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A. Clawson

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MASTER

REON

ROCKET ENGINE OPERATIONS — NUCLEAR

Informal Monthly Progress Letter No. 25 237 pp

to

AEC-NASA SPACE NUCLEAR PROPULSION OFFICE
for
NERVA PROGRAM

Contract SNP-1
(U)

Letter Report No.-L0560-10-25

Covering Period of July 1963

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I. INTRODUCTION

This document is the twenty-fifth in a series of informal monthly letters reporting progress of the NERVA engine development program and its associated tasks, and is submitted in partial fulfillment of AEC-NASA Contract SNP-1. This document covers the month of July 1963, and is the tenth monthly report to be submitted during NERVA Contract Year 1963 (1 October 1962 through 30 September 1963).

Work performed in each reporting period is discussed by task item number as defined in the contract. In order to restrict the amount of material presented to a convenient quantity, the intent is to include in each monthly report only that discussion which is required to provide the reader with a concise summary of the work performed. In general, detailed technical information, lengthy theoretical derivations, and extensive data tabulations have been purposely omitted. These details will be provided as appropriate in special technical reports.

This document is the result of combined input data from REON; Westinghouse Astronuclear Laboratory; Bendix Products Aerospace Division; AMF Atomics, a Division of American Machine and Foundry Co.; and Liquid Rocket and Downey Plants of Aerojet-General Corporation.

II. SUMMARY

During the report period, extensive efforts by all Program Participants were directed towards preparation of the Program Plan for CY 64.

A preliminary draft of Revision D of the EX Model Specification (S-RD) was submitted to SNPO-C on 12 July. This major revision and updating of the Engine Specification will be issued in final form after review by SNPO-C.

A new thrust bearing design was evaluated at 16,000 rpm in the turbine tester, performing satisfactorily with an Armalon thin line cage for 9 2 minutes at a thrust lead of 2000 lb

Preliminary results of the three hydrostatic test phases on the titanium pressure vessel indicate that all objectives were achieved.

A round-trip shipping demonstration test of a dummy reactor was successfully conducted between the Astronuclear Laboratories at Large, Pa., and the MAD Building at NRDS.

Orificing and clustering for Phase I vibration reactor has been completed, and all clusters have been assembled into the core.

All unloaded core elements for the NRX-A1 core, including elements modified for instrumentation, were received from UCNC, and 80% of the loaded elements for NRX-A2 core are now in process.

Two failures of the dynamic shaft seal used on the TPCV actuator occurred during room-temperature acceptance testing. Alternate seal configurations are being manufactured and tested to prevent future failures

The NRX-A1 Operational Support Plan was issued.

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SECTION III

TECHNICAL DISCUSSION

TASK 1.0 ENGINE DEVELOPMENT

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Item 1.1 ENGINE SYSTEM

A. SUB-SUBTASK 1.1.0 - SYSTEMS

1. E-Block I - Engine Design

Revisions were completed of REON drawings 089507 and 088255, Block I Engine Assembly and Installation, respectively. These revisions include relocation of the pump discharge line and the turbine inlet line, and addition of a diluent extraction line from top of pressure vessel outlet to turbine inlet and the General Electric drum control actuators. Drawing modifications are being made to reflect the latest E Engine design for release by September 14 (Milepost 10). This is a continuation of the effort previously reported.

Revision "F" of the planning parts list for the Hot-Bleed NERVA Engine was issued during this month. The compilation of data for Revision "G" was initiated.

Design effort continued on an interface control drawing establishing the remote disassembly and assembly sequence for the E-Block Engine.

REON drawings 086864 and 086865, Hot-Bleed Installation and Assembly, respectively, for the FX engine were completed in accordance with program commitments, to revise the FX Engine Model Specification, AGC-10095.

A layout drawing was completed of the control-drum actuator interfaces between the LRP pressure vessel and the GE actuator mounting flanges, showing a candidate manifolding system with the amplifiers mounted integral with the actuators. This drawing is being used as an interface control document.

2. Interface Gages

The NRX-A2 tool design revisions of the shield-to-reflector match plate and the pressure vessel closure-to-cylinder match plate, as well as the master gages for pressure-vessel cylinder and closure, were completed. Fabrication of other match plates and master gages are continuing on schedule.

3. Specifications and Documentation

A preliminary outline of the Block I Design Specification is being studied by REON.

Revision D of the FX-Engine Model Specification was forwarded to SNPO-C on 12 July 1965 as a preliminary issue. After review by the customer and other authorized recipients, a final draft will then be submitted.

Effort was continued on the forthcoming revision to the Engine System Data Book.

B. SUB-SUBTASK 1.1.2 - COLD FLOW DEVELOPMENT TEST SYSTEM (CFDTS)

1. Design

The turbine inlet line configuration was reviewed and defined for final design.

The study of the assembly, handling, and transportation of the CFDTS is continuing.

The completed conceptual design of the propellant supply from the H-5 tank to the CFDTS tank shut-off valve was reviewed and revised. Detailed design is now in progress. A test facilities instrumentation list is currently being compiled for the CFDTS.

Work on the sequence plan drawing and design of the sequence assembly was continued.

2. Test

Ground rules are being established for the development of a test program, to evaluate the effects of changing the turbopump assembly and varying the propellant tank pressure and the TPCV and diluent valve settings.

The preliminary pre-test analysis, which defines the expected operational range of the CFDTS, was released. Based upon this analysis, the operational limits for the CFDTS ejector system are being evaluated.

Efforts continued on revisions to the preliminary test plan.

The measurement requirements list is being revised, utilizing the pre-test analysis and the latest NRX-A1 information.

C. SUB-SUBTASK 1.1.6 - ENGINE SYSTEMS ANALYSIS

1. Steady-State Analysis

The modification of the nuclear engine analysis program to allow analysis of the NRX-A system has been completed. Based on the proposed test run profile, various steady-state operating points were established. Cycle schematics using these various operating points were issued.

An investigation was completed of the core-fuel-channel orifice sizes necessary to provide equal exit gas temperatures in all fuel channels at design point. This involved a modification to the core, fuel element, and tie rod program to automatically give optimum orifices. Currently, the program is being modified to provide optimum tie rod channel orifices to allow equal exit gas temperatures at design-point operation.

Several nozzle transient analyses were made of jacket temperatures for tube and cast aluminum as anticipated for LO_2-LH_2 simulation tests. Runs were made using an experimentally determined value of contact conductance between the tube and jacket and a conductance one order of magnitude greater. Other runs have been made using other possible Kiwi nozzle configurations. In none of the runs were the temperature differences in the aluminum jacket greater than $50^{\circ}R$, except for the case of the high-contact conductance, where the temperature difference was $95^{\circ}R$.

The component analysis program, written to predict component limiting temperatures and pressures, was modified and included in a reactor kinetics code. Integration of these two programs will allow analysis of possible reactor accidents.

A metal bottom support plate subroutine intended for inclusion in the nuclear engine analysis program was completed and checked out. An analysis of a possible Westinghouse bottom support plate design has been initiated.

Investigation of the Kiwi B-2 core perimeter installation was completed, as was the B-2 support rocker arm thermal analysis. It was found, for the cooling scheme considered, that no serious thermal gradients existed in the rocker arms, and that any possible gradients might be avoided by cooling

[redacted]

holes in the rocker arms. Analyses of other thermal details of the Kiwi B-2 core were completed. An analysis of Kiwi B-2 core flow characteristics for full range of laminar and turbulent flow during cooldown was begun.

The hydrogen properties deck was extended to include entropy in the two-phase region. Currently, sonic velocities over the full range of two-phase flow conditions are being calculated.

A digital computer model of two-phase flow was written. It is intended to use this model to correlate theoretical two-phase heat-transfer correlations with experimental data.

2. Transient Analysis

a. CFDTS Dynamic Analysis

A preliminary pre-test analysis of the Cold-Flow Development Test System was completed and the results reported in REON Technical Memo 738:63-204. Start transients were obtained for the power-range analog simulation of the AJ30-5 Hot-Bleed Cycle engine. The effect of various initial TPCV settings on the attained peak pressure was determined with zero power input and for two cases of diluent bleed flow. The computer results were then used as a basis for recommending instrument ranges for the CFDTS.

b. Power-Range Simulation

The mathematical engine models used in the linear analysis and on the analog computer were checked, showing consistent results.

The effect of the latest mathematical model on the control system compensations was investigated. The three-section core representation had to be re-examined to insure that accurate core transients would be generated during start-up and steady-state operation. Various three-section core models were tried on the analog computer and checked with the linear analysis to determine the most accurate method of representing core transients.

Gains and time constants representative of the NERVA engine dynamics were calculated for five different power level points. Agreement between the calculated time constants and those measured on the analog computer has been established.

The results of the linear analysis and the computer simulation of the Hot-Bleed NERVA engine system are being integrated into a report which, it is anticipated, will be issued near the end of August.

c. Cool-down

Work on the cool-down transients has been devoted principally in reduction of the analog computer, and initiation of a report covering the preliminary results of the cool-down study. This report is scheduled for issuance during the next report period.

d. Data Analysis

Data reduction and analysis plans for NRX A-1 were reviewed. Procedures are being developed to permit "quick-look" presentation of the information recorded on magnetic tape.

Debugging continues, of the LRP NERVA data package, the time series data edit program, and the program to rearrange the data from the LASL format into the LRP format.

D. SUB-SUBTASK 1.1.7 - INTERFACE MOCKUP

The test plan for the pressure-vessel closure interface mockup was completed and fabrication is continuing.

E. SUB-SUBTASK 1.1.8 - NRX-A INTEGRATION AND DOCUMENTATION

1. Design Integration

a. NRX-A Assembly

REON drawing 092349, NRX-A1 Final Assembly, was not released as scheduled due to lack of design information related to installation of reactor instrumentation. The required input is expected during the next reporting period.

REON drawing 091882, NRX-A Nozzle Interface, was revised to include mounting provisions for the planned instrumentation. These revisions will allow the instrumentation to be interchangeable between the Rocketdyne and Aerojet nozzle.

REON drawing 091390, Interface Control NRX-A2, is being revised at the present time, to incorporate the design detail necessary for instrumentation boom attachment. This drawing will be used as a control drawing for both NRX-A2 and NRX-A3.

REON drawing 091250, Propellant Supply Line Interface, was issued showing required instrumentation bosses.

REON drawing 284044, showing the diagnostic instrumentation on the pressure vessel and nozzle, is not yet released due to extensive drafting requirements.

b. Test Car Installation

WANL Drawing 9363445, Test Car Assembly, was not released due to the requirement for the incorporation of instrumentation boom support detail. Due to this delay and because of lack of instrumentation interface information, preparation and release of the REON drawing 092346, Test Article Installation, was also delayed.

2. NRX-A Documentation

a. NRX-A1 Test Specification

The first rough draft of the NRX-A1 test specification was completed by WANL and transmitted to REON and LRP for review. The document was reviewed and an integrated list of significant comments prepared. During early August this list will be reviewed with WANL to upgrade the document as required. These agreements will form the basis for a "smooth" draft of the document which will be transmitted to the other participating organizations and non-contractor agencies for final review during August 1963.

b. NRX-A2 Test Plan

The NRX-A2 test plan has been initiated, based upon a test profile of 100% power conditions during the test. This information will be transmitted during August to WANL for preparation of a rough draft of the NRX-A2 test plan.

c. NRX-A1 Test Procedures

Definition of the various procedures which will be prepared by NTO in support of the NRX-A1 test activity was made during this report period and reviewed by representatives from NTO, REON, and SNPO-C. Most of these procedures are in preparation and will reflect the applicable requirements of the NRX-A1 test specification as that document is finalized. A rough draft version of the test specification was transmitted by WANL to NTO for review and to expedite technical coordination between the organizations involved in NRX-A documentation.

d. NRX-A1 Non-Nuclear Hardware Acceptance Test Plan

Work was completed on the first draft of the NRX-A1 Cold Flow Acceptance Test Plan. It is expected that the plan will be reviewed and approved by LRP and REON and issued during August.

F. SUB-SUBTASK 1.1.[illegible] - NERVA/RIFT COORDINATION

1. Interface Coordination

A NERVA/RIFT mechanical interface meeting was held at SNPO-C on 9 July 1963 with personnel from SNPO-C, NVPO, LMSC, WANL, and REON in attendance. A general review was made of NERVA/RIFT mechanical interface work accomplished to date.

A second similar meeting was conducted on 18 July at REON, with LMSC and REON personnel in attendance. A decision was made to study both the AGC thrust-vector-control engines and LMSC thrust-vector-trim engine configurations, which would result in a joint AGC/LMSC report.

2. Support Studies - NERVA Engine Operational Requirements

The major effort to date has been concerned with establishing the design growth potential for operational engines based on NERVA/RIFT technology. Ground rules were selected from which various engine categories, based on mission requirements, were defined in terms of operational and performance capabilities.

The following engine categories were selected for investigation:

Mod 0 - NERVA Flight Test Engine

Mod 1 - Early Operational NERVA Engine

Mod 2 - Fully-Operational Orbital-Start NERVA Engine

Mod 3 - Fully-Operational Sub-Orbital-Start NERVA Engine

Within the Mod 2 and 3 categories, variations may be identified, depending upon the mission mode. For example, the number of starts and cool-down cycles may differ from one sub-Mod to another, resulting in significantly different propulsion systems.

Preliminary analyses have indicated that the nozzle-wall temperature is the major limiting parameter in achieving higher engine performance. Based on this constraint, two major categories of operational engines appear possible within the existing NERVA design. The first category identified above as Mod 2 is based on the growth potential within the present design without modifications. The second category referred to as Mod 3 is based on the growth potential within the present reactor design with major modifications or new non-nuclear components.

Item 1.2 PROPELLANT FEED SYSTEM

A. PROPELLANT FEED SYSTEM ASSEMBLIES

The Mark IV, Mod 2 installation and interface layout of the Propellant Feed System was completed.

The preliminary mechanical interface control drawing for installation of the PFS at NARF was completed.

A post-irradiation test disassembly and inspection procedure for the Radiation-Effects Static-Seal Test Assembly was published.

This assembly was subjected to a radiation environment at the General Dynamics facility, Fort Worth, Texas. Following sufficient cooling to allow manual handling, it will be returned to LRP, where the post irradiation portion of the test will be conducted.

Test cells have been fabricated which simulate the butt welds between flange and tubing joints of the Propellant Feed System joints. Burst tests were conducted with these test cells. The cells burst at 840 and 1240 psig, respectively. The test cell with the higher burst pressure had been heat treated after welding to restore it to its original T6 condition.

Design analysis of the Mk IV TPA turbine exhaust line is complete.

Completion of the prototype pump suction line fabrication has slipped to the first week in August due to fabrication problems.

Analyses were accomplished in July of the pump-discharge turbine-exhaust manifold, turbine-inlet, diluent-section tube assemblies, and of the coupling tube. All components were found to have adequate structural integrity. In addition, the analysis of the single Conoseal quick-disconnect joint was completed.

B. VALVES

The radiation effects test plan for the TSOV and the post irradiation test disassembly and inspection procedure for the TSOV and TSOV-PV were published. The acceptance test requirements for the tank shutoff valve were completed.

The first Configuration II TSOV kit was received and assembled, and a dry functional test was successfully performed.

A Configuration I TSOV and a Configuration II TSOV-PV were subjected to radiation environment at the General Dynamics facility, Fort Worth, Texas. When the valves have cooled sufficiently, they will be returned to LRP where the post-irradiation portion of the test will be conducted.

An initial loading test was performed on a TSOV remote disconnect coupling, establishing that flange loading was relatively uniform. A torque of only 30 in.-lb was required to operate the coupling.

Turbine power control valves tested during the report period incorporated a separate thrust bearing to absorb the thrust transmitted by the gate to the body bore. Tests using the thrust bearing indicated no body damage or discrepancy in function of the TPCV.

A post irradiation test disassembly and inspection procedure for the Configuration I TPCV was published, and the acceptance test requirements for the turbine power control valve were completed.

The radiation effects plan for the RCDV for Radiation Effects Test (RET) No. 903 was published.

A Configuration I TPCV was subjected to a radiation environment at the General Dynamics facility, Fort Worth, Texas. When the radiation level has reduced sufficiently to allow manual handling, it will be returned to LRP where the post irradiation portion of the test will be conducted.

C. TURBOPUMP

Fabrication of a D-979 turbine rotor to fit a Mk III TPA was completed.

Assembly of Mk III TPA, S/N [illegible]8, was completed without a rotor for mock-up in the H-6 facility.

Six Mk III Mod 3 turbopump development tests were conducted in this report period. Run No. 1.2-08-NNP-004 was conducted using H_2-O_2 hot-gas

drive. Total run duration was 60.83 sec, of which 43.8 sec were at or above FX pump power and 1100°R turbine inlet temperature. Run 1.2-08-NNP-005 used the same hot gas supply. Run duration was approximately 52 sec, of which 27 sec were at FX pump power. Turbine inlet temperature was approximately 1230°R. Run 1.2-08-NNP-006 had a run duration of approximately 40 sec, of which 5 sec was at FX power. Run 1.2-08-NNP-007 was successfully completed with a duration of approximately 62 sec, of which 42 sec was at FX pump power. Run 1.2-08-NNP-008 was prematurely shut down after approximately 20 sec because of a hot-gas leak from the gas generator. Post-fire inspection revealed no significant damage. The turbine inlet temperature for runs 006 through 008 was approximately 1160°R. Run 1.2-08-NNP-009 had a total duration of approximately 81 sec, of which 60 sec was at FX pump power. Turbine inlet temperature during this run was approximately 1260°R.

Design engineering effort was continued on the Mk IV Mod 2 turbopump and a conceptual layout drawing was completed. A structural report on the Mk IV thrust balancing piston was issued, and structural analysis of the wet pump seal disc was completed.

D. BEARINGS

A new thrust bearing design was evaluated at 16,000 rpm in the turbine tester (Test 1.2-04-NNW-019). This bearing performed satisfactorily with an Armalon thin line cage for 9.2 minutes at a thrust lead of 2000 lb.

Three combined flow and dynamic tests were run on the electric-motor-driven bearing tester to check out both the motor and the axial loading device. The unit was run at full speed and load on one thrust bearing for 5 minutes. Early tests showed that the seal leakage rate on the axial loader was very low, and the motor performed satisfactorily. Post-test examination of the tester showed that the carbon shaft riding seals had worn grooves, due to an interference fit, in the sleeve on which the seals ride. The ball bearings were in excellent condition, but the roller bearings showed some scuffing of the inner races, probably due to operation in an unloaded condition.

Static tests on the radial loading device demonstrated the adequacy of the design in providing a gas cushion between the loader pad and the shaft.

The first Radiation Effects Test (RET) was conducted on 17 July 1963 at the General Dynamics Fort Worth reactor facility, utilizing a NERVA electric-motor-driven bearing tester with LH_2 flow as coolant. The motor was operated for a period of 155 seconds, shut-down becoming necessary when the kill parameter of -150°F bearing temperature was reached. The temperature rise was possibly due to insufficient flow of LH_2 through the tester. This problem is being investigated.

Item 1.3 NUCLEAR SUBSYSTEMS

Item 1.3.0 INTEGRATION AND TECHNICAL MANAGEMENT

A. NRX-A DESIGN AND COMPONENT DEVELOPMENT PROGRAM REVIEW

The design review effort initiated during the last report period will be continued. Interim documentation will be prepared as necessary.

On 29, 30, and 31 July 1963, a design review meeting was conducted at WANL. These areas were covered during this review:

Mechanical design
Fuel properties
Vibration stability
Thermal and fluid flow analysis
Mechanical analysis
Work to be accomplished before system tests.

The review of the component test program continued during this report period with emphasis on the proposed G-3 plugged core tests. Alternate methods of conducting plugged core tests are presently being considered. Definition of the test plan is expected during the next month.

A component test program review was conducted at WANL on 22 and 23 July. The revised program plan outlined in WANL-TMR-095 was discussed in detail along with the component test priorities.

B. REACTOR REVIEW COMMITTEE

The dynamic analysis of the Kiwi-B4A reactor core structure was completed. The analysis is reported in REON Technical Memo No. 746-10.

Item 1.3 NUCLEAR SUBSYSTEMS

Item 1.3.1 REACTOR MECHANICAL DESIGN

A. NRX-A REACTOR MECHANICAL DESIGN

1. Core

a. Stress Analysis

Two stress analysis reports relating the the NRX-A core were issued during July.

WANL-TME-585, Stress Analysis of the Pyrolytic Tie Rod Insulating Tube, shows that the tube will divide into a series of concentric cylinders as it cools from formation to room temperatures. Tests conducted at room temperature indicate that this dividing, or delamination, does not prevent the sleeve from functioning properly.

WANL-TME-407, Stress Analysis - NRX-A Fuel Elements, presents an elastic stress analysis of the regular fuel elements in the NRX-A core.

b. Tie Rods

Heat Treatment of the first production batch of tie rods has been completed. The processed tie rods shown an even, blue-black discoloration, believed to be due to impurities in heat treat atmosphere. Measurements indicate that the heat treatment decreases the length of the tie rods approximately 0.036 inches. Conversely, there is no significant increase in length during the proof load tests which are conducted at 600 pounds. The operating load is 550 pounds.

Preliminary calculations indicate that the tie rod stresses might be considerably higher than originally expected, because of the redistribution of load brought about by temperature and bundling pressure. The nominal tie rod stress caused by the 130-psi core pressure drop on a regular cluster is 52,000 psi. Under the assumption that the core is bundled as a solid cylinder, and taking into account the deflection of the aluminum support plate and that the tie rods at the center of the core are hotter, it is found that

the stresses in the peripheral tie rod can be as high as 75,800 psi. If the core is eccentric, the additional localized bending will produce a stress above the 80,000-psi yield specification. A low cycle fatigue analysis shows that the tie rod can withstand a stress appreciably in excess of 80,000 psi.

c. Liner Tubes

Two prototypes of the spiral-grooved liner tube have been completed. These parts were made by modifying two standard liner tubes, forming the spiral indentation with a carbide ball tool. This indentation serves as a tie rod "stand-off" to prevent a hot spot which might occur if the tie rod should contact the liner and locally block the coolant flow. The two samples indicate that all the standard liner tubes can be modified to provide this design improvement.

d. Gap Measurements

The gaps between elements of a 9 inch length core have been measured on a steel-banded core and on a core held in a simulated lateral support system. The analysis indicated that the gap decreases slightly as bundling force increased.

In order to measure the effects of vibration, the gaps on a test section of the core were measured before the specimen underwent vibration tests. The vibration tests consisted of acceleration loads ranging from 1 to 10 g over a frequency which varied from 10 to 1000 cps. After vibration, the gaps were again measured and it was found that they were not affected significantly. Average gap increase was .04 mils. Detailed information on the analysis was released in WANL-TME-427, Gap Measurements Between Elements of a 9-Inch Core.

e. Lateral Support Systems

The resonant and shock response characteristics of the NRX-A lateral support system are discussed in a report issued as WANL-TME-428.

Summarized, the findings of this report are:

The natural frequency of the lateral support system's 12 cps provides a satisfactory margin above the 1 to 5 cps expected from the gimballing and rocket body bending frequencies.

The natural frequency of the lateral support system is different than the frequency of its components.

The core deflection does not exceed the shock capabilities for the anticipated 5g - 10 millisecond equivalent rectangular shock pulse.

It is not anticipated that lateral cracks will occur in the core, but if they should be induced by some unlikely condition such as unsymmetrical pressure loads or shock and vibration, the core support system has the potential to close these cracks.

f. Shipping Poison

The design of a segmented plate which will retain poison wires during shipment was completed, and drawings were released. The difficulties experienced in trying to attain the specified straightness and coating thickness for poison wires have been resolved.

2. Inner Reflector

WANL-TME-415, Sealing of NRX-A Core Peripheral Seals by Angled Lateral Support Plungers, showed that there is no positive assurance that all of the NRX-A core peripheral seals will seat if pressure drops are the only driving force. As a result of these analyses, a 30° angle, which will provide the necessary force to seat the seals, has been incorporated on the seal contact area and the lateral support plunger.

WANL-TME-422, Unseating of NRX-A Inner Reflector and Cluster, analyzes the maximum bundling pressure that can be exerted on the core, and the critical combination of system pressure drops which could cause the inner reflector to lift off the nozzle. To ensure adequate margin against lift-off, the axial preload spring force was increased. This redesign prevents the nozzle from lifting off when there are high pressure drops in the inner reflector

during transient and gas flow testing. It was generally concluded that the inner reflector will not lift off the nozzle.

Slotted seal segments will be incorporated in all reactors, beginning with NRX-A1. The slots, to be located on the inside diameter of the lateral support seal segments, will control the seal by-pass coolant flow necessary for pressure balancing and thermal gradient control. This new configuration includes constant width (0.440-in.) slots, and a staggered pitch which locates a slot at each filler strip interface around the core periphery.

A recent analysis of the inner reflector cylinder indicates that the first mode of buckling would be stopped immediately because the clearance between the outside diameter and the outer reflector is very small. Furthermore, since higher buckling modes require higher pressure drops than exist in the NRX-A, the inner reflector will not buckle.

Manufacturing difficulties in the 2219 aluminum barrel may cause a delay in obtaining a barrel. The re-solutioning quench of test pieces has produced excessive distortion in the free state. Solutions to the problem in the form of additional sizing and restrained aging are being investigated. A back-up aluminum barrel of 6061-T6 has been released as a substitute for the NRX-A1 in case the difficulties cannot be resolved.

3. Outer Reflector

Development of electron-beam welding techniques for the control drum assemblies is continuing, and satisfactory welds have been made in test samples.

Magneforming, while in the development stage, is being used as the back-up design for electron-beam welding. Several samples of magneformed assemblies have been received and tested.

4. Instrumentation

Tests have been made to determine the adequacy of various cements for their planned application in the NRX-A1 reactor. National Carbon No. 14 has been successfully tested in liquid nitrogen. In several tests,

applied loadings have broken away parent graphite material rather than failing at the cement bond.

Additional tests and investigations are proceeding on methods of applying instrumentation leads to such materials as aluminum and titanium. Tests using aluminum foil bonded with epoxy cements have shown satisfactory results.

Release was made of the adapters and seals which are to be installed in two actuator drive shaft ports to accommodate instrumentation leads for the NRX-A1 cold flow test. Two of the three stationary drive shafts (for cold-flow test only) will be omitted from the NRX-A1 assembly to facilitate routing instrument leads to the test car

5. Shipping Containers

The shipping demonstration tests conducted from June 2[illegible] to July 6 during the round-trip from Large to Las Vegas by railroad, and from Las Vegas to the MAD building by trailer truck, showed acceleration loads as high as 2 g were attenuated by the container by factors of 3 to 5. The trailer truck transportation imposed acceleration loads somewhat larger than the railroad transports.

The design requirements were defined as reusable, wooden shipping containers which will accommodate the shield-flow screen, control drum drive shafts, and miscellaneous instrumentation hardware.

B. REACTOR SHIELD MECHANICAL DESIGN

Detail drawings of the NRX-A1 aluminum replacement unit have been released. These drawings include provisions for the necessary instrumentation.

The design of a reusable stainless-steel shipping container for the NRX-A simulated shield was completed and drawings were released. This container protects the shipment from normal environmental hazards, and limits the shock and vibration input to the instrumentation on the simulated shield to 10 g in any direction during normal handling and transportation.

C. EVALUATION AND DEVELOPMENT OF REACTOR NON-FUEL MATERIALS

Reported under Item 1.9, B

D. MECHANICAL ANALYSIS AND TEST PROGRAM

1. A-1 Fuel Element Mechanical Tests

Test A-1-1 test data from 16 Westinghouse-Cheswick unfueled elements showed a dynamic modulus of elasticity of 2,600,000 psi at low stress values (200 psi), in a lateral direction.

Test A-1-2 test data from the same 16 Cheswick unfueled elements showed a dynamic modulus of elasticity of 2,500,000 psi at low stress values (200 psi) in longitudinal direction.

Test A-1-5 - An average fracture stress for Cheswick elements was 12,800 psi, while for Oak Ridge elements, an average value of approximately 11,000 psi has been obtained to date.

Test A-1-8 - unloaded Oak Ridge fuel elements were tested with hinged-hinged and clamped-hinged end conditions. Elements with hinged-hinged end conditions were able to withstand 15-g acceleration at side clearances up to 0.2-in. for over 100,000 cycles (approximately one hour). Elements with clamped-hinged end conditions failed in a range of 100 to 2000 cycles with 14-g acceleration and 0.1 inches side clearance. With the same end conditions, elements failed at approximately 700 cycles with 4-5 g acceleration, and 0.2-in. side clearance.

2. A-5 Support Block and Insulating Parts Mechanical Test

The detailed drawings of the temperature gradient test rig have been completed and test specimens have been ordered.

The shear tests of the interlocking support blocks have been completed.

3. A-6 Tie Rod Tests

A limited number of test specimens were received.

Test A-6-1 - A test of a production tie rode of Inconel X-750 has been completed. Results show approximate values of the proportional limit of 72,000 psi - 0.2% yield strength of 92,000 psi.

4. A-9 Fuel Cluster Assembly Mechanical Tests

Fabrication, procurement, and assembly of test fixtures have been completed. The fuel cluster assemblies have been received.

5. B-4 Graphite Barrel Test

Design has been initiated on the testing machine for fatigue tests on threads in graphite.

6. E-5 Vibration Test of Partial Core

The vibration tests of the simulated Kiwi-B4A lateral support system have been concluded. High-speed moving pictures of the core were taken.

The inner reflector was excited at frequencies from approximately 5 to 2000 cps. At low levels of excitation (below 3.0 g) no motion was transmitted to the core due to the low spring rate of the Kiwi-B4A design. Core motion was observed only when the inner reflector was impacted against it. At 8 cps and 4.5 g, some separation of the fuel elements was noted.

The Kiwi springs were replaced by the NRX-A1 coil springs in the lateral support system. The shock machine had been calibrated and high-speed moving pictures of the lateral support system have been taken.

7. C-2 Support System Tests

Fabrication of the axial load test rig was begun and is expected to be completed in August.

The hydraulic power supply components were assembled and operational tests of the system were performed. Flow rates, pressure fluctuations, and fluid temperatures were measured and found to fall within procurement specifications.

8. D-1 Reflector Segment Mechanical Tests

Test D-1-1 - Tests were conducted to evaluate surface galling of two metal combinations, titanium on aluminum with poxylube (baked-on epoxy-bonded molybdenum disulfide coating) and titanium on beryllium. The first of these combinations provided satisfactory, but the second combination galled severely.

Test D-1-2 - Thread galling tests were conducted on titanium bolts with titanium nuts, with and without surface coatings on the bolts; titanium bolts with silver plated Ni-Span-C nuts; and silver plated stainless steel bolts with beryllium nuts. The titanium nuts were found to gall, but silver plating of the bolts corrected this difficulty. The other coatings, such as "Tuftride," TD1124P, and dry film lubricants, were not satisfactory. Tests are being continued on other material combinations.

Test D-1-3 - All the reflector tie-bolt test fixtures, fittings, hardware, and test equipment have been procured.

Test D-1-4 - The test rig was assembled, and the first reflector thermal shock test was conducted with a temperature gradient of approximately 120°F between the I.D. and the O.D. of the test specimen. No evidence of damage of the test specimen was observed after the test, although the gradient imposed in this test is about five times as large as the maximum design gradient calculated. Tests will be continued in order to find the gradient required to fracture the specimen.

9. D-3 Control Drum Evaluation Tests

Static pressure and axial vibration shakedown tests of the environmental test chamber were carried out with a simulated control drum installed in the chamber. The static pressure test was performed with nitrogen at a pressure of 650 psia and at 300°F, for a period of eight hours. The vibration tests were carried out at 1-g acceleration with frequencies from 20 to 200 cps, while the static pressure test conditions were maintained in the chamber. No evidence of malfunction or damage of the chamber was observed during the tests.

A drawing was completed specifying the type and location of accelerometers, displacement transducers, thermocouples, and static pressure probes for measuring drum accelerations, displacements and temperatures, support barrel accelerations and temperatures, and gas temperatures and pressures.

A study was performed to evaluate commercial pulse generators for use with the electrodynamic shaker for shock testing. The study showed that the exact type 200 pulse generator will provide the pulse width and acceleration required for the shock tests. This equipment, as well as other associated electronic instrumentation, is being procured.

The test stand which will support the electrodynamic shaker for the lateral vibration tests was completed.

10. G-1 Reactor Assembly Mechanical Tests

All test fixtures have now been received, with the exception of the barrel, for the axial core assembly test.

The control room for the vibration console and instrumentation has been completed. The Ling 30,000 shaker system installation will be completed by early August.

The following two documents relative to core component instrumentation were released for publication:

Specification PS 294580 Strain Gage Installation for ND 201 Reactor Components

WANL-TME-377 Instrumentation for G-1 Reactor Assembly Mechanical Tests.

Twenty-seven fuel elements, 12 leaf springs, and 6 tie rods were instrumented with strain gages and delivered to the assembly area.

11. Analytical Studies

A good theoretical simulation was indicated by plotted computer response curves, derived from simple mathematical models and the response curves obtained during the B-5 partial core test subjected to sinusoidal force

input. Based on this correlation, the G-1 core assembly models have been computed by using a variable force input to maintain a constant input displacement, or acceleration level. The input motion of the inner reflector when subjected to a sinusoidal force is non-sinusoidal. The analog computer results indicate that a maximum acceleration of 6 g may be attained in the core at resonance without impacting, and that, similarly, 5 g input may be attained at the inner reflector.

A mathematical model which incorporates rotation and translation of the core in the lateral core assembly series is being analyzed. This model will indicate the degree of rocking, and its effect upon the response magnitude.

12. Friction Test

a. Space Environment

The following materials have been tested in a simulated space environment test sequence, and test results are being analyzed:

Materials	Number of Tests
HLM-Inconel X	1
HLM-347 S.S.	1
HLM-ZTA	4
AL(2219-T31)-titanium	3
Titanium-Ni-Span-C	2

b. Ground Environment

Preliminary results indicate that static micro (s) and dynamic micro (d) coefficients of friction decrease at high temperature in a hydrogen environment for HLM-ZTA, HLM-304 Stainless Steel, HLM-aluminum (2219-T31), and increase under the same condition for niobium-niobium. The test equipment is being modified to eliminate possible error sources. After changes are complete, the test results will be verified.

13. Graphite Cement Test

Several graphite cement bending tests have been run, on cements P-510, P-511, and P-514, all manufactured by Great Lakes Carbon Company.

Preliminary data indicates the possibility that flexural strength decreases with increasing curing temperatures. All tests were conducted at room temperature and pressure. Many more tests will be run to verify present results.

14. Study of Modes of Fracture and Deformation

HLM, ZTA, and AXF graphite were tested at atmospheric pressure. Three specimens in each grade were fractured. Preliminary data indicates tensile strength of HLM grade to be considerably greater than specifications listed by the manufacturer.

Other specimens will be tested to verify the preliminary findings.

15. NRX-B Cooled Support Plate

The installation of strain gages and wiring on the plastic model of the plate was completed. Quality control of the strain-gage application technique was maintained by periodic applications of similar gages on the plastic test beams. These were applied with the same techniques used on the plastic plate to insure truly representative conditions. Strain-gage measurements were made during the load tests of the test beams, and compared with strains measured with a Tuckerman gage. These measurements agreed within 10%, providing a high degree of confidence in the strain-gage applications.

Assembly of the test fixture has been started, and operational checks of the strain measuring equipment are presently being conducted.

E. NRX-B REACTOR MECHANICAL DESIGN

1. Core Cage Structure

Work is continuing on the layout of the metal internal core structure. This design accommodates 37 hexagonal modules each containing 61

fuel elements. Preliminary stress calculations, using estimated mechanical loads only, indicate that the design is feasible. An effort is being made to further resolve the problems associated with the axial control rod drive mechanisms.

2. Core Cage Structure with Multiple Propelling Nozzles

Layout work has started on a metal internal core structure using 61 hexagonal modules each containing a cluster of 37 fuel elements. Each cluster of fuel elements discharges into a small propelling nozzle. The 61 small nozzles are designed as an integral part of the core cage outlet end structure and discharge into a single large nozzle skirt section. The divergent portions of the 61 small nozzles, together with the adjoining large skirt section, are fabricated as a single cooled metal structure. The inside surfaces of this structure are insulated with a zirconium oxide coating. The throat areas of the small nozzles are insulated with pyrolytic graphite liners. Work is proceeding on the fabrication and assembly problems associated with this arrangement.

3. Graphite Modular Core Structure

A conceptual design layout has been completed which defines a core consisting of a number of graphite modules supported in pin ended fashion between cooled metal support plates at the inlet and outlet ends. A peripheral lateral support mechanism is not required in this design. The structural integrity of the individual 19-element modules, acting as beams, is relied on for the stability of the core against the forces arising from lateral shock and vibration. The entire core is surrounded by a cooled metal barrel which isolates the hot end of the core from the cool reflector coolant flow.

A bending analysis has been performed on three module configurations designed to accommodate the 19 hole Kiwi-B4 type of fuel element. The 7-element configuration appears impractical for a core 52 inches long. The two 19-element configurations appear more promising, with module stresses of approximately 500 to 700 psi, depending on the detailed geometry and material of the module. The corresponding module deflections range from 0.05 to 0.11 inches and the natural frequencies from 26 to 38 cps.

Drawings have been completed which define graphite module structural test components. Three different materials have been specified for the module case: HLM-85 graphite, laminated graphite cloth (PT series) material, and a combination of these two using an HLM-85 tubular core with an external wrapping of the laminated material. It is proposed to procure samples of all three varieties for structural test purposes.

Work is continuing on other versions of modular core arrangements. Emphasis has been given to minimizing leakage flow around the fuel elements and modules. Study is being made of the possibility of providing positive seals at both ends of the module cases where they contact the inlet and outlet end support plates. Such an arrangement would help to minimize corrosion in the event of fuel element damage. It is, however, necessary that the modules be designed to resist both internal and external pressure loads. A 19-element module created by bonding together fuel elements (with no module case) has considerable merit if bonding problems and differential thermal expansion problems can be solved.

Work has also started upon a core design featuring a graphite module similar in cross-section to that of the 7-element Kiwi B1 type. The method of support differs from that used in the B-1 reactor, as a metal cooled outlet end support plate is employed, holding the module in compression rather than in tension. The mechanical ruggedness of this design is attractive, as well as the potential for fully confined flow through the fuel elements.

4. Graphite Support Plate Structure

Drawings have been completed defining structural test components for the segmented and one-piece graphite support plate designs. Material drawings have been released and graphite material is being procured for the segmented plate. Work is underway to obtain a small plastic model of the segmented plate to study the fit-up between segments and structural characteristics. A manufacturing procedure has been suggested that might essentially eliminate gaps between segments.

A computer program has been written to define the flow passages of both the solid and segmented graphite support plates. The program input consists of element spacing, core diameter, plate bottom curvature, minimum hole diameter, reamer taper, etc. The output includes X and Y coordinates of top and bottom, hole angle, top and bottom diameters, reamer insertion data, etc.

5. Counterflow Cooled Tie Tube Structure

A conceptual design layout has been completed of a two-pass support tube design. Similarities exist between this design and that of the NRX-A, the primary differences being in the core configuration. Two-pass support tubes are used, in place of the NRX-A type tie rods, to reroute the support-tube coolant flow through the core. A ratio of 2 support tubes to 12 elements has been used in this design as compared to 1 for 7 in the NRX-A. Another significant difference is the dissociation of the support tubes from one specific cluster or transition block, thus resulting in axial load path redundancy. Failure of any given support tube should not result in the loss of an entire cluster. This feature was achieved by locating the support tubes at the outer periphery of the cluster support blocks rather than in the center.

6. Forged Support Plate

A mechanical analysis of the metallic portions of the forged support plate has been completed, and shows a maximum stress due to the core pressure drop of less than 60,000 psi. A cumulative fatigue analysis will be conducted when both start-up and decay heat transients are defined.

Consideration is being given to the possible use of a spray coating of zirconia (Rokide Z) as a thermal insulator on the cooled support plate. Evaluation of data indicates that such a coating could be easily applied to the plate and would be approximately 50% as effective as pyrolytic graphite, for equal thicknesses. Coating thicknesses of zirconia up to 1/8 inch appear feasible.

[redacted]

7. Transition Blocks

A correlation has been made between analysis and test for the early transition block design. It was concluded that it is possible to design a 19-element graphite transition block to meet NERVA functional requirements with a high level of reliability. Survival at the design load for the 2 inch ZTA block is calculated to be in the order of .999999.

8. Lateral Support

Analysis has indicated that a design incorporating the following parameters should be capable of meeting the NERVA design requirements with a shock limit of 5, rather than 6 g. for 1 millisecond.

Core weight	5,000	lb
Lateral spring rate	587,150	lb/in.
Radial spring preload	6	psi
Coulomb damping	9,430 to 14,140	lb

Problems have developed from efforts to design a graphite wedged-ring lateral-support system using axial springs at the inlet end to apply the wedging pressure. Due to the force attenuation resulting from the interaction of forces and friction between the wedged rings, a high axial spring preload is necessary to impart the minimum acceptable bundling pressure to the core. Abnormally high pressures are imparted to the core as it starts to expand radially. For wedge angles between 15 and 45°, in a system having two wedges in series, the average radial pressures on the elements range from 60 to 130 psi. These pressures increase as the core continues to expand. Additional wedging rings in the two-wedge system series intensify the problem and result in a still greater variation of radial pressure during expansion and contraction.

9. Two-Pass Reactor Core

A conceptual layout of a two-pass reactor configuration with a plug type nozzle has been made. In this design the core is divided into two concentric circles with the first flow pass occurring in the central portion of

[redacted]

the core, the flow being introduced from a plenum formed by the interior of the plug nozzle. The flow is then turned and mixed with reflector coolant flow. The coolant then makes a 180° turn and receives its final heating as it passes through the outer concentric ring of fuel elements, from whence it flows through the annular throat of the nozzle with most of the supersonic expansion taking place externally. The interior of the plug nozzle is utilized in this configuration as a housing for the core shutdown rods. The rods would be inserted into the first-pass fuel elements.

10. Thermal and Fluid Flow Analysis

Additional performance studies have been made of the operation of counterflow tie tubes at reduced power levels. The studies were made based on a design which passes 35% of the flow through tie tubes when operating at full-power design conditions. It was found that a 35% power and propellant flow, the fraction of flow through the tie tubes is reduced from 35 to 21% by the increase in tie tube hydrogen temperatures. Under these temperatures, the inner load bearing tube reaches a maximum temperature of 1550°R and the outer unloaded tube has a maximum temperature of 2000°R. This latter temperature may be considered as an operating limit for unloaded tubes of this type. At a core power level of 20%, it is necessary to use 27% propellant flow to hold the outer tie tube temperature below 2000°R and reactor exit gas temperature is reduced to 3450°R.

Flow distribution studies on the forged base plate have been completed. Using a total of 15 types of flow tube orificing (for a total of 121 flow tubes), it is possible to maintain the mass velocity in each flow tube to within 2% of the nominal value, while requiring a total pressure drop of 28 psi across the plate at full propellant flow. A plastic model of a 60° sector of the plate is available, and a test fixture for its support is in fabrication.

Temperature distribution studies of the forged plate have continued. Part power performance studies have been conducted down to 10% power and flow. Under these circumstances maximum metal temperature is 1600°R, approximately 450°F hotter than under full-power conditions. This is deemed

fully satisfactory. Studies of the part power accident condition (loss of graphite liner and pyrolytic graphite insulation from a flow tube) are now under way. The accident condition at full power has been examined, with the assumption of an inner liner of 20 mils of spray coated Rokide. Metal temperatures reach a local maximum of 2350°R, approximately 700° below the melting point for A-286. Since the average temperature through the metal section is appreciably less than the local maximum, this performance is considered satisfactory.

Temperature and pressure-drop studies have been continued on the cooled metal core cage structure. The version described in the previous progress report incorporated 61 fuel elements per module, surrounded these elements with a corrugated cooled stainless steel structure, and insulated the stainless steel from the elements with graphite felt and pyrolytic graphite. The felt served the dual purposes of an insulator and of a graphite spring for accommodating internal temperature expansions of the fuel elements. Because of fears concerning the corrosion resistance of the felt, it was replaced by steel springs backing the corrugations. The earlier configuration with the felt was overinsulated (this frequently occurs when heat is generated within the insulating material), and removal of the felt reduced the stainless steel temperatures by 100°R. The new hot-spot stainless steel temperature is 954°R at full power. Partial power temperature calculations are under way. Pressure drop through the core cage system is estimated at 57 psi in addition to the reflector and fuel pressure drops in this relationship:

First pass down control rod channels	9 psi
Flow reversal through bottom support structure	24 psi
Second pass up through steel corrugations	15 psi
Third pass down through shield to fuel-inlet plenum	9 psi

Steady-state and transient temperature distributions have been calculated for the webs of the uncooled graphite support plate. These will be used to determine steady-state thermal stresses, and to evaluate the need for start-up rate limitations which might be imposed by transient temperatures in the webs.

11. Nuclear Design

Primary effort continued on the cooled core cage structure incorporating control rods. Control rods were originally sized for this core through the use of simplified hand calculation models, and an attempt was made to provide sufficient control so that the core would be shut down in a flooded condition (thus eliminating the need for a poison wire system). The original hand calculations were confirmed through the use of four-group transport-theory cell calculations. It was also determined that the thickness of the hafnium blades could be reduced from 0.200 to 0.125-in. without substantial effect on the control, thereby permitting a simplified mechanical arrangement. The original concept employed control rods in all available locations. Studies were made to determine the effects of deleting rods at the periphery, and it was found that such deletions are accompanied by a rapid loss of control. While final design studies might permit a limited number of such deletions, it is recommended that present efforts assume a full complement of control rods if the objective of flooded shutdown is to be retained.

Since the control-rod system incorporates much greater control than the conventional drums, it was thought desirable to raise the excess reactivity of the core to provide added margin for reactivity uncertainties and for reactivity losses resulting from corrosion. Provision of $12 of excess is estimated to require a fuel loading approaching 600 mg/cc.

F. E-ENGINE REACTOR MECHANICAL DESIGN

There has been no activity on this project.

G. KIWI-B6 SUPPORT

Developed methods of brazing and fixturing are being applied in the fabrication of test plates.

Instrumentation for the 7-hole plate is defined and will be ordered early in August.

Internally attached instrumentation consisting of thermocouples for the sandwich structure, 12 thermocouples for shroud structure, and 23 pressure probes for sandwich structure will be supplied to vendor prior to braze operation.

Instrumentation for the 91-hole plate is being studied.

Item 1.3 NUCLEAR SUBSYSTEMS

Item 1.3.2 NUCLEAR SUBSYSTEM THERMAL AND FLUID FLOW DESIGN

A. CORE COMPONENT ANALYSIS

Analyses have been completed to resize the tie-rod centering bushing orifices due to a change in core inlet temperature to 248°R resulting from a change in nozzle exit estimated temperature. The selected orifice size was 0.0325-in.-dia, based on a core inlet pressure of 689 psia and outlet pressure of 560 psia, resulting in an average tie rod exit temperature of 800°R. The following perturbations were studied with the new orifice size:

Insertion of shim material in unfueled graphite,
Manufacturing tolerances on hydrogen gaps,
Variation of pyro-thermal conductivity,
Variation of inlet loss coefficient and
Variation of heating the unfueled graphite.

For the 0.110-in.-dia. tie rods, the tie rod channel exit temperatures for the entire core were within the limitation of 950 to 650°R.

The core inter-element analytical flow model was modified to include the radial variation in the interelement gap widths, the undercut at the bottom of the elements, the clearance between support blocks, and the axial variation in filler gap widths. This model has been used to calculate the core pressure distribution for the lateral support pressures given in WANL-TME-368. These pressures are for 16 effective lateral support seals and 8 mils clearance. In addition, core pressures for 100%, with 15 effective seals having 8 mils clearance, have been calculated. Results have been determined for the case of 30-lb/sec hydrogen flow at ambient conditions with a 15-effective-seal model, including machined slots in the seals to provide clearance and the filler strip gap leakage.

A three-dimensional flow model was set up on TOSS to analyze the vibrations of the Kiwi-B4 core due to radial inter-cluster flow. Pressure distributions found from TOSS are being used to calculate cluster accelerations and displacements. For each time step of 0.003 seconds, new inter-cluster gaps are

calculated and new pressures are found from TOSS. To date five time steps have been completed and the results are inconclusive.

Preliminary hydrogen corrosion tests of elements have given pressure loss data at conditions of temperature and Reynold's numbers comparable to reactor conditions. MCAP runs were made at the same flow conditions as the hydrogen corrosion tests, and the calculated pressure flow was compared with the measured loss. The calculated loss varied from 50 to 150% of the measured loss, but the average of 29 test runs varied only 2% from the calculated loss. There were obvious inconsistencies among the measured loss data.

A hot-channel analysis was completed, including the effect of radial conduction between channels in an element and present specification limits for fuel elements. The effect of radial conduction was analyzed for the case in which all hot-channel factors were concentrated in the center channel. A second case, in which all hot-channel factors were concentrated on a channel adjacent to the center channel, was analyzed. Maximum temperatures in the two cases agreed within 3%.

Resulting hot channel temperatures are listed below, reflecting the difference in types of analysis -

<u>All Hot-Channel Factors Applied to One Channel as Multipliers</u>

Without radial conduction between channels	-	Max. Fuel Temp. 9817°R
With radial conduction between channels	-	Max. Fuel Temp. 6265°R

<u>Hot-Channel Factors Applied Statistically</u>

Without radial conduction between channels	-	1 channel above 6500°R
With radial conduction between channels	-	1 channel above 5725°R

Element arrangments for the vibration I core, have been completed. This listing includes elements for 8 clusters which were to have coated elements. Coated elements for the vibration I core are not available, and element assignments for these 8 clusters are being revised.

Selection has been made of master orifices for use in the production acceptance test device for the NRX-A1 cold flow core production orifice jets.

Element assignment for the NRX-1 cold-flow core has been initiated. Computer punch cards which describe element channel diameters have been received from Oak Ridge, and the assignment of elements by serial number to specific core locations, as well as the orifice assignments, is underway.

B. LATERAL SUPPORT THERMAL DESIGN

Further estimates of hydrogen corrosion of graphite in the seal region of the NRX-A were made and the results presented in WANL-TME-432. These estimates for 20-min. full-power operation indicate a maximum of 12-mil corrosion between the seals near mid-core and a maximum of 0.53-mil at the seal face in the same region. Experimental studies have been initiated to study the many factors which affect the corrosion rate and to provide data for verification of these calculations.

The seals on the NRX-A will be slotted to provide a desired pressure distribution and flow. The slots will have a width of 0.440 in. and will provide a 65.5% open circumference for flow at the filler block-seal interface. The depth of the slot will be fixed at the latest date which will not adversely affect the assembly schedule, in order to allow the maximum time for analytical and experimental investigations.

Modifications to the heat conduction analytical model on the TOSS code, which were made to include the radial filler strip gaps at the seal interfaces, required more effort than first anticipated. Consequently, the effects of filler-strip gap and seal gap are being investigated for zero-power operation with ambient hydrogen.

Because of relatively small flow rates passing the inlet core band, additional coolant will be provided from the outer reflector-aluminum barrel annulus.

C. REFLECTOR THERMAL DESIGN

The reflector flow balance has been modified to include the current reflector inlet conditions of 162°R and 750 psia, and the experimental loss coefficients have been obtained for the beryllium reflector sector flow.

A two-dimensional analog solution was initiated for the temperature distribution in the nozzle end outer reflector support ring. The effect of heat transfer in the third direction will be studied using the THT conduction code.

The sizing of radial pressure relief holes at the interface between the graphite barrel and the nozzle flange has been initiated. These relief holes have such high impedance that they will not affect leakage at this joint. The temperature distribution in the graphite barrel as affected by these holes is still to be determined before the hole configuration can be established.

An analog solution is complete for the temperature distribution in the beryllium sector for a reflector inlet temperature of 126°R. It will be necessary to update this information to reflect the effect of the currently prescribed inlet temperature of 162°R.

D. SHIELD THERMAL DESIGN

The latest heat generation rate profiles in the shield replacement unit, as presented in WANL-TME-366, together with the latest fluid temperature and pressure conditions reflecting the new 162°R inlet temperature, have been incorporated into the fluid-flow analysis.

E. THERMAL PERFORMANCE ANALYSIS

The NRX-A2 design-cycle state points were revised compatibly with the change in nozzle heat-transfer correlations. This change increased the nozzle exit temperature from 125°R to 162°R and required reorificing the core to give design core-exit conditions.

The TNT and TRATH computer code models of the NRX-A2 were revised to include the nozzle and core changes. Both codes were checked out and are now operational for design studies.

Calculation has been initiated of the reactor chamber pressure-temperature maps and emergency cool-down characteristics for the NRX-A2 final design report.

F. REACTOR TEST ANALYSIS AND REQUIREMENTS

A preliminary study for the NRX-A1 gaseous tests has been completed on methods of simulating design core and reflector pressure drop. The investigated methods included a plugged core and gas injection in the dome end of the pressure vessel. The most feasible method of plugging the core would be through the insertion of graphite pencils into the support block holes and gluing them. Plugging of orifices would require a major disassembly and re-instrumentation, and plugging of the core to get design pressure drops would require that about 55% of the channel be plugged

The more attractive method of obtaining gas runs with design pressure drops on the NRX-A1 is to inject additional gas at the dome end of the reactor in such manner that the flows through the core and reflector section differ. The ratio of core pressure drop to reflector pressure drop can be varied over a considerable range by varying the ratio of nozzle to dome end flow.

The molybdenum tie-rod core is being investigated with respect to run profile for the NRX-A1 cold-flow tests. Its ductile-brittle transition temperature is -30°F, and the minimum core temperature during a cold-flow profile could be -170°F.

