NDS-17
VOLUME I

PROJECT PLANS
PROGRAM A, PHASE I
LMFBR LARGE VALVE TECHNOLOGY DEVELOPMENT
TO THE
ATOMIC ENERGY COMMISSION
SAN FRANCISCO OPERATIONS OFFICE
MAY 1969

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CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
	Introduction	1
	Summary	2
I	Requirements and Design Criteria	9
II	Selection of Concepts	10
III	Preliminary Valve Designs	10
IV	Refinement of Valve Designs	11
V	Finalize Preliminary Valve Designs	14
VI	Engineering Analysis	14
VII	Valve Analysis	19
VIII	Materials Selection	19
IX	Inspection and Maintenance	20
X	Test Planning	21
XI	Engineering Guide	22
XII	Program Management	23
XIII	Analytical Computer Codes	28
XIV	Quality Assurance	30
XV	Reliability	31
	Appendix A	

FIGURES

<u>No.</u>	<u>Title</u>	<u>Page</u>
1	Overall Progress Chart	4
2	Logic Network Diagram	7
3	Task and Subtask Identification	24
4	Financial Status Report	25
5	Cumulative Cost Status Form	26

INTRODUCTION

This document is submitted in compliance with the requirements of Scope of Work (Paragraph 2.00, Project Plans), Appendix D to Contract AT(30-1)4026, Large Valve Technology Development, as revised by preliminary issue of March 28, 1969.

The project plans are contained in two volumes: Volume I, Project Plans (including an annotated logic diagram and narrative descriptive material); and Volume II, Manpower Cost Estimate. Each volume covers only Program A, Phase I, dealing with Exhibit "A" valves.

The project plan envisions Exhibit "A" valves as being prototypes of those required for large LMFBR plants. Their service life, operating environment, size range, and inherent reliability require a relatively long-duration development program. In addition to the development and verification of these valves, a significant product of this plan is a comprehensive and detailed engineering guide to facilitate the future design, manufacture, and application of valves by industry on a competitive basis. The Phase I effort is expected to contribute materially toward these two major objectives since it requires preliminary design of the valves and preparation of a preliminary version of the guide.

Program objectives will be achieved by combining the total technology base currently available within the valve industry with the advanced analytical tools developed within the aerospace industry (including the rigorous aerospace approach to reliability and quality assurance).

The resources of the Aerojet-General Corporation and the William Powell Company (in the form of consultant services during Phase I) will be combined in this undertaking.

SUMMARY

This program plan covers Program A, Phase I (preliminary design), of the LMFBR Large Valve Technology Development Program and is reported in two volumes: Volume I, Project Plans; Volume II, Manpower Cost Estimate.

The overall objective of Phase I is to perform the engineering design, analysis, and supporting work required to produce: (1) complete, preliminary designs of three concepts for each of four different valve types; and (2) a preliminary version of the engineering guide. The planned duration of Phase I is eight months. The design concepts that appear to be the most promising for development will be selected early in the program and actual design will start without delay. For convenience of control, the design work will be separated into preliminary, refinement, and final phases. Technical analysis and other support effort will be utilized by the valve designers as soon as required.

Monitoring of actual progress as compared with the planned work schedule will be accomplished by means of the overall progress chart for the complete Phase I Program. The chart will be as shown in Figure 1. Critical mileposts are also shown on the overall progress chart with the symbol "M" appearing immediately adjacent to an element completion symbol. The combination appears as "◊M".

In order to provide suitable identification of the various increments of planned work, the activities of the program are divided into tasks, subtasks, and elements. The overall progress chart divides the work by subtask, using the number series 01-100 through 05-400. The digits 01- through 05- represent the task category and use of the five digit combination identifies the representative subtasks. For example, subtask 02-200 refers to the work planned for the "Full-Range Flow Control Valve, Design."

To portray smaller increments of the work on the logic network diagram, elements are shown by the number series 1/2 through 91/92 (see Figure 2). The digits before and after the slash indicate the start and completion points of each element of work, respectively. For example, 33/34 represents the preparation of the final design of concept number 2 of the isolation valve design: i.e., the element of work between points 33 and 34 on the logic diagram. This numbering system is uniformly used throughout the program plan, being cross-referenced between the various associated documents. In addition, a cross-reference of the contents of this program plan listed by task element numbers is included as Appendix A.

