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**FINAL TEST REPORT
FOR
PEWEE 2 INTEGRATED FACILITY
TEST SERIES
(FEP 1 & FEP 2)**

MASTER

DECEMBER 11, 1970

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NRTO-R-0202

NUCLEAR ROCKET TEST OPERATIONS

FINAL TEST REPORT

FOR

PEWEE 2 INTEGRATED FACILITY TEST SERIES
(FEP I AND FEP II)

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APPENDIX A

TEST FACILITY SYSTEM ENGINEERING DATA

APPENDIX B

CHRONOLOGY, FACILITY EXPERIMENTAL PLAN I

September 17, 1970

CHRONOLOGY FOR PEWEE 2, INTEGRATED FACILITY
TEST SERIES, FEP-II

October 8, 1970

APPENDIX C

LOSS OF POWER TESTS

1.0

INTRODUCTION

The Pewee 2 Integrated Facility Test Series Report has been prepared by Nuclear Rocket Test Operations to summarize the results, describe the test operations, and present the final chronologies for the integrated facility system tests that were performed in support of the Pewee 2 reactor tests to be conducted at the Test Cell "C" facility at the Nuclear Rocket Development Station (NRDS), Jackass Flats, Nevada.

The Pewee 2 Integrated Facility Test Series was performed to provide a final integrated checkout of certain Test Cell "C" facility systems and operating procedures prior to the conduct of the Pewee 2 reactor tests. The test objectives and test system operational requirements established preceding the tests are given in the FEP-I Test Description, NRTO-R-0193; and the FEP-II Test Description, NRTO-R-0199.

2.0 SUMMARY AND CONCLUSIONS

2.1 TEST SERIES

The Pewee 2 Integrated Facility Test Series was successfully completed on October 8, 1970. The test series consisted of loss-of-power tests conducted on September 16, 1970; the FEP-I tests conducted on September 17, 1970; and the FEP-II tests conducted on October 8, 1970. These tests were performed based on the requirements established preceding the tests as given in the FEP-I Test Description (NRTO-R-0193), and the FEP-II Test Description (NRTO-R-0199). Tests in addition to those described in these documents were performed based on data review conducted during run day operations.

The Emergency Shutdown Tests that were not performed in accordance with the FEP-I Test Description included those planned to determine the effect of an H-60 fail close and L-21 fail open malfunctions on the system performance at simulated Pewee 2 full power operating conditions. Since these were planned as secondary objectives, the overall success of the test series was not affected by the fact that these tests were not accomplished.

2.2 TEST CELL "C" SYSTEMS

The Test Cell "C" facility systems that were operated during the Pewee 2 Integrated Facility Tests were those required to conduct the Pewee 2 reactor tests, except the Borated Water System, the Drums Hydraulic System, the FROG System, the Neutronic Systems, the Reactor Temperature-power Control Systems, the Reactor and Cart Shield System, the Reactor and Cart Purge Systems, and those portions of the Test Cell "C" facility systems required to support the Pewee 2 Side-by-Side Experiments.

The test facility reconfigurations, applicable to future Pewee 2 reactor tests, which were incorporated and checked out during FEP-II included installation of mechanical blocks to L-109, L-11, and L-21; and a change in the Specific Speed controller compensation.

The L-109 actuator was provided with an internally mounted mechanical block based on the results of FEP-I, to prevent damage to the Mark 35 pump and limit the maximum Pewee 2 reactor nozzle inlet pressure dip in the event of an open failure of L-109. The mechanical block limits the maximum opening position of L-109 to 17.3%, which corresponds to an effective flow area of 1.05 in^2 based on FEP-II test data.

The L-11 valve was provided with an externally mounted mechanical block to allow Pewee 2 reactor power operations with L-11 at a throttled position with the Hold Open Circuit active. Throttled operation in conjunction with a time delay closure of L-11 was established based on FEP test data and subsequent analysis in order to improve Emergency Shutdown System performance capability for Pewee 2. The mechanical block limits the maximum opening position of L-11 to 37.3%, which develops a pressure drop of 100 psid (LP-11D) at a main line flow rate of 24.1 pps LH_2 based on FEP-II test data.