Expected pressure ranges have been issued for selection of instruments for the NRX-A1 and NRX-A2 reactor tests.

G. HEAT TRANSFER DATA

A report is in preparation comparing Lewis Research Center experimental two-phase flow and heat-transfer data with calculated values from the

the transient analysis thermal (TRATH) code. Comparison with experimental data appears good for approximately the first half of the test section. The difference increases as the axial station increases beyond two feet. The calculated pressure loss across the test section was an average of 17% higher than the experimental data. The differences are believed attributable to the assumption in the TRATH code of two-phase equilibrium of the fluid.

3. TRANSIENT FLOW ANALYSIS AND TEST

Flow tests, which have been performed through a heated test section, indicate no significant effects on the fluid flow and heat transfer. A higher resistance test section, now being fabricated, will be used to verify this behavior at higher power levels.

Additional tests have been performed using a modified aluminum test section at flow conditions which approximate the conditions which will prevail in the reflector of the engine.

Analytical studies and tests have been performed to determine the frequency response of the thermocouples used in the test system. Results indicate that the frequency response ranged from 20 to 50 cps. In addition, cursory evaluations of optical techniques to discriminate flow conditions have been performed. Results indicate feasibility, and additional studies are being made to determine equipment requirements for a laboratory system.

1.3.3 NUCLEAR SUBSYSTEM

A. REACTOR NUCLEAR DESIGN AND RADIATION ANALYSIS

1. NRX-A2 Fuel Loading

Since the new fuel gradation differs appreciably from the earlier tentative zoning described in WANL-TME-273, the NRX-A2 reactivity and power distribution are being re-examined. Two-dimensional R-Θ calculations have been made with the revised loading for both the cold and operating conditions. Comparison of the cold problem with a similar calculation for Kiwi B-4A, both with control drums at 90°, indicates that NRX-A2 is $0.48 more reactive than Kiwi B-4A.

Since the NRX-A2 reactivity is reduced below previous estimates, the margin available to cover uncertainty in calculation and tolerance buildup has been reduced. Should it prove necessary to recover this loss, the feasibility of two modifications of the NRX-A design is under consideration:

a. Introduction of a higher loading. It appears that a higher loading, say 450 Mg/cc, could be utilized in place of the remainder of the central loading zone not yet fabricated. Roughly $1.0 in reactivity could be gained by this method.

b. Substitution of single-hole unfueled elements for the shimmable thirteen-hole elements in NRX-A. About $.50 may be gained by this approach above that obtained by inserting graphite shim pencils in the present thirteen-hole design.

2. Axial Power Study

Because of the difficulty in procuring gadolinium - stainless steel cluster plates, the plates for NRX-A2 are to be made of a silver-indium-cadmium alloy. Consistent one-dimensional transport calculations for this composition, for the 1-wt% gadolinium in stainless steel and for 1-wt% boron 10 in stainless steel, were prepared.

The centerline peaking, as calculated with two-dimensional transport theory, agrees very well with such one-dimensional predictions.

Off-centerline, an increase of 5% was observed in R-Z calculations. The effect of streaming through the coolant holes in the cluster plate was found to be very small.

3. NRX-A Experiments Performed in Kiwi-B4 ZEPO

The NRX-A fuel substitution experiments, tantalum carbide shim experiments, and experiments in shipping poison wire are undergoing detailed study to confirm the results obtained in the preliminary investigation. Chemical analysis is being made of a sampling of NRX and Kiwi elements used in the ZEPO experiment. Several numerical calculations were performed to yield accurate extensions of the measured ZEPO reactivity values to full core values.

The analysis of the B(4)C wire experiments indicated that the preliminary results reported for the wet case correspond to about a 50% flooded core. An analytical method of extrapolating these results to a fully flooded core is being devised.

4. Methods Development

Comparisons were made of the power distributions calculated through use of the Standard Design Method (SDM), with fuel-element gamma scan measurements made in Los Alamos Kiwi-B4 ZEPO. The calculated edge power peaking was found to agree with extrapolation of gamma scan data to approximately ±5%. Investigation was made of the effect on calculated power distributions of increasing the number of thermal groups from the presently used 5 thermal group scheme. Increasing the number of thermal groups from 5 to 12 increased the edge peaking by approximately 5% in cold reactors. The effect of thermal group numbers on hot reactor power is underway.

Several hot beryllium-reflected, graphite-moderated UCRL hot-box experiments were analyzed. The SDM appeared to adequately calculate reactivity for low C/U ratio (approximately 300) cores, underestimating K_{eff} by approximately 1%.

Formulation was completed of the model to be used in the calculation of power factors for each coolant channel and of the method for determining

correction factors from analysis of PAX power distribution measurements. This was embodied in a digital program, which is in its initial stages.

A procedure has been developed for accurate representation of the control vanes in one thermal group R and R, Z calculations. This procedure gives good agreement on power distribution and eigenvalue when compared to problems having explicitly represented control planes. The extension of this procedure to multi-thermal group problems is underway.

B. SHIELDING AND RADIATION ANALYSIS

1. NRX Radiation Analysis

The calculation of secondary gamma source terms in the NRX components, including the flight type shield and the mockup shield, was completed. These sources include neutron capture gamma rays and gamma rays from inelastic scattering.

A major effort was exerted to obtain heating rates in the NRX-A2 assembly. All necessary core gamma rays, secondary gamma rays, and neutron heating data have been calculated. Total heating rates are being determined and reduced to a form suitable for thermal analysis.

A comparison of calculated and measured radiation levels around the Kiwi-B reactor was initiated.

The specifications of impurities in electrolytically and chemically refined beryllium are being reviewed to establish the conditions for reuse of reflectors in the NRX test program. The original study was based on three full power exposures in 30 days. Since these conditions may not be reached until late in the program, it is desired to establish the exposure limit at which each material will not exceed acceptable radiation levels.

A report of the factors which will affect the flight shield design criteria is being prepared. This report will include the interrelation of several parameters which must be considered simultaneously to establish the optimum shield system weight.

2. Methods Development

The Monte Carlo Program 18-0 was used to generate heating rates in all NRX components (excluding the shield) due to gamma rays born in each component. These heating rates are being reduced to a form suitable for thermal analysis.

Program 18-0 was used to calculate heating from core gamma rays in the flight-type shield. Sufficient runs were made to obtain acceptable statistics. The heating rate data are being reduced to a useable form.

A FORTRAN code was written which computes the average axial and radial heating rate distribution in a region from Programs 14-0 and CURE data. Another code was written to facilitate the reduction of the Program 18-0 output data. This code calculates the average energy deposited in each region as well as the statistical fluctuation in each region.

Modifications were made in the neutron balance program in an effort to obtain a more favorable comparison with the DTK code.

C. REACTOR CRITICAL TESTS

A prototype control-drum drive was successfully conducted through all functional performance tests. It was then put on life test and completed 2300 operational cycles (rotate full out and scram) before a failure. Subsequent disassembly and inspection placed the failure at the shaft - bearing nut interface. Design review of the failure is expected to eliminate the type of failure by tolerance adjustment and quality control and inspection techniques. Vendor deliveries are not affected by the design resolution.

The following documents were completed in draft form and submitted to the WANL Nuclear Safety Committee for review:

WANEF Operations Manual

WANEF Experimental Plan for PAX

WANEF Operating Limits

Other documentation required for facility activation is in preparation and is expected to be completed in the next report period.

D. REACTOR PHYSICS AND MATHEMATICS

1. Physics

The non-separable reactor kinetics program is complete. This program solves the time-dependent multigroup diffusion equations in two dimensions with any number of delayed neutron groups. A full report on this program will be completed in September.

Work is continuing on the preparation of a new cross-section library.

The revised conditional Monte Carlo program is complete and debugged. Present work on this program is directed toward reducing computer time by reprograming some sub-routines in machine language.

2. Mathematics

A spectral analysis of some data taken from the Kiwi B-4A cold-flow test is complete. Several computer programs have been written to facilitate the analysis; the most important being an auto- and cross-correlation followed by auto- and cross-spectrum calculations.

A theoretical model to simulate vibration of fuel clusters has been programmed for the 7094 digital computer. This program takes account of collision of clusters, but, while successful for small amplitude vibrations, it fails at large amplitudes. A reformulation of the problem has also been programmed, but is not yet debugged.

Item 1.3.4 **NUCLEAR SUBSYSTEMS REACTOR CONTROL SYSTEM**

Reported under Items 1.3.2, 1.5, and 2.4.

Item 1.3.5 FUEL ELEMENT FABRICATION AND DEVELOPMENT

A. FABRICATION

1. Raw Materials

3M fuel is being delivered on schedule and with minor exceptions meets specification requirements. A preliminary batch of fuel elements has been fabricated and has been processed through leaching. These elements are being used to determine the processing characteristics of the 3M particles so that process adjustments can be made if they behave differently than the NUMEC particles.

Recent data received from Davison indicates that considerable improvement has been made in the quality of their product. It is expected that Davison will be permitted to begin the enriched order in the near future.

2. Process

The processing of fuel elements for NRX-A2 and special test pieces has continued. The only major problem continues to be that of cooling-passage coating, and all efforts are being directed toward the elimination of this problem.

3. Inspection

Improvements in the R-F bridge portion of the eddy current system have yielded a much better trace with minimal background noise. All components for the second system have been received, and this system is being built.

The Strontium-90 microspheres for the "Beta Back Scatter" equipment have been received and are being incorporated into probes. The coating thickness of blocks is being measured with this equipment, and longer probes for element usage are being constructed.

4. Equipment

Both dual furnaces are activated and suitable for support-block coating. The new vapor deposition furnace is installed and undergoing final checkout. First coating runs should begin the first week in August.

B. FUEL ELEMENT PROCESS DEVELOPMENT AND CONTROL

The binder viscosity work which had been planned for this month has been delayed. This work was intended to determine the feasibility of increasing the efficiency of the mixing operation by a change in binder viscosity.

Drawings have been completed for a modified extrusion-die feed-hole insert. This modification is intended to substitute a hex-shaped feed hole of a size equal in area to the twelve feed holes presently used. The intent of the modification is a further reduction in extrusion pattern in the web sections between the outer twelve holes.

The Hang-Firing experiments in bake have been conducted on enriched fuel elements with satisfactory results. Two enriched elements of 485 mg/cc loading were processed together. One was baked in the normal manner and one Hang-Fired. The results indicate a maximum bow of 0.032-in. at 37-in. for the standard element, and 0.013-in. at 51-in. for the one which was suspended. The longitudinal shrinkage for these elements was 1.98% for the standard element and 1.96% for the suspended element. The across-flats measurements for both elements were between 0.7882 and 0.7899.

A bake run of 90 ea. 13-hole elements was made with all of the elements suspended. These have not been graphitized, however, and no data is available.

All of the above pieces were suspended within the normal bake fixture. A fixture has been fabricated which will permit the elements to hang free.

One enriched fuel element (No. 7057 - 458 mg/cc) was extruded with tooling intended to yield holes of finished diameter in the "as graphitized" condition. Measurements indicated the spread of hole diameter, As-Graphitized, was 0.0979 to 0.0991.

The element was given a simulated coating cycle, sectioned into 2 inch pieces, and each piece checked for hole diameters.

Tooling to permit sizing of both holes and hex shape is scheduled to be delivered early in August.

Shipment will be made during the first week of August of the remainder of the special particles produced by 3M and Davison which contain a range of substrate carbon levels and coating densities. These particles are to be used for evaluation of the independent effects of substrate carbon and coating density (and deposition temperature) on uranium migration.

The techniques for measuring particle coating density have been re-examined in view of discrepancies encountered when measuring the density of crushed pyrographite of known density when using water, mercury, and kerosene in the pycnometer. It now appears that the best results can be obtained by using conventional pycnometer techniques with water. Fuel particle specifications will be altered to reflect this change.

C. REACTOR COMPONENT FLOW AND CORROSION PROPERTIES

1. A 2 - Single Element Corrosion and Flow Tests

A total of 17 elements were tested during this report period (Nos. 54 to 70), including 2 each, coated and enriched fuel in graphite; 7 each, coated and natural fuel in graphite; and 8 each, coated and graphite only. Five of these survived five minutes or longer. The surviving elements all tend to show a corrosion rate of approximately one gram per minute of operation at an element maximum surface temperature of 4400 to 4900°R.

The use of a newly designed chuck, with ample clearance for expansion and flexible power leads, has eliminated chuck arcing problems in the test series for elements 5 through 70. Modifications were also made in the helium storage bank to permit more tests, of longer duration runs during each day.

2. A 4 - Support Block Flow Tests

Furnace chucks for mounting the bottom-support blocks in the high temperature furnace completed during June were recalled from the fabricator, and are being modified to reflect the successful experience recently gained during A-2 tests.

3. A 8 - Fuel Element Orifice Flow Tests

Production type fuel element orifices of all twelve sizes have been examined. Flow experiments were conducted and master orifices for the cold-flow test have been selected for nine sizes. From the data collected a partial curve has been established showing loss coefficient as a function orifice diameter. The coefficients are slightly higher than those obtained by LASL.

4. A 10 - Fuel Cluster High Temperature Test

Final design drawings are complete for the furnace, heat exchanger, and filter. Bids have been requested for the heat exchanger; the furnace and filter are ready for bid when the specifications are completed. Preliminary layout drawings of the helium and hydrogen systems are complete. The elbow transition (from the furnace to the heat exchanger) is in final design stage.

Long-lead items such as instruments and stainless steel fittings have been ordered. Approximately 25% of the test components have been requisitioned.

Investigation of a cluster electrical insulator medium between the center element and its surrounding elements has been initiated.

5. A 11 - Flow Induced Vibration Test

The construction of the hydrogen test facility was completed. The supplier for the fabrication and erection of the piping system was selected and the erection of the piping, pipe hangers, and supports was started.

The nitrogen supplier has started construction and erection of foundations and tanks for GN_2 and LN_2.

A specification for the gaseous hydrogen supply contract was written, bids were solicited, and an award made for the gaseous hydrogen supply contract. This contract includes provision for the leasing of two hydrogen storage trailers for two months until the GH_2 storage sphere is completed.

Installation of the instrumentation has started in the recently completed control room.

6. B 3 - Lateral Support and Seal Tests

A series of tests has been conducted to determine the influence of the size of the gap between filler strips on the flow past a lateral support segment. These tests were conducted using air at low pressure in a small plastic test rig with a single seal segment. The data are being analyzed. These tests conclude the tests planned for this rig.

The high-pressure single-seal test rig has been fabricated and is being installed in hydrogen Test Cell No. 1.

The design for the high pressure flat multiple seal test rig has been completed and is being detailed. Fabrication has been started using the layout. Bid requests for a pressure vessel for this test rig have been issued.

The design of a high pressure single seal test rig with heated graphite is 90% completed.

7. C 1 - Impedance Rings

Air tests are continuing on a model of the impedance rings for the inner reflector - outer reflector annulus. Impedance rings having various flow areas have been received, and the flow-pressure drop characteristics are being established.

Construction is continuing on a model of a larger section of the impedance ring for the inner reflector-outer reflector annulus.

Construction is continuing on the model to measure the loss coefficient for the impedance ring in the outer-reflector pressure vessel annulus.

8. D 2 - Beryllium Reflector Assembly Flow Tests

Installation of the facilities to conduct hydrogen experiments on the model of the beryllium reflector assembly is 95% complete. Test

procedures and check-off lists have been completed. A computer program for data reduction is being written.

9. D 4 - Flow Tests of Control Drum Shaft and Orifices

WANL-TME-403, describing preliminary experiments on a model of the control drum drive shaft, has been completed.

Tests are being continued on the model which reflects the redesigned parts. Calibration tests have been completed on a drive shaft having discharge holes 0.200-in.-dia. The remaining three drive shafts and five nozzle end bearing shafts, with various sizes of flow holes, are being calibrated.

Procurement of the parts for the scale model of the control drum, to determine the loss coefficients, is continuing.

10. G 2 - Flow Distribution Scale Model

Three designs of a scaled model are being analyzed concerning possible ranges of operation with various fluid mediums (water, gases, low viscosity liquids).

11. G 3 - Plugged Core Flow Tests

The design and specifications for the high pressure test vessel were completed. The drawing and specifications were sent out to eight fabricators for bids, and bids are to be received in early August 1963.

The test cell floor at WANHEF was modified by installing a larger foundation pad to accommodate the G-3 Test Unit.

A tentative pressure instrumentation scheme was developed which included the number of pressures required in the core and in the lateral support seal system of the test reactor.

Provisions are being made in the design of the instrumentation system at WANHEF so that the G-3 test requirements can be met without major modifications.

D. EVALUATION AND DEVELOPMENT OF REACTOR FUEL MATERIAL

1. Fuel Element Evaluation

a. Physical Properties

(1) Thermal Expansion

Thermal expansion measurements on niobium carbide, tantalum carbide, fueled graphite, and graphite cloth were made in the high-temperature dilatometer. The parametric study of graphite shrinkage as a function of time and temperature has been initiated. The cryogenic range dilatometer was calibrated and preliminary runs are being made.

(2) Thermal Conductivity

The room temperature thermal conductivity unit was completed and calibration studies are in progress. All components of the high-temperature thermal conductivity device have been received and final assembly is in progress.

b. Mechanical Properties

A series of room temperature tensile tests on specimens cut from beaded fueled graphite (180 mg u/cc) was performed. The results were comparable to tests performed previously on unfueled graphite specimens cut from the 19-hole geometry (i.e., wide scatter in the data, with average transverse tensile strengths of 2000 to 2100 psi, and average longitudinal tensile strengths of 3200 to 3500 psi).

Room-temperature compression tests were made on a series of full cross-section specimens of fueled graphite covering the loading range from 0 to 444 mg u/cc. The data do not indicate any effect which could be attributed to loading.

The first high temperature compression tests on fueled graphite were also accomplished during the report period. Two specimens, loaded to 440 mg u/cc, were tested at 2500°C at strain rates of 0.02 and 0.2 in./min, respectively. Although both specimens exhibited approximately the

same compressive strength (10,000 to 11,000 psi), the specimen tested at the slower strain rate showed approximately 20% plastic deformation, as compared with about 6% for the sample strained at the faster rate. These studies will be continued with particular emphasis on the plastic deformation and creep-rate characteristics of the fuel material.

The second half of the quality-control elements for the Vibration I core were received from Oak Ridge. The elements have been sectioned and are being tested in flexure.

A number of Vibration I elements which were rejected by radiography were selected for eddy current testing to correlate radiography and eddy current testing. These correlation studies are to be followed by flexure testing in an attempt to establish improved standards for eddy-current testing of fuel elements. Fuel elements having representative transverse and longitudinal cracks, inclusions, and excessive porosity were selected for the study.

c. Hydrogen Corrosion Studies

Exhaustive studies of elements previously tested were undertaken in an attempt to define the adequacy of the present test conditions and to improve the evaluation procedures being used.

Careful metallographic and mercury porosimetry studies of an element (S/N 4050 exposed to 2 5-min hydrogen corrosion tests at 3550°F) along its length, and correlation of these results with the temperature profile prevalent during the tests revealed a corrosion region (undercutting and pore enlargement) corresponding to temperatures of 1500 to 1700°C; above 1700°C there was a decrease in corrosion for about 100 to 150°C followed by a second region of high corrosion at the high-temperature end of the element. The extensive corrosion at 1500 to 1700°C has been attributed to local attack near cracks in the niobium carbide coating which would not be expected to close-up until the coating temperature was attained (i.e., at about 1900°C). This result points out that a 2475°C test may not necessarily be the most severe test of fuel-element performance, and reveals the necessity of carrying out studies over a range of temperature and time conditions.

These studies also showed that corrosion in the low-temperature region is characterized by local undercutting below a crack, whereas at higher temperatures, the undercutting is more general in appearance. Corrosion at 1500 to 1700°C and above 1900°C exhibited similar pore enlargement characteristics.

Consideration is being given to the development of electrical resistivity and gas permeability tests to evaluate the extent of hydrogen corrosion along the length of a fuel element. Both of the methods under consideration will reveal the extent of carbon loss from small sections of the fuel element.

d. Reactor Shut-Down Corrosion Studies

The reaction of niobium carbide slugs which were treated with dry nitrogen at 700°C with a flow rate of one liter per minute showed

Weight Gain micrograms/cm^2	After Time in hr
8.1	7.4 hr at 700°C
52.9	25 hr at 700°C
409.8	53 hr at 700°C

This gain in weight was much greater than for slugs treated with nitrogen at 550°C:

16.5	20 hr at 550°C

These results are different than those obtained on niobium carbide powder which showed little difference in behavior at 550 and 700°C reaction treatments. From studies of the type described above, and observations of the physical behavior of the various forms of niobium carbide during exposure to nitrogen, the following tentative conclusions are offered.

(1) Hot-pressed niobium carbide slugs and vapor deposited niobium carbide form a blue surface coating after about seven hours

at both 550 and 700°C. These surface coatings then change to gray and finally to white as exposure times are extended. After about 50 hours, the coating appears to exfoliate, and the reaction proceeds at a relatively high and constant rate. Niobium carbide powder seems to follow a similar reaction pattern initially, but apparently the reaction products are more adherent and the reaction slows down even at 700°C.

(2) The color sequence produced on the coating surface as the reaction proceeds suggests (although it has not been confirmed) that oxygen may be the principal reacting gas, even though it is present in relatively small amounts (approximately 200 ppm) in dry nitrogen.

(3) The results indicate that 700°C is too high a temperature for nitrogen cooling following a hot test. Further study is required before a conclusion can be reached regarding the use of nitrogen at 550°C.

e. Hydrolysis Studies

Heat treatment of 3M and numec particles at temperatures of 2400 and 2600°C for 1/2 hour results in rapid weight increases during hydrolysis at 100°F at 100% relative humidity. Heat treatment at 1800 and 2200°C for the same time results in weight losses during subsequent hydrolysis. The weight changes observed do not stabilize in one week of the hydrolysis. The hydrolysis tests are continuing for longer exposure to the moist air.

f. Fuel Element Thermal Stress Experiments

A probing experiment to define conditions for thermal stress testing of graphite matrix fuel elements has been completed. The test involved a self-resistance heated segment of unfueled B-4 element, 5-in.-long, with a graphite sheath broached to accept the element as a circumferential container. The sheath was further broached with an axial channel allowing the flow of a coolant gas stream along one full face of the element. Temperature measurements were made through small holes in the heat shields and sheath with a micro-focusing optical pyrometer. A smaller hole was drilled to the center of the element to furnish temperature reference from the specimen interior.

Temperatures to 2200°C were readily obtained in the specimen interior. Future experiments will be carried out up to 2600°C. Helium was utilized as the coolant, with the heat capacity of its mass flow referenced to equivalent hydrogen flows. Experiments now in progress are expected to give rise to center-to-surface temperature differences of 200 to 600°C.

2. Basic Fuel Material Studies

a. X-ray Studies

The study of the ordering and graphitization of the pyrocarbon coatings removed from numec fuel particles has continued at temperatures of 1800, 2200, and 2400°C, and at times of 1-1/2 and 3 hours. The effect of the uranium carbide present during the heat treatment upon the transformation of described pyrocarbon to an ordered structure is marked. It has been observed that the breadth of the (002) line from the pyrocarbon coating first decreased, and later increased, with increasing heat treatment time at 2400°C.

The feasibility of measuring the preferred orientation (P.O.) of the graphite matrix in the extruded fuel was demonstrated using an hexagonal section of a pre-production element. The P.O. increases considerably from the center of the element to the external flat surfaces.

b. High-Temperature Behavior of Fuel Elements

A program has been initiated to determine the effect of heat treatment on the leaching loss of uranium from pyrocarbon coated fuel particles at 1900°C in hydrogen chloride gas. Particles from 3M, with and without heat treatment, will be leached, and the leaching loss determined by measuring both the uranium chloride in the hydrogen chloride effluent gas, and the uranium remaining in the particles after leaching.

Full hexagonal cross-sections (about 15 mils thick) of pre-production elements are now being examined by radiography. Individual particles and the particle distribution within the transverse section are

visible. An attempt to measure the uranium distribution is being made by means of an X-ray densitometer.

The electron micro-probe analysis for uranium distribution in 3M coated fuel particles has continued. A comparison of metallographic pictures with the electron microprobe results has shown that

> The migration zone observed metallographically corresponds to a plateau in uranium concentration of approximately 7 v/o.
>
> There are large uranium losses from sectioned fuel particle surfaces during heat treatment at 2200°C for 1/2 hour.

Electron microscopic examination of 3M and numec coated fuel particles has been initiated.

3. Fuel Element Development

a. Coated Particle Development

Sufficient information has been obtained from the room temperature fluidization tests in a glass apparatus to permit design of a high-temperature graphite-fluidized bed system. Design of the system for deposition of refractory metals from halide vapors on uncoated fluidized uranium carbide particles has been started. It is planned to use a 1-in.-dia graphite tube, in which approximately 50 gm of uranium carbide particles (approx. 100 microns diameter) can be fluidized over a 4-in. tube length with helium flow rates of 6 to 12 cu ft/hr.

b. Fuel Element Coating Development

Design has been completed of a chemical vapor deposition system for niobium carbide coating of sections of fuel elements. About half the components are assembled and orders have been placed for the remaining components. Limited quantities of all raw materials necessary for niobium carbide deposition are now on hand.

Following assembly and checkout of the system, it is planned first to perform a parametric study of the effect of fuel-element temperature on niobium-carbide formation.

A parallel effort of longer range utility is being undertaken, wherein the possible use of niobium metal-organic compounds to form vapor deposited coatings will be investigated. The use of metal-organics holds promise that the present uranium leaching problem may be allowable with metal-organics, thus permitting a greater measure of control over the integrity of the coating in the critical range between 1600 and 1800°C.

c. Binder Development

Preliminary observations of the DTA analysis of coke samples made with monomer-free Varcum 8251 in Dioxane showed low-curing exotherms, and unusually pore-free bodies. Studies of the extrusion behavior of small batches of material containing the monomer free Varcum have been initiated.

4. Irradiation Experiments

a. Thermal Stress Experiments in Treat

The initial thermal stress experiments carried out in TREAT were reported last month. The following metallographic examination of sample CEN-148 revealed some microcracking in the graphite matrix. It is considered significant that micro- and macro-cracking of beaded fuel samples occurs in the temperature range between 2380 and 2700°C with temperature differences of the order of 180 to 250°C.

Work continued in preparation for the experiments on 6-inch long sections of NERVA fuel. Equipment design concepts were reviewed and approved by Argonne National Laboratory (TREAT) personnel. The shielding cask design was reviewed and approved by the Bureau of Explosives, Interstate Commerce Commission.

b. GETR Fuel Material Irradiation Experiments

The planned irradiation of a series of six capsules, designated the WANL-TT series, has been delayed from GETR Cycle 46 to Cycle 47. All steel and graphite parts for the series of capsules have been machined, and capsule assembly will begin shortly.

An insertion mock-up was assembled to test possibility of the insertion of the capsule design through the bends of the Trail Cable Facility. The insertion test is planned for the re-fueling shutdown during Cycle 46, on or about August 2.

An addendum to the original Safeguards Analysis Report is being prepared which will request approval for irradiation of fuel containing 600 to 650 mg U/cc in one of the capsules.

c. High Temperature In-Pile Loop

The availability of in-pile facilities for studying NERVA fuel behavior in a dynamic environment was explored with Phillips Petroleum Personnel.

Item 1.3.6 DEVELOPMENT, FABRICATION, PROCUREMENT, MANUFACTURING

A. DEVELOPMENT FABRICATION, AND PROCUREMENT

Procurement effort continued for all reactor component testing. This included procurement modifications consistent with design revisions and new procurement of design releases to meet test program schedule objectives.

1 Shield

Simulated shield machining for NRX-A1 was modified to include instrumentation machining. Machining of the NRX-A2 simulated shield is in process. All miscellaneous shield items have been released for fabrication.

2. Inner Reflector

The inner reflector cylinder, lateral support seal segments, lateral support seal springs, and lateral support seal brackets for initial vibration core testing were delivered.

3 Outer Reflector

Delivery of outer reflector components for the Phase I vibration test is essentially completed.

The split tubes, control drum cylinders, and miscellaneous items of hardware have been delivered for NRX-A1 and NRX-A2 outer reflectors.

4. Core

All unloaded core elements for NRX-A1, including elements modified for instrumentation were received from UCNC, Y-12. The vendor began extrusion of elements for the plugged channel core. Of the loaded elements for NRX-A2, 80% are now in process.

Astrofuel facility produced qualifying coating of sample support blocks. All irregular support blocks for Phase I vibration test reactor were received. Partial delivery was made for NRX-A1. Increased effort was directed towards development of a second coating source.

Silver - indium - cadmium NRX-A2 cluster plate material was received and the machining order was placed. Gadolinium strip material for sample cluster plates was received and found acceptable. An order was placed for machining these plates.

Two-thirds of the jet orifices for NRX-A1 were received. Initial delivery of tight tolerance orifices for NRX-A2 was received.

Sample liner tubes of the spiral groove design were produced from delivered straight tubes and passed initial inspection.

B. MANUFACTURING ENGINEERING AND SERVICES

1. Poison Rods

Development of braze closure of tube for retention of boron carbide is continuing. An alternate method of closure is under study for future use.

Polyethylene coating of rods has been established by use of shrink tubing. This operation is proceeding.

2. Tie Rods

Manufacture of specification grade tie rods is proceeding. 172 completed rods have been received, 58 rods are at heat treat, and 60 additional rods are ready for heat treat. Forty more will be ready for heat treat early in August.

The first rods received from heat treat showed some slight oxidation. Corrective action has been initiated with the supplier.

3. Orifices

Quantities of each size of orifices are available. Flow check by quality control is proceeding in line with assembly requirements.

Master orifices for each size have been selected.

Plastic caps for identification use are available.

4 Fabrication of 2219 Al Material for Application on Core Barrel and Dome End Seal

Necessary processing procedures for dome end seal are established. For the 54-inch high barrel, considerable distortion was occasioned during cold-water quench. These corrective methods are being developed: use of fog or hot water quench, increasing of sizing up to 2.0%, and restrainment of aging

5. Control Drum - 6061T6 Aluminum

Electron beam welding technique is being developed. Some adjustments will be needed after introduction of heat-sink effect of both fixture and control drum assembly

6 Flow Screen Fabrication

More definitive standards are being set up for sintering. A problem of excess braze alloy fluidity around the outer most 2 inches of the periphery was encountered on the production piece. The corrective action planned is use of stop off and reduced amounts of alloy in this area. For the future it may be necessary to develop a braze alloy with broader latitude in respect to manufacturing parameter.

7. Fabrication of Nickel Alloys for Application on Nozzle End Seal and Spring

Correction factors and fabrication methods are still under development to compensate for dimensional changes of inconel 718 during aging. Resistance and TIG welding techniques have been determined for the Inconel 718 nozzle seal and Inconel-X seal spring.

C REACTOR ASSEMBLY, PACKAGING AND SHIPPING

Orificing and clustering for Phase I vibration reactor has been completed and all clusters have been assembled into the core.

A mockup inner reflector, outer reflector, and core are being assembled for familiarization and tool try-out for NRX-A1. NRX-A1 instrumentation mockup work is being conducted on a second mockup inner reflector.

The round trip test run by railroad to NRDS of a reactor shipping container with a dummy load was completed. The container (inner and outer), dummy load, and railroad cars were instrumented throughout the test run.

Preparations are being made to start the assembly of NRX-A1.

Item 1.3.7 NUCLEAR SUBASSEMBLY

DEVELOPMENT TEST PLANNING AND OPERATION

There was no activity on this project.

Item 1.3.8 DEVELOPMENT TEST PLANNING AND ANALYSIS

A. GENERAL

WANL has been authorized to issue Revision 1 of the NRX-A1 Test Plan, subject to the removal of the preliminary Test Plan Section, NRX-A2 through NRX-A4, from this document.

A tentative power run profile for the NRX-A2 test was transmitted to REON.

Work continues on the preparation of the NRX-A1 Test Specification and the NRX-A2 Test Plan.

Meetings were held at LASL to discuss hot cell facility requirements for post-operational examination of the NRX-A2 reactor components. The discussions included the availability of necessary facilities at NRDS to perform these examinations.

B. NRDS, TEST OPERATIONS

On-the-job training of both technicians and engineering personnel continued.

Checkout of Test Cell "A" facility for NRX-A1 cold flow was started. An incomplete preliminary checkout of mixing chamber of Test Cell "A" was conducted.

A design package for modifications to the movable shed at Test Cell "A" was issued.

Data equipment was requisitioned through AGC and SNPO-N.

A preliminary design for the modification of Test Cell "A" Neutronics System was forwarded to LASL for approval.

Personnel buildup has continued as planned.

C. NUCLEAR SUBSYSTEM ASSEMBLY, DISASSEMBLY, AND POST-OPERATIVE OPERATIONS AT NRDS AND LASL

On-the-job training of both technicians and engineering personnel continued.

Test car assembly work has been started.

Effort has been spent writing procedures for reactor assembly, and for test car assembly, disassembly, and post operative inspection.

Item 1.3.9 PROJECT NE 1390 - REACTOR MODELS AND MOCKUPS

A. MODELS AND MOCKUPS

Both the instrumentation and assembly mockups for the HRX-A1 are now being assembled. These mockups reflect the latest design considerations.

Full-scale mockups of the inner reflector and core support plate, simulated transducers, and the core support ring were completed for the instrumentation mockup. In addition, graphite blocks have also been completed for use in simulation of the inner reflector cylinders during evaluation of instrumentation cement. Instrumentation stalk assembly braze plugs and fixture cylinders have been completed. These will be used for pressure testing the seal assembly.

B. REACTOR ANALYSIS FOR NON-NUCLEAR TEST SYSTEM (SIMULATORS)

There has been no activity on this project.

Item 1.4 THRUST CHAMBER ASSEMBLY

A. ASSEMBLY

The cryogenic pressure vessel seal testing feasibility study is continuing. The basic method of leak detection and measurement will be similar to the ambient seal tests which will utilize a bleed hole to collect leakage from a seal gland on each flange end of the pressure vessel. Liquid nitrogen is the tentative test fluid, and tests at -320°F are planned for December 1963 at the LRP Cryogenics Laboratory.

The ambient seal tests, which were to be performed during this report period, were postponed due to fabrication delays on the Structural Nozzle S/N 0000003. Tentative plans call for completion of the ambient seal tests during the month of August.

Special clamps were designed and put into fabrication to retain the forward metallic seal in the pressure vessel cylinder during assembly operations. The test specifications were modified to collect leakage of helium from holes drilled through the pressure vessel cylinder flanges into the metallic seal grooves.

Dynamic analyses in support of the TCA dynamic test program are continuing.

Five sets of metallic seals have been received at LRP and another seven sets are being lead-plated at the vendor.

Fabrication of the mass core simulator is continuing.

B. NOZZLES AND NOZZLE EXTENSIONS

1. Heated - Bleed Nozzles

a. NERVA Nozzle S/N 001N

The nozzle is scheduled to be cast at Howard Foundry next month.

b. Reactor Back-Up Nozzles - S/N 001L and S/N 002L

Reactor back-up nozzle S/N 001L will be cast next month at LRP Foundry.

Analysis of the flange failure of S/N 002L indicates that a high thermal stress is induced at the flange joint. This is caused by the large difference in temperature, during the start transient, of the aluminum nozzle flange and stainless steel ring on the nozzle-to-injector adapter. To correct this, a forged aluminum ring will be made which will more closely simulate the NERVA pressure vessel loads.

2. NRX-A Nozzles

Final drawings on the three-port nozzle, NRX-A1(CF) S/N 0000010, have been released. The weld procedure on the coolant tube joint has been corrected and incorporated.

NRX-A nozzle S/N 0000004 was completed and assembled with the nozzle-to-injector adapter. The complete nozzle jacket, flange, and part of the adapter will be glass wrapped. By totally encapsulating the flange, the thermal stress problem experienced on Reactor Backup S/N 002L will be eliminated.

NRX-A S/N 0000005 will be cast at Howard Foundry. NRX-A nozzle S/N 0000010, scheduled for NRX-A1, was prepared for casting at the AGC Foundry. NRX-A S/N 0000006 is being prepared for aluminum casting. The tubes for NRX-A nozzle S/N 0000011 were received and loaded on the mandrel. NRX-A nozzle S/N 0000007 was completed through furnace brazing and hydrotesting. Leakage occurred and the tube bundle is to be rebrazed.

3. Hot-Bleed Nozzles

Analyses were completed for Hot-Bleed port simulation testing at reactor conditions.

The final report is being prepared for the six Hot-Bleed port firings, using titan hardware, conducted earlier in this contract year.

Three sets of tubes have been repaired by removing the end fittings and welding new fittings to the inlet end of the tubes. These have been receive and inspected. Two sets (S/N 0000011 and S/N 0000012) have been diverted to NRX-A nozzle.

4. Adapters

a. Test Stand - Nozzle Water-Cooled Adapters

All work on this item was temporarily suspended this month to concentrate more effort on nozzle problems. Activity will be resumed next month.

b. Nozzle - Injector Adapters

Rework of adapter S/N 002K manifold bosses and installation of auxiliary passages from the overboard dump torus are complete. The flange which accepts the 4-in. valve has been removed and the adapter is prepared for installation of the dump system flange, which will accept a 5-in. valve.

Investigations are still underway in an effort to pinpoint the location and cause of the leakage between the casting and injector mounting flange of Adapter S/N 001N. Adapter S/N 002N is complete. No work was completed on Adapter S/N 003N, since it is waiting for rework of the proof and leak hydro tooling. Furnace brazing of Adapter S/N 004N has been completed.

As discussed in paragraph B,1, design has been initiated to replace the existing steel ring, bolted to the nozzle flange, with a 6061-T6 forged aluminum ring which will more closely simulate the pressure-vessel loads.

5. Injectors S/N 0241, 0242, 0260, 1482, 0112

The orifice pattern for S/N 0241, which will be used with the first NRX-A test assembly, is a modification of the pattern used for S/N 1482 and is calculated to reduce the total oxidizer orifice area.

Injector S/N 0241 is complete with the installation of copper face plates and baffles, and with the new orifice pattern drilled. The eroded channel of S/N 1482 has been removed, and brazing of the replacement ring is being done. This injector will also be modified to increase the pressure-drop across the oxidizer orifices. Injector S/N 0112, which was previously fired during the injector development program and resulted in the erosion of the outermost three channels, is being changed to convert the three outermost channels to copper face plates. Injectors S/N 0242 and 0260 will be changed to incorporate

copper face plates and copper baffles. With the additional rework which is necessary, these injectors are now only 40% completed. At present all weldable components such as manifold segments, inlets, gimbal pads, and ribs are being welded into place.

6. Extensions

The heat-transfer report on the nozzle skirt is being prepared.

All work on this item was temporarily suspended this month to concentrate effort on nozzle problems. Activity will be resumed next month.

C. THRUST STRUCTURE AND GIMBAL

The design of modifying S/N 0000001 lower thrust structure for use in the TPA tests was completed.

Work on the detail drawings of the upper thrust structure electrical connector mounting flange for the CFDTS is continuing.

Fabrication is continuing on the second, third and fourth thrust structure assemblies.

Fabrication is continuing on the TVCA simulators for the thrust structure resonance survey and the TCA dynamic tests.

All component parts for the first gimbal assembly have been completed. Fabrication of the component parts for the second and third gimbal assemblies is 50% complete. Fabrication of the gimbal fairings to be used in the TPA, TCA and CFDTS tests is continuing.

Static limit load testing of the lower thrust structure was initiated. Preliminary results indicate that the unit satisfactorily withstood the required boost load.

The test specification for the static limit load test of the upper thrust structure was completed. A portion of the instrumentation was installed for this test. All test tooling fabrication was completed.

The thrust structure resonance survey test specification was completed. Dynamic analyses in support of this test are continuing.

D. PRESSURE VESSEL

Project coordination of the titanium pressure vessel structural development program was provided by the structures test laboratory. The hydrostatic testing of the titanium pressure vessel was successfully completed. Test phases consisted of the instrumented limit proof test, the stress-coat test, and the limit load and deflection survey. Recorded data are being reduced to strains and deflections.

Preliminary results of the three hydrostatic test phases on the titanium pressure vessel indicate that all objectives were satisfied. Cycles of 100% (3 cycles), 107.5%, and 110% of limit proof were applied during the program without any visual detrimental effects to either the pressure vessel or structural nozzle (S/N 0000015). The stress analysis for the above two-zone hydrostatic test revealed that the theoretical strains compared quite favorably with the experimental data.

A test data report for the hydrostatic pressure test of the aluminum pressure vessel, S/N 000002, has been prepared and is ready for publication.

A test plan for vendor acceptance proof testing of aluminum pressure vessels was prepared and will be sent to the vendor for proof testing of pressure vessels S/N 0000003 through S/N 0000007.

Pressure vessel S/N 0000001 which was reworked for the WANL criticality test was shipped to WANL early in this report period.

Structural nozzle S/N 0000015 which was used in structural tests is being prepared for shipment to WANL for use with the criticality vessel.

The closure of pressure vessel S/N 0000002 was shipped to the vendor to have the two instrumentation ports repaired. The unit has been returned to LRP and inspection indicates that the weld repair was successful.

Fabrication of pressure vessels S/N 000003 and S/N 000004 is progressing on schedule. Fabrication of the closure for pressure vessel S/N 0000003 was initiated.

Fabrication of structural nozzle S/N 0000003 is continuing. The nozzle was re-heat-treated to the T-6 condition after weld repair and grinding was performed on some voids and cracks.

E. KIWI-B NOZZLE S/N 001K

Additional heat transfer analysis shows that thermal shock is not the prime cause of failure. However, thermal stresses and stress concentrations which exist in the aluminum jacket (created by the interlocks attached to the tubes), combined with pressure loading, caused some failure. A topical report will be prepared on this subject.

F. ROLL CONTROL NOZZLES

This effort has been deferred to CY 1964.

G. HYBRID NOZZLES S/N 001H and S/N 002H

Hybrid nozzle S/N 001H was cast at Howard Foundry and has been received by LRP. X-rays indicate round gas porosity in the convergent portion of the nozzle.

Hybrid nozzle S/N 002H was cast at AGC Foundry and radiographically inspected, test samples from the flange area were removed and tested, and the machining operations which were required prior to heat treatment of the nozzle were completed. For seventeen specimens machined from the flange of S/N 002H and heat treated to the T-6 condition, the average tensile properties were:

ultimate tensile strength	- 41 ksi
yield tensile strength	- 27 ksi
elongation	- 15%

Heat treatment consisted of solution treating at 1010°F for 18 hours, holding for 18 hours, and aging at 310°F for 2 hours. Round gas porosity up to 1-1/2 inches in diameter was observed in the X-rays; however, the nozzle is repairable by grinding and weld repairing.

H. ALTERNATE NOZZLE DESIGN

The U-tube brazing samples have been subjected to hydrostatic structural testing. The first sample was given a satisfactory proof and leak test

and a destruct test, in which failure occurred at 9800 psig. The part was returned to Materials Engineering for evaluation.

The second sample did not pass the leak test and was returned to Materials Engineering for study. Brazing methods are still under investigation both by REON and the Marquardt Corporation.

Marquardt is continuing fabrication of the first U-tube nozzle, and has completed the rough machining and the ultrasonic inspection of the jacket forging. The forging is now going into the intermediate machining operation. Rough machining of the second forging has been initiated at AGC. Ultrasonic methods and levels of quality have been investigated and will be evaluated for applicability on this nozzle

J. HYBRID NOZZLE - ACPI PRESSURE VESSEL HYDROTEST

The final report of the NERVA hydrostatic test is in publication.

K. APPLIED RESEARCH PROGRAM

During this report period, analysis of the data on the reaction of graphite with H_2-O_2 combustion products was essentially completed.

The nozzle hot-gas heat transfer tests are 40% complete.

Preliminary bottom support plate tests with Lucite (Polymethyl Methacrylate) coating of the inside surfaces of the nozzle cylindrical and convergent sections and the bleed port were completed. The objective of the preliminary tests is to visually inspect flow patterns and hot spots in the nozzle and bleed port, and to facilitate locating the thermocouples and slope calorimeters for the subsequent heat transfer runs.

Work on correlation of the LH_2 heat-transfer data was continued.

L. PROPELLANT FEED LINE FOR RN-6

The design of the propellant feed line for use with the Rocketdyne RN-6 nozzle was completed. Purchasing procedures were started.

M. CAMERAS AND LIGHTS

Data relative to this effort is reported in Item 2.2.

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Item 1.5 ENGINE CONTROLS

A. CONTROL SYSTEM ANALYSIS

The major portion of the analysis effort at REON performed during this period was related to engine system analysis and has been reported under Task Item 1.1.6.

Analog studies have shown that the Kiwi-B4A controls will function adequately for NRX reactors. These studies were made with the latest models and included in a log-kinetics simulation for possible extension to malfunction studies.

The NRX reactor control hardware was tested with the analog model and found to work satisfactorily.

A study is being conducted of the feed system for use with the gas mixing chamber. Preliminary results of this study indicate a reasonable correlation with the test results. A temperature control system is presently being designed.

B. REACTOR CONTROL SYSTEM DESIGN

A reactor controller which operates on the same power supply voltage as the engine control system has been designed, and construction of a breadboard has commenced. This is a solid-state (with no relays) controller operating on a control cycle similar to the reference reactor control system.

A reactor simulator has been designed for use in the control development electronics lab which will close the loop around the breadboard controller. The reactor simulator will be used to ensure that the controller is operating correctly prior to the system computer analysis.

The fabrication and assembly of the NRX control equipment has been completed, and acceptance tests are in process. The following equipment has completed inspection and is available for shipment to NRDS:

1. Individual drum positioner
2. The electronic variable base programmer
3. The controller/sequencer

4. The automatic cooldown system
5. Power supplies
6. Power-control signal calibration unit

C. ACTUATORS

1. TPCV Actuator and Drive Amplifiers

Difficulties were encountered with the dynamic shaft seal. Two failures occurred during room-temperature acceptance tests. The carbon-face seal ring failed under hoop stresses, and alternate seal configurations are being manufactured and tested. Preliminary testing of five Hi-T lubricated metal rings after run-in, while using gaseous nitrogen, showed an equivalent hydrogen leakage up the shaft of 0.004 lb/sec.

Ball-bearing tests are being conducted using SP polymer retainers and Hi-T lubricated retainers. Sufficient data has not yet been assembled to determine the best configuration or material. Additional bearings have been purchased for further testing.

The liquid-nitrogen heat exchanger was checked out at Azusa. The high-temperature stand to be used in conjunction with the heat exchanger for environmental testing was readied for installation. Testing using these devices should be ready to start in September.

The test console and cabling for the August TPCV radiation test were shipped to Fort Worth.

Negotiations were completed with General Electric on the piston-type TPCV, and a contract to start design and fabrication is expected to be let early in August.

2. Drum Actuators and Drive Amplifiers

The preliminary design of the second generation prototypes of the electro-pneumatic drum control actuators has been developed in accordance with WANL Specification E-675378.

A preliminary mechanical design layout was started and design details were studied. Tests on components to be used in the design were conducted.

Equipment and fixtures for future tests are being procured. Test components and related fixtures for future radiation tests at GTR, Fort Worth, are being installed and checked out. WANL Equipment Specification 675383 for drive amplifiers for the drum actuators was completed.

The hydraulic drum actuator assembly for NRX tests have been checked out at ACFI. The torque transducers which will be coupled to the actuators have been assembled and are under test. These actuators and transducers will be shipped to the test site from ACFI next month.

D. SYSTEM AMPLIFIERS

The evaluation of magnetic core characteristics at various temperatures was completed and data submitted in Bendix Report 2353. The results of the evaluation indicate that special annealed square Permalloy 80 Nickel-Iron cores with an M_gO damping agent have the best performance.

Four input stages were fabricated for evaluation in combined cryogenic vibration and shock tests.

Temperature tests are completed on the second set of experimental amplifiers, which are ready for final assembly.

A ceramic tube difference amplifier was completed and delivered for radiation effects testing in GTR test No. 7 in August.

E. PROGRAMMER AND REMOTE ENGINE CONTROL

The Remote Engine Control System simulation work was continued. The Engine Control console will be finished next month and ready for check-out. The other consoles will be completed later.

Sixteen six-conductor cables and their terminations in the controls lab and the analog computer room are on order.

The Ground Test Programmer will be located in the computer room. This unit includes the mode selector circuits and the manual control circuits. Malfunction, Facilities, and Engine Programmer systems will be included in accordance with future scheduling.

Coordination meetings were held with AGC-LRP test and facility personnel concerning the CFDTS.

F. ENGINE HARNESS

Preparation of a preliminary electrical harness schematic for the CFDTS engine was completed.

The vendor capability study, conducted to obtain qualified vendors for NEMA cables and connectors, has been completed. The results will be published during the month of August.

The thermal analysis results expected this month have been delayed due to the additions of a moisture barrier to the analytical model and required further analysis. The results of the analysis will be published next month.

Item 1.6 DESTRUCT SYSTEM

A. BASIC FRAGMENTATION RESEARCH

1. Explosive Fragmentation Tests

Experiments were conducted, as part of the fragmentation research program, to provide an additional basis for evaluation of the adequate nature and further utility of the full-scale simulated targets currently being used in ACDS and PODS concept tests.

In previous explosive fragmentation tests (which were conducted in air), it was not possible to completely recover all of the fragmented graphite particles because a portion of these were transformed either into dust or large pieces which were dispersed beyond the area of recovery. As a result, such tests were of questionable value because a portion of the resulting fragmented material was not available for analysis. This fragmentation recovery problem was recently overcome by the use of a setup in which graphite targets were explosively fragmented within a water filled tank. The water in the tank was used to reduce particle velocities to a point at which fragmented material could be retained by the tank walls. After each test the tank was drained and fragmented particles of various sizes were recovered on screens of different mesh sizes. The quantities of material recovered on different size screens provided a means of evaluating the capability of different explosive and rod target configuration and combinations.

Recent tests so conducted have provided some insight into the fragmentation process. In these tests, explosive charges were placed at the center of three layered cylindrical bundles of 3/4-inch-dia. by 6-inch-long solid graphite rods. Rod shaped explosive charges were placed at the center of the bundle, which was then placed in a polyethylene bag and immersed in the completely enclosed and water filled tank. After detonation of the explosive charge it was possible to recover all of the fragmented particles in every instance.

Tests were conducted in which explosives weighing from 24 to 132 gm were detonated, while the rod bundles were confined within a 6-in.-O.D. x 0.75-in.-wall steel pipe. It was found that increasing the explosive weight from 24 to 132 grams resulted in a decrease of fragments over 0.433 inch screen size from 70 to 52%. In another experiment, the ends of the steel pipe were confined with 0.75-in. steel plate held in place with four 0.375-in.-dia. steel bolts. After this test, with greater confinement, it was found that over 60% of the rods remaining were over 1.25 inches long, as compared with a test in which the ends of the steel pipe section were not closed and approximately 7% of the remaining rods exceeded this length. A subsequent test in which the graphite rods were taped together and not inserted into steel pipe resulted in approximately 50% of the remaining pieces exceeding this length. These tests indicate that a certain amount of confinement assists in the fragmentation, while too great an amount of confinement results in poor fragmentation. It would appear from these tests that there is an optimum confinement and explosive charge weight which will result in the achievement of the greatest degree of fragmentation for a given target.

It was additionally observed that rod fragmentation was greatest for those rods adjacent to the steel pipe wall when higher explosive weights were used. In the test where confinement was the greatest, a larger percent of the remaining fragments was compressed and showed evidence of plastic deformation. These results indicate that careful consideration should be given to the adequacy of end confinement simulation on full-scale PODS and ACDS targets.

2. Photographic Display of Shockwaves

In other tests it was possible to develop photographic techniques which were successful in displaying the progress of a shockwave through plexiglass material having holes to simulate in some degree the holes in fuel elements. The shockwave was observed as a dark front due to density change in the plexiglass material. Tests of this nature are intended to provide additional information on the attenuation of shockwave fronts and to assist in determining

the extent from the walls of a projectile in which this phenomena may be considered to contribute appreciably to the fragmentation process.

3. Time of Arrival Instrumentation

Experiments with piezoelectric transducers were performed in a continuing investigation of shock phenomena in graphite samples, an area in which photographic techniques have proven to be unsuccessful. Measurements of time of arrival have been successful at distances as far as 4 inches from the explosive charge. Beyond this distance, interference from other waves has presented problems in isolating the wave of interest.

B. ANTICRITICALITY STUDY

As a further demonstration of the Mark A concept feasibility and also to determine whether proximity to the ground has affected the results of previous ACDS tests, the destruction of a full-scale engine target from the top of a 50-foot tower is planned. The results of this test will be compared with an identical previous test from the top of a 10-foot stand to provide the basis for a determination of ground proximity effects should this positional test demonstrate that such effects exist.

C. RADIATION EFFECTS EXPERIMENTS

In development of an irradiation capsule to withstand the detonation of 3.0 gm of PETN explosive, a method was developed in which an impact would cause the detonation of the explosive while the capsule was in a water displacement apparatus which is used to indicate whether small quantities of gas are evolved. Four tests were performed testing each of these gasket sealant methods: a small lead gasket, a Flexitallic gasket, a Flexitallic gasket with a blast cup, and a small lead gasket with a blast cup.

In the test using only the small lead gasket, a steady stream of bubbles began to leak from the capsule following detonation of the explosive. After approximately 5 minutes, 2120 cc of gas had escaped, following which the capsule was opened and another 130 cc of gas evolved. This test was considered to be unsatisfactory, therefore no additional testing of this design was planned.

In the test using only Flexitallic gasket, bubbles began to appear around the gasket approximately 1 minute after detonation. These bubbles finally began releasing at the rate of approximately one bubble every four seconds. After four minutes, the capsule was opened and 2280 cc of gas was released.