Figure 1 - Overall Progress Chart (Sheet 1 of 2)

Figure 1 - Overall Progress Chart (Sheet 2 of 2)

PROGRAM A
PHASE I: PRELIMINARY DESIGN

The objective of the preliminary design phase is to delineate the design criteria for the four types of valves. This will be accomplished by iterative steps to establish where the state-of-the-art is adequate and where it must be extended to provide the technology necessary for the proper design, manufacture, and use of valves for liquid sodium service. These steps include requirements analyses, establishment of design criteria, preliminary designs, and engineering cost, weight, and value analyses. The steps are described in the following paragraphs and appear on the overall progress chart (Figure 1). A minimum of three design concepts for each of the functional types will be provided and will cover the complete range of design requirements given in the Scope of Work. All information and data gained from this effort will be used to prepare the preliminary engineering guide.

I. REQUIREMENTS AND DESIGN CRITERIA

01-100*	Element 1/2*	Isolation Valve
02-100	Element 3/4	Full Range Flow Control Valve
03-100	Element 5/6	Check Valve
05-100	Element 7/8	Low Range Flow Control Valve

The objective is to establish: (1) the performance, environmental, and storage requirements which each valve concept must meet; and (2) those design criteria (e.g., materials, producibility, and service) which produce guidelines for design. Most of this information is obtained from existing literature and will be organized in one document which will be useful to designers, supporting technical personnel, and supervision. A general specification for each valve type will be formulated.

*The numerical notations are used to tie the logic diagram, progress chart, task descriptions, and costs together. As an example, 01 means the isolation valve task, -100 is the subtask "Requirements and Design Criteria", and 1/2 is the start and completion block of this element of work as shown on the logic diagram.

II. SELECTION OF CONCEPTS

01-150	Element 9/10	Isolation Valve
02-150	Element 11/12	Full Range Flow Control Valve
03-150	Element 13/14	Check Valve
05-150	Element 15/16	Low Range Flow Control Valve

The objective is to select (for each valve type) the three concepts considered best for the preliminary design. The best concepts will be chosen after a matrix study of requirements and design criteria as compared with those concepts available within the state-of-the-art or which will require a "minimum-risk" development effort. This study will be made from existing literature, tempered by engineering experience in applicable fields. Because the concept selection must be made before the designers can proceed beyond the fundamentals, it is planned that this task will be completed by the end of the third week of the program. A document will be prepared summarizing this effort, outlining the basis for selection of specific concepts, and discussing the reasons for rejecting others.

III. PRELIMINARY VALVE DESIGN

01-200	Element 17/18	Isolation Valve
02-200	Element 19/20	Full Range Flow Control Valve
03-200	Element 21/22	Check Valve
05-200	Element 23/24	Low Range Flow Control Valve

The objective is to develop layout drawings for each functional-type valve required by the program. These drawings will portray at least three different design concepts (all to scale) for each functional-type valve and will reflect all known critical parameters, including functional dimensions, clearances and materials.

Advantage will be taken of proven technology and of additional data developed by concurrent engineering-analysis efforts. The number of body-size groups required to cover the entire size range will be minimized. Maximum interchangeability of parts will be utilized. New and unproven valve element designs will be identified. The necessary feasibility test plan will be prepared as described in Section X.

Valve design work will continue from the beginning of preliminary design through completion of the finalized design. However, at the scheduled completion of the preliminary design tasks, sufficient progress will have been made to permit preparation of preliminary layout drawings which will be furnished to support any analytical groups.

The objective is to refine and expand the valve designs to include new information as it is developed. This includes the iterations required as a result of information provided by the supporting technical groups (particularly engineering analysis and materials investigations) and by the Commission and suppliers.

IV. REFINEMENT OF VALVE DESIGN

01-200	Task 25/26	Isolation Valve
02-200	Task 27/28	Full Range Flow Control Valve
03-200	Task 29/30	Check Valve
05-200	Task 31/32	Low Range Flow Control Valve

Following completion of the preliminary design tasks, the design effort will continue on all concepts to refine and expand the earlier work. This will include the iterations required as information is acquired from the supporting technical groups (particularly engineering analysis and materials investigations) and from the Commission and suppliers.

Also included in the valve refinement phase will be the more detailed consideration and definition of the following associated items: (1) valve operators; (2) preheater requirements; (3) mounting and interfaces; and (4) instrumentation.

At the conclusion of the design refinement task, layout drawings of all concepts will be made available to the supporting groups. These associated design activities are:

A. VALVE OPERATORS

The objective is to determine the specifications for the valve operator best suited to operate each concept of each of the three valve types (the check valve is excluded). The valve operator may be electrical, pneumatic, hydraulic, or manual. The interface with the valve will require engineering design and analysis since the operators alter stresses by adding restraint, additional body loads, and alteration of thermal gradients. The effort will also include a definition of valve operating forces, response time, power required, actuator weight, and envelope as it applies to each valve concept.