The L-21 valve was provided with an externally mounted remotely operated mechanical block in order to prevent an L-21 fail closed malfunction during Pewee 2 reactor tests. The mechanical block limits the minimum opening position of L-21 to 14.7%, which corresponds to an effective flow area of 0.20 in^2 based on FEP-II test data.

The Specific Speed controller compensation was changed by -6DB based on the results of FEP-I, to improve turbopump operation in Specific Speed Control.

The Test Cell "C" facility systems that were operated during this test series performed successfully during FEP-II, and it is expected that they will successfully and safely support the conduct of the Pewee 2 reactor tests.

2.3

TEST FLOW CAR SYSTEM

A Test Flow Car System was used during the Pewee 2 Integrated Facility tests to provide the capability to simulate the actual Pewee 2 reactor and cart flow impedances for those flow tests involving the main and moderator line systems.

The test flow car reconfigurations that were made between FEP-I and FEP-II included removal of an impedance orifice (BF-014) and installation of a close coupled pressure transducer (BP-014).

The orifice which was installed in the Test Flow Car main line prior to FEP-I had the same pressure drop characteristics as that originally planned to be installed on the actual Pewee 2 reactor cart. The cart mounted orifice was planned prior to FEP-I, since it was expected that the orifice would attenuate pressure oscillation expected at BP-015 during Emergency Shutdown tests. This orifice was removed prior to the FEP-II tests, since it was determined based on the results of FEP-I tests and subsequent analyses, that the orifice did not attenuate pressure oscillations and, therefore, would not be required for the actual Pewee 2 reactor cart.

A close coupled pressure transducer (BP-014) was installed in the Test Flow Car main line upstream of the terminal control valve prior to FEP-II in order to determine the effect of sensor line length on the measurement of the pressure oscillations near BP-015, which had a longer sensor line length. FEP-II tests determined that although less secondary line ringing was measured by BP-014 than by

BP-015, BP-015 provided accurate transient data including measurement of pressure dips.

The Test Flow Car System successfully supported the conduct of the Pewee 2 Integrated Facility Tests.

2.4

TURBOPUMP PERFORMANCE

The Rocketdyne Mark 25 Turbine (Serial No. R-005R) successfully supported the conduct of FEP-I and FEP-II tests. This turbine had a total accumulated operating time of six hours and 19 minutes, including an accumulated operating time of three hours and 42 minutes at or above Pewee 2 full power operating speed of 23,000 rpm at the completion of FEP-II.

The refurbished Rocketdyne Mark 35 Pump (Serial No. R001R-3) installed for FEP-II, successfully supported the conduct of FEP-II tests. This pump had a total accumulated operating time of one hour and 26 minutes, including an accumulated operating time of 38 minutes at or above Pewee 2 full power operating speed of 23,000 rpm at the completion of FEP-II.

The Rocketdyne Mark 35 Pump (Serial No. R002R-2) successfully supported the conduct of FEP-I tests, except for its failure to rotate following the Emergency Shutdown Test performed during FEP-I, wherein L-109 was commanded to the full open position upon an ESD.

The failure of the Mark 35 to rotate on dewar pressure only was determined from post-test disassembly inspections to be due to damage to the rub-ring. Data analysis has shown that for this test, the pump discharge pressure decreased faster than the balance piston cavity pressure, forcing the balance piston against the rub-ring. The installation of the mechanical block on L-109 after FEP-I will

protect the pump against this type of damage due to open failures of L-109.

The Rocketdyne Mark 35 Pump (Serial No. R002-R-2), at the end of FEP-I had a total accumulated operating time of three hours and 28 minutes, including an accumulated operating time of two hours and seven minutes at or above the Pewee 2 full power operating speed of 23,000 rpm. This pump operated normally during FEP-I with no apparent degradation in performance, even though damage to the outboard forward bearing was revealed during post-test disassembly inspections.

Post-test data analysis of the performance of both the Mark 35 pumps has shown that zero bearing pressure differential exists at operating speeds below 10,000 rpm and for certain other operating regions of the pump map. The only predicted pump operating conditions for the Pewee 2 reactor tests for which zero bearing differential pressures should exist are at speeds less than 10,000 rpm. The predicted pump operating time at less than this speed for Pewee 2 reactor tests is approximately 15 minutes. This compares with an accumulated operating time at speeds less than 10,000 rpm of 38 minutes on the Mark 35 pump used during FEP-I, and of 30 minutes on the Mark 35 pump used during FEP-II.