Before conducting the tests with capsules having blast cups, it was considered desirable to increase from 1.5 to 1.8 grams the explosive to be irradiated, to allow for spillage when performing impact tests. Because of this new requirement, it was decided that the quantity of explosives to be tested in the irradiation capsules having blast cups should be increased from 3.0 to 3.6 grams.

The next test was conducted to determine whether 3.6 grams of PETN explosive could be detonated without gas leakage in a capsule having a blast cup and a Flexitallic gasket seal. Following the detonation of the explosive, the gas leakage rate was found to be comparable to the test in which 3.0 grams were detonated in a capsule having a Flexitallic gasket without a blast cup. A crude measurement indicated that approximately 16 cc of gas escaped over a four-minute time period, with a bubble escape rate equivalent to approximately 0.067 cc/sec.

In the next test, 3.6 grams of PETN explosive was detonated in a capsule having a blast cup and a thin lead gasket. Following detonation of the explosive 2.2 cc of gas was evolved. Again upon opening the capsule, approximately 3,000 cc of gas was evolved.

Other crude measurements were taken to determine the extent of damage which might occur to surrounding structures or parts when explosives within the capsule were detonated in a tank filled with water. In a test where 3.6 grams of PETN was detonated in a capsule located under water at a distance of 19 inches from a similarly immersed 150-watt light bulb, the light bulb survived without breakage. In another test a .0008 inch thickness of aluminum foil located in a fixture seven inches from a capsule survived without damage the shock of explosive, the detonation of which, within the capsule, was transmitted through surrounding water.

The results of these tests indicate that sealing methods employing a blast cup and either a lead or a Flexitallic gasket or a Flexitallic gasket without a blast cup are suitable for containing the gases resulting from detonation of contained explosives. The method employing a lead gasket without a blast cup was found to be unsatisfactory.

A continuing study is being conducted to determine the radiation effects, such as heat transfer, upon bolts used to hold the cap on the capsule, the material or materials used in the sealing gasket, and the explosive to be contained in the capsule.

D. MECHANICAL FEASIBILITY STUDY

The mechanical feasibility study during this period was primarily concerned with an operational analysis of a bifunctional ACDS destruct system.

In a study of system simplicity, the use of the PODS system during anti-criticality as well as post-operation modes was considered. The "over-kill" produced by such a system during the anti-criticality period could provide the necessary energy to remove interstage structure without the employment of auxiliary cutting and ejection charges. This method might be modified by employing one or more projectiles positioned in the reactor core to create destruct action, while using the detonation of the other projectiles in their respective launch tubes to remove the interstage structure and permit dispersal of the core material.

In a consideration of ejectable Mark A and Mark D ACDS systems, used in conjunction with a Mark D PODS system, it was concluded that these ACDS systems were not conducive to incorporation into a bifunctional system.

Item 1.7 PNEUMATIC SYSTEMS

A weight study was conducted of three engine pneumatic systems, covering a system which would only supply gas for actuator purposes; a system, presently proposed by Aerojet, which would supply both actuator fluid and tank pressurization; and a third system, the same as the first, except that no roll or thrust vector controls are included. This information was utilized in a joint AGC-LMSC report of the interface problem areas.

Component and system analyses were continued, to upgrade the design criteria.

Work continued in the area of component selection and instrumentation on the pneumatic systems layout for the Cold Flow Development Test System.

The Relief Valve Specification, AGC 42256, was released. Work on the burst diaphragm specification was discontinued when it was found that the general specification for burst diaphragms, AGC 42255, prepared for the M-1 program, would be applicable to NERVA.

The specification and specification control drawings for the following components were sent to vendors with a request for quotation.

1/2 inch filter
1-1/4 inch filter
3/4 inch regulator
1/2 inch relief valve

Evaluation of vendor proposals for the 3/4-and 1-1/4-inch check valves was initiated. Three proposals have been received to date.

Item 1.8 NRDS OPERATION

A. ETS-1 ACTIVATION

A detailed outline of test procedures for operational checks to verify the integrity of contractor-installed systems, and a detailed test procedure for operational checkout of the diesel generator sets, was submitted to SNPO-C for evaluation. A procedure for conducting the water system flow test is under preparation. Coordination of engine interfaces and steam generator test requirements is continuing.

B. TEST CELL "A" OPERATIONS

The following modifications have been made to further adapt this cell for NRX-A testing:

Installation of mixing chamber and checkout under cold-flow conditions.

Installation and checkout of a new core purge line.

Issuance of drawings for the construction of a flow pipe for facility checkouts.

Pouring of foundations for the 100,000-gallon dewar.

Design package (including work order request) for the modification of the movable shed for the reactor has been forwarded to SNPO-N for implementation.

C. NRX - R-MAD OPERATIONS

On-the-job functional training of both technicians and engineering personnel is continuing.

Assembly operations have been started on the NRX Test Car.

Procedures are being written for reactor assembly, test car assembly, disassembly, and post-operative inspection.

D. CONTROL POINT OPERATIONS

A preliminary design on the modification of the Neutronics System was forwarded to LASL for evaluation.

Item 1.9 RADIATION EFFECTS PROGRAM

A. PROGRAM PLANNING

The Radiation Effects Testing Program for Contract Year 1964 has been outlined and the work statement, Technical Administration Document, and the General Dynamics/Fort Worth Program Planning details are being prepared.

B. RADIATION EFFECTS REPORTS AND INFORMATION

REON Report 2622, Final Test Specifications for Ground Test Reactor Tests of 27 July 1963, was issued. The specifications included are listed below by test number:

Test	Component
14/W001	Control drum actuator components
23/W004	Accelerometers
23/W104	Resistance thermometers
23/W203	Linear motion displacement transducers
23/W302	Thermocouples and connectors
23/W404	Strain gages
23/W503	Pressure transducers

REON Report 2626, Preliminary Test Specifications for Ground Test Reactor Tests of 24 August 1963, was also issued. The specifications included are listed below by test number:

Test	Component
14/W002	Control drum actuator components
23/W005	Accelerometers
25/W504	Pressure transducers
37/W001	Tie rod materials

REON Report 2641, Preliminary Test Reports for Ground Test Reactor Tests During 13 Thru 19 May 1963, was issued. Included were:

Test	Component
22/W006	Fission counter pulse preamplifier
23/W002	Accelerometers
23/W102	Resistance thermometers
23/W201	Linear velocity displacement transducers

Test	Component
23/W402	Strain gages
23/W502	Pressure transducers
31/W011	Electrical components
40/W001/2	Control drum bearing

C. NUCLEAR ANALYSIS

A neutron dosimetry program for NERVA irradiation tests to be conducted at PBRF has been established in collaboration with PBRF personnel. The program includes a method for determining gamma and neutron fluxes for the W-2 capsule test position in Horizontal Thru-Hole-1. Determination of the W-2 capsule reactivity worth and flux mapping in Horizontal Thru-Hole-1 are in progress.

Total isodose contours about the NERVA engine were generated using the most recent data on fast neutron and gamma-ray fluxes.

An analysis program was initiated for prediction of the neutron activation of all components of the NERVA engine.

D. RADIATION EFFECTS TESTING PROGRAM — COMPONENTS

1. Electrical Components

Efforts are continuing on engineering design of the electrical irradiation test pallets and fixtures for all CY 1963 tests, and on long-lead procurement and fabrication for all CY 1963 pallets.

Completion of fabrication of Electrical Irradiation Test (EIT) No. 501 (first LRP electrical test pallet) was delayed, but it is anticipated that this will not affect the test schedule.

2. Mechanical Components

Efforts continued on engineering design of the mechanical irradiation test pallets and fixtures for all CY 1963 tests and on long-lead procurement and fabrication for all CY 1963 pallets.

Completion of MIT No. 902 (second mechanical test pallet) was delayed, but it is not anticipated that this will effect the test schedule.

3. Tests

The MIT No. 901 radiation effects test was conducted at GD/FW on these items:

Test	Component
1/L001	Tank shutoff valve
3/L001	Turbopump assembly bearing set
4/L001	Turbine power control valve - Configuration No. 1
8/L001	Static flange and seal

Irradiation Test No. 7 at GTR originally scheduled for July 1963 has been delayed because of reactor scheduling problems at the General Dynamics facility. This test has been tentatively rescheduled for completion in August 1963.

4. Test Facilities - Special Test Equipment

Interim utilization of Horizontal Thru-Hole-1 has been substituted for vertical tube utilization; however, no schedule is available at this time. Reactivity measurements and flux mapping in Horizontal Thru-Hole-1 is currently in progress.

Installation of all piping and instrumentation for the W-2 water-cooled test loop was completed and the entire system is being checked out to meet Plum Brook approval. The capsule and sample fixture have been installed and are being checked out. It is estimated that full-power will commence in early August.

A design manual and hazards analysis for the W-2 water-cooled loop was submitted to Plum Brook and received full PBRF Safeguards Committee approval.

The final design package for the PBRF W-1 cryogenic loop has been approved and SNPO comments on the Vitro specifications are being incorporated.

E. MATERIALS PROGRAM — NON-NUCLEAR

1. Reactor Materials — Non-Fuel

a. Shield Materials

Post-irradiation examination of the shield capsules was started. The eight unirradiated control capsules were subjected to their respective thermal treatments. The results obtained from this portion of the program will make it possible to distinguish between thermal and irradiation effects.

b. Reactor Structural Materials

Results from chemical analysis and metallography of the 60-lb air induction-melted ingot of 304 gadolinium containing stainless steel for cluster plates, indicated cross segregation of gadolinium. Success in forging this 5-in. diameter ingot is considered significant progress, however. In reviewing the data generated on previous vendor experimental heats, a correlation between unbalanced composition (nickel content adjusted to give retained ferrite at room temperature) and forgeability was discovered. It was also apparent that vacuum induction melting gives better homogeneity than air induction melting. Thus, a vacuum induction-melt to achieve a 7-in. ingot of unbalanced composition will be evaluated.

The evaluation of an amount of gadolinium-containing stainless steel sufficient for nine cluster plates for PAX was completed. The material averaged,

	at Room Temperature	at -320°F
Yield Strength	31,300 psi	56,000 psi
Ultimate Strength	80,500 psi	169,000 psi
Total Elongation	78%	to 64%

The gadolinium content averaged 0.83% with a range of 0.80 to 0.84%.

Tensile testing of the alloys

80% silver 15% indium 5% cadmium	75.5% silver 11.5% indium 8.5% cadmium 4.5% tin

which are being evaluated for cluster plate applications, showed these results:

Test Temperature (°R)	Ultimate Strength (psi)	Yield Strength (0.02% Offset) (psi)	Elongation (%)
	Silver-Cadmium-Indium		
300	48,000	23,000	70
540	45,000	22,000	60
750	41,000	19,000	62
1000	20,000	15,000	52
	Silver-Cadmium-Indium-Tin		
300	53,000	27,500	36
540	53,000	26,000	35
700	30,500	23,500	7.5
1100	16,500	14,000	[illegible]
1460	2,700	2,000	1[illegible]

Analysis of the technical requirements f[illegible]hite inner reflector cylinders and discussions with vendors have re[illegible] the preparation of a specification, PDS 30073, Graphite Cylinder. [illegible] study of graphite tensile specimen designs showed that two of five experimental designs gave satisfactory tensile data.

The fabrication development for tie rods, both regular and instrumented, has been completed by the vendor with adequate results. The following table lists the average tensile properties of 18-in. long tie-rod specimens:

Type of Tie Rod	No. Tested	Test Temperature Conditions	Ultimate Strength (psi)	Yield Strength (0.02% Offset) (psi)	Elongation (%)	Area Reduction (%)
			X-750			
Regular	3	Room	169,000	108,000	16.5	26.3
	3	Liquid Nitrogen	199,000	127,000	13.6	19.
Instru.	12	Room	1,709,000	101,000	14.1	28.8
	6	Liquid Nitrogen	200,000	112,000	18.9	25.1
			718			
Regular	21	Room	196,000	166,000	14.5	47.6
	3	Liquid Nitrogen	241,000	190,000	16.8	43.9
Instru.	8	Room	210,000	182,000	8.0	22.1
	4	Liquid Nitrogen	263,000	206,000	14.5	30.5

c. Control Materials

Production of aluminum-natural-boron control plates has continued and material to fill all current orders is in various stages of processing. The first plate assemblies will be prepared after the first group of completed plates has been final-inspected. Samples of the aluminum-natural-boron sheet have been tensile tested at several temperatures and strain rates, and further tests of mechanical and physical properties are planned. Chemical analysis of aluminum-natural-boron sheet have shown the boron content to be close to the intended values, with some being slightly over the specified range of 18 to 22%.

d. Thermal Capsules

Non-consumable arc melted buttons of the following analyses are being made for conversion to wire:

21% tantalum	+79% niobium
67%	+33%
78%	+22%
90%	+10%

2. Non-Radiation Program

a. Thrust Chamber Assembly (Item 1.4.6)

(1) Cast Aluminum Jacket Materials Development

Hybrid nozzle S/N 001H was cast at Howard Foundry (Chicago) and has been received. X-rays indicate round gas porosity located in the convergent portion. Average properties from R-3 specimens are:

Ultimate tensile strength	38,400 psi
Yield tensile strength	25,500 psi
Elongation	10.9%

Heat treatment consisted of solution threating at 1010°F for 18 hours, water quench, holding for 24 hours, and aging for 2-1/2 hours at 310°F.

Hybrid nozzle S/N 002H was cast at AGC Foundry (Sacramento). Mechanical properties, microstructure, and chemical composition were determined of bars separately cast with S/N 002H nozzle. Several heat treatments were applied to the test bars. The average tensile properties of 17 specimens machined from the flange of this nozzle and heat treated to the T-6 condition were:

Ultimate tensile strength	42,000 psi
Yield tensile strength	27,700 psi
Elongation	14.8%

Heat treatment consisted of solution treating at 1010°F for 18 hours, hold for 18 hours, water quench, holding at room temperature for 24 hours, and aging at 310°F for 2 hours.

The X-rays indicated round gas porosity up to 1-1/2 in. in diameter. The nozzle is considered reparable by grinding and weld repairing. The evaluation of the effects of chilling and sodium modifications were completed.

(2) Nozzle Braze Alloy Development Program

X-rays, hydrotest, and metallographic examinations were completed on two brazed test specimens. The -[illegible]0 and +100 Taylor mesh size was established for future grit blasting. Forming procedures for braze alloy foils and specifications for clean room requirements were prepared. Welding procedures for tube-to-tube joints using AGC 44078 filler material were established.

(3) Thrust Chamber Assembly Materials Investigation

Tensile testing was completed of A-286 bolt material from Standard Pressed Steel Co. and 18[illegible] nickel maraging bar stock (min. F_{ty} = 250 ksi), at temperatures ranging from -320 to +600°F.

Cold drawn and aged Inconel 718 bolt material was ordered from Voi-Shan Manufacturing Company.

b. Pressure Vessel Material Development

Tensile specimens from a welded section of 001T-PV test ring were fabricated and tested at room temperature. The specimen failed in the parent metal. Microphotographs of broken specimens indicate typical fractures.

Tensile properties of [illegible]Al-4V-ELI forged titanium plate were obtained at room temperature, -100, -320, and -423°F.

3. Irradiation Tests on Structural Materials (Item 1.9.6)

a. Tensile Tests

Preliminary results of tensile tests at -423°F, following General Dynamics data reduction, are:

Average Tensile Properties at -423°F

Material	Ultimate Strength (psi)	Notched Ultimate (psi)	Yield Strength (0.2% Offset) (psi)	Elongation (%)	Area Reduction (%)
Aluminum Alloys					
2219-T81	95,400	81,300	67,100	13.2	25.6
5456-O	83,300	57,400	43,900	12.1	10.8
6061-T6	74,700	61,400	46,500	24.0	32.4
7075-T6	110,400	70,500	94,900	6.4	7.0
7079-T6	108,800	81,500	95,900	6.1	6.3
Stainless Steels					
302/304, annealed	251,000	121,400	60,300	38.8	27.5
321, annealed	244,800	168,200	37,000	41.8	29.2
347, cast	117,300	99,200	83,000	7.7	8.8
AM350 (SCT, 850)	335,300	327,900	313,300	1.0	1.3
A286 (aged)	223,600	185,800	135,900	37.5	31.0
440-C	217,400	-	-	-	-
Nickel-Base Alloys					
Hastelloy C	-	-	215,200	39.2	32.6
Inconel X-750	253,300	191,600	135,800	31.2	27.1
Inconel 713c (cast)	111,600	127,700	108,000	3.0	7.0
H Monel (cast)	103,600	102,600	58,900	23.2	28.1
Titanium Alloy					
Ali0-AT, ELI, annealed					
Transverse	216,400	171,000	199,500	17.1	17.8
Longitudinal	239,200	210,200	217,000	12.7	15.1
Ali0-AT, ELI, welded					
Transverse	214,600	118,100	198,000	5.9	9.4
Molybdenum Alloy					
TZM	72,800	-	-	-	-
Plastic Materials					
Teflon	9,800	-	-	-	-
Armalon	30,200	-	-	-	-
Rulon A	14,000	-	-	-	-

b. Dewar Design

The new dewar design, for future cryogenic-irradiation tests, has been completed. Copies of the design drawings have been submitted to SNPO-C for approval, and have been sent out to potential fabricators for quotation.

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SECTION III (cont.)

TECHNICAL DISCUSSION

TASK 2.0 ENGINE SUPPORT SYSTEMS

[redacted]

DECLASSIFIED

Item 2.1 REMOTE HANDLING EQUIPMENT

A. INTEGRATION AND TECHNICAL MANAGEMENT

An interface liaison meeting was held at New York on 26 July with representatives from REON, Vitro, and SNPO attending. The two major topics of discussion were the external configuration of the wall-mounted handling system, and the modifications required for the swingout rails to accommodate the OPS busbar mounting.

A technical direction meeting was held at Azusa on 18-19 July, between AMF and REON. The meeting agenda centered on a discussion of the reliability and quality assurance aspects of the AMF supplied equipment and current equipment and design problems.

The development of the NRX-A2 equipment is in progress.

Operating instruction manuals for the ACFI equipment are being written.

B. OVERHEAD POSITIONING SYSTEM (OPS)

Procurement documents have been approved for the OPS mast, bridge, and trolley subassemblies, and for the associated electrical systems and variable speed drives. Bids are being solicited on these items.

Design effort is being concentrated in the areas of the OPS floating head and the E-MAD building interfaces. Design of the OPS floating heads is in progress A liaison meeting to review the preliminary design of the mechanical floating heads was held in Stamford, Connecticut, on 29 July. A meeting to review the complete preliminary design layouts is scheduled for 15 August.

C. FLOOR MOUNTED HANDLING SYSTEM (FMHS)

Design of the portable turntable, mobile carriage, and dolly is proceeding on schedule. Requests for Quotes on these items are scheduled to be issued during August.

A study was made to evaluate the tolerance build-up between the pressure vessel and the core.

D. NRX EQUIPMENT

A design and status review meeting was conducted at REON at LRP from 15 to 16 July. A review of the technical design of each NRX [illegible] status report of the design, fabrication, and delivery of each item was presented. This meeting covered all non-nuclear NRX-GOE items [illegible] subtasks 2.1, 2.2, and 2.5

A review meeting was held at WANL, Large, Pennsylvania, on [illegible] July, with representatives from REON, WANL and SNPO attending. The meeting agenda centered on the approval of the NRX-A1 operational support plan (WANL-TNR-115) and the status of all NRX-A1 equipment.

Preliminary layouts are being developed from these test car areas: the reactor pressure transducer panel, the emergency purge systems for the NRX-A1 and NRX-A2, and the Instrumentation Room attachment to the nozzle.

The non-nuclear portion of the NRX-A2 operational support plan is nearing completion.

The simulated NRX reactor demonstration by rail was successfully completed. The document describing the shipment (WANL-TML-458) has been initiated, and will be published during the next report period.

Status summary for this task of the NRX-A1 support equipment to be supplied by various program participants follows:

	Provisioning List Item No.	Title	*Status Design	Fab.
ACFI	1135	Sphere Handling Fixture		X
	1147	Reactor Trunnion Cage		X
	1150	Reactor-Vessel Trunnion Cage		X
	1152	Reactor Adaptor Ring Handling Fixture		X
	1153	Screen Handling Fixture		X
	1137	NRX-A1 Test Car		X
	1182	Reactor Trunnion Fixture		X

	Provisioning List Item No.	Title	*Status Design	Fab.
WANL	1113	Outer Reflector Sector Container	F	
	1165	Cluster Nut Hardware Container	P	
	1170	Filler Strip Container	P	
	1203	Fuel Cluster Liner Tube Container	P	
	1217	Lateral Support Container	P	
	1252	Fuel Cluster Tie Rod Container	P	
	1258	Element Cask Insert	GFE	
	1260	No. 2 Hardware Container	P	
	1261	Tie Rod Insulating Parts Container	P	
	1262	Support Fuel Cluster Container	P	
	1263	Plate Fuel Cluster Container	P	
	1271	No. 3 Hardware Container	P	
LRP	N-211	Forward Closure Rocket Engine Lifting Fixture - Remote		

* Status Symbols - Status of first unit only indicated

P = Preliminary Design Complete

F = Final Design Complete

I = In Fabrication

X = Completed

E. NERVA EXHAUST SYSTEM (NES)

A handling concept has been chosen for the NES duct. Based upon consideration of economy and handling convenience, a trailer system was selected for further development. Operational requirements and the outline configuration of the NES trailer have been established. The design criteria and the conceptual drawing of the NES trailer are in the process of development.

Development criteria has been initiated for the NES inspection and decontamination systems.

F. E-ENGINE EQUIPMENT

Preliminary design criteria is in the process of development to be used with the E-engine during transport and storage

The preliminary design and drafting of design criteria for protective dust covers used with the EIV during E-engine storage and transport are in the process of development.

The E-engine operational support plan has been initiated.

Reports covering tests for the actuator shipping container and packaging instructions for the system amplifiers were submitted by Bendix Products Aerospace Division for review

G. EIV, MCC, AND LOCOMOTIVE

Fabrication of the EIV and MCC is proceeding on schedule. A vendor was selected and approved to construct the shielded cab of the MCC.

Design of the nitrogen purging system, cab windows, and fresh-air filtering unit to be used in the MCC were approved. The following design plans were also approved:

EIV longitudinal carriage fore and aft assembly
Inching drive and the stop mechanism
Azimuth drive assembly
Jacking system stability analysis
Lateral carriage drive assembly
50- and 20-ton jack assemblies
Truck jack assembly

H. FACILITIES SUPPORT EQUIPMENT (E-MAD COMPLEX)

A draft of the intercell transfer system design criteria is being developed.

A total of six interface control drawings were initiated to cover interfaces between AMF and the NRDS Facility.

I. TEST STAND EQUIPMENT

The Test Stand malfunction study effort continued with emphasis on methods of performing the required operations and the delineation of equipments.

Development of the preliminary design criteria for the Radioactive Hot Engine Hold Stand (RHEHS) is in process.

Item 2.2 GROUND SUPPORT EQUIPMENT - CHECKOUT AND TEST SYSTEMS

A. INTEGRATION AND TECHNICAL MANAGEMENT

A status report of all Subtask 2.2 and 2.3 support equipment was submitted to Mr. E. Burciaga of NASA-WOO following a review meeting at Azusa on 30 July.

B. NRX EQUIPMENT

The NRX-A1 operational support plan was completed and published. The NRX-A2 operational support plan has been initiated.

The WANL purchase order for the "Single Mode Memory Matrix" was approved, and one for the "Portable Air Hydraulic Test Stand" has been submitted for approval.

Design review meetings on NRX equipment were held between REON and LRP, and REON and WANL, as noted in Item 2.1.

A status summary of NRX-A1 support equipment supplied under this task item by program participants follows:

	Provisioning List Item No.	Title	Status* Design	Status* Fab.
WANL	1402	Control Drum Servo Checker	F	
	1406	Wiring and Transducer Checker, Test Car	F	
LRP	450	Rocket Engine Pressure Testing Closure Kit		I
	451	Rocket Engine Nozzle Throat Pressure Testing Closure Kit		I

*Status Symbols - Status of first unit only indicated.
F = Final Design Complete
I = In Fabrication

C. E-ENGINE EQUIPMENT

Preliminary design criteria for the E-engine simulator and the remote engine control system is being prepare[illegible] Work has been initiated on the operational support plan for the E-engine.

D. CHECKOUT TRAILER

Requirements for the checkout trailer have been developed and preliminary design criteria is being prepared.

E. TEST STAND EQUIPMENT

Requirements for the ETS-1 checkout system are being generated.

F. CAMERAS AND LIGHTS

Preliminary lighting and camera studies showing the effect of nozzle surface color and light intensity were completed. The positioning, by angulation, of the lights in the fixed holes in the nozzle was determined. The design of the camera housing envelope was completed and released for fabrication. The following equipment is on hand:

1. TV camera and control unit
2. 2 ea. 10 mm f. 1.8 Angenieux lenses for the movie cameras
3. 1 ea. 10-mm f. 1.4 Angenieux quality lens for the TV camera
4. The cable for the connection of the TV camera to its control units.

The two movie cameras were ordered. All basic design is completed.

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Item 2.3 GROUND SUPPORT EQUIPMENT
LOGISTICS, TRANSPORT, AND MAINTENANCE

A. INTEGRATION AND TECHNICAL MANAGEMENT

An SNPO/WANL/ACFI design and status review meeting was held at WANL, Large, Pennsylvania, on 10-11 July. Subtasks 2.2 and 2.3 were discussed.

A status review meeting was held at Azusa with Mr. E. Burciaga of NASA-WOO on 30 July, concerning Subtask 2.2 and 2.3 equipment.

B. NRX EQUIPMENT

The WANL purchase order for the "Inner Reflector Handling Fixture" (Item 1236) was approved.

Design review meetings on NRX equipment were held between WANL and REON, and LRP and REON, as noted in Item 2.1.

The non-nuclear portion of the preliminary draft of NRX-A2 operational support plan is nearing completion as noted in Item 2.1.

Status Summary of Support Equipment

	Provisioning List Item No.	Title	Status* Design	Status* Fab.
WANL	1729	Reactor Assembly Shipping Container		X
	1208	Semi-Trailer-Reactor & Shield Shipping		X
	1126	Inner Shipping Container Stand		X
	1127	Reactor Instrumentation Support Sling		X
	1128	Reactor Instrumentation Pallet		X
	1143	Reactor Assembly Lifting Fixture		I
	1160	Shipping Container Lifting Fixture		X
	1161	Inner Shipping Container Fixture		X
	1162	Shipping Container Cover Pallet		X
	1163	Inner Shipping Container Cover Pallet		X
	1131	Universal Handling Fixture		X
	1138	Privy Plug Assembly Stand		X

	Provisioning List Item No.	Title	Status* Design	Status* Fab.
WANL (cont.)	1181	Instrumentation and Shaft Control Support Fixture		X
	1247	Reactor Vessel/Car Personal Platform	F	
	1232	Core Loading Fixture	F	
	1233	Core Barrel Handling Fixture	F	
	1235	Seal Retainer Fixture	F	
	1236	Inner Reflector Handling Fixture	F	
	1239	Cluster Assembly Fixture-Regulator	F	
	1240	Cluster Assembly Fixture-Irregular	F	
	1241	Control Drum Lifting Fixture	F	
	1242	Outer Reflector Sector Lifting Fixture		X
	1243	Control Drum Storage Rack	F	
	1244	Cold Reactor Disassembly Stand	F	
	1246	Inner Reflector Lifting Fixture Ring	F	
	1256	Barrel Support Stand	F	
	1264	Simulated Shield Container	F	
	1265	Flow Screen Container	P	
	1266	Control Drum Shafts Container	P	
	1267	Instrumentation Hardware Container	P	
	1119	Lateral Support Parts Container	P	
	1259	No. 1 Hardware Container	F	
	1272	Element Cask Insert Shipment Container Initiated	P	
LRP	704	Rocket Engine Nozzle Shipping and Storage Container		I
	724	Rocket Engine Semi-trailer		I
	801	Multiple Leg-Multiple Purpose Sling (3000 lb cap.)		X
	803	Rocket Engine Forward Closure Lifting Fixture		I

	Provisioning List Item No.	Title	Status* Design	Status* Fab.
LRP (cont.)	809	Beam Type Sling		I
	813	Rocket Engine Nozzle Hoisting Beam		I
	817A	Multiple-Leg Sling (12,000 lb cap)		I
	914	Rocket Engine Handling Adaptor		I
	915	Rocket Engine Stand		I
	916	Rocket Engine Maintenance Platform		I
	917	Rocket Engine Forward Closure Stand		X
	918	Rocket Engine Nozzle Stand		X

*Status Symbols - Status of first unit only indicated.

P = Preliminary Design Complete

F = Final Design Complete

I = In Fabrication

X = Completed

Item 2.4 INSTRUMENTATION

A. INSTRUMENTATION DATA BOOK

The July 1963 edition of the Instrumentation Data Book was published. The data book was expanded into three volumes:

Volume I - Measurement Summary and Measurement Requirements Lists

Volume II - Development Programs for Engine Instrumentation

Volume III - Development Programs for Reactor Nuclear and Non-Nuclear Instrumentation

B. NRX-A INSTRUMENTATION

The NRX-A1 Cold-Flow instrumentation systems drawing has been modified in accordance with the latest engine nozzle design changes in order to incorporate camera ports. All instrumentation on the nozzle was affected and, consequently, had to be relocated. The mounting hardware has been redesigned, and the drawing is now in the first stages of checking prior to release.

The fabrication drawing for the tungsten-rhenium thermocouple has been completed for the NRX-A2 Hot-Flow engine, and the design for the port adapter to be used with the LASL NRX-A thrust chamber simulator furnace was completed. The port adapter drawings were forwarded to LASL for review. The adapter was found to be incompatible with LASL facilities. In lieu of the dynamic calibration and testing of this thermocouple at LASL, it is presently planned to statically calibrate and test the unit at the AGC-SRP Aerophysics Laboratory.

Engineering work was initiated on the NRX-A2 Hot-Flow instrumentation system drawing, specification control drawings, and schematic diagrams. These documents are required for component procurement.

Approximately 24 drawings were in various stages of completion at the end of this report period, and completion of the entire NRX-A2 Hot-Flow drawing package is expected by 15 August.

Preliminary frequency response tests on the Statham Model PA732TC-1M-350 pressure transducers indicate that these units are within the vendor-quoted

specifications. The NRX-A1 instrumentation installation drawing, schematic, and all detail drawings were completed and sent to check for processing and release. The NRX-A2 measurement list was defined sufficiently to start instrumentation specification control drawings, and installation and schematic drawings. NRX-A1 specification control drawings for engine instrument installation were released.

Based upon a review of facilities and personnel available for instrumentation installation work at NRDS, a decision was made to perform all such work at NRDS.

CFDTS instrumentation procurement action has started and the first draft of the NRX-A2 planning parts list was prepared.

C. MECHANICAL COMPONENTS IRRADIATION TESTS (MCIT)

Specifications and specification control drawings have been released for all instrumentation components for the MCIT series, through MCIT-908, except for the pressure switch and flowmeter measurement parameters. Extensive work is now being accomplished to complete component specification control drawings for these last two items. Procurement activities continued to be expedited to assure stocking of all required MCIT components and components for two Instrumentation Control Pallets in accordance with dates established by project.

Fabrication of two RTT calibration sets was 50% completed.

D. CRYOGENIC TEMPERATURE TRANSDUCER DEVELOPMENT

1. Electro-Optical Transducers

After satisfactory performance during dynamic engine component tests, a high precision transducer (Silicon Temperature Sensor Serial No. 1, manufactured by Electro-Optical Systems) was recalibrated in liquid neon (-410.8°F point). Repeatability at this point was found to be 0.06°F. The repeatability of this unit has been established at 0.15°F at the -422°F point.

The reduction of data on Silicon Sensors No. 3 and 4 has been completed. Special curves are being prepared to fit the data from each sensor,

and the sensors are being installed for dynamic engine test runs. Special curves are required because the individual sensors exhibit differences of as much as 4°F.

2. Rosemount Transducers

A recalibration of the Rosemount Model 134 EB platinum temperature sensor (radiation resistant design) indicates repeatability to be within the 0.02°F figure claimed by the vendor.

The temperature calibration data taken at 20, 25, and 28°K on each of six Rosemount Model 134 CT evaluation sensors have been reduced. Sixteen data points out of a total of 18 points repeated to within 0.02°F of the original data points. Data at the two points indicating sensor resistance shifts was questionable, and the data will be re-examined. A report is being completed to document the formulation of Code N and its data acquisition capability for the temperature range of -425 to -300°F. The Code N intermediate range was needed to measure cryogenic temperatures in the gaseous hydrogen region. It provides a greater accuracy than the Code L and covers a wider temperature range than the Code K. The sensitivity for the Code N at -380°F is 12.8 millidegrees/digital count, as compared with 17.3 millidegrees/digital count for the Code L.

An interim potentiometric RTT simulator has been designed and fabricated. It has a three-channel capability for Codes K, L, and N. Assembly drawings have been released, and calibration has been completed by the Measurement Assurance Laboratory. The interium simulator will be used in conjunction with potentiometric RTT system accuracy studies.

A Rosemount Model 134 CT 400 temperature sensor (Serial No. 5394) was received on 16 July. It will be calibrated and used in stem conduction studies.

3. AGC Transducers

A detailed calibration procedure has been completed for platinum resistance temperature transducers manufactured in accordance with AGC specifications. Comprehensive studies have been made of liquid hydrogen properties

to determine valid parameters for vapor-liquid volume ratio as a means for hydrogen quality detection. Preliminary design studies were made to determine the feasibility of several different techniques. The capacitance density sensor was selected as the method compatible with the environmental conditions, present plant facilities, and the required development time. A prototype transducer is currently being studied to determine fabrication techniques. Static and dynamic calibration procedures have been developed to obtain design data for an electronic unit to give direct phase, density and quality readouts. Preliminary designs have been made for the calibration and testing hardware.

4. Physical Sciences Corp.

The preliminary transducer design for a hydrogen quality detector has been submitted to Physical Sciences Corp. for a feasibility study of the required ceramic to-steel bonding technique. Results of this investigation are required before the final prototype design and fabrication can begin.

E. THRUST CHAMBER CONTROL TEMPERATURE TRANSDUCER DEVELOPMENT

Previous tests of the Rosemount Engineering Co. resistance temperature transducer indicated that the particular heat source used for test (an arc image furnace) was quite limited in heat capacity, and that, quite probably, specific heat rise increments would be difficult to control. Work on resistance probe configuration studies was therefore reduced for the present, to permit concentration on laboratory tests of existing heat sources and laboratory measurement techniques. Work has been initiated to investigate the thermal stability of two existing furnaces and the comparative performace of three independent methods of high temperature measurement.

A proposed contractual work statement for the development of an experimental resistance thermometer has been forwarded to the General Electric Company for consideration. Replies are slightly delayed due to vacation shutdown at General Electric. A review of accuracies reported by various laboratories making high temperature measurements was completed for the purpose of establishing more realistic development goals.

F. THRUST CHAMBER CONTROL PRESSURE TRANSDUCER DEVELOPMENT

Preliminary checkout of all pressure transducers has been made, before irradiation in the General Dynamics ground test reactor. The test fixture accommodates nine pressure transducers. Eight pressure transducers are of the potentiometer type and one made by Statham, is of the strain-gage type.

Irradiation testing of the pressure transducers was postponed, due to reactor modifications, to August 5, 1965.

G. REACTOR NUCLEAR INSTRUMENTATION

Four prototype fission counters-type WX-5436 for source range applications were completed for testing. Four prototype fission counters, type WX-5400. for intermediate range application were completed, and are undergoing leak tests over a period of time prior to final sealing.

Parts for four WX-5302 gamma compensated ionization chambers for power-range application are completed. These detectors are undergoing gamma compensation tests with subsequent disassembly for necessary adjustments to achieve optimum compensation. A design modification has been incorporated into the detectors to achieve closer gamma compensation with varying gamma energy spectra.

H. REACTOR NON-NUCLEAR INSTRUMENTATION LABORATORY TEST PROGRAM

High temperature testing of thermocouples is continuing. The high-temperature lifetime of 0.035 O.D. tungsten-tungsten rhenium thermocouples was extended considerably by the addition of a protection tube of tantalum with an 0.012-inch wall. One of the tantalum-sheathed thermocouples was operable at 4460°R for 15 minutes. The temperature was then increased to 4720°R, at which point its operation became erratic. Three other tungsten sheathed thermocouples were operated at 4460°R and 4942°R respectively. None of these thermocouples failed and readings agreed with the optical pyrometer readings.

Several types of experimental thermocouples of 0.090-inch diameter have been ordered for further testing.

Qualification tests have been completed on NRX-A1 linear displacement transducers (LVDT type) at ambient and LN_2 temperatures (candidate sheets LR-3 and LR-4 and part numbers 964B002H01 and 964B023H01 respectively). The units tested indicated excellent results well within the specified requirements for NRX-A1 application.

Laboratory testing was completed on Statham gas clamped accelerometers and Physical Science reluctance type vibrometers prior to radiation testing. The Physical Sciences units were returned to the manufacturer for design changes.

Tests have been run on Wiancko qualification and subsequent irradiation testing, including combined vibration ambient and LN_2 environments. The units tested were within specification and are to be irradiation tested at GTR for NRX-A2 qualification.

Qualification testing is in process for the Kistler Dynamic pressure transducers for NRX-A1 (PR-9). Temperature tests completed on 20 units at the vendor's facility have indicated no apparent change in performance from ambient to LN_2 temperature. Additional testing, including vibration, is being conducted on four units in WANL Laboratories.

J. RADIATION EFFECTS TEST PROGRAM

1. Plum Brook Test Facility

WANL-TME-421, Supplement 1, was issued to complete the test specification requirements for the following tests to be conducted in August:

Test	Component
23/W103	Resistance Thermometers
23/W403	Strain Gages
23/W301	Thermocouples

2. General Dynamics Ground Test Reactor

Irradiation Test No. 7 at GTR has been delayed because of reactor scheduling problems at the General Dynamics Facility. This test has been tentatively rescheduled for completion in August.

K. BENDIX SUBCONTRACT

One report was issued by Bendix during the month of July; Evaluation of Beryllia and Thoria as Electrical Insulators for Extreme High Temperature Transducers, Bendix Research Laboratories Report No. 2563.

L. SURFACE MOUNTING TRANSDUCERS

Studies are being conducted to obtain strain-type surface transducers that will provide a consistent output of ± 1 Volt. A fixture using a constant stress beam is being considered for this purpose.

Final radiation effects on the test conducted at GTR on 74 strain gages on 13 May 1963 have not been released.

M. ENGINE INSTRUMENTATION EVALUATION

Two laboratories previously submitting proposals for environmental testing of NRX-A1 cold flow instrumentation were visited and their facilities reviewed. A purchase order was awarded to the Component Evaluation Laboratories (South El Monte, California). Environmental tests were started on 9 July.

Item 2.5 FIELD SUPPORT (RIFT)

General exchange of engineering information and liaison activities continued throughout the month.

Details of activities are reported under individual task items concerned.

Item 2.6 RELIABILITY AND QUALITY ASSURANCE

WANL conducted a formal quality-assurance review of the Astrofuel Facility to determine the status of the fuel quality control and other items affecting fuel reliability. Corrective action recommendations were made where appropriate, and follow-up action initiated. In addition, a review has been initiated on the NRX-A1 test specification.

A survey was made by WANL to define the cleanliness control problem as a basis for writing specifications and procedures.

Three suppliers were approved by WANL as a result of supplier surveys. Supplier surveillance surveys are being conducted on a continuous basis to ensure that all quality requirements are being met.

LRP reliability personnel have begun a review of the preliminary input for the NRX-A1 test specification, in conjunction with radiation-effects studies of NRX-A1 non-nuclear engine materials under Item 1.9.

Evaluation of the final Cold-Flow Development Test System plan and the development of a statistical test plan for the Cold-Flow Development Test System has been started by LRP.

Two modes-of-failure analysis have been completed by LRP, concerning modes-of-failure analysis for the radiation-effects pallet No. 903 and for the radiation-effects control pallet.

LRP has completed a review of the final NRX-A1 Cold-Flow assembly and disassembly procedures and of the final NRX-A2 hot assembly and disassembly procedures.

The LRP Quality Control Division conducted five vendor evaluations and, in addition, completed three internal Quality Control audits.

Reliability monitoring by Bendix of in-house major actuator assembly components resulted in focusing attention on the need for suitable containers or wrappings for the heavier parts during interdepartmental movement to protect critical machined surfaces. Corrective action is now being accomplished.

[redacted]

Continued design analyses by Bendix revealed a possible interference fit of 0.0001 inch in the alignment slots on the base of the Midwestern Torque Motor. Further investigation resulted in a change of dowel pins which fit into the alignment slots, thus correcting the possible interference.

The design review effort by AMF continues and includes review and approval of the N_2 purge system, MTC cab-door drive, EIV truck jacks, EIV connectors for manipulator or remote connections, and the EIV vertical-carriage assembly.

Consultation was provided by the REON Reliability Department to ER&W to establish the ground rules for their reliability and quality-assurance program plan. Additional meetings have been scheduled to clarify any possible problem areas.

Further reliability effort continues in the analysis of methods of estimating NERVA engine reliability from data obtained during development testing. Several different plans and approaches are being considered.

An extensive survey by the REON Quality Assurance Department has been made of the Thiokol Chemical Corporation, Shawnee Division, Shawnee, Oklahoma, in regard to the procurement of the ETS-1 Steam Generation System. In addition, a survey has been completed for the Associated Piping and Engineering Company, Compton, California, in relation to the procurement of cryogenic piping for the NERVA Program.

Monitoring of the reliability and quality assurance activities of the participating plants by REON is on a continuing basis. More detailed information concerned with reliability and quality-assurance activities is separately reported.

[redacted]

Item 2.7 SAFETY

A. SAFETY AND HAZARDS EVALUATION

1. Reports

Work continued on the NRX Safety Analysis Report. Emphasis was placed on the meteorological aspects of the site, and the radiological consequences which might occur downwind of fission products released during normal operation or following a nuclear excursion. Available computer codes for determining downwind concentration of fission products are being evaluated. The nocturnal drainage phenomenon is under consideration to evaluate its implied restraint on test operations.

A review of the safeguards to insure against accidental criticality during reactor assembly at WANL has been completed and a report was prepared, including facility design and operating procedures.

The RAC Subroutines LOWTMP and SCRAM have been combined as a separate program to facilitate debugging. Debugging of this program is near completion.

2. In-Flight Poison Removal System

A core-nozzle test rig was used during recent poison-wire withdrawal tests. During these tests, two sets of clusters were evaluated; one set used 8 clusters of 24 uncoated, 0.063-in.-dia stainless-steel wires, and the other, 8 clusters of 24 teflon-coated, 0.047-in.-dia stainless-steel wires. In both cases, the wires were withdrawn from the clusters at the maximum radius of the core. The breakaway load for the uncoated wires was 140 lb and the load required to clear the core support blocks was 414 lb. The corresponding values for the coated wires were 33.4 and 121.2 lb. These tests further emphasize the desirability of coating poison wires to make it easier to remove them during flight.

Further investigations were made concerning methods of coating small-diameter stainless-steel wires. The most promising approach

appears to be utilization of teflon tubing. In this case, the tubing will be slipped over the wire and the assembly will then be drawn through a heat gun. This will cause the tubing to shrink and simultaneously will permit its expansion evenly over the wire, thereby forming a tight assembly. This process is similar to the one being used for shipping poison wires, with the exception that polyethylene is used as the coating in the latter case.

B. FISSION PRODUCT DIFFUSION STUDIES

A fission product inventory program has been written and debugged. The program calculates the activities in microcuries, as a function of time after reactor shut-down, of fission products resulting from thermal fission of U-235. Any operating history, such as a series of start-ups and shut-downs at various power levels, can be treated. The program is being expanded to include the gamma and beta source energies resulting from decay. Four gamma and five beta energy groups are being considered.

The results of the program are compatible with results obtained at NRDL, and will be incorporated into the source term program.

The radio-chemistry on the fuel samples in FP-2 has been completed. The fission product inventory was higher by an approximate factor of ten in FP-2 than in FP-1. Data are now under review for interpretation.

Post irradiation heat treatment has been completed on capsule WANL-FP-3. The flux monitor wires have been analyzed and it appears that the flux level for FP-3 was comparable to FP-2. The samples have been dissolved and radio-chemical analysis has been initiated.

Capsule WANL-FP-4 has been irradiated and at present is in transit to the WTR facility.

Capsule WANL-FP-4A was prepared for irradiation of re-entry burn-up samples. It arrived at GETR on 21 June 1963 and has entry burn-up samples.

C. MECHANICAL AND PHYSICAL ASPECTS OF REACTOR EXCURSIONS

1. Electrical Transient Experiments

Experiments were continued to determine the magnitude of conductive heat losses through the copper electrodes of the sample holder assembly. Two runs were made in which 2.71 Kw were supplied for 100-sec to 70 gm of graphite having NERVA fuel geometry with, and without, a heat sink affixed to the electrodes. For the first 20 sec the heating rates were identical, but at the end of the 100-sec heating period, the sample with the heat sink reached a temperature of 1020°C, while the sample without the heat sink was 5% higher. It appears that conductive heat losses also are negligible during the duration (100 millisec or less) of tests at high power inputs. The optical pyrometer (thermoscope), previously used unsuccessfully to measure the transient temperatures, has been modified to read actual temperature measurements during the transients.

A feasibility report, Electrically Simulated Nuclear Transients, is in final preparation.

The water immersion topical report, WANL-TNR-117, Hydrodynamics of NERVA Core Immersion, has been completed.

D. RE-ENTRY SAFETY STUDIES, RESEARCH AND DEVELOPMENT

The results of simulated re-entry tests for the burn-up of graphite spheres in the transition flow regime have been completely analyzed. Mass loss rates for 1/2 and 1/8-in.-dia spheres are reported in terms of simulated altitude and velocity data. The data are being interpreted in terms of a generalized mass loss rate equation which will be used in the WANL re-entry code. Data for samples of other geometries are currently being analyzed.

An analytical study was undertaken to formulate a computer program for predicting the dispersal patterns of reactor fragments on the earth's surface as the result of explosive destruct. The results of this study are to be incorporated in the existing re-entry burnup code as part of the overall source term program.

Various analytical methods for determining the decay time from elliptical orbits are being investigated for their feasibility of being programmed as an adjunct to the re-entry code. A parallel effort has been made to locate existing analyses and/or computer programs that will include such refinements as earth rotation and non-conservative gravitational fields.

An information flow diagram for the source term program has been prepared.

A summary screening report on chemical destruct system, WANL-TME-399, has been completed.

E. STUDY OF FUEL ADDITIVES FOR ENHANCEMENT OF FLIGHT SAFETY

The preliminary feasibility report on the use of additives has been completed as WANL-TNR-114.

Work has been initiated on the second phase of the additives program, which has as its objective an intensive study of the mechanical properties and oxidation behavior under more advanced types of destruct testing.

Approximately 20 chemical destruct tests will be conducted to determine the effects of gaseous halogens on the enhancement of the primary destruct operation.

Item 2.8 **TRAINING**

A 45-hour indoctrination course relating to Test Cell "A" was given to the second class of eleven trainees, and to seven Aerojet Rocket Test Technicians assigned to Test Cell A. Additional and improved instructional materials generated for this course were presented.

On-the-job training of both technicians and engineering personnel is underway for the various positions at the Control Point. Preparation of the Operator's qualification program has been initiated. Operator training is effectively being conducted through the use of the Control Point Simulator System.

Item 2.9 LASL SUPPORT

Thirty-six technical personnel are currently assigned to LASL support activities.

DECLASSIFIED

SECTION III (cont.)

TECHNICAL DISCUSSION

TASK 3.0 NRDS SUPPORT

DECLASSIFIED

Item 3.0 GENERAL SUPPORT FACILITIES

A review was completed of the final status report prepared by the Ralph M. Parsons Company for the Preliminary Master Plan for NRDS under contract with SNPO-N.

Item 3.1 NERVA EXHAUST SYSTEM (NES)

A. SCALE MODEL DEVELOPMENT

1. Sub-Subtask 3.1.2, Scale Model R & D Program

The first series of pumping tests utilizing the high chamber pressure (P_{s_1} optimum = 400 psia) secondary ejector has been completed, and the data are being analyzed. For the second series of tests, which are in progress, the secondary ejector duct has been increased in diameter to improve the performance. A preliminary test, conducted with cold nitrogen for both primary and secondary systems, indicates an increase in performance due to this modification. For the third series of tests, an annular nozzle will replace the individual nozzles that now comprise the secondary ejector nozzle.

The Dynamic Science Corporation is continuing its studies on the supersonic gas mixing problem. Equations have been developed for the mixing region with the assumption that this region begins at the plane in which the static pressures of the outer and inner stream are equal. The major problem remaining in the analytical effort is the derivation of the mechanism by which the pressures in the two streams are equalized.

2. Sub-Subtask 3.1.3, ETS-1 NES Configuration

Leakage tests of the SST-2 configuration continued during this report period. These tests indicate that the most satisfactory manner in which turbine exhaust flow can be handled is with two supersonic ($\epsilon \approx 4:1$) nozzles located at the nozzle exit plane. Tests performed on the twenty-four sonic nozzles at the nozzle exit plane and a parallel flow cylinder located in the engine compartment did not give results comparable to those obtained with the supersonic nozzles.

The completion of the latest series of leakage tests on the SST-2 configuration completed the testing program associated with Sub-subtask 3.1.3.

[redacted]

B. SUB-SUBTASK 3.1.4, DESIGN OF ETS-1 DUCT

1. Duct Preliminary Design

The NES ETS-1 duct preliminary design study phase was continued during this report period. The following is a description of the contributions of the study groups.

a. Coolant Flow Analysis

All available past history and current criteria data was assembled. Duct-coolant-water tube-section pressure drop, velocity, temperature, and water flow rates were established. Steam and shield system data were obtained and evaluated to determine the overall process system response.

The water system was analyzed for pipe size, velocity, and pressure drop. Maximum duct section outlet orifice diameters were determined. Flow pressures were calculated based on system capacity available for pre-start, run, and cool-down.

Analysis of the system is being continued using "K" factors for available pressures and flow capabilities after pre-start, engine run, and cool-down, with either pulsing or partial flow.

b. Preliminary Design

Design work has continued during the past month which will mechanically describe the fabrication and assembly of the NES ETS-1 duct.

The following drawings were completed during this report period and are being reviewed within RECN:

Primary Duct - Upper Assembly, and Coolant Passage Assembly
90° Elbow - Tubing Assembly, and Fixed Hinge Support
Water Shield
Upper Seal Assembly
Instrumentation

[redacted]

c. Instrumentation and Control

A review of the duct instrumentation and controls conducted during this report period, are based on the latest duct configuration.

RECM Drawing RD-1125, Duct Instrumentation Flow Diagram, was completed, and a channel list was compiled.

An RCM cost of the instrumentation was prepared based on the present duct I&C requirements.

d. Preliminary Design Review

A meeting between RECM and SNPO-C on July 17 and 18 was held at AGC-Azusa to review the progress of the NES ETS-1 system.

The review included discussion of progress in the areas of: NES I&C requirements, process-water-system calibration test, duct design, stress, and sub-scale structural testing.

e. Sub-Scale Seal Testing

The results of this testing program are being compiled for submission in a final report.

f. Duct Fabrication

A follow-up letter, including drawings, was transmitted to all potential fabrication vendors Discussion covered the duct design freeze, including use of Type 347 SS, tubular construction in the elbow only, and rectangular coolant passage in the remaining duct sections.

g. Sub-Scale Structural Testing

The sole-source procurement of the testing portion of this program was disallowed by SNPO-C. Therefore, the continuation of this program was initiated at Azusa.

h. Thermal Cyclic Structural Test

A proposal is in process outlining the tests required to simulate the internal wall thermal gradient expected in the NES duct

operation. This will be accomplished by attaching a duct specimen to a liquid chemical engine exhaust flange. A series of engine firings can then subject the specimen to the thermal and mechanic loading approximately equivalent to that anticipated in the NES duct operation. This information will be used to predict the cyclic life of the NES ETS-1 duct.

2. Stress Analysis

A loads profile for all duct operating and static conditions has been completed, and is available for use in design of the duct and truss structures. A report will be prepared for inclusion in the duct design criteria.

A sub-scale thermal stress test is being prepared for rectangular and tubular coolant channel specimens to duplicate the circumferential thermal stress in the tubular and rectangular coolant channels. From this test, the elastic-plastic strain in the coolant channel can be determined, and thermal and strain data recorded. All data from this test will be correlated and an appropriate design value for the minimum cyclic life will be determined.

The coolant channels have been analyzed, and a cycle life was determined, based on elastoplastic strain conditions in the channel membranes.

A structural analysis of the duct manifolds has been conducted; the proposed design is compatible with current design requirements.

Other structural analyses are in progress for the duct severance plane, the seal-bellows attachments, associated problems with the water shield, and the secondary ejector plenum chamber.

The structural ring frames, which are required to prevent buckling from external pressure and to provide dynamic rigidity, have been sized and incorporated in the duct drawings.

All loads have been determined for the carrying truss, based on the five support systems, and most members have been sized. The "two-piece" truss layout concept has been completed to accommodate all interference conditions. Details of special joints have been located and detailed.

C. SUB-SUBTASK 3.1.5, STEAM GENERATOR SYSTEM

The proposals were evaluated, for fabrication of the ETS-1 Steam Generator System, and Thiokol Chemical Corp. was selected as the contractor. Placement of the contract is anticipated during the next report period, pending approval of the selection by SNPO-C.