B. VALVE PREHEATER REQUIREMENTS

The objective is to analyse the requirements and available methods of providing preheater capabilities for the sodium valves. The liquid sodium system must be filled and drained with sodium at a temperature of more than 208°F to prevent freezing of the metal. Thus, the valves in the sodium line will require some method of preheating to prevent freezing of the sodium during the fill and drain operations, or possibly during a short-term nonoperational period with a full system. Preliminary design activities will include a study of optimum methods of accomplishing this function as it applies to each valve concept.

C. VALVE MOUNT AND INTERFACE

The objective is to establish the physical and functional valve interfaces. An important part of this work is to determine external loads and to establish limits. The loads result from expansion of the piping, valve supports, and weight of the valve. It will be necessary to factor these loads into the basic valve design or to provide an auxiliary load-takeout structure. The latter approach will prove advantageous if jacketed-type valve construction is found to be feasible. Thus, the outer shell could be designed to absorb both axial loads and a portion of the support load.

D. INSTRUMENTATION

The objective is to determine instrumentation requirements, instrumentation that is available, and to assure that the valve concepts provide for instrumentation. This will be accomplished by reviewing available literature, valve concepts, and the preliminary test plans, as well as by obtaining information from the testing agency. Instrumentation recommendations will be made for the element feasibility, acceptance, and proof test plans, and for in-service plant operation.

V. FINALIZE PRELIMINARY VALVE DESIGNS

- 01-200 Element 33/34 Isolation Valve
- 02-200 Element 35/36 Full Range Flow Control Valve
- 03-200 Element 37/38 Check Valve
- 05-200 Element 39/40 Low Range Flow Control Valve

The objective is to incorporate into the designs the information furnished by the supporting technical groups, and to update the layout drawings of all concepts. This phase of the design is a continuation of the previous preliminary and refinement design phases. At task completion, three layout drawings of each valve type will be available for distribution and valve analysis.

VI. ENGINEERING ANALYSIS

- 01-300 Element 41/42 Isolation Valve
- 02-300 Element 43/44 Full Range Flow Control Valve
- 03-300 Element 45/46 Check Valve
- 05-300 Element 47/48 Low Range Flow Control Valve

The objective is to perform the technical analyses believed necessary to effectively support the preliminary design task in Phase I. The information will also influence the valve element feasibility tests that will be required. This effort will result in valve operational and component definition, as well as compilation of engineering data for an optimum value analysis study. The Phase I analytical effort will involve the following disciplines.

A. STRUCTURAL ANALYSIS

Stress analysis will be conducted to determine objective stresses resulting from temperature gradients as well as from mechanical loads. An iterative relationship exists between heat-transfer analysis (which includes radiation-induced heating) and stress analysis because wall thickness affects the temperature gradient as well as the resultant mechanical and thermal stresses.

A layout or conceptual design, utilizing preliminary wall thicknesses, will be made for heat-transfer and stress analysis. The results of this "first-run" analysis will be used to modify the conceptual design with the process repeated until final drawings have been established which satisfy all criteria.

To most efficiently achieve the Phase I requirement of preliminary analysis, preliminary stress calculations will be performed using standard, currently available techniques. Mathematical modeling of portions of a particular valve concept will be accomplished and evaluated to assist in the determination of design adequacy.

B. FLUID DYNAMICS

This effort will determine hydraulic resistance and cavitation characteristics for the various candidate valve designs. The primary effort will be devoted to the flow control valves to determine flow-rate versus valve-position. The low range flow control valve will produce the most severe conditions with respect to cavitation and thus will require additional detailed analysis.

Analysis of the various configurations will be accomplished using available empirical relations (References 1 and 2) combined with more detailed potential flow⁽³⁾ and boundary-layer⁽⁴⁾ equations. The method of approach will depend on the type of valve to be analyzed. For example, in the globe-type valve the contraction coefficient at the vena contracta (important for cavitation calculations) could be determined from potential flow equations. The

Ref. 1. Crane Technical Paper No. 410, Engineering Division of Crane Company, Chicago, 1957.

2. Fluid Flow/Density Calculator Handbook, Calmec Manufacturing Corporation.

3. "Theoretical Hydrodynamics," by L. M. Milne-Thomson, The MacMillan Co., New York.

4. "Boundary Layer Theory," by H. Schlichting, McGraw-Hill Book Company, Inc.

flow in the separated region downstream of the seat could be characterized using appropriate boundary-layer equations. For simpler designs, (e.g., gate valve or butterfly valve), it may be practical to characterize the entire flow field using two-dimensional potential flow equations as cited in References 5 and 6.