2.5

EMERGENCY SHUTDOWN OPERATIONS

CTO initiated Emergency Shutdown operations were successfully performed during FEP-I and FEP-II from flow and pressure conditions corresponding to Pewee 2 reactor operating conditions at fuel exit temperatures of 4400°R (FPH) and 2500°R (MPH).

The Emergency Shutdown operations from Pewee 2 MPH conditions were performed to obtain system performance data without the accumulator

on-line, since this type of shutdown is planned to be performed during Pewee 2 reactor tests.

The Emergency Shutdown operations from Pewee 2 FPH conditions were performed in order to demonstrate an acceptable Emergency Shutdown System for Pewee 2 reactor tests. The effects of accumulator operating conditions, L-11 initial position preceding the ESD, the L-11 closing delay time after ESD, a full open failure of L-109 upon ESD, and a full open failure of H-11 before ESD on system performance were also investigated. The criterion used during FEP testing to judge the acceptability of Emergency Shutdown System performance, was that the initial pressure dip at BP-015 must be less than 70 psi upon a CTO initiated ESD from Pewee 2 FPH conditions.

The CTO initiated Emergency Shutdown tests performed during FEP-I from FPH conditions demonstrated that: (1) the impedance orifice installed in the test car main line, similar to that originally planned for the Pewee 2 reactor, was not effective in reducing the initial pressure dip that occurred at the nozzle flow impedance simulation valve (B-015) upon shutdown; (2) acceptable pressure dips could be achieved with L-11 demanded close to 6.3% without a time delay upon ESD from an initial throttled position of 37%; (3) a full open failure of L-109 upon shutdown would result in damage to the Mark 35 pump, and an unacceptable initial pressure dip with L-11 initially at full open position; and (4) the accumulator operating pressure had a significant effect on the initial pressure dips for ESD conducted with L-11 initially at full open position.

The test facility system was reconfigured, as discussed in Section 2.2, based on FEP-I test results and subsequent analysis.

The CTO initiated Emergency Shutdown tests performed during FEP-II demonstrated that, with L-11 demanded closed to 6.3% from the

mechanical block position, the initial pressure dip at BP-015 was not significantly affected by either (1) H-11 being in a failed open position during the ESD, (2) L-11 starting to close at 0.050 or 0.43 seconds after the ESD, or (3) the accumulator being at main line pressure or off-line. These tests showed that the pressure decay at BP-015 after the initial pressure dip was affected by the time at which L-11 starts to close upon ESD, and the accumulator pressure.

The Emergency Shutdown performed from Pewee 2 FPH conditions with H-11 in a full open failure position did not have any significant effect on either the TES performance, or the pressure transient at BP-015.

The transition between "L", "X" and "K" System supplied flows to the moderator and main lines following Emergency Shutdown operations did not result in any unacceptable change in fluid conditions at the simulated moderator and main line terminal valve locations.

The referenced Pewee 2 Emergency Shutdown System, which was developed during this test series, consists upon ESD of: an L-109 open demand to 15%; an L-11 close demand to 6.3% from mechanical block position (37%) with time delay of 0.45 seconds; full open demands to H-142 and H-180; full closed demand to H-11, H-60, H-53, X-53, X-161, H-70 and H-175; and H-101 open demand to 10% after 0.5 seconds. This referenced Emergency Shutdown System was demonstrated during FEP-II to be acceptable for Pewee 2 reactor power tests based on the established acceptance criteria. Reliable data for the effects of accumulator off-line (i.e. H-75 fail closed or H-175 fail open), accumulator at line pressure (i.e. H-175 fail closed), L-11 time delay failure, and H-11 fail open on system performance following ESD has also been obtained.

2.6

PEWEE 2 NORMAL PROFILE OPERATIONS

Pewee 2 normal profile operations including Initial Condition Gas, Initial Condition Liquid, and Run Program Operations were successfully performed during FEP-I and II. The tests were performed to demonstrate the capability of the facility systems to accomplish Pewee 2 normal profile operations. The effects of alternate operating procedures and system controls on system performance were also investigated.