Reconsideration of the site location for the steam generator system at ETS-1 has been undertaken. Since the selected site (on the vertical wall) has the disadvantages of high radiation environment and inaccessibility, a new site is currently being considered near the shadow wall. However, completion of water-flow tests will be necessary to establish whether an adequate pressure can be delivered at this elevation.

Preliminary design of the temporary instrumentation and controls for the steam-generator development program at ETS-1 was initiated during this report period.

Effort has been continued to obtain GFE trailers located in the United Kingdom for the development I&C for the SGS. However, no firm delivery date has yet been established.

An anticipated steam-generator test program has been established. The program consists of two test phases: system development test utilizing trailer-mounted I&C, and a formal system demonstration test program patterned after preliminary flight rating test models.

D. SUB-SUBTASK 3.1.7, NES INTEGRATION

1. Uncooled Sheet Metal Duct

It is proposed to construct and install in ETS-1, a full-scale sheet-metal duct to be used for a series of tests to substantiate information obtained from the scale model tests; and other tests are proposed which cannot be conducted on sub-scale models. This test data is required for the design of the NES duct.

Cost estimates were received and reviewed for: transportation of sheet metal, instrumentation of sheet metal duct, installation of

sheet-metal duct in the vault at EIS-1, and procurement of the upper bellows assembly.

2. Duct Decontamination and Particle Penetration Studies

The problems of core particle penetration and fission product plateout were the main areas of effort in the past month.

Analysis and studies indicate that any particle larger than a grain of sand, if accelerated to the velocity approaching the engine exhaust gas velocity, will do severe damage in the elbow of the duct upon impact. This problem is being further investigated.

After each run, duct assemblies in current use at LRP require resoldering in areas of particle impingement caused by particle penetration. Similar repairs may be needed on the NES duct. Studies are continuing toward evaluating suitable coatings to prevent or attenuate particle penetration of the duct. A report showing the latest analysis on particle dynamics and metallurgical compatibility is being prepared.

The fission product plateout test program was prepared for the [illegible]-1964 Program. Current literature dealing with fission product plateout is being assembled and analyzed.

A method was proposed for prediction of the velocity of flake-off particles in the EIS 1 ejector system, as a function of particle size, shape, density, and duct location.

3. EIS-1 Duct Acceptance Criteria and Minimum Acceptable Standards

A rough draft of the NES Duct Fabrication Criteria was prepared.

4. GSE and Duct Installation and Removal

The Operational Support Plan is being prepared.

5. Use and Operational Analysis

Preliminary duct design data were compiled as a function of duct station.

6. Malfunction Analysis and Interface Control

As a result of the work in progress, a Design Handbook of the NES will be prepared.

A preliminary flow diagram of the NES cooling water system was prepared. In addition, preliminary diagrams of the duct cooling water operating time sequence (to show a typical valve operation without regard to engine operation), and of the existing facility instrumentation and controls (to show valve operation in detail) were prepared. These diagrams illustrate the operation of the water automatic control system. A detailed facility instrumentation hardware list is included.

A preliminary diagram of the duct instrumentation has been initiated. This diagram is used in conjunction with the cooling water system diagram and will include a detailed duct instrumentation hardware list.

A study is in progress to determine the effect of the fire protection water demand on the cooling system.

Pictorial schematic diagrams of the ETS-1 steam generator and fire protection systems including sequence of operation, instrumentation, and hardware lists, are in process.

A schedule of pressure temperatures and flow rates of the process and water requirements for ETS-1 is being prepared.

The above documents will be used to determine the life expectancy of NES components for use in establishing the service maintenance policies.

Item 3.2 **TEST STAND**

REON review comments on specifications and drawings of the ETS-1 fire-protection system and facility additions and modifications were completed and submitted to SNPO-C.

The ETS-1 PERT network, as prepared by SNPO, was reviewed in comparison with the network prepared by REON. The REON ETS-1 completion and activation-checkout PERT were updated to reflect the current proposed engine test date.

Efforts were continued in establishment and upgrading of ETS-1 Facility Functional Requirements, consistent with engine design and program requirements, in the following areas:

A. Preperation and updating of design criteria for the adapter assembly and the Test-Stand thrust structure.

B. Evaluation of the Cold-Flow Test System propellant-line designs, now in use at H-5 area of LRP, for use in ETS-1.

C. Revision and expansion of the ETS-1 test procedures and countdown schedule.

D. Coordination of ETS-1 construction and activation with NES "Tin Can" duct and steam generator testing.

E. Coordination of NERVA Exhaust System I&C requirements and control console layouts.

F. Initiation of ETS-1 Facility-To-Engine Interface preliminary design criteria for previously undefined areas.

Item 3.3 ETS-1 INSTRUMENTATION AND CONTROLS SYSTEM

A. GENERAL

Review comments of the ETS-1 I&C System preliminary-design package were presented by REON to SNPO-C at a meeting in Azusa, on 8 and 9 July for concurrence prior to submittal to EG&G as technical direction. Subsequent meetings between SNPO-C, WANL, LASL, LRP, and REON resulted in incorporation of joint REON and SNPO comments as Addendum No. 7 to the ETS-1 I&C Design Criteria, which was published and transmitted to SNPO-C for concurrence and transmittal to EG&G. The following technical direction, required to complete the revision to the ETS-1 I&C System Design Package, was transmitted:

Attachment No. 1:	Instructions for preparation and packaging
Attachment No. 2:	Addendum No. 7
Attachment No. 3:	List of required drawings for design package
Attachment No. 3a:	List of drawings required
Attachment No. 4:	List of required technical specifications.

REON is currently reviewing the ETS-1 Control Room Console Design Package submitted by EG&G. The console control and display tabulations are being updated in conjunction with this review by REON to reflect the latest requirements, including those in Addendum No. 7. The Control Point Building I&C Equipment Proposed Layout is currently being revised to provide an LSE Console common to both ETS-1 and -2, instead of one console for each test stand. The comments on the console-design package, the updated control and display tabulations, and the revised control-center equipment layout will be transmitted simultaneously to EG&G.

The final design vellums and cost estimates for Facilities Modification of test-stand terminal boxes and cable trays, submitted by EG&G, are currently being reviewed for final signoff by REON.

REON is preparing technical direction to EG&G for implementation of a Reliability and Quality Assurance Program that will apply to the ETS-1 I & C design effort. The program will include monitoring and maintaining surveillance of EG&G's reliability and quality assurance system, procedures, reports, and performance.

Work is currently in progress and will continue in the areas of:

Interface integration of GSE, engine simulator, and checkout.

Review and updating of the ETS-1 electrical power requirements.

Review and definition of the color requirements of the consoles and racks in the Control Room.

Review of I&C System components and provision of critical failure data.

Review and comments on B&G Drafting Room Manual.

Determination of the cabling requirements for three-way vent valves. Furnishing of detail listing of control function requirements.

Joint definition with B&G of the performance requirements for the Thermocouple Ovens. Preparation of justification letter to SNPO-C for use of ovens instead of wells.

Review and updating of the Control-Room Layout utilizing a common LSE Console for ETS-1 and ETS-2.

Review of previously stated functional requirements for the combustible gas and oxygen detectors in the engine compartment.

Definition of method of detection of air flow into the CP, with readout in the Control Room.

Preparation and transmission to SNPO-C of a cost analysis for a proposed 32-channel FM wide band recording system.

Determination of an acceptable method for provision of control lockout being shared between ETS-1 and ETS-2.

Completion of review and sign-off of final vellums for cable trays and test stand terminal boxes, facilities modification.

Revision of ETS-1 I&C Criteria Addendum No. 4 and 5 in accordance with SNPO-C comments.

Completion of review and comments on ETS-1 control-room console design package submitted B&G.

Determination of the requirements and proposed implementation to provide lighting for TV Stations 9, 10, and 11.

Definition of the space requirements on the TOC for the REC System controls and displays.

Definition of the Data Reduction requirements BTS-1 I&C.

Review and comment on Digital Data System Functional Specification (Rev. C), as based on changes necessary to transform this document into a procurement specification.

3. GENERAL REVIEW AND CLARIFICATIONS

Detailed review and clarifications were made by REON, with subsequent transmittal to EG&G and SFPO-1, on the following:

1. Safety System

Provision for an alarm at the LSE for hydrogen detector at the air inlet to the CPB: The following requirements were defined: the Radiation Monitor Recorders on the LSE, recorders for the combustible gas and oxygen monitoring stations, local aural alarm requirements at the radiation monitoring stations, and space requirements on the Facility Console for the fire-protection system deluge switches.

2. Television System

The sensitivity of the television system was defined. EG&G was directed to perform photographic survey of TV Stations 1, 2, 4, and 5, and proposed Station 3, in order to determine whether the 25-ft tower for Station 3 can be eliminated. This study was completed and it was concluded that the tower could be deleted, and that Station 3 could be relocated to the roof of Photo Station No. 6B. This direction was defined in Addendum No. 7.

3. Signal Conditioning System

Various agreements reached at a technical meeting held at AGC, Azusa, on 19-20 June 1963 and subsequent telecons concerning this system were confirmed.

4. Electrical Power System

The recording resolution and accuracy requirements for the Electrical Power System were confirmed.

Item 3.4 TEST STAND

REOW Report 2502 Basic Criteria - Engine Test Stand No. 2 at NRDS was revised in accordance with SNPO-C direction and issued during this reporting period as a basis for proceeding with the design of ETS-2 and its integration with ETS-1. This report presents data obtained through an evaluation of the NERVA Engine Development Test Requirements, including operational requirements for the NERVA Engine, the Engine Static Test Complex utilization, ETS-2 functional requirements, and ETS-1 and ETS-2 integration.

Work has been initiated on the development of the technical data required from REOW for the ETS-2 design delineated in the above report. In general, this is information relative to interfaces, including those of the engine-to-Test Stand, particularly the run-tank bottom; Test Stand ETS-1 to Test Stand ETS-2; and Test Stand-to-Exhaust System. The schedule for submittal of this data will be made when the design needs of the Architect-Engineer are known.

A study has begun to determine the ETS-1 and ETS-2 control system interfaces, and areas potentially requiring interlocks or lock-outs, as directed by SNPO-C. The study will consist of:

a determination of the common system and components,

an evaluation of the common shared system relative to need for interlocks, lockouts, common controls, and other potential areas of interferences,

preliminary evaluation of methods of integration of ETS-1 control system with ETS-2,

preparation of flow diagrams and control schematics that will depict the areas where interlocks or lockouts may be required to assure safety of ETS-1/ETS-2 operations.

This study is scheduled for completion in the next reporting period.

Item 3.5 **E-MAD BUILDING**

A. OPERATIONAL REQUIREMENTS

NERVA operational requirements were expanded and updated, to assist the Architect-Engineer in upgrading design criteria and in establishment of final design, specifically in the following areas:

Dimensional requirements of provisions for transfer opening in cell doors

Viewing ray plots; which were transmitted, including REON's comments, to SNPO-C in response to their request of June 13

NERVA operational requirements are currently under study for Phase III of the feasibility study for E-MAD facilities and railspurs to accomodate concurrent use of NRX and E-Engine operations in the E-MAD complex.

B. DESIGN REVIEW

In accordance with SNPO-C Procedures, REON completed transmittal of the review backup data for the manipulator specifications; the "Y" radiation-monitoring design drawings and the system specification remain to be transmitted. This review is to be based on SNPO-C decisions at a radiation-monitoring meeting which has not yet been scheduled by SNPO-C.

In accordance with SNPO-C Procedures, REON completed review of the 700 Series "Certified for Construction" Phase II drawings.

NERVA operational, functional and safety requirements were established as required, in order to conduct a comprehensive review of E-MAD design specific items and areas expanded upon during this report period. Items of this nature which have been transmitted to SNPO-C, or are in preparation, include rectilinear and master slave manipulators.

A meeting was held with SNPO-C personnel at Azusa during the week of July 24 for review of rough draft relative to recommendations for total manipulator requirements.

A meeting was held at AEC office, Las Vegas, between personnel of SNPO-N, VITRO, and REON for discussion of scope and additional required data to define items planned by SNPO-C to be procured for E-MAD 1964 modifications.

REON attended a meeting held in New York to give SNPO-C direction to Vitro on changes to E-MAD Phase II "For Approval" drawings and specifications.

C. E-MAD ACTIVATION PLANNING AND PROCEDURES

Recommended equipment lists for E-MAD were transmitted to SNPO-C to clarify Vault-Assay and Counting Room equipment and total manipulator requirements.

Preparation of the E-MAD Activation Guide continued during this period. The guide is approximately 25% complete for the E-MAD Phase I cold-bay activation section.

Item 3.6 REACTOR DEVELOPMENT FACILITY

The final report on the cold-gas mixer model tests conducted at Azusa has been written and will be released in the near future by REON.

Technical discussions with cognizant NRDS personnel were held to ascertain the progress status and schedules of Test Cell A modifications. The following items have resulted from these discussions:

A. COLD GAS MIXER

Flow tests were conducted on the LASL Cold Gas Mixer at NRDS, utilizing open loop or manual control. The results indicated that the mixing chamber was satisfactory for the flow conditions to which it was subjected. Closed-loop tests will be conducted during August.

B. WIDE BAND INSTRUMENTATION

Purchase orders have been issued for the equipment required for the 195 channels of wide-band instrumentation. LASL estimated that 30 to 35 channels would be installed by 15 September 1963 and the remainder by 1 October 1963.

C. SIGNAL CONDITIONING EQUIPMENT

LASL has designed a new bridge-type signal conditioner for strain-gage type channels which will provide capabilities for bridge completion, zero suppression, bridge balance, voltage substitution, calibration, and resistance shunting of the bridge for checkout purposes. The resistance shunt will not be used for calibration purposes because the required six wires from the transducer to the signal conditioner are not now available. Sixty of these units will be ordered, but will probably not be available for NRX-A1.

D. TEST CELL A OPERATIONAL PROCEDURES

Operating procedures for Test Cell A Facility System have been written, and are in process of internal review. Documentation of Test Cell A Control-Point operating procedures in support of WANL Operator Training Program will be developed in the near future.

Item 3.7 RADIATION EFFECTS FACILITY (REF)

During the meetings of 18 and 19 June at SNPO-C, redirection of the REF was established by SNPO-C personnel in the following areas:

> The REF Cryogenics facility will be sized for a 10-minute run capability in lieu of the 20-minute run capability previously established.
>
> Facility start-up requirements will be based on ASTR start-up time, but will not exceed 20 seconds.
>
> LH_2 NPSP tolerance at the inlet to the pump will be increased from ±0.1 psi to ±0.2 psi.
>
> NPSP need not be held at the steady-state point during start-up.

REON's evaluation and study of this redirection, based on current materials radiation-effects testing and operating requirements for the Propellant Feed System (PFS), established that the objectives of the PFS testing would not be adversely effected.

The facilities Minimum Start-up Requirements at NARF for PFS tests were transmitted to SNPO-C on 11 July 1963.

Personnel of SNPO-C, GD/FW, and M. W. Kellogg visited PFS testing facilities at LRP on 23 and 24 July 1963. During this visit additional operating requirements of the NARF Facility were requested from REON by SNPO-C and M. W. Kellogg personnel. This information is being generated.

On 31 July, SNPO-C requested by telecon that REON review a proposal that PFS tests be conducted at NARF with the PFS in a horizontal position, rather than in a vertical position. This proposal is now being studied by REON. It would require repositioning the reactor so that the same relationship between the PFS and reactor would be maintained.

Item 3.8 **NRDS RADIOACTIVE MATERIALS HANDLING, DECONTAMINATION, AND STORAGE COMPLEX**

A meeting between personnel of SNPO, WANL, and REON was held in Cleveland on 19 July to review SNPO-C comments concerning preliminary releases of the following REON reports.

REON Report 2592 - Radioactive Materials Handling, Decontamination, and Storage Complex Design Concept and Criteria

REON Report 2592 - Supplement Detail Data for Cost Summary in Report 2592

REON Report 2603 - Engine Transport System Maintenance Building Design Criteria

REON Report 2603 - Supplement Detail Data for Cost Summary in Report 2603

At the meeting, SNPO-C directed REON to defer issuance of Report 2592 until released by SNPO-C and to issue Report 2603 as corrected by SNPO-C in meeting, but not to reissue the cost supplements.

SNPO-C requested REON and WANL to review and re-evaluate the engine cooling and radiation monitoring requirements. Work has been initiated to meet this instruction.

The minutes of this meeting were transmitted on 29 July 1963.

Report 2603 has been revised in accordance with SNPO-C comments, and is scheduled for publication in August.

Report 2592 is being upgraded in accordance with SNPO-C comments, and an August meeting is planned for SNPO-C review of the revised report draft. REON is awaiting further instructions before release of subject report.

The Action Item Summary Report was updated and transmitted on 29 July 1963.

Item 3.9 RIFT STAGE DEVELOPMENT FACILITIES

There was no activity on this task item during this report period.

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SECTION III (cont.)

TECHNICAL DISCUSSION

TASK 4.0 PROGRAM MANAGEMENT

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Item 4.1 PROGRAM PLANNING AND CONTROL

Contract Year 1964 planning was continued and extended to preparation of preliminary detailed planning networks for all significant subtasks. Preliminary schedule interface review meetings were held with all principal plants.

NEX-A1 planning and schedule coordination meetings were held with WADD. NEX-A1 Task Force supporting efforts were continued.

Bi-weekly PERT reports were submitted to SMPO-C as required.

Item 4.2 FISCAL CONTROL

Preparation of the Program Planning Document for CY 1964 continued. Preparation of the data for Change Order No. 1 to Mod 8 was initiated. The Monthly Fiscal Supplement to the June Progress Letter was prepared and submitted to SNPO-C.

Item 4.3 ADDITIONAL DOCUMENTATION

The following additional documents were prepared and published by RE N during the report period.

RE Report No.	Date Transmitted	Title	Report Classification
2275	7-29-63	Materials Properties Data Book (2nd Rev)	UNCL
2320	7-1-63	Instrumentation Data Book (2nd Rev)	C-RD
2502	7-15-63	EIS-2 Criteria	S-RD
2543	6-30-63	Gen II Mod 1 NERVA Engine Simulator	C-RD
L0560-10-24	7-17-63	Informal Monthly Progress Letter No. 24	C-RD
L0560-10-24	7-23-63	Reliability & Quality Assurance Supplement to Monthly Progress Letter No. 24	UNCL
L0560-10-24	7-22-63	Fiscal Supplement to Monthly Progress Letter No. 24	UNCL
-37	7-2-63	Weekly Highlights Report (TWX) No. 37	UNCL
-38	7-9-63	Weekly Highlights Report (TWX) No. 38	UNCL
-39	7-16-63	Weekly Highlights Report (TWX) No. 39	UNCL
-40	7-23-63	Weekly Highlights Report (TWX) No. 40	UNCL
-41	7-30-63	Weekly Highlights Report (TWX) No. 41	UNCL
-13	7-2-63	Weekly Significant Events & Reactor Component Test Program Progress Report No. 13	C-RD
-14	7-9-63	Progress Report No. 14	C-RD
-15	7-16-63	Progress Report No. 15	C-RD
-16	7-23-63	Progress Report No. 16	C-RD
-17	7-30-63	Progress Report No. 17	C-RD
63-20	7-5-63	PERT Report	CONF
63-21	7-19-63	PERT Report	CONF

REON Report No.	Date Transmitted	Title	Report Classification
	7-16-63	Subcontractor Monthly Progress Report for June (WANL, Bendix, AMF)	UNCL
	7-19-63	NRES SS Materials Accountability Station Manual	UNCL

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Item 4.4 CENTRAL DATA SYSTEM

Approximately 2,000 engineering drawings and specifications were processed in the engineering data system. The file now contains nearly 7,000 current documents and includes drawings from LSP, BE[illegible], WAM, Bendix, AMF, ACFI, LASL, and [illegible].

Development of the support equipment data system is continuing.

Effort is continuing on the engineering data system to provide microfilm input to [illegible] from all participants for document submittals.

Item 4.5 SUBCONTRACTS ADMINISTRATION

A. SUBCONTRACT NP-1 - WESTINGHOUSE

Discussions were held with WANL relative to the Program Plan for Contract Year 1964. Preliminary information was received during the early part of the month; the revised Work Program and Budget were received 30 July, and further revisions and discussion will take place in August.

B. SUBCONTRACT NP-2 - BENDIX

Amendment No. 1 to Supplemental Agreement No. 2 was completed during July and mailed to Bendix for their review and execution.

Bendix Program Plan and Cost Study Proposal, Report No. BPAD-863-381-R1, for Contract Year 1964 was received on 30 July.

C. SUBCONTRACT NP-3 - AMF ATOMICS

Supplemental Agreement No. 2 was approved by SNPO on 11 July.

The AMF Program Plan for Contract Year 1964 was received on 22 July.

Amendment No. 1 to Supplemental Agreement No. 2 was forwarded to AMF for approval and signature on 3 July.

D. SUBCONTRACT NP-11 - GENERAL ELECTRIC, VALLECITOS

Facilities survey of the General Electric Vallecitos plant was accomplished on 5 July.

Negotiations were completed and subcontract executed by General Electric on 29 July and forwarded to SNPO-C for approval.

E. PROPOSED SUBCONTRACT NP-12 - GENERAL ELECTRIC, WEST LYNN

Negotiations were completed with General Electric, West Lynn, Massachusetts, on the piston-type TPCV, and a contract to start design and fabrication is expected to be let early in August.

F. PROPOSED SUBCONTRACT FOR STEAM GENERATOR SYSTEM - TASK 3.1

Following evaluation of all proposals received, purchase order was prepared for award to Thiokol on the basis of low bid. Facility survey was made on 19 July. Purchase order was forwarded to SNPO-C for review and approval.

G. PROPOSED SUBCONTRACT FOR ANALYTIC DUCT SYSTEM PROGRAMMING

Requests for Quotation were issued for the analytic duct system programming.

H. EDP PROPERTY CONTROL SYSTEM

An EDP property control system similar to the LRP system is being set up. A meeting is planned at Westinghouse in August to integrate control system for tooling and special test equipment.

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SECTION III (cont.)

TECHNICAL DISCUSSION

TASK 5.0 SPECIAL TEST EQUIPMENT

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Item 5.1 SPECIAL TEST EQUIPMENT
AGC (LRP - TEST ZONE "C")

Fabrication of the TSOV vessel for Test Stand C-7 was essentially completed during the month, and the vessel is currently being prepared for delivery to LRP.

Formal bids covering the installation of the vessel and related piping systems were requested early in July, and contract award followed shortly after. Test Stand modifications were initiated by contractor personnel on 23 July 1963. Rerouting of the C-6 LH_2 fill line was successfully completed by AGC personnel.

Design work, as associated with the modifications to Test Stand C-6 to accommodate NRX-A cold flow nozzle testing, was completed, formal bids were solicited, and a contract was awarded, scheduling completion of fabrication to be within 19 days. Installation of contractor fabricated STE and checkout of the modified stand is scheduled for early September.

Design work associated with the TPCV testing on Test Stands C-7, C-8 was completed, and drawings prepared covering the piping installation by Test Operations personnel.

Item 5.2 SPECIAL TEST EQUIPMENT
AGC (LRP CRYOGENICS LABORATORY - TEST ZONE "A")

The fabrication and installation of the TSOV test setup was essentially completed in the Cryogenic Laboratory during the month of July. Only minor piping hookups remain to be completed.

Fabrication and installation work on the LH_2 transfer piping systems was initiated by formal contract. This work is scheduled for completion in September.

Active work on the remaining items of CY 1963 contractual requirements continued throughout the month.

Item 5.3 SPECIAL TEST EQUIPMENT
AGC (LRP - TEST ZONE "H")

Contractor fabrication of the ejector system for Test Stand H-5 was completed in July, and shipment to LRP accomplished by late July. Actual installation of the complete ejector system will be initiated in CY 1964.

Shop drawings for the Test Stand H-6 TSOV vessel were approved by Test Division design and AETRON. Fabrication of the vessel was continued throughout the month and is currently approximately 50% complete.

Details of work involved in the Instrumentation and Controls activation change order were transmitted to the electrical contractor for price determination. Subsequently, contractor activation contracts for Test Stand H-6 were awarded to the mechanical and electrical contractors, and a completion date of mid-August was established. AGC activation completion and the first IPA testing are scheduled for the week of 23 September.

Activation of Zone H propellant and pressurant storage and transfer systems was initiated with the loading of GN_2, LN_2, GH_2, and LH_2.

Work on the supersonic diffuser, vacuum vessel, and handling system for Test Stand H-4 progressed, and deliveries of portions of the diffuser assembly are scheduled for August and October.

The bidders' proposals for test area additional readout equipment to accommodate CFDIS instrumentation was forwarded by Test Division to SNPO-C for approval.

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SECTION III (cont.)

TECHNICAL DISCUSSION

TASK 6.0 GOVERNMENT PROPERTY

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Item 6.0 GOVERNMENT PROPERTY

There was no activity in this task during the reporting period.

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SECTION IV

PROGRESS STATUS

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IV. PROGRESS STATUS

The accompanying charts present task milestones as selected for the various contract tasks of the contractual Work Statements. Certain of the items cannot be readily programmed by discrete milestone events, and charts have not been prepared for these items.

These milestone charts include those presented with the various NERVA Technical Administration Documents presented in REON Report RN 63002 (C-RD), entitled NERVA Engine Development Program and Associated Tasks, Contract Year 1963 (Revised), June 1963, and all have been expanded and modified as necessary to reflect the redirected program.

These charts have been upgraded to reflect progress through July 1963. Where milestones have been accomplished, the appropriate completion symbols have been added to the chart. If a scheduled milestone has not been accomplished, a re-scheduling has been indicated and a discussion is presented in the following paragraphs.

Task Item 1.1 Engine System

Milestone No. 14 - Ship Shield Reflector Match Plate

Rescheduled because of delay in obtaining drawing approval for single source vendor.

Milestone No. 28 - REON Submit Final Test Specs. to SNPO-C, NRX-A1 Cold-Flow Test at NRDS

Rescheduled because of rescheduling of NRX-A Program.

Milestone No. 32 - LRP Complete Acceptance Test NRX-Ap Cold Flow

Rescheduled because of rescheduling of NRX-A Program

Milestone No. 39 - Complete Requirement for Block I Engine Control Loops

Rescheduled because of additional time required to obtain complete analysis.

[redacted]

Task Item 1.2 Propellant Feed System

Milestone No. 4 - Select and Procure Candidate Check Valves

Rescheduled. Valves ordered but delivery by vendor delayed until the end of September for the cooldown check valve.

Milestone No. 10 - Complete Design and Layout of Mk-IV TPA

Change in guide lines by SNPO-C resulted in rescheduling of completion.

Milestone No. 18 - TPA - Suction Line - TSOV Test (Start)

Rescheduled because of delay in C-7 facilities modification at LRP.

Task Item 1.3 Nuclear Subsystems

Milestone No. 10 - Vibration Phase II

Cancelled by program redirection.

Milestone No. 15 - Vibration Phase II

Cancelled by program redirection.

Milestone No. 2 - Report on Outer Reflector Stress Analysis

Rescheduled pending final review.

Milestone No. 52 - Test Specimen Procurement Complete

Rescheduled pending vendor delivery.

Milestone No. 64 - Test Specimen Procurement Complete

Rescheduled because of delay in procurement of filler strips and pyrolite.

Milestone No. 69 - Test Specimen Procurement Complete

Rescheduled because leaf springs and core barrel are not yet available.

Milestone No. 71 - Test Specimen Procurement Complete

Rescheduled because of vendor delay.

Milestone No. 72 - Test Rig Procurement Complete

Rescheduled because of vendor delay.

Milestone No. 75 - Test Spec. Procurement Complete

Rescheduled because vendor is unable to supply the tie bolts.

Milestone No. 77 - Test Specimen Procurement Complete

Rescheduled because of vendor delay.

Milestone No. 87 - Initial Tests Complete

Rescheduled because application of the strain gage required additional time.

Milestone No. 90 - Test Rig Procurement Complete

Cancelled as a result of a review of the component program.

Milestone No. 1[illegible] - Initial Report Issued

Rescheduled because the redirection of the component program took a higher priority.

Milestone No. 106 - Test Specimen Procurement Complete

Cancelled as a result of a review of the component program.

Milestone No. 107 - Test Rig Procurement Complete

Cancelled as a result of a review of the component program.

Milestone No. 108 - Initial Tests Complete

Cancelled as a result of a review of the component program.

Milestone No. 117 - Start Fabrication Plate, Castings and Tooling

Cancelled because of program re-direction.

Milestone No. 125 - Complete Fabrication of 7 Hole Test Plate

Rescheduled because of procurement problems.

Milestone No. 129 - Start 7 Hole Plate Tests

Rescheduled pending completion of fabrication.

Milestone No. 138 - Statistical Prediction of Maximum Fuel Temperature Issued

Rescheduled, now in final draft form and being prepared for review.

Milestone No. 143 - Preliminary NRX-A3 Thermal Test Request Issued

Rescheduled because of the latest demands of the reactor test schedule.

Milestone No. 151 - NRX-A3 Core Loading and Tolerance Specifications Issued

Rescheduled consistent with latest demands for fuel fabrication.

Milestone No. 152 - Preliminary NRX-A3 Nuclear Test Request Issued

Rescheduled because of the latest demands of the reactor schedule.

Milestone No. 177 - Preliminary Control Malfunction Studies on the NRX-A2 Complete

Rescheduled because of effort expended on component engineering and vibration studies.

Milestone No. 211 - Approval of Design of Instrumentation System Installation by Instrumentation Laboratory

Rescheduled pending drawing availability.

Milestone No. 212 - Complete Proof-Testing and Evaluation Report of Instrumentation

Rescheduled pending issuance of data sheets and reports on accelerometers and pressure gages.

Milestone No. 217 - Approval of Design of Instrumentation System Installation by Instrumentation Laboratory

Rescheduled pending drawing availability.

Milestone No. 218 - Complete Proof-Testing and Evaluation Report of Instrumentation

Rescheduled pending completion of the radiation test program.

Milestone No. 219 - Complete Procurement Specification for Instrumentation

Rescheduled pending further detail definition.

Milestone No. 220 - Complete Specification Acceptance Testing and Calibration of Instrumentation

Rescheduled. Specifications will be written as part of the procurement specifications.

Milestone No. 223 - Complete Proof-Testing and Evaluation of Report of Instrumentation

Rescheduled because the transducer development program affects this milestone.

Milestone No. 224 - Complete Procurement Specification for Instrumentation

Rescheduled pending radiation test results.

Milestone No. 226 - NRX-A2 Fuel Element Fabrication Complete

Rescheduled because of fabrication problems.

Milestone No. 230 - Process Specifications for Fuel Elements for NRX-A3 Issued

Rescheduled pending resolution of the fabrication problems.

Milestone No. 236 - Initial Report Issued

Rescheduled. Draft is complete and report is in process of being issued.

Milestone No. 238 - Test Specimen Procurement Complete

Rescheduled because of specimen supply proble

Milestone No. 239 - Test Rig Procurement Complete

Rescheduled pending final check of the redesign.

Milestone No. 240 - Test Complete

Rescheduled pending check of the redesign and hardware problems.

Milestone No. 246 - Test Complete - Redesigned Components

Rescheduled because of late availability of component.

Milestone No. 255 - Test Specimen Procurement Complete

Rescheduled because of project redirection.

Milestone No. 256 - Test Rig Procurement Complete

Rescheduled because of project redirection.

Milestone No. 262 - Test Complete

Rescheduled because of expanded program.

Milestone No. 267 - Report Issued

Rescheduled because of heat exchanger failure.

Milestone No. 274 - H_2 Test Complete

Rescheduled because of redesign of the control drum shaft required additional tests.

Milestone No. 277 - Test Rig Procurement Complete

Rescheduled because of procurement problems

Milestone No. 284 - NRX-A Phase I Vibration Core Hardware Procurement Complete

Rescheduled pending receipt of final hardware.

Milestone No. 286 - NRX-A2 HF Reactor Parts Procurement Complete

Rescheduled because of vendor delivery schedule.

Milestone No. 288 - NRX-A1 Cold Flow Shield Replacement Unit Fabrication Complete

Rescheduled because of late vendor delivery.

Milestone No. 291 - Initiate Long Lead Hardware Procurement of Replacement Hardware for NRX-A3 (Hot Test)

Cancelled because the nature of the reactor has changed from cold to hot.

Milestone No. 296 - NRX-A1 Reactor Assembly Complete

Rescheduled because of late delivery of parts.

Milestone No. 297 - Ship Complete NRX-A1 CF (NRDS)

Rescheduled because of delayed start of shipment.

Milestone No. 296 - Start PAX Assembly NRX-A2

Rescheduled pending vendor delivery of parts

Milestone No. 301 - NRX-A1 Final Test Specification

Rescheduled because of revisions and engineering comments change in types of tests.

Milestone No. 303 - NRX-A2 Hot Test

Rescheduled pending detailed requirements definition.

Milestone No. 304 - NRX-A3 Cold Flow

Rescheduled pending detailed requirements definition.

Milestone No. 305 - NRX-A3 Hot Test

Rescheduled pending detailed requirements definition.

Milestone No. 312 - NRX-A1 Available at NRDS

Rescheduled because of scheduled delivery date from WANL.

Milestone No. 313 - PX Nozzle Available at NRDS

Rescheduled because of scheduled delivery date from LRP.

Milestone No. 316 - NRX-A1 NRDS Assembly Procedures Complete

Rescheduled pending procedures detail definition.

Milestone No. 321 - Complete Design, Procurement and Assembly of a Complete Reactor Mockup for Check-Out of NRX-A Assembly/Disassembly Equipment

Rescheduled pending hardware delivery.

Task Item 1.4 Thrust Chamber Assembly

Milestone No. 1 - Complete Fabrication of Hybrid Nozzles

Rescheduled because of nozzle fabrication problems.

Milestone No. 3 - Complete Fabrication Reactor Backup Two (2) NERVA Nozzles for LASL

Rescheduled because of nozzle fabrication problems.

Milestone No. 4 - Complete Fabrication Pressure Vessel and NRX-A Nozzle

Rescheduled because of delay in nozzle fabrication.

Milestone No. 7 - Initiate ICA Dynamic Tests

Rescheduled because of redesign and fabrication problems.

Task Item 2.1 Remote Handling Equipment

Milestone No. 12 - EIS

Rescheduled but no anticipated slip in final delivery.

Task Item 2.6 Reliability and Quality Assurance

Milestone No. 9 - Complete Review of NRX-A1 Cold Flow Non-Nuclear Assembly Acceptance Test Data (LRF)

Cancelled because of cancellation of test upon which it was based.

Task Item 2.7 Safety

Milestone No. 8 - Issue Revised RLMT Safety Report on NERVA Engine Description

Rescheduled to incorporate data from 1X engine Model Specification.

Milestone No. 13 - Reactor Shipping Safeguards Report Complete

Rescheduled pending data analysis.

Milestone No. 14 - Report on Feasibility of Flight Version of a Full Core Nuclear Poison System Issued

Rescheduled because of new project direction.

Milestone No. 20 - Initial Re-entry Simulation Runs on Irradiated Fuel Complete

Rescheduled because of sub-contractor problem.

Task Item 5.1 Special Test Equipment AGC (LRP-Test Zone "C")

Milestone No. 11 - Fabricate and Install Transducers Similator System

Rescheduled. Program constraints improves transducer and system calibration capability.

Task Item 5.3 Special Test Equipment AGC (LRP-Test Zone "H")

Milestone No. 4 - Fabricate and Install Supersonic Diffuser and Engine Chamber Vessel

Rescheduled because of fabrication delay by the vendor. This will have no effect on the current test plan. Installation will commence with scheduled T.S. downtime.

Milestone No. 11 - Fabricate and Install Gas Generator for Simulator and TPA Testing

Rescheduled because of installation delay to match activation schedule of H-6.

Milestone No. 23 - Fabricate and Install Instrumentation and Control STE TS-H-4-5-6

Rescheduled because of additional time required to complete contractual effort necessitating reprogramming of H-6 testing to October 1963.

Task Item 5.5 Special Test Equipment AGC (STE-AGC) Downey Plant

Milestone No. 1 - Complete Procurement Electrical-Instrumentation Equipment

Rescheduled because test requirements necessitated re-evaluation of purchased items resulting in equipment replacement.

Milestone No. 3 - Complete Procurement Radiological Equipment

Rescheduled because additional items added for procurement.

Task Item 5.9 Special Test Equipment LRP - Controls and Chemical Laboratory (Building 2002)

Milestone No. 2 - Fabricate and Install LN_2 Pipe System Extension to Elec Laboratory

Rescheduled to permit removal of program constrains which will provide more economical test capability.

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.1

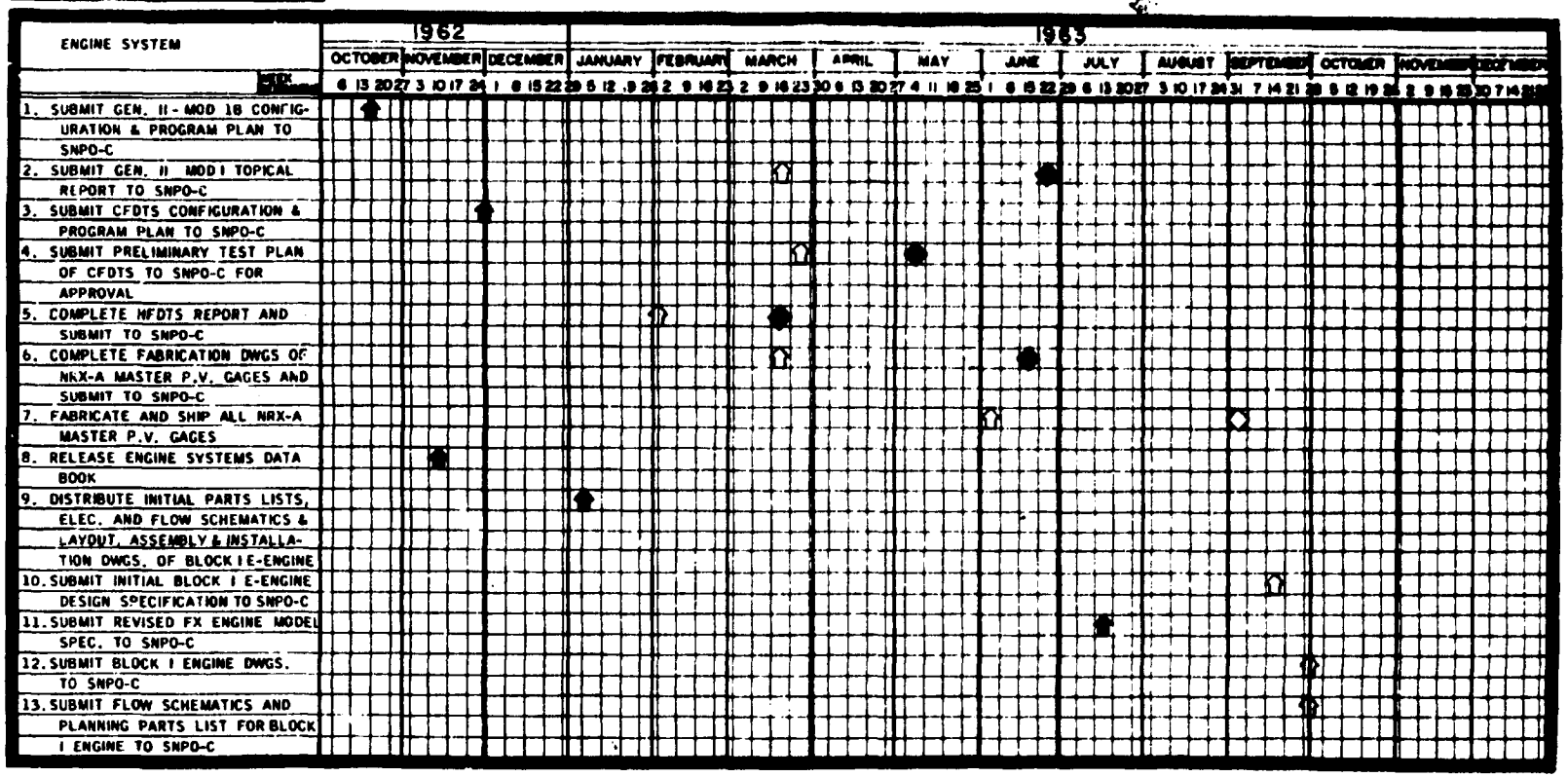

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Figure 1
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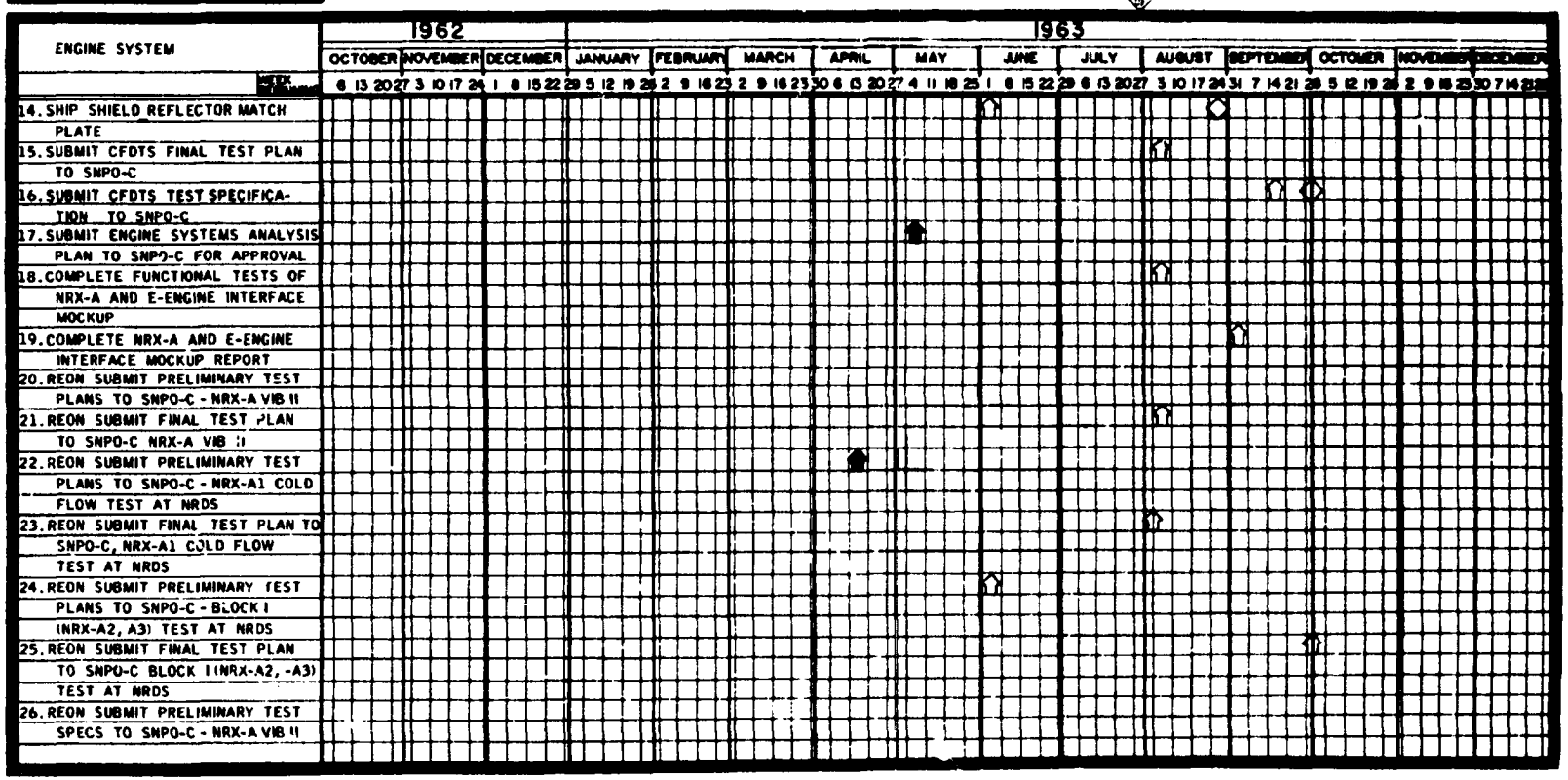
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.1



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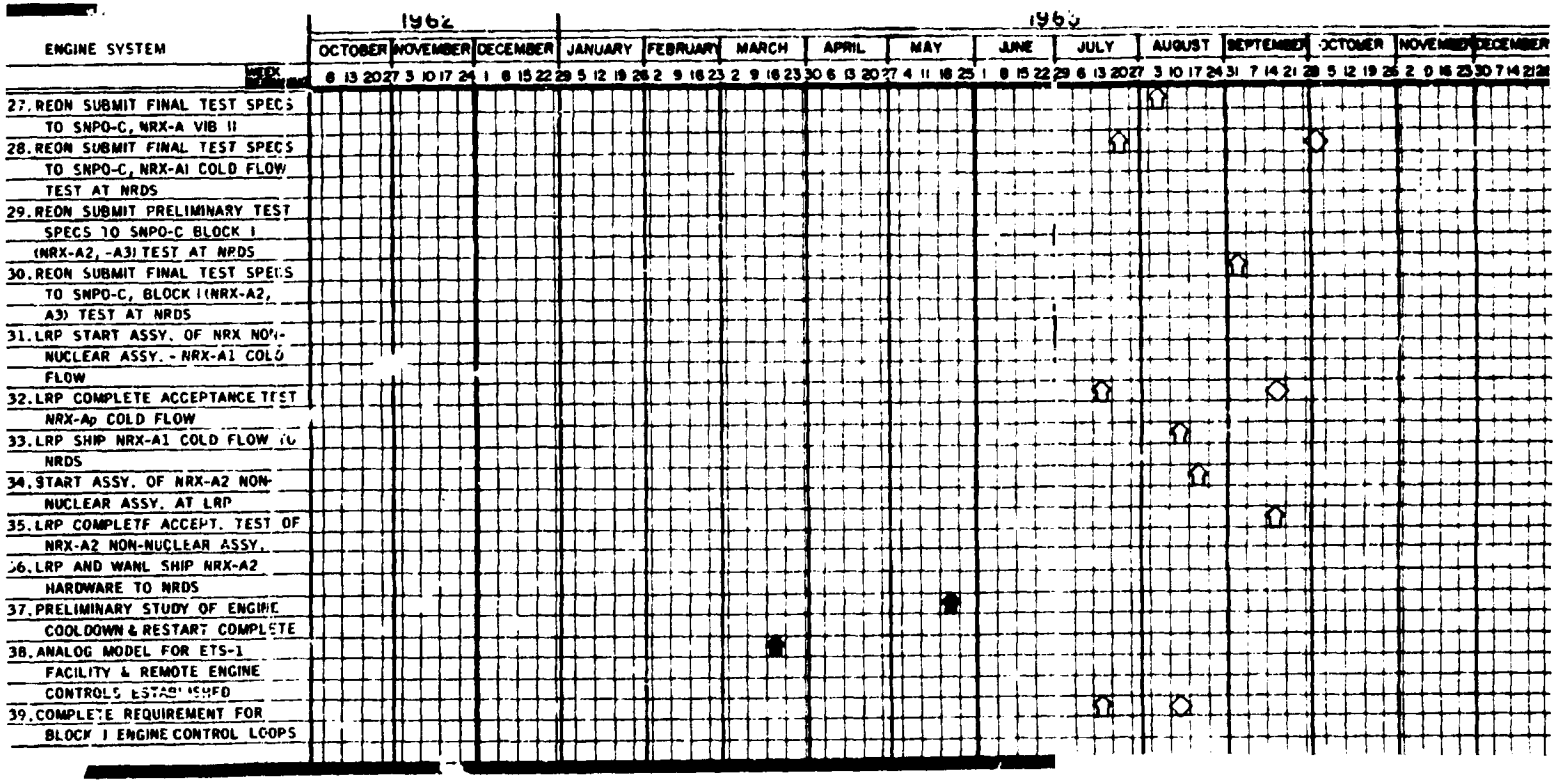
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.1



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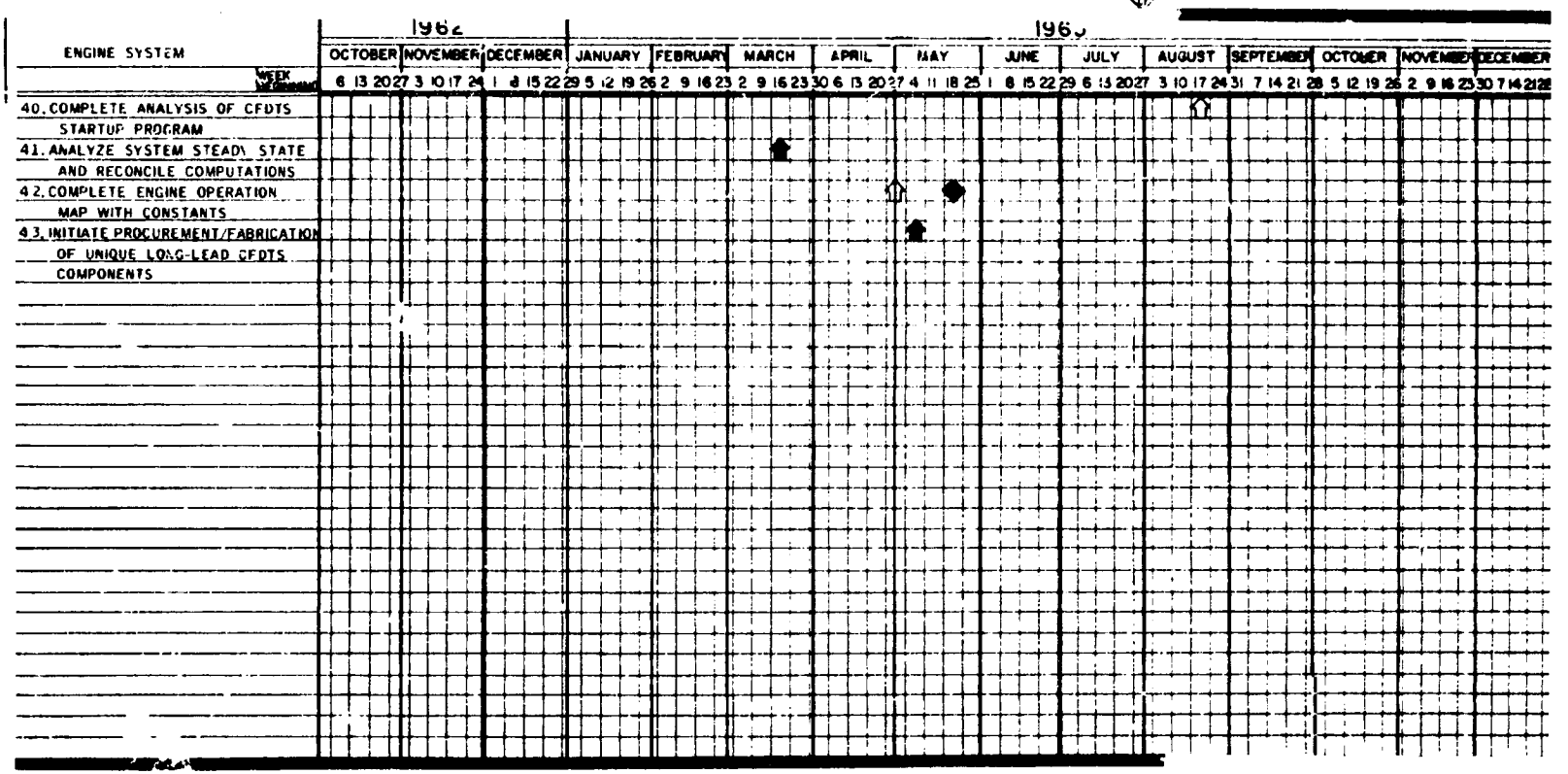
SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.1



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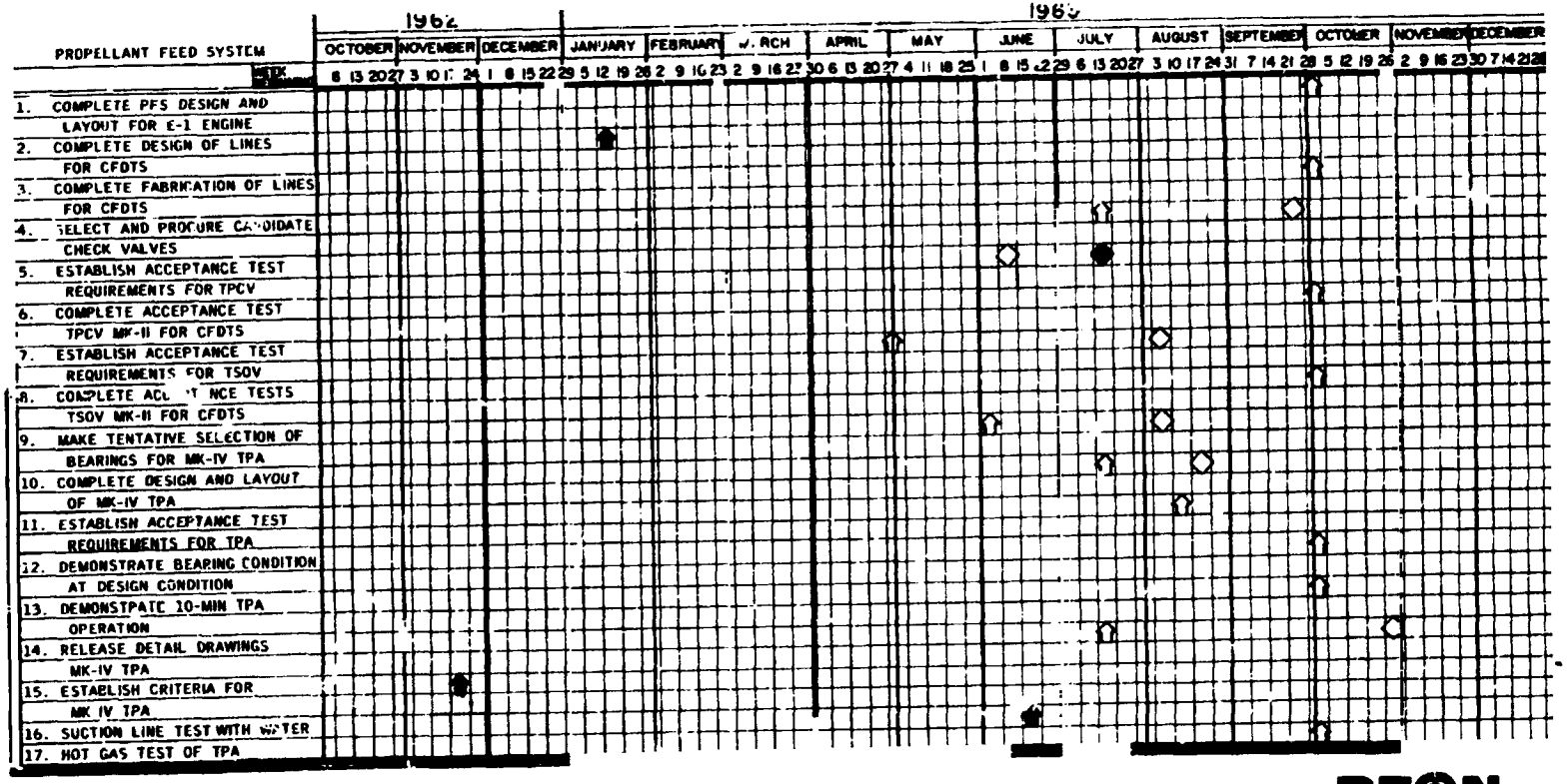
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.2