To improve both the accuracy of the Phase I analysis and confidence in the recommended Phases II and III fluid-dynamics programs, it will also be desirable to conduct parallel water subscale tests. This program is discussed in Section XIII,B, Element 91/92.

C. STRUCTURAL DYNAMICS

The structural system of the proposed valve concepts will be evaluated for mathematical representation as a lumped parameter, mass-spring-damper system. Depending upon the type of solution required, equations of motion can be written and solved in one of the following forms:

1. Sectional Coordinates

These will be used if the physical deflections are the dependent variables. The equations are strongly cross-coupled in the mass and stiffness expressions. This format is especially useful where large numbers of parameter changes are to be evaluated.

Ref. 5. "The Hydrodynamics of Flow Regulation," by Fredric F. Ehrich, Ph.D. Thesis, Massachusetts Institute of Technology, 1951.

6. "Torque and Cavitation Characteristics of Butterfly Valves," by Turgut Sarpkaya, Journal of Applied Mechanics, December 1961.

2. Normal Coordinates

The normal modes of vibration are computed, yielding frequencies, and mode shapes. Each vibration mode then constitutes the basis for a normal coordinate with its generalized mass and spring constant. The equations of motion are uncoupled.

The equations of motion may be used in conjunction with applied forces and vibration inputs to compute dynamic loads (internal stresses) resulting from the operating environment. The response to sinusoidal or random vibration is best computed by using the equations in their normal coordinate form: each normal mode may be treated as a "narrow band oscillator" and the various contributions summed to arrive at total or rms dynamic loads.

3. Thermal Analyses

Thermal analyses will provide: (1) detailed temperature profiles within the material of the structure; (2) maximum temperature to determine material strength; (3) temperature gradients; and (4) maximum temperature differences to establish thermal stresses and strains. The analyses will also include, in terms of fluid flow and temperatures, the normal steady-state and transient operating conditions.

4. Nuclear Analysis

The effects of nuclear-environment will be included as a boundary condition imposed on thermal and materials analyses. A gamma radiation level of 10^6 R/hr will result in internal heat generation in all irradiated components and a change in their physical properties. In particular, large and rapid changes in reactor power levels can result in a concurrent variation of internal heat generation rates in the irradiated structures and the sodium coolant. This, in turn, causes rapid material and thermal stress changes in the component.

5. Weight Analysis

The weights of the various concepts will be calculated from the preliminary valve designs of the valves. The estimated weight will be one of the parameters considered in the valve analysis of each valve type and in cost analysis studies.

6. Cost Analysis

A preliminary cost analysis for each valve concept designed in Phase I will be made. This information will be of assistance in program budgeting and will also be a parameter considered in the valve analysis study. It is intended that the cost analysis will be upgraded on a continuous basis as designs of the various valves are refined during Phase II.

VII. VALUE ANALYSIS

01-400	Element	49/50	Isolation Valve
02-400	Element	51/52	Full Range Flow Control Valve
03-400	Element	53/54	Check Valve
05-400	Element	55/56	Low Range Flow Control Valve

The objective is to determine the test design of the three concepts developed for each of the four valve types. The design value analysis, or trade-off studies, of the various valve concepts will be conducted during the sixth, seventh, and eighth months of the Phase I. During the course of this analysis, all parameters and considerations which influence the respective designs will be evaluated and compared. From these data a final conclusion will be reached that certain individual valve designs will best be capable of performing its required mission with maximum efficiency and reliability and at minimum procurement and maintenance costs. A recommendation will be made to continue development of the best design of each type of valve for each of the two external environments.

VIII. MATERIALS SELECTION

04-100	Element	57/58	Preliminary Material Selection Schedules
04-100	Element	59/60	Finalize Material Selection Schedules

The objective is to provide current materials recommendations and materials properties data for the valve concepts throughout the program.

Materials data in the existing pressure-vessel and piping codes will serve as a basic reference, but the allowables accepted in these codes are intended for either ambient or relatively moderate service temperatures, with stresses given in percentages of the yield or ultimate stress.

With the introduction of 30-year life at high-temperature requirements, creep behavior becomes significant. It is therefore necessary to establish allowable stresses that will prohibit undue dimensional change or rupture during service life and assure functioning of internal valve parts.

