation programs. An example is the position of a control knob on one of the control panels.
- Analog Outputs (AOs) - continuous outputs from the simulation programs to the control room. An example is a meter reading on one of the control panels.

These data present a comprehensive description of the simulator's status and provide a detailed record of the exercise.

Special scoring programs were written to aid in the evaluation of each of the operating sequences. These programs detected the occurrence and time of system parameter changes serving as cues for initiating tasks involving control manipulations, checked to see if preconditions and limits such as pressures, temperatures, or required sequence of actions had been satisfied, determined whether task success criteria had been met, and, if both cue occurrence and task success were determined by system status information recorded by the PMS, timed the tasks.

3.4.2 Observational Data

All experimental sessions were observed by a researcher and a subject matter expert (a simulator instructor) who used a scenario-specific Task Performance Identification Checklist (TPIC) to record the occurrence of task-critical communications and monitoring, and to note which

operator performed each task. The TPIC was a listing of the scoreable tasks and task elements, with spaces for checking which operator was observed to perform each element and the time when the elements occurred. The complete set of TPICs used in the experiment is presented as Appendix D.

Operators assigned to the training group who were not participating in the experiment acted as additional observers and also completed TPICs. The observer's TPICs provided information about tasks performed out of the camera's field of view, and also about unusual occurrences during the simulator runs.

All experimental sessions were videotaped, and an additional TPIC was completed by the experimenter during his review of the videotapes. This TPIC was used for scoring performance.* Times were recorded for appropriate elements (those that could not be timed by the PMS sequence analysis programs, such as verifications or communications) during the review of the videotapes, as it was impossible to watch the operators, complete the checklist, and time the actions as they were happening.

3.4.3 Questionnaire Data

During the classroom briefing period prior to the day of data collection, each participant (RO, SRO, and STA) completed a one-page biographical questionnaire (a copy is included in Appendix E). This questionnaire requested the respondent's age, number of years of college education, number of years of commercial nuclear power plant experience as a control room operator, number of years in commercial power plants outside the control room, and number of years of U. S. Navy nuclear power experience.

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*An analysis performed in conjunction with the 1983 experiment suggested that the TPICs could not be completed in real time with sufficient accuracy to be used as a data-collection instrument in lieu of the videotapes because the forms were too detailed.

At the completion of each exercise the operators filled out the one-page "Event Questionnaire" that was used to collect subjective workload data. A sample Event Questionnaire is contained in Appendix E. The subjective workload data are presented in Section 7.

3.5 Procedure

Data collection began on the first day of the operators' quarterly requalification training, with a classroom briefing of the participants, followed by instructions and scale development for the Subjective Workload Assessment Technique (SWAT) workload rating forms (the SWAT workload scale is discussed in Section 7). The utility very generously allowed four hours of simulator training time on the second day of training for the experiment. In the simulator, the participating operators were requested to perform all exercises as they would in the plant, and the four exercises (operating sequences) for which data were collected were run. The instructor then told them to respond to their indications as they would normally (i.e., not to let their imaginations carry them away).* The operators were not informed in advance what scenarios were to be run. However, they were told that elements of one exercise might strain the limits of credibility, and that that exercise would be the last one performed.** At the conclusion of the session the operators were thanked for their participation and requested not to tell other operators what exercises were used in the experiment. The SWAT card-sort performed in the classroom session was reviewed with individual operators in the breaks between exercises. The set of materials given to the operators is presented in Appendix E.

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*Fairly routine exercises like LOAD and SGTR are usually "spiced-up" by the addition of one or more instrument failures.

**It was anticipated (correctly) that the fact that one of the exercises was something they had not seen before would spread among the operators as the experiment progressed. Informing them that this exercise would be the last one performed was intended to reduce the effect that any anxiety about being "put on the spot" in a novel situation might have on their performance during the other exercises.

4. PERFORMANCE EVALUATION

4.1 Task Performance Measures

Each operating sequence, such as responding to an SGTR, was subjected to a task analysis to determine the tasks required and how they are performed. The task analysis procedure employed in this study was that employed by the NRC Crew Task Analysis project described in Reference 3. The task analysis was based on the operating procedures prescribing operator actions and videotapes of a rehearsed real-time run in the simulator. Decisions, information requirements, feedback, communications, and control actions were recorded on a Task Data Form (Descriptive) [TDF(D)], an example of which is presented in Appendix C. Figure 4-1 is a simplified sample from the task analysis for the task "Cooldown the Reactor Coolant System (RCS)." This task is a part of the three casualty sequences.

OPERATOR	PANEL	BEHAVIOR	OBJECT OF ACTION/ COMMUNICATION	SYSTEM
RO-2[a]	M-4	Positions	Steam Dump Mode Controller to STEAM PRESSURE MODE	Main Steam
RO-2	M-4	Adjusts	Steam Dump Valve OPEN	Main Steam
RO-2	M-4	Positions	Steam Dump Interlock "A" BYPASS	Main Steam
RO-2	M-4	Positions	Steam Dump Interlock "B" BYPASS	Main Steam
RO-2	---	Informs	Cooldown of RCS Initiated	
RO-1	M-5	Monitors	Pressurizer Level	Reactor Coolant
RO-1	M-4	Monitors	RCS Temperature	Reactor Coolant

a. In the convention employed in the task analysis, RO-1 was the designation used for the reactor operator (LO), and the BOP operator was called RO-2.

Figure 4-1 Task analysis of "Cooldown the RCS" (simplified form).

The TDF(D)s produced by the task analysis provide a detailed record of the tasks comprising the operating sequence, as the tasks were performed during the rehearsed performance. To arrive at performance requirements, the major elements of each task were outlined on a second form, the Task Performance Measures Worksheet (an example is given in Appendix C), on which were listed criteria for task success and documentable constraints on performance, such as required sequences of action, as determined from an additional in-depth review of system operating procedures and technical specifications. These constraints, in combination with the required operator actions (task elements), constituted a set of performance criteria, which were recorded on a Task Performance Criteria (TPC) form. The TPC also lists cues for task initiation, how task initiation may be observed, and the criteria for task success. The "source" column lists how the individual actions may (potentially) be observed. A section of the TPC for "Cooldown the RCS" is shown in Figure 4-2.

Task Cue: #4 SG MSIV closed (LO 2820)

Task Initiation: Steam dump in steam pressure mode (DI 2078)

Task Success: Loop 1 hotleg temperature (AO 375) at target value based on #4 SG pressure (AO 525) ± 10°

ELEMENT	SOURCE	PRECONDITIONS/LIMITS
1. Place steam dump controller in STEAM PRESSURE MODE (DI 2078)[a]	PMS	After #4 SG MSIV closed (LO 2820)
2. Adjust steam dump valve position (DI 1950 <u>or</u> AI 55)[b]	PMS	After Element #1
3. Monitor RCS temperature	VT/PMS	Loop 1 T-cold change by no more than 100° (AO 377)
4. Position steam dump "A" train interlock to BYPASS (DIs 2039 or 2041)[c]	PMS	After lo-lo T-ave annunciator ON (AN 2774)
5. Position steam dump "B" train interlock to BYPASS (DIs 2040 or 2042)	PMS	After lo-lo T-ave annunciator ON (AN 2774)
6. Monitor pressurizer level	VT	(not observable)
7. Inform crew that cooldown is in progress	VT	-----

Sources: PMS = simulator's performance measurement system
VT = videotape: actions are recorded on a checklist

a. DIs, LOs, etc., are PMS data types, explained in Section 3.4.1. Briefly, they correspond to: switch positions (DIs); indicator lamps (LOs); controller settings (AIs); annunciator tiles (ANs); and meter readings (AOs).

b. The steam dump valve can be throttled with a switch (DI) or a controller (AI).

c. The steam dump interlocks spring-return to a second position after being taken to BYPASS. Momentary contacts may sometimes be missed by the PMS, so the second DI is included as a backup measure.

Figure 4-2 Section of Task Performance Criteria form for the task "Cooldown the RCS".

The "Cooldown the RCS" task was timed from the closing of the main steam isolation valve (MSIV-part of an earlier task), which served as an enabling cue and as the first precondition/limit (P/L) in the task. This action is enabling in the sense that closing the MSIV clears the way for the cooldown via the steam dumps: to dump steam with the MSIV open would result in severe radioactive contamination of the condenser. Closure of the MSIV was used for timing because it is desirable to cool down and depressurize as rapidly as possible in order to minimize the transfer of radioactive primary coolant into the secondary side of the plant.

The task success criterion was taken from the emergency operating procedures, which contain a table relating steam generator (SG) pressure to the temperature required to depressurize the primary system to match that pressure. The $\pm 10^{\circ}$ is an arbitrary* margin of error added to compensate for the fact that the PMS records the signal going to the control room instruments, and an error in the instrument could cause the operator to think he had reached the target value when the simulator computer indicated he had not.

The alternative actions represented in element 2 were included because there is more than one way to achieve the desired result. In this case, manually throttling the steam dump valve open or adjusting the setpoint on the controller has the same effect on the valve.

Although monitoring of system parameters is a large component of the operator's job, it could not be measured directly because an observer could not be certain that an operator has not checked a particular reading. This is because the majority of control room instruments (including the pointers showing the current position of the pens on chart recorders) were large enough to be read very quickly, or at a distance of 10-15

*The scale divisions on the wide-range temperature recorder are in increments of 10°. A precise digital readout can be obtained from the plant process computer, but the computer was often out of service in the simulator.

feet. For this reason, element 6 in Figure 4-2 is listed as "not observable." In the case of element 3, while it was not possible to determine directly if the operator had monitored the temperature, it was possible to determine if he has failed to comply with system limitations by allowing the system to cooldown too much. This could be the result of ignorance of the 100^{o}/hr. cooldown limit (not likely) or the result of poor monitoring, but from a system point of view, exceeding the cooldown rate is an error, regardless of how it happened.

Performance of each task in the operating sequence was described by five measures:

A. Whether the task was initiated (scored as 1 or 0);

B. The number of elements (control actions, communications) performed correctly (counts);

C. The number of preconditions or limits (P/Ls) complied with (counts);

D. Whether task success criteria were met (scored as 1 or 0);

E. Time elapsed from the appearance of the cue to initiate the task until the task was completed (seconds).

For the "Cooldown the RCS" task, there were five scored elements, four taken from the PMS records and one from the videotape. The PMS elements were the four control actions: placing the steam dump controller in STEAM PRESSURE MODE; adjusting the steam dump valve (by manually throttling it or by adjusting the controller setpoint); and setting the two interlocks to BYPASS. The presence or absence of the communication that the cooldown had been initiated was taken from the TPIC record of the videotape review. Elements 3 and 6, monitor RCS temperature and pressurizer level, were <u>not</u> included in the scoring because they could not be reliably detected unless they were mentioned by the operators. There were also five P/Ls: steam dump controller to STEAM PRESSURE MODE <u>after</u> the #4 SG MSIV had been closed; the steam dump valve not adjusted until <u>after</u> the controller had been placed in STEAM PRESSURE MODE; Loop 1

T-cold changed by no more than 100^{o} after the steam dump valve adjusted; and the "A" and "B" train interlocks set to BYPASS only after the lo-lo T-ave annunciator had come on (one P/L for each train).

To determine overall performance for an operating sequence, which may have been composed of between 17 (LOAD) to over 40 (MSLB) scoreable tasks, the performance scores for individual tasks were summed across all tasks in the sequence and converted to percentages, i.e., the ratio of elements performed to elements required, for the sequence as a whole. The first score was the percentage of required tasks that were initiated; the second was the percentage of required elements (in only the tasks that were initiated) that were performed; the third was the percentage of preconditions/limits (for the tasks initiated) complied with; and the fourth was the percentage of the tasks initiated that were successfully completed.

The averaging of times across tasks required a more complicated approach, since the time required to complete individual tasks varies substantially from task to task. Task times were therefore "standardized" and expressed not as seconds but as deviation scores (also called "Z-scores"). Given an individual task time (t_i), and the mean (T), and the standard deviation (sd.) of the distribution of times recorded for all successful completions of the task, the formula for calculating the standardized time (t_z) is:

$$t_z = \frac{t_i - T}{sd.}$$

Standardized times indicate relative performance, so variations in task duration inherent in the tasks themselves are factored out. Thus each task is given equal weighting in the resulting sequence average.

4.2 Functional Performance Measures

In addition to the five task performance measures, a set of functional measures was also employed. These indicate how well the crew controlled selected critical parameters. The parameters selected were

derived from the four Critical Safety Functions (CSFs) identified in the emergency operating procedures for Plant A:

(1) Achievement of Subcriticality
(2) Maintenance of Core Cooling
(3) Maintenance of a Heat Sink
(4) Maintenance of Containment Integrity

The scenarios employed did not challenge CSFs 1 or 4, but CSFs 2 and 3 were challenged to varying degrees by the three casualties simulated, though not by the LOAD sequence. The subcooling margin (SCM) was selected as the parameter most closely related to maintenance of core cooling. A second function vital to the maintenance of core cooling is primary inventory control, as indicated by pressurizer level (P-lvl). A third function, maintenance of adequate steam generator levels (SGL), is important to insuring an adequate heat sink. From these three functions, six functional measures were derived:

F. Time (seconds) subcooling margin $< 40^{\circ}$
G. Root-Mean-Square (RMS) error in subcooling margin for the time subcooling margin $< 40^{\circ}$
H. Time (seconds) pressurizer level < 20%
I. RMS error (below the limit of of the 20-80% operating band) for pressurizer level
J. Time (seconds) level in no one of the four steam generators > 79% (wide range)
K. RMS error in SG level for the time the highest SG level < 79%

These six functional measures were combined with the five task performance measures to provide an 11-variable metric of crew performance for the operating sequence.

4.3 The Validity of the Performance Scores

A preliminary validation analysis was conducted using ratings of crew performance provided by the simulator instructors. This analysis is reported in detail in Appendix F. The correlations between the instructors ratings and the task performance measures were significant for only one of the four exercises, and correlations between the ratings and the functional measures were significant for only one of the three exercises for which the functional measures were computed. However, the ratings used as the criterion measure in these analyses were provided by eight different instructors, which undoubtedly had a negative effect on interrater reliability and may have contributed to the failure to establish predictive validity. An analysis of the raters' responses to three open-ended questions suggested that the performance measures employed did have a substantial degree of content validity.

4.4 Data Reduction

4.4.1 Scoring

Each exercise was recorded on videotape and a record of system parameters and control actions was produced by the simulator's PMS. Elements 1 through 7 of the TPC were also included on the Task Performance Identification Checklist (described in Section 3.4.2) completed by observers during the exercise and during review of the videotapes.

Scoreable task elements were of two kinds, 1) control actions and 2) other discrete interactions with the system (e.g., verifications, using the steam tables) or with other operators (internal and external communications). As explained in Section 4.1, some required behaviors, such as monitoring temperature, level, or power, were not scored because they could be accomplished without distinctive overt behavior (e.g., close inspection of the instruments) and thus could not be reliably detected.

For the PMS data, scoring programs were written to identify clusters of control actions and milestones (e.g., values of selected parameters) serving as task cues or indicating task success. The PMS records were used for timing those tasks where both cue and task success criteria were annunciators, control activations, or changes in system state. Separate PMS scoring programs were written to determine time-out-of-band and RMS error for the functional measures.

The TPICs completed during the review of the videotapes were the source of data for those tasks or elements which could not be recorded by the PMS. Elements from both the TPICs and PMS records were combined to score a task. For example, in the task "Cooldown the RCS" described earlier, there are four control actions and one communication, for a total of five task elements. Success on this task could be achieved without informing the rest of the crew, but this would result in one of the task elements not being performed and a lower score on the "elements" measure. Because the success criterion for this task was the attainment of the target temperature, it is also possible for the operators to have performed all the task elements and still not have been successful.

Scoring of the "Cooldown the RCS" task is illustrated in the following example:

> The Lo-Lo T-AVE annunciator came on at 8:14 into the sequence. At 9:12, some 5 minutes and 39 seconds after the first indication of an abnormal condition (the PRESSURIZER PRESSURE LOW, BACKUP HEATER ON annunciator) the BOP operator closed the MSIV to the damaged SG. At 12:19 the SUP directed the BOP operator to cool down the plant by depressurizing the three intact SGs, and at 12:28 the BOP turned the A and B train steam dump interlocks to BYPASS. At 12:53 he placed the steam dump controller in STEAM PRESSURE MODE. Over the next few minutes, beginning at 12:59, he adjusted the steam dump controller several times. At 14:10 the BOP, responding to an inquiry from the SUP, said that yes, the cooldown had been initiated, and at 15:22

the Loop 1 hotleg temperature was within 10° of the target value. So far, everything had gone pretty much "by the book". However, the crew apparently failed to terminate the cooldown in a timely manner, and cooling exceeded 100° at 29:18.

The task data from the PMS and TPIC records were combined into a single line summarizing performance for each scored task in the operating sequence. For the example given above, the summary was:

26 1 1 5 5 5 4 370 1 101

The first entry is the task number, 26. The pair of 1s indicates that the task was required and was initiated. The pair of 5s gives the number of elements required and the number actually performed. The next pair of numbers shows that there were five preconditions or limits, of which four were satisfied. The crew's error in not terminating the cooldown is reflected in the one P/L missed. The 370 is the task time, in seconds, from the closing of the MSIV for SG #4 (the cue enabling the task) until the target temperature was reached. The 1 following the task time indicates the task was successfully accomplished, and 101 indicates the operator who operated the controls.*

4.4.2 Deviations From the Analyzed Scenario

One problem in measuring performance is how to measure the performance of tasks that are slightly different from those expected. The task analysis assumes a given set of conditions which require all groups to respond in the same manner. However, in a dynamic system as complex as a nuclear plant, every action may affect subsequent actions. Thus how a group performs early in the scenario may change the nature of the tasks to be performed later in the scenario.

*Numbers were assigned to all participants and observers, in the order of their participation in the experiment. These numbers served only to provide a unique identifier for each individual's data.

Discussions with the instructors during the experiment and a review of their notes afterward made it possible to identify some cases where the task standards were to be modified. For the purposes of computerized scoring, such situations were treated as alternate versions of the same task, for example "Depressurize the SGs in MANUAL" versus "Depressurize the SGs in AUTOMATIC." In addition, as data collection progressed it became evident that crews often forgot to block the low pressure safety injection (SI) initiation signals, which resulted in an inadvertent SI during the LOFW exercise.* Receiving an SI adds a number of tasks to the exercise that would not be required if there were no SI: the SI must be terminated, charging and letdown restored, and the feedwater isolation reset.

Generally, if it was evident that conditions required extensive modification of task standards, that task was accorded "task not required" status and performance scores were calculated from the scores on the reduced number of tasks from the standard sequence (as described by the task analysis) that were still required in the altered sequence.

4.4.3 Scoring From Incomplete Records

Equipment malfunctions and mistakes in operating the recording equipment resulted in incomplete records for four of the 79** exercises. The affected teams are listed in Table 4-1.

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*Blocking the low pressure SI signals appears in the task analysis as two elements of the "Depressurize the steam generators" task. Receiving an inadvertent SI is a conspicuous, though not particularly critical, error. In order to discriminate those crews who forgot to block the SI, this task was considered unsuccessful if the SI signals were not blocked, even if depressurization was achieved.

**One LOAD exercise was not performed because the simulator failed and was out of commission for one of the four hours allotted for the experiment.

Table 4-1 Missing Data

Group	Crew	Sequence	Data Missing
SUP-high, No-STA	14	SGTR	Exercise stopped after 15 minutes by simulator failure
SUP-high, STA	7	MSLB	Small segment of PMS data missing in middle of exercise - PMS write queue overfilled
SUP-high, STA	17	LOFW	PMS started late - experimenter error
SUP-low, No-STA	15	LOAD	Wrong record program for first half of exercise - experimenter error

Due to the small number of crews in each condition of the experiment, the planned analyses could not be performed with incomplete data. The experiment employed virtually all of the licensed operators at the participating plant, and having a crew repeat an exercise would not have yielded data comparable to that obtained from crews with no foreknowledge of the exercise. Thus it was necessary to score some performances from incomplete records.

For two exercises, PMS records of the first half of the exercise were not available. To overcome this problem, the videotapes were analyzed in much greater detail. By carefully reviewing the videotapes, it was generally possible to identify the initiation of tasks and the performance of elements related to control manipulations and communications. However, in cases where task success or compliance with preconditions/limits could not be determined accurately from the videotapes, the average task scores from the 19 other groups performing the same task during the same exercise were used. The practice of using the exercise grand mean (computed for each separate task) as an estimate of missing data is conservative. Since there were only five crews in each cell of the experimental design, the effect of this treatment is to pull the group means toward the grand mean, and thus reduce the magnitude of between-group differences.

In cases where the videotape data were insufficient to accurately determine whether or not a task had been initiated, the tasks were set to "task not required," and performance scores were calculated on the basis of the reduced set of scored tasks. For the SGTR sequence terminated by failure of the simulator, only those tasks that had been (or should have been, i.e., the immediate actions required following a reactor trip and SI) completed before the simulator failed were scored.

Crews 12 and 16 were unable to complete the LOAD sequence because they repeatedly tripped the reactor on low SG levels. For these two crews, those tasks completed before the trip were scored in the usual way, and later tasks in the sequence were set to "task not required." Their difficulty in controlling SG levels was reflected in low scores for task success (the lowest for any of the crews who performed the exercise), but not necessarily in the four other measures based on the reduced set of scores.

5. THE EFFECTS OF SUPERVISOR EXPERIENCE AND THE PRESENCE OF AN STA ON CREW PERFORMANCE

The performance of each crew was described in terms of the 11 performance measures presented in Section 4. Measures A through E describe performance of the individual tasks comprising an operating sequence. In order to achieve a single set of scores describing crew task performance for an operating sequence, the scores for each of the five task variables were averaged across all of the tasks required by the scenario. The resulting five average task values were combined with the six functional performance indices (measures F through K as defined in Section 4.2) to yield a set of 11 variables describing the team performance of the operating sequence. The 20 sets of weighted team performance scores for each of the four exercises are presented in Appendix G.

5.1 Adjustments to the Data

The multivariate analysis employed requires a balanced data set, i.e., an equal number of cases in each cell of the design. This posed a problem because five crews did not perform the SGTR exercise, and one crew did not perform LOAD. To make matters worse, three of the missing SGTRs were from a single group, SUP-high, No-STA.

Estimating the values for the missing data appeared to be the least unattractive alternative available for dealing with this problem. Substituting the appropriate exercise mean values for each of the missing data points is the most conservative approach to estimating them, in that using the means will reduce rather than accentuate between-group differences, and thus will militate against spurious rejection of the null hypothesis. This of course means lessening the chance of finding statistically significant differences between groups. However, it was judged that group-related performance differences were not likely to be evident for the LOAD and SGTR exercises. Both were familiar to the operators, procedure-driven, and were not complicated by equipment failure or unavailability. Thus, although we have some misgivings about using

estimates for such a high proportion of the SGTR data, it was judged that the estimated data would not seriously distort the outcome of the analysis.

Preliminary analyses were performed on the same performance data presented in Appendix G. This analysis indicated no significant effects for supervisor experience or presence of the STA. Inspection of the weighted task performance summaries presented in Appendix G shows that, in general, crews from Plant A (crews 1-12) received higher scores than crews from Plant B (crews 13-20). Small differences in the control boards and procedures may have put the crews from Plant B at a disadvantage when performing in Plant A's simulator. In the statistical analysis, differences in performance which are not related to the blocking variables increase the error variances and make it harder to detect relative differences between the experimental groups. The purpose of the present experiment is to compare differences in crew composition, so it was the relative performance of the various experimental groups that was of interest, rather than the absolute performance of any one crew or group of crews. Therefore a second adjustment was performed on the (weighted) task performance data to standardize the data within plants. That is, each of the exercise task performance measures was expressed as a deviation score (see Section 4.1, page 26) relative to the distribution of scores for crews from the same plant. Standardizing within plants eliminated variance due to an average difference in performance scores between crews from the two plants.

5.2 Statistical Analysis

Because the three sets of functional measures were calculated for only the three casualty scenarios, the statistical analysis was divided into two sections, analysis of the five task performance measures and a parallel analysis of the six functional measures.

5.2.1 Task Performance Scores

The performance scores for the 20 teams were analyzed by means of a multivariate analysis of variance (MANOVA). The program used to perform the MANOVA was the "General Univariate and Multivariate Analysis of Variance and Covariance, Including Repeated Measures (BMDP4V)" program of "BMDP Statistical Software" (Ref. 5), which computes Hotelling's "t^2" and the equivalent approximate F values as the test statistics. The group averages for the five standardized task performance measures for all four sequences are presented in Table 5-1 (these numbers can be derived from the weighted performance scores in Appendix F with a hand calculator using the formula given in Section 4.1).

The MANOVA used to evaluate the results of the experiment had two between-subjects factors, "SUP experience level (high or low)" and "presence of STA," and one within-subjects factor, "scenarios." The main effects and possible interaction of the between-subjects factors provide tests of the hypotheses (H-1, H-2, and H-4) regarding these factors expressed in Section 2. The averages on which the tests for main effects are made are given in Table 5-2.

In this analysis, Hypothesis H-1, that crews led by high-experience SUPs will exhibit better performance than crews led by low-experience SUPs, is represented by the main effect of "SUP Experience." Differences in overall performance between groups led by "high" (23 - 57 months) and "low" (3 - 18 months) experience SUPs did not achieve statistical significance: multivariate $F(5,12) = 1.12$, $p > 10$.