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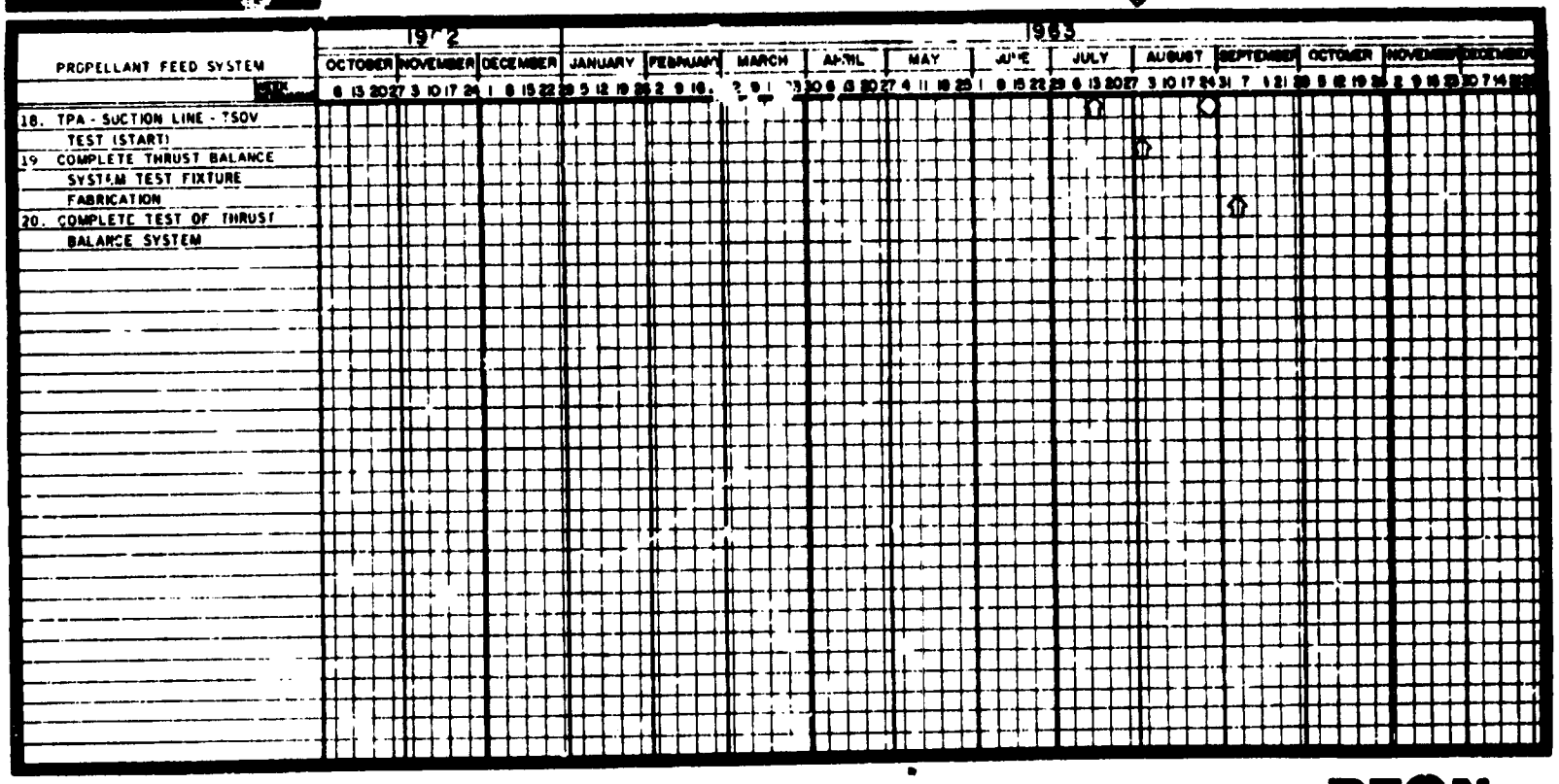
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.2



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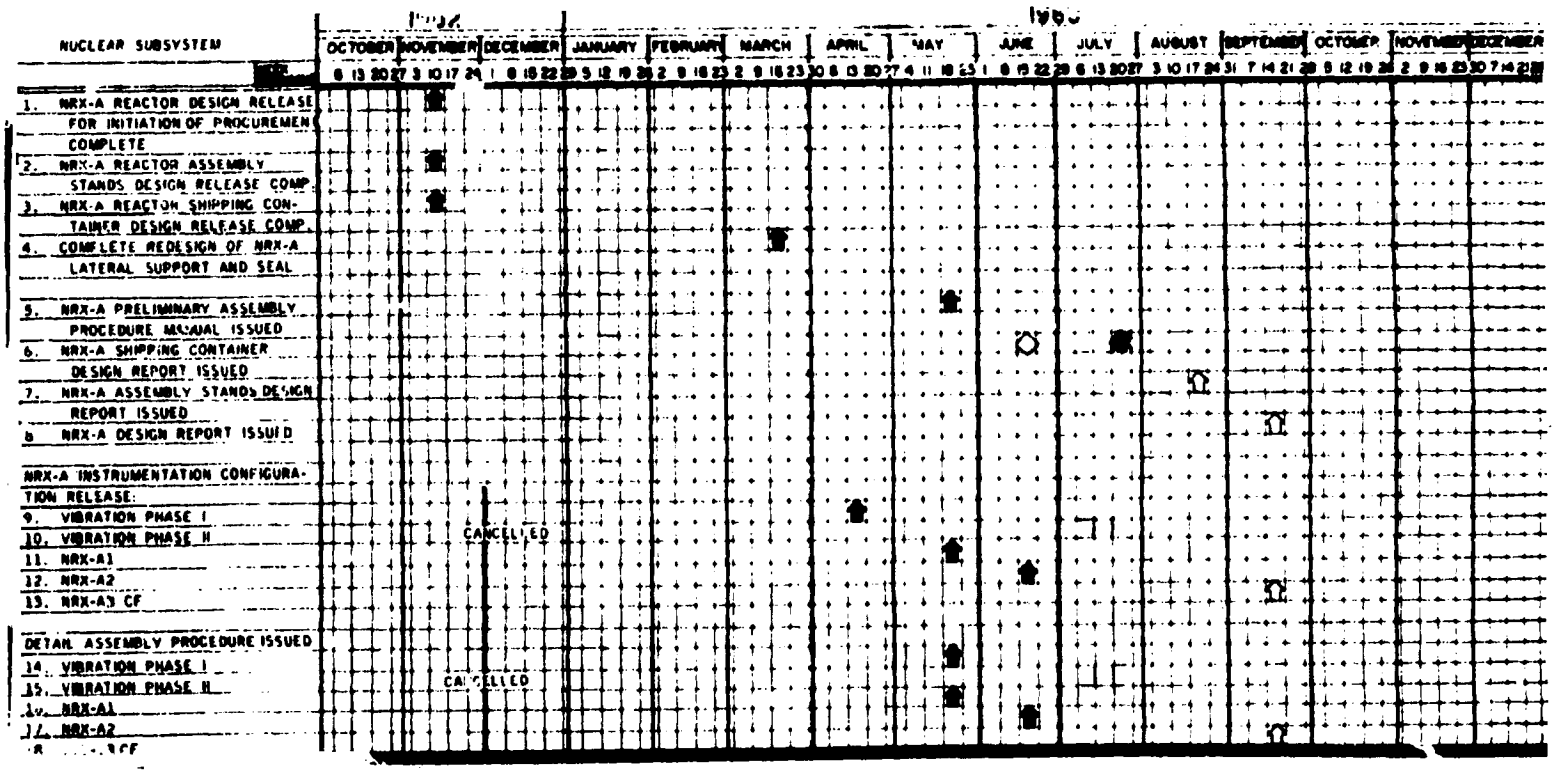
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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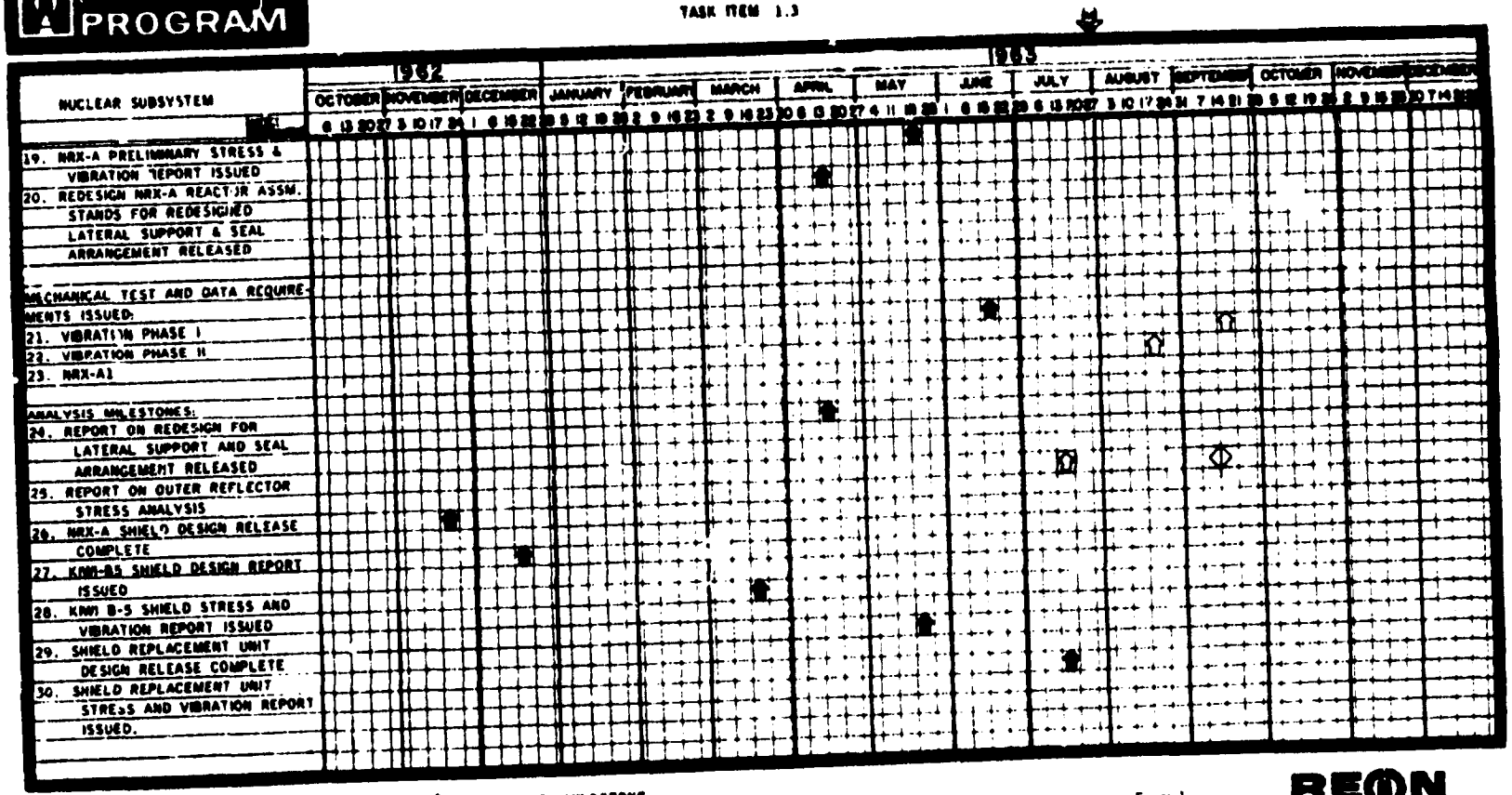
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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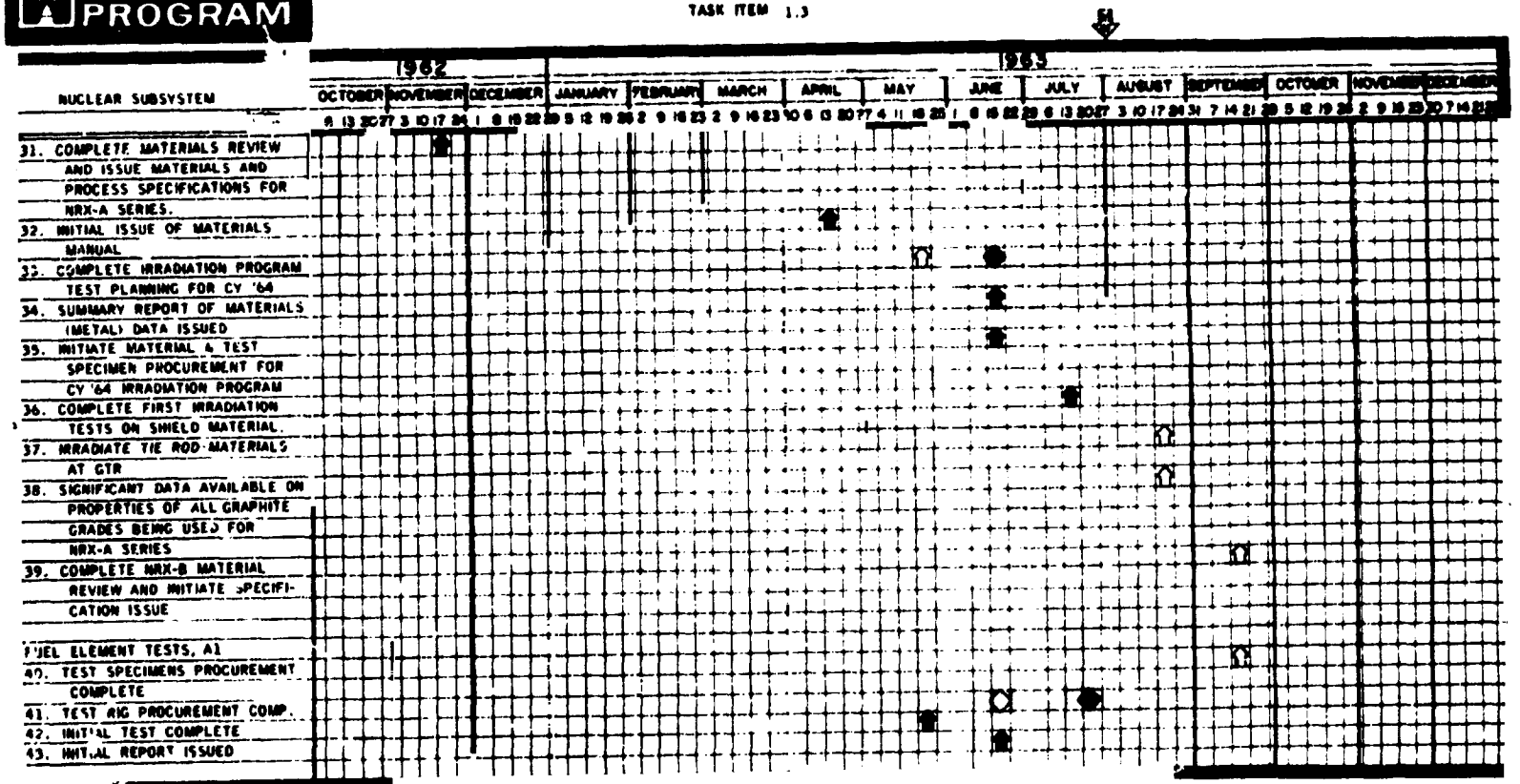
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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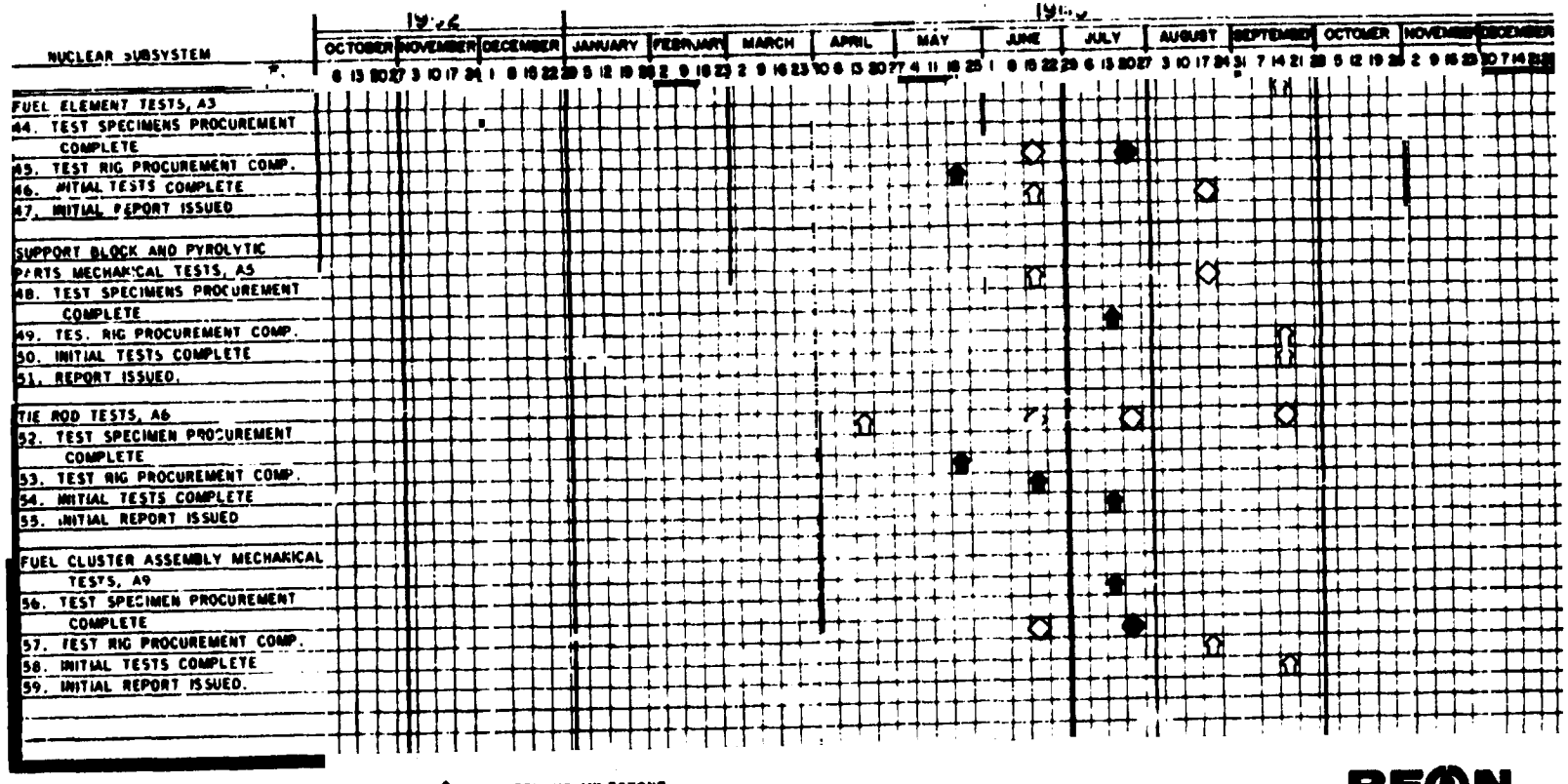
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3

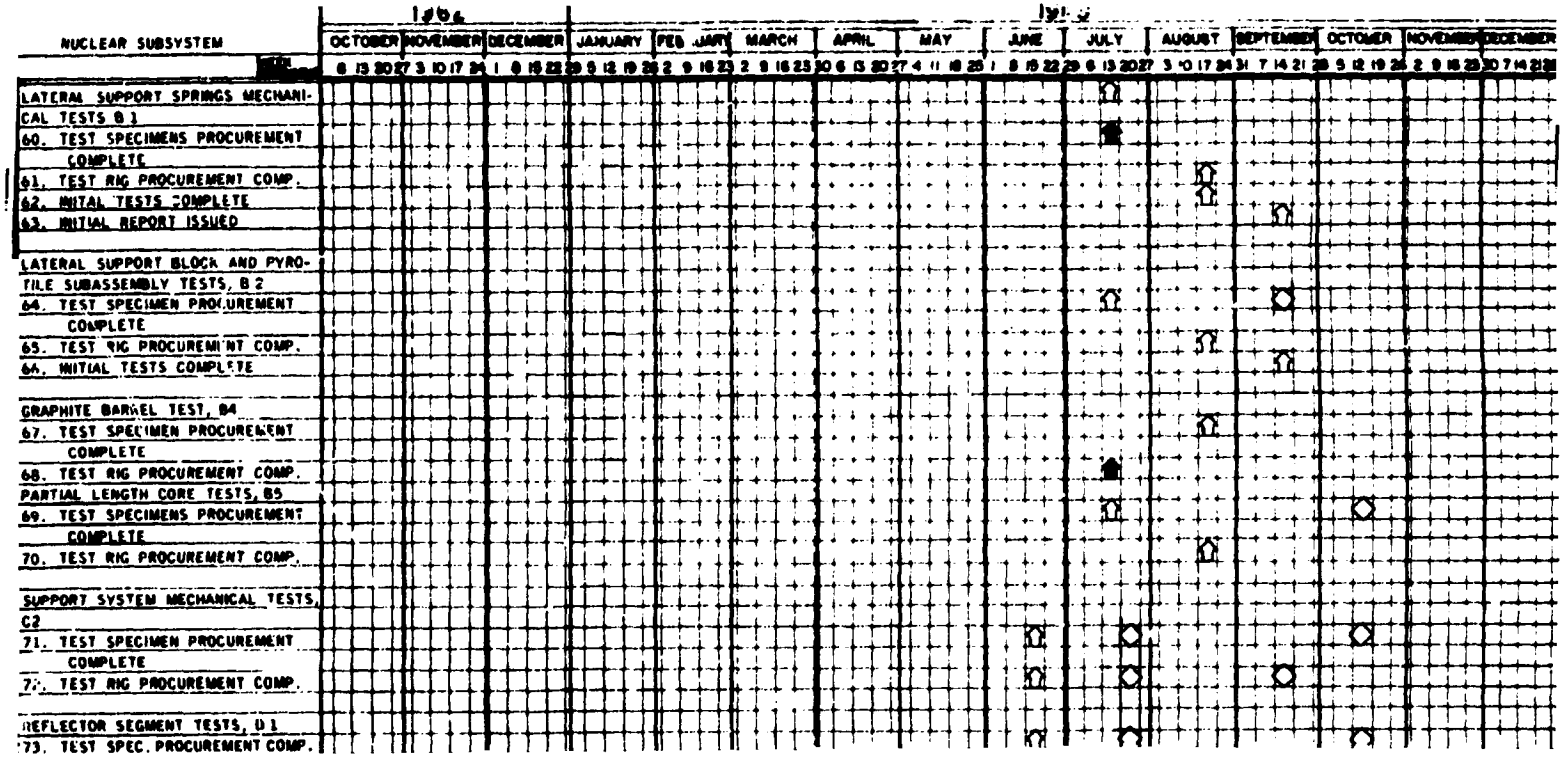

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Figure 1
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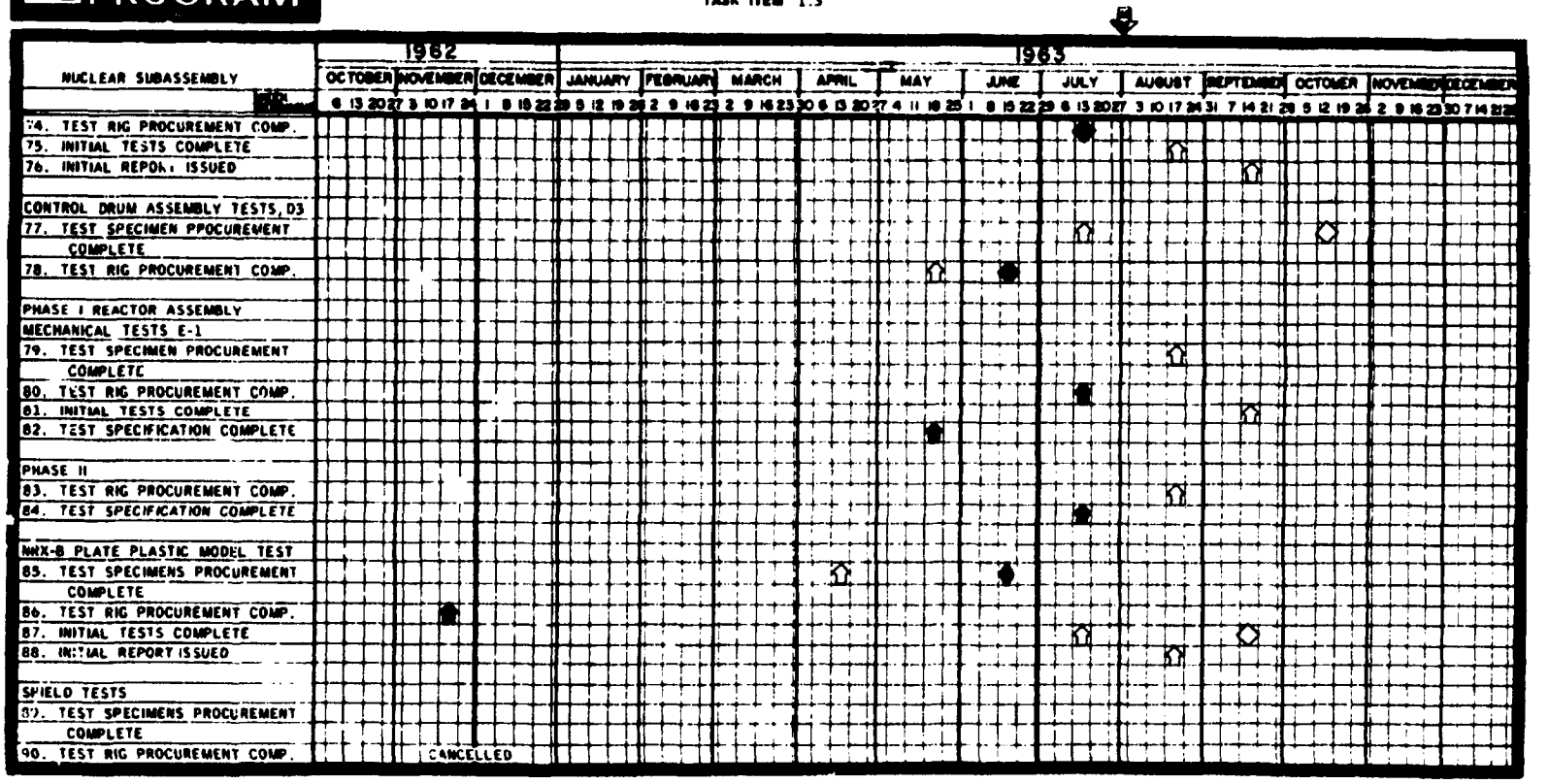
REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



DATE:

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MILESTONE ACHIEVEMENT

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RESCHEDULED MILESTONE ACHIEVEMENT

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NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3

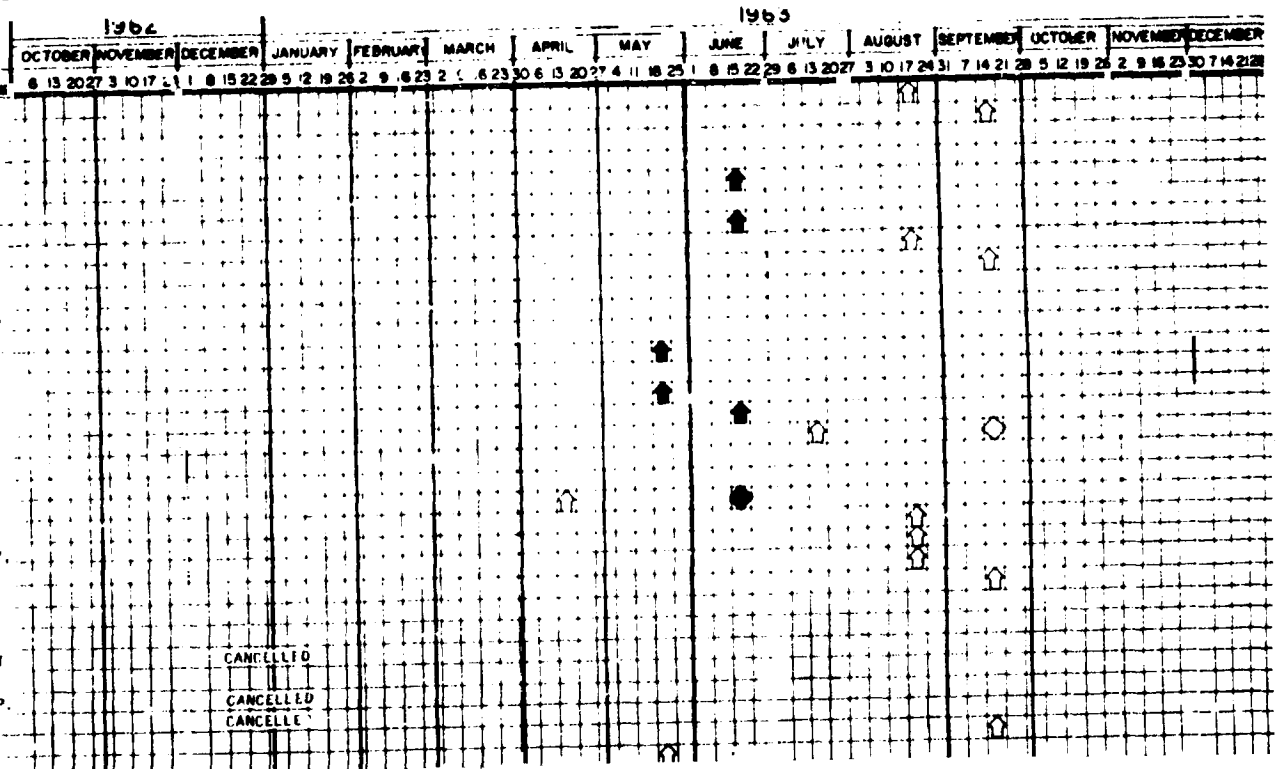

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Figure 1
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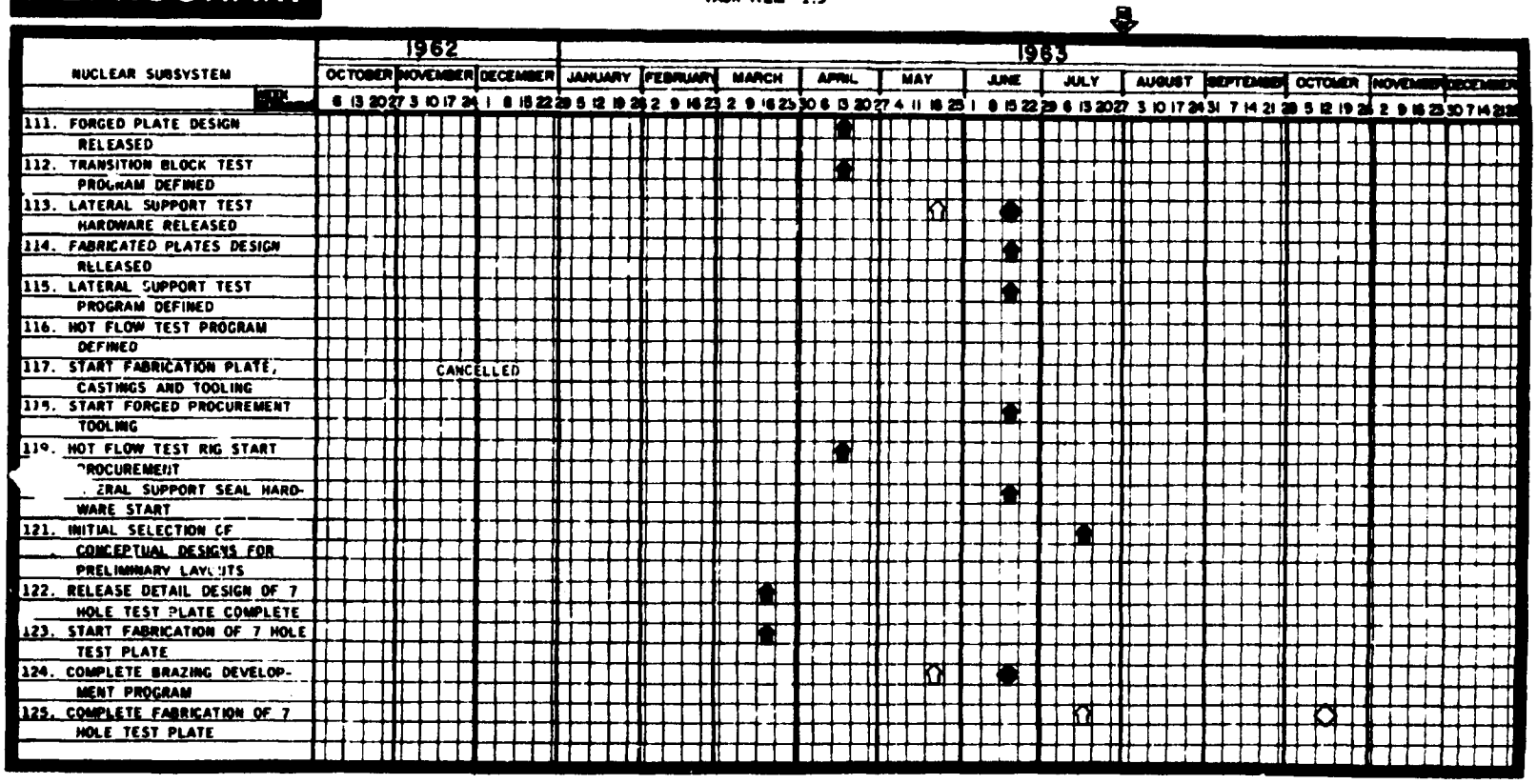
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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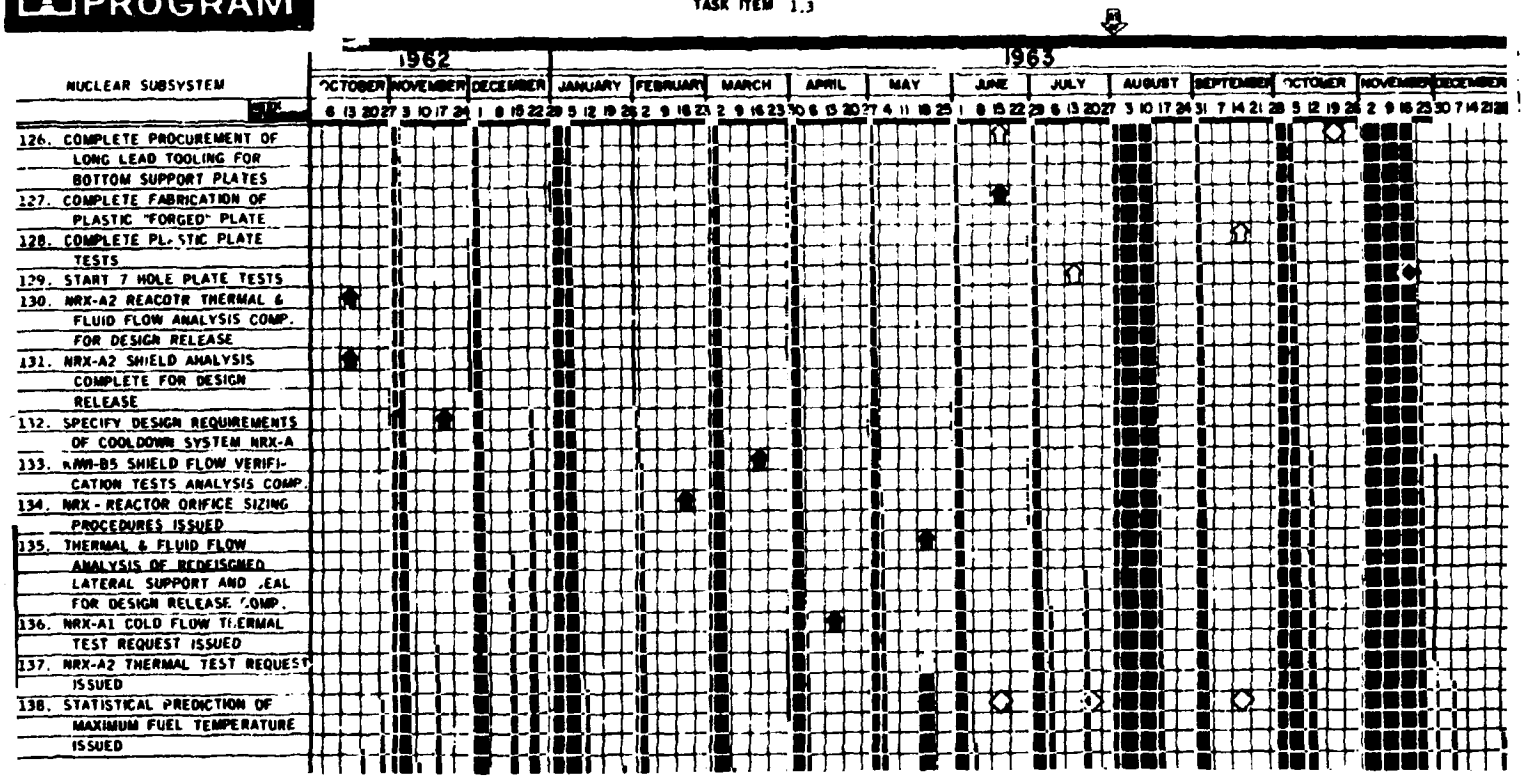
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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⇧ SCHEDULED MILESTONE
◇ RESCHEDULED MILESTONE
MILESTONE ACHIEVEMENT
◆ RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
Sheet 15 of 63

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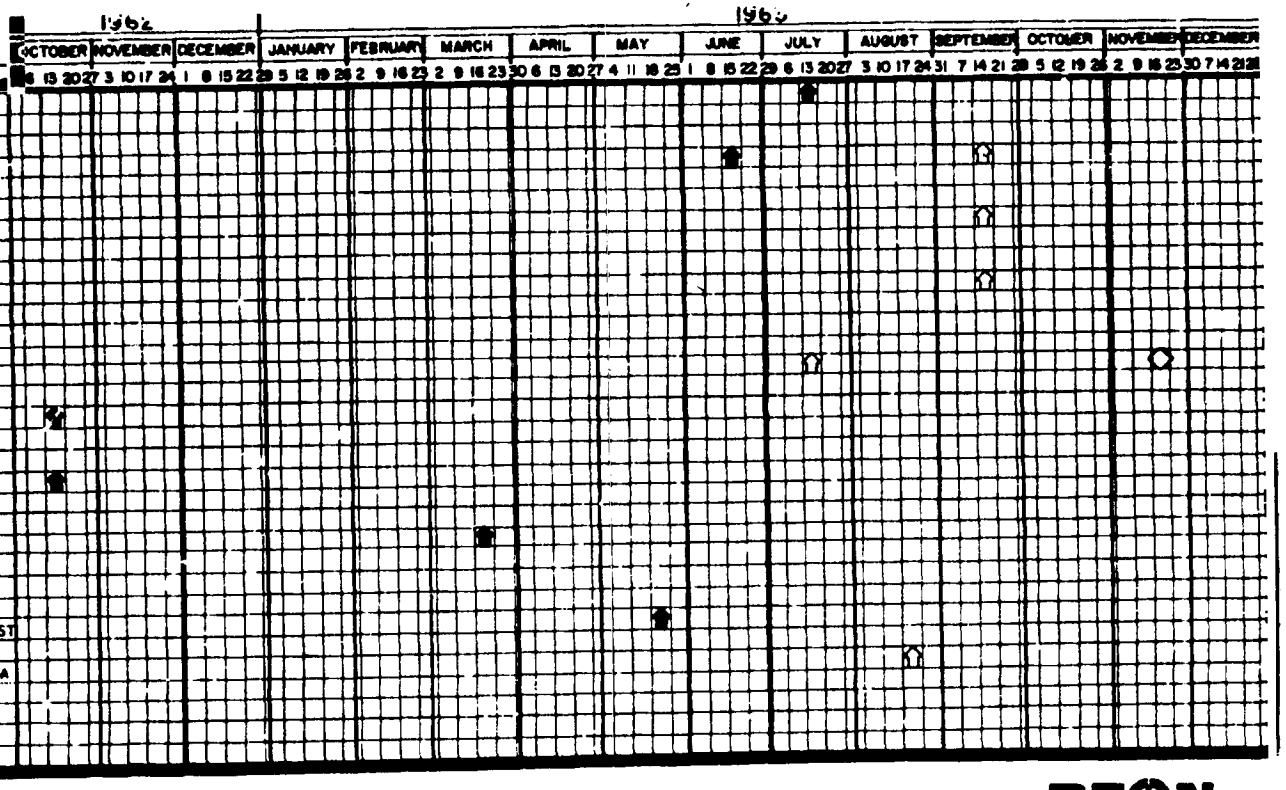
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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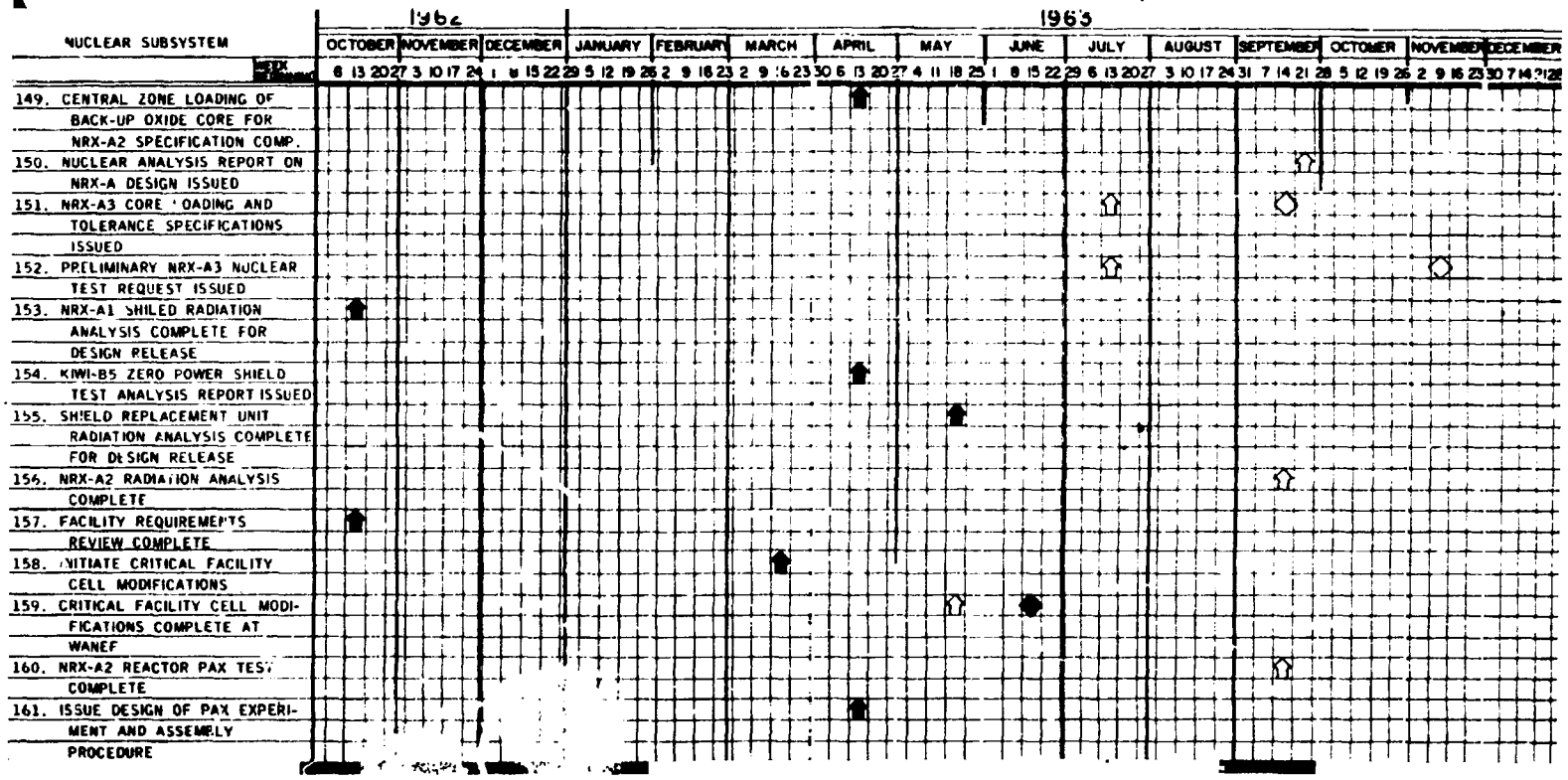
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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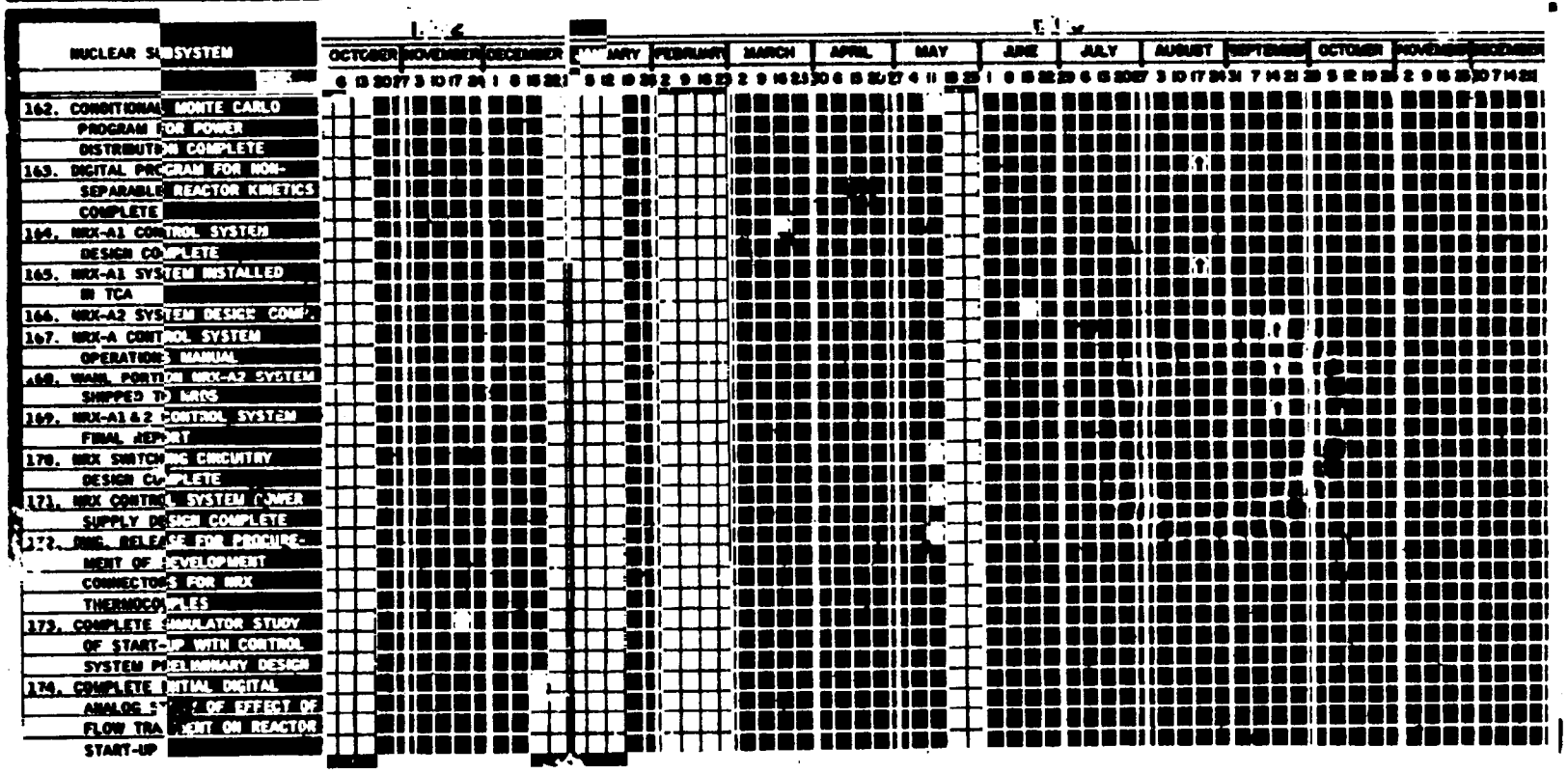
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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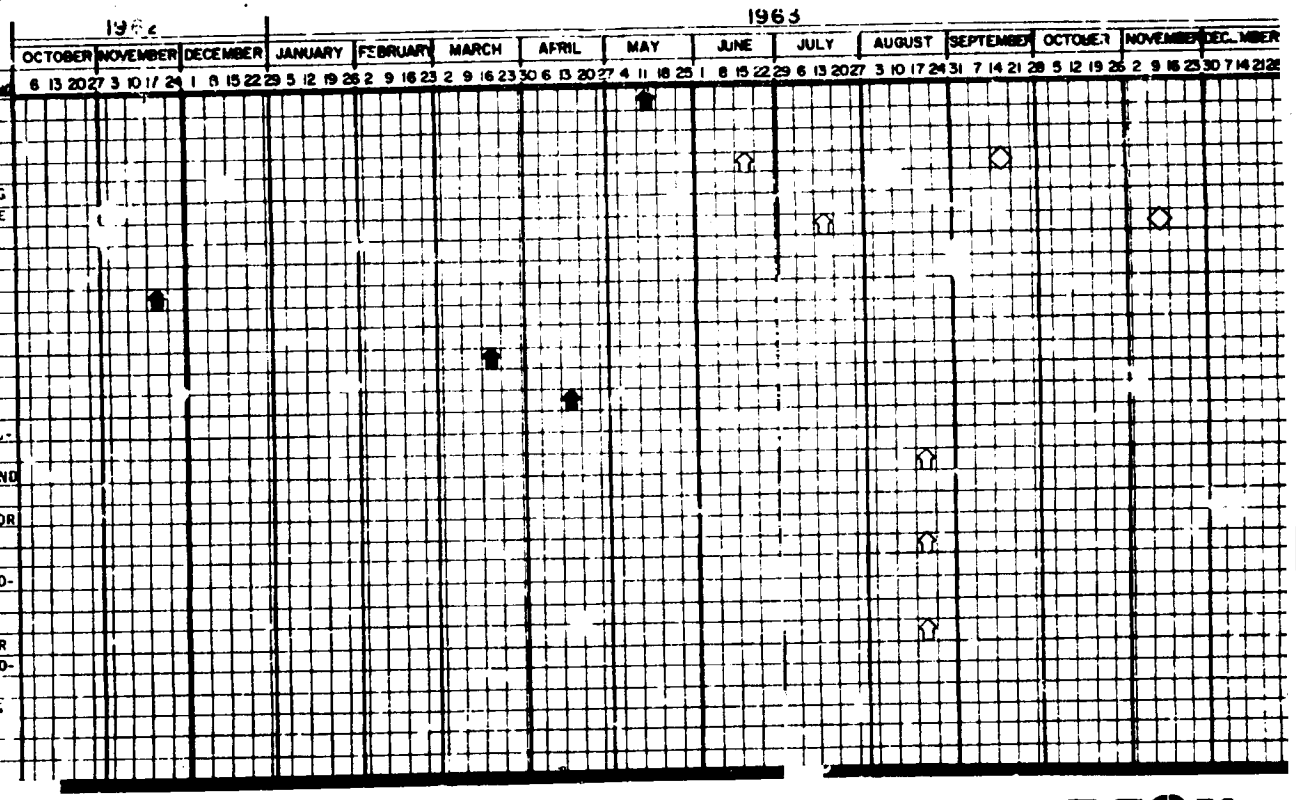
NERVA PROGRAM