Materials properties data for valve seat and bearing materials will be obtained from the LMFBF program and from a review of applicable literature from the Commission. Where information is unavailable, recommendations will be made in the valve element feasibility test plan of Phase I

Materials properties data can also be drawn from the Materials Properties Data Book*, which was prepared by Aerojet-General as a design guide for materials usage within the NERVA program. These data were selected by a critical review of the content of nearly 500 sources and tabulated in two reference volumes which now serve as a standard reference for materials properties.

IX. INSPECTION AND MAINTENANCE

04-200 Element 61/62 Preliminary

04-200 Element 63/64 Finalize Study and Plan

The objective is to determine the inspection requirements of the valve development program and to determine maintenance feasibility. Inspection requirements include procedures and parameters which will be used during the fabrication and development-test phases of the program and the inspection procedures applicable to the valves while they are in operation.

Maintainability studies are considered part of the failure mode and effects analysis. Valve maintainability will be insured by:

* Report 2275, Materials Properties Data Book, Nuclear Rocket Operations, Aerojet-General Corporation, 15 September 1967, Contract SNP-1.

1. Selection design approaches conducive to good maintainability.
2. Elimination of potential sources of human-induced failures.
3. Parallel or supportive studies of maintenance action requirements.
4. Application of fault-detection techniques.
5. Evaluation of assembly, installation, and repair processes as they involve to accessibility, ease of assembly and disassembly, and system consideration (e.g., remote-control constraints).

The Phase I effort, in support of the preliminary designs and the Engineering Guide, will focus mainly on configuration analysis with regard to concepts conducive to good maintainability. This survey will begin when the various concepts are selected.

X. TEST PLANNING

04-300 Element 65/66 Valve Element Feasibility Test Plan
04-300 Element 67/68 Proof Tests

A. VALVE ELEMENT FEASIBILITY TEST PLAN

The objective is to identify valve elements that are beyond the present scope of technology and to provide a plan to prove the concepts and design elements. Support will be received from the various engineering analysis efforts. The test plan will be implemented immediately upon the start of Phase II to provide information required during the detail valve design.

B. PROOF TESTS

The objective is to provide verification of the hydraulic and mechanical characteristics of each valve. Testing will be performed at suppliers' plants. Test procedures required when the valve is installed in the LMFBR liquid-sodium test loop will be established. This information will be utilized during the value analysis effort and for future planning.

XI. ENGINEERING GUIDE

04-400 Element 69/70 Prepare Preliminary Outline
04-400 Element 71/72 Finalize Outline
04-400 Element 73/74 Preliminary Version of the Guide

The objective is to prepare a preliminary engineering guide with the expectation that expansion and improvement will be accomplished as information becomes available. The purpose of the guide is to provide the technology to design, specify and fabricate valves for service in 1200°F liquid sodium. A preliminary outline and a plan for documenting the basis and rationale for use of incoming data will be submitted to the Commission for approval. This outline will be available approximately two months after the start of the program. The outline will be revised following review by the Commission.

The guide will be designed to accommodate new material, allow refinement of existing information, and provide for the removal of data found to be no longer pertinent. There will be a balance between adequacy and conciseness. Much of the information appearing in the guide will provide data concerning liquid metal valves and control systems in the same manner as standard engineering handbooks provide data concerning present-day conventional valves.

At the end of Phase I, a preliminary version of the guide will be made available as part of the final Phase I documentation.

XII. PROGRAM MANAGEMENT

04-500 Element 75/76 Program Management

The objective is to manage the program effectively and efficiently. The task will include project supervision and engineering, implementation of planned fiscal controls, and adherence to schedules. Some examples of the management techniques that will be used are:

A. LOGIC NETWORK

A logic network will be supplied which will display the program in conventional form, defining critical path schedule requirements as shown in Figure 2. The network will be revised as required and supplied to the Commission with regular reports.

B. COST SCHEDULE

The cost schedule will show incremental and cumulative costs by cost accounting task numbers as shown in Figure 3. Information reported will include: (1) actual incremental and cumulative costs and budget; (2) estimated cost to complete; and (3) variances between actual and budgeted costs. The cost control form to be used will be similar to that shown in Figure 4. The cumulative status of program expenditures will be maintained on "percentage - versus - time" charts similar to that shown in Figure 5.

C. PROGRESS REPORTS

After approval of the basic schedule, informal monthly progress reports will be supplied to: (1) describe progress, (2) relate significant problems that could have an adverse effect on the program; and (3) report work planned for the next month. Semiannual progress reports also will be provided. Topical reports will be prepared as directed by the Commission.