Hypothesis H-2, that crews assisted by an STA will perform better than similar teams without an STA, is represented by the main effect of "STA Presence." The MANOVA showed no significant differences in overall performance were associated with the presence of an STA: multivariate $F(5,12) < 1$.

Table 5-1 Group averages for standardized (weighted) task performance measures used in analysis of operator performance, by operating sequence

Group		Sequence	Task Performance Measures[a]				
			% Init	% Elem	% P/L	% Succ	Z-time
No-STA,	SUP-high	LOAD	.143	-.206	.076	.301	-.38
	SUP-high	SGTR	.004	.279	-.454	.395	+.05
	SUP-high	LOFW	.548	.582	.391	.950	+.19
	SUP-high	MSLB	-.014	.077	.060	-.178	-.02
No-STA,	SUP-low	LOAD	-.260	-.204	.447	-.138	+.38
	SUP-low	SGTR	.355	-.121	.046	.200	+.03
	SUP-low	LOFW	-.554	-.364	.099	-.665	-.11
	SUP-low	MSLB	.091	-.474	-.545	.265	-.04
STA,	SUP-high	LOAD	-.478	.144	-.690	.249	+.14
	SUP-high	SGTR	-.286	-.413	.158	-.574	-.01
	SUP-high	LOFW	-.326	.031	-.932	-.139	-.14
	SUP-high	MSLB	-.537	-.122	.358	-.256	-.08
STA,	SUP-low	LOAD	.596	.265	.167	-.413	-.16
	SUP-low	SGTR	-.073	.256	.249	-.020	-.13
	SUP-low	LOFW	.332	-.249	.441	-.146	-.35
	SUP-low	MSLB	.460	.519	.127	.168	+.14

a. All measures in the tables are deviation scores. The measures are:

Init: the proportion of required tasks initiated;
Elem: the proportion of task elements performed;
P/L: the proportion of preconditions and limits satisfied;
Succ: the proportion of tasks successfully completed (of those tasks that were initiated);
Z-time: average standardized task time.

There was no significant interaction between the SUP experience and STA presence factors: $F(5,12) = 1.20$, $p > .10$. Thus the analysis offers no support for Hypothesis H-4, that the benefit afforded by the STA will be greater for crews led by relatively less experienced SUPs than for crews led by more experienced SUPs.

Hypothesis H-3, that the difference in performance between the STA and No-STA groups will be larger for the more difficult exercises than for the less difficult exercises, is represented by the interaction of

Table 5-2 Comparisons corresponding to main effects in the statistical analysis of team performance measures

Effect	Group	Init[a]	Elem	P/L	Succ	Z-time
SUP Experience	SUP-high	.118	-.047	.129	-.094	+.03
	SUP-low	-.118	.047	-.129	.094	-.03
STA Presence	No-STA	.039	-.054	.015	.141	+.01
	STA	-.039	.054	-.015	-.141	-.02

a. All measures are reported as deviation scores (Z-scores).

the between-subjects factor "STA Presence" and the within subjects factor "Scenario." In the analysis, this term was not significant: $F(15,2) < 1$.

The analysis of the standardized task performance scores gave no support to any of the four hypotheses stated in Section 2. That is to say, the differences in the average performance scores for the experimental groups were small compared to the differences among the individual crews comprising the groups, even after the within-plant standardization of scores to remove the variance associated with the fact that the crews were from different plants. Although crews did differ in performance, those differences do not appear to be systematically related to the grouping variables, supervisor experience and the presence or absence of an STA.

For example, there were significant differences in performance scores across the four scenarios. These did not appear as a "scenario" effect in the analysis of the standardized scores because the scores were standardized within scenarios. The scenario averages for the weighted, unstandardized scores are presented in Table 5-3.

A second MANOVA similar to the one described above for the standardized task performance measures was performed on the unstandardized measures. The terms relating to the four hypotheses were all non-significant (all Fs < 1), and the multivariate F for "scenarios" was also non-significant: $F(15,2) = 8.96$, $p > .10$. However, four of the univariate

Table 5-3 Mean weighted (unstandardized) task performance scores for the LOAD, SGTR, LOFW, and MSLB sequences

Sequence	Task Performance Measures				
	% Init	% Elem	% P/L	% Succ	Z-time[a]
LOAD	.922	.845	.674	.954	.02
SGTR	.957	.850	.640	.950	.01
LOFW	.927	.762	.504	.806	-.03
MSLB	.886	.781	.551	.879	.00

a. The value for Z-time is expected to be zero.

analyses of variance (ANOVAs) computed on each of the five measures did indicate significant differences: for % Init, $F(3,48) = 6.76$, $p < .01$; for % Elem, $F(3,48) = 9.93$, $p < .01$; for % P/Ls, $F(3,48) = 12.42$, $P < .01$; and for % Succ, $F(3,48) = 23.27$, $p < .01$. The Z-time variable was standardized within scenarios and so could not differ. Inspection of Table 5-3 shows that performance scores tended to be somewhat lower for the more complicated sequences, LOFW and MSLB, than for the more straightforward and familiar sequences, LOAD and SGTR.

5.2.2 Functional Performance Measures

The analysis of the functional measures was essentially the same as the analysis of the task performance measures, except that there were six variables instead of five, and only three scenarios, SGTR, LOFW, and MSLB. The six functional performance measures are described in Section 4.2. The data used in this analysis were not standardized because the functional performance requirements are the same for both plants. The group averages for the six functional performance measures for the three casualty sequences are presented in Table 5-4. The individual crew values from which these averages were calculated are presented in Appendix G.

Table 5-4 Group averages for functional performance measures for SGTR, LOFW, and MSLB

		Functional Performance Measures					
Group	Sequence	TOB[a] SCM[c]	RMS[b] SCM	TOB P-Lvl[d]	RMS P-Lvl	TOB SGL[e]	RMS SGL
No-STA, SUP-high	SGTR	272	3.3	630	15.2	52	3.7
	LOFW	0	0.0	895	8.9	2031	20.2
	MSLB	374	14.8	911	13.9	789	9.9
No-STA, SUP-low	SGTR	350	3.7	747	13.9	121	4.6
	LOFW	2	1.0	507	9.9	1863	18.5
	MSLB	347	12.4	874	15.6	677	10.6
STA, SUP-high	SGTR	381	6.0	786	15.0	183	5.7
	LOFW	247	6.2	162	2.3	2038	17.6
	MSLB	699	10.2	562	15.8	912	9.6
STA, SUP-low	SGTR	318	3.5	678	15.2	129	3.5
	LOFW	32	3.3	506	7.2	2055	23.2
	MSLB	461	11.2	706	15.7	630	9.9

a. TOB = time-out-of-band (seconds).
b. RMS = root-mean-square (in % level or degrees F).
c. SCM = subcooling margin < 40°.
d. P-Lvl = pressurizer level < 20%.
e. SGL = level in no one of the steam generators > 79% (wide range).

The group average corresponding to the main effects, supervisor experience and the presence of an STA, are presented in Table 5-5.

The main effect of supervisor experience (H-1) was not significant: (multivariate $F(6,11) < 1$), nor was the effect of STA presence (H-2): $F(6,11) = 2.00$, $p > .10$. However, the univariate ANOVAs did indicate that time-out-of-band for pressurizer level was significantly lower for the crews assisted by an STA: $F(1,16) = 6.07$, $p < .05$.

As was the case with the analysis of the task performance measures, the interaction between the SUP experience and STA presence factors was not significant: ($F(6,11) < 1$. The analysis of the functional performance measures thus offers no support for hypothesis H-4.

Table 5-5 Comparisons corresponding to main effects in the statistical analysis of functional performance measures

Effect	Group	Functional Performance Measures					
		TOB SCM	RMS SCM	TOB P-Lvl	RMS P-Lvl	TOB SGL	RMS SGL
SUP Experience,	SUP-high	329	6.7	658	11.8	1001	11.1
	SUP-low	252	5.8	670	12.9	908	11.6
STA Presence,	No-STA	224	5.9	760	12.9	918	11.2
	STA	357	6.7	567	11.9	991	11.5

Hypothesis H-3, that the difference in performance between the STA and No-STA groups will be larger for the more difficult exercises than for the less difficult exercises, was tested by the interaction of the "STA presence" and "scenario" factors. In the analysis of the functional performance measures, this interaction was significant: multivariate $F(12,5) = 4.88$, $p < .05$. The data described by this interaction are presented in Table 5.6.

Table 5-6 The interaction of "STA presence" with "scenario"

Sequence	STA/No-STA	Functional Performance Measures					
		TOB SCM	RMS SCM	TOB P-Lvl	RMS P-Lvl	TOB SGL	RMS SGL
SGTR	No-STA	311	3.5	689	14.6	87	4.2
	STA	350	4.8	732	15.1	156	4.6
LOFW	No-STA	1	0.5	701	9.4	1947	19.4
	STA	140	4.8	344	4.8	2047	20.4
MSLB	No-STA	361	13.6	893	14.8	733	10.3
	STA	580	10.7	634	15.8	711	9.8

The pattern of scores shown in Table 5-6 is difficult to describe. The presence of an STA was not an asset for the SGTR sequence, more or less neutral for the LOFW, and perhaps beneficial (the differences

between the STA and No-STA groups are very small) for the MSLB sequence. In spite of the significant multivariate F, none of the univariate ANOVAs for the individual measures is significant, so they offer no guidance in interpreting this finding. Inspection of Table 5-6 suggests, however, that the data offer no support for Hypothesis H-3 because the pattern of functional performance scores is clearly not that suggested by the hypothesis.

Inspection of Table 5-6 suggests that there were rather substantial differences in the functional performance measures across the three exercises. These differences were reflected in a significant multivariate F for "scenario" ($F(12,5) = 68.40$, $p < .01$), and are shown more clearly in Table 5.7. The three casualties can be fairly easily ranked in terms of the ability of the crews to control the three critical parameters examined. For the two parameters related to the critical safety function of core cooling (i.e., SCM and P-Lvl) the MSLB exercise was clearly the most difficult, followed by the SGTR and the LOFW. This result is consistent with an engineering analysis of the transients since both the MSLB and SGTR involve a loss of coolant inventory and associated plant depressurization. The LOFW sequence had the largest values for the measures associated with steam generator level, which would be expected since this was the only transient which challenged the secondary heat sink function.

Table 5-7 Functional performance measures for the SGTR, LOFW, and MSLB sequences

	Functional Performance Measures					
Sequence	TOB SCM	RMS SCM	TOB P-Lvl	RMS P-Lvl	TOB SGL	RMS SGL
SGTR	331	4.1	710	14.8	121	4.4
LOFW	70	2.6	517	7.1	1990	19.8
MSLB	470	12.2	763	15.2	751	9.9

5.2.3 Individual Performance

The majority of tasks, as "task" was defined in the task analysis, were performed by a single operator. The man performing each task was recorded on the TPICs and his operator number was recorded with the task performance data. For the occasional task that was a coordinated effort (for example, restore charging and letdown), the task performance was attributed to the man who performed the control manipulations, as the majority of the task elements were manipulative and the manipulations were usually performed by only one of the operators engaged in the task. The data used to determine the crew performance scores were sorted and combined across the four operating sequences to yield average task performance scores for the proportion of task elements accomplished, the proportion of preconditions and limits satisfied, the proportion of tasks successful, and the time to complete the tasks for each individual operator. The measure "proportion of required tasks initiated," was not used in these analyses, as responsibility for tasks that were not initiated was generally assigned to the supervisor.

The task performance data for individuals were subjected to regression analysis to determine the relation between the operators' task performance and two experience variables: 1) operating experience (months as a licensed operator); and 2) the number of months elapsed since last training in the simulator, as reported on the Biographical Questionnaire. Inspection of the biographical data provided by the operators revealed that there was a small but statistically significant correlation ($r = .278$) between the months since the first license and the time elapsed since the last simulator training session. Further examination of the data revealed that this correlation was especially pronounced for the ROs in the study ($r = .666$) and also for the SROs who were filling RO positions ($r = .501$). In order to obtain a more accurate indication of the relation between the performance scores and the two variables of interest, the correlations between months since licensed and months since last simulator training were used to calculate <u>partial correlations</u>. The

partial correlation is used to describe the relation between two variables when that relation is confounded by relations of both variables of interest to a third variable. That is, the partial correlation compensates for the fact that months since licensed and months since last simulator training are themselves correlated. The partial correlations with months since licensed are shown in Table 5-8.

Table 5-8 Partial correlations between performance scores and months since first licensed for SROs and ROs, with the effects of months since training removed

			Task Performance Measures			
Operators	n[a]	CV[b]	% Elem	% P/L	% Succ	Z-time
All	60	.255	.111	-.140	-.230	.082
SRO-SUPs	20	.444	.411	.300	-.214	-.253
SRO-"ROs"	15	.514	.145	-.019	-.117	.298
ROs	25	.398	.373	.158	-.302	-.067

a. n = the number of subjects for which the correlation was computed.
b. CV = the minimum value of r required for significance at $p < .05$.

Inspection of Table 5-8 shows that the correlation of experience (months since first licensed) with the four task performance measures tends to be slight, and does not reach the magnitude required for statistical significance.

The correlations of the four task performance scores with the number of months between participating in the experiment and the last simulator training received are shown in Table 5-9.

Table 5-9 Partial correlations between performance scores and months since last simulator training, with the effects of months since licensed removed

Operators	n[a]	CV[b]	Task Performance Measures			
			% Elem	% P/L	% Succ	Z-time
All	60	.255	.193	-.216	-.192	-.327
SRO-SUPs	20	.444	-.127	-.403	-.279	-.398
SRO-"ROs"	15	.514	.268	.265	-.047	-.254
ROs	25	.398	.093	-.037	.055	-.037

a. n = the number of subjects for which the correlation was computed.
b. CV = the minimum value of r required for significance at $p < .05$.

Inspection of Table 5-9 shows that the partial correlations between the individual performance measures and the number of months since the operator's last simulator training were generally small and statistically insignificant. We would expect the effects of time since training to be pronounced if the exercises were conducted soon after the last training session for some of the crews. However, the range of values for months since training was relatively small (sd. = 2.5) and the average time since the last session was 6.2 months. These conditions were decidedly suboptimal for demonstrating the effects of recency of training.

6. SUBJECTIVE WORKLOAD

In the 1983 experiment, subjective workload data were collected to determine the effect of assistance by an STA on the workload of the SRO. In that experiment, there was no difference in the reported workloads of SROs in the STA and No-STA groups. The workload data thus paralleled the performance data, which also exhibited no significant differences between groups with and without STA assistance.

The workload data did, however suggest that the scenarios used in the 1983 experiment varied in difficulty, and the ordering of scenarios in terms of subjective workload was in approximate agreement with both an intuitive ranking of difficulty and the ordering of scenarios in terms of performance scores. On the basis of this observation, it was suggested that the perceived workload associated with an operating sequence might be a meaningful index of scenario difficulty. For this reason, subjective workload data were collected in the 1984 experiment.

6.1 The Subjective Workload Assessment Technique (SWAT)

There are four major approaches to the measurement of mental workload: performance on the primary tasks; performance on secondary tasks; physiological measures such as heart rate variability; and subjective measures, which elicit, usually with the aid of rating scales, a report of the subjects' perceptions of workload (Refs. 6 and 7). The use of primary task performance as an indication of workload assumes that degraded performance is a correlate of excessive workload. However, the operator can often adapt to high but sub-critical loading and maintain a high level of performance by exerting extra effort. Such measures thus may not discriminate very well among workloads in the low-to-intermediate range. Of the three remaining approaches to the measurement of mental workload, subjective measures are both the least intrusive and the easiest to implement in the simulator, and were chosen for these reasons.

The Subjective Workload Assessment Technique (SWAT) developed by Ried, Shingledecker, and Eggemeier (Ref. 8) was chosen for use in this

study. This instrument was chosen because there is a growing body of research employing the SWAT scales, including preliminary documentation of validity and sensitivity (Refs. 8 and 9), and because the procedure for eliciting mental workload estimates provides judgments of three separate dimensions of workload: time pressure, mental effort or concentration required, and perceived stress. The technique also allows the development of interval-level rating scales for each individual using the SWAT scale, thus helping to avoid the problem of identical ratings having different meanings for different raters (Ref. 10), and enabling meaningful quantitative comparisons between workload estimates.

6.1.1 Description of the SWAT Scale

The SWAT scale uses the technique of conjoint measurement (Refs. 11 and 12) to combine separate ratings of the dimensions "time load," "mental effort (mental load)," and "stress load," each rated on a 3-point scale, into a single scale of subjective workload which possesses interval-scale properties. The statements defining the levels of each category are presented in Table 6-1. The ratings are made by the subject's selection of the one statement which best describes his perception of time load, mental load, and stress load during the activity being evaluated.

Subjective workload estimation employing SWAT required the collection of two kinds of data. Before the scale could be used, each subject participated in a scale development exercise which served to familiarize him with the scale's underlying concept (that workload can be thought of as having three basic components) and the categories he would employ for making his ratings, and also provided the data required to produce a conjoint scale customized for his individual way of perceiving workload. The workload ratings were then produced by selecting the one statement from each of the three categories that best described his subjective experience of load during the operating sequence he had just completed.

Table 6-1 Statements defining SWAT category scales

A. <u>Time Load</u>

1. Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.
2. Occasionally have spare time. Interruptions or overlap among activities occur frequently.
3. Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.

B. <u>Mental Load</u>

1. Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.
2. Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.
3. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

C. <u>Stress Load</u>

1. Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.
2. Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.
3. High to very intense stress due to confusion, frustration, or anxiety. High to extreme determination and self-control required.

6.1.2 SWAT Scale Development

In the scale development phase, a two-page "description of scale dimensions"* explaining the concept of workload embodied in the SWAT was given to participating operators, and read aloud by the experimenter. A copy is contained in Appendix E.

The data required to develop each individualized workload scale were obtained by having each participant rank order the 27 possible combinations of levels of the three dimensions. This was done by arranging a set of cards in order of increasing workload represented by the combinations of time load, mental load, and stress load given on each card. The instructions for performing the card-sort were given in the "individualized scale determination" handout (presented in Appendix E), which was also read aloud to the subjects. After the researchers answered any questions about the scales and card-sorting task, the subjects performed the card sort, which took between 15 and 45 minutes.

After the classroom session the order of the cards in each subject's deck was recorded and the cards arranged in a predetermined random order (the same for all subjects) for use by the next group. A preliminary screening of the data was conducted at this time and any obvious errors in sorting were noted. The algorithms used for scale development are tolerant of small errors, such as transpositions of one or two cards. The results of the card sort were reviewed with the subjects during the simulator session.

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*The "description of scale dimensions" and "individualized scale determination" handouts are nearly verbatim copies of materials supplied to the project and currently employed by the U. S. Air Force Aerospace Medical Research Laboratory (AMRL) researchers who developed the SWAT. Very minor changes in wording were made to adapt the instructions to the context of the present experiment (e.g., the word "experiment" was substituted for "test"). The project is indebted to Mr. Gary Ried of AMRL for supplying the SWAT scaling materials and performing the computations required for scale development.

At the conclusion of the experiment the card-sort data were sent to the U. S. Air Force Aerospace Medical Research Laboratory (AMRL) for development of the workload scales. Two analyses were performed by AMRL: each subject's card-sort data were scaled to determine which of six prototype classifications (ways of perceiving workload) he belonged to, and then the data for all individuals of a given prototype were combined to determine a group scale for the members of each prototype (Ref. 10).* The scales and a key showing the prototype represented by each subject were returned for use in scaling the workload ratings produced during the experiment.

The scaling performed by AMRL categorized the 70 subjects (operators and STAs)** from whom workload estimates were obtained into three prototypes; those who felt time load was the most important determinant of workload (25 subjects); those who felt mental effort was most important (7); and those who felt stress was the most important (38). The three separate category ratings were converted to a single estimate of overall workload by means of the scaling keys for each of the three prototypes derived by AMRL. The scaled workload estimates are standardized to range from 0 to 100. Scaled values are comparable across prototypes, whereas the category ratings are not.

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*The prototypes describe the relative emphasis placed on time, effort, and stress in the card-sort rankings. For example, the cards may be ordered with primary emphasis on time (T), with a secondary emphasis on effort (E) and the least importance assigned to stress (S), which is described as the TES prototype. A primary emphasis on time with a secondary emphasis on stress would be described as the TSE prototype. Similarly, primary emphasis on effort can be described as either ETS or EST, and the prototypes SET and STE describe sorts by persons who believe that stress is the primary determinant of workload. In this study, subjects were grouped according to the highest-weighted dimension only.

**The seven trainees in the two certification groups analyzed are not included in these totals.

6.1.3 Workload Estimation

The packet of materials given the subjects contained four "Event Questionnaires" (a sample form is presented in Appendix E) which consisted of the statements defining the SWAT category scales and two questions for determining whether and when the subject had previously experienced the simulated event. An Event Questionnaire was completed immediately following the termination of each exercise. Instructions requested the subject to circle the one statement in each of the three categories which best described his experience of workload during the exercise.

6.2 Results and Discussion

6.2.1 Scenario-Related Differences in Perceived Workload

It is clear that the operating sequences encountered by NPP operators differ in a number of ways. Imposed workload is a strong candidate for a behaviorally meaningful dimension along which operating sequences differ. One question of interest, although not specifically stated in the hypotheses presented in Section 2.2, is whether the crews perceived the four different scenarios as being different in terms of workload, and if so, to what degree. Table 6-2 below presents the mean subjective workload for each crew member according to scenario.

A mixed factor ANOVA having one between subjects factor, "position," and one within-subjects factor, "scenario," was performed on SWAT data summarized in Table 6-2 to investigate whether the scenarios (LOAD, SGTR, LOFW, MSLB) differed significantly in terms of perceived workload for all members of the crew (SRO, LO, BOP and STA).

The ANOVA results indicated that the scenarios differed substantially when collapsed across position: $F(3,198) = 43.54$, $p < .001$. In addition, there was a significant difference between positions: $F(3,66) = 4.81$, $p < .005$; and the interaction was also significant: $F(9,196) = 5.56$, $p < .001$.

In investigating these effects, several points of interest emerge upon inspection of Table 6-2. First and most obvious is that the perceived workload of the SROs, LOs and STAs increased with the level of severity of the scenarios. The increase in perceived workload for the SROs and LOs is consistent with the expectation that the time requirements and complexity of operating the primary plant and emergency systems are higher for the more severe transients. Second, the BOPs' perceived workload was fairly constant across scenarios, including the relatively routine LOAD sequence. This is consistent with the task analysis data, which indicate the BOP operator's tasks related to shutting down the secondary plant systems are similar for each of the accident scenarios. For the LOAD sequence, the BOP operator's workload is the highest of the four crew members. In this exercise, most of his time and attention are devoted to manually controlling the levels in the four SGs, which is one of the most demanding of all control room tasks.

Table 6-2 Mean subjective workload for each position (SRO, LO, BOP, and STA) according to scenario

Scenario	Position				Scenario Average
	SUP	LO	BOP	STA	
LOAD	16.54	34.15	60.61	0.79	31.91
SGTR	50.89	59.32	56.58	41.21	53.54
LOFW	65.72	63.70	63.74	46.03	61.76
MSLB	72.91	83.99	62.98	54.03	71.25
Position Average	51.52	60.29	60.98	36.77	

For the operating sequences examined, the data in Table 6-2 show that the perceived workload of the STAs is lower than that of the ROs and SROs and is very small for the LOAD sequence. This may reflect the fact that the STAs were not involved in the physical operation of the plant. However, like the licensed operators, the STAs' workload varied as a

function of the operating sequence being performed. This suggests that the STA's involvement increased with the severity of the casualty scenarios.

It is interesting to note that the ordering of operating sequences in terms of perceived workload is the approximate inverse of the ordering in terms of measured performance given in Table 5-3. That is, the two sequences with the lowest workloads, LOAD and SGTR, also tended to have the highest task performance scores, and the two with the highest workloads, LOFW and MSLB, had the lowest performance scores. The differences in subjective workload are, however, more clear-cut than differences in performance.

6.2.2 The Effect of STA Presence on Supervisor Workload

In the 1983 experiment, it was hypothesized that the perceived workloads of SROs (supervisors) would be lower for the STA than for the No-STA groups. The data from that experiment suggested that this hypothesis was not, in genéral, true, since the contribution of the STA appeared to be small in the scenarios used. However, the present study employed a wider range of scenario difficulty, and it was hypothesized (H-3 in Section 2.2) that the contribution of the STA would vary as a function of the difficulty of the operating sequence being performed. It is thus likely that the effect of STA assistance on the perceived workload of the supervisor would also vary with the scenario. Specifically, in regard to workload, it is hypothesized that the difference between the workloads of the supervisors in the STA and No-STA groups will be larger for the more difficult scenarios (as determined by the average reported workload of all crew members) than for the less difficult scenarios (H-5).

At the outset of the present study, it was also tentatively hypothesized that the benefit afforded by the STA would be greater for crews led by relatively less experienced supervisors than for crews led by more experienced supervisors (H-4 in Section 2.2). Although H-4 was primarily intended to refer to crew performance, it is reasonable to explore the

subjective workload data for a similar effect. The SWAT data used to test these two hypotheses appear in Table 6-3 (data from the two trainee crews from Plant A do not appear in this table).

Table 6-3 Mean subjective workload of supervisors according to supervisor experience level, STA vs. No-STA conditions, and scenario.