SCHEDULES AND MILESTONES

CONTRACT YEAR 1963

TASK ITEM 1.3



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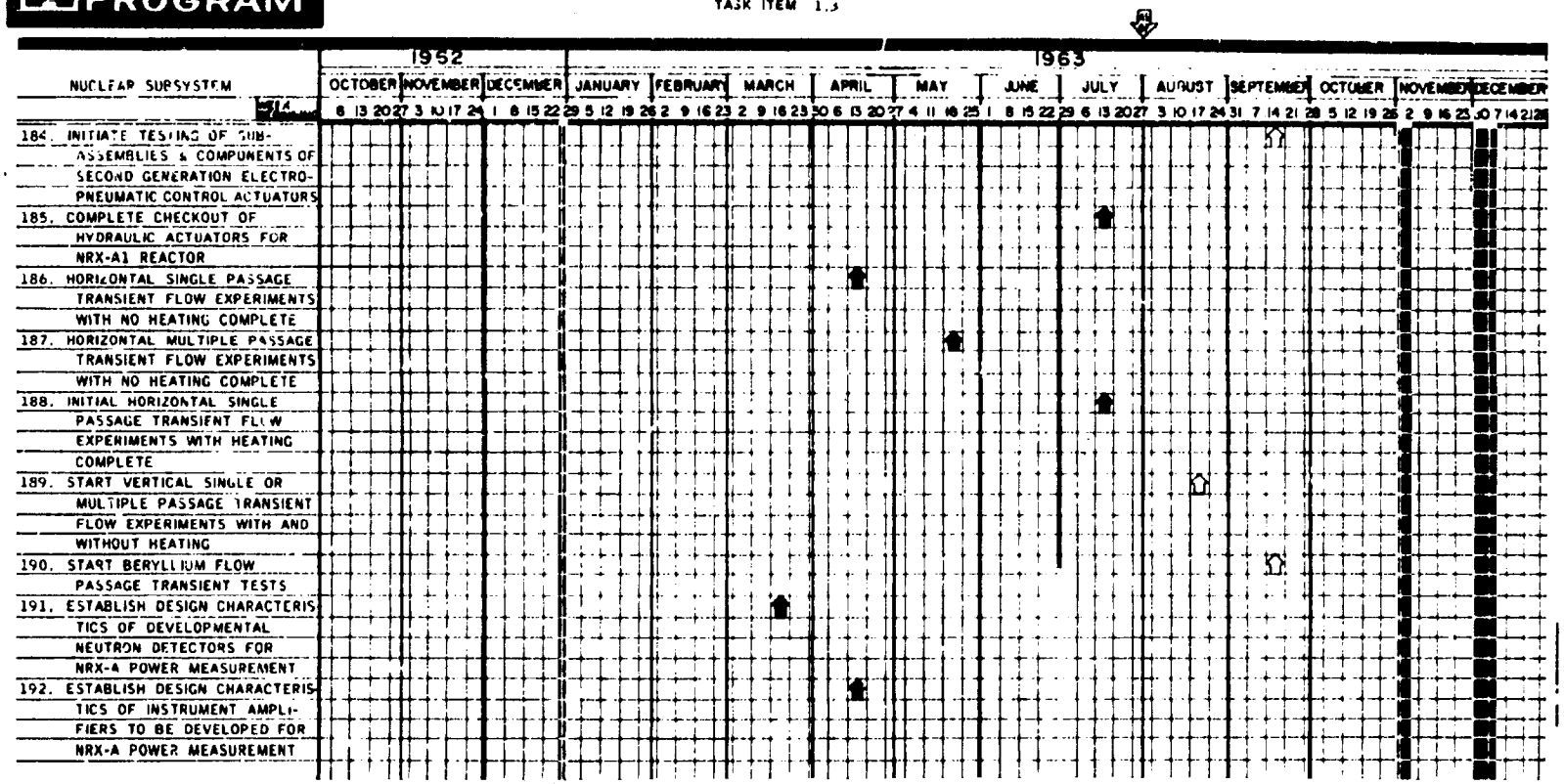
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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◆ RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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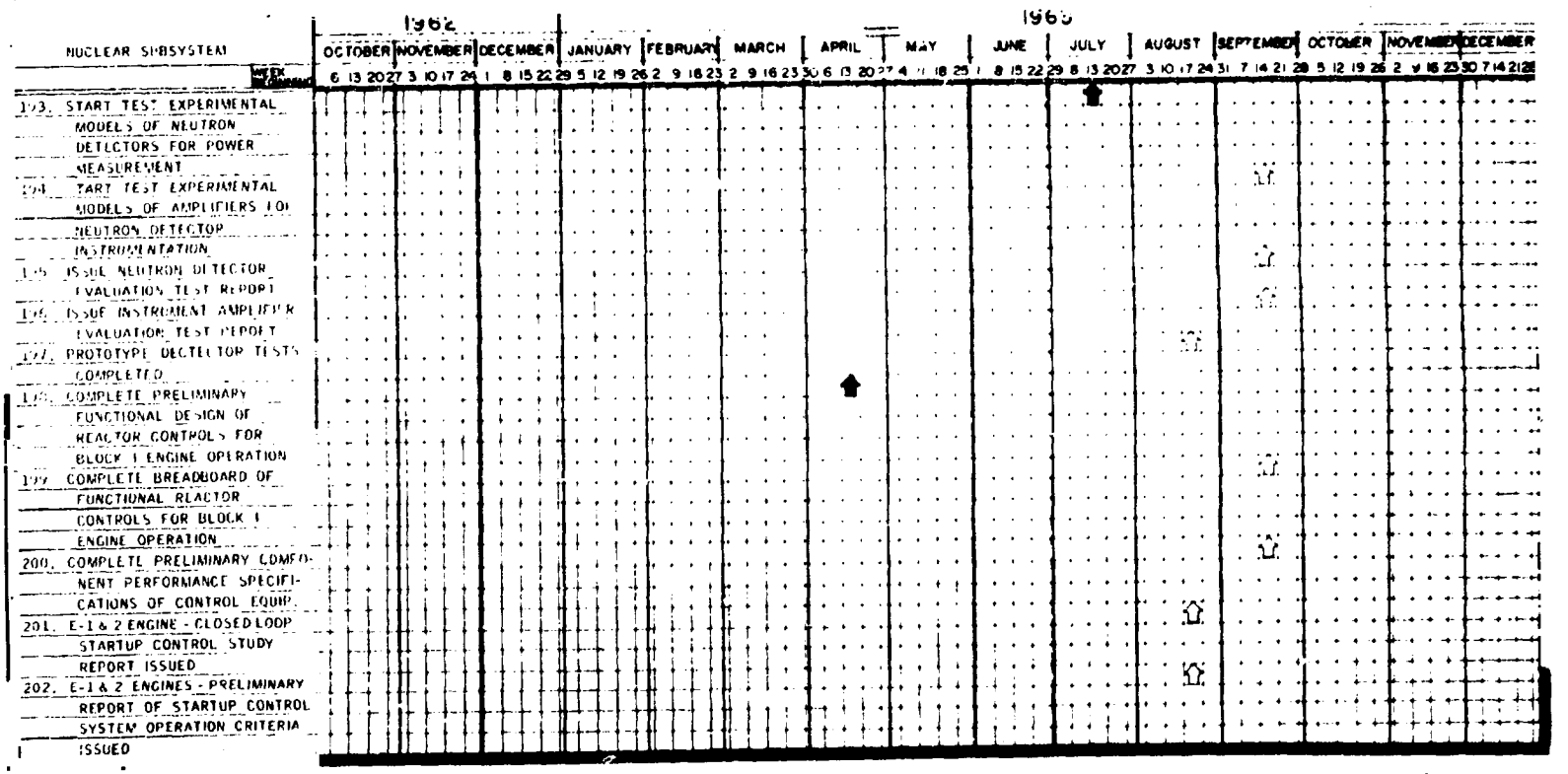
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1962
TASK ITEM 1.3



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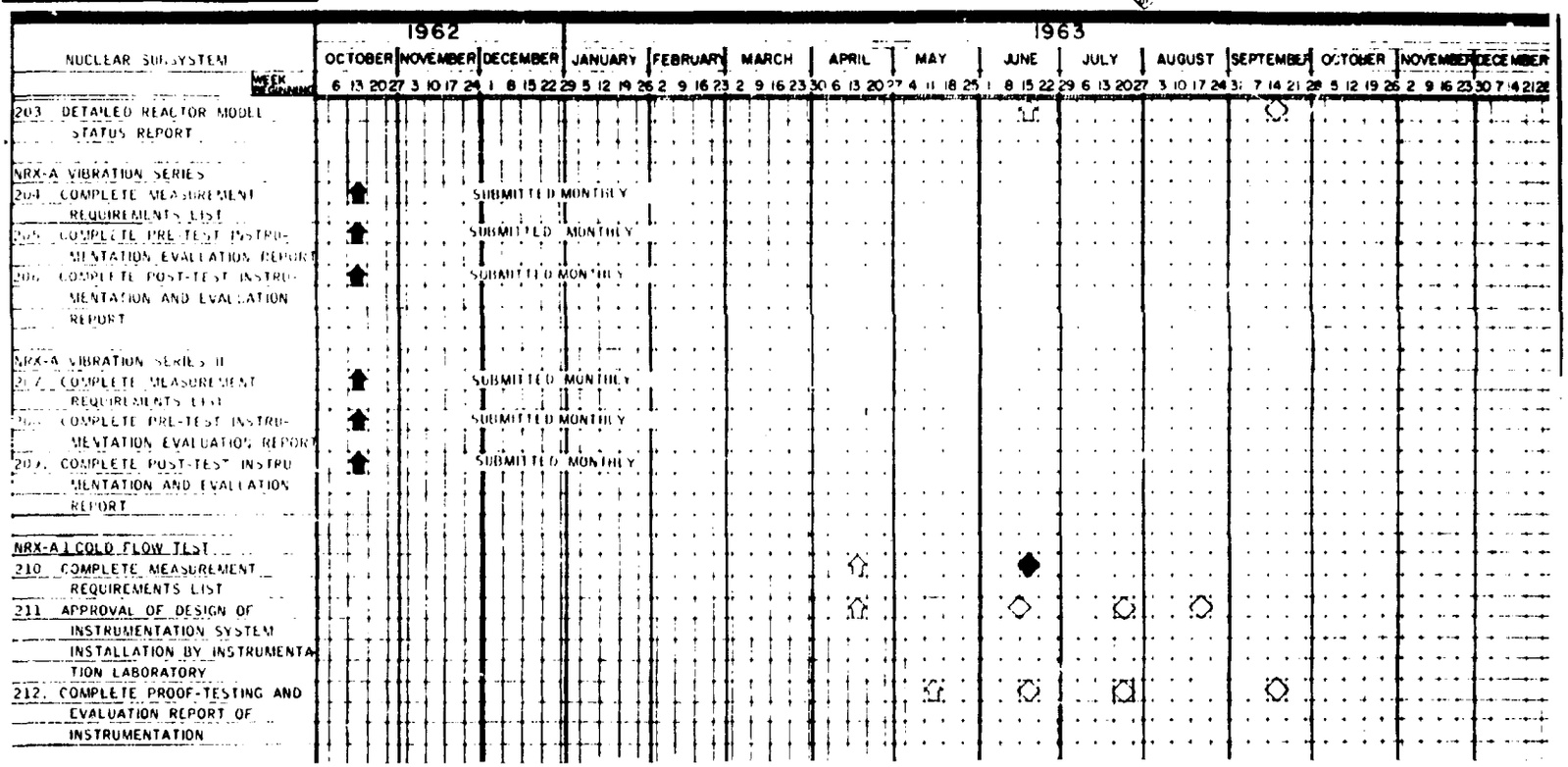
NERVA PROGRAM

SCHEDULES AND MILESTONES

CONTRACT YEAR 1963

TASK ITEM 1.3



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- ◇ RESCHEDULED MILESTONE
- ⬆ MILESTONE ACHIEVEMENT
- ◆ RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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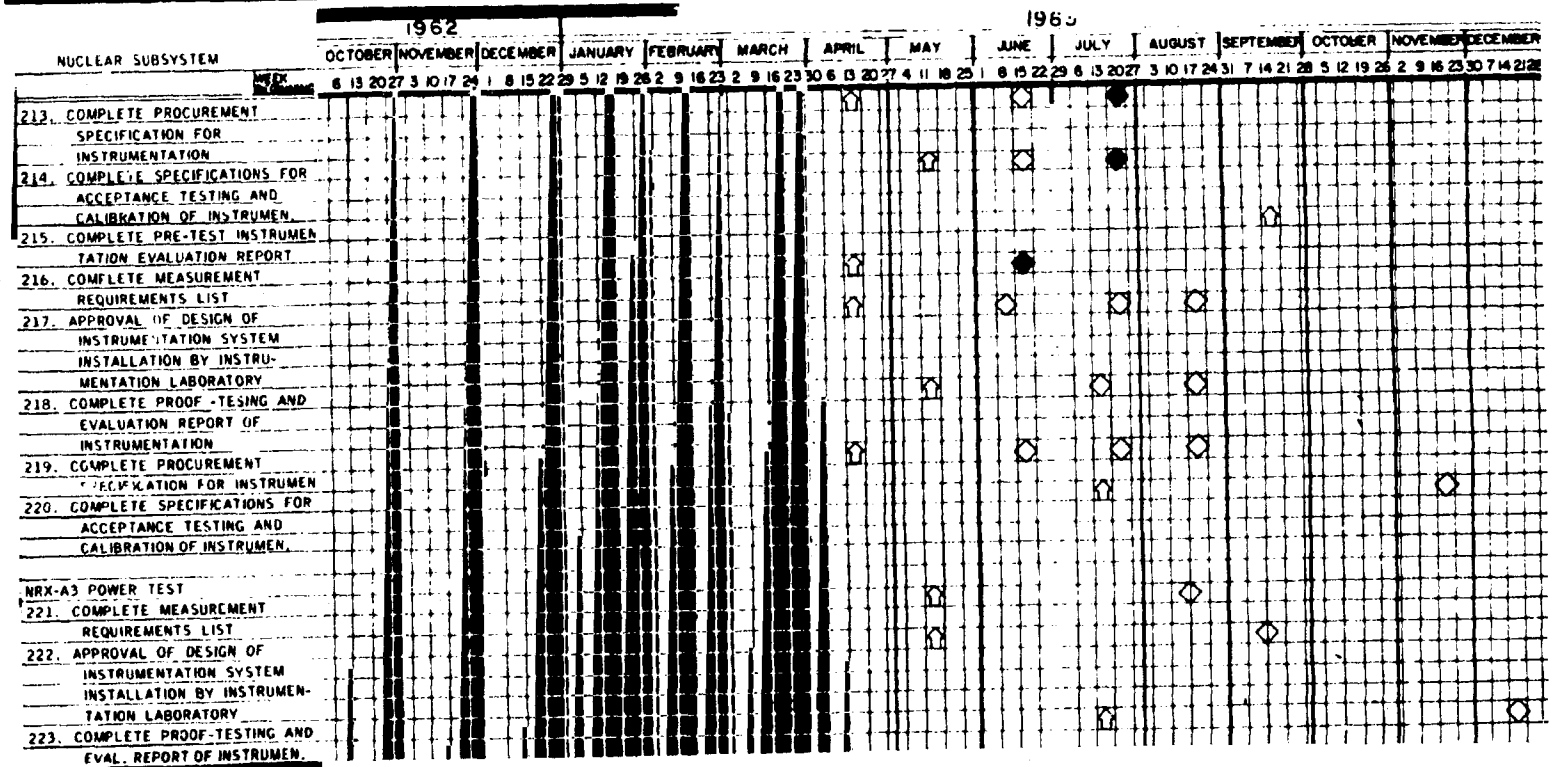
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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MILESTONE ACHIEVEMENT

RESCHEDULED MILESTONE

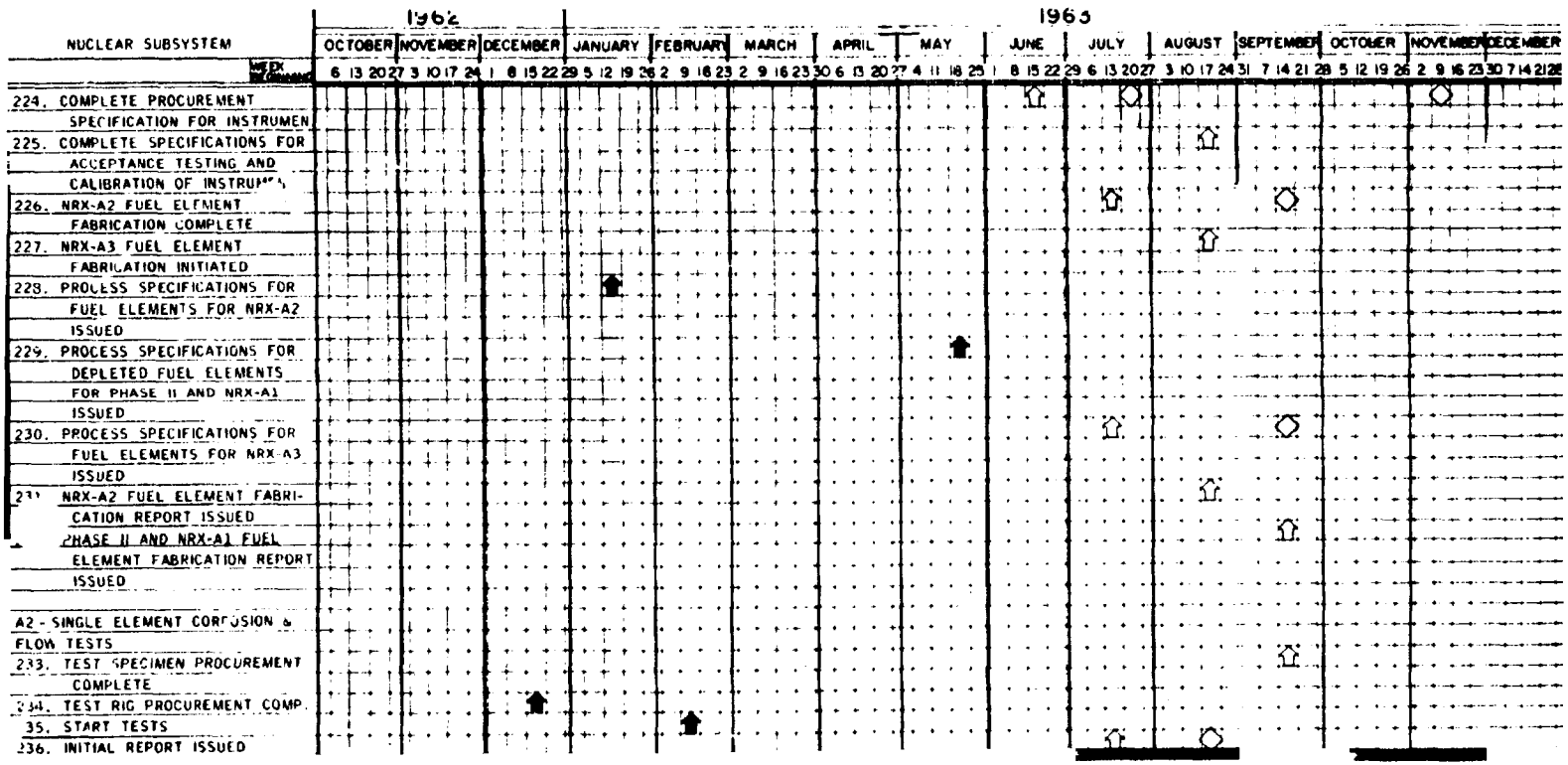
RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
Sheet 23 of 63

REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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- ◇ RESCHEDULED MILESTONE
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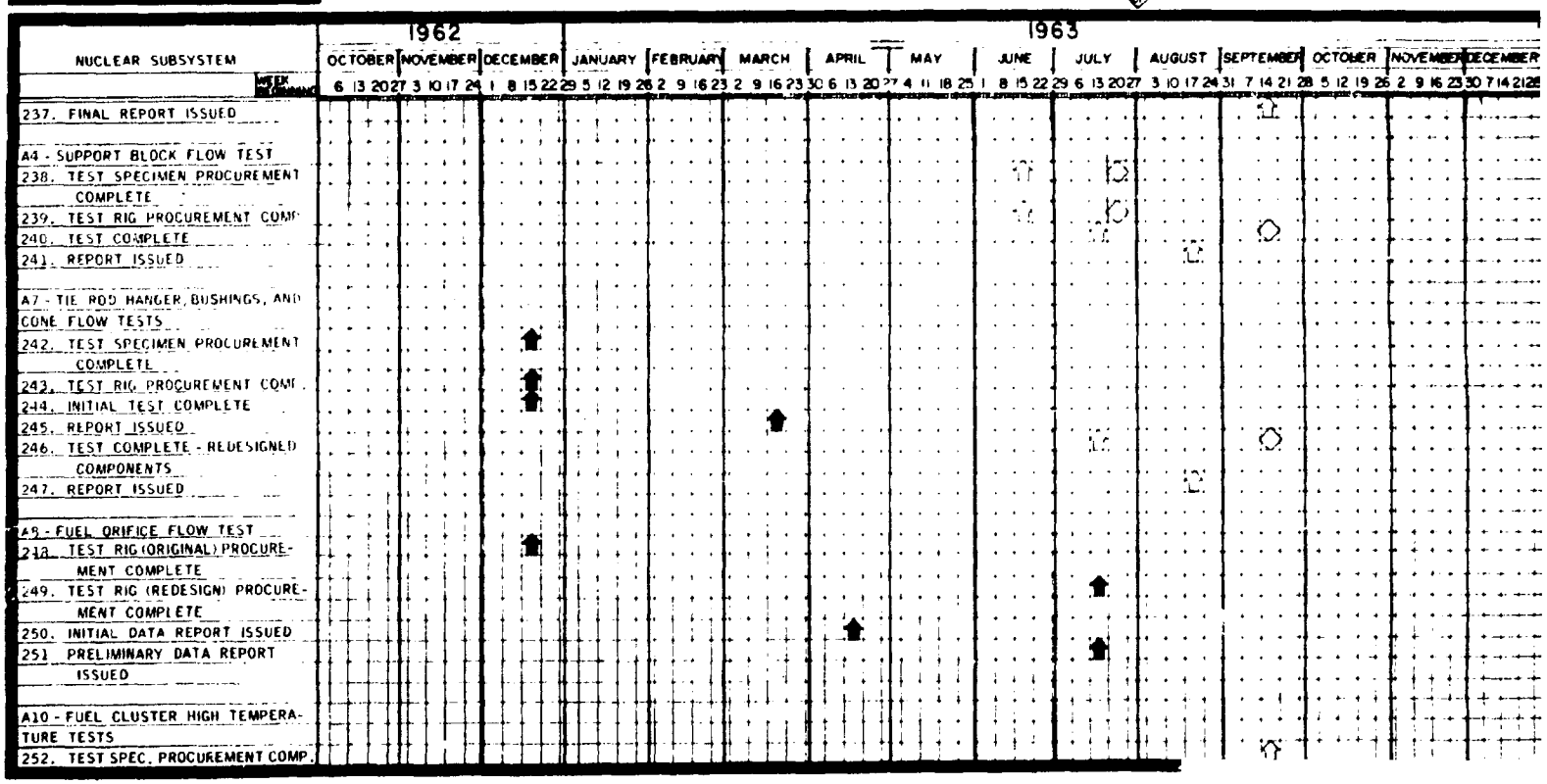
- ● RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
Sheet 24 of 63

REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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⬆ MILESTONE ACHIEVEMENT
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◆ RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3

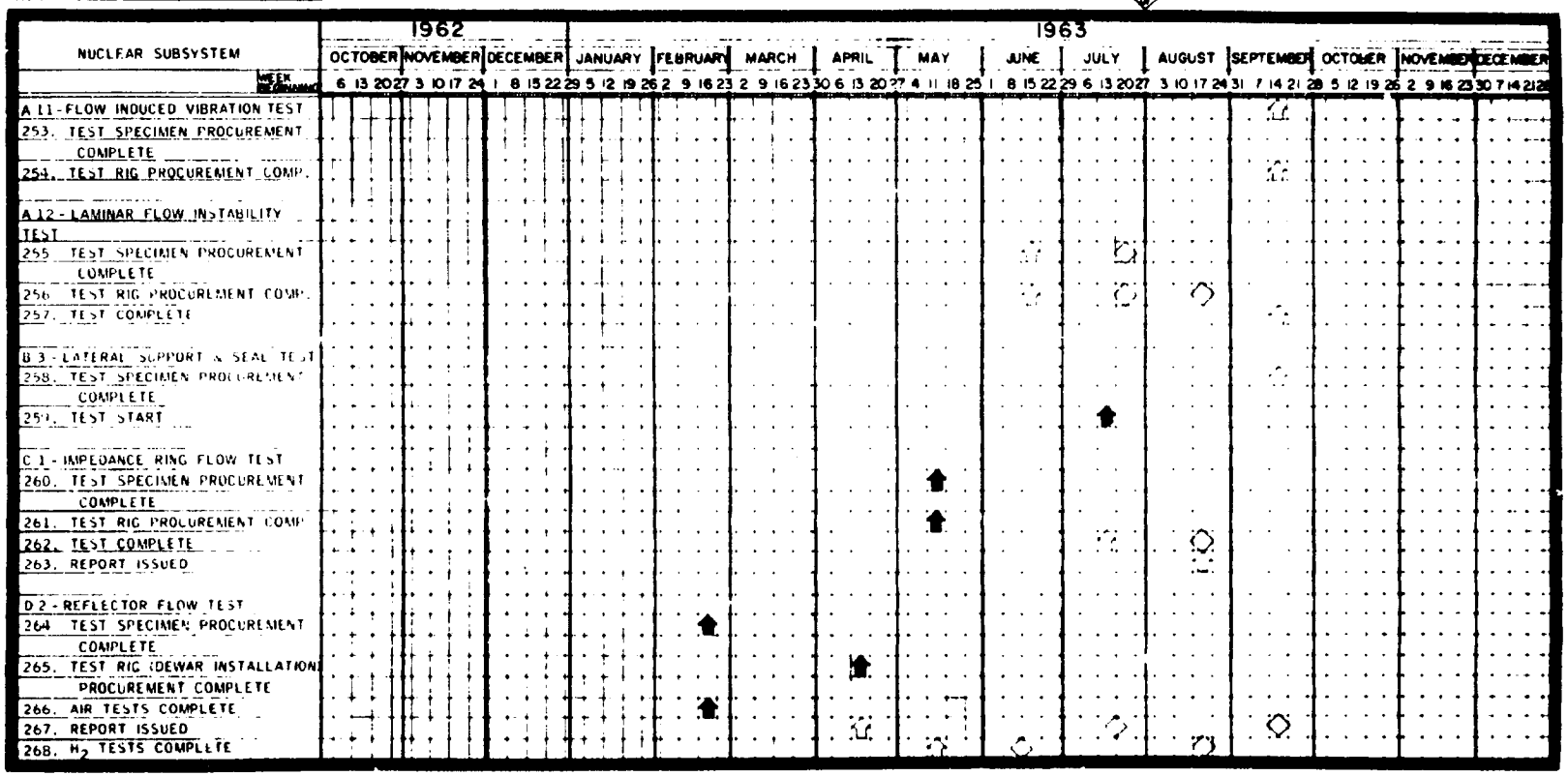

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Figure 1
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REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3

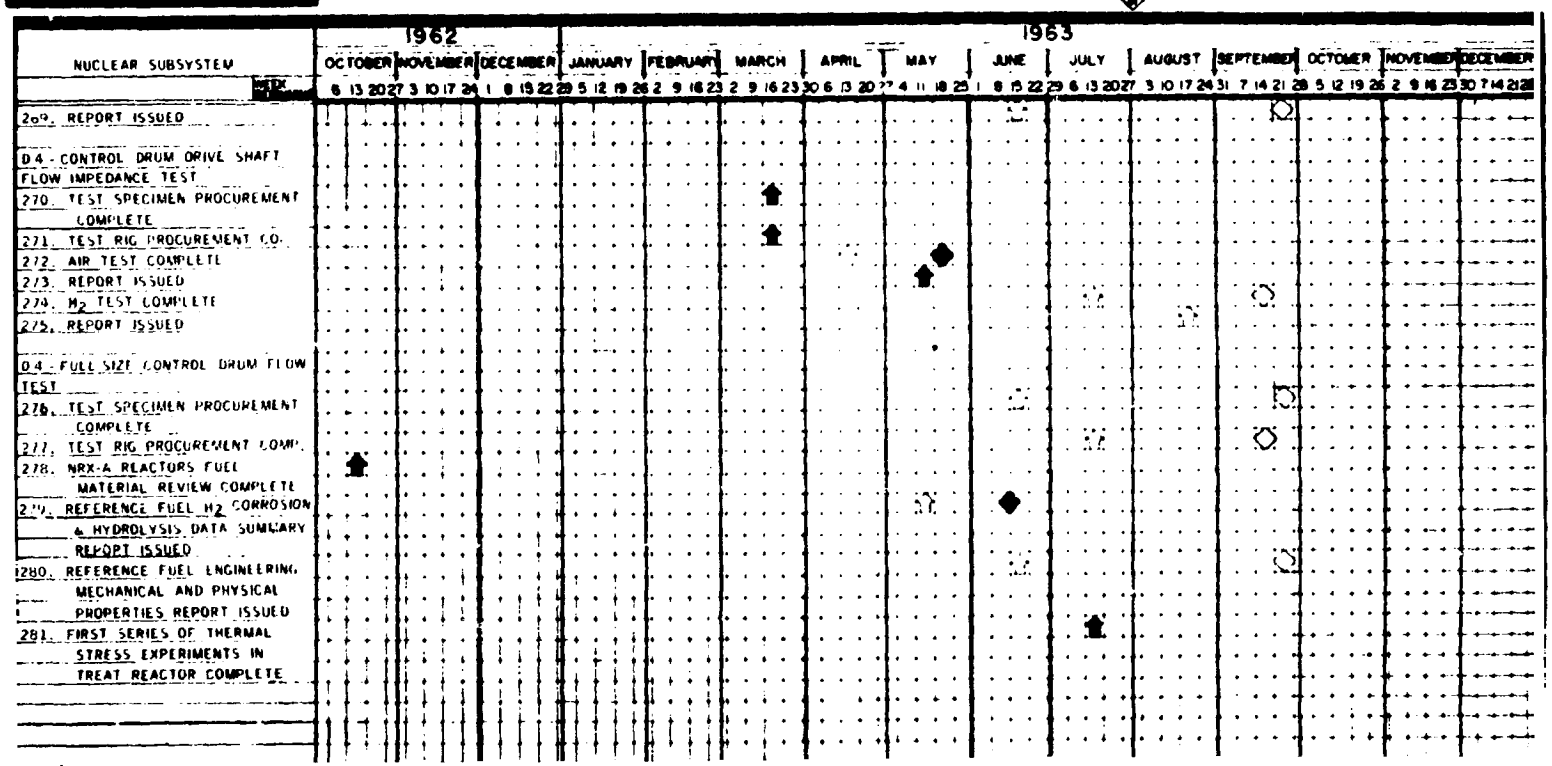

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Figure 1
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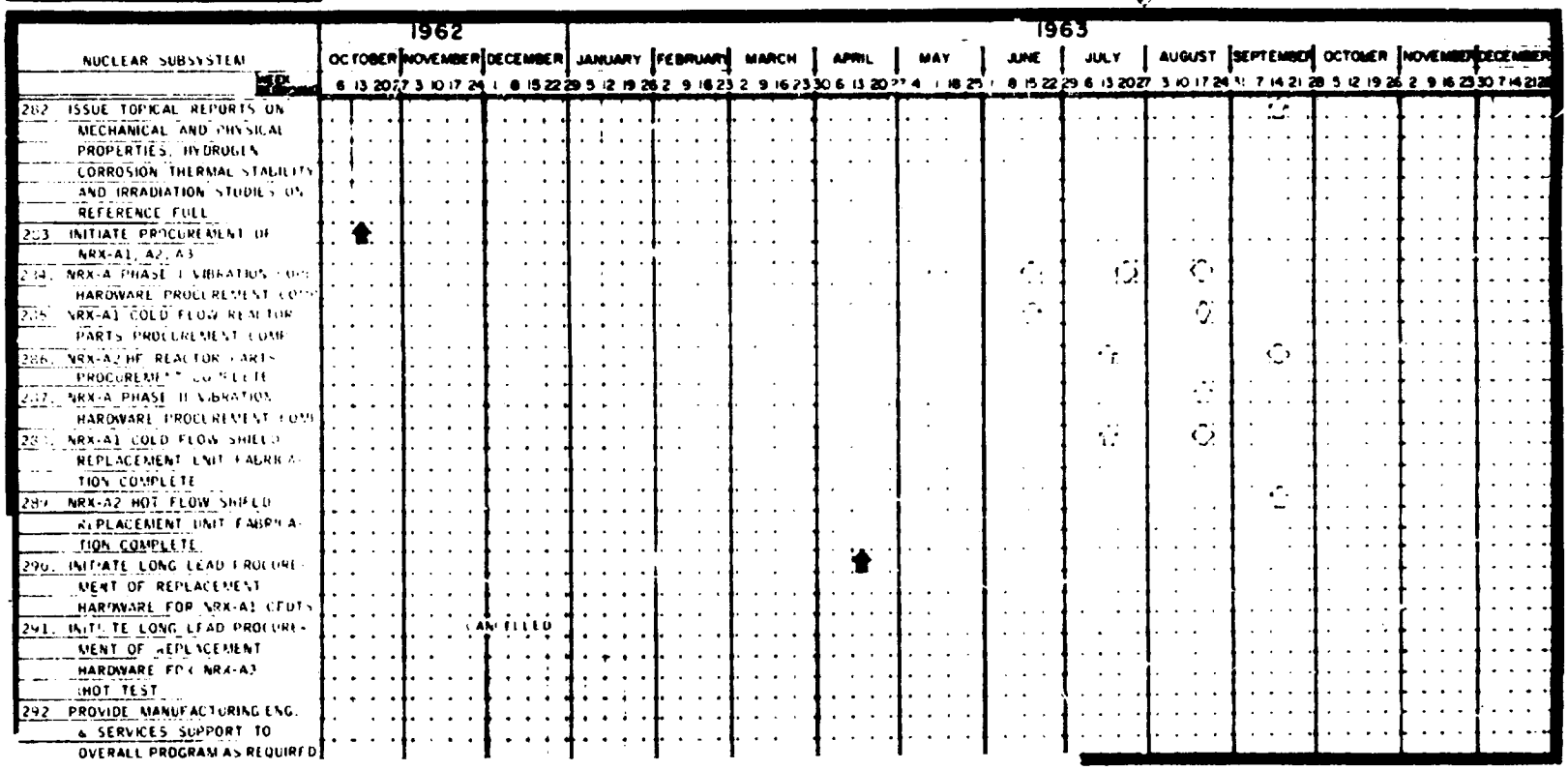
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1 3

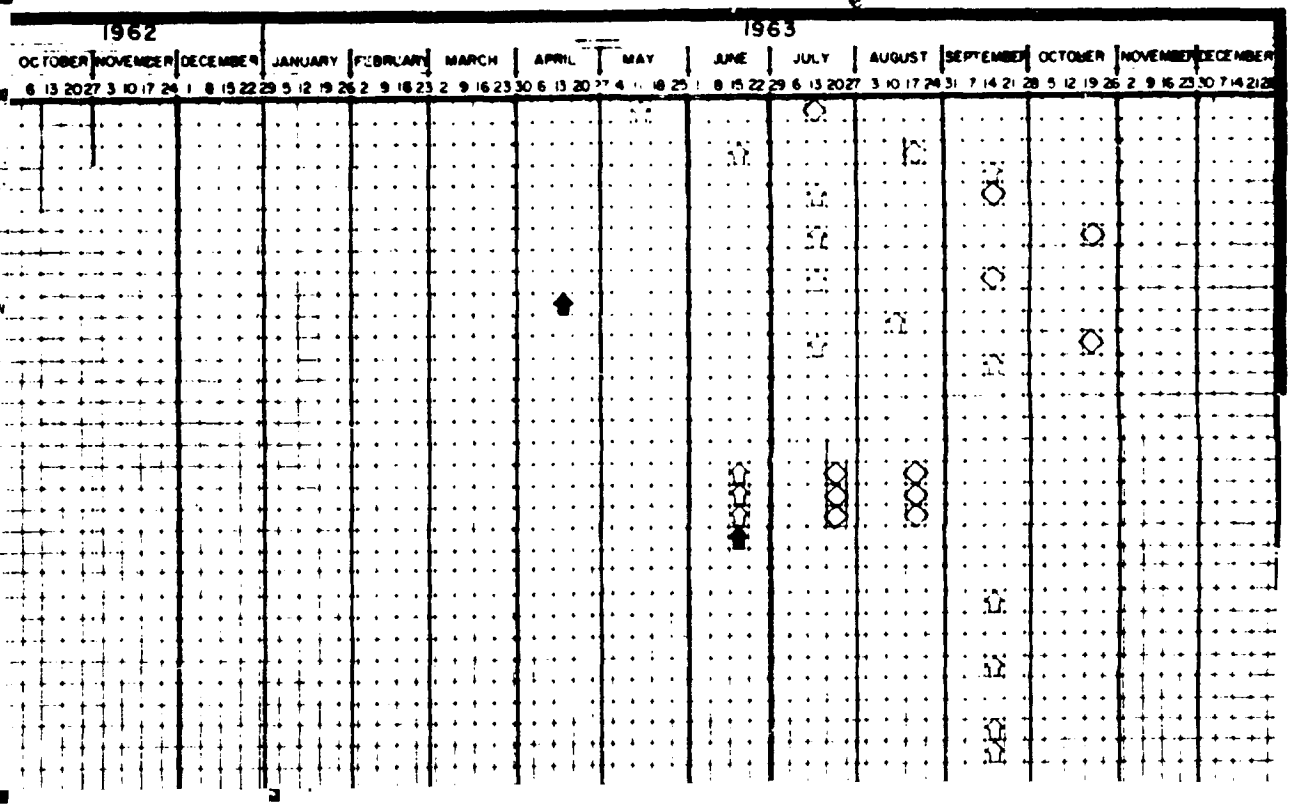

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Figure 1
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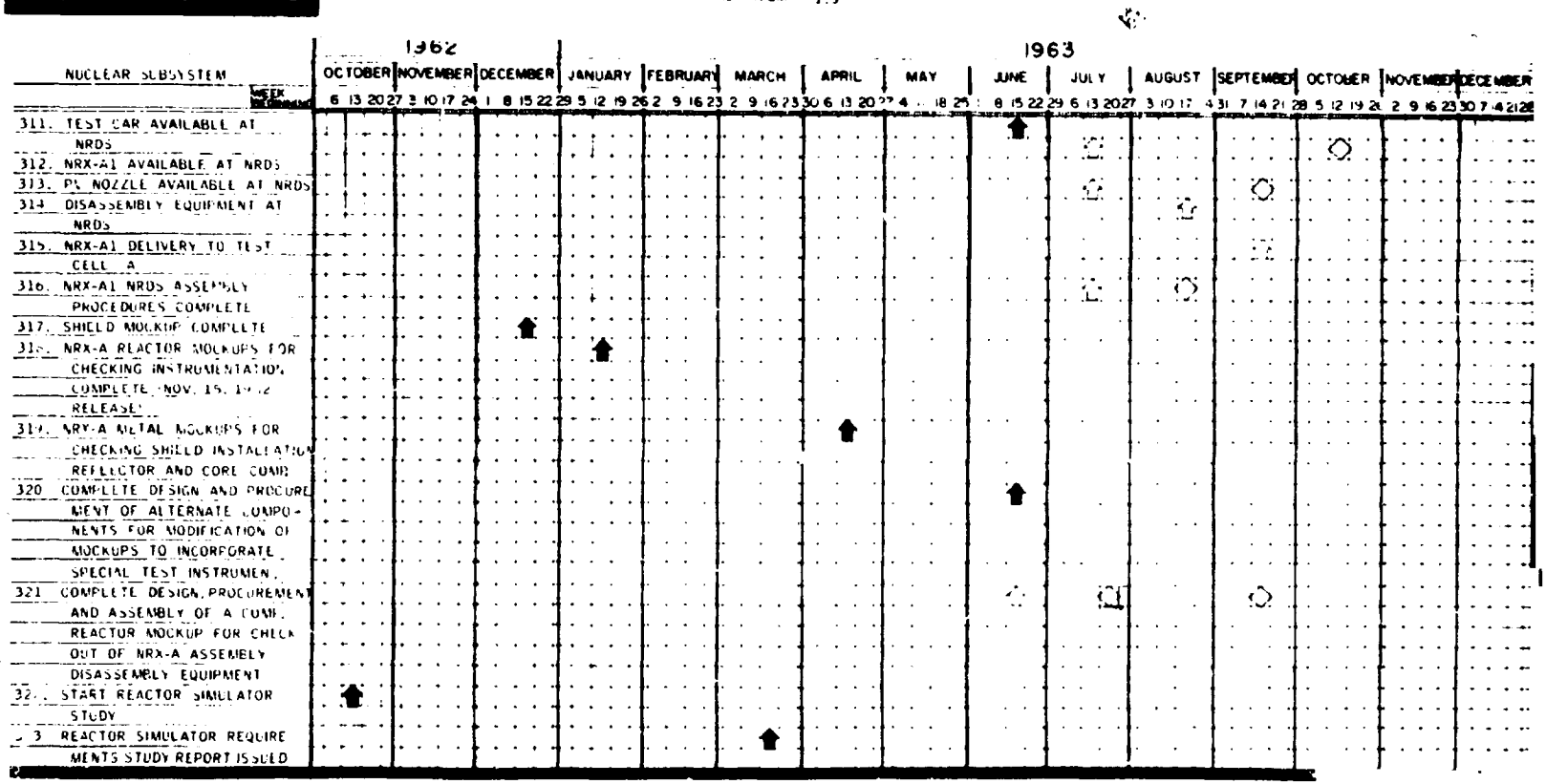
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.3



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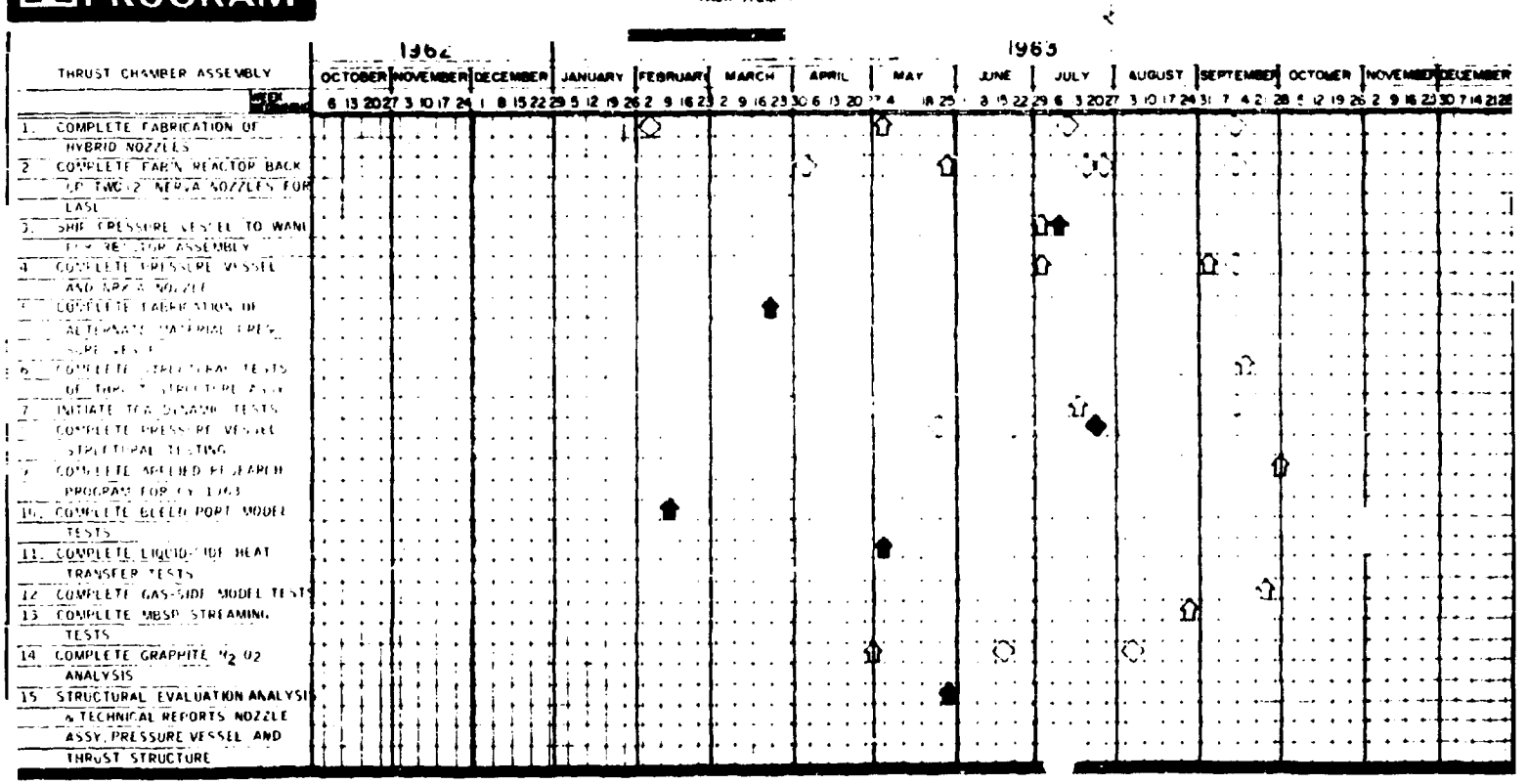
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1



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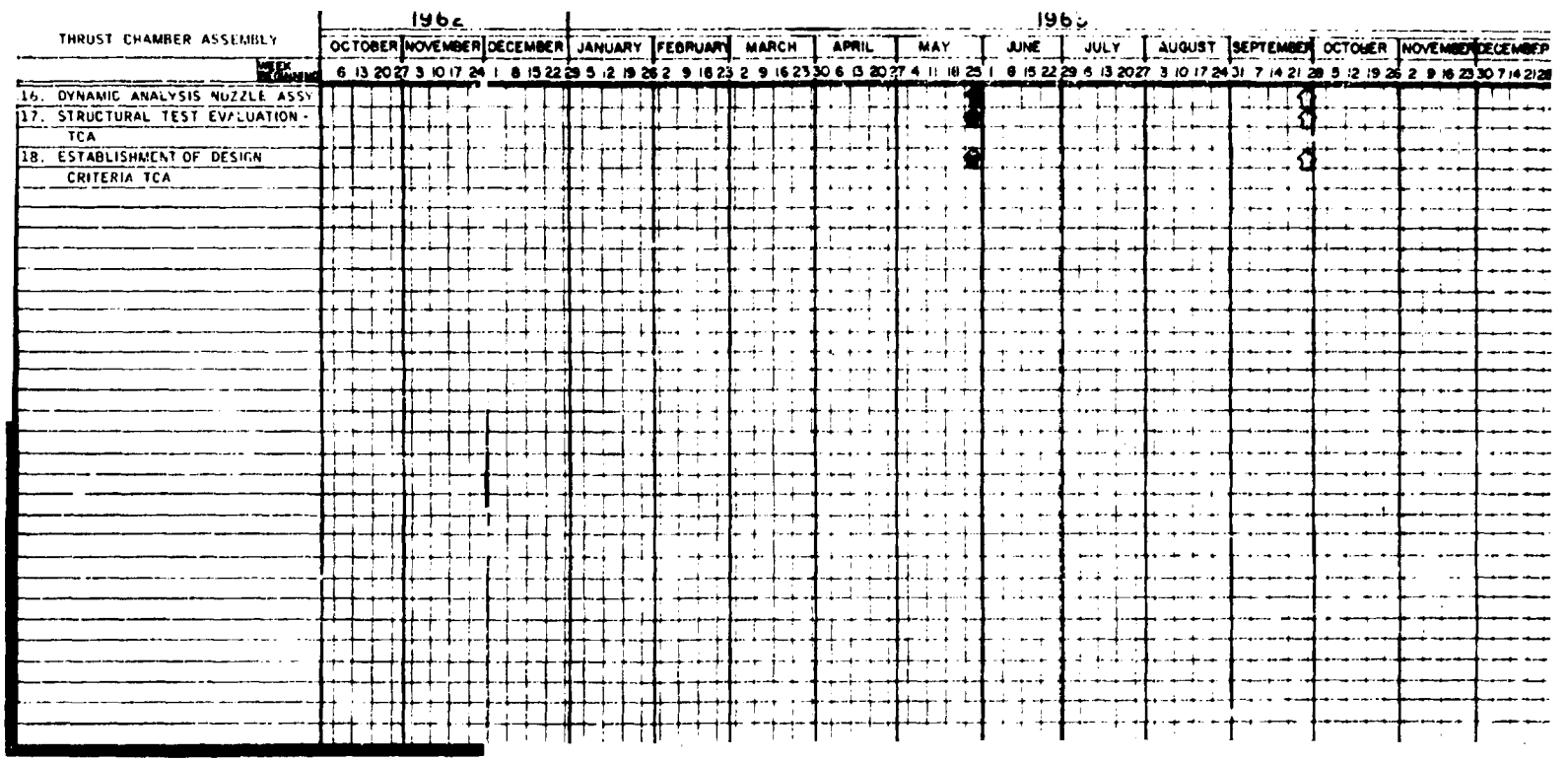
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.4 (CONT.)



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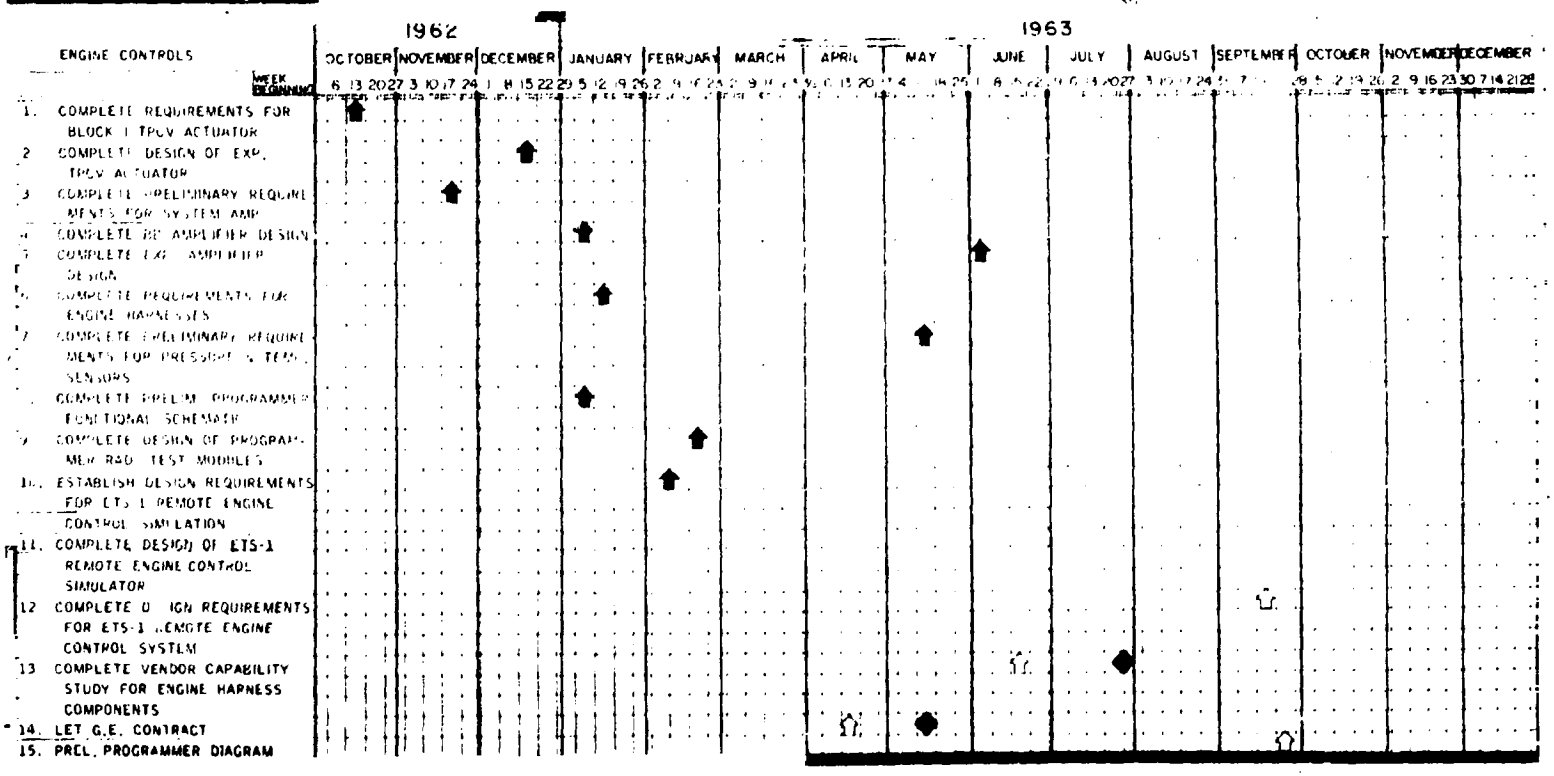
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.5



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NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.5 (CONT.)