These tests demonstrated that acceptable Pewee 2 normal profile operations can be achieved with (1) manual closure of G-3 in 10 - 20 seconds to transfer nozzle and moderator flow from gaseous to liquid hydrogen; (2) manual opening of L-21 to transfer the moderator flow from the 'K' to the 'L' System without the use of L-121 to pre-chill to L-21; (3) the facility system controls to be used for Pewee 2; (4) the DDP-116 generated programs originally planned for Pewee 2; (5) H-11 operated in either delta-pressure (30 or 50 psid) or full open in position control; (6) a range in Dewar 3 ullage volume and gaseous hydrogen header pressures typical of those expected during Pewee 2; and (7) H-175 operated either partly open or closed. The turbopump performance is discussed in Section 2.4. The turbopump operating conditions (i.e. speed, pressure and flows) for simulated Pewee 2 nozzle and moderator pressure and flow condition were slightly higher than predicted due to leakage through L-109. The L-109 leakage rate at Pewee 2 FPH Operating Conditions with the valve commanded closed was 1.6 lb/sec during FEP-II.

These tests also demonstrated that, although the Dewar 3 level instrumentation is not reliable during refill operations at low pressures, satisfactory Dewar 3 refills can be achieved based on time criteria. FEP tests showed that a 10% (480 pounds) increase in Dewar 3 level can be obtained in approximately 60 seconds.

2.7

SIMULATED PEWEE 2 NORMAL COOLDOWN OPERATIONS

Simulated Pewee 2 normal cooldown operations including emergency shutdown from programmed shutdown holds were performed successfully during FEP-I and FEP-II. The tests were performed to evaluate operating procedures to accomplish acceptable simulated cooldown operations with and without the low pressure LH_2 cooldown system operational.

These tests demonstrated that acceptable Pewee 2 cooldown operations can be achieved with the low pressure LH_2 Cooldown System operational using (1) a CTO initiated emergency shutdown from the Shutdown Hold to transfer moderator and main line flows from the "L" to the "K" System, (2) K-6 in Flow Control to provide continuous and pulse cooling down to 1.25 pps and (3) G-3 to expel the LH_2 in the moderator and main lines prior to using G-13 for helium cooldown during FROG installation.

These tests also demonstrated that it is possible to transfer the LH_2 cooldown flow supply from Dewar 4 to 5 without significant effect on the LH_2 fluid conditions at the reactor, and to refill Dewar 4 remotely during cooldown operations.

The tests further demonstrated that acceptable initial Pewee 2 cooldown operation can be achieved without the low pressure LH_2 cooldown system operational using a CTO initiated Emergency Shutdown from the Shutdown Hold with (1) the "X" System pressurized to 100 psi, (2) L-21 full open, and (3) L-11, L-109, H-101 and H-142 in Override before initiation of the ESD. The reactor moderator and main line flows are both transferred from the "L" to "X" Systems with acceptable fluid conditions being maintained following initiation of ESD. Although the moderator and main line flows were steady after the transfer from

the "X" to the "I" Systems upon closure of X-3, the fluid temperatures rose to saturated temperatures at both the terminal valve locations.

2.3

LOSS-OF-POWER TESTS

Loss-of-power tests were successfully performed during FEP-I dry run operations. These tests were performed to determine the effects of loss of utility and critical power systems on facility systems' operating capability.

The facility system operating capability on the critical power system with and without commercial power fed to the critical power bus was verified from the R-CP over a total time interval of 2-1/2 hours. These tests demonstrated the capability of the facility to support Pewee 2 reactor test operations on generator supplied power only, without undesirable power transient effects upon loss of utility and commercial power.

The facility system operating capability on the Emergency Power System was verified from the R-CP over a time interval of 25 minutes after the loss-of-critical power system. The long-term decay characteristics of the Emergency Power System (i.e. 28 vdc and 110 vdc battery systems) have been determined and reported in Reference NRT0-M-29665. These tests showed that although an Emergency Shutdown occurred upon loss of critical power, not all the facility valves on the Emergency Shutdown chain performed normally. The slight opening of H-175, H-60, H-53, H-11, X-53 from their normal operating position before closing upon ESD is considered acceptable for Pewee 2 reactor testing. The L-109 valve, which drifted full open upon loss of critical power during this test, is provided with a mechanical block (as discussed in Section 2.2) for Pewee 2 reactor tests. The L-11 valve, which drifted closed from a full open position upon loss of critical power

during this test, is being supplied with emergency power for Pewee 2 reactor tests. The H-70, H-101, and H-180 valves which remained in their normal operating position upon loss-of-critical power, are considered satisfactory.