Scenario	High Experience SUPs STA	High Experience SUPs No-STA	Low Experience SUPs STA	Low Experience SUPs No-STA	Scenario Average
LOAD	10.40	22.54	14.48	18.72	16.54
SGTR	44.40	50.88	39.24	69.02	50.89
LOFW	48.86	60.08	59.54	94.38	65.72
MSLB	50.38	64.02	80.14	97.08	72.91
Average	38.51	49.38	48.35	69.80	

The SWAT data summarized in Table 6-3 were analyzed to determine if the perceived workload of the supervisor varied as a function of the principal factors in the experiment, "supervisor experience level" and "presence of the STA." Hypothesis H-5 and a paraphrase of hypothesis H-4 to the effect that the reduction in supervisor perceived workload in the STA groups as compared to the No-STA groups would be larger for the less experienced supervisors than for the more experienced supervisors (H-6) were tested using a mixed-factor ANOVA with two between subjects factors, "supervisor experience level" and "presence of STA," and one within subject factor, "scenario." Specifically, H-5 was tested by the "presence of STA" by "scenario" interaction term, while H-6 was tested by the "presence of STA" by "supervisor experience level" interaction term.

Inspection of Table 6-3 reveals several points of interest. The scenario averages indicate a highly significant main effect for "scenario": $F(3,48) = 27.47$, $p < .001$, which supports the finding reported for all operators. A more interesting finding, however, was the discovery of a significant main effect for "presence of STA": $F(1,16) = 4.62$, $p <$

.05. This is revealed by the bottom row averages in Table 6-3. Collapsing these across "supervisor experience level" results in average SWAT values of 43.43 for the "STA" condition and 59.59 for the No-STA condition. Therefore, the presence of an STA did indeed seem to be associated with a reduction in the supervisor's workload. However, the analysis revealed that this "presence of STA" effect did not interact with either of the other two factors: "scenario" and "supervisor experience level." To illustrate, further inspection of Table 6-3 reveals that the mean differences between the STA and No-STA conditions, collapsing across supervisor experience level for each scenario (LOAD, SGTR, LOFW, MSLB) are, respectively 8.19, 18.13, 23.03, and 15.29. These differences, however, were not found to differ significantly from one another: $F(3,48) < 1$. Thus, the data do not support hypothesis H-5 due to the absence of a significant "presence of STA" by "scenario" interaction. Also, inspection of the group averages on the bottom row of Table 6-3 indicates that the mean differences in perceived workload between the STA and No-STA conditions, collapsing across scenario, are 10.87 for the high supervisor experience level, and 21.45 for the low supervisor experience level. Although the reduction in perceived workload with the presence of an STA is indeed greater for low-rather than high-experienced supervisors, as was hypothesized, the reductions do not differ significantly: $F(1,16) < 1$. Thus it appears that hypothesis H-6 is also not supported by the data.

In contrast to the performance data presented in Section 5, the SWAT data suggest a tangible benefit conferred by the STA. It was usually the case that the SUP called on the STA for assistance in interpreting the various levels of alert described by the Radiological Emergency Plan, and in making the required notifications. In many individual instances, the STA made other substantial contributions to the performance of the crew. For example, the LOAD sequence was performed as a restart, with significant xenon levels. Xenon burnout resulted in a steady power escalation without movement of the control rods. Although the xenon level was mentioned by the instructor in his briefing at the start of the exercise,

LOs in two crews were baffled by the increase in power. The STA convinced one that the power escalation was due to xenon burnout. The other crew, without an STA, spent a good deal of time investigating what they thought was an unexplained boron dilution. In another instance, the STA was the first to call the crew's attention to the loss of RWST level in the MSLB exercise. In another MSLB exercise, the STA was the crew member who pointed out that the pressure transient associated with the steam line break may have damaged the SG, and called for tests which confirmed his suspicion. While these were real contributions to the crew's performance (and were reflected in the scores for the tasks mentioned), they are also things that were done by other crew members when no STA was available.

6.2.3 The Relation Between Perceived Workload and Performance

To investigate the relation between perceived workload and measured performance, the workload estimates provided by the individual operators (STAs were excluded from this analysis because they were responsible for very few tasks) were averaged across the four operating sequences to provide a single SWAT value for each operator. These average SWAT values were then correlated with the set of four task performance measures (B, C, D, and E) used for the analysis of the relation of performance and operating experience presented in Section 5.2.3 The resulting multiple correlation coefficient was small ($R = .247$) and not statistically significant: $F(5,54) < 1$.

7. SUMMARY AND CONCLUSIONS

The initial experiment performed for this project was conducted at a BWR simulator in the fall of 1983 (Ref. 1). The second experiment, which is described in this report, was intended to refine and extend the findings of the 1983 experiment.

The purpose of both experiments performed for this project was to investigate the contribution of supervisor experience and the presence or absence of an STA to operating crew performance during plant operating sequences including normal evolutions and transient events. The questions addressed by the two experiments were:

(1) Do operating crews led by more experienced supervisors perform better than operating crews led by relatively less experienced supervisors?

(2) Do operating crews assisted by an STA perform better than operating crews without STAs?

In the 1983 experiment it was concluded that, while the experiment failed to support the positions that higher experience in the supervisory position or the presence of an STA contribute to crew performance, limitations in the data may have affected the results.

The present experiment was a partial replication and extension of the 1983 experiment, but with PWR operators, and was undertaken to ensure the reliability and generality of the findings of the 1983 experiment. The 1984 experiment was designed to correct certain limitations of the previous experiment by:

(1) employing SUPs having a wider range of experience than the SUPs in the 1983 study,

(2) including more complicated scenarios not fully covered by available procedures, and

(3) using crews of the normal complement (three operators) instead of the minimum complement (two) used in the 1983 study.

7.1 Validity of Performance Measures

Two sets of performance measures were used in the 1983 and 1984 experiments. One set of measures focused on the correct and timely execution of operator tasks identified by a task analysis of the correct performance of the operating sequences employed in the study. The task analysis is based largely on the applicable operating procedures, and was supplemented by additional information from system operating procedures and technical specifications. At the level of individual tasks, the method of derivation insures that each of the constituent measures has a high degree of content validity.

A second set of functional performance measures was based on maintaining parameters identified as important to maintaining the critical safety functions of reactor cooling and maintenance of a secondary heat sink.

Three sets of data were examined to assess the validity of the task performance measures.

First, instructors rated the performance of each crew for each exercise, and the correlation between the ratings and the task performance measures was completed. While the pattern of correlations was consistent with that expected, most of the correlations were too small to achieve statistical significance. However, the nature of the rating instrument and, (especially) the fact that there were eight raters for the 22 crews, give reason to suspect that the reliability of the ratings was suboptimal.

Second, specific actions that were reported by the instructors to have influenced their evaluations of the MSLB exercise were reviewed to determine if the actions cited could have been reflected in the task performance measures. The results of this qualitative analysis showed that the majority of the actions cited would have been reflected in one

or more of the task performance scores. This line of evidence tended to confirm the initial claim to content validity.

Third, a comparison of the performance scores of two groups of trainees showed that they received low scores on the one exercise where they could reasonably have been expected to perform poorly, but not on two other exercises they had practiced recently. This comparison also tended to support the claim for validity of the performance scores.

7.2 The Effects of Supervisor Experience and the Presence of an STA on Crew Performance

The first major finding of this investigation is that overall crew performance was not significantly related to the operating experience of qualified supervisors. This finding is not particularly surprising, as the licensing process is intended to guarantee a high standard of competence for control room personnel.

The effects of increased experience may be reflected more in the operator's attitudes or strategies of performance than in his knowledge or technical skills *per se*. For example, a study by McLeod (Ref. 13) compared the performance of naive subjects (naval personnel) with that of experienced operators in changing power levels on a simulated nuclear reactor. The performance of the naive subjects was "better" than that of the experienced operators in terms of the time required to stabilize at the desired power level, the RMS error during the transition, and the number of control actions executed during the transition. More detailed examinations of the data suggested that the experienced operators were following a much more "conservative" strategy aimed at avoiding an overshoot of the desired power level.

In a second study, which examined the performance of experienced and inexperienced air traffic controllers, the technical performance of the inexperienced controllers (for example, numerical estimates of the future separations of the aircraft) was superior to that of the experienced controllers (Ref. 14). The experienced controllers made more false alarm

errors (stated that two aircraft were potentially in conflict when in fact they were not). That is to say that they were less precise, but more cautious in their judgments, which tend to maximize safety rather than efficiency.

The second finding of the experiment was that the overall performance of crews assisted by an STA was not significantly better than the performance of crews without such assistance when the average performance of the two groups is compared. This was true even in the case of the MSLB, which was included specifically to involve the STAs. There were, however, several instances when the STA solved a problem for the crew, or directed their attention to certain parameters.

This finding is consistent with operational experience. On the basis of a series of interviews with STAs and other plant personnel, the authors of Reference 15 concluded that "... reported performance by STAs under off-normal conditions has been mixed. At some plants there have been specific instances of significant contributions by STAs, while at other plants there has been very limited assistance ... (Ref. 15, p. 9)."

The findings of the present experiment with regard to the effects of supervisor experience and the assistance of an STA on crew performance, even in the two exercises not well covered by available procedures, are thus the same as the findings of the 1983 experiment, where all transients were addressed by procedure. However, the assistance of an STA was associated with an apparent reduction in the supervisors' workload in the 1984 study, which was not found in the 1983 study.

7.3 Individual Performance

For the licensed operators, the correlation between individual performance (as measured by four of the task performance measures) and experience (as measured by months as a licensed operator) was not statistically significant. This finding is not unexpected, as previous investigations have reported an absence of significant correlation

between operator experience and response time (Ref. 16) or operator errors (Ref. 17).

The correlation between the task performance of the licensed operators and recency of simulator training, as measured by months since the last simulator training session attended, was not significant. However, the training schedule was such that the majority of operators had not been in the simulator within four months prior to their participation in the experiment. This schedule may well have helped to minimize performance differences due to recency of training.

7.4 Perceived Workload

The self-reported workload of STAs was lower than the workload of ROs and SROs for all sequences, and was near zero for the turbine loading sequence.

There were significant differences in workload for the four operating sequences. The MSLB was highest, followed by LOFW, followed by SGTR and LOAD. The ordering of sequences in terms of reported workload was similar to the ordering of sequences in terms of scores on the task performance measures used. This correspondence lends additional support to our suggestion (Ref. 1) that subjectively evaluated imposed workload may be a strong candidate for a psychologically meaningful dimension on which operating sequences may be differentiated.

The correlation between individuals' task performance and perceived workload was not statistically significant. The correlation between subjective workload ratings and task performance is often significant only in very high workload situations where a high level of performance cannot be maintained at the cost of increased effort (Ref. 18).

7.5 Conclusions

As was the case of the 1983 experiment, the results of the current experiment did not support the specific hypotheses tested. The generality of the present findings is, however, made much more likely

because they are based on two studies conducted at different types of plants, a wide range of operating sequences, and a wide range of supervisor experiences. However, in addressing the more general questions from which the hypotheses were derived, the results of both experiments tend to support current SRO licensing and control room staffing practices. Specifically, the following conclusions are suggested:

(1) The experimental results provide no basis for using months of control room experience as an important predictor of performance for SROs who are otherwise qualified for their positions.

(2) Although the presence of the STA does not measurably improve crew performance, the STA does contribute to a reduction in the workload of the supervisor.

These conclusions are consistent with the results of related research reported in the literature (References 13, 14, 15, 16, and 17).

In accepting the finding of no significant differences between experimental conditions as meaningful, two limitations of the present study must be considered. First, only 20 full crews could be formed from virtually the whole complements of the two plants that participated in the present study. An inevitable consequence of the small subject population is that effects due to the variables of interest must be fairly large if they are to be reliably detected. This limitation appears to be unavoidable in operator performance research employing a plant-referenced simulator and operators who are trained to operate it. Second, accepting a finding of "no difference" at face value requires that the performance measures be both valid and sensitive to operationally significant variations in performance (Ref. 2). Although the validation analysis presented in Appendix F supports a claim to a degree of content validity, the failure of the task performance measures to correlate significantly with the instructors' ratings means that the validity of the measures has not been proven.

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Appendix A

SUBJECT BIOGRAPHICAL DATA

Appendix A contains two tables listing the experience, educational level, and time since last simulator training for operators and STAs who participated in the experiment.

PLANT A BIOGRAPHICAL DATA

Table A-1 Qualifications and Training of Participating Operators from Plant A

		LICENSE/CERTIFICATION			COLLEGE		SIMULATOR TRAINING	
GROUP	POSITION	TYPE	FIRST	CURRENT	YEARS	DEGREE	Last	Total
01	SUP	BOTH	39[a]	28[a]	1.0	---	5[a]	12.5[b]
	LO	RO	8	8	3.0	AA	5	6.5
	BOP	BOTH	54	54	0.0	---	7	11.5
02	SUP	BOTH	36	24	5.0	BSE	5	11.0
	LO	RO	8	8	0.0	---	5	6.5
	BOP	RO	51	51	0.0	---	5	11.5
03	SUP	SRO	57	57	1.0	---	9	11.5
	LO	RO	18	18	3.7	---	9	7.5
	BOP	RO	33	33	2.5	---	9	9.0
04	SUP	BOTH	45	3	1.0	---	4	11.0
	LO	RO	9	9	4.0	BS	8	6.5
	BOP	RO	9	9	0.0	---	8	6.5
05	SUP	BOTH	37	10	4.0	BS	7	11.0
	LO	RO	31	31	4.0	BA	7	9.0
	BOP	BOTH	55	55	2.0	---	7	11.5
06	SUP	BOTH	35	5	0.0	---	7	11.0
	LO	BOTH	57	38	1.5	MISSING	9	11.0
	BOP	RO	11	11	0.0	---	8	6.5
07	SUP	BOTH	44	23	3.0	AA	5	12.5
	LO	RO	9	9	7.0	BS	8	6.5
	BOP	BOTH	56	21	1.0	---	8	11.0
	STA	STA	--	--	4.0	BSE	3	3.0
08	SUP	SRO	56	56	0.0	---	7	11.5
	LO	RO	3	3	0.0	---	5	6.0
	BOP	SRO	56	56	0.0	---	7	11.5
	STA	STA	--	--	4.0	BS	4	3.5

(Table Continued on next page)

a. Months since license or last simulator training.
b. Weeks.

Table A-1 Qualifications and training of participating operators from Plant A - continued

		LICENSE/CERTIFICATION			COLLEGE		SIMULATOR TRAINING	
GROUP	POSITION	TYPE	FIRST	CURRENT	YEARS	DEGREE	Last	Total
09	SUP	BOTH	55[a]	55[a]	2.2	AA	7[a]	11.5[a]
	LO	RO	9	9	3.5	BS	7	6.5
	BOP	RO	9	9	0.0	---	7	6.5
	STA	STA	--	--	4.0	BSE	11	2.5
10	SUP	BOTH	56	16	0.0	---	7	11.0
	LO	SRO	56	56	2.0	---	7	11.5
	BOP	RO	3	3	4.0	AA	3	6.0
	STA	STA	--	--	5.0	BS	3	4.5
11	SUP	BOTH	57	18	4.0	BS	8	11.0
	LO	RO	24	24	3.0	---	9	8.0
	BOP	RO	18	18	2.0	---	9	7.5
	STA	STA	--	--	4.0	BS	4	5.0
12	SUP	BOTH	39	12	0.0	---	3	11.0
	LO	BOTH	58	39	2.0	---	8	11.0
	BOP	RO	18	18	0.0	---	8	7.5
	STA	STA	--	--	5.0	BS	5	5.5
21[c]	ALL	O	0	0	2.1	AA	0	5.0
	ALL	O	0	0	5.5	MSE	0	5.0
	ALL	O	0	0	4.5	AA	0	5.0
	ALL	0	0	0	4.0	AA	0	5.0
22[c]	ALL	O	0	0	2.5	AA	0	4.0
	ALL	O	0	0	4.0	BS	0	4.0
	ALL	O	0	0	2.0	AA	0	4.0

a. Months since license or last simulator training.

b. Weeks.

c. Groups 21 and 22 were trainees.

APPENDIX B

OPERATING SEQUENCE OVERVIEWS AND TASK SEQUENCE CHARTS

The Operating Sequence Overviews(OSOs) and Task Sequence Charts (TSCs) for the four PWR transients for which performance was evaluated are included in this appendix.

(1) Turbine Loading (LOAD)

(2) Steam Generator Tube Rupture (SGTR)

(3) Total Loss of Feedwater/Loss of 6.9 KV Shutdown Board (LOFW)

(4) Main Steam Line Break with SGTR and Loss of RWST (MSLB)

In the LOAD sequence, tasks 1 and 5 were combined for scoring purposes.

In the SGTR, LOFW, and MSLB sequences, alternate forms of a task, or tasks that are required only if certain conditions arise, are labeled with letters, e.g., "35B."

Operating Sequence Overview

Plant: 50

Operator Function/Subfunction: Supervise and control plant operations/generate power

NSSS/Type: W/PWR

Operating Sequence ID: 04

CR Type: Multiple

Operating Sequence: Turbine loading

Initial Conditions: The plant is in mode 2 with the reactor critical and the turbine running at 1650 rpm on the throttle valves (I.C. 17).

Sequence Initiator: The crew is directed to continue the startup.

Expected Progression of Action: The crew will complete the turbine startup and notify the load dispatcher that the generator is ready to tie into the grid. The generator will be synchronized with the grid and loaded to 18 percent power. During the load increase, the crew will perform the following actions: transfer feedwater flow from the bypass valves to the main regulating valves, block the intermediate range and low power range reactor trips, transfer the reactor control system to automatic, transfer steam dump control to the T-avg mode, transfer 6.9 KV load boards from the start buses to the station service transformers, and transfer feedwater control to automatic. The crew will then begin a load increase to 30 percent power and dispatch the chemistry section to determine steam generator chemistry.

Final Conditions: The plant is operating at 30% power.

Major Systems: Main Turbine, Main Steam, Main Feedwater, Condensate, AC Power, Rod Control, Chemical and Volume Control, Reactor Protection, Neutron Monitoring.

Operating Sequence Overview

Plant: 50

Operator Function/Subfunction: Supervise and control plant operation/mitigate consequences of an accident

NSSS/Type: W/PWR

Operating Sequence ID: 13

CR Type: Multiple

Operating Sequence: Steam Generator Tube Rupture

Initial Conditions: The plant is at full power with equilibrium xenon early in core life (I.C. 10).

Sequence Initiator: A failure at the tube-plate interface in #4 steam generator results in a leak rate of 600 GPM at full load conditions (Malfunction 42D, 60% severity).

Expected Progression of Action: The steam generator (SG) tube rupture causes an immediate decrease in pressurizer (PZR) level and reactor coolant system (RCS) pressure and an increase in charging flow. The crew will start additional charging pumps and observe indications to determine the cause of the inventory loss. The release of fission product gases in the steam generator causes an increase in radiation levels at the condenser vacuum pump vents and SG blowdown lines, resulting in radiation monitor alarms. The crew will diagnose that a tube rupture has occurred and implement the Radiological Emergency Plan by notifying the Operations Duty Specialist and sounding the emergency siren. The crew will manually trip the reactor and initiate Safety Injection. The crew will verify the reactor trip, turbine trip, the transfer of electrical loads, containment isolation, and the proper operation of the emergency core cooling systems (ECCS) and auxiliary feedwater (AFW) system. The crew will identify and isolate the faulted SG and begin a rapid cooldown of the RCS using the steam dumps. Health Physics personnel will be dispatched to survey the turbine building.

When the RCS temperature has been reduced sufficiently to maintain subcooling, the crew will begin RCS depressurization using normal pressurizer spray until RCS pressure is below the pressure in the faulted steam generator. When PZR level and RCS pressure have stabilized, the crew will terminate safety injection.

Final Conditions: The faulted SG is isolated. SG pressure and RCS pressure are equalized. Safety injection has been terminated.

Major Systems: Main Steam, Main Feedwater, Auxiliary Feedwater, Condensate, Main Turbine, Neutron Monitoring, Chemical and Volume Control, Safety Injection, AC Power, Reactor Coolant, Upper Head Injection, Pressurizer Pressure Control, Containment Isolation.

Operating Sequence Overview

Plant: 50

Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident.

NSSS/Type: W/PWR

Operating Sequence ID: 52

CR Type: Multiple

Operating Sequence: Total Loss of Feedwater/Loss of 6.9 KV Shutdown Board

Initial Conditions: The plant is at full power end of life conditions (IC-19). The "A" auxiliary feedwater (AFW) pump is out of service for maintenance (Malfunction 53A).

Sequence Initiator: Operation of a protective relay on 6.9 KV shutdown board 1B-B deenergizes that board and prevents alternate and emergency power breakers from closing (Malfunction 111B). A loss of condenser vacuum (Malfunction 98) results in a trip of the main feedwater pumps on low suction. The turbine AFW pump fails to start due to a trip of the steam isolation valve (Malfunction 53C).

Expected Progression of Action: The loss of vacuum will cause and a turbine trip and reactor trip. The crew will verify automatic actions associated with a reactor/turbine trip and recognize the loss of shutdown board 1B-B and all AFW pumps. After unsuccessfully attempting to energize the shutdown board, the crew will dispatch an operator to return the steam-driven AFW pump to service.

The crew will reset the main feedwater isolation and depressurize the steam generators by dumping steam through the SG power operated relief valves to establish condensate flow to the steam generators.

Final Conditions: The plant is shutdown with 6.9 KV shutdown board deenergized, RCS temperature stabilized at approximately 400 degrees, and SG level stabilized at 20-25%.

Major Systems: Main Steam, Main Feedwater, Auxiliary Feedwater, Condensate, AC Power, Diesel Generator, Neutron Monitoring, Safety Injection, Essential Raw Cooling Water, Main Turbine.

Operating Sequence Overview

Plant: 50

Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident.

NSSS/Type: W/PWR

Operating Sequence ID: 53

CR Type: Multiple

Operating Sequence: Main Steam Line Break/Steam Generator Tube Rupture/Loss of Refueling Water Storage Tank

Initial Conditions: Plant is at full power, with equilibrium xenon late in core life (IC-19).

Sequence Initiator: A fracture of the main steam line (MSL) in the vicinity of the refueling water storage tank (RWST) (Malfunction 80). The main steam isolation valve (MSIV) for #4 steam generator (SG) fails to close (Malfunction 82D).

Expected Progression of Action: The MSL break causes a rapid cooldown and depressurization of the reactor coolant system (RCS). High steam flow in coincidence with low RCS temperature causes the MSIVs to close and initiates a safety injection (SI) signal.

The crew will verify the reactor trip, turbine trip, transfer of electrical loads, containment isolation, and the proper operation of the emergency core cooling system (ECCS) and auxiliary feedwater (AFW) system. The crew will diagnose the failure of the MSIV and Isolate AFW to #4 steam generator. The depressurization of the SG causes a rupture of one of the tubes (Malfunction 42D, 60%). The steam generator tube rupture causes a loss of RCS inventory, and an increase in #4 SG inventory. The crew will initiate the Radiological Emergency Plan and begin a rapid cooldown of the RCS using power operated relief valves (PORVs) in the unaffected steam generators.

Fragments from the MSL break damage the RWST, causing a large leak (Malfunction 121). Upon receipt of the RWST low level alarm, the crew will diagnose that loss of the RWST is imminent and take action to line up alternate sources of makeup water. The crew will begin a rapid depressurization of the RCS using normal spray to reduce the flow rate through the tube rupture. The crew will secure the SI pumps and RHR pumps when the low level in the RWST causes loss of suction.

Final Conditions: The plant is shutdown and depressurized to atmospheric pressure.

-- continued on next page --

Major Systems: Main Steam, Main Feedwter, Auxiliary Feedwater, Emergency Core Cooling, AC Power, Upper Head Injection, Neutron Monitoring, Safety Injection, Chemical and Volume Control, Radiation Monitoring.