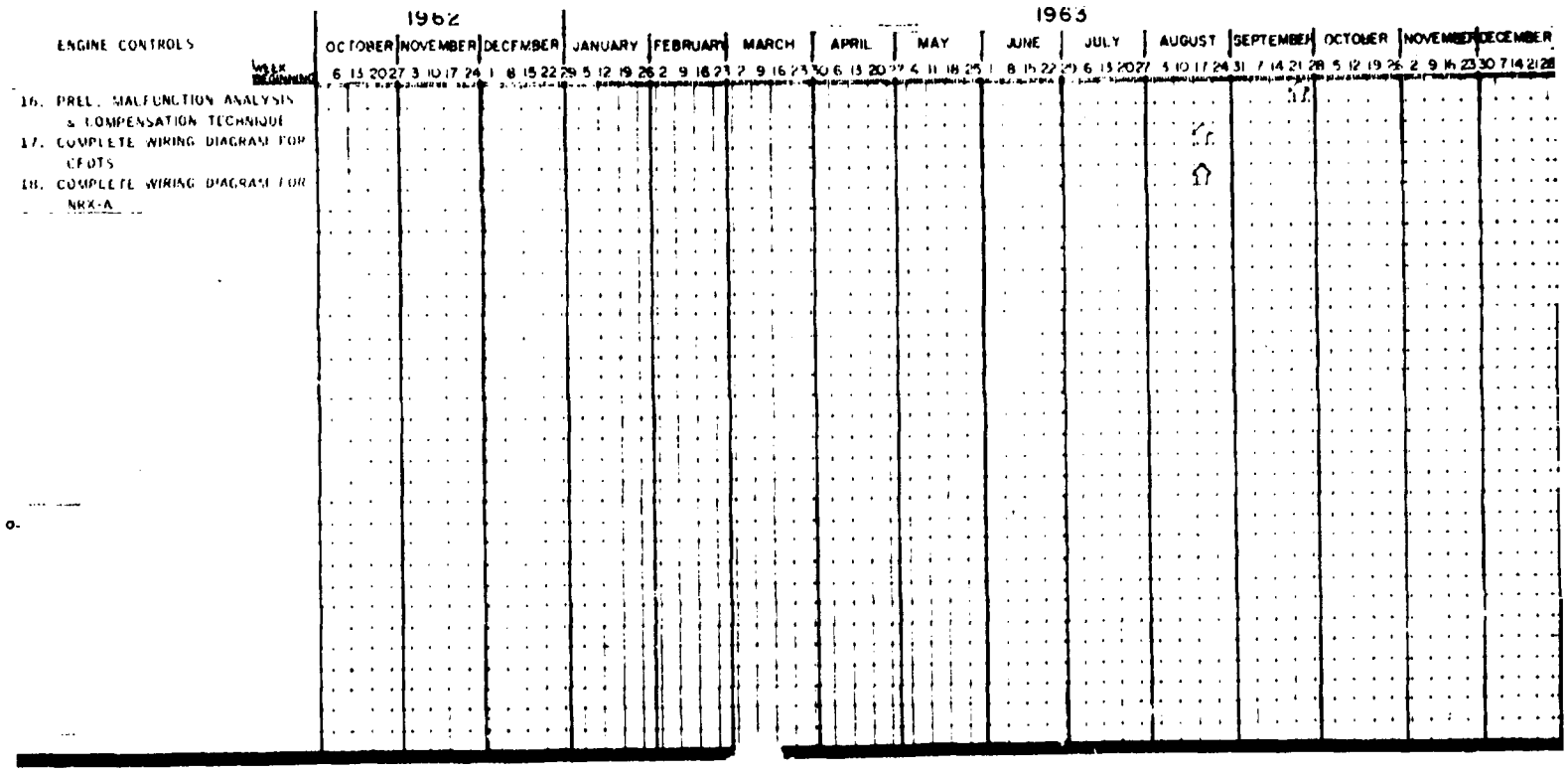

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Figure 1
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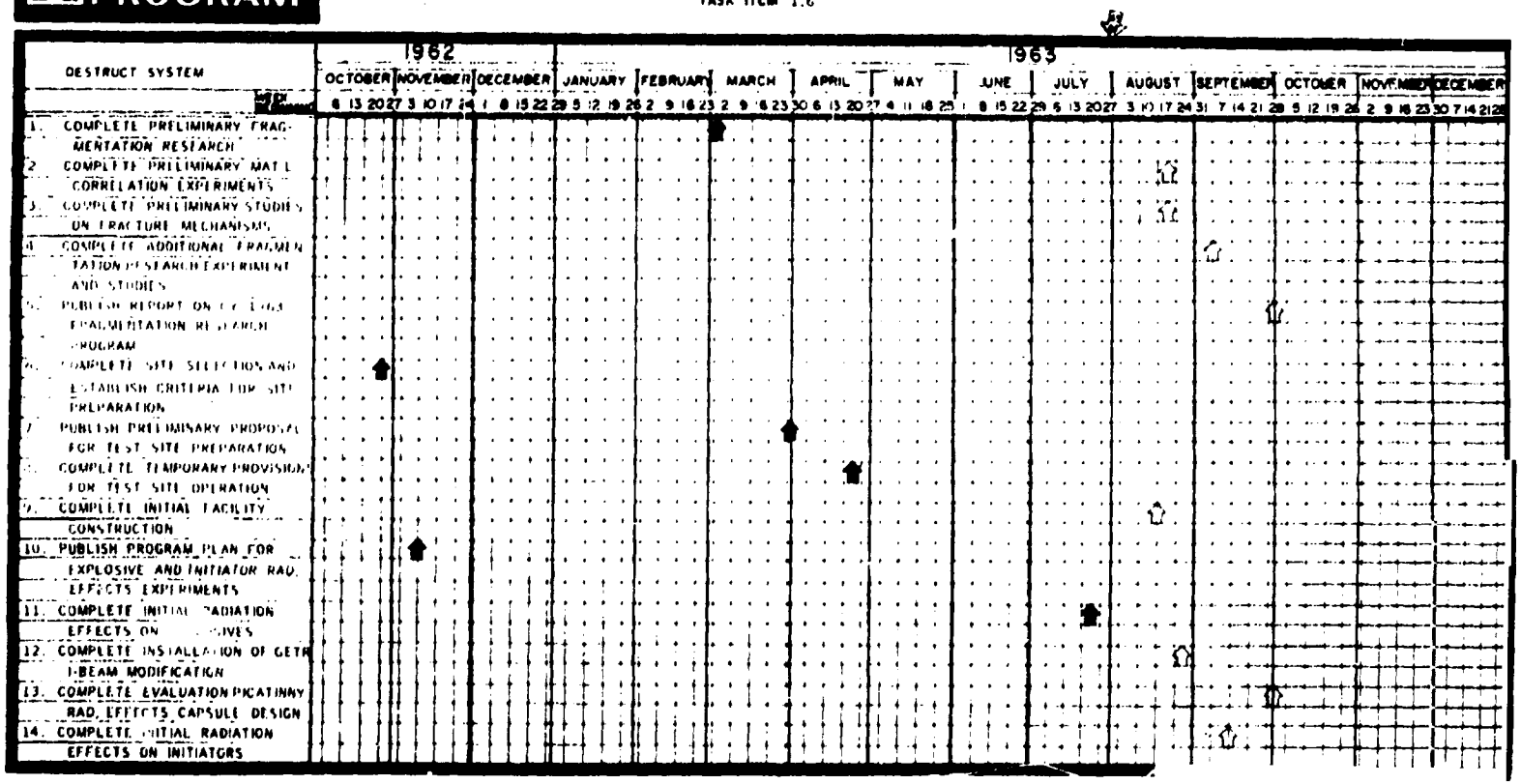
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.6



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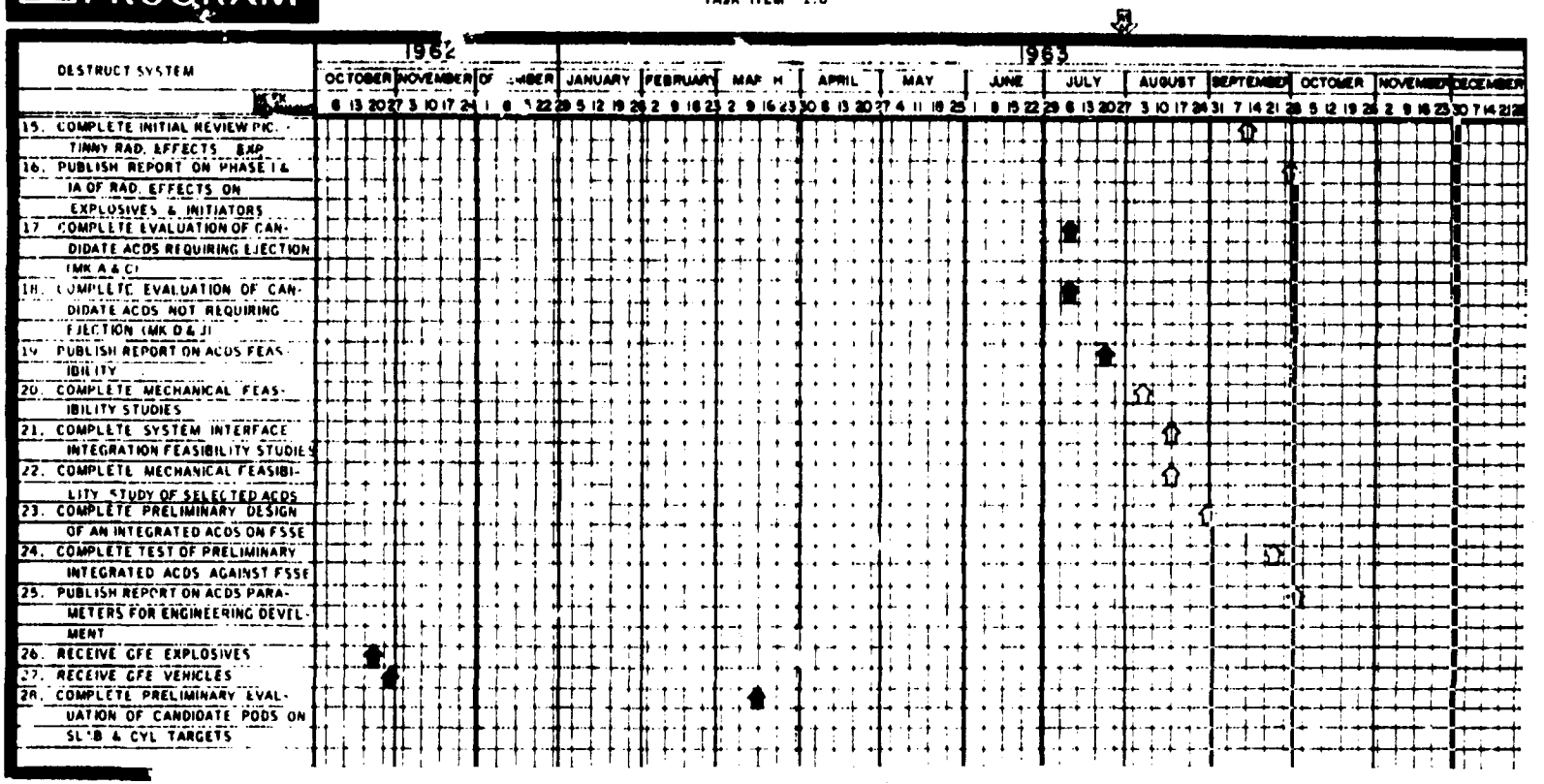
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.6



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NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.6

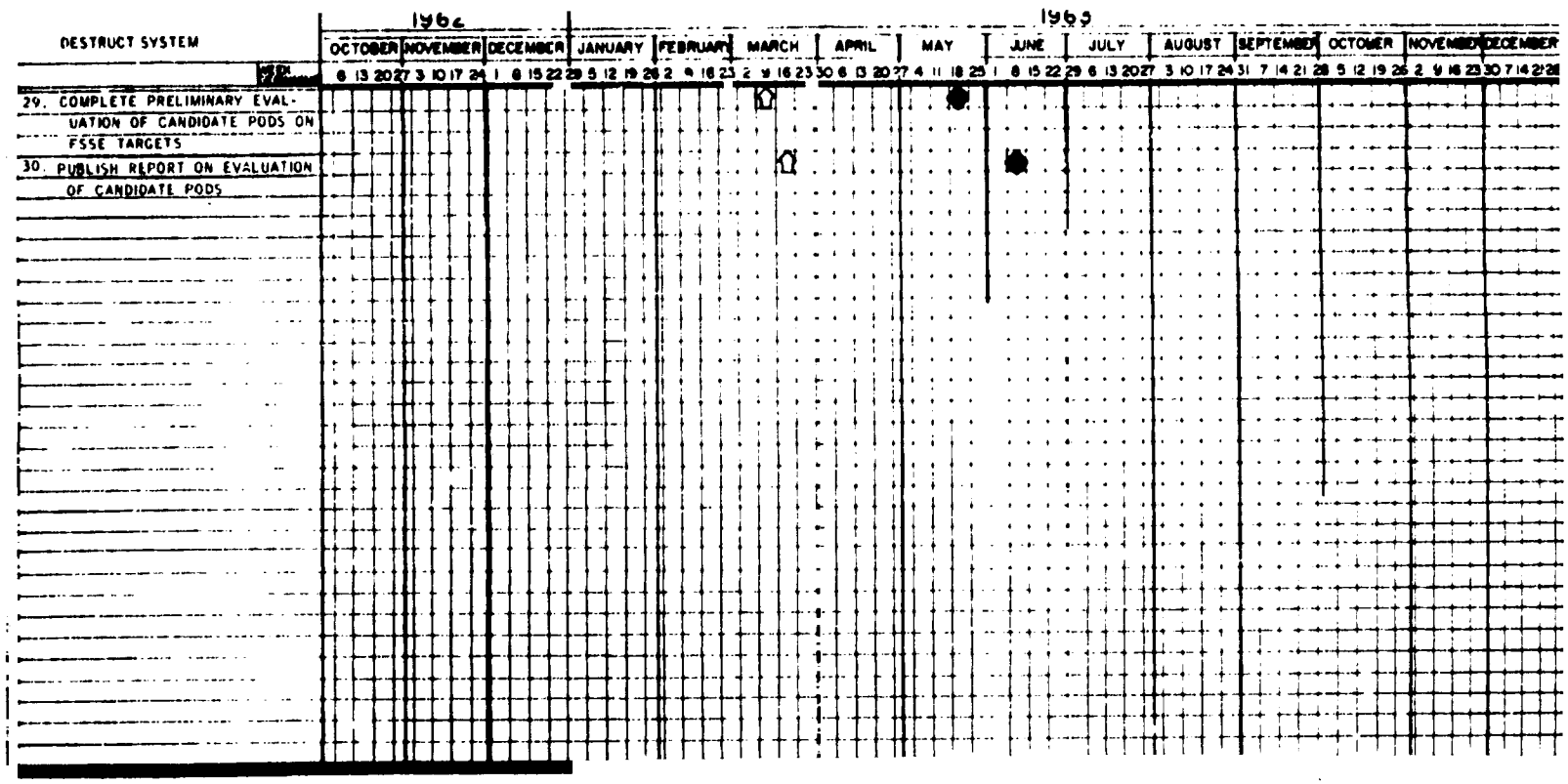

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Figure 1
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NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.7

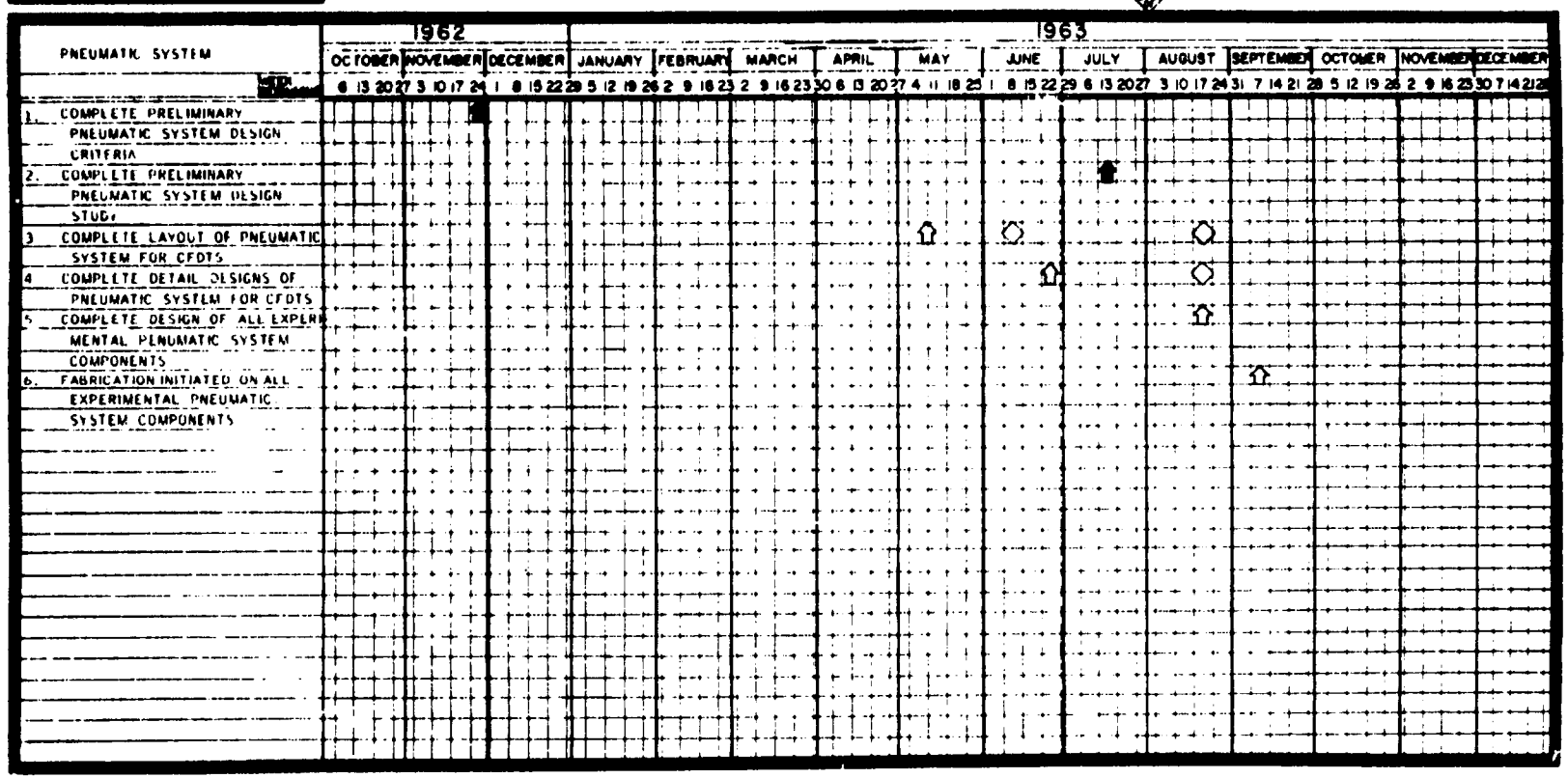

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Figure 1
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NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.9

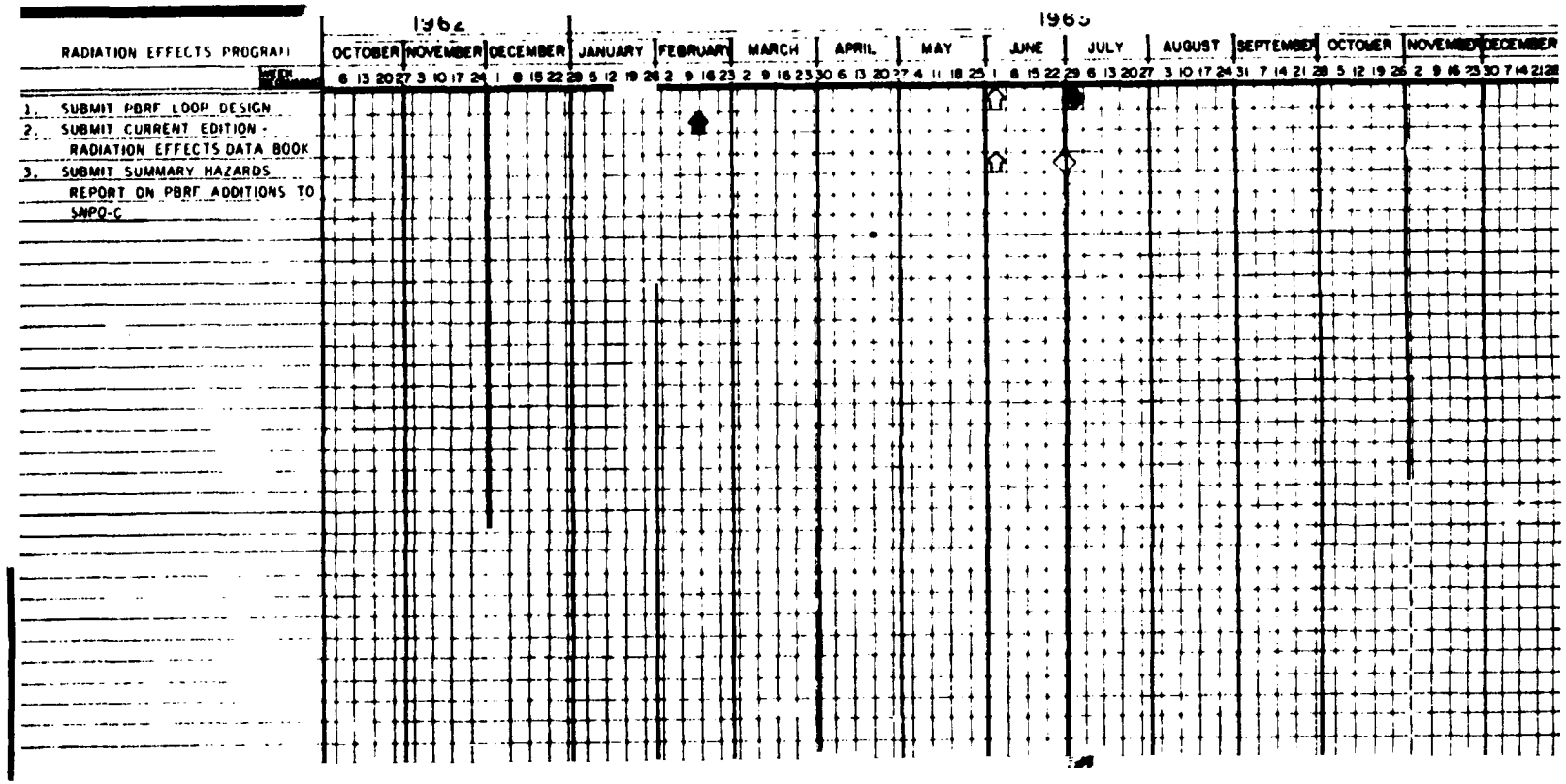

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Figure 1
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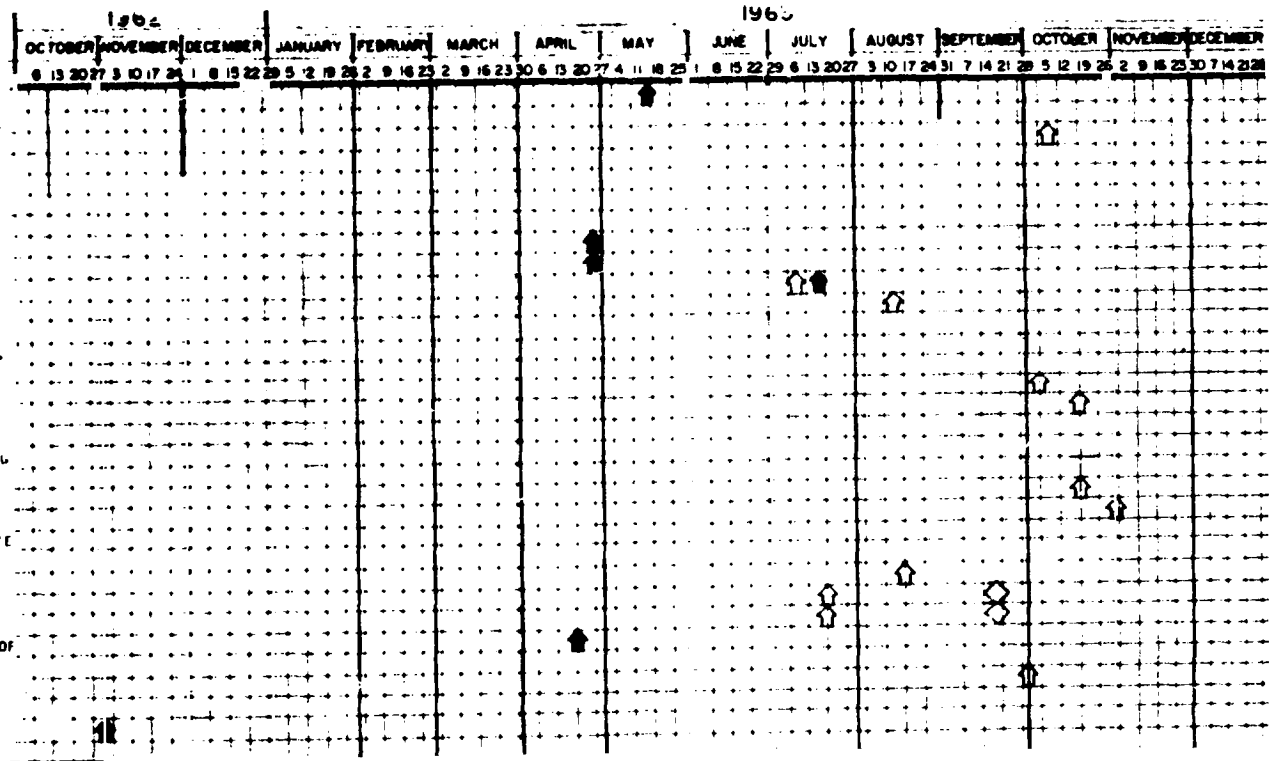
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.1



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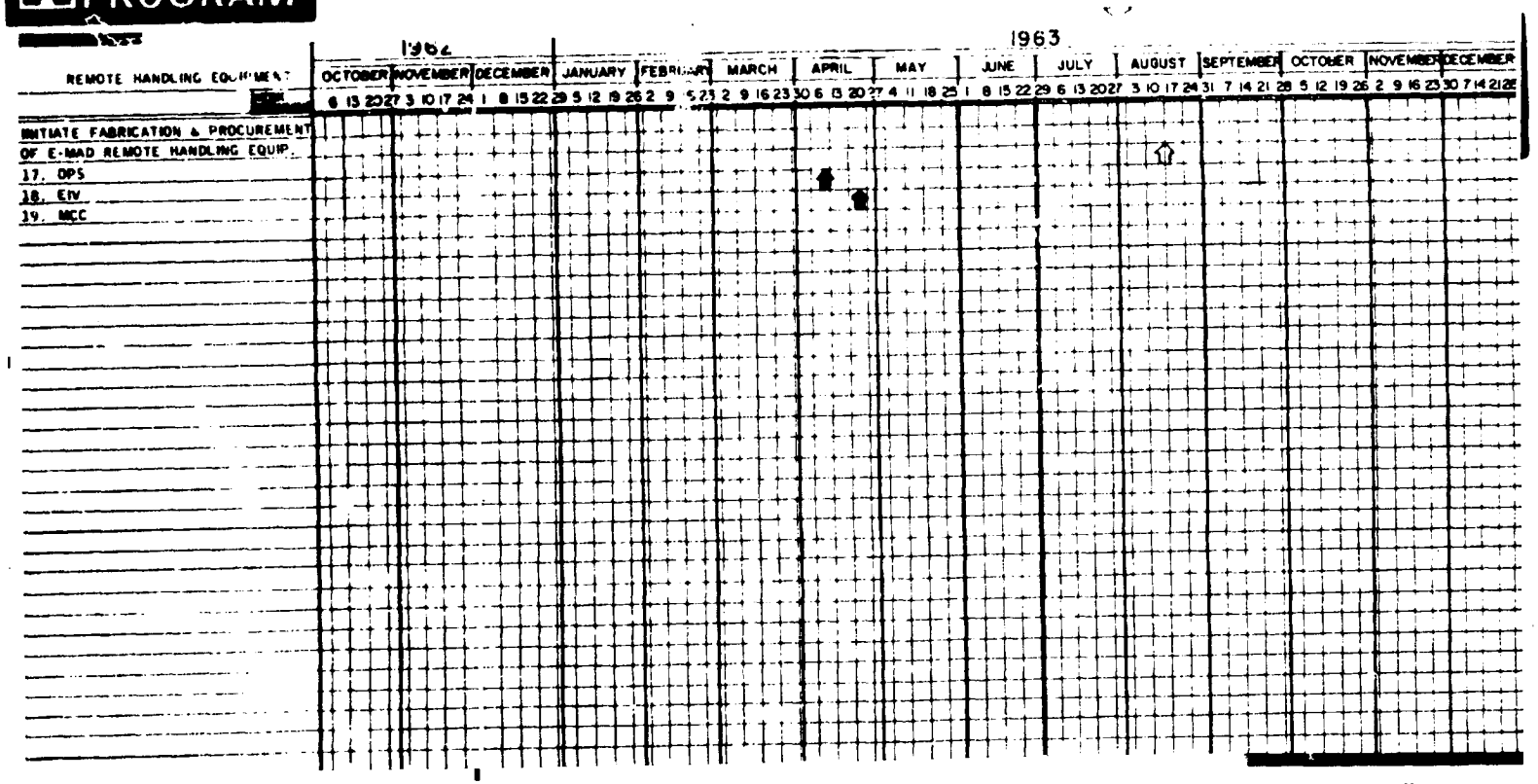
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.1



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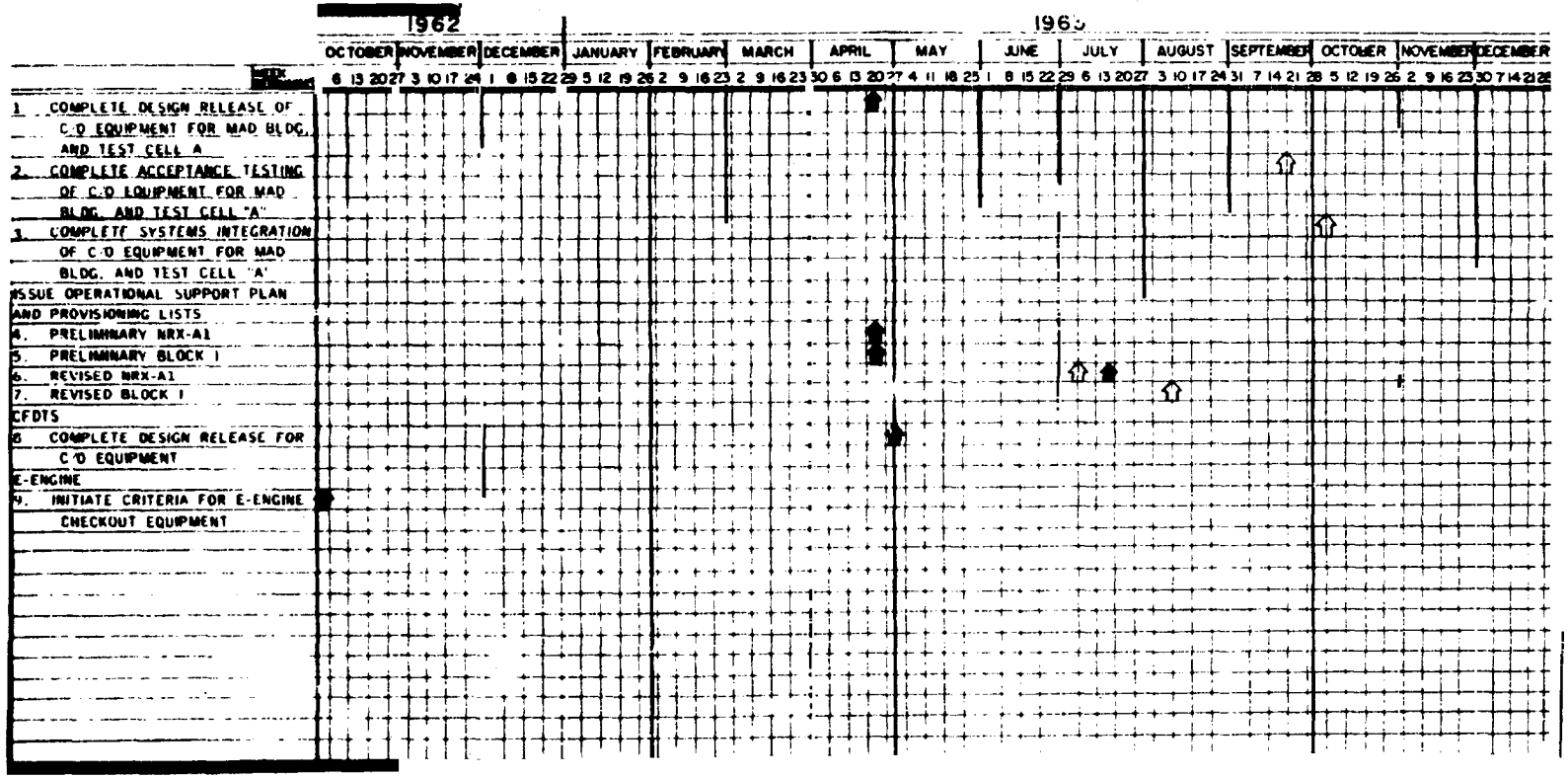
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.2



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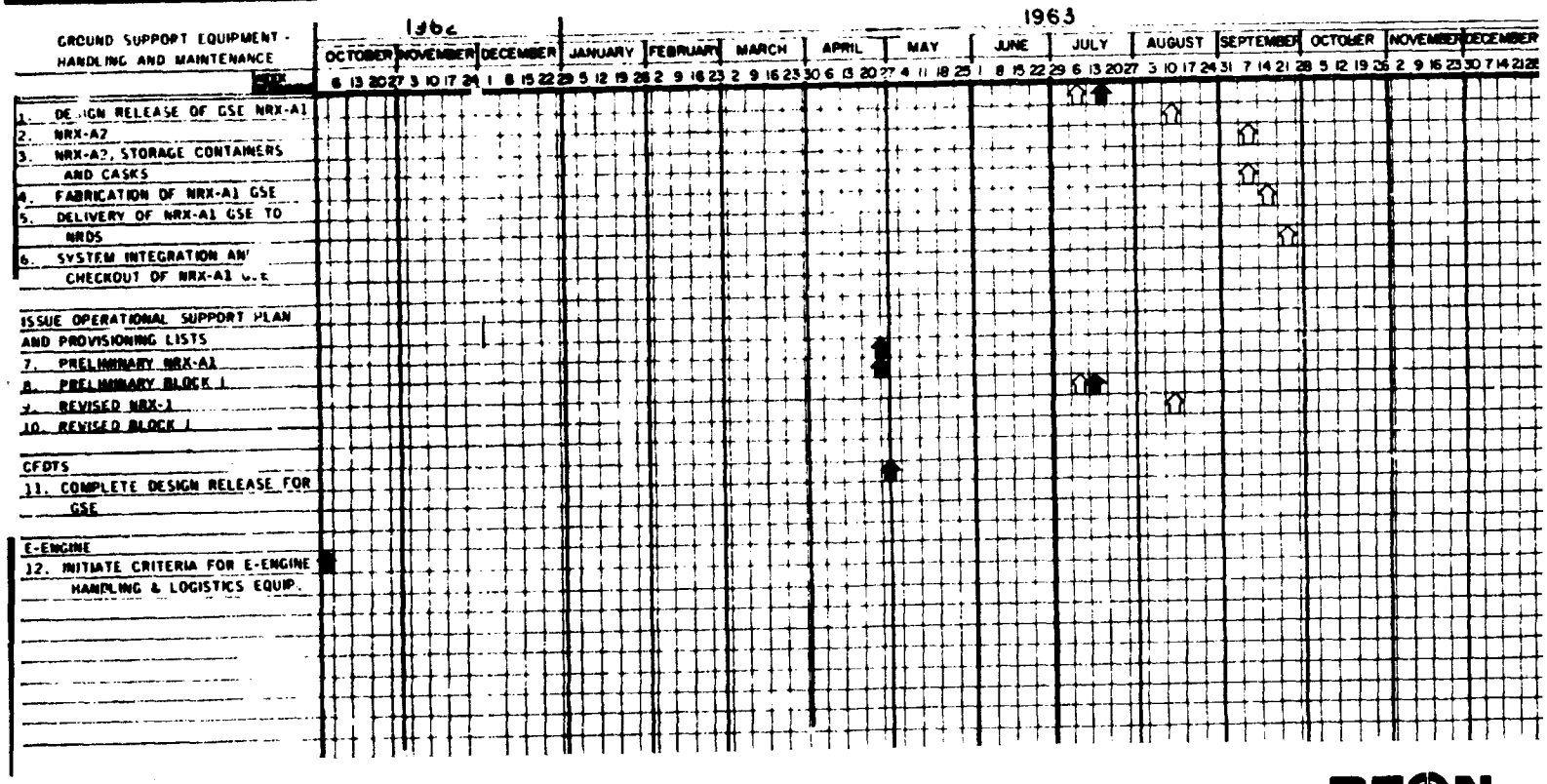
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.3



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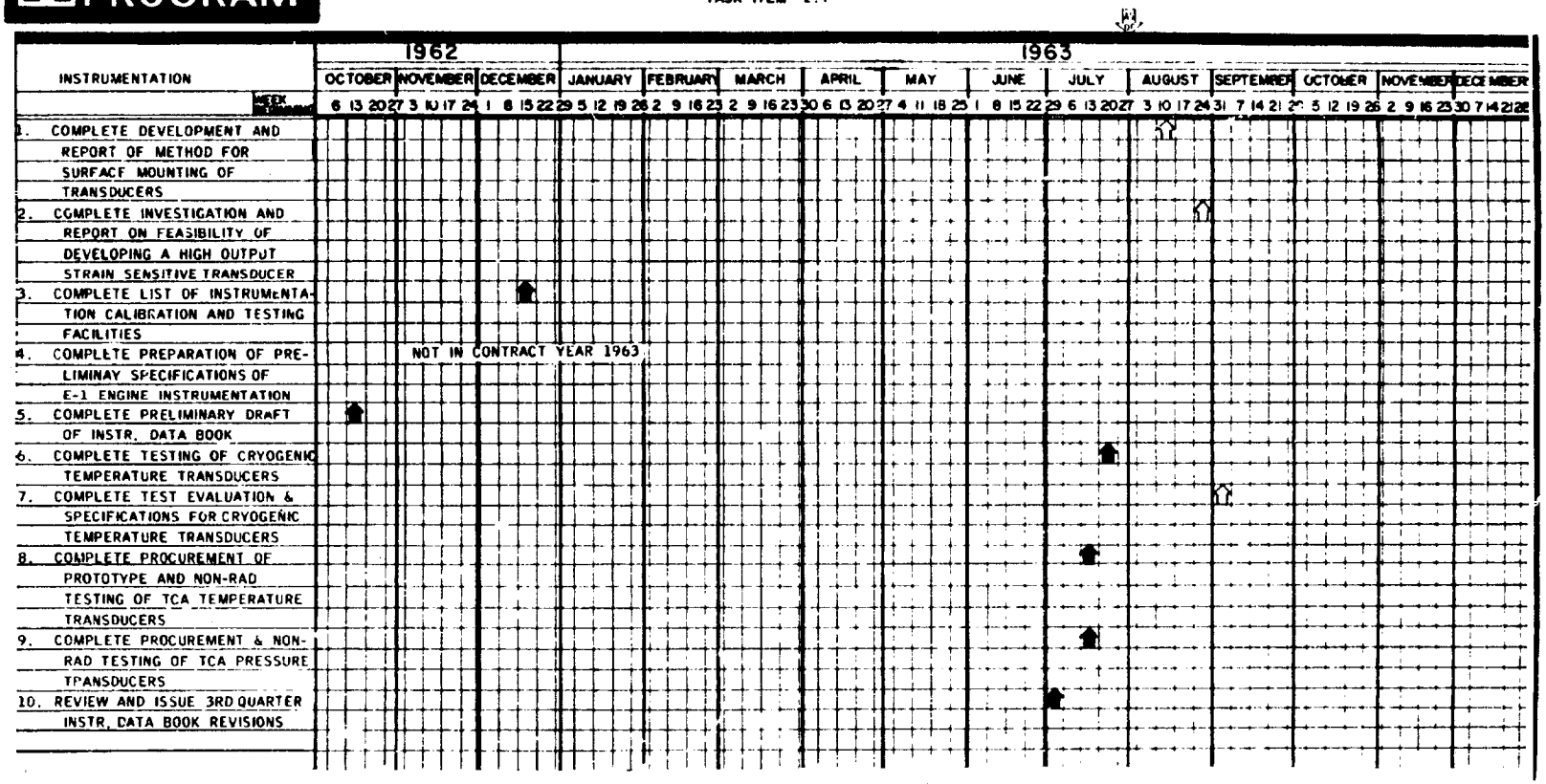
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.4



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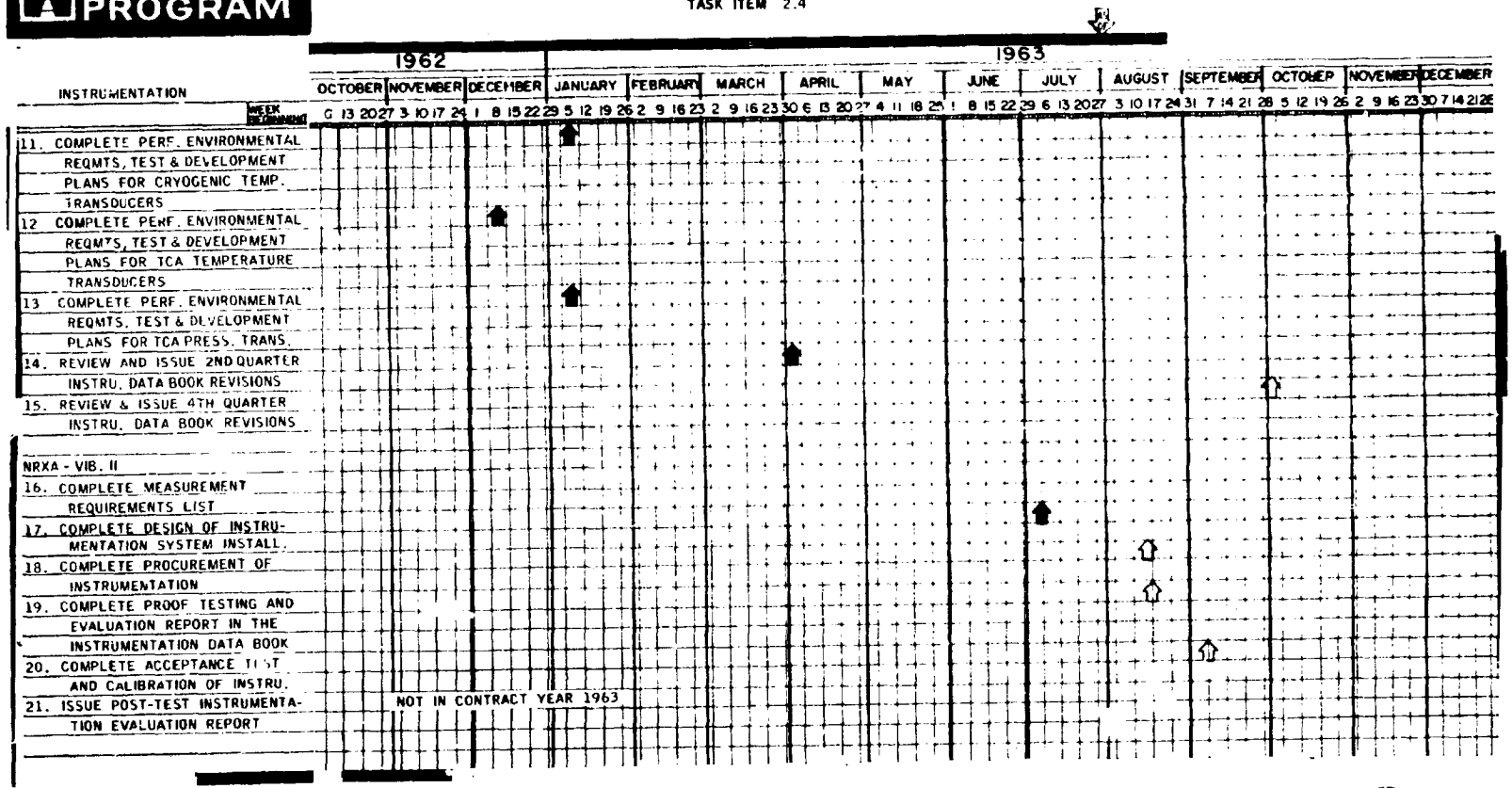
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.4



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MILESTONE ACHIEVEMENT
RESCHEDULED MILESTONE
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Figure 1
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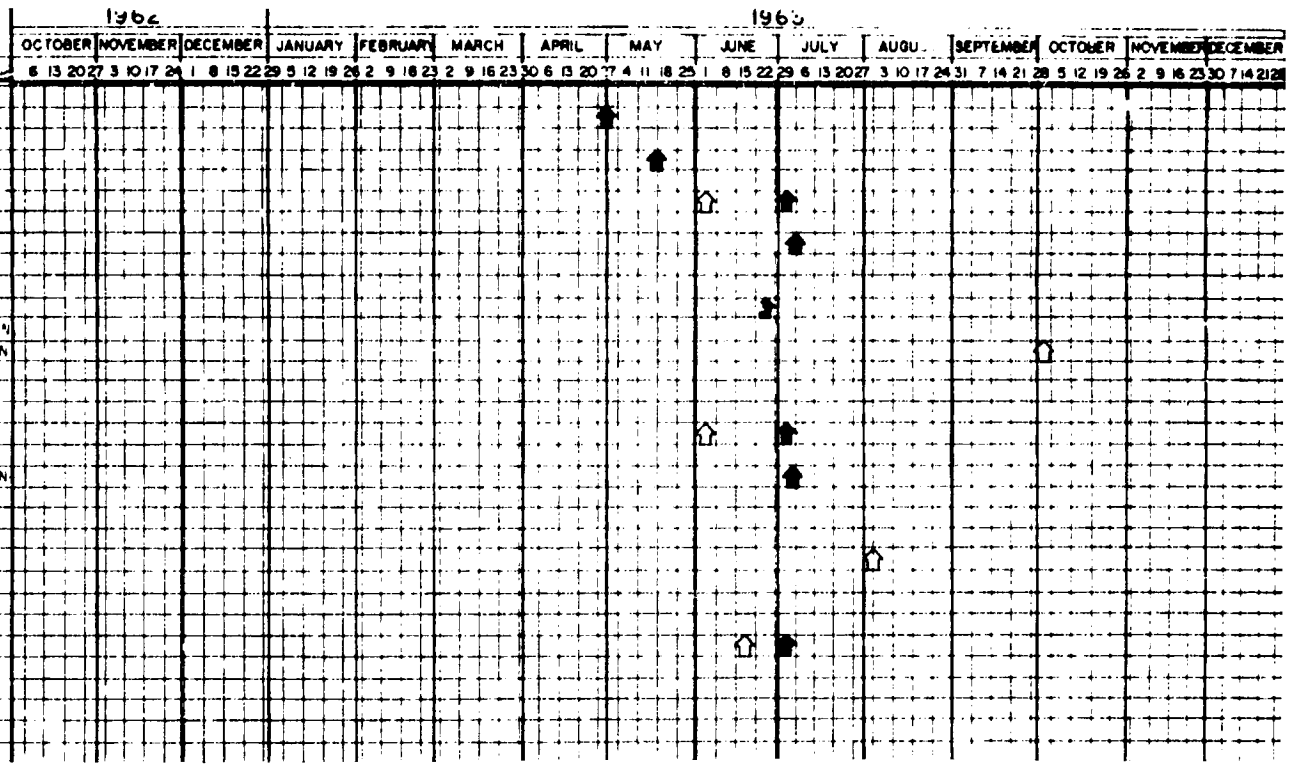
NERVA PROGRAM

SCHEDULE AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.4



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- ◆ RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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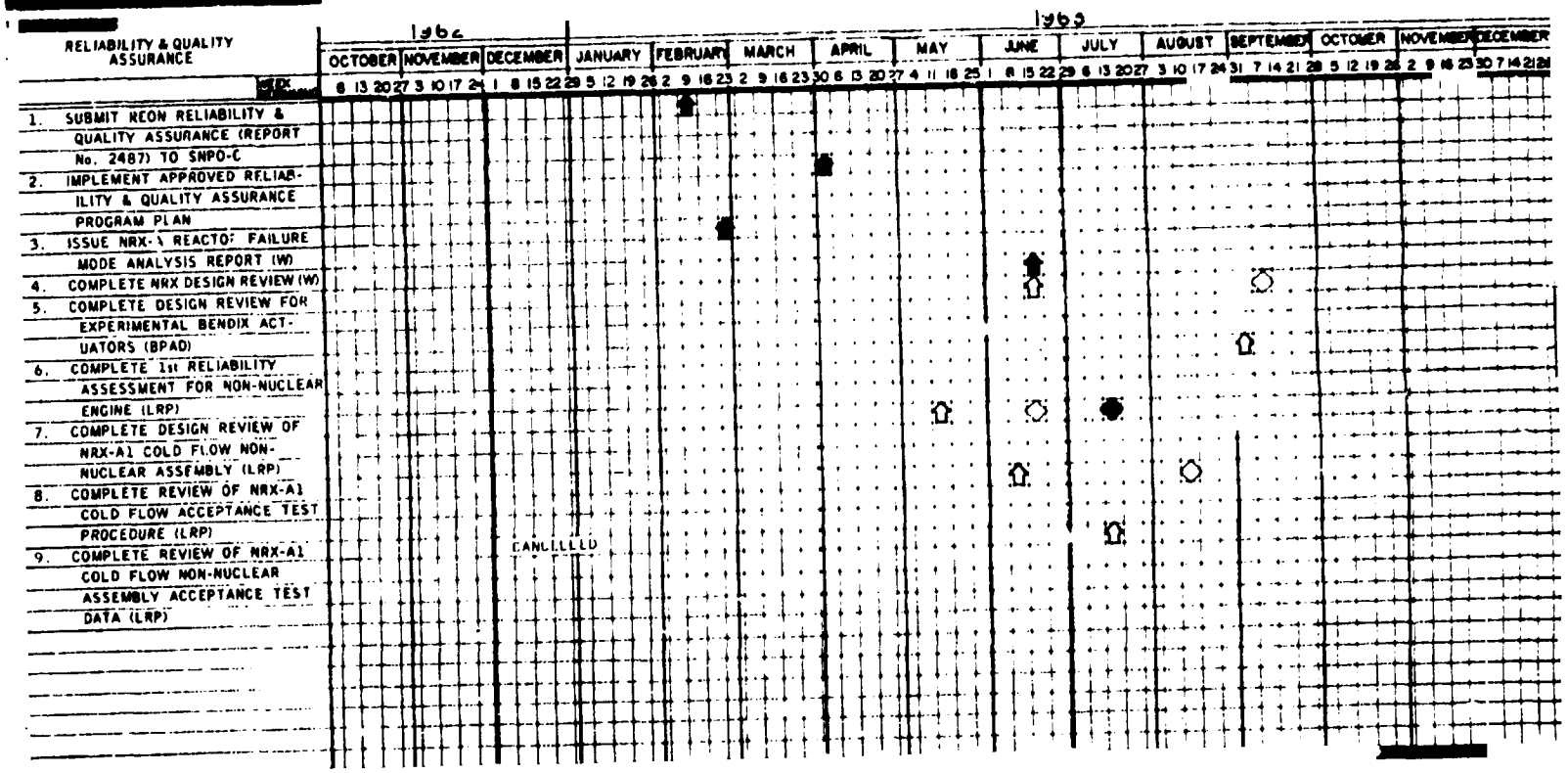
REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.6



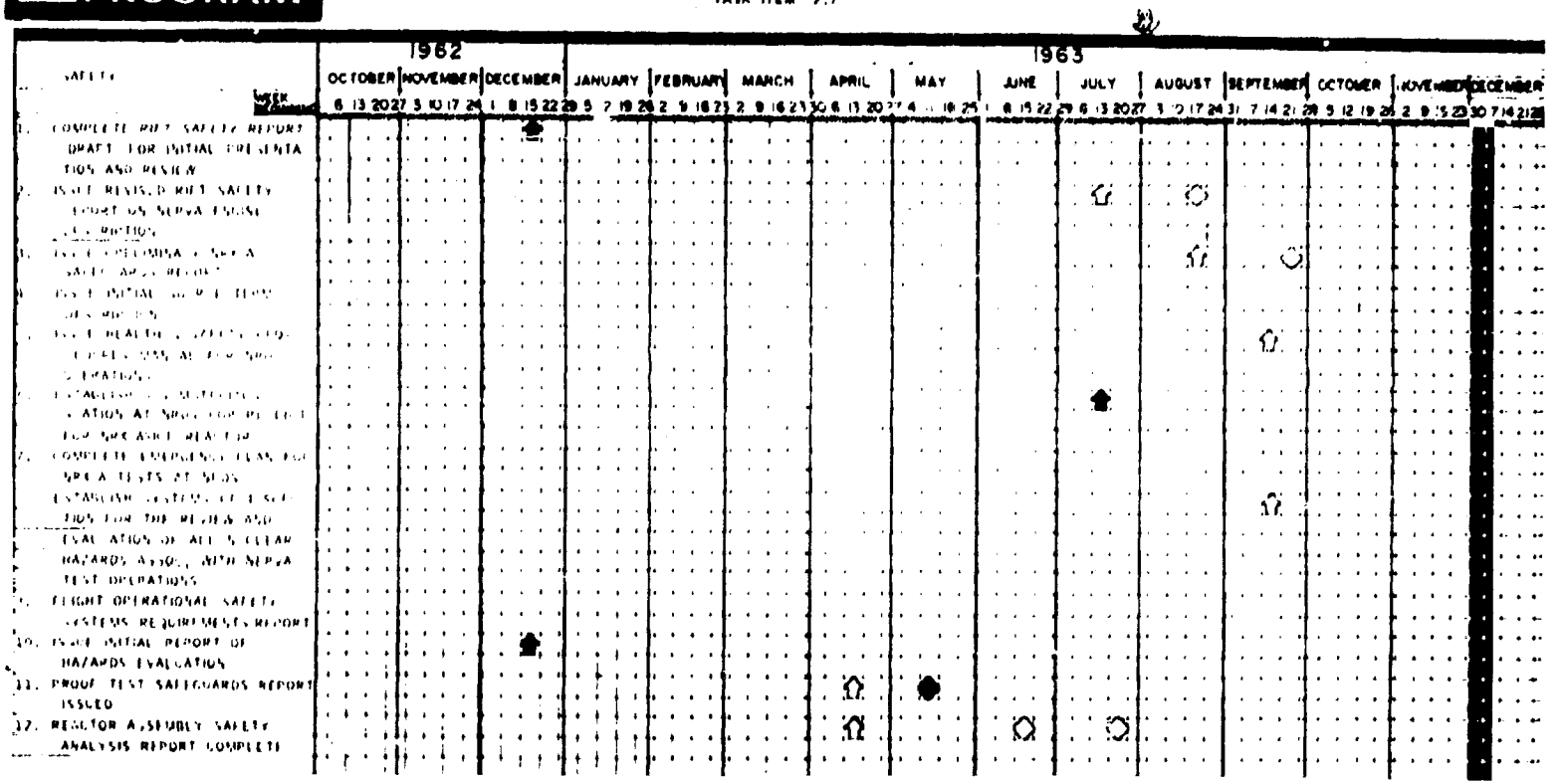
SCHEDULED MILESTONE
MILESTONE ACHIEVEMENT
RESCHEDULED MILESTONE
RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
Sheet 47 of 63

REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.7



DATE:

SCHEDULED MILESTONE
MILESTONE ACHIEVEMENT
RESCHEDULED MILESTONE
RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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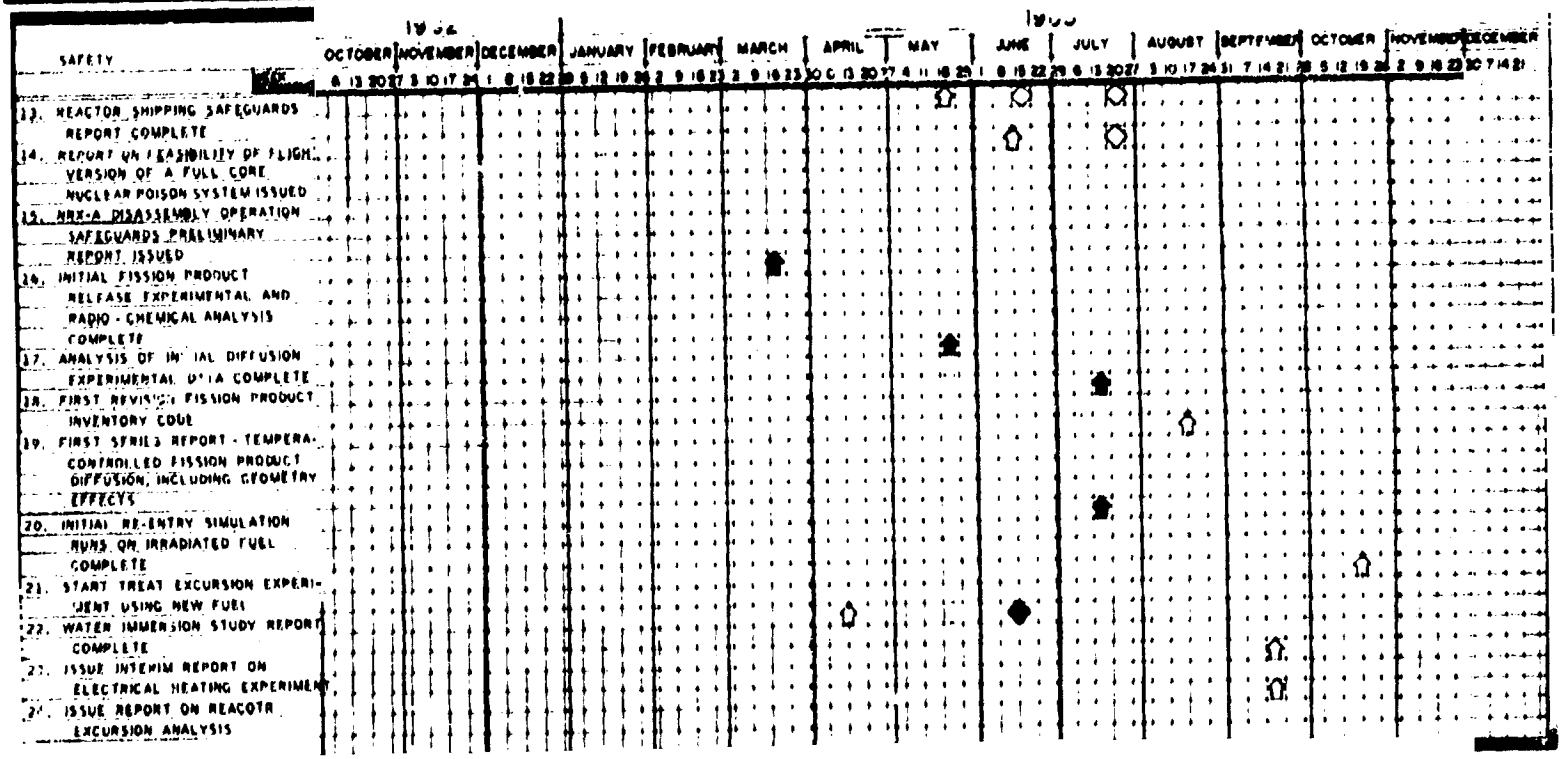
REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.7



DATE:

SCHEDULED MILESTONE

MILESTONE ACHIEVEMENT

RESCHEDULED MILESTONE

RESCHEDULED MILESTONE ACHIEVEMENT

Figure 3
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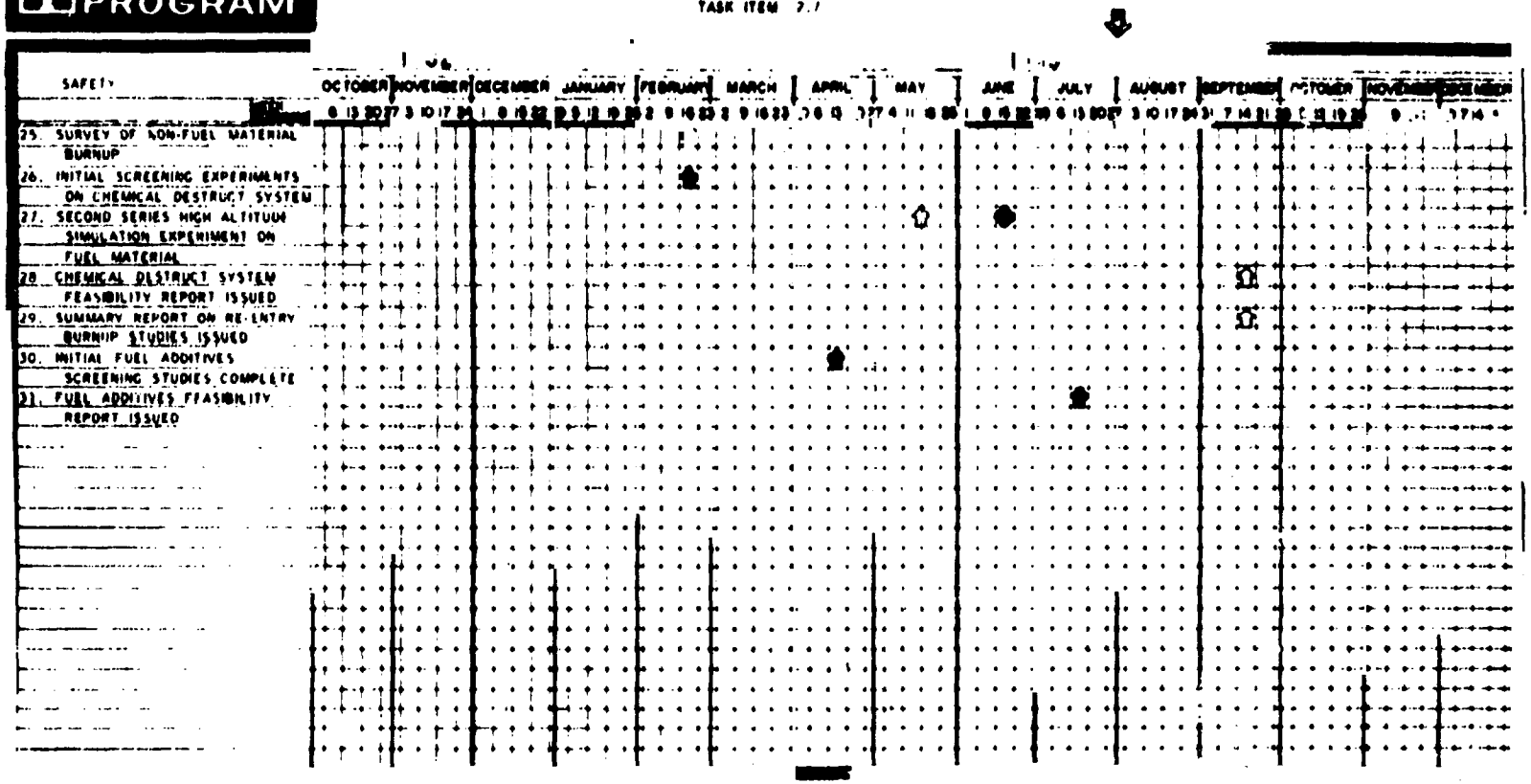
REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.1



DATE:

SCHEDULED MILESTONE

MILESTONE ACHIEVEMENT

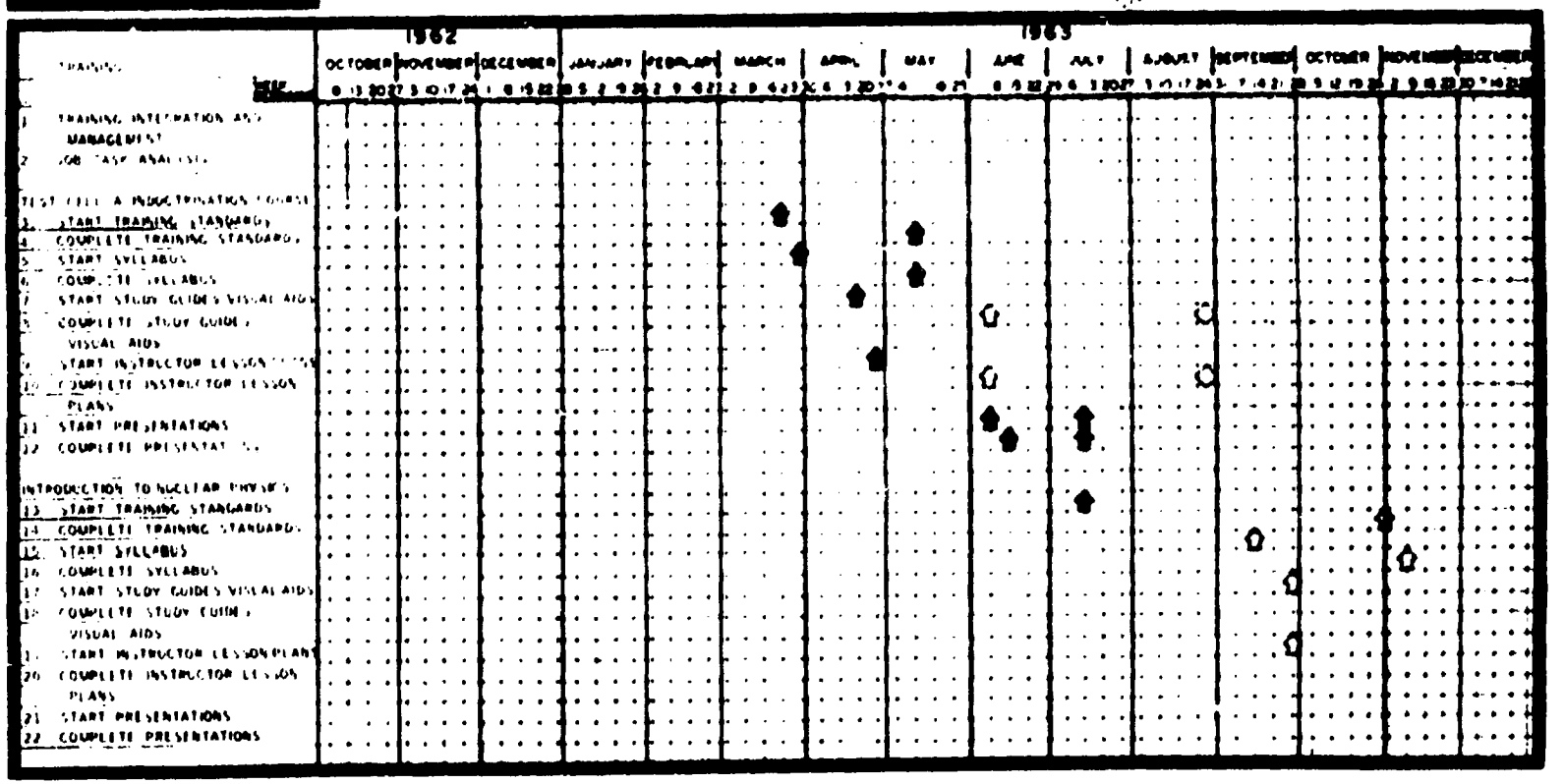
RESCHEDULED MILESTONE

RESCHEDULED MILESTONE ACHIEVEMENT

REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM



DATE:

SCHEDULED MILESTONE

MILESTONE ACHIEVEMENT

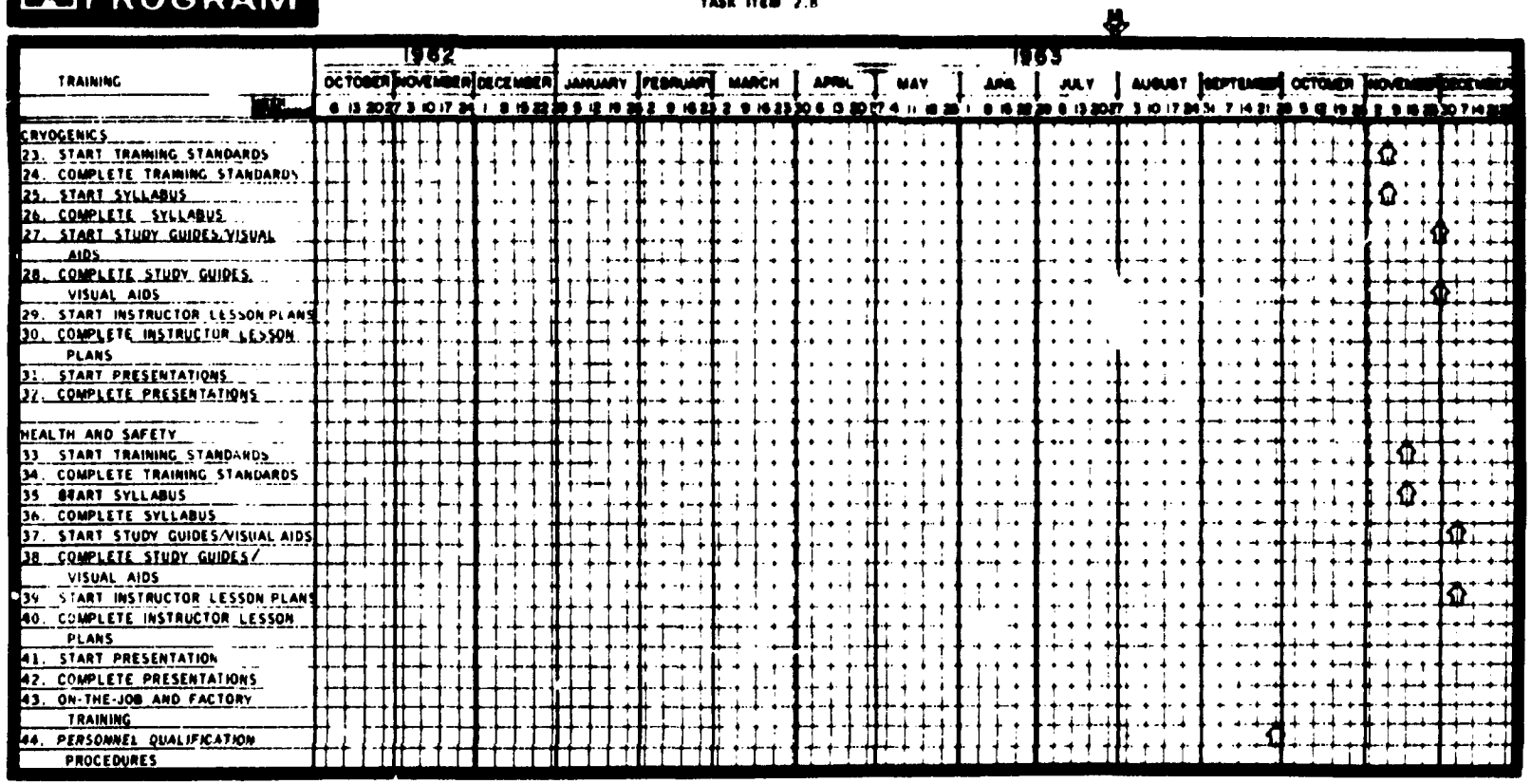
RESCHEDULED MILESTONE

RESCHEDULED MILESTONE ACHIEVEMENT

REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.8



DATE:

⇧ SCHEDULED MILESTONE

◇ RESCHEDULED MILESTONE

⬆ MILESTONE ACHIEVEMENT

◆ RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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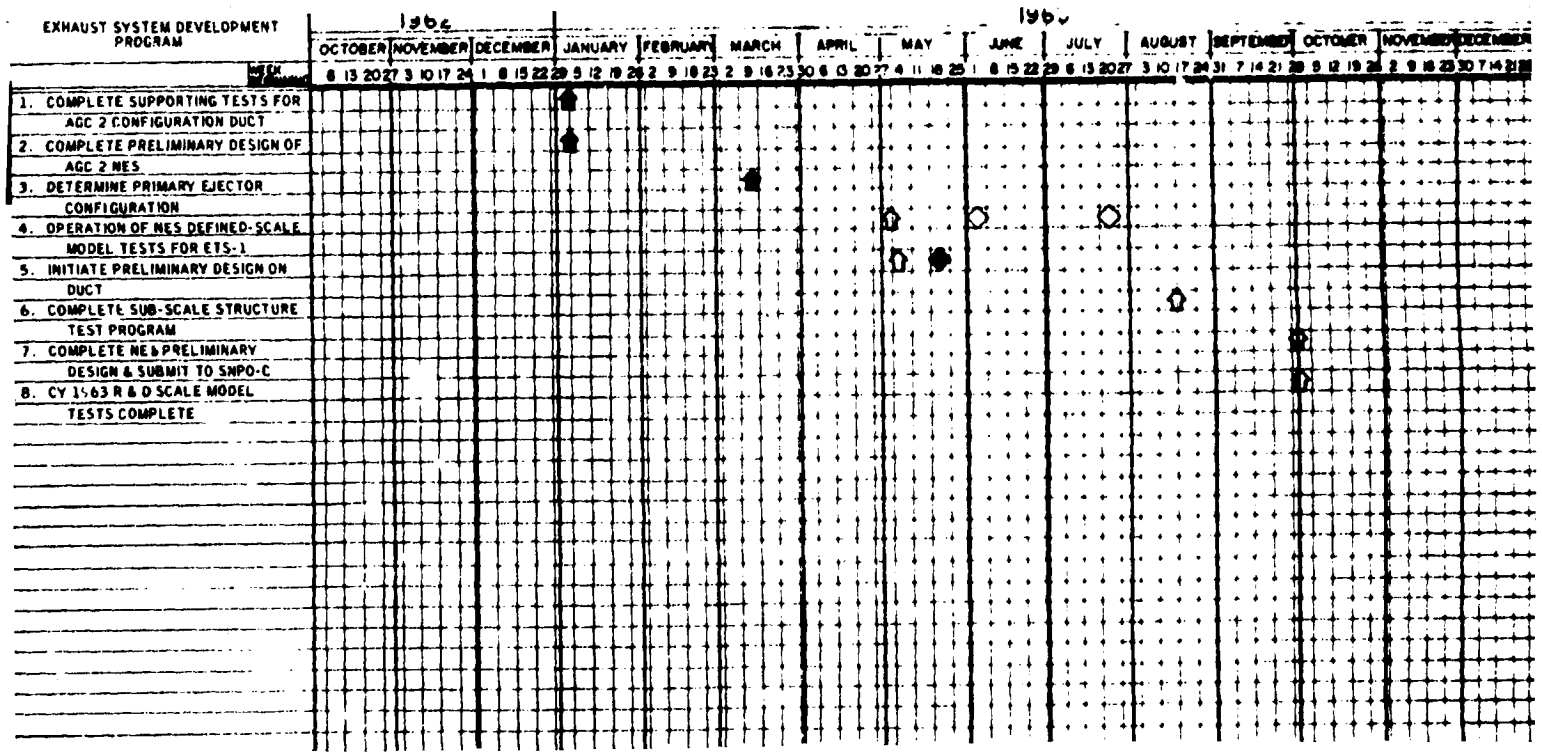
REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 3.1



SCHEDULED MILESTONE
MILESTONE ACHIEVEMENT
RESCHEDULED MILESTONE
RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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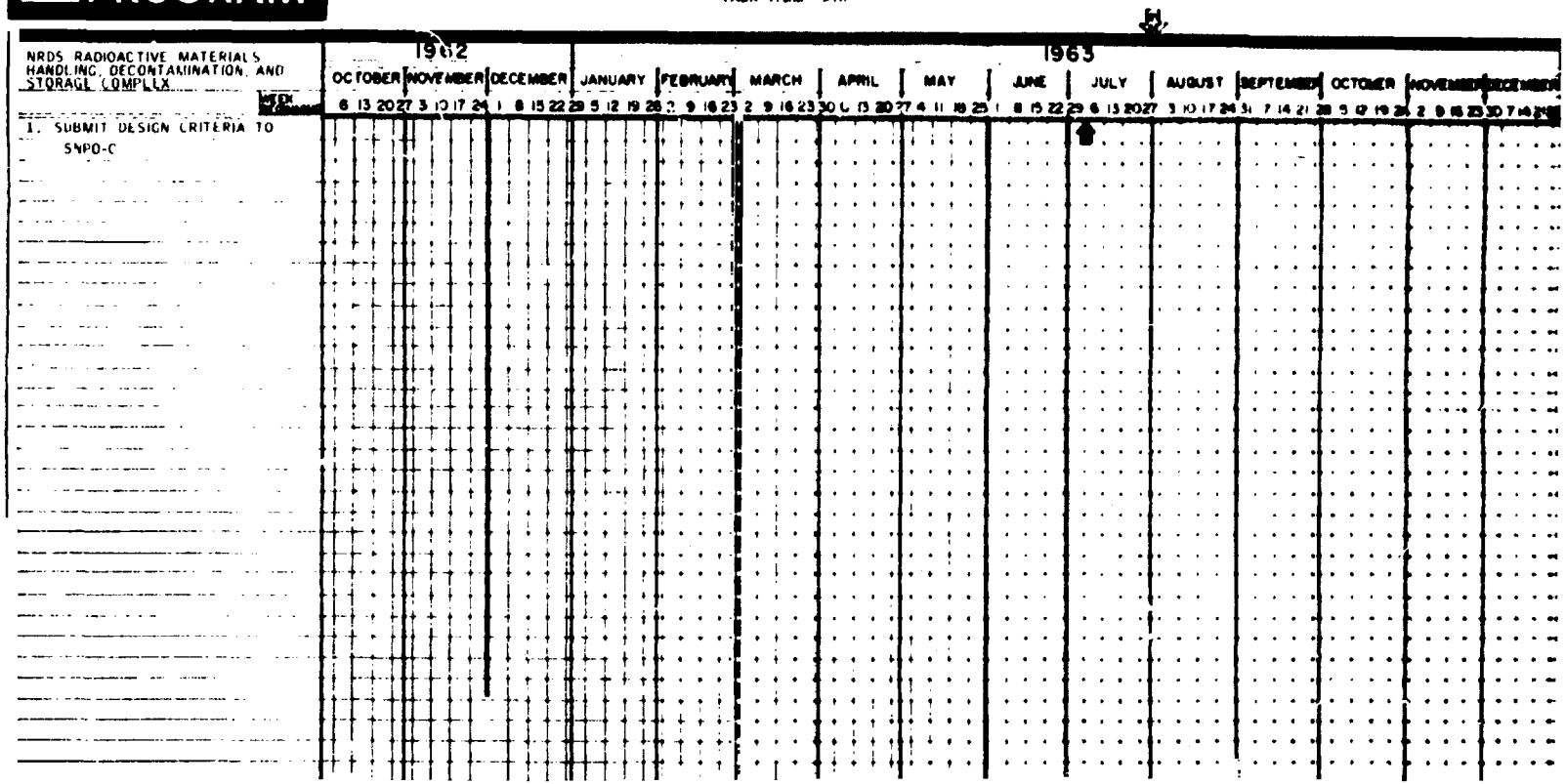
REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 3.H



DATE:

- ⇧ SCHEDULED MILESTONE
- ◇ RESCHEDULED MILESTONE
- ⬆ MILESTONE ACHIEVEMENT
- ◆ RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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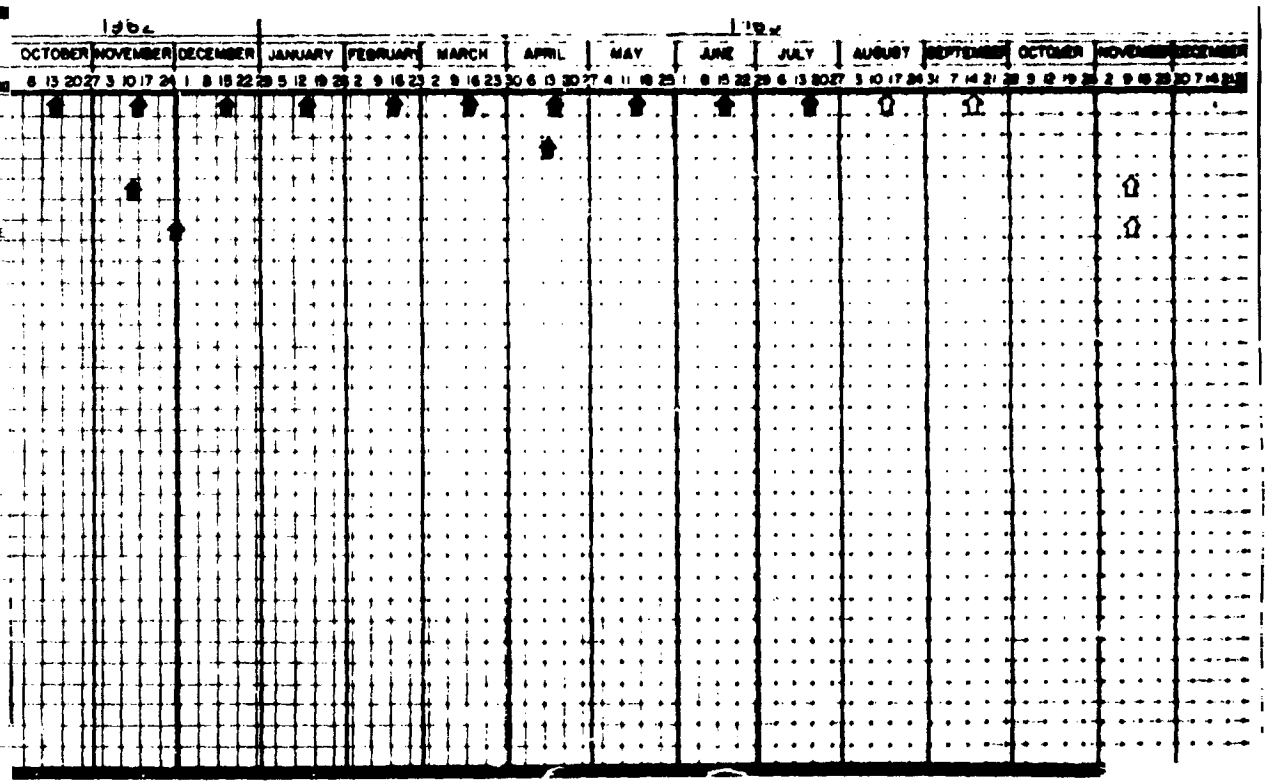
NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 4.3
ADDITIONAL DOCUMENTATION

CONTRACT SNP-1
CONTRACT YEAR 1963



SCHEDULED MILESTONE
MILESTONE ACHIEVEMENT
RESCHEDULED MILESTONE
RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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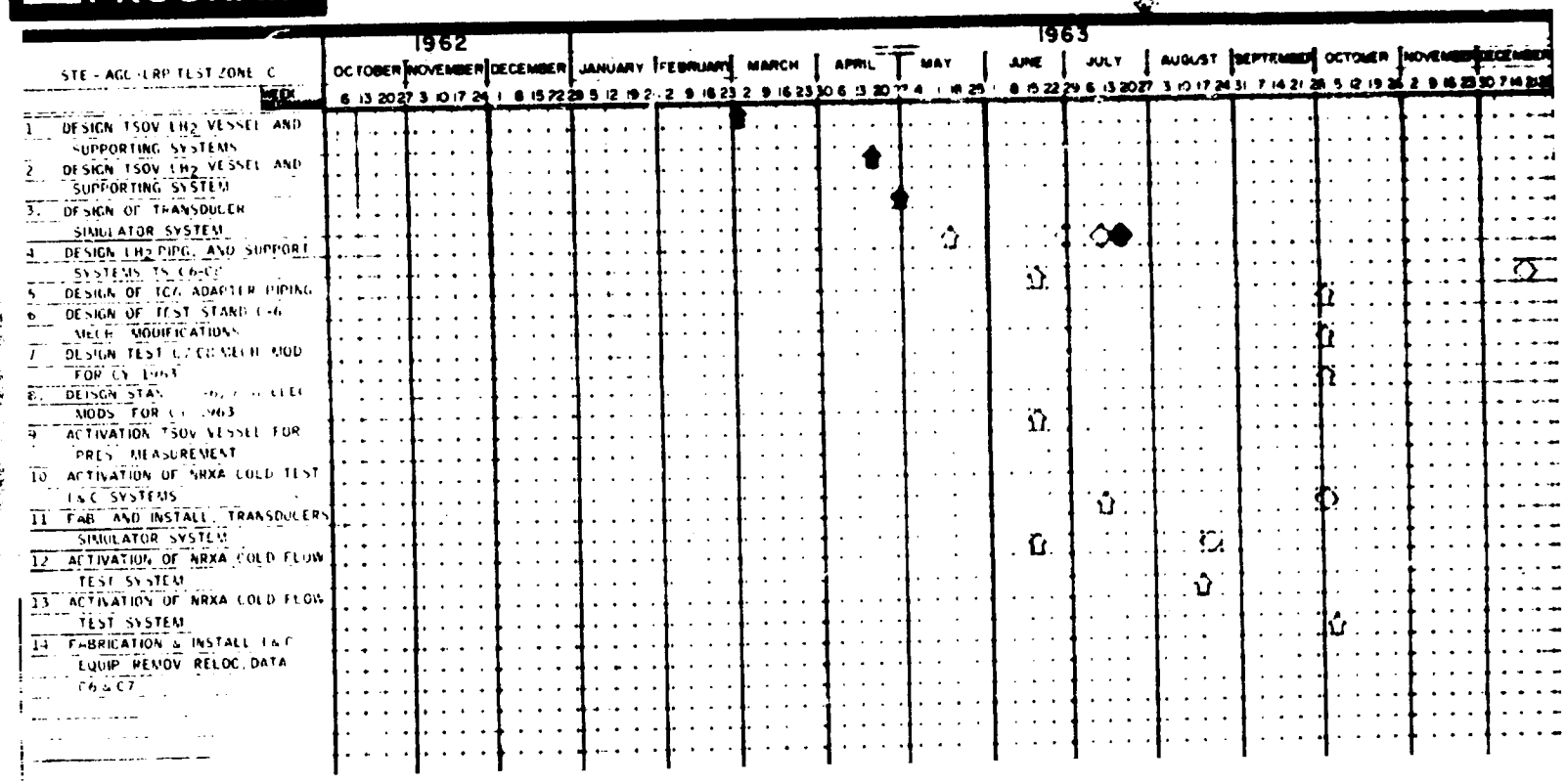
REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 5.1



DATE:

SCHEDULED MILESTONE

MILESTONE ACHIEVEMENT

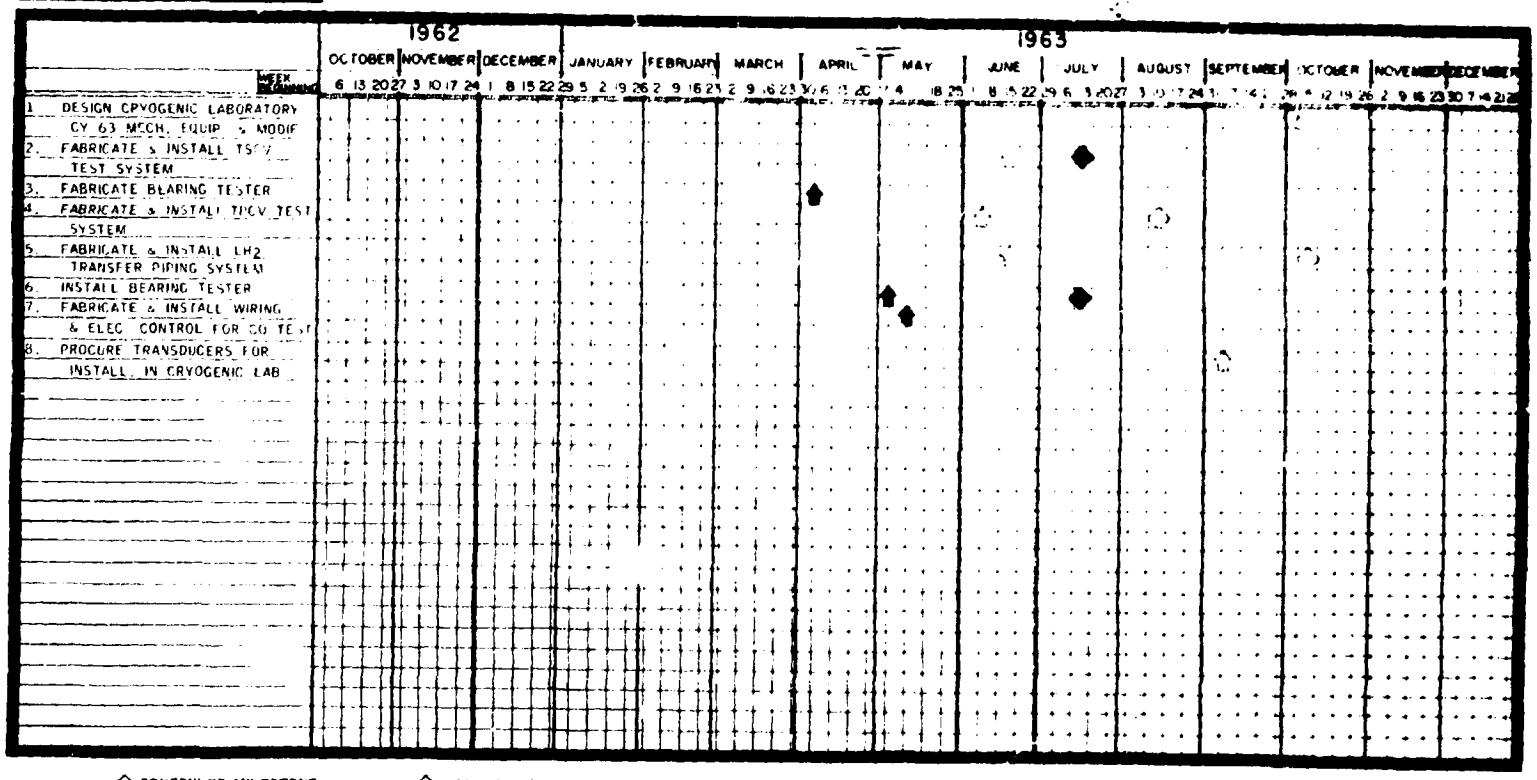
RESCHEDULED MILESTONE

RESCHEDULED MILESTONE ACHIEVEMENT

REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM



DATE:

⇧ SCHEDULED MILESTONE

⬆ MILESTONE ACHIEVEMENT

◇ RESCHEDULED MILESTONE

◆ RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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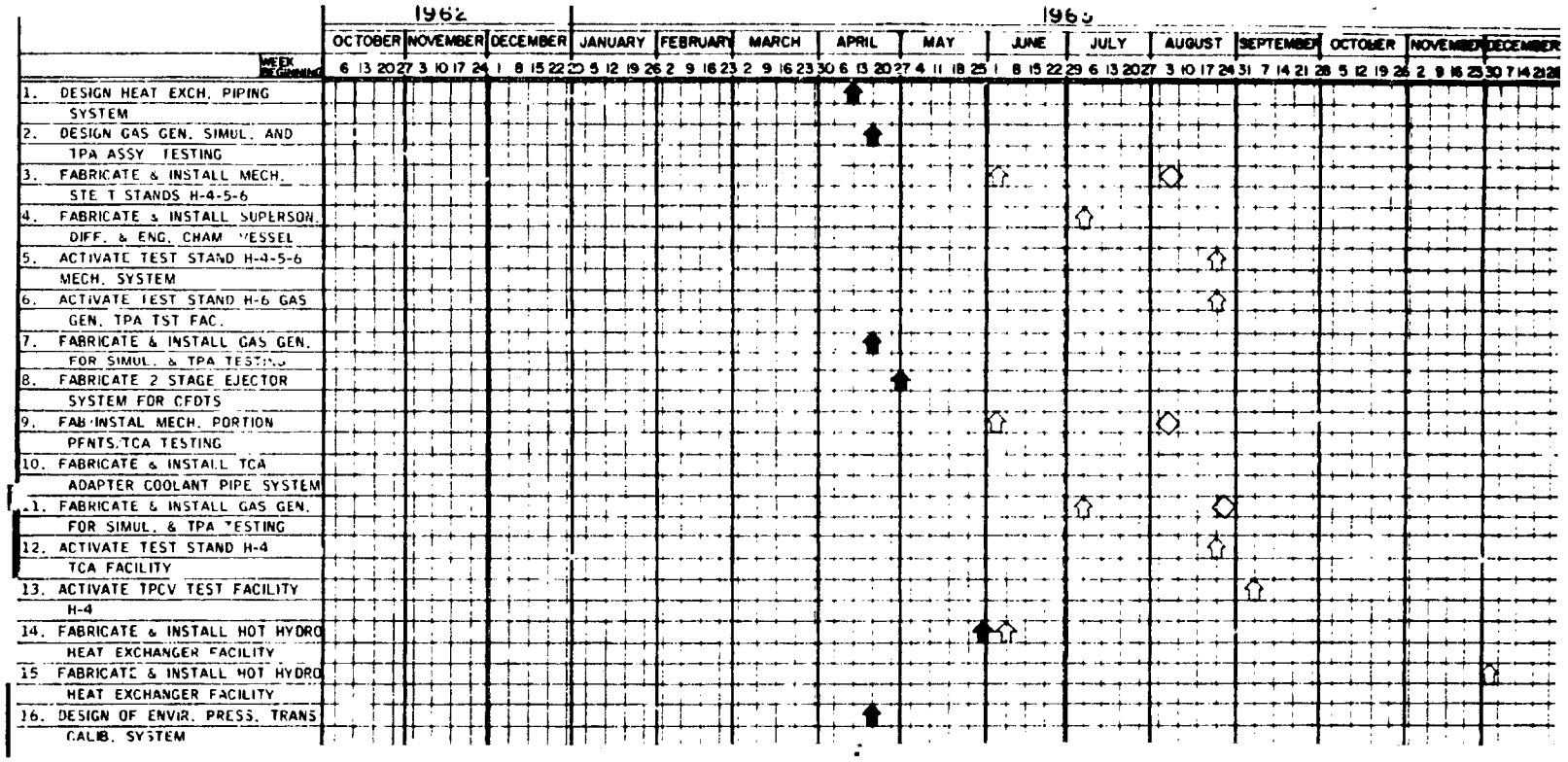
REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 5.3



DATE:

SCHEDULED MILESTONE

MILESTONE ACHIEVEMENT

RESCHEDULED MILESTONE

RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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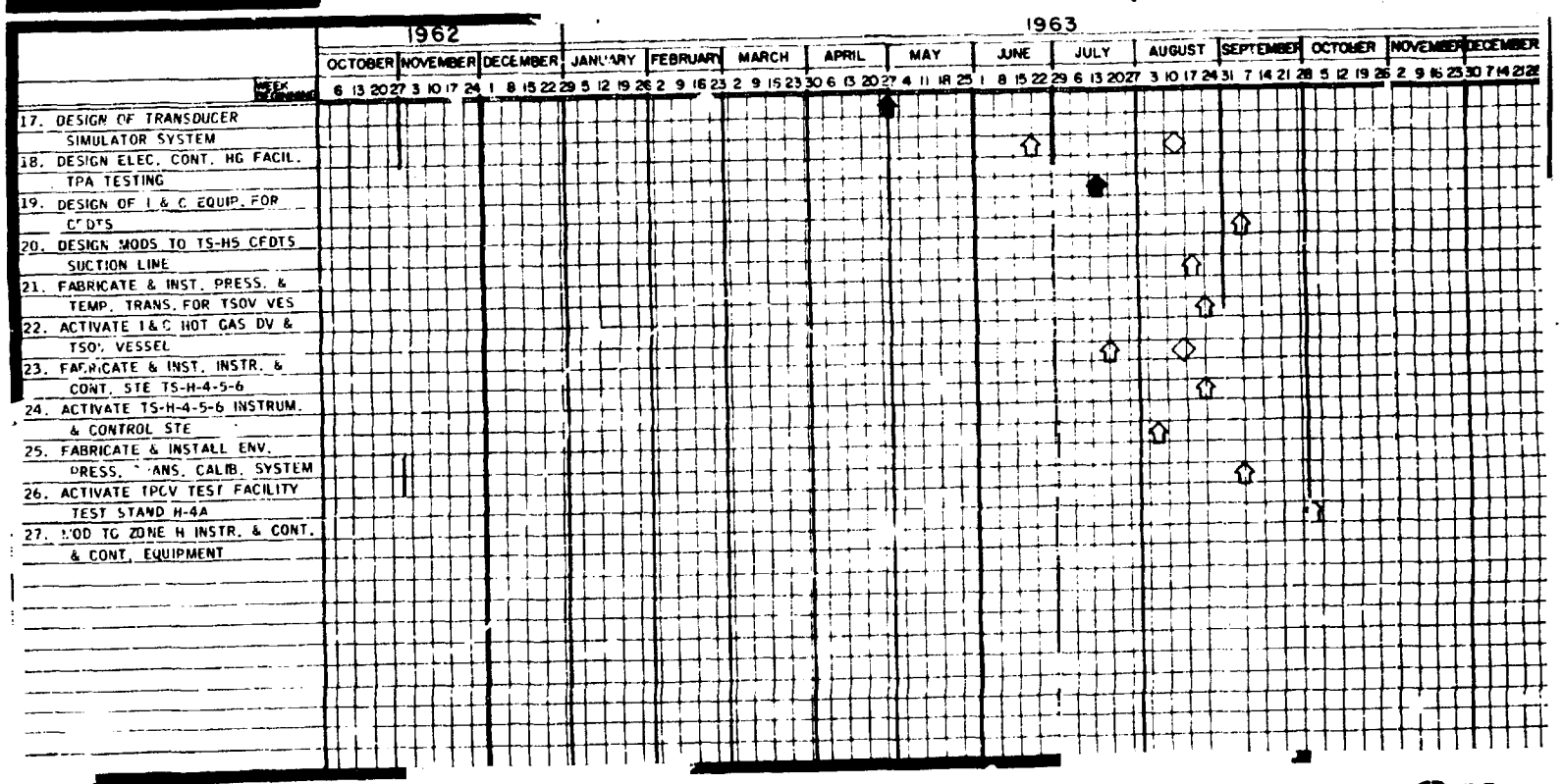
REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 5.3



DATE:

SCHEDULED MILESTONE

MILESTONE ACHIEVEMENT

RESCHEDULED MILESTONE

RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 5.4

STE - AGC (AZUSA PLANT)
ANALOG COMPUTER

1962: OCTOBER, NOVEMBER, DECEMBER
1963: JANUARY, FEBRUARY, MARCH, APRIL, MAY, JUNE, JULY, AUGUST, SEPTEMBER, OCTOBER, NOVEMBER, DECEMBER

WEEK: 6 13 20 27 3 10 17 24 1 8 15 22 29 5 12 19 26 2 9 16 23 2 9 16 23 30 6 13 20 27 4 11 18 25 1 8 15 22 29 6 13 20 27 3 10 17 24 31 7 14 21 28 5 12 19 26 2 9 16 23 30 7 14 21 28

1. PACE - 231R CONSOLE RECEIVED
2. MODERNIZATION PACE 24D COMPLETE
3. MODERNIZATION PACE 231R COMPLETE
4. DELIVER 231R ADDITIONAL EQUIPMENT
5. DELIVER CONTROL SYSTEM [illegible] 0 EQUIPMENT
6. PROTOTYPE THERMAL CONDUCTIVITY EQUIPMENT DEMONSTRATION
7. THERML CONDUCTIVITY EQUIPMENT DELIVERED TO GENERAL DYNAMICS/FT. WORTH

DATE:

- ⇧ SCHEDULED MILESTONE
- ◇ RESCHEDULED MILESTONE
- ⬆ MILESTONE ACHIEVEMENT
- ◆ RESCHEDULED MILESTONE ACHIEVEMENT

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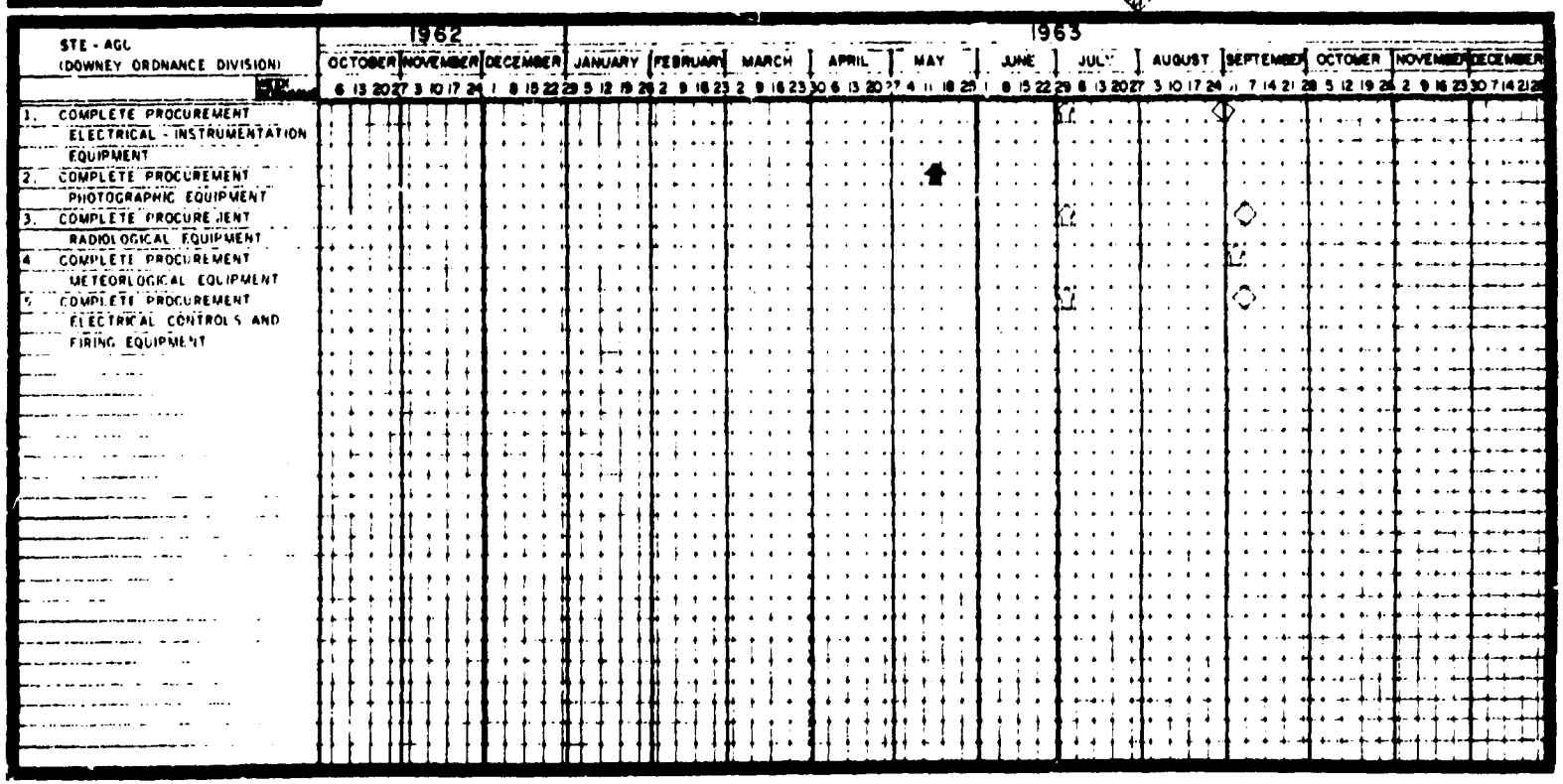
REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 5.5



DATE:

- ⬠ SCHEDULED MILESTONE
- ◇ RESCHEDULED MILESTONE
- ⬟ MILESTONE ACHIEVEMENT
- ◆ RESCHEDULED MILESTONE ACHIEVEMENT

Figure 3
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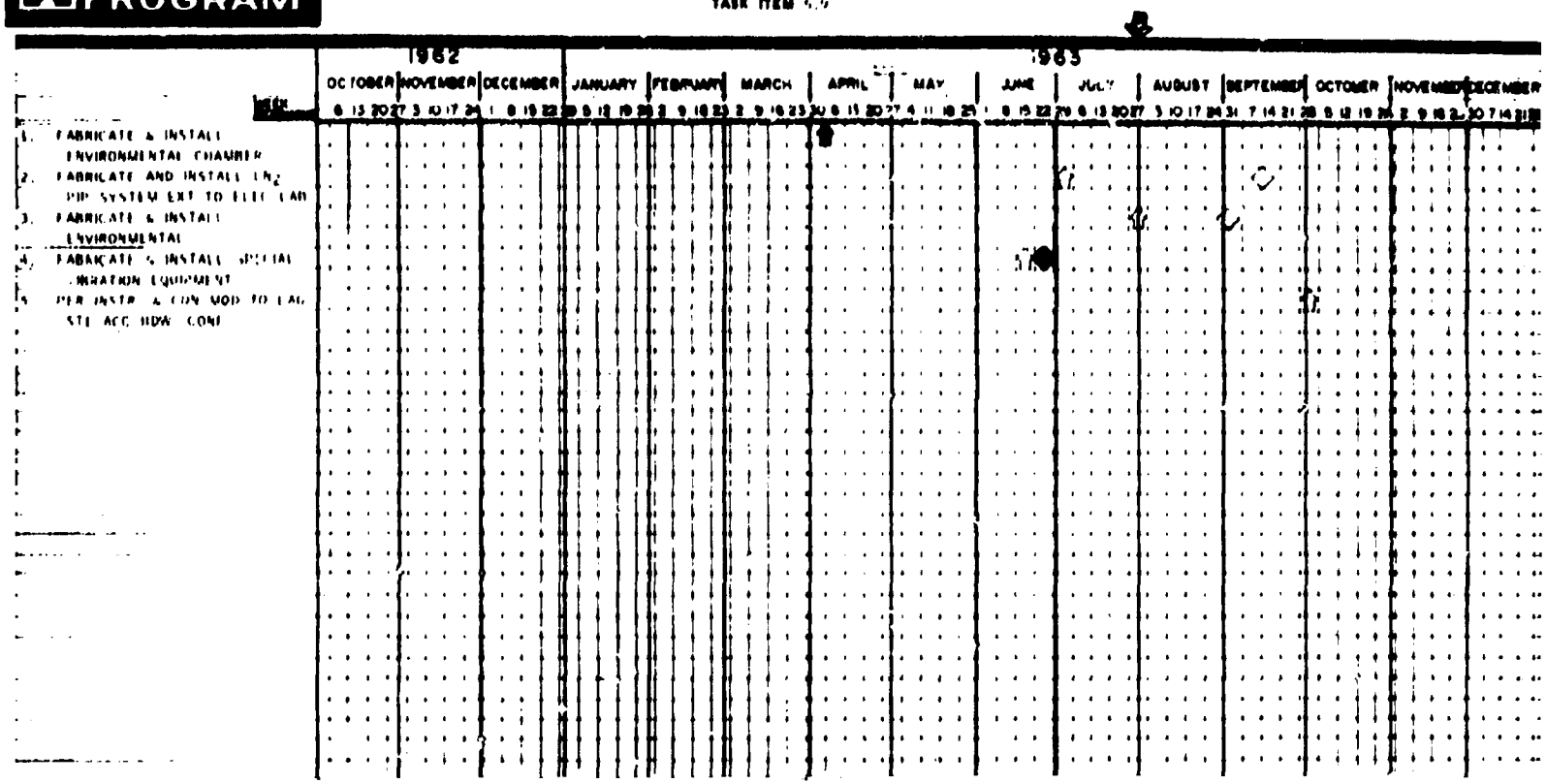
REON

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM [illegible]



DATE:

SCHEDULED MILESTONE

MILESTONE ACHIEVEMENT

RESCHEDULED MILESTONE

RESCHEDULED MILESTONE ACHIEVEMENT

Figure 1
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REON