3.0 TEST SYSTEM DESCRIPTION

This section provides a description of the Test Flow Car and Test Facility Systems that were used during this test series including a description of the reconfigurations that were made between FEP-I and FEP-II.

Figure 3.0 shows a simplified schematic of the test system used during the FEP tests. This schematic shows only those valves which were operated, and the instrumentation which was monitored in the Control Room during the tests.

3.1 TEST FLOW CAR SYSTEM

A Test Flow Car System was used in place of the actual Pewee 2 reactor and car to provide simulation of the Pewee 2 reactor and car flow impedances required for the Pewee 2 Integrated Facility Tests.

The Test Flow Car System consisted of main and moderator line systems mounted on a standard car which was positioned against the Test Cell Wall and locked in place. The Test Flow Car main and moderator lines were connected to their corresponding interface facility lines in the Hook-up Room. Figure 3.1.1 is a photograph showing the Test Flow Car installed at Test Cell "C". The Test Flow Car main and moderator line systems are shown isometrically in Figure 3.1.2. The Test Flow Car main line system consisted of foam insulated three inch schedule 40 stainless steel pipe and the associated reducers required to interface with the 10-inch main propellant line in the facility, a flow venturi (BF-13) an impedance orifice, a relief valve, a control valve (BO-15), and associated instrumentation. The Test Flow Car sensor line data for the pressure instrumentation installed for FEP-I is given in Appendix A.

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PEWEE 2 TEST FLOW CAR
AT TEST CELL "C"
Figure 3.1.1

FLOW CAR SCHEMATIC
Figure 3.1.2

The impedance orifice and associated instrumentation was installed in the main line for FEP-I since it was originally planned to provide a similar orifice for Pewee 2 reactor tests. The impedance device consisted of a 1.685 inch diameter sharp edge orifice designed to provide a net pressure differential of 100 psid at a Pewee 2 nozzle flow rate of 24.1 pps. This impedance orifice and associated differential pressure instrumentation (BP-014D) were removed before the FEP-II tests, since FEP-I tests showed that the orifice did not significantly improve the pressure oscillations expected upstream B-015 during Emergency Shutdown Tests.

A pressure transducer (BP-014) was installed for FEP-II using the orifice downstream pressure tap. This pressure transducer, shown in Figure 3.1.1 was installed for FEP-II in order to evaluate the effect of pressure transducer sensor line length on the pressure oscillations observed upstream B-015 during FEP-I tests.

The control valve (B-015) installed in the Test Flow Car main line was used to simulate the Pewee 2 reactor nozzle flow impedance required for the FEP tests. This valve was an equal percentage analog control valve having a maximum rated C_v of 110.

The flow venturi (BF-013) installed in the Test Car main line was used to measure main line flow. This venturi had a 2.56 inch diameter throat with a 4 inch inlet diameter. Upstream and downstream reducers were provided to interface with the 3 inch diameter test car main line piping.

A relief valve set to relieve at 1500 psig was installed upstream B-015 to provide thermal relief protection for the main line.

The Test Flow Car moderator line system consisted of foam insulated 3 inch schedule 40 stainless steel pipe and the associated reducer required to interface with the 2 inch moderator line in the facility, a relief valve, a control valve (B-215) and associated instrumentation.

The control valve (B-215) installed in the Test Flow Car moderator line was used to simulate the Pewee 2 reactor moderator flow impedance required for the FEP tests. This valve was an equal percentage analog control valve having a maximum rated C_v of 46.

A relief valve set to relieve at 1600 psig was installed upstream B-215 to provide thermal relief protection for the moderator line. The hydraulic fluid used to actuate the Test Flow Car control valves was supplied from the Servo Hydraulic System through B-801. The main and moderator line effluent was ignited and burned as required during the test by the reactor flare.