Task Number	Task Description	Work Scope Paragraph #	End Item
01-	Isolation Valve		
01-100	Isolation Valve, Reqs. & Design Criteria		
01-150	Isolation Valve Sel. of Concepts	3.30.1	3 Design Concepts Report
01-200	Isolation Valve, Valve Design	3.10, 3.20, 3.30.1, .2, .4 & .5	Conceptual Layout Drawings
01-300	Isolation Valve, Analysis	3.30.6	Analysis Report
01-400	Isolation Valve, Value Analysis	3.30.10 & .11	Tradeoff Study
02-	Full Range Flow Control Valve		
02-100	Full Range Flow Control Valve, Reqs & Design Criteria	-----Same as 01-100 above-----	
02-150	Full Range Flow Control Valve, Sel. of Concepts	Same as 01-150 above	
02-200	Full Range Flow Control Valve, Valve Design	Same as 01-200 above	
02-300	Full Range Flow Control Valve, Analysis	Same as 01-300 above	
02-400	Full Range Flow Control Valve, Value Analysis	Same as 01-400 above	
03-	Check Valve		
03-100	Check Valve Reqs. & Design Criteria	-----Same as 01-100 above-----	
03-150	Check Valve Sel. of Concepts	Same as 01-150 above	
03-200	Check Valve, Valve Design	Same as 01-200 above	
03-300	Check Valve, Analysis	Same as 01-300 above	
03-400	Check Valve, Value Analysis	Same as 01-400 above	
04-	General		
04-100	Materials Selection Schedules	3.30.3	Material Selection Report
04-200	Inspection and Maintenance	3.30.7	Insp. & Maint. Procedure
04-300	Test Planning		Test Plans
04-400	Engineering Guide	3.30.12	Engr. Guide & Outline
04-500	Program Management	3.40.1	Progress Reports
04-600	Selection & Verification of Computer Codes	3.30.6	Computer Codes Plan
04-700	Quality Assurance	3.40.2	Quality Assurance Plan
04-800	Reliability	3.40.3	Reliability Plan
05-	Low Range Flow Control Valve		
05-100	Low Range Flow Control Valve, Reqs. & Design Criteria	-----Same as 01-100 above-----	
05-150	Low Range Flow Control Valve, Selection of Concepts	Same as 01-150 above	
05-200	Low Range Flow Control Valve, Valve Design	Same as 01-200 above	
05-300	Low Range Flow Control Valve, Analysis	Same as 01-300 above	
05-400	Low Range Flow Control Valve, Value Analysis	Same as 01-400 above	

Figure 3 - Task and Subtask Identification

SAMPLE

LMFBR VALVE TECHNOLOGY
FINANCIAL STATUS REPORT

TASK	CONTRACT TOT		ACTUALS				CUMULATIVE BUDGET		ESTIMATE TO COMPLETE		ACTUALS + EST. TO COMPL.		VARIANCE		ACTUAL % COMPL.	FORECAST % COMPLETE
			THIS PERIOD		CUM. TO DATE											
	HRS	\$	HRS	\$	HRS	\$	HRS	\$	HRS	\$	HRS	\$	HRS	\$		
01 - Isolation Valve	5,100	97,000	100	1,000	5,100	98,000	5,100	97,000	-0-	-0-	5,100	98,000	-0-	(1,000)	100.0	100.0
02 - Flow Control Valve	5,100	97,000	500	10,000	4,300	83,000	4,300	82,000	900	17,000	5,200	100,000	(100)	(3,000)	83.0	84.5
03 - Check Valve	5,100	97,000	500	10,000	3,500	67,000	3,500	67,000	1,500	29,000	5,000	96,000	100	1,000	69.7	69.0
04 - General	13,600	247,000	1,000	25,000	5,100	125,000	5,100	126,000	8,500	120,000	13,600	245,000	-0-	2,000	51.0	51.0
05 - Flow Control Valve, Low Range	5,100	97,000	100	1,000	100	1,000	-0-	-0-	5,100	99,000	5,200	100,000	(100)	(3,000)	0.1	0.0
Program Summary	34,000	635,000	2,200	47,000	18,100	374,000	18,000	372,000	16,000	265,000	34,100	639,000	(100)	(4,000)	58.5	58.6

SAMPLE

Figure 4 - Financial Status Report

Figure 5 - Cumulative Cost Status Form

D. PROGRESS CHART

Technical progress will be monitored by a bar chart depicting overall performance by task. This chart will reflect week-by-week progress and show major deviations from planned schedules. The chart to be used is shown in Figure 1. Critical mileposts are also shown on the overall progress chart with the symbol "M" appearing immediately adjacent to an element completion symbol. The combination appears as " $\diamond$ M".