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/generate power

Operating Sequence: Turbine Loading (LOAD) Operating Sequence ID: 04

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
1.*	Operate main feedwater (MFW) bypass valves to monitor steam generator (SG) levels	-NONE- (sequence starts with this task in progress)	GOI-2	Condensate and Feedwater		20% (NR) < levels < 60%			Trip/FW isolation set-points (SP)
2.	Call load dispatcher to notify grid controller that unit is about to tie onto grid		GOI-2					Before tying onto grid	
3.	Increase turbine speed to 1700 RPM to prepare for TV-GV transfer		GOI-2	Electro-Hydraulic Control					
4.*	Determine if turbine overspeed test has been performed to satisfy administrative requirement		GOI-2						
5.	Operate MFW regulator valves to control SG levels until automatic level controllers will function properly		GOI-2	Condensate and Feedwater		20% (NR) < levels < 60%			Trip/FW isolation SP

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/generate power

Operating Sequence: Turbine Loading (LOAD) Operating Sequence ID: 04

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
6.	Perform throttle valve-governor valve (TV-GV) transfer to permit governor valve control	Turbine RPM = 1700	GOI-2	Electro-Hydraulic Control					
7.	Align turbine auxiliary systems for at power operation to prepare for power escalation		GOI-2	Hydrogen System, Raw Cooling Water System					
8.*	Start preferred transformer cooler and verify transformer bushing oil pump running to insure cooling for main transformer		GOI-2						
9.	Parallel unit generator with distribution grid to enable unit generator to provide power to distribution grid	Generator speed 1800 RPM	GOI-2						
10.	Increase generator load to bring load up to 18%	Turbine tied onto grid	GOI-2	Electro-Hydraulic Control					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/generate power

Operating Sequence: Turbine Loading (LOAD) Operating Sequence ID: 04

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Req.	Op.	
11.	Block intermediate - and power range trips to prevent inadvertent reactor trip during power escalation		GOI-2	Reactor Protection		> 10% Power		< 20% Power	
12.*	Warm feedwater heaters to prepare for power escalation		GOI-2	Extraction Steam					
13.	Calculate axial flux distribution to verify proper flux pattern		GOI-2	Nuclear Instrumentation		> 10% Power			
14.	Transfer 6.9 KV unit boards from start buss to station service transformer to align station electrical systems for at-power operation		GOI-2			> 15% Power			
15.	Place steam dumps in T-ave mode of control to prepare for power escalation	C-5 interlock reset	GOI-2	Steam Dump System		> 15% Power			

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/generate power

Operating Sequence: Turbine Loading (LOAD) Operating Sequence ID: 04

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR) H/W	Req.	Op.	PR Source
16.	Transfer rod control system from manual to automatic control mode to prepare for power escalation		GOI-2			> 15% Power			
17.*	Place #1 feedwater heaters in service to align secondary plant for power escalation		GOI-2	Extraction Steam					
18.	Warm up moisture separator reheaters to align secondary plant for at-power operation		GOI-2	Main Steam					
19.	Increase generator load to 30% to increase power output		GOI-5A						
20.	Transfer turbine EHC system to "impulse" mode of control to align system for at-power operation	Turbine load < 25%	GOI-5A	Electro-Hydraulic Control		> 25% Load			
21.	Align non-operating main feed-water pump turbine for operation to prepare for power generation above 30% power	= 30%	GOI-5A	Condensate and Feedwater		Prior to 40% Power			

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant ope ations/generate power

Operating Sequence: Turbine Loading (LOAD) Operating Sequence ID: 04

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
22.	Maintain RCP seal injection flow to insure RCP seal integrity END OF SEQUENCE	-NONE- (continuing task)	SOI-68.2	Reactor Coolant, Chemical Volume Control					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequence of an accident

Operating Sequence: Steam Generator Tube Rupture (SGTR) Operating Sequence ID: 13

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
1.	Diagnose SGTR to determine appropriate response	Annunciator (AN) "Pzr Pres. Lo-B/U Htrs ON"							
2.	Increase charging flow to maintain pressurizer level	AN: "Pzr level Lo"	AOI-24	Chemical and Volume Control				Start additional charging pump	
3.	Start an addtional component cooling pump to provide cooling for charging pumps	Additional charging pump started	SOI-62.1	Component Cooling				Within 90 sec of starting charging pump	
4.	Identify faulted steam generator (SG) to determine appropriate actions	Condenser vacuum pump rad monitor alarm	E-3	Radiation Monitors				Crew knows which SG is faulted	

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequence of an accident

Operating Sequence: Steam Generator Tube Rupture (SGTR) Operating Sequence ID: 13

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
5.	Trip the reactor to halt power generation	When evident pressurizer level cannot be maintained	AOI-24	Reactor Protection					
6.	Verify shutdown boards energized to assure continuity of electrical power	AN: "Turbine shutdown"	E-0						
7.	Initiate safety injection to maintain RCS pressure	Procedure	AOI-24						
8.	Verify reactor trip to ensure subcriticality	Rx trip breaker open	E-0	Reactor Protection, Annunciator, Nuclear Instrumentation					
9.	Verify turbine trip to ensure performance as expected	Rx trip	E-0	Electro-Hydraulic Control					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequence of an accident

Operating Sequence: Steam Generator Tube Rupture (SGTR) Operating Sequence ID: 13

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR) H/W	Performance Requirements (PR) Reg.	Performance Requirements (PR) Op.	PR Source
10.	Match electrical breakers (clear breaker disagreement lights) to assure continuity of electrical power	AN: "6900V unit board 1A transfer"	SOI-55-M1						
11.	Verify secondary heat sink (auxiliary feedwater operation) to ensure heat removal capability	Rx trip	E-0	Auxiliary Feedwater					
12.	Verify main feedwater isolation to assure control of cooldown rate	AN: "RX coolant loop Lo T-ave"	E-0	Condensate and Feedwater					
13.	Verify operation of cooling systems to ensure cooling of initial equipment	SI initiated	E-0	Component Cooling, Essential Raw Cooling Water					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequence of an accident

Operating Sequence: Steam Generator Tube Rupture (SGTR) Operating Sequence ID: 13

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
14.	Verify gas treatment systems to ensure performance as expect-ed	SI initiated	E-0	Auxiliary Building Gas Treatment, Emergency Gas Treat-ment					
15.	Verify diesel generators running to ensure source of emergency power	SI initiated							
16.	Review procedures to insure all appropriate actions accomplished	Diagnosis of SGTR							
17.	Verify containment conditions to confirm diagnosis	SI initiated	E-0						
18.	Isolate the faulted SG to contain radioactivity	Completion of Task 4	E-3	Main Steam, Auxiliary Feedwater					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequence of an accident

Operating Sequence: Steam Generator Tube Rupture (SGTR) Operating Sequence ID: 13

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Req.	Op.	
19.	Shutdown unnecessary equipment to mainimize electrical load	Rx trip	ES-3.1	Condensate and Feed-water, Ex-traction Steam, Heat-er Drains and Vents					
20.	Align moisture separator reheaters to normal to place plant in shutdown lineup/to protect equipment	Rx trip	ES-3.1	Main Steam					
21.	Shut extraction steam and drain valves to remove unnecessary equipment from service	Rx trip	ES-3.1	Extraction Steam					
22.	Energize source range instru-ments to monitor shutdown flux	AN: "In-termediate range per-missive" OFF	ES-3.1	Nuclear In-strumentation		Power $< 10^{-10}$ amps			

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50   Operator Function/Subfunction: Supervise and control plant operations/mitigate consequence of an accident

Operating Sequence: Steam Generator Tube Rupture (SGTR)   Operating Sequence ID: 13

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR) H/W	Performance Requirements (PR) Reg.	Performance Requirements (PR) Op.	PR Source
23.	Check turbine generator to ensure performance as expected	AN: "Turbine shutdown" AN: "Rotor zero speed"	ES-3.1	Turbine Turning Gear		< 2 rpm			
24.	Shutdown generator voltage regulator to secure unnecessary equipment	AN: "Turbine shutdown"	ES-3.1						
25.	Implement radiological emergency plan to allow depressurization	AN: "Condenser vacuum pump air exhaust hi rad"	REP						
26.	Cooldown the RCS to allow depressurization	MSIV for faulted SG closed	E-3	Main Steam, Reactor Coolant					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequence of an accident

Operating Sequence: Steam Generator Tube Rupture (SGTR) Operating Sequence ID: 13

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
27.	Depressurize the RCS to terminate tube leakage	MSIV for faulted SG closed	E-3	Pressurizer and Pressurizer Spray Control					
28.	Isolate upper head injection system to prevent unnecessary injection	RCS pressure < 1900 psig	E-3	Safety Injection System		Before RCS pressure = 1250 psig			SP for automatic injection
29.	Terminate safety injection to establish control of RCS inventory and pressure	SI initiated	E-3						
30.	Restore charging and letdown to allow control of pressurizer level	AN: "Auto SI blocked"	ES-3.1	Chemical and Volume Control					
31.	Maintain stable plant conditions to insure plant safety	AN: "Auto SI blocked"							

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequence of an accident

Operating Sequence: Steam Generator Tube Rupture (SGTR) Operating Sequence ID: 13

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
32.	Secure diesel generators to protect equipment	SI initiated							
33.	Reset first-out annunciators to allow detection of future alarm conditions END OF SEQUENCE	SI initiated		Annunciator					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50   Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Total loss of feedwater/loss of 6.9 KV shutdown board (LOFW)   Operating Sequence ID: 52

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
1.	Recognize loss of 6.9 KV shutdown board to determine appropriate actions	AN: "Rx MOV or vent BDS train B UV"							
2.	Identify deenergized equipment to evaluate plant status	AN: "480 shutdown bd 1B1-B fail on UV"							
3.	Recognize loss of vacuum to determine follow-up actions	AN: "Condenser vacuum lo"							
4.	Verify reactor trip to ensure subcriticality	Rx trip breaker open	E-0	Reactor Protection, Annunciator, Nuclear Instrumentation					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Total loss of feedwater/loss of 6.9 KV shutdown board (LOFW) Operating Sequence ID: 52

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
5.	Verify turbine trip to ensure performance as expected	AN: "Auto stop-turbine trip"	E-O	Electro-Hydraulic Control					
6.	Verify "A" shutdown boards energized to assure continuity of electrical power	AN: "Turbine shutdown"	E-O						
7.	Check for actuation of safety injection system to determine plant status	Rx trip	E-O	Safety Injection System				Crew aware SI has not occurred	
8.	Recognize loss of auxiliary feedwater to determine appropriate actions	Rx trip	ES-0.1	Auxiliary Feedwater					
9.	Verify main feedwater isolation to assure control of cooldown	AN: "Rx coolant loop lo T-ave"	ES-0.1	Reactor Protection, Condensate and Feedwater					
10.	Review procedures to insure all appropriate actions accomplished	Rx trip							

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50   Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Total loss of feedwater/loss of 6.9 KV shutdown board (LOFW)   Operating Sequence ID: 52

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
11.	Evaluate RCS indications to determine plant conditions	Rx trip	ES-0.1	Reactor Coolant				Crew aware of RCS status	
12.	Verify containment conditions to verify diagnosis (exclude LOCA)	Rx trip	ES-0.1					Crew aware of containment conditions	
13.	Verify CVCS operation to assure control of RCS inventory	Rx trip	ES-0.1	Chemical and Volume Control					
14.	Establish condensate flow path to prepare to feed SGs with condensate pumps	Lo-Lo level in any SG	FR-H.1	Condensate and Feedwater					
15.	Shutdown unnecessary equipment to minimize electrical load	Rx trip	ES-0.1	Condensate and Feedwater, Extraction Steam, Heater Drains and Vents					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Total loss of feedwater/loss of 6.9 KV shutdown board (LOFW) Operating Sequence ID: 52

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
16.A	Depressurize SGs in MANUAL to reduce SG pressure to below the shutoff head of the condensate pumps	Lo-Lo level in any SG	FR-H.1	Main Steam, Steam Dump					
16.B	Depressurize SGs in AUTOMATIC to reduce SG pressure to below the shutoff head of the condensate pumps (alternate form of 16.A)	Lo-Lo level in any SG	FR-H.1	Main Steam, Steam Dump					
16.C	Restore CVCS operation (task required only if cue - often not necessary) to control pressurizer level	AN: "Pzr level lo, Htr off and L/D secured"	SOI-62.1	Chemical and Volume Control		Pressurizer Level > 17%			
16.D	Terminate safety injection (task required only if SI actuated - often not necessary) to allow restoration of secondary heat sink	SI actuated	Beyond Scope of Procedures						

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Total loss of feedwater/loss of 6.9 KV shutdown board (LOFW) Operating Sequence ID: 52

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
16.E	Restore charging and letdown (task required only if SI) to allow control of pressurizer level	AN: "Auto SI blocked"	ES-0.2	Chemical and Volume Control		SI Reset			
16.F	Reset feedwater isolation following SI (task required only if SI) to restore secondary heat sink	SI actuated	Beyond Scope of Procedures	Reactor Protection		SI Reset			
17.	Align moisture separator reheaters to normal to place plant in shutdown lineup/to protect equipment	Turbine trip	ES-0.1	Main Steam					
18.	Realign extraction steam and drain valves to remove unnecessary equipment from service/to protect equipment	Turbine trip	ES-0.1	Extraction Steam					
19.	Match electrical breakers (clear breaker disagreement lights) to assure continuity of electrical power	AN: "6900V unit board 1A transfer"	SOI-55-1M1						

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Total loss of feedwater/loss of 6.9 KV shutdown board (LOFW) Operating Sequence ID: 52

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
20.	Shutdown generator voltage regulator to prevent equipment damage	AN: "Turbine shutdown"	ES-0.1						
21.	Energize source range instruments to monitor shutdown flux	AN: "Intermediate range permissive" OFF	ES-0.1	Nuclear Instrumentation		Power $< 10^{-10}$ amps			
22.	Check turbine generator to ensure performance as expected	AN: "Turbine Shutdown" AN: "Rotor zero speed"	ES-0.1	Turbine Turning Gear		< 2 rpm			
23.	Depressurize the RCS to keep differential pressure across SG tubes within limits	AN: "Rx coolant loops Lo-Lo T-ave"		Pressurizer and Pressurizer Spray Control		RCS pressure < SG pressure + 1600 psig			Differential pressure limit for SG tubes

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TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Total loss of feedwater/loss of 6.9 KV shutdown board (LOFW) Operating Sequence ID: 52

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
24.	Isolate upper head injection system to prevent unnecessary injection	RCS pressure < 1900 psig	GOI-3	Safety Injection System		Before RCS pressure = 1250 psig			SP for automatic injection
25.	Establish condensate flow to maintain secondary heat sink	AN: "SG loops steam line isolation pressure Lo"	FR-H.1	Condensate and Feedwater					
26.	Monitor diesel generator operation to prevent equipment damage	AN: "D/G Lo auto start failure"							
27.	Make notifications to notify appropriate personnel/ authorities END OF SEQUENCE	Rx trip	REP						

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Main steam line break with SGTR and loss of RWST (MSLB) Operating Sequence ID: 53

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Req.	Op.	
1.	Recognize main steam line break to determine appropriate response	Annunciator (AN): "SAF hi stm flow with lo T-ave or stm pressure Rx trip"	E-0	Annunciator					
2.	Verify reactor trip to ensure subcriticality	Rx trip breaker open	E-0	Reactor Protection, Nuclear Instrumentation					
3.	Verify turbine trip to ensure performance as expected	Rx trip	E-0	Electro-Hydraulic Control					
4.	Verify shutdown boards energized to assure continuity of electrical power	AN: "Turbine shutdown"	E-0						
5.	Verify safety injection to ensure performance as expected	SI actuated	E-0	Safety Injection					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Main steam line break with SGTR and loss of RWST (MSLB) Operating Sequence ID: 53

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
6.	Verify containment conditions to confirm diagnosis (exclude LOCA)	SI actuated	E-0						
7.	Isolate faulted SG to mitigate uncontrolled RCS cooldown	AN: "SAF hi stm flow with lo T-ave or stm pressure Rx trip"	E-2	Main Steam, Auxiliary Feedwater					
8.	Verify auxiliary feedwater status to ensure secondary heat sink is maintained	SI actuated	E-0	Auxiliary Feedwater					
9.	Verify main feedwater isolation to assure control of cooldown rate	AN: "Rx coolant loop lo T-ave	E-0	Condensate and Feed-water					
10.	Break condenser vacuum to minimize equipment damage (turbine seals)	AN: "SG loops stm line isol press lo"							

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Main steam line break with SGTR and loss of RWST (MSLB) Operating Sequence ID: 53

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
11.	Shutdown unnecessary equipment to minimize electrical load	Rx trip	ES-0.1	Condensate and Feedwater, Heater Drains and Vents					
12.	Shutdown generator voltage regulator to secure unnecessary equipment	AN: "Turbine shutdown"	ES-0.1						
13.	Align moisture separator reheaters to normal to place plant in shutdown lineup/to protect equipment	Rx trip	ES-0.1	Main Steam					
14.	Shut extraction steam and drain valves to remove unnecessary equipment from service	Rx trip	ES-0.1	Extraction Steam					
15.	Match electrical breakers (clear breaker disagreement lights) to assure continuity of electrical power	AN: "6900V unit board 1A transfer"	SOI-55-M1						

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Main steam line break with SGTR and loss of RWST (MSLB) Operating Sequence ID: 53

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Req.	Op.	
16.	Verify operation of cooling systems to ensure cooling of vital equipment	SI actuated	E-0	Component Cooling, Essential Raw Cooling Water					
17.	Verify gas treatment systems to ensure performance as expected	SI actuated	E-0	Auxiliary Building Gas Treatment, Emergency Gas Treatment					
18.	Isolate upper head injection system to prevent unnecessary injection	RCS pressure < 1900 psig	E-1	Safety Injection		Before RCS pressure = 1250 psig			SP for automatic injection
19.	Review procedures to insure all appropriate actions accomplished	Diagnosis of casualties							
20.	Implement radiological emergency plan to notify appropriate personnel/authorities	SI actuated	REP						

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Main steam line break with SGTR and loss of RWST (MSLB) Operating Sequence ID: 53

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Req.	Op.	
21.	Cooldown the RCS to prepare for operation of residual heat removal system	AN: "SAF hi stm flow with lo T-ave or stm pressure Rx trip"	E-1	Main Steam, Reactor Coolant					
22.	Check secondary side radiation to assess extent of release of radioactivity/to aid in determining extent of damage to SGs	AN: "SAF hi stm flow with lo T-ave or stm pressure Rx trip"	E-2	Radiation Monitoring					
23.	Recognize loss of RWST to assess plant condition	AN: "RWST level lo"	SOI-55-1M6	Safety Injection					
24.	Increase makeup from volume control tank to establish alternate coolant injection source	AN: "RWST level lo"	Beyond Scope of Procedures	Chemical and Volume Control					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Main steam line break with SGTR and loss of RWST (MSLB) Operating Sequence ID: 53

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
25.	Restore charging flow to establish injection flow path	AN: "RWST level lo"	Beyond Scope of Procedures	Chemical and Volume Control					
26.	Depressurize the RCS to establish conditions for RHR operation	AN: "Stm loop 4 to pressure"	Beyond Scope of Procedures	Pressurizer and Pressurizer Spray Control		Achieve RCS pressure < 380 psig			Injection head of RHR system
27.A	Terminate safety injection to prevent equipment damage	AN: "Auto SI blocked"	Beyond Scope of Procedures	Safety Injection					
27.B	Terminate safety injection to prevent equipment damage	Loss of suction to SI pumps	Beyond Scope of Procedures	Safety Injection					
27.C	Restart a charging pump to replace RCS inventory	AN: "Auto SI blocked"	Beyond Scope of Procedures	Chemical and Volume Control					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Main steam line break with SGTR and loss of RWST (MSLB) Operating Sequence ID: 53

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
28.	Restore letdown flow to establish RCS inventory control	Pressurizer level > 17%	Beyond Scope of Procedures	Chemical and Volume Control					
29.	Recognize steam generator tube rupture to determine further action	AN: "SG loop 4 hi stm flow" OR report from Health Physics	E-2						
30.	Monitor subcooling to ensure adequate core cooling	RCS depressurization	E-0						
31.	Energize source range instruments to monitor shutdown flux	AN: "Intermediate range permissive" OFF	ES-0.1	Nuclear Instrumentation		Power $< 10^{-10}$ amps			

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Main steam line break with SGTR and loss of RWST (MSLB) Operating Sequence ID: 53

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR) H/W	Performance Requirements (PR) Reg.	Performance Requirements (PR) Op.	PR Source
32.	Check turbine generator to ensure performance as expected	AN: "Turbine shutdown" AN: "Rotor zero speed"	ES-0.1	Turbine Turning Gear		< 2 rpm			
33.	Secure diesel generators to protect equipment	SI actuated	ES-0.2						
34.A	Establish cooling with residual heat removal (RHR) to cooldown plant for maintenance	T-hot < 350° and RCS pressure < 380 psig	GOI-3C	Residual Heat Removal		Pressure < 380 psig			Isolation Valve Interlock SP
34.B	Establish RHR letdown to insure RCS inventory and pressure control	RHR in service	GOI-3C	Residual Heat Removal					
35.A	Secure reactor coolant pumps during RHR cooldown to allow cooldown	RHR in service	GOI-3C	Reactor Coolant					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Main steam line break with SGTR and loss of RWST (MSLB) Operating Sequence ID: 53

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR) H/W	Req.	Op.	PR Source
35.B	Secure reactor coolant pumps due to low RCS pressure to prevent damage to RCPs	AN: "RCP Δ P lo"	SOI-68.2	Reactor Coolant		Δ P > 200 psid			SOI-68.2
35.C	Restart a reactor coolant pump to enhance core cooling	All RCPs OFF and RCS temp > 160°	GOI-3B	Reactor Coolant					
35.D	Verify natural circulation to ensure core cooling	All RCPs OFF and RHR OFF	E-1	Reactor Coolant					
36.	Isolate SI accumulators to prevent unnecessary injection	RCS pressure between 500 and 1000 psig and pressurizer level > 20%	GOI-3B	Safety Injection		Pressure < 1000 psig			Isolation Valve SP

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

TASK SEQUENCE CHART

(OAK RIDGE NATIONAL LABORATORY)

Plant Name: 50 Operator Function/Subfunction: Supervise and control plant operations/mitigate consequences of an accident

Operating Sequence: Main steam line break with SGTR and loss of RWST (MSLB) Operating Sequence ID: 53

Task Seq. No.	Task	Cue	Procedure Name & Number	Plant Specific System Name	INPO System Number	Performance Requirements (PR)			PR Source
						H/W	Reg.	Op.	
37.	Reset first-out annunciators to allow detection of future alarm conditions END OF SEQUENCE	SI actuated		Annunciator					

*Adapted from the TSC form used for "Task Analysis of Nuclear Power Plant Control Room Crews," NUREG/CR-3371

APPENDIX C

SAMPLE TASK ANALYSIS MATERIALS

Appendix C contains the Task Data Form (Descriptive), Task Performance Measures Worksheet, and Task Performance Criteria forms for the task "Cooldown the RCS" from the Steam Generator Tube Rupture sequence.

(1) Task Data Form (Descriptive)

(2) Task Performance Measures Worksheet

(3) Task Performance Criteria

TASK DATA FORM (DESCRIPTIVE)

Page No. 1/2

PLANT IDENTIFICATION

Plant Name 50

Unit Number II

NSSS Vendor Westinghouse

A-E

TG Vendor

CR Type Multiple

OL Date

TASK IDENTIFICATION

Operating Sequence SGTR

Operating Sequence ID 13

Operator Function Sup and control plant ops.