3.2

TEST FACILITY SYSTEM

The Test Cell "C" facility systems that were operated during the Pewee 2 Integrated Test Series consisted of all those systems required to conduct Pewee 2 reactor power tests except for the Borated Water System, the Drum Hydraulic System, the FROG System, the Reactor Shield System, the Neutronic System, the Basement Inerting System, the various GN_2 purges associated with the Pewee 2 reactor and car, and those portions of the Test Cell "C" facility systems required to support Pewee 2 side by side experiments.

The significant test facility configuration that existed during FEP-I and FEP-II is contained or referenced in Appendix A. Those significant test facility system reconfigurations that were made between FEP-I and FEP-II are discussed below.

The Mark 35 pump (Serial Number R002R-2) used for FEP-I tests was replaced with a Mark 35 pump (Serial Number R001R-3) for FEP-II tests. The Mark 35 pump (Serial Number R002R-2) which had an accumulated run time of 127 minutes at or above Pewee 2 full power operating speed of 23,000 rpm at the completion of FEP-I was sent to Rocketdyne for inspection and refurbishment.

The L-109 valve (Serial Number 8900852) was returned to Rocketdyne after FEP-I for installation of a mechanical block internal to the valve actuator. The mechanical block, which was designed to prevent L-109 from opening beyond a nominal effective flow area of 1.00 in^2 , was provided for subsequent test operations to prevent damage to the Mark 35 pump and to limit the maximum Pewee 2 nozzle inlet pressure dip in the event of an open failure of L-109.

The L-11 valve was provided with an externally mounted mechanical block after FEP-I. The mechanical block was designed to enable operation of L-11 with the Hold Open Circuit active at a position corresponding to an 100 psid pressure differential (Lp-10d) at a LH_2 flow rate of 24.1 pps. Emergency Shutdown Tests performed during FEP-I showed that significant reduction in pressure dips upstream B-015 could be achieved with L-11 initially at this position upon ESD. In conjunction with this reconfiguration, the DDP-116 generated program profile for L-11 was changed between FEP-I and FEP-II to reduce the opening rate of L-11 as it contacts the mechanical block.

The L-21 valve was provided with a remotely operated mechanical block after FEP-I. The mechanical block, which was designed for Pewee 2 reactor power test to prevent L-21 from closing beyond a nominal effective flow area of 0.20 in^2 , was incorporated to evaluate its performance during FEP-II.

The orifice installed in the recirculation line downstream of L-90 for performance of turbopump duration tests during FEP-I, was replaced with a line blind prior to FEP-II.

The specific speed controller compensation for FEP-II was changed by -6DB from that used during FEP-I. This reconfiguration was made to improve system performance from that observed during FEP-I.

4.0 TEST OPERATIONS DESCRIPTION

This section provides a summary description of the operations performed during FEP-I and FEP-II. Appendix B presents the detailed chronologies of the Control Room Operations for FEP-I and FEP-II. The loss-of-power test performed on R-1 of FEP-I is described in Appendix C.

4.1 FACILITY EXPERIMENTAL PLAN I

The operations and operating conditions described herein for FEP-I were based on the pre-test requirements given in NRTO-R-0193 and as modified based on data reviews conducted during run day activities. The test facility and test flow car configuration that existed during FEP-I were as referenced in Section 3.0.

4.1.1 Preoperational Phase (CRT *03387-11557)

The preoperational phase was initiated with the transfer of valves and systems to CP Control. Valves in the areas to be inerted were exercised. After the correct operation of the shutdown chain was verified, the inerting of the Flow Control Room, Pump Room and High Pressure Room was commenced. The remaining valves were exercised, and voltage and zero pressure calibrations were performed. After the forward area was cleared of all personnel, the GHe, GH₂, and GN₂ headers were pressurized. The GH₂ header was pressurized with Bottle #4 only to prepare for the tank farm maneuver in a subsequent run phase. The initial chilldown of the "X", "K" and "L" Systems to X-3, K-6 and L-11 and L-21, respectively, were then started. The initial chill-downs included a cryogenic soak period. During the cryogenic soak, the water system was set up to provide 35 psig at WP-45.

* CRT is the control room time in seconds after 0700 (00000).