XIII. ANALYTICAL COMPUTER CODES

04-600 Element 77/78 Selection of Analytical Methods and Plans for
Use of Computer Codes

04-600 Element 91/92 Modification, Expansion, and Verification of
Computer Codes

A. SELECTION OF ANALYTICAL METHODS AND PLANS FOR USE OF COMPUTER CODES

The objective is to select and refine those analytical methods and computer codes which will offer the greatest utility to the program. Prior to initiation of the engineering analysis effort the analytical methods and the plans for utilization of computer codes will be compiled. Each engineering discipline will select the most applicable computer codes and will verify their applicability by sample calculations and actual use.

B. MODIFICATION, EXPANSION, AND VERIFICATION OF COMPUTER CODES

The objective is to identify analytical areas which can be modified or expanded to benefit the program. Application of detailed computer analysis to the design of LMFBR valve applications will expose areas that could not be completely defined prior to initiation analysis. These include computer program modifications and expansions to meet accuracy requirements and design schedules, to achieve compatibility with the other computer programs, and to develop greater analytical capability. In this section it is intended to identify these areas, on an individual basis, as they become apparent, so that a judgment based on program needs and available funding can be made. The following areas should be considered for increased effort.

1. Fluid Dynamics Test Program

The development of very large flow control valves for an LMFBR facility will require a more detailed analytical effort than has been applied

to facility valves in the past. It appears highly desirable that ultimately the capability to predict flow characteristics, the pressure profile across the fluid stream, and the cavitation tendency, as well as the accuracy of these predictions, be known while an LMFBR plant is in the preliminary design stage. This should include the ability to predict the effects of geometry changes of the LMFBR installation and internal valve parts.

A first step toward this ultimate objective is the formulation of the analytical program of paragraph VI,B. The second step described below, is model flow testing which will provide an improvement in selecting the best concept. This effort should also provide an improved insight into what would be required to achieve the ultimate long-range objective of accurate predictions during preliminary design.

The purpose of the hydraulic test program would be to verify and/or refine the assumptions of the fluid flow models of the various candidate valve concepts. The test hardware would consist of "off-the-shelf" valves or components or simple flow simulators with appropriate instrumentation. The tests would be conducted in the Aerojet Hydro-Lab. Details of the test program would be formulated early in Phase I with the actual testing conducted late in Phase I.

2. Structure Analysis Capability

A preliminary valve concept will be selected, an analysis plan formulated, and sample calculations performed to verify the analytical capability.

The most difficult valve concept to analyze (i.e., 30-in. globe type valve) will be selected and a three-dimensional finite element method of analyses applied. The capability to analyze valves will be satisfactorily demonstrated. Present techniques may, however, be time consuming relative to program schedule and it may be that the computer program could be modified and expanded in order to achieve economies in Phase II schedules and manpower estimates.

XIV. QUALITY ASSURANCE

04-700 Element 79/80 Preliminary Quality Assurance Plan

04-700 Element 81/82 Finalize Quality Assurance Plan

04-700 Element 83/84 Review Preliminary Valve Designs

The objective is to formulate a plan which will define those practices and procedures considered essential to assuring that quality products will be produced, capable of performing as expected. The following elements will be included:

1. Participate in the preparation of data items that require quality assurance review or input.
2. Provide support to project engineering in the preparation of design criteria specifications by recommending: (1) process control specifications, standards and provisions; (2) workmanship standards and personnel qualification requirements; and (3) special process and nondestructive testing qualification requirements.
3. Assist in the preparation of quality assurance provisions.
4. Provide support to project engineering by reviewing drawings and providing information relative to measurability and quality, standards, and control capability.
5. Prepare a quality program plan that will provide for the controls that will assure the implementation of the quality assurance requirements set forth in the Scope of Work.

XV. RELIABILITY

04-800 Element 85/86 Preliminary Reliability Plan

04-800 Element 87/88 Finalize Reliability Plan

04-800 Element 89/90 Review Preliminary Valve Designs

The objective is to formulate a reliability plan and to develop a failure mode and effects analysis (FMEA). In conjunction with the FMEA, reliability personnel will perform a review of the preliminary designs. Included in this review will be:

1. Coordination of the FMEA among the project and design engineers and stress, materials, thermal and radiation specialists as appropriate.
2. Initiation of a reliability design review check list and provision of design recommendations.
3. Assurance that quality control provisions have been considered.
4. Issuance of the results of preliminary reliability predictions, based on the results of the completed FMEA, and of a summary of applicable failure data and performance history.