Operator Sub function mitigate consequences of accident

Comments

CUE MSIV for faulted SG closed

Task Statement Reduce steam generator pressure

Task Purpose Reduce primary pressure/temperature

INPO Task Code

Task Sequence No. 26

Task Duration

Procedures E-3

Data Collected at: Simulator

Who Takes Action JOBCAT	Location of Means of Action LOC	Behavior		Object of Action						Means of Action MEANS	Communication Link		
		TIME	VERB	COMPONENT	PARAMETER	STATE	OTHER OBJECT	PLANT SYSTEM	INPO EQUIV		RESPOND.	RLOC	CONTENT
RO-2	M-4	11:59	Positions	controller (steam dump mode)		steam press. mode				DC			
RO-2	M-4	12:02 ↓ 13:24	Adjusts	valve (steam dump)	Position					CVC			
RO-2	M-4	12:00 ↓ 12:30	Monitors				RCS temperature			Meter			
RO-2	M-4	12:30	Positions				SIS train B main stm SI block to "bypass"			DC			
RO-2	M-4	12:30	Positions				SIS train A main stm SI block to "bypass"			DC			

TASK DATA FORM (DESCRIPTIVE)

Page No. 2/2

PLANT IDENTIFICATION

Plant Name ________

Unit Number ________

NSSS Vendor ________

A E ________

TG Vendor ________

CR Type ________

OL Date ________

TASK IDENTIFICATION

Operating Sequence ________

Operating Sequence ID ________

Operator Function ________

Operator Sub function ________

Comments ________

CUE ________

Task Statement ________

Task Purpose ________

INPO Task Code ________

Task Sequence No. 26

Task Duration ________

Procedures ________

Data Collected at: ________

Who Takes Action JOBCAT	Location of Means of Action LOC	Behavior		Object of Action						Means of Action MEANS	Communication Link		
		TIME	VERB	COMPONENT	PARAMETER	STATE	OTHER OBJECT	PLANT SYSTEM	INPO EQUIV		RESPOND.	RLOC	CONTENT
RO-1	M-4/ M-5	12:30 ÷ 12:40	Monitors		Pressurizer level					Meter/ Recorder			
RO-2		12:35	Informs							Verbal	SRO-2		Cooldown initiated

TASK PERFORMANCE MEASURES WORKSHEET

Plant 50 **Sequence** SGTR **Task No.** 26

Task Statement Reduce steam generator pressure

Task Purpose to reduce primary pressure/temperature

Task Standards cool to target temperature specified in table on p. 4 of E-3 / cooldown not to exceed 100°F

References E-3

No.	Element	Standard	Reference	Control/Display	Potential Error	Method of Detection
1	RO-2 positions steam dump mode to steam pressure mode	- required step - before 2	E3.5.b	DI 2078	- omission - selection	PMS, VT, TPIC
2	RO-2 adjusts steam dump valve position	- required step	E3.5.b	DI 1950	- omission - selection - qualitative	PMS, VT, TPIC
3	RO-2 monitors RCS temperature	- required step	E3.5.b	1 TR - 412 TI-68-2E TI-68-25E TI-68-44E TI-68-67E	- omission - selection	VT, TPIC
4	RO-2 positions steam dump "A" interlock to bypass	- required step		DI 2039/2041	- omission	PMS, VT, TPIC
5	RO-2 positions steam dump "B" interlock to bypass	- required step		DI 2039/2041	- omission	PMS, VT, TPIC
6	RO-1 monitors Pzr level	- required step	E3.5.b	LR-459 LI-459A LI-460A LI-461	- omission - qualitative	VT, TPIC

TASK PERFORMANCE MEASURES WORKSHEET

Plant 50 Sequence SGTR Task No. 26

No.	Element	Standard	Reference	Control/Display	Potential Error	Method of Detection
7	RO-2 informs SRO-2 cool-down is initiated				- omission	VT, TPIC

TASK PERFORMANCE CRITERIA

Plant 50 Sequence SGTR Task No. 26

Task Statement Cooldown the RCS

Task Purpose To allow depressurization

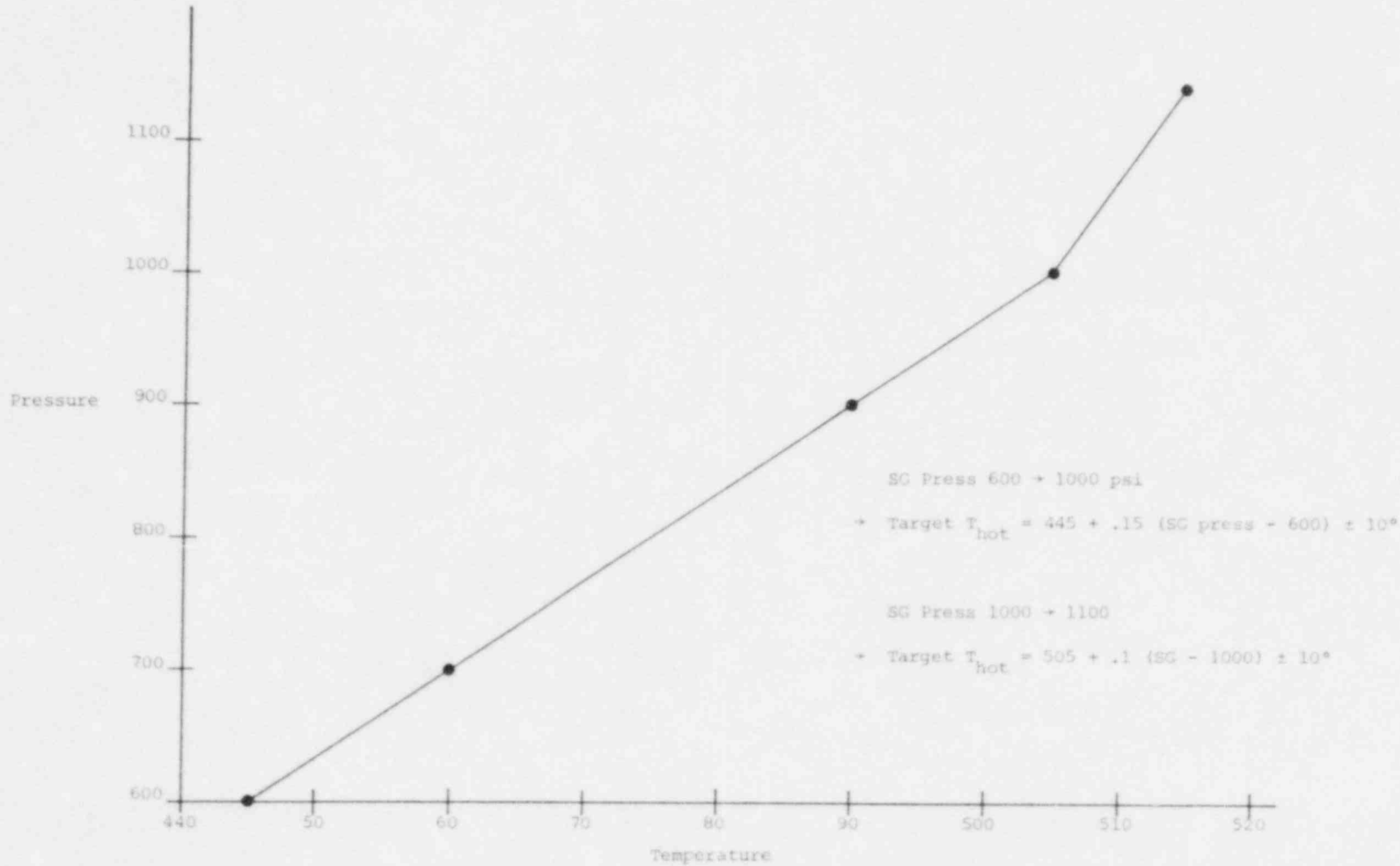
Task Cue #4 SG MSIV closed (LO 2820)

Task Initiation Steam dump in steam pressure (DI 2078)

Task Success Loop 1 hot leg temp (AO 375) at target value based on SG #4 pressure (AO 525) (± 10°) See attached graph

No.	Element	Source	Preconditions/Limits	
1.	Place steam dump controller in STEAM PRESSURE MODE	PMS	After #4 SG 1 MSIV closed (LO 2820)	DI 2078
2.	Adjust steam dump valve positions	PMS	After Element #1	DI 1950 or AI 55
3.	Monitor RCS temp	VT/PMS	Loop 1 T cold change by no more than 100° after doing Element #2 AO 377	
4.	Position steam dump A train interlock to BYPASS	PMS	After Lo-Lo Tave AN 2774	DI 2039 or 2041
5.	Position steam dump B train interlock to BYPASS	PMS	After Lo-Lo Tave AN 2774	DI 2040 or 2042
6.	Monitor Pzr level	VT	None	
7.	Inform crew that cooldown is in progress	VT		

4 Elements	5 P/L
1 DI 2098	1 DI 2078 after LO 2820
2 DI 1950 or AI 55	2 Ele. 2 after DI 2078
3 DI 2039 or 2041	3 AO 377 Δ ≤ 100° after Ele. 2
4 DI 2040 or 2042	4 Ele. 3 after AN 2774
	5 Ele. 4 after AN 2774


Pressure
1100
1000
900
800
700
600
440
50
60
70
80
90
500
510
520
Temperature
SG Press 600 → 1000 psi
→ Target T_{hot} = 445 + .15 (SG press - 600) ± 10°
SG Press 1000 → 1100
→ Target T_{hot} = 505 + .1 (SG - 1000) ± 10°

APPENDIX D

TASK PERFORMANCE IDENTIFICATION CHECKLISTS

Appendix E contains examples of the brief given to the observers in the simulated control room and copies of the Task Performance Identification Checklists (TPIC).

(1) Instructions for Using the Task Performance Identification Checklist
(2) TPIC A - Turbine Loading (LOAD)
(3) TPIC D - Steam Generator Tube Rupture (SGTR)
(4) TPIC C - Loss of Feedwater (LOFW)
(5) TPIC E - Main Steam Line Break (MSLB)

The TPICs presented are the versions used for review of the videotapes. Shorter versions based on the preliminary task analysis and not containing alternate action paths (extra tasks that may sometimes be required) were used by the observers during the simulator exercises.

GP/ORNL SIMULATOR EXPERIMENT

Instructions for Using the

Task Performance Identification Checklist

One purpose of this Experiment is to determine if it is possible for observers familiar with control room operations to record the performance of a crew while an exercise is in progress. You, as an operator, are ideally qualified as an observer because you are more familiar with the control panels and better able to see what a fellow operator is doing than any outside observer can hope to be.

The Task Performance Identification Checklist (TPI) is used for recording data not captured by the simulator's "record" program:

A) expected verbal communications
B) phone communications
C) references to procedures
D) who performed particular actions

The TPI gives the major actions expected during an exercise, listed in the approximate order they will happen. The format is shown below:

EVALUATION STANDARDS	PERFORMANCE				NOTES
	YES			NO	
TASK ELEMENT	SUP	PO	STA		TIME
11. 1. Recognize possible SRV failure	✓				
2. INFORMS Sup. SRV "A" and "K" Open		✓			
13. 1. Cycle SRVs		✓			
2. Verify valves did not close		✓			

Your task as observer is to record which operator performed each action. You will do this by placing a check next to the action in one of the columns headed SUP, PO, or STA. The checks in the example indicate that the SUP recognized that the alarm indicated a possible SRV failure (you know he recognized it because he told the PO to check the SRVs), and the PO informed the SUP that "A" and "K" were open and attempted to cycle them.

When using the checklist, do not check that an action was performed unless you SAW an operator do it. In particular, do not check that an action was performed because, although you didn't see it, you know it "should have" been done. There is only one exception to this rule: if an action involves controls or displays located on a back panel, you should record which operator you saw leaving the control room in the direction of the required panel.

The TPI forms are very detailed, and almost half of the actions you are to observe will happen within two minutes of the first alarm. Take time to read through each set of TPIs before the exercise, so you will know what you are looking for, and the page on which the appropriate sections of the checklist are to be found. Note that the TPI forms have been organized by systems, and do not reflect the order in which those systems will be used. You should try to record the actions as you see them happen, even though you will have to flip back and forth between pages.

Use the NOTES column to record any unusual happenings, such as failure of a system to restart, expected isolations that did not occur, etc.

During an exercise, please be as unobtrusive as possible. Do not ask another rater if he saw such-and-such an action, and do not talk to the operators performing the exercise.

Thank you for helping us to collect this data.

A

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Turbine Loading								FILE NUMBER: PMS: VIDEO/AUDIO:
TASK	ELEMENTS	LOC	PERFORMANCE					NOTES
			YES				NO	
			SUP	LO	BOP	STA		Time
1.	Operate MFW Regulator Bypass Valves to Maintain SG Level							
	a. Adjust valve position	M-3						
	b. Monitor SG levels	M-4						
	c. Compare steam flow - feed flow	M-4						
	d. Observe annunciators	M-3						
	e. Inform crew when level is stable	___						
2.	Notify Load Dispatcher							
	a. Inform Load Dispatcher	19						
3.	Increase Turbine Speed							
	a. Adjust speed setpoint	M-2						
	b. Adjust Acceleration rate	M-2						
	c. Push GO button	M-2						
	d. Observe turbine RPM	M-2						
	e. Monitor turbine temperature	M-2						
	f. Monitor turbine vibration	M-2						
4.	Determine if Turbine Overspeed Test Required							
	a. Inform crew test not required	19						
5.A.	Transfer Feedwater Control to FW Regulator Valves							
	a. Adjust FW regulator valves open (4)	M-3						
	b. Adjust FW regulatory bypass valves closed (4)	M-3						
	c. Monitor SG levels	M-4						
	d. Monitor FW flows	M-4						
	e. Monitor steam flows	M-4						
5.B.	Transfer Feedwater Control to Automatic							
	a. Monitor SG level	M-4						
	b. Compare feed flow - steam flow	M-4						
	c. Adjust controller setpoint	M-3						
	d. Position MFW controller to automatic	M-3						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Turbine Loading									FILE NUMBER: PMS: VIDEO/AUDIO:
TASK	ELEMENTS	LOC	PERFORMANCE YES				NO	NOTES	
			SUP	LO	BOP	STA		Time	
5.B.	Transfer Feedwater Control to Automatic (continued) e. Repeat for other 3 controllers f. Inform crew that feedwater control is in automatic	 M-3 M-4							
6.	Perform "TV-GV" Transfer a. Depress "TV-GV" trans" button b. Adjust speed setpoint to 1800 c. Push GO button d. Observe turbine RPM e. Inform crew turbine speed increasing	 M-2 M-2 M-2 M-2							
7.	Align Turbine Auxiliary Support Systems for Power Operation a. Stop the turning gear oil pump and seal oil backup pump by placing handswitch in auto. b. Verify generator H_2 pressure is within requirements of generator capability curve. c. Verify H_2 coolers temperature controller set to maintain $100^{o}F - 105^{o}F$. d. Verify raw cooling water is in service for the stator cooling water system. *	 M-2 M-2 M-2 M-27A							
8.	Start Preferred Transformer Cooling a. Turn transformer cooler test switch to "preferred" b. Verify main transformer coolers ON c. Inform crew transformer coolers are ON	 M-2 M-2							

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Turbine Loading								FILE NUMBER: PMS: VIDEO/AUDIO:
TASK	ELEMENTS	LOC	PERFORMANCE					NOTES
			YES				NO	
			SUP	LO	BOP	STA		Time
9.	Synchronize Generator to the Grid							
	a. Dispatch AO to reset 86C lockout relays.							
	b. Close field breaker	M-1						
	c. Place voltage regulator in "test" position							
	d. Start voltage regulator	M-1						
	e. Position sync scope	M-1						
	f. Adjust generator speed	M-1						
	g. Monitor synch scope	M-1						
	h. Adjust generator voltage	M-1						
	i. Close generator PCB	M-1						
	j. Inform crew the generator is being loaded							
	k. Verify MVARs	M-1						
	l. Verify EHC system in load control	M-2						
	m. Repeat steps d i	M-1						
10.	Increase Generator Load to 18 Percent							
	a. Adjust load setpoint	M-2						
	b. Adjust load rate	M-2						
	c. Position GO button	M-2						
	d. Inform crew that load is increasing	M-2						
	e. Monitor generator currents	M-1						
11.	Block Low Power Trips							
	a. Monitor Neutron Flux	M-4						
	b. Verify P-10 light on	M-4						
	c. Verify P-7 light out	M-4						
	d. Verify P-13 light out	M-4						
	e. Block I.R. power trip	M-4						
	f. Block P.R. low power trip	M-4						
12.	Warm-Up Feedwater Heaters							
	a. Verify MSR starting vents open	M-2						
	b. Open A2, B2, and C2 extraction steam isolation valves	M-2						
	c. Inform crew feedwater heaters are warming							3 of 6

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Turbine Loading									FILE NUMBER: PMS: VIDEO/AUDIO:
TASK	ELEMENTS	LOC	PERFORMANCE YES				NO	NOTES
			SUP	LO	BOP	STA		Time
13.	Calculate Axial Flux Difference							
	a. Perform S.I.-44							
	b. Inform supervisor S.I.-44 completed satisfactory							
14.	Transfer 6.9 KV Unit Boards to Station Service							
	a. Verify station service transformer voltages	M-1						
	b. Close station service breaker	M-1						
	c. Trip start bus breaker	M-1						
	d. Place transfer selector in auto	M-1						
	e. Repeat steps b d for 3 remaining boards	M-1						
	f. Place 6.9 KV common board transfer selector in auto							
	g. Inform crew 6.9 KV boards transferred to station service							
15.	Transfer Steam Dump Control to T-ave Mode							
	a. Verify C-5 reset	M-4						
	b. Compare SG pressure to steam dump setpoint	M-4						
	c. Place controller in T-ave	M-4						
	d. Inform crew steam dumps in T-ave							
16.A.	Operate Rod Control System to Maintain Temperature							
	a. Monitor T-ave	M-5						
	b. Compare T-ave to T-ref	M-5						
	c. Adjust control rods	M-4						
16.B.	Obtain Value of Xenon Concentration							
	a. Recognize reactor power increase due to Xenon burnout.							4 of 6

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Turbine Loading	FILE NUMBER: PMS: VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
16.C.	Transfer Rod Control to Auto							
	a. Compare T-ave - T-ref	M-5						
	b. Place rod control in automatic	M-4						
	c. Inform crew rods are in auto							
17.	Place #1 Feedwater Heaters In Service							
	a. Open A1, B1, and C1 feedwater heater extraction steam isolation valves	M-2						
	b. Inform crew #1 feedwater heaters in service							
18.	Place Main Steam Reheaters In Service							
	a. Verify MSR starting vents open	M-2						
	b. Open MSR warming valves (6)	M-2						
	c. Open extraction steam isolation valves (6)	M-2						
19.	Increase Generator Load to 30 Percent							
	a. Adjust load setpoint	M-2						
	b. Adjust load rate	M-2						
	c. Position GO button	M-2						
	d. Monitor generator load	M-2						
	e. Monitor neutron flux	M-4						
	f. Inform crew load is increasing							
20.	Transfer EHC to Impulse IN Mode							
	a. Observe power above 25%	M-4						
	b. Position impulse - IN	M-2						
	c. Inform crew impulse - IN							
21.	Align Non-Operating Main Feed Pump for Operation							
	a. Reset MFP turbine controller	M-3						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE:									FILE NUMBER: PMS: VIDEO/AUDIO:
TASK	ELEMENTS	LOC	PERFORMANCE						NOTES
			YES				NO		
			SUP	LO	BOP	STA			Time
21.	Align Non-Operating Main Feed Pump for Operation (continued) b. Open MFP condenser "B" isolation valve c. Inform crew MFP is aligned and reset	 M-3							
22.	Maintain RCP Seal FLow a. Monitor seal flows b. Adjust seal flow controllers as needed	 M-5 M-5							

OBSERVER: ________
DATE: ________
OPERATORS:
SUP: ________
LO: ________
BOP: ________
STA: ________

D

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: SGTR	FILE NUMBER: PMS: VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
1.	Diagnose SGTR							
	a. Observe Pzr pressure low	M-5						
	b. Observe Pzr level decrease	M-4						
	c. Observe charging flow increased	M-5						
	d. Observe B.U. heaters on	M-4						
	e. Observe condenser vacuum pump radiation high *	M-12						
	f. Observe blowdown radiation high annunciator *	M-12						
	g. Observe VAC pump radiation indication	M-12						
	h. Inform crew SGTR has occurred	___						
2.	Increase Charging Flow							
	a. Start charging pump B	M-5						
	b. Observe charging flow	M-5						
	c. Adjust charging FCV	M-5						
	d. Inform crew that charging flow has been increased							
3.	a. Start component cooling pump within 90 seconds of CCP *	M-27B						
	b. Observe CCS flow	M-27B						
4.	Identify Faulted SG							
	a. Compare steam flow - feed flow	M-4						
	b. Compare SG levels	M-4						
	c. Close SG blowdown valves	M-4						
	d. Cycle #4 SG B.D. valve	M-4						
	e. Monitor blowdown radiation *	M-12						
	f. Inform crew that SG 4 is faulted	___						
	g. Inform HP to survey MSL and B.D. lines							
5.	Trip the Reactor							
	a. Position trip switch	M-4, M-6						
	b. Inform supervisor reactor is tripped	___						1 of 8

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: SGTR

FILE NUMBER:
PMS:
VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
6.	Verify Shutdown Boards Energized							
	a. Observe generator breakers open	M-1						
	b. Observe alternate feeder breakers closed	M-1						
	c. Observe bus voltages	M-1						
	d. Inform crew shutdown boards energized							
7.	Initiate Safety Injection							
	a. Position S.I. switch	M-4, M-6						
	b. Verify S.I. pumps on	M-6						
	c. Verify charging pumps on	M-5						
	d. Verify RHR pump on	M-6						
	e. Observe BIT flow	M-6						
	f. Check 6 status monitor light panels	M-6						
	g. Inform supervisor S.I. is initiated							
8.	Verify Reactor Trip							
	a. Observe control rods	M-4						
	b. Observe neutron flux	M-4						
	c. Observe scram breakers open	M-4						
	d. Inform crew "all rods are in"							
9.	Verify Turbine Trip							
	a. Observe turbine stop valves closed	M-2						
	b. Inform crew "turbine is tripped"							
10.	Match Electrical Breakers							
	a. Trip 6 breakers	M-1						
	b. Place 4 transfer selectors in manual	M-1						
11.	Verify Secondary Heatsink							
	a. Observe AFW pumps on	M-3						
	b. Observe SG inlet flow	M-4						
	c. Observe SG level	M-4						
	d. Observe AFW level control valves in automatic	M-4						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: SGTR	FILE NUMBER: PMS: VIDEO/AUDIO:

TASK ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
11. Verify Secondary Heatsink (continued)							
e. Observe blowdown valves closed	M-4						
f. Observe steam dumps closed	M-4						
g. Inform crew AFW is operating							
12. Verify MFW Isolation							
a. Observe MFW isolation valves closed	M-4						
b. Observe MFW regulator valves closed	M-3						
c. Observe MFW bypass valves closed	M-3						
d. Observe MFW pumps tripped	M-3						
e. Inform crew MFW is isolated							
13. Verify Cooling Systems							
a. Observe component cooling pumps on *	M-27B						
b. Observe ERCW pumps on *	M-27A						
c. Inform crew cooling systems are running							
14. Verify Gas Treatment Systems							
a. Verify EGTS *	M-27B						
b. Verify ABGTS *	18						
c. Inform crew that Gas Treatment Systems are running							
15. Verify Diesel Generators							
a. Observe D.G.s running *	M-26						
b. Observe D.G. cooling valves open *	M-27						
c. Inform crew D.G.s are running							
16. Review Procedures							
a. Check E-0	19						
b. Check E-3	19						
c. Check REP-IP-1	19						
d. Check ES-3.1	19						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: SGTR								FILE NUMBER: PMS: VIDEO/AUDIO:
TASK	ELEMENTS	LOC	PERFORMANCE					NOTES
			YES				NO	
			SUP	LO	BOP	STA		Time
17.	Verify Containment Conditions a. Observe containment pressure meter b. Observe containment humidity and temp * c. Observe containment radiation * d. Inform crew containment conditions are normal	 M-6 M-9 M-12						
18.	Isolate Faulted S.G. a. Close MSIV on #4 S.G. b. Verify S.G. N.R. level above 5% c. Verify S.G. PORV closed d. Close #4 AFW isolation valves e. Verify BD valves closed f. Inform crew that #4 S.G. is isolated	 M-4 M-4 M-3 M-4 M-4						
19.	Shutdown Unnecessary Equipment a. Position hotwell pump off b. Position 2 condensate booster pumps off c. Position 3 D.I. booster pumps off d. Position 5 heater drain tank pumps PTL e. Close 6 heater drain tank discharge valves f. Inform crew equipment is secured	 M-3 M-3 M-3 M-2 M-2						
20.	Align MSRs to Normal a. Reset MSR controller b. Close 6 extraction isolation valves c. Open starting vent valves d. Close operating vent valves e. Inform crew equipment is secured	 M-2 M-2 M-2 M-2						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: SGTR

FILE NUMBER:
PMS:
VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
21.	Shut Extraction Steam and Drain Valves							
	a. Shut 6 HP FW heaters extraction valves	M-2						
	b. Open MFPT drains (2)	M-2						
	c. Open turbine drain valves	M-2						
22.	Energize Source Range Instruments							
	a. Monitor I.R. neutron flux	M-4						
	b. Verify S.R. detectors energized	M-4						
	c. Transfer NR-45 to I.R. & S.R.	M-4						
	d. Adjust audio count rate monitor *	M-9						
	e. Inform crew S.R. is energized							
23.	Check Main Turbine							
	a. Observe oil pumps running	M-2						
	b. Observe lift pumps running	M-2						
	c. Verify turbine on turning gear > 2 rpm	M-2						
	d. Verify turbine drain valves open automatically	M-2						
24.	Shutdown Generator Exciter							
	a. Open exciter field breaker	M-1						
	b. Place voltage regulator in off	M-1						
25.	Implement the Radiological Emergency Plan							
	a. Inform ODS	19						
	b. Inform NRC	19						
	c. Inform on-site personnel	19						
26.	Cooldown the RCS							
	a. Place steam dumps in steam pressure mode	M-4						
	b. Adjust steam dump valve positions	M-4						
	c. Monitor RCS temperature	M-5						
	d. Bypass steam dump interlock	M-4						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: SGTR

FILE NUMBER:
PMS:
VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
26.	Cool The RCS (continued)							
	e. Block MSL S.I. signals (P-12)	M-4						
	f. Inform crew MSL S.I. (P-12) is blocked							
	g. Monitor Pzr level	M-4						
	h. Inform crew cooldown initiated							
27.	Depressurize the RCS							
	a. Place spray valves in manual	M-4						
	b. Adjust Pzr spray valves	M-4						
	c. Monitor Pzr pressure	M-5						
	d. Calculate sub-cooling	M-4						
	e. Verify Pzr heaters off	M-4						
	f. Inform crew when RCS pressure equals S.G. pressure							
28.	Isolate Upper Head Injection							
	a. Start UHI pump	M-13A, M-13B						
	b. Position controller to charge	M-13A						
	c. Close accumulator isolation valves (2) *	M-13A						
	d. Shut gag valves	M-13A						
	e. Position controller to charge	M-13B						
	f. Close accumulator isolation valves (2) *	M-13B						
	g. Shut gag valves	M-13B						
	h. Stop UHI pump	M-13B, M-13A						
	i. Inform crew UHI is isolated							
29.	Terminate S.I.							
	a. Reset S.I. controller	M-6						
	b. Stop RHR pumps	M-6						
	c. Stop S.I. pumps	M-6						
	d. Stop one charging pump	M-5						
	e. Reset containment isolation signal	M-6						
	f. Inform crew S.I. terminated							

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: SGTR

FILE NUMBER:
PMS:
VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
30.	Establish Normal Charging and Letdown							
	a. Align charging flow path (6 valves)	M-5						
	b. Adjust charging flow	M-5						
	c. Monitor seal flows	M-5						
	d. Monitor Pzr level	M-4						
	e. Open letdown isolation valves (3)	M-6						
	f. Adjust letdown pressure controller	M-6						
	g. Open orifice valve	M-6						
	h. Monitor letdown heat exchanger temperature	M-6						
	i. Close BIT isolation valves (2)	M-6						
	j. Open VCT outlet valves (2)	M-5						
	k. Close RWST outlet valves (2)	M-5						
	l. Inform crew that charging and letdown are restored							
31.	Maintain Stable Plant Conditions							
	a. Monitor Pzr level	M-4						
	b. Compare RCS pressure to SG pressure	M-5 M-4						
	c. Monitor RCS temperature	M-4						
32.	Stop Diesel Generators							
	a. Dispatch AO to restore diesel lockout relays	19						
	b. Positon D.G. controllers to stop *	M-26						
	c. Inform crew D.G. are shutdown							
33.	Reset First Out Alarms							
	a. Record first out indications							
	b. SRO directs first out reset							
	c. Position reset switch to reset	M-4						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: SGTR								FILE NUMBER: PMS: VIDEO/AUDIO:
TASK ELEMENTS	LOC	PERFORMANCE						NOTES
		YES				NO		
		SUP	LO	BOP	STA			Time
OBSERVER: ______ OPERATORS: SUP: ______ LO: ______ BOP: ______ STA: ______								8 of 8