4.1.2 Turbopump Green Run (CRT-12420-13320)

This test was performed to provide an initial checkout of the turbopump installed for FEP-I to obtain calibration data in H-60, and to checkout the specific speed controller. The LH_2 flow path for this test was from Dewar 2 through the turbopump and out L-109 and L-111. L-11, L-90, H-11 and H-75/70 were maintained closed throughout this run phase and the turbopump was powered through H-53/H-60 using gaseous hydrogen from the tank farm. The turbopump used for FEP-I was a Rocketdyne Mark 35 pump (SN-RO02R-2) and a Rocketdyne Mark 25 turbine (SN-RO05R).

The initial conditions for this run phase were:

- a. GH_2 Bottle #4 was secured at approximately 1700 psig; the GH_2 header was then pressurized with the remaining five tank farm bottles.
- b. Dewar 2 was pressurized to 60 psig.
- c. 400 psig was established at HP-60 using GH_2 from the tank farm.
- d. The N_s Loop was set to control at $N_s=700$.
- e. L-111 was opened to 36% ($N_s=550$).

Figure 4.1.1 presents the on-line pump map for this run phase. The predicted pump operating conditions corresponding to Pewee 2 operations at SDH, IPH and FPH are also shown. The CTO established 23,500 rpm at a specific speed ($N_s = 700$) in speed control with intermediate holds at 10,000 rpm, 15,000 rpm and 20,000 rpm to evaluate pump operating characteristics. After a short hold at 23,500 rpm, the N_s was decreased to a minimum of 625 using L-109 in N_s Control. Specific Speed was then increased to approximately 650 and L-111 was closed to 33%. Using L-109 in N_s Control, the N_s was again decreased to approximately 625. Specific Speed was

then adjusted to 760 and L-111 was closed to 30%. Again the N_S was decreased to approximately 640 in N_S Control. The turbopump speed was then decreased to 15,000 rpm. L-109 was then used in N_S Control to increase the N_S to 760. Zero speed was then demanded to terminate this run phase.

4.1.3 Pewee 2 Normal Profile Operation(s)

The Pewee 2 Normal Profile Operations performed during FEP-I included establishment of Initial Condition Gas (ICG), Initial Condition Liquid (ICL) and Run Program Operations. Two normal profile operating tests were performed during FEP-I as described in the following section:

4.1.3.1 Pewee 2 Normal Profile Test No. 1 (CRT 15700-17930)

This test was performed to investigate the interactions between the "L", "H", "X" and "K" Systems and associated support systems under simulated Pewee 2 normal profile operating conditions. These operations included the establishment of the Initial Condition Gas (ICG), the Initial Condition Liquid (ICL) and programmed profile operations. The programmed profile included the Intermediate Power Hold, the Full Power Holds and the Shutdown Holds. Dewar 3 refill operations were also conducted during the last shutdown hold.

The fluid flow path for this test were: (1) from the GH_2 storage vessels through G-3 and K-7/21 to the simulated nozzle and moderator impedance valves B-15/215, respectively, for ICG; (2) from Dewar 5 through K-6 and K-7/21 to the simulated nozzle and moderator impedance valve B-15/215, respectively, when conditions stabilized L-21 was opened for ICL; and (3) from Dewar 2 through the turbopump and L-11/21 to the simulated nozzle and moderator system impedance valves B-15/215,

respectively, for the Pewee 2 normal program operation. The DDP-116 generated programmed profiles are presented in Section 5.3.3.

Prior to the establishment of the Initial Conditions Gas Hold (ICG), the following preparations were performed:

- a. Dewar 2 was pressurized to 60 psig.
- b. Dewars 4 and 5 were pressurized to 100 psig.
- c. The initial "K" System was chilled to K-6 using LH_2 from Dewar 5 only.
- d. Using the LH_2 cross-connect line, Dewar 3 was chilled and filled from Dewar 2.
- e. Two ullage bottles were put on-line in the Dewar 3 pressurization system.
- f. 100 psig was established at HP-60.
- g. The N_s Loop was set to control at $N_s = 575$.
- h. The accumulator was put on-line with H-175 set at 17%.
- i. Section 1 of the TES was switched to ΔP control (HP-11D = 50 psid)
- j. Water flow was established to the TES.
- k. B-15 and B-215 were initially set to 94% and 72%, respectively, the predicted impedance for the ICG.