Phase I reliability activities will also include the preparation of a reliability program plan for Phases I, II, and III. The plan, to be submitted within two months, will be constituted accordingly to the following outline:

1. Organization
2. Design review (to include trade-off studies).
3. FMEA (to include identification of all critical items and compilation and statistical analysis of historical data, failure history, and failure ratings).

4. Reliability assessment (to be coordinated with the Commission to assist in establishing a system reliability goal as well as a valve reliability goal).
5. Safety analysis (to include input for a system fault tree analysis).
6. Testing and reliability evaluation (to include reliability aspects of developmental and design verification testing).
7. Failure analysis and corrective action.
8. Maintainability and elimination of human-induced failures.
9. Fabrication (i.e., procurement review).

The reliability plan will be finalized during the fifth and sixth months of the program following Commission approval of the preliminary version.

Appendix A

SUPPLEMENTARY LISTING

(By Task Element Numbers)

Sheet 1 of 2

<u>Task Element</u>	<u>Sub-Task</u>	<u>Title</u>	<u>Page</u>
1/2	(01-100)	Requirements and Design Criteria, Isolation Valve	9
3/4	(02-100)	Requirements and Design Criteria, Full Range Flow Control Valve	9
5/6	(03-100)	Requirements and Design Criteria, Check Valve	9
7/8	(05-100)	Requirements and Design Criteria, Low Range Flow Control Valve	9
9/10	(01-150)	Selection of Concepts, Isolation Valve	10
11/12	(02-150)	Selection of Concepts, Full Range Flow Control Valve	10
13/14	(03-150)	Selection of Concepts, Check Valve	10
15/16	(05-150)	Selection of Concepts, Low Range Flow Control Valve	10
17/18	(01-200)	Preliminary Design, Isolation Valve	10
19/20	(02-200)	Preliminary Design, Full Range Flow Control Valve	10
21/22	(03-200)	Preliminary Design, Check Valve	10
23/24	(05-200)	Preliminary Design, Low Range Flow Control Valve	10
25/26	(01-200)	Refinement of Design, Isolation Valve	11
27/28	(02-200)	Refinement of Design, Full Range Flow Control Valve	11
29/30	(03-200)	Refinement of Design, Check Valve	11
31/32	(05-200)	Refinement of Design, Low Range Flow Control Valve	11
33/34	(01-200)	Finalize Preliminary Designs, Isolation Valve	14
35/36	(02-200)	Finalize Preliminary Designs, Full Range Flow Control Valve	14
37/38	(03-200)	Finalize Preliminary Designs, Check Valve	14
39/40	(05-200)	Finalize Preliminary Designs, Low Range Flow Control Valve	14
41/42	(01-300)	Engineering Analysis, Isolation Valve	14
43/44	(02-300)	Engineering Analysis, Full Range Control Valve	14
45/46	(03-300)	Engineering Analysis, Check Valve	14

Appendix A

SUPPLEMENTARY LISTING (CONT.)

<u>Task Element</u>	<u>Sub-Task</u>	<u>Title</u>	<u>Page</u>
47/48	(05-300)	Engineering Analysis, Low Range Flow Control Valve	14
49/50	(01-400)	Value Analysis, Isolation Valve	19
51/52	(02-400)	Value Analysis, Full Range Flow Control Valve	19
53/54	(03-400)	Value Analysis, Check Valve	19
55/56	(05-400)	Value Analysis, Low Range Flow Control Valve	19
57/58	(04-100)	Preliminary Materials Selection Schedules	19
59/60	(04-100)	Finalize Materials Selection Schedules	19
61/62	(04-200)	Preliminary Study, Inspection and Maintenance	20
63/64	(04-200)	Finalize Study and Plan, Inspection and Maintenance	20
65/66	(04-300)	Valve Element Feasibility Test Plan	21
67/68	(04-300)	Proof Test Plan	21
69/70	(04-400)	Preliminary Outline, Engineering Guide	22
71/72	(04-400)	Finalize Outline, Engineering Guide	22
73/74	(04-400)	Preliminary Version of the Engineering Guide	22
75/76	(04-500)	Program Management	23
77/78	(04-600)	Selection of Analytical Methods and Plans for Use of Computer Codes	28
79/80	(04-700)	Preliminary Quality Assurance Plan	30
81/82	(04-700)	Finalize Quality Assurance Plan	30
83/84	(04-700)	Quality Assurance Review of Preliminary Valve Designs	30
85/86	(04-800)	Preliminary Reliability Plan	31
87/88	(04-800)	Finalize Reliability Plan	31
89/90	(04-800)	Reliability Review of Preliminary Valve Designs	31
91/92	(04-600)	Modification, Expansion and Verification of Computer Codes	28