C

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Loss of Feedwater

FILE NUMBER:
PMS:
VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
1.	Recognize Loss of 6.9 KV SD Board 1B							
	a. Observe annunciators	M-3						
	b. Check which boards are deenergized	M-1						
	c. Observe Ckt breakers open	M-1						
	d. Inform crew SD board 1B deenergized							
	e. Dispatch electrician to check on SD board 1B	19						
	f. Observe DGs on *	M-26						
2.	Identify Deenergized Equipment							
	a. Observe MOV lights out	ALL						
	b. Observe rad monitors *	M-12						
	c. Observe RCP thermal barrier booster pump off	M-27						
	d. Inform crew some rad monitors are off	____						
3.	Recognize Loss of Vacuum							
	a. Observe vacuum decrease	M-3						
	b. Verify vacuum pumps on	M-3						
	c. Verify circ water pumps on	M-3						
	d. Inform crew of loss of vacuum							
4.	Verify Reactor Trip							
	a. Observe control rods	M-4						
	b. Observe neutron flux	M-4						
	c. Observe trip breaker open	M-4						
	d. Inform crew "all rods are in"							
5.	Verify Turbine Trip							
	a. Observe turbine stop valves closed	M-2						
	b. Inform crew "turbine is tripped"							
6.	Verify "A" Shutdown Boards Energized							
	a. Observe generator PCBs open	M-1						
	b. Observes alternate feeder breakers closed	M-1						1 of 9

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Loss of Feedwater								FILE NUMBER: PMS: VIDEO/AUDIO:
TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
6.	Verify "A" Shutdown Boards Energized (continued)							
	c. Observes bus voltages	M-1						
	d. Inform crew SD boards transferred							
7.	Check for S.I. Actuation							
	a. Observe valve lineup on S.I. system	M-6						
	b. Observe annunciator	M-6						
	c. Observe status lights	M-6						
	d. Inform crew S.I. not actuated							
8.	Recognize Loss of AFW							
	a. Observe TDAFW pump off	M-3						
	b. Observe MD AFW pumps off	M-4						
	c. Attempt to start TDAFW	M-3						
	d. Observe feed flow = 0	M-4						
	e. Observe SG levels decreasing	M-4						
	f. Inform crew of loss of AFW							
	g. Dispatch AO to check TDAFW	M-4						
9.	Verify MFW Isolation							
	a. Observe MFW isolation valves 2 open/2 closed	M-4						
	b. Observe MFW regulator valves closed (4)	M-3						
	c. Observe MFW bypass valves closed (4)	M-3						
	d. Observe MFW pumps tripped	M-3						
	e. Inform crew MFW isolated							
10.	Review Procedures							
	a. Check E-0							
	b. Check ES-0.1							
	c. Check FR-H.1							
	d. Check REP							
11.	Evaluate RCS Indications							
	a. Observe Tave decreasing	M-5						
	b. Observe Pzr pressure in band 1870 - 2235	M-5						
	c. Observe Pzr level trending to 25%	M-4						2 of 9

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Loss of Feedwater

FILE NUMBER:
PMS:
VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE					NOTES
			YES				NO	
			SUP	LO	BOP	STA		Time
11.	Evaluate RCS Indications (continued)							
	d. Verify RCPs on	M-5						
	e. Inform crew RCS indications are stable							
12.	Verify Containment							
	a. Observe containment pressure meter	M-6						
	b. Observe containment humidity and temperature *	M-10						
	c. Observe containment radiation *	M-12						
	d. Inform crew containment conditions are normal							
13.	Verify CVCS Operation							
	a. Observe charging flow	M-5						
	b. Verify charging pump on	M-5						
	c. Observe letdown flow	M-5						
	d. Monitor seal flow	M-5						
	e. Monitor VCT level							
14.	Establish Condensate Flow Path							
	a. Reset MFW isolation train "A"	M-3						
	b. Reset MFW isolation train "B"	M-3						
	c. Close MFW regulator valves (4)	M-3						
	d. Open MFW pump bypass valve (1)	M-3						
	e. Open MFW isolation valves (SGs 1 and 3)	M-4						
	f. Verify hotwell pump on	M-3						
	g. Verify condensate booster pump on	M-3						
	h. Observe hotwell level	M-3						
	i. Observe CST level	M-2						
	j. Inform crew that condensate flow path established							
15.	Shutdown Unnecessary Equipment							
	a. Position hotwell pump off	M-3						
	b. Position 2 condensate booster pumps off	M-3						3 of 9

TASK PERFORMANCE IDENTIFICATION CHECKLISTS

OPERATING SEQUENCE: Loss of Feedwater

FILE NUMBER:
PMS:
VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
15.	Shutdown Unnecessary Equipment (continued)							
	c. Position 3 D.I. booster pumps off	M-3						
	d. Position 5 heater drain tank pumps off	M-2						
	e. Close 6 heater drain tank discharge valves	M-2						
	f. Inform crew equipment is secured							
16.A	Depressurize Steam Generators in Manual							
	a. Adjust SG PORVs (4) open	M-4						
	b. Monitor SG pressure	M-4						
	c. Monitor RCS Tave	M-5						
	d. Monitor RCS pressure	M-5						
	e. Monitor Pzr level	M-4						
	f. Block low pressure S.I. signal (P-11)	M-4						
	g. Block steam line S.I. signal (P-12)	M-4						
	h. Inform crew P-11 and P-12 blocked	——						
	i. Adjust PORV controller setpoints	M-4						
	j. Place SG PORV controllers in automatic	M-4						
	k. Calculate subcooling margin							
16.B	Depressurize Steam Generators in Automatic (Not required if 16.A done)							
	a. Adjust SG PORV controller output (4)	M-4						
	b. Monitor SG pressure	M-4						
	c. Monitor RCS are Tave	M-5						
	d. Monitor RCS pressure	M-5						
	e. Monitor Pzr level	M-4						
	f. Block low pressure S.I. signal (P-11)	M-4						
	g. Block steam line S.I. signal (P-12)	M-4						
	h. Inform crew P-11 and P-12 blocked	——						
	i. Calculate subcooling margin	M-5						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Loss of Feedwater								FILE NUMBER: PMS: VIDEO/AUDIO:
TASK ELEMENTS	LOC	PERFORMANCE						NOTES
		YES				NO		
		SUP	LO	BOP	STA			Time
16.C Restore CVCS Operation (Required only if ANN M5A31 on)								
a. Shut SG PORVs (4)	M-4							
b. Observe Pzr level	M-5							
c. Observe charging flow	M-5							
d. Reset group "D" Pzr heaters	M-4							
e. Open letdown isolation valves (2)	M-6							
f. Adjust letdown pressure regulator	M-6							
g. Open orifice isolation valve (1)	M-6							
h. Place letdown pressure regulator in auto	M-6							
i. Inform crew letdown restored								
16.D Terminate Safety Injection (Required only if SI)								
a. Reset S.I.	M-6							
b. Stop RHR pump "A"	M-6							
c. Stop S.I. pump "A"	M-6							
d. Stop one charging pump	M-5							
e. Reset containment phase "A" isolation signal	M-6							
f. Inform crew S.I. reset	M-6							
g. Inform crew containment isolation is reset								
16.E Restore Charging and Letdown (Required after S.I.)								
a. Open charging isolation valves	M-6							
b. Adjust charging flow	M-5							
c. Monitor seal flow	M-5							
d. Monitor Pzr level	M-5							
e. Open seal return valves (2)	M-5							
f. Open letdown isolation valves (3)	M-6							
g. Adjust letdown pressure controller	M-6							
h. Open orifice isolation valve	M-6							

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Loss of Feedwater								FILE NUMBER: PMS: VIDEO/AUDIO:
TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
16.E	Restore Charging and Letdown (continued)							
	i. Inform crew charging and letdown restored							
	j. Close BIT outlet and inlet isolation valves	M-6						
	k. Open VCT outlet valves	M-5						
	l. Position VCT outlets to auto	M-5						
	m. Close RWST valves	M-5						
	n. Position RWST valves to auto	M-5						
	o. Monitor VCT level	M-6						
	p. Inform crew charging is aligned to VCT and BIT is isolated							
16.F	Reset FW Isolation Following S.I.							
	a. Reset S.I.	M-6						
	b. Block low pressure S.I. if below P-11	M-4						
	c. Block low low Tave S.I. if below P-12	M-4						
	d. Close reactor trip breakers	M-4						
	e. Close MFW regulator valves	M-3						
	f. Reset FW isolation	M-3						
	g. Inform crew FW isolation reset							
	h. Open FW isolation valves (2)	M-4						
17.	Align MSRs to Normal							
	a. Reset MSR controller	M-2						
	b. Close 6 extraction isolation valves	M-2						
	c. Open starting vent valves	M-2						
	d. Close operating vent valves	M-2						
18.	Align Extraction Steam and Drains							
	a. Close 6 extraction steam isolation valves	M-2						6 of 9

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Loss of Feedwater								FILE NUMBER: PMS: VIDEO/AUDIO:
TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
18.	Align Extraction Steam and Drains (continued)							
	b. Open turbine drain valves	M-2						
	c. Open MFW pump turbine drain valves (2)	M-3						
19.	Match Electrical Breakers							
	a. Positon bus PCBs (2) to trip							
	b. Trip 4 breakers	M-1						
	c. Place 4 transfer selectors in manual	M-1						
20.	Shutdown Voltage Regulator							
	a. Open generator field breaker	M-1						
	b. Position voltage regulator to off	M-1						
21.	Energize Source Range Instruments							
	a. Monitor I.R. neutron flux	M-4						
	b. Verify S.R. detectors energized	M-4						
	c. Transfer NR-45 to I.R. & S.R.	M-4						
	d. Adjust audio count rate monitor *	M-9						
22.	Check Main Turbine							
	a. Verify oil pumps running	M-2						
	b. Verify lift pumps running	M-2						
	c. Verify turbine on turning gear	M-2						
23.	Depressurize the RCS							
	a. Place spray valves in manual	M-4						
	b. Adjust Pzr spray valves	M-4						
	c. Monitor RCS pressure	M-5						
	d. Calculate subcooling	M-4						
	e. Verify Pzr heaters off	M-4						
24.	Isolate Upper Head Injection							
	a. Start UHI pump	M-13A, M-13B						7 of 9

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Loss of Feedwater

FILE NUMBER:
PMS:
VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
24.	Isolate Upper Head Injection (continued)							
	b. Position controller to charge	M-13A						
	c. Close accumulator isolation valves (2) *	M-13A						
	d. Shut gag valves	M-13A						
	e. Position controller to charge	M-13B						
	f. Close accumulator isolation valves (2) *	M-13B						
	g. Shut gag valves	M-13B						
	h. Stop UHI pump	M-13B, M-13A						
	i. Inform crew UHI is isolated							
25.	Establish Condensate Flow							
	a. Open MFW regulator bypass valves	M-3						
	b. Monitor feed flow	M-4						
	c. Direct D.I. room to make up to CST							
	d. Monitor SG level	M-4						
	e. Monitor hotwell level	M-3						
	f. Inform crew that feed is established to SGs, and levels are increasing							
26.	Monitor Diesel Generator Operation							
	a. Monitor DG parameter	M-26						
	b. Reset DG alarms	M-26						
27.	Implement the Radiological Emergency Plan							
	a. Inform ODS	19						
	b. Inform NRC	19						
	c. Implement REP	19						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Loss of Feedwater								FILE NUMBER: PMS: VIDEO/AUDIO:
TASK	ELEMENTS	LOC	PERFORMANCE					NOTES
			YES				NO	
			SUP	LO	BOP	STA		Time
OBSERVER: ____ DATE: ____ OPERATORS: SUP: ____ LO: ____ BOP: ____ STA: ____								9 of 9

E

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Main Steam Line Break	FILE NUMBER: PMS: VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
1.	Recognize MSL Break							
	a. Observe annunciators	M-4						
	b. Observe SG pressures	M-4						
	c. Observe MSIV open	M-4						
	d. Inform crew of MSLB							
2.	Verify Reactor Trip							
	a. Observe control rods	M-4						
	b. Observe neutron flux	M-4						
	c. Observe trip breakers	M-4						
	d. Inform crew "all rods are in"							
3.	Verify Turbine Trip							
	a. Observe turbine stop valves closed	M-2						
	b. Inform crew "turbine is tripped"							
4.	Verify Shutdown Boards Energized							
	a. Observe generator breakers open	M-1						
	b. Observes alternate feeder breakers closed	M-1						
	c. Observes bus voltages	M-1						
	d. Inform crew shutdown boards have transferred							
5.	Verify Safety Injection							
	a. Check pumps on (6)	M-6						
	b. Check BIT flow	M-6						
	c. Check status monitor panels (6)	M-6						
	d. Inform crew of BIT flow							
6.	Verify Containment Condition							
	a. Observe containment pressure meter	M-6						
	b. Observe containment temperature	|						
	c. Observe containment radiation *	M-12						
	d. Inform crew containment conditions are normal							

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Main Steam Line Break	FILE NUMBER: PMS: VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
7.	Isolate Faulted SG							
	a. Attempt to close MSIV	M-4						
	b. Close AFW supply valves (3)	M-4						
	c. Verify blowdown valves closed	M-4						
	d. Inform crew that MSIV failed open							
	e. Verify TDAFW not supplied from faulted SG	M-4						
8.	Verify AFW Status							
	a. Check AFW pumps on (3)	M-4						
	b. Check level controls in automatic (6)	M-3 M-4						
	c. Check SG levels	M-4						
	d. Check blowdown valves closed	M-4						
	e. Inform crew AFW is operating							
9.	Verify MFW Isolation							
	a. Observe MFW isolation valves closed	M-4						
	b. Observe MFW regulator valves closed	M-3						
	c. Observe MFW bypass valves closed	M-3						
	d. Observe MFW pumps tripped	M-3						
	e. Inform crew MFW is isolated							
10.	Break Condenser Vacuum							
	a. Position Vac pumps (3) PTL	M-3						
	b. Open Vac breaker	M-2						
	c. Observe condenser vacuum	M-3						
11.	Shutdown Unnecessary Equipment							
	a. Position hotwell pump off	M-3						
	b. Position 2 condensate booster pumps off	M-3						
	c. Position 3 D.I. booster pumps off	M-3						
	d. Position 5 heater drain tank pumps off	M-2						
	e. Close 6 heater drain tank discharge valves	M-2						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Main Steam Line Break								FILE NUMBER: PMS: VIDEO/AUDIO:
TASK	ELEMENTS	LOC	PERFORMANCE					NOTES
			YES				NO	
			SUP	LO	BOP	STA		Time
12.	Shutdown Generator Exciter							
	a. Position exciter regulator to off	M-1						
	b. Position exciter field breaker to trip	M-1						
13.	Align MSRs to Normal							
	a. Reset MSR controller	M-2						
	b. Close 6 extraction valves	M-2						
	c. Open starting vent valves	M-2						
	d. Close operating vent valves	M-2						
14.	Realign Extraction Steam and Drain Valves							
	a. Close 6 extraction isolation valves	M-2						
	b. Open MFPT drain valves	M-3						
	c. Verify turbine drain valves open	M-2						
15.	Match Electrical Breakers							
	a. Trip 6 breakers	M-1						
	b. Place 4 breaker transfer switches in manual	M-1						
16.	Verify Cooling Systems							
	a. Observe component cooling pumps on *	M-27B						
	b. Observe ERCW pumps on *	M-27A						
	c. Inform crew cooling systems running							
17.	Verify Gas Treatment Systems							
	a. Verify EGTS on *	M-27B						
	b. Verify ABGTS on *	18						
	c. Inform crew EGTS and ABGTS on							
18.	Isolate UHI System							
	a. Verify RCS pressure under control	M-5						
	b. Start hydraulic pump	M-13A						
	c. Position man/auto to charge	M-13A						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Main Steam Line Break

FILE NUMBER:
PMS:
VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
18.	Isolate UHI System (continued)							
	d. Close accumulator isolation valves (2)	M-13A						
	e. Close gag valves (2)	M-13A						
	f. Position man/auto to manual	M-13A						
	g. Position man/auto to charge	M-13B						
	h. Close accumulator isolation valves (2)	M-13B						
	i. Close gag valves (2)	M-13B						
	j. Position man/auto to manual	M-13B						
	k. Stop hydraulic pump	M-13B						
	l. Inform crew UHI is isolated							
19.	Review Procedures							
	a. Check E-0							
	b. Check E-1							
	c. Check E-2							
	d. Check E-3							
	e. Check REP							
20.	Implement the Radiological Emergency Plan							
	a. Inform ODS	19						
	b. Inform NRC	19						
	c. Inform on-site personnel	19						
	d. Sound emergency siren *	21						
21.	Cooldown the RCS							
	a. Adjust SG PORVs open (3)	M-4						
	b. Monitor SG levels (3)	M-4						
	c. Monitor hot leg temperature	M-5						
22.	Check Secondary Side Radiation							
	a. Dispatch HP to survey all MSLs	19						
	b. Dispatch chemical lab to sample SG activity	19						
23.	Recognize Loss of RWST							
	a. Observe annunciator	M-5						
	b. Observe RWST level	M-5						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Main Steam Line Break								FILE NUMBER: PMS: VIDEO/AUDIO:
TASK	ELEMENTS	LOC	PERFORMANCE					NOTES
			YES				NO	
			SUP	LO	BOP	STA		Time
23.	Recognize Loss of RWST (continued)							
	c. Dispatch AO to check RWST	19						
	d. Observe CCP amps (2)	M-6						
	e. Observe CCP flow	M-6						
	f. Inform crew RWST level is decreasing rapidly							
24.	Increase VCT Makeup							
	a. Position VCT makeup controller to manual	M-6						
	b. Adjust BA flow controller	M-6						
	c. Adjust PMW flow controller	M-6						
	d. Adjust BA batch counter	M-6						
	e. Adjust PMW batch counter	M-6						
	f. Place makeup control to start	M-6						
	g. Open makeup valve	M-6						
25.	Restore Charging Flow							
	a. Reset S.I. signal	M-6						
	b. Open VCT outlet valves (2)	M-5						
	c. Close RWST outlet valves (2)	M-5						
	d. Open charging header valves (2)	M-6						
	e. Close BIT isolation valves (4)	M-6						
	f. Adjust RCP seal injection flow	M-5						
	g. Inform crew charging is restored							
26.	Depressurize the RCS							
	a. Adjust Pzr pressure control	M-4						
	b. Adjust Pzr spray control	M-4						
	c. Monitor Pzr pressure	M-5						
	d. Calculate sub-cooling	M-4						
	e. Verify Pzr heaters off	M-4						
27.A	Terminate S.I.							
	a. Stop RHR pumps	M-6						
	b. Stop S.I. pumps	M-6						
	c. Stop one charging pump	M-5						5 of 8

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Main Steam Line Break

FILE NUMBER:
PMS:
VIDEO/AUDIO:

TASK ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
27.A Terminate S.I. (continued)							
d. Reset containment isolation signal	M-6						
e. Reset containment ventilation isolation	M-6						
27.B Terminate S.I.							
a. Place RHR pumps in PTL	M-6						
b. Place SI pumps in PTL	M-6						
c. Place CC pumps in PTL	M-5						
27.C Restart Charging Pump							
a. Start one CC pump	M-5						
b. Observe charging flow	M-5						
c. Adjust seal flow	M-5						
28. Restore Letdown							
a. Open seal return valves (2)	M-5						
b. Open regenerator Hx inlet valves (2)	M-6						
c. Open letdown isolation valve (1)	M-6						
d. Adjust back pressure regulator	M-6						
e. Open orifice isolation valve	M-6						
29. Recognize SGTR							
a. Observe #4 SG steam flow recorder	M-4						
b. Observe #4 SG pressure	M-4						
c. Inform crew							
30. Monitor Subcooling							
a. Observe hot leg temperature	M-5						
b. Observe RCS pressure	M-5						
c. Read subcooling chart	M-4						
d. Observe thermocouple temperature	M-9						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Main Steam Line Break

FILE NUMBER:
PMS:
VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
31.	Energize Source Range Instruments							
	a. Monitor I.R. neutron flux	M-4						
	b. Verify S.R. detectors energized	M-4						
	c. Transfer NR-45 to I.R. & S.R.	M-4						
	d. Adjust audio count rate monitor *	M-9						
32.	Check Main Turbine							
	a. Observe oil pumps running	M-2						
	b. Observe lift pumps running	M-2						
	c. Verify turbine on turning gear	M-2						
	d. Verify turbine drain valves open	M-2						
33.	Stop Diesel Generators							
	a. Dispatch AO to restore diesel lockout relays	19						
	b. Positon D.G. control to stop *	M-26						
34.A	Establish RHR Cooling							
	a. Check hot leg temperature below 350	M-5						
	b. Check RCS pressure below 380	M-5						
	c. Close RHR suction valve from RWST	M-6						
	d. Open RHR system isolation valves (2)	M-6						
	e. Open HTX outlet valves (2)	M-27B						
	f. Start RHR pumps	M-6						
	g. Monitor RHR temperature	M-6						
	h. Monitor RHR flow	M-6						
34.B	Establish RHR Letdown							
	a. Direct PEO to open valves							
	b. Adjust RHR letdown control	M-6						

TASK PERFORMANCE IDENTIFICATION CHECKLIST

OPERATING SEQUENCE: Main Steam Line Break	FILE NUMBER: PMS: VIDEO/AUDIO:

TASK	ELEMENTS	LOC	PERFORMANCE YES SUP	LO	BOP	STA	NO	NOTES Time
35.A	Secure RCPs During RHR Cooldown							
	a. Start oil pumps							
	b. Position RCPs off	M-5						
	c. Position oil pumps off	M-5						
35.B	Secure RCPs Due to Low Pressure							
	a. Start oil pumps	M-5						
	b. Position RCPs off	M-5						
	c. Position oil pumps off	M-5						
35.C	Restart an RCP							
	a. Start oil pump	M-5						
	b. Start RCP	M-5						
	c. Stop oil pump	M-5						
35.D	Verify Natural Circulation							
	a. Verify subcooling	M-5						
	b. Verify SG pressure	M-4						
	c. Verify Thot stable	M-5						
	d. Verify incore thermocouples							
	e. Verify Tcold and SG pressure	M-4, M-5,						
	f. Inform crew of natural circulation							
36.	Isolate SI Accumulators							
	a. Close accumulator outlet isolation valves (4)	M-6						
37.	Reset First Out Alarms							
	a. Record first out indications							
	b. SRO directs reset							
	c. Position reset switch							

OBSERVER: ______________
DATE: ______________
OPERATORS:
SUP: ______________
LO: ______________
BOP: ______________
STA: ______________

APPENDIX E

MATERIALS FOR SUBJECTS

This appendix contains examples of the documents which were used to brief and collect data from the participants during the data experiment. The training department memo has been edited to remove all references which might identify the plant.

(1) Training Department Memo (from Plant A)
(2) Information for Participating Operators
(3) Background Questionnaire
(4) SWAT - Description of Scale Dimensions
(5) SWAT - Individualized Scale Determination
(6) Instructions to Participating Operators
(7) Event Questionnaire
(8) Instructor Rating Form

September 14, 1984

All License Personnel and
License Certification Trainees

Subject: SIMULATOR TRAINING EXPERIMENT DURING REQUALIFICATION WEEK #4 1984 AND DURING PRELICENSE TRAINING

Starting September 24, 1984 through December 1984, General Physics Corporation will be performing an experiment with licensed plant personnel on the simulator. General Physics has been contracted to conduct this experiment by Oak Ridge National Laboratory for the N.R.C. The experiment has three goals:

1. to develop objective measures of crew performance to supplement the instructor's subjective evaluation,
2. to compare the performance of crews assisted by an STA with the performance of crews not assisted by an STA,
3. to determine how the years of operating experience of crew members affects performance.

The experiment will involve plant licensed personnel and certification classes during Tuesday of Week #4 simulator retraining. No significant loss of simulator training time will occur since the exercise's run will be of training value. The simulator exercises will be video taped and each participant will wear a wireless microphone. Individual participant's names are not used, however, the group evaluations are used to meet the above objectives.

More details will be given when you attend training. Your cooperation and professionalism will be greatly appreciated.

Training Shift Engineer

GP/ORNL SIMULATOR EXPERIMENT

Information for Participating Operators

The experiment examines the effects on performance caused by variations on a basic crew of a Supervisor (SUP) and two Reactor Operators (RO), sometimes augmented by the addition of a Shift Technical Advisor (STA). The planned analyses will study the effects of (1) SUP experience, and (2) adding an STA to the crew.

Each crew will perform 5 exercises. Extra operators in the training group will serve as observers for the exercises. One half of the crews will be led by a SUP with more than the plant average years of nuclear power experience, and the other half will be led by a SUP with less than average experience. One half of the teams will be aided by a qualified STA acting in an advisory capacity, i.e., monitoring the plant and making suggestions, but not operating any of the controls.

Events should be conducted as if on shift in the control room of the operating plant. Interactions with the instructor should be limited to communications which would normally occur with stations outside of the control room.

All exercises will be videotaped. Copies of selected tapes will be given to the Training Center for use as training materials. Otherwise the videotapes will be viewed only by human factors researchers at General Physics and Oak Ridge National Laboratory for research purposes.