In G-3 Flow Control, a GH_2 flow rate of 2 lbs/sec was established. Using B-15 and B-215, the pressure at BP-15 and BP-215 was adjusted to 66 psig and 87 psig, respectively. (ICG). B-15 was 87% and B-215 was 84%. The GH_2 flow rate was then increased to establish 120 psig at KP-7. After K-6 was opened to its 35% clamp, G-3 was closed. The G-3 Hold Closed was activated. This initiated LH_2 flow from the "K" System through K-6. When BT-15 and BT-215 were 50°R and stable, B-15 and B-215 were set to 59% and 38%, respectively, the predicted FPH impedance settings.

After the Dewar 3 final chill, X-103 was closed and X-53/X-161 was switched to Pressure Program and X-3 was opened. L-111 was opened to 32% and switched to Program. L-11 was then switched to Program (0% demand). H-60 was switched to Flow Program (0 lbs/sec at LF-10 demand). Using Flow Bias, the turbopump was started to establish 165 psig at HP-541. The TES bootstrap operation was accomplished by this time to provide turbine drive gas and Dewar 2 pressurization gas from the TES. When conditions were stable, L-21 was opened to 18.5% (ICL).

X-303 was then closed and with the loss of flow inputs ($\dot{W}$'s: LV-12 and LV-25) to the Shutdown Chain active, when stable LH_2 conditions were obtained at BT-15/215, the CTO switched to Run for the programmed ramp to the Intermediate Power Hold (IPH). L-11 was programmed open and simultaneously L-111 was programmed closed. The $\dot{W}/N$ input to the Shutdown Chain was activated at 18,000 rpm. After a short hold at the IPH to evaluate the facility performance, the programmer was switched to Run for the ramp to the first Full Power Hold (FPH #1). At FPH #1, valves B-15, B-215 and L-21 were adjusted to establish approximate Pewee 2 operating conditions. H-175 was adjusted to establish approximately 100 psid between the pump discharge line and the accumulator.

With the loss of flow inputs bypassed, a pseudorandom noise experiment was performed on the Flow Loop. Frequency response measurements were then performed on the Flow Loop and the Speed Loop. The inputs used for these measurements are given in Section 5.14 (Controls).

At the conclusion of the frequency response measurements, the loss of flow inputs were activated, and the programmer was switched to Run for the ramp to the first Shutdown Hold (SDH #1). At 18,000 rpm, the $\dot{W}/N$ input was bypassed. SDH #1 was a programmed 10-second hold at an LF-10 flow rate of approximately 12 pounds per second.

At the end of SDH #1, the programmer started the ramp to FPH #2. At 18,000 rpm, the $\dot{w}/N$ input was activated. After a short hold at FPH #2, the programmer was switched to Run for the ramp to SDH #2. At 18,000 rpm, the $\dot{w}/N$ input was bypassed. SDH #2 was a programmed 30-second hold. At the end of SDH #2, the programmer started the ramp to FPH #3. The $\dot{w}/N$ input was again activated at 18,000 rpm.

At FPH #3, the Dewar 3 level was decreased below the 20% level using X-103. When the dewar cross-connect line was chilled to Dewar 3, the programmer was switched to Run for the ramp to SDH #3, a programmed 10-second hold. At 18,000 rpm, the $\dot{w}/N$ input was bypassed. When Dewar 3 pressure (XP-61) was less than 60 psig, the cross-connect shutoff valve to Dewar 3 (X-303) was opened to initiate a Dewar 3 refill at SDH #3. At SDH #3, the programmer was switched to hold to allow sufficient time for an adequate Dewar 3 refill.

After approximately 90 seconds, the CTO switched the programmer to Run for the ramp to the fourth Full Power Hold. The Dewar 3 refill operation was secured immediately, the $\dot{w}/N$ input was activated at 18,000 rpm.

At FPH #4, the L-21 mapping experiment was performed. L-21 was opened from 20% to 100%, closed to 10% and then opened to 20%. Pewee 2 full power operating conditions were then re-established in preparation for ESD #1. When conditions were stable, the profile run was terminated with a