The experiment is undertaken to evaluate the effects of SUP experience and the presence of an STA, not the proficiency of individual operators. Neither the plant nor individual participants will be identified in the report.

In order that the next teams do not have advanced notice about the events they will be asked to contend with (which might bias the results of the experiment), it is requested that all members of the training group not discuss the experiment with other operators at the plant.

By your participation in this experiment you will be providing valuable information which can ultimately be used to enhance plant safety.

Operator #: ____________ Name: ____________________

Date: __________________

GP/ORNL SIMULATOR EXPERIMENT

BACKGROUND QUESTIONNAIRE

1. Age: ______________
2. Nuclear power plant training (not including Navy)
   a. Classroom (total weeks): ______________
   b. Simulator (total weeks): ______________
3. Years in Navy nuclear program: ______________
4. a. Number of years college: ______________
   b. College degree (please list): ______________
   c. College major: ______________
5. a. Do you have any commercial non-nuclear power plant experience? ______
   b. Years of non-nuclear power plant experience: ______________
6. Commercial nuclear power plant experience.
   a. Date started working in a nuclear power plant: ______________
   b. How long have you worked in the <u>control room</u> as a licensed operator or supervisor? (total time-years) ______________
   c. List all NRC licenses earned: ______________
   d. Date first license awarded: ______________
   e. Current license and date awarded for this plant: ______________
   f. How many of the last 12 months have you spent as an operator or observer in the <u>control room</u> of an operating plant? ______________
7. Current position (circle one):
   a. Assistant Unit Operator (unlicensed)
   b. Unit Operator (licensed)
   c. Unit Supervisor (licensed)
   d. Shift Supervisor (licensed)
   e. Shift Technical Advisor
   f. Other (please specify): ____
8. If you do not <u>currently</u> work in the control room as a licensed operator or supervisor, when did you last work in the control room in one of these jobs? ______________
9. Date of last simulator training: ______________

GP/ORNL SIMULATOR EXPERIMENT

SUBJECTIVE WORKLOAD ASSESSMENT TECHNIQUE

DESCRIPTION OF SCALE DIMENSIONS

Mental workload refers to how hard you work to accomplish some task, group of tasks or an entire job. Many factors can potentially contribute to how hard you must work. For this experiment, we will consider three: Time Load, Mental Effort, and Psychological Stress.

TIME LOAD. Time load refers to the fraction of the total time that you are busy. When time load is low, you have plenty of time to complete all of your mental work with some time to spare. As time load increases, spare time drops out and some aspects of performance overlap and interrupt one another. This can come from performing more than one task or from different aspects of performing the same task. At higher levels of time load, aspects of performance often occur simultaneously, you are constantly busy, and interruptions are very frequent. In this experiment, you will be asked to judge the time load dimension of mental workload on the following three-point scale:

(1) Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.
(2) Occasionally have spare time. Interruptions or overlap among activities occur frequently.
(3) Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.

MENTAL EFFORT. Time load refers to the amount of time one has available to perform a task or group of tasks. In contrast, the mental effort scale has been designed to serve as an index of the amount of attention or mental effort required by a task, regardless of the number of tasks to be performed or any time limitation. When mental effort load is low, the concentration and attention required by a task is minimal and performance is nearly automatic. As the demand for mental effort increases, the degree of concentration and attention required to perform increases, due to task complexity or the amount of information which must be dealt with in order to perform adequately. High mental effort load demands total attention or concentration due to task complexity or the amount of information to be dealt with. The following three-point scale has been devised for you to judge the mental effort dimension of mental workload during this Experiment.

(1) Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.
(2) Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.
(3) Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

PSYCHOLOGICAL STRESS. To accomplish any task or group of tasks you generally must deal with confusion, frustration, or anxiety. This is the psychological

stress dimension of workload. Like time and mental effort, the psychological stress factor of task accomplishment can also be viewed as a load factor contributing to the overall perception of workload. Thus, psychological stress can be viewed as a contribution to total workload of any conditions that produce anxiety, frustration and confusion while performing a task or tasks. At low levels of psychological stress, one feels relatively relaxed. As stress increases, confusion, anxiety, or frustration increase and greater concentration and determination are required to maintain control of the situation. During this Experiment, you are to judge psychological stress on the following three-point scale:

(1) Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.
(2) Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.
(3) High to very intense stress due to confusion, frustration, or anxiety. High to extreme determination and self-control required.

Each of the three dimensions just described contribute to workload during performance of a task or group of tasks. Note that although all three factors may move together in the same direction and at a similar rate, that need not be the case. For example, one can have many tasks to perform in the time available (high time load) but the tasks may require little concentration (low mental effort). Likewise, one can be anxious and frustrated (high stress) and have plenty of spare time between relatively simple tasks. Moreover, the workload in a given task may differ over time. This may be caused by some new factor being added to the task, such as a need to finish by a certain time. Or the need to get the same job done despite greater background disturbance. Or the need to get the same job done after a less than full night's sleep. Or any of a number of things that differ from one rating to another.

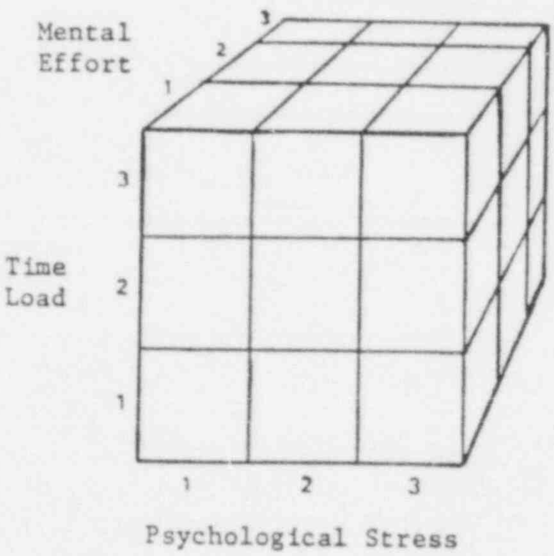
During this Experiement you will be asked to judge the workload you experienced during each exercise. Please treat each dimension individually, and give independent assessments of the Time Load, Mental Effort, and Psychological Stress experienced each time you rate the workload for the exercise. It is very important for the Experiment that every judgement be as considered and independent as possible.

GP/ORNL SIMULATOR EXPERIMENT

SUBJECTIVE WORKLOAD ASSESSMENT TECHNIQUE

INDIVIDUALIZED SCALE DETERMINATION

During the course of the Experiment you will be asked to rate the workload experienced during each exercise you will be performing. The workload imposed on you at any one time can be thought of as the combination of the particular levels of three dimensions that contribute to the subjective understanding of that workload. These dimensions are: (1) time load, that fraction of the total time that you are occupied in doing the task; (2) mental effort, the amount of attention, concentration or other mental effort required by a task; and (3) psychological stress, the extent to which the task is accompanied by frustration, confusion, or anxiety. During the Experiment, your rating of the workload you experienced during each exercise will be made by selecting the best combination of three choices for each of these dimensions. The possible combinations of the three dimensions can be represented as shown here. Each cell in the cube represents one possible combination of each of the three types of load.



One of the most important features of this technique is its unique scoring system. This scale uses a procedure which finds separate scoring weights for each rater. Thus, a distinctive scale is determined for each person using the scale. This greatly improves the precision of each rating you make. In order to develop your individual scale, we need information from you regarding the amount of workload imposed by various combinations of the dimensions illustrated above. We can get the necessary information by having you rank order the workload associated with each of the combinations.

In order for you to rank order the workload for each of the combinations, you have been given a set of 27 cards with the combinations from each of the three dimensions. Each card contains a different combination of levels of Time Load, Mental Effort, and Psychological Stress. Your job is to sort the cards so that they are rank ordered according to the level of workload represented on each.

The first card in the deck has a space for your name, todays date, and your job in the plant. Please fill out that first card and set it and the rubber band to the side, you'll need them again when you have finished. Now sort the cards from the least to the most difficult levels of workload. When you are sorting the cards, please consider the workload imposed on a person by the combination of the levels of each dimension represented on each card,

and arrange the cards so they range from what you recognize as the lowest workload condition through the highest condition.

You may use any strategy that you choose in ordering the cards. One strategy that has proven useful to others is to first arrange the cards into several preliminary stacks representing "high," "moderate," and "low" workload. Individual cards can be exchanged between stacks, if necessary, and then rank ordered within stacks. Stacks can then be combined and checked to be sure that they represent your ranking of lowest to highest workload. However, the choice of strategy is up to you. Choose one that will work best for you. When you have completed the sorting, put the card with your name on it on top of the stack and secure the sorted cards with the rubber band. When finished, please give the sorted cards to the person who gave them to you.

There is no "correct" order for the cards. The correct order is what, in your judgement, best describes the progression of workload from lowest to highest. That judgement differs for each of us. The letters you see on the back of the cards are to allow us to arrange the cards in a previously randomized sequence so that everyone gets the same order. If you examine your deck you will see that the order on the back runs from A through Z and then ZZ.

From this point until you have completed the sorting will probably take between 15 to 30 minutes.

Please feel free to ask questions at any time. Thank you for your cooperation.

GP/ORNL SIMULATOR EXPERIMENT

Instructions to Participating Operators

Today you will be performing five exercises, four of which involve transients of varying degrees of complexity. Your instructor will program each exercise and brief you on the status of the simulated plant. Once the simulator is taken out of "freeze", you are on your own. Your interaction with the instructor should be limited to communications that would normally occur with stations outside of the control room.

At the conclusion of each exercise you will fill out the "Event Questionnaire" describing the workload you experienced during the event.

For those groups where there is an STA, he is to serve in an advisory capacity to the supervisor. In the exercises performed for this experiment, the STA may not operate any controls.

You should respond to the situations presented as if you were on shift in the plant. Please try to forget that this is just a simulator and do everything as you would in a similar situation in the plant.

GP/ORNL SIMULATOR EXPERIMENT

EVENT ID: _____

EVENT QUESTIONNAIRE

1. Please circle the one number of the statement which most accurately describes your perception of (A) time load, (B) mental load, and (C) stress load during this exercise.

   A. Time Load

      1. Often have spare time. Interruptions or overlap among activities occur infrequently or not as all.
      2. Occasionally have spare time. Interruptions or overlap among activities occur frequently.
      3. Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.

   B. Mental Load

      1. Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.
      2. Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.
      3. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

   C. Stress Load

      1. Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.
      2. Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.
      3. High to very intense stress due to confusion, frustration, or anxiety. High to extreme determination and self-control required.

2. A. Have you ever experienced this event in an operating plant?
   Yes ___ No ___

   B. If you answered yes, when (month/year). _______________

3. When was the last time you practiced this event in a simulator (month/year)? _______________ OR Never seen this event _____

4. Was your job assignment for this event (circle one):
   a) Lead RO b) BOP c) SUP d) STA

Team: ______________

Exercise: ______________

GP/ORNL SIMULATOR EXPERIMENT

INSTRUCTOR RATING FORM

The purpose of this form is to record your overall evaluation of the performance you have just observed. The ratings and comments you provide will assist in refining and evaluating the other performance measures developed for this project. Please complete this form during the closing or at the end of this exercise and before you start the next exercise.

Question 1. Circle the appropriate numbers corresponding to the adjectives which best describe the performance of the crew and of individuals in the crew. Complete all appropriate lines.

NOTE: These scales are intended for use with licensed operators (requalification classes). If this team consisted of pre-license trainees, please rate them against the same standards you would apply to licensed operators (that is, do not make any allowances for the fact that they have not yet completed their training).

		Poor			Average			Superior
	a. Rate Crew Performance	1	2	3	4	5	6	7
____	b. Rate SUP Performance	1	2	3	4	5	6	7
____	c. Rate RO Performance	1	2	3	4	5	6	7
____	d. Rate BOP Performance	1	2	3	4	5	6	7
____	e. Rate STA Performance (if applicable)	1	2	3	4	5	6	7

Question 2. What general factors or evaluation categories are important in evaluating this exercise? (fill in before exercise is performed)

Team: ____________________

Exercise: ________________

Question 3. What specific actions or behaviors were especially good and significantly influenced your evaluation?

Question 4. What specific actions or behaviors could have been performed better? Briefly describe how.

Rater: ________________________

APPENDIX F

VALIDATION ANALYSIS

In considering the results of the experiment in relation to the issues associated with operational safety of NPPs discussed in Section 1.1, the validity of the performance measures used in the experiment should be examined. We believe the derivation of the performance measures from an analysis of the tasks making up the operating sequences insures a substantial degree of content validity (see Ref. 1, pp. 311-346). However, the question of validity is one that can be addressed empirically.

One way to approach the validity question is to assess the "predictive" validity of the measures, the degree to which scores on one set of measures are correlated with (and thus can be used to predict) scores on another (criterion) set of measures. In situations where there are no validated criterion measures, expert ratings are often used as the criterion, though the validity of such ratings is itself usually unknown. For the 1984 experiment, the simulator instructors provided an overall rating of the performance of each crew at the completion of each exercise. Additionally, the experiment included crews of pre-license trainees to determine if the performance measures were effective in discriminating between groups presumed to have different levels of proficiency. The use of these ratings and other information provided by the instructors as well as the trainee to licensed operator performance comparison in assessing the validity of the performance measures is described in this section.

F.1 Description of the Instructor Rating Form

Data collected from instructors using an Instructor Rating Form (IRF) to rate individuals' and crews' performance during the various

exercises were used to assess the validity of the task performance measures. An example of the IRF appears in Appendix E. The IRF consisted of a rating scale and three open-ended response questions. The first question asked the instructor to rate the crew's performance and each crew member's (SUP, RO, BOP, STA) individual performance during the exercise on a seven-point ordinal scale. Ratings of 1, 4, and 7 correspond to "Poor," "Average," and "Superior" performance respectively. The second question asked the instructor to list those factors which he believed to be important in evaluating the exercise. For example, if good communications among crew members and proper use of procedures were believed important for this particular exercise, the instructor would list these in response to this question before the exercise was performed. At the completion of the exercise, the instructor completed the final two questions. Question 3 asked what specific actions taken by the crew were carried out well, while question 4 deals with those actions by the crew that were not performed well during the exercise.

F.2 Limitations of the Instructor Rating Form

There are several limitations that can hinder the interpretability of data obtained from rating instruments. Such limitations are of the variety that mainly affect the validity of the instrument, particularly with regard to the reliability of measurement (see Ref. 2, pp. 39-44). With respect to this experiment, these limitations fall into three broad categories: those concerning the raters, those concerning the experimental situation, and those concerning the instrument itself.

Several factors concerning the raters could render interpretation of the IRF data difficult. First, the 22 crews were evaluated by eight different raters. Having this many raters can lead to large inconsistencies in the ratings due to the fact that ratings are subjective in nature. Second, of the eight raters, two were new instructors who had little experience in evaluating simulator exercises; a fact which could affect their ratings in ways different from the other, more experienced raters.

Third, raters from the same plant as the crew they are rating may tend to rate that crew differently from an unfamiliar crew from another plant, even though the two crews actually have equivalent performance. That is, a rater might evaluate the familiar crew either more leniently or more strictly. These first three possible sources of confounding with respect to rater performance ultimately lead to the fourth: that of low interrater reliability. The interrater reliability of the IRF in this experiment is unknown due to the fact that the experimenters could not control either the selection of raters or assignment of raters to particular crews. It was not possible to assign two or more raters to the same crew for each exercise and compare IRF data across raters to obtain an interrater reliability index. If such an index were obtained, a reliability correction could be incorporated into the IRF data to better reflect the raters' evaluations, and the ratings would be more useful as a validation measure against crew performance. A fifth possible problem concerns the "halo" effect. When rating performances, a halo effect can occur when a crew's performance (whether poor, average, or superior) on an exercise influences the rater's evaluation of the next exercise, usually resulting in a similar rating for the second exercise regardless of the actual performance. Finally, a sixth problem is a possible reluctance to rate a crew's performance as poor.* This is known as leniency and can result in a distribution of ratings skewed toward the middle to upper end of the rating scale. Skewness of this kind is exhibited by the ratings obtained with the IRF, which are summarized in Table F-1 (the ratings for each crew are presented with the crew performance data in Appendix G).

*Two instructors provided ratings for 11 of the 22 crews. One split his ratings evenly between 4s and 5s, and the other's ratings formed a broader and symmetrical distribution. Some of the first instructor's 4s may have been due to leniency. Judging from his comments during the simulator sessions, one instructor also appeared to be markedly stricter than the others.

Table F-1 Distributions of IRF ratings

Exercise	Plant	"Poor" 1	2	"Average" 3	4	5	"Superior" 6	7	Mean
LOAD	A[a]			1	3	4	4		4.9
	B			1	2	1	1	1	4.8
SGTR	A				2	4	5	1	5.4
	B				2	1	2		5.0
LOFW	A	1		2	7	3	1		4.0
	B			1	3	3	1		4.5
MSLB	A		1		2	7	2		4.8
	B			1	5		2		4.4

a. The ratings of the two trainee teams from Plant A are included in the summaries for LOAD, SGTR, and LOFW.

A second category of factors limiting the interpretation of IRF data concern those dealing with the experimental situation. For example, of the 22 crews for which IRF data were obtained, 14 were from Plant A, and eight from Plant B. The simulator used in this experiment is located at Plant A, and differs slightly from Plant B in terms of control panel layout. In addition, the emergency operating procedures differ between plants. Finally, the average experience for crews from Plant B is lower than for crews at Plant A. All of these were well known to the raters. Although all raters received both verbal and written instructions to use the same standards for rating all crews, at least one rater told us that the above factors were "factored into" his ratings.

The last factors contributing to limitations of the IRF concern the IRF itself. Basically there are two problems in the design of the form. First, there are only seven points and three adjectival anchors on the rating scale, which allows the rater great freedom of interpretation. A ten-point scale with more behaviorally-defined anchors would promote more consistent discriminations of rated performance, but the primary purpose of the IRF was to gather information with which to define the important

dimensions of performance. Second, although the open-ended questions present problems in relation to the analysis of the content of the raters' responses, analysis of these answers will aid in the development of a more structured rating instrument with improved operationalizations of the constructs involved. Also, because the responses to the open-ended questions are much more easily related to specific aspects of performance than are the summary numerical ratings, they provide a second set of data against which the validity of the performance measures may be assessed.

F.3 Comparison of Task Performance Scores to IRF Ratings

A correlational analysis was performed to obtain a quantitative assessment of the relation between the task performance scores and the IRF ratings. In this analysis the IRF ratings served as the criterion for judging the validity of the task performance scores.

F.3.1 Weighting of Task Performance Scores

In scoring the exercises, it became apparent that a number of tasks, primarily realigning systems on the secondary side of the plant for shutdown, were often omitted or performed incompletely. These omissions were quite conspicuous when looking at the scoring summaries, but were seldom mentioned as something that could have been done better on the IRFs. It thus appeared that some tasks were simply more important than others, and should be given a greater weight in calculating the task performance scores for the exercise.

To obtain the task weights, we requested the lead instructor to assign a weight to each task listed on the TPICs for the four exercises. Tasks judged to be critical were assigned a weight of 3, less important tasks a weight of 2, and tasks not important (in the time-frame of the

exercise) were assigned a weight of 1 (the task weights are presented in Supplement 1 to this Appendix). All task data were then multiplied by the appropriate task weights before the performance scores for the scenario were computed.*

The tasks most frequently omitted were those considered least important, so the effect of weighting the task data was generally to increase the overall performance scores slightly. Since tasks with a weight of 3 were those mentioned most frequently on the IRFs, the weighted task performance scores may also more closely approximate the way the instructors judged the exercises, and would be expected to yield a higher correlations with the IRF ratings. The weighted team performance scores are presented in Appendix G.

F.3.2 Correlations between Task Performance Scores and IRF Ratings

The number of exercises for which both IRF ratings and task performance data were available is shown below:

LOAD 18: 16 requalification crews and 2 teams of trainees (IRFs were not completed for crews 12 and 16 who did not complete the exercise, crew 14 did not perform it, and no rating was given for crew 10)

SGTR 17: 15 crews (crews 1, 2, 13, 15, and 17 did not perform the exercise) and 2 teams of trainees

LOFW 22: 20 crews and 2 teams of trainees

MSLB 20: 20 crews and no trainees

*For the task times the deviation score was calculated prior to weighting.

Pearson product-moment correlations (r) between the IRF ratings for each team and the five task performance measures were computed using the BMDP1R multiple linear regression program of the BMDP statistical software package (Ref. 3). These correlations for both weighted (w) and unweighted (u) measures are shown in Table F-2.

From the definitions of the individual performance measures, we would expect that the first four would be positively correlated with rated performance and the Z-time would be negatively correlated with it. The overall pattern of correlations in Table F-2 is gratifyingly consistent with this expectation, although only for LOFW are the individual measures highly correlated with the ratings. Note also that weighting the tasks has only a small effect on the correlations, except in the case of the SGTR, where the unweighted data yielded correlations more nearly in accord with the a-priori expectations regarding the sign of the correlation.

Table F-2 Correlations between task performance scores and IRF ratings

Exercise	n[a]	CV[b]	Task Performance Scores				
			% Init	% Elem	% P/L	% Succ	Z-time[c]
LOAD - w	18	.468	.356	-.273	.106	.140	-.379
- u			.285	-.301	.099	.101	-.212
SGTR - w	17	.482	-.422	-.065	.101	.214	.149
- u			-.151	-.101	.108	.324	-.144
LOFW - w	22	.423	.714	.483	.287	.544	-.015
- u			.659	.421	.288	.587	-.070
MSLB - w	20	.444	.281	.213	.344	.115	-.117
- u			.208	.096	.341	.179	-.121

a. n = the number of teams.

b. CV = the critical value, the minimum value of r required for significance at the $p < .05$ level.

c. the correlations with Z-time are expected to be negative because smaller Zs represent shorter times.

Does the absence of signficant correlations with the IRF ratings mean performance measures are invalid? No. The absence of significant correlations does imply no one of the measures is an adequate reflection of the raters' criteria by itself, but the measures were not intended to be used separately, as they reflect different aspects of performance.*

How the set of performance measures correlates with the IRF ratings is indicated by the coefficient of multiple correlation, R. The R indicates the correlation between a hypothetical variable representing an optimal linear combination of the independent variables and the criterion variable. The Rs for both the weighted and unweighted data for the four exercises are presented in Table F-3. When the multiple correlations are considered, the set of performance measures looks somewhat more successful, in that the R for LOFW is statistically significant. Again, the differences between weighted and unweighted measures are small.

Table F-3 Multiple correlation between task performance scores and IRF ratings

Exercise	R	F[a]	df[b]	p
LOAD - w	.531	.94	5, 12	> .20
- u	.484	.73	5, 12	> .20
SGTR - w	.512	.78	5, 11	> .20
- u	.452	.56	5, 11	> .20
LOFW - w	.763	4.45	5, 16	< .01
- u	.687	2.38	5, 16	< .05
MSLB - w	.532	1.11	5, 14	> .20
- u	.494	.91	5, 14	> .20

a. The "F" statistic is used for testing the significance of Rs.
b. df = degrees of freedom for the calculated F.

*The correlation matrices also produced by the BMDP1R program show that the measures were, in general, not highly correlated with one another, which indicates that they are in fact fairly independent.

Still, the Rs for three of the four exercises are not statistically significant. One possible explanation may be found in a restriction in the range of values assumed by the performance measures. Table F-4 presents the means ($\overline{X}$) and standard deviations (sd.) of the sets of performance data used in the correlations. In the LOAD and SGTR sequences, the measures we might expect to be most easily tracked by an observer, % Init and especially % Succ, exhibit high mean values, which is not surprising since both exercises were familiar to the operators and procedure-driven.

Table F-4 Means and standard deviations for weighted task performance scores with which correlations were computed

Exercise	n[a]		Task Performance Measures % Init	% Elem	% P/L	% Succ	Z-time
LOAD	18	$\overline{X}$	.921	.852	.685	.969	.032
		sd.	.055	.035	.051	.043	.519
SGTR	17	$\overline{X}$	.959	.849	.646	.942	.005
		sd.	.032	.044	.075	.051	.186
LOFW	22	$\overline{X}$	.913	.750	.501	.796	-.007
		sd.	.076	.111	.125	.080	.352
MSLB	20	$\overline{X}$	.886	.781	.551	.879	-.002
		sd.	.073	.063	.147	.064	.249

a. n = the number of teams.

As mentioned in Section 3.2, it was the experimenters' impression that the SGTR was handled well by all teams, including the trainees. The instructors were very familiar with this sequence, and considered it to be an important one in that it is one of the more likely major casualties. For these reasons, they may have expected very good performance to be the norm (an average rating assigned to the SGTR performances was 5.3, the highest of the four sequences rated) and used a set of criteria not well reflected in the task performance measures to differentiate among performances, all of which were acceptable.

In addition, it is also probable that inconsistencies in the ratings contribute to the low correlations obtained: the fact that there were eight raters makes a degree of inconsistency almost inevitable. In particular, some of the instructors had little familiarity with the MSLB exercise, and thus may not have had stable criteria with which to judge it. This would have a negative effect on interrater reliability and the validity of the ratings. Thus it is desirable to look for additional evidence before forming conclusions as to the validity of the task performance measures. Fortunately, the open-ended questions on the IRF provide a source of such evidence.

F.4 Content Analysis of Open-Ended Questions on the IRFs

To what extent are the things the instructors are focusing on in arriving at their performance evaluations reflected in the performance measures used in this study? This is the first question that comes to mind when considering the correlations between the instructor ratings and the summary performance measures.

The answer is given by a content analysis of the instructors' responses to questions 2, 3, and 4 on the IRFs. Table F-5 lists the most frequent responses to question 2 in the IRF, "What general factors or evaluation categories are important in evaluating this exercise?" Single asterisks (*) denote categories that would be reflected in one or more of the performance measures used; double asterisks (**) mark criteria that would not be reflected in the performance measures.

Inspection of Table F-5 shows that the majority of the evaluation categories recorded by the instructors are reflected in some way in the task performance measures. This is not to say that there is anything like a one-to-one correspondence. For example, the instructors appear to place a great emphasis on communications and teamwork. "Teamwork" is not directly addressed by the performance measures, nor is "communications" *per se*. However, a substantial number of tasks (in the casualty sequences especially) are verifications. For these tasks, failure to

Table F-5 Evaluation criteria most frequently mentioned by instructors

Exercise			
LOAD	SGTR	LOFW	MSLB
Communications/ teamwork (15)[a]*	Communications/ teamwork (14)*	Communications/ teamwork (13)*	Diagnosis of MSLB (11)*
Follow instructions (12)*	Identify & isolate faulted SG (9)*	Diagnosis (12)*	Communications/ teamwork (9)*
Control of SG levels without swings (8)**	Cooldown & depressurize to stop leak (8)*	Establish flow to SGs (9)*	Recognition of SGTR (8)*
Load rate (time management) (4)*	Timely response (8)*	Dispatch personnel to investigate (6)*	Recognize implications of Loss of RWST (7)*
Observation of boards & clearing of alarms (4)**	Follow procedures (6)*	Use of procedures (5)*	Request MSIV closed locally (5)**
Transfer SG control to automatic (3)*	Use & management of alarms (3)**	Timely response (4)*	Establish RHR cooling (5)*
		Recognition of failure modes and emergency start modes of equipment (4)**	Follow procedures & improvise where needed (5)*
			Supply borated water to core (3)*

a. The numbers in parentheses following each category are the number of times the category was mentioned on the IRFs completed for each exercise.

* Evaluation category reflected in task performance measures.

** Evaluation category <u>not</u> reflected in task performance measures.

communicate the results of the verification (i.e., failure to inform the SUP) was scored as failure on the task. Thus communication of a small set of factual data was accorded a very high importance. However, it should be recognized that what the instructors mean by "communications" undoubtedly covers more than the restricted set of communications included as task elements.

The use of procedures is also not directly addressed in the task performance measures. Although there is a task called "consult procedures" in the three casualty sequences, the task is considered successful if the procedures were referenced, even if they were improperly used or ignored. However, since the task elements, P/Ls, and success criteria more often than not come directly from the procedures for Plant A, failure to follow procedures will usually be reflected in one or more of these measures.

Table F-5 suggests that there is a general correspondence between the kinds of things the instructors say their evaluations are based on and the set of task performance measures. Questions 3 and 4 of the IRFs supply data with which to make a more detailed comparison. Question 3 asks "What specific actions or behaviors were especially good and significantly influenced your evaluation?" Table F-6 presents a listing of all such actions cited by more than one instructor for the MSLB sequence, and the specific measures in which they are reflected. The task numbers given in the table correspond to the tasks listed in the TSC for this event given in Appendix B. Inspection of Table F-6 shows that a clear majority of the commended actions would be reflected in the task performance measures. However, these "especially good" actions would not "significantly influence" the overall evaluation because the system allows no extra credit. That is, those teams who performed the action would certainly receive credit for it, but these actions would be accorded no special weight: everyone was <u>expected</u> to do them.

Table F-7 presents a similar comparison of comments in response to question 4 of the IRF, "What specific actions or behaviors could have

Table F-6 Actions commended by instructors in the MSLB exercise

Action Commended	How Reflected in Task Performance Measures
Communications (8)[a]	Communication of specific information required for success in tasks 1-6, 8, 9, 16, 17, 23, 29, 35d, & 37
Requested local survey of steam lines (7)	Required for success task 22
Aligned BAT to RCS when RWST empty (6)	Required for success task 24
Requested pulling fuses to MSIV (attempt to close MSIV) (4)	-NOT REFLECTED IN MEASURES-
Recognized steam line break (3)	Required for success task 1
Checked incore thermocouples often (3)	Checking (once) is an element in in tasks 30 and 35d
Feed & steaming to SG (3)	(meaning of comment unclear)
Decided to go on RHR cooling (3)	Task 34a
Recognized <u>all</u> malfunctions (2)	Recognition of 3 of the 4 malfunctions treated as separate tasks: tasks 1, 23, and 29. Recognition of MSIV failure is one element in task 7.
Followed procedure until no longer helpful (2)	-NOT REFLECTED IN MEASURES-
Makeup to VCT and realign charging pumps to VCT (2)	Tasks 24 and 25

a. The numbers in parentheses following each category are the number of times the category was mentioned on the IRFs completed for each exercise.

Table F-7 Specific criticisms of performance in the MSLB exercise

Criticism	How Reflected in Task Performance Measures
Did not request enough assistance (5)[a]	Omission of task 22, missing elements in task 23
Two slow in recognizing SGTR (5)	Omission or long task time, task 29
Too slow in going on RHR (4)	Omission of task 34a or long time for tasks 21 and 26, which establish the preconditions for the employment of RHR
Too slow to recognize loss of RWST (4)	Long task time, task 23
Too slow in depressurizing RCS (3)	Long task time, task 26
Immediate actions not thorough (2)	Omission or failure on one or more of tasks 2-6, 8, 9, 16 or 17
Didn't recognize increase in pressurizer level (2)	-NOT REFLECTED IN MEASURES-
Did not attempt to close MSIV (2)	1 element missing, task 7
Did not put pumps back on VCT (2)	Omission of task 25
Did not start makeup to VCT at maximum rate (2)	Failure or long task time, task 24
Slow response to alarms (2)	Long task time, tasks 23 & 35a (if 35a required); otherwise not reflected in performance measures

a. The numbers in parentheses following each category are the number of times the category was mentioned on the IRFs completed for each exercise.

been performed better?" Again, inspection of the table shows that the majority of criticisms are directed at aspects of performance that would be reflected in the task performance measures.

Five of the 11 criticisms in Table F-7 are focused on slowness of response. Although speed of response is reflected in the standardized task times, it is likely that the instructors have something more in mind than the number of seconds elapsed between the task cue and task success. Slow response may be, or be inferred to be, an indication of an inadequate understanding of what is going on and/or what to do about it. If such an inference (correct or not) is made, it is to be expected that it would weigh heavily in the instructor's evaluation of the crew. The system of task performance measures makes no such inferences, and so may not accord the times for certain tasks anywhere near the weight an instructor might.

The above review and content analysis of the comments recorded on the IRFs suggests that the system of task performance measures is looking at the same sorts of things that the instructors are. Although it does not capture everything they take into account, there are few glaring omissions.

F.5 Comparison of Trainees to Licensed Operators

A third way to demonstrate a degree of validity is to demonstrate the ability of the proposed measures to discriminate between the performance of groups of operators known (or presumed) to exhibit different levels of proficiency, such as pre-license trainees and licensed operators. Two groups of trainees were available, and performed three of the experimental scenarios. The same data were collected from them as from the crews of licensed operators. Standardized scores describe the relation of a single score to the mean and standard deviation of a distribution of scores. Thus they provide a convenient way of showing the relation between task performance scores of the two trainee groups and those of the 12 teams of licensed operators from Plant A. The

standardized scores for the three sequences performed by the trainees, LOAD, SGTR, and LOFW, are presented in Table F-8.

Table F-8 Standardized task performance scores for trainees relative to licensed operators

			Standardized Task Performance Scores[a]				
Exercise	Team	IRF[b]	% Init	% Elem	% P/L	% Succ	Z-time
LOAD	21	3	.222	-1.142	- .517	-1.353	.663
	22	5	.401	- .920	1.634	- .541	.005
SGTR	21	5	- .227	- .123	.560	.060	.011
	22	5	1.258	-1.216	.446	1.452	.078
LOFW	21	1	-2.300	- .860	- .758	-1.212	.688
	22	3	-1.190	-1.479	- .134	-1.453	-.624

a. Scores with negative signs are smaller than the mean; scores with positive signs are larger.
b. Instructor's rating of performance.

Inspection of the standardized scores for the trainee groups shows that both groups tended to score near or below the mean on all measures except Z-time, where their scores were a little above the mean (slower). However, the scores also show that the trainee groups were not the worst performers in the LOAD and SGTR sequences (team 22 did very well on the SGTR), though they did perform poorly in the LOFW exercise. Although the correlation between the task performance measures and IRF ratings is not large for the sample as a whole, the ratings shown in Table F-8 are roughly in accord with the impression of relative performance conveyed by the standardized task performance scores.

The data from trainee groups were collected at the end of their fourth week of simulator training, and they had practiced both the LOAD and SGTR sequences during this time. In addition, both exercises were not complicated by additional malfunctions and were well covered by available procedures. Thus it is to be expected that they would perform fairly well, even in comparison to licensed operators who had not been in

the simulator recently (the presumption that they would perform poorly just because they were trainees was simply incorrect).

However, in the LOFW exercise they were faced with a very complicated situation involving multiple malfunctions. This exercise had not been practiced in the simulator. Both of these factors combine with relative inexperience to reinforce the expectation that the trainee crews would not perform as well on this sequence as they did on the more familiar ones, which is exactly what happened.

Although the sample is much too small to allow any conclusions to be drawn, the pattern of the trainees' task performance scores is consistent with the instructors' evaluations, and is also consistent with a claim that the task performance scores are responsive to differences in performance.

F.6 The Validity of the Task Performance Scores

To assess the validity of the task performance measures used in this study, three lines of evidence have been examined.

The first of these, the correlations of the task performance scores with the instructors' IRF ratings, produced significant correlations for one exercise, but not for the other three. The results of the correlational analysis thus fail to support a claim to predictive validity, but the large number of raters and unknown interrater reliability when using the IRF severely limits the importance that can be attached to this result as evidence either against the validity of the task performance scores in general or <u>for</u> their validity when applied to the LOFW exercise. We have argued that there was in fact little variation of the adequacy interrater reliability when using the IRF severely limits the importance that can be attached to this result as evidence either against the validity of the task performance scores in general or <u>for</u> their validity when applied to the LOFW exercise. We have argued that there was in fact little variation of the adequacy of performance in the LOAD and SGTR sequences, so the instructors' ratings may reflect

differences (leniency or severity) in judging these (and other) exercises.

The second line of evidence, the content analysis of the open-ended questions about the MSLB exercise, shows that the majority of specific criticisms pertain to things that are reflected in the task performance measures. Because the instructors' comments were addressed to the same level of detail as the performance measures, and in this sense more objective than the summary ratings, we believe that the content analysis offers fairly strong support for a claim of content validity for those measures.

Third, the comparison of the performance scores of the two trainee groups to those of the licensed operators was based on too little data to be persuasive, but it, too, was consistent with a claim to a degree of validity for the task performance measures.

F.7 Comparison of Functional Performance Measures to IRF Ratings

As was done with the task performance scores, a correlational analysis was performed to obtain a quantitative assessment of the relation between the six functional performance measures and the IRF ratings of team performance.

Functional performance measures were recorded for three of the four exercises performed, SGTR, LOFW, and MSLB, but not for the turbine loading exercise. Examination of the data presented in Appendix G suggests that the six measures may not be equally appropriate for the three casualty scenarios: for example, in the LOFW exercise, only 5 of the 22 crews had non-zero scores for the two measures related to subcooling margin, time SCM < 40° and RMS error in SCM, and neither subcooling margin nor steam generator level was seriously challenged by the SGTR sequence. The distributions of values for these measures for the LOFW exercise are not appropriate for correlational analysis, so they were excluded from the analysis. Also, in the MSLB exercise the distributions of the two SCM measures are markedly skewed, and thus not

wholly suitable for calculating correlations, while for the SGTR the distribution of these measures are fairly symmetrical.

The correlations between each of the six functional performance measures and the IRF ratings are presented in Table F-9.

Table F-9 Correlations between functional performance scores and IRF ratings

			Functional Performance Measures					
Exercise	N	CV	TOB[a] SCM[c]	RMS[b] SCM	TOB P-Lvl[d]	RMS P-Lvl	TOB SGL[e]	RMS SGL
SGTR	17	.482	.090	.085	-.029	.075	.099	.058
LOFW	22	.423	--	--	.268	.029	.224	.125
MSLB	20	.444	-.534	-.629	.125	-.432	-.198	.012

a. TOB = time-out-of-band (seconds).
b. RMS = root-mean-square (in % level or degrees F).
c. SCM = subcooling margin < 40^{o}.
d. P-Lvl = pressurizer level < 20%.
e. SGL = level in <u>no</u> one of the steam generators > 79% (wide range).

Inspection of Table F-9 shows that the correlations for the SGTR and LOFW sequences are small, and not statistically significant. For the MSLB sequence, the correlations for the two SCM measures are large enough to achieve statistical significance, and are of the expected sign.* For the three exercises, the coeficients of multiple correlation were: SGTR, $R = .202$; LOFW, $R = .364$; and for MSLB, $R = .720$. The R of .720 for the MSLB sequence is marginally significant: $F(6,13) = 2.43$, $p < .10$.

The derivation of the functional performance measures from the critical safety functions identified in Plant A's procedures should insure a high degree of content validity. The generally disappointing

*Because the functional performance measures are error scores, they should exhibit negative correlations with the IRF ratings.

correlations may indicate that a) the instructor's evaluations were not much influenced by the variables selected as functional performance measures, which are time integrals not displayed to them, or b) the influence of the measured variables was obscured by inconsistencies in the ratings due to the large number of raters.

F-8 References

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Supplement 1

Rated importance (task weights of individual tasks)

LOAD		SGTR				LOFW		MSLB			
Tsk[a]	Wt*	Tsk	Wt	Tsk	Wt	Tsk	Wt	Tsk	Wt	Tsk	Wt
1	--	1	3	25	2	1	3	1	3	27a	2
2	2	2	3	26	3	2	3	[illegible]	3	27b	2
3	3	3	3	27	3	3	2	3	3	27c	2
4	--	4	3	28	3	4	3	4	3	28	2
5	3	5	3	29	3	5	3	5	3	29	1
6	3	6	3	30	3	6	3	6	3	30	2
7	2	7	3	31	7	3	7	3	3	31	1
8	--	8	3	32	1	8	3	8	3	32	1
9	3	9	3	33	2	9	3	9	3	33	1
10	3	10	1			10	3	10	1	34a	3
11	2	11	3			11	3	11	1	34b	3
12	--	12	3			12	3	12	1	35a	2
13	2	13	3			13	2	13	1	35b	3
14	2	14	3			14	3	14	1	35c	2
15	2	15	3			15	1	15	1	35d	3
16	2	16	3			16a	3	16	3	36	3
17	--	17	3			16b	3	17	3	37	2
18	3	18	3			16c	1	18	2		
19	3	19	1			16d	3	19	3		
20	1	20	1			16e	3	20	3		
21	2	21	1			16f	3	21	3		
22	--	22	1			17	1	22	3		
23	2	23	1			18	1	23	3		
		24	1			19	1	24	2		
						20	1	25	2		
						21	1	26	2		
						22	1				
						23	2				
						24	3				
						25	3				
						26	1				
						27	3				

*Meaning of weights:

1: not important

2: should do, but not critical immediately

3: critical, must do

a. Task number as given in the TSCs in Appendix B.

APPENDIX G

TEAM PERFORMANCE DATA

This appendix contains group performance data for

Turbine Loading (LOAD)

Steam Generator Tube Rupture (SGTR)

Loss of Feedwater (LOFW)

Main Steam Line Break (MSLB)

This Appendix contains the weighted team performance scores for the task performance measures (A-E) and the three pairs of functional measures, time-out-of-band (TOB) and RMS error for subcooling margin (measures F and G), pressurizer level (H and I), and steam generator level (J and K). These measures are explained in Section 4.

Table G-1 Team Performance: Turbine Loading (LOAD)

	MEASURES												
Crew	A	B	C	D	E	F	G	H	I	J	K	w/u	IRF
1	.950	.816	.611	.947	-.925							W	5
2	.950	.876	.698	1.000	-.462							W	6
3	1.000	.813	.722	1.000	-.722							W	6
4	.944	.850	.716	1.000	.230							W	4
5	.950	.858	.683	1.000	-.231							W	5
6	.868	.840	.701	.939	.676							W	6
7	.921	.841	.711	1.000	-.017							W	6
8	.900	.866	.623	1.000	-.399							W	5
9	.925	.869	.579	1.000	.414							W	4
10	1.000	.864	.683	1.000	-.168							W	--
11	1.000	.865	.706	.875	-.243							W	4
12	1.000	.769	.514	.800	-.338							W	trip
13	.850	.836	.680	1.000	.194							W	4
14												W	--
15	.947	.856	.720	1.000	1.032							W	6
16	.846	.732	.686	.727	.213							W	trip
17	.800	.830	.656	.906	.624							W	4
18	.950	.816	.631	.921	.092							W	7
19	.900	.933	.754	1.000	-.475							W	5
20	.821	.929	.719	1.000	.445							W	3
21	.944	.819	.653	.912	.582							W	3
22	.950	.824	.770	.947	-.010							W	5

A: % initiated
B: % elements
C: % P/L met
D: % success
E: $\bar{x}$ std. time
F: - not used -
G: - not used -
H: - not used -
I: - not used -
J: - not used -
K: - not used -
w/u: weighted?

Table G-2 Team Performance: Steam Generator Tube Rupture (SGTR)

Crew	MEASURES											w/u	IRF
	A	B	C	D	E	F	G	H	I	J	K		
3	.962	.956	.638	.961	.049	203	2.5	581	15.9	101	2.91	W	6
4	1.000	.874	.658	1.000	-.254	801	7.7	613	12.5	226	7.71	W	6
5	.988	.851	.597	.950	-.117	287	3.3	520	17.5	91	2.43	W	4
6	.938	.837	.755	.934	.322	172	2.1	611	12.7	157	4.78	W	6
7	.938	.856	.648	.816	.176	446	6.6	776	17.7	183	6.52	W	6
8	.963	.844	.617	.897	-.203	243	2.9	629	10.5	207	7.72	W	5
9	.975	.870	.755	1.000	-.258	211	2.9	831	14.8	334	4.32	W	6
10	.926	.820	.643	.967	-.078	265	4.5	566	17.0	108	3.56	W	7
11	1.000	.835	.648	.938	-.462	196	2.3	500	15.9	170	4.20	W	5
12	.962	.938	.730	.921	-.059	252	3.4	719	13.1	152	4.46	W	4
14	.945	.801	.438	1.000	.208	219	2.8	437	15.4	114	2.61	W	6
16	.963	.824	.[illegible]91	.962	.213	179	2.1	879	11.8	114	3.77	W	5
18	.913	.782	.622	.945	.219	693	13.7	982	17.0	176	5.57	W	4
19	.987	.848	.592	.949	.406	428	3.8	739	17.7	148	3.52	W	5
20	.88[illegible]	.821	.643	.969	.130	451	3.4	867	12.4	68	1.75	W	6
21	.96[illegible]	.857	.704	.934	-.079	216	2.9	667	9.5	247	6.97	W	5
22	1.000	.809	.699	.848	-.066	132	1.6	418	3.0	242	6.41	W	5

- A: # initiated
- B: # elements
- C: # P/L met
- D: # success
- E: $\bar{X}$ std. time
- F: time-out-of-band SCM
- G: RMS error, SCM
- H: time-out-of-band P-Lvl
- I: RMS error, P-Lvl
- J: time-out-of-band SG level
- K: RMS error SG level
- w/u: weighted?

Table G-3 Team Performance: Total Loss of Feedwater (LOFW)

Crew	MEASURES												
	A	B	C	D	E	F	G	H	I	J	K	w/u	IRF
1	.984	.704	.507	.918	-.237	0	0.0	1864	11.0	2210	10.1	W	4
2	.944	.801	.465	.836	.549	0	0.0	541	5.6	2485	22.2	W	5
3	1.000	.963	.709	.949	.079	0	0.0	600	13.3	1358	16.5	W	6
4	.938	.811	.457	.852	-.198	0	0.0	1035	16.1	1660	18.1	W	4
5	.930	.821	.625	.788	.007	1	1.3	669	12.0	2276	18.8	W	4
6	.765	.666	.547	.673	-.087	8	3.6	366	16.2	983	20.6	W	3
7	.955	.770	.471	.828	.235	0	0.0	0	0.0	1992	15.7	W	5
8	1.000	.831	.562	.817	-.117	0	0.0	619	4.1	2549	19.4	W	5
9	.942	.707	.317	.837	.034	0	0.0	44	0.5	2162	18.1	W	4
10	.971	.587	.395	.735	-.159	0	0.0	645	14.9	1161	11.0	W	4
11	.930	.869	.605	.848	-.081	0	0.0	728	5.3	2422	20.3	W	4
12	.951	.887	.761	.879	.443	159	16.3	78	1.1	2804	41.1	W	4
13	.926	.851	.528	.841	.307	0	0.0	346	3.3	2120	24.9	W	5
14	.944	.303	.560	.836	.246	0	0.0	1125	11.3	1981	27.4	W	6
15	.875	.683	.543	.755	-.178	0	0.0	463	5.3	2033	23.1	W	4
16	.957	.631	.409	.716	-.075	0	0.0	0	0.0	2226	12.1	W	3
17	.857	.868	.267	.854	-.582	1237	30.9	0	0.0	1702	23.3	W	4
18	.800	.632	.302	.643	-.259	0	0.0	147	6.9	1783	9.3	W	4
19	.941	.733	.628	.781	.182	0	0.0	622	13.0	1654	22.3	W	5
20	.938	.597	.411	.733	-.561	0	0.0	259	1.5	2233	21.2	W	5
21	.717	.667	.435	.711	.725	0	0.0	128	3.6	1828	23.4	W	1
22	.821	.598	.510	.691	-.561	553	27.8	506	16.4	663	12.1	W	3
	% initiated	% elements	% P/L met	% success	$\overline{X}$ std. time	time-out-of-band SCM	RMS error, SCM	time-out-of-band P-Lvl	RMS error, P-Lvl	time-out-of-band SG level	RMS error SG level	weighted?	

Table G-4 Team Performance: Main Steam Line Break (MSLB)

Crew	MEASURES												
	A	B	C	D	E	F	G	H	I	J	K	w/u	IRF
1	.798	.823	.506	.621	-.212	51	2.4	692	14.3	2006	8.6	W	4
2	.988	.826	.712	.855	.586	265	11.4	744	14.1	272	10.6	W	5
3	.965	.905	.750	.940	-.276	0	0.0	1329	7.19	423	10.6	W	5
4	.949	.773	.211	.986	-.298	445	18.7	952	15.8	689	10.5	W	5
5	.907	.786	.571	.782	.066	6	1.7	1706	15.7	746	10.1	W	5
6	.929	.815	.675	.937	.106	759	18.7	545	16.4	622	9.0	W	5
7	.833	.742	.739	.867	-.155	5	1.1	766	13.5	709	10.0	W	6
8	.906	.797	.478	.909	-.270	2078	35.3	599	17.0	720	9.9	W	5
9	.938	.815	.534	.947	-.392	51	2.4	540	15.4	695	10.3	W	6
10	.920	.813	.481	.914	.159	1871	36.0	640	18.4	662	10.4	W	2
11	.977	.823	.539	.860	-.023	30	0.9	585	16.5	575	9.6	W	5
12	.913	.647	.547	.890	.307	395	19.1	626	14.8	522	9.6	W	4
13	.753	.669	.590	.787	-.443	1203	36.1	474	18.3	681	10.3	W	3
14	.923	.650	.234	.944	.249	351	24.1	1315	15.4	561	9.5	W	4
15	.784	.697	.409	.845	-.102	306	14.4	370	17.9	662	10.4	W	4
16	.886	.725	.478	.935	.032	217	6.3	796	12.2	666	10.3	W	4
17	.733	.815	.632	.745	.448	1363	12.4	375	18.1	1856	8.4	W	4
18	.852	.741	.644	.826	-.009	0	0.0	541	14.9	579	9.2	W	6
19	.883	.805	.700	.882	.258	9	0.1	808	12.7	682	10.2	W	6
20	.886	.750	.588	.914	-.029	0	0.0	873	16.2	707	9.9	W	4
	% initiated	% elements	% P/L met	% success	$\bar{X}$ std. time	time-out-of-band SCM	RMS error, SCM	time-out-of-band P-Lvl	RMS error, P-Lvl	time-out-of-band SG level	RMS error SG level	weighted?	

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Report describes the second experiment using a training simulator to evaluate effects of experience level of Senior Reactor Operators (SRO) in the supervisor's role, and presence of a Shift Technical Advisor (STA) on performance of nuclear power plant control room operators/crews.

The experiment was conducted in pressurized water reactor (PWR) plant-referenced simulator. Data collected on 20 three-man crews of licensed operators, performing four sequences.

Performance measures were derived from task analyses of the sequences. One set of measures focused on task performance; the second set measured control of system parameters. Instructors' ratings and performance scores of trainees were compared to scores of operators/crews, to validate the performance measures.

System parameters and control manipulations were recorded by the simulator's computer. Communications and selected verifications were recorded on checklists and videotapes. Questionnaires recorded biographical information and self-reported workloads.

No significant differences in overall performance were found attributable to experience of supervisors, nor to presence of an STA. Results were similar to results of an earlier experiment performed with boiling water reactor (BWR) crews. These results are also reported. Reported workloads of supervisors assisted by STAs were significantly lower than workloads reported by those unassisted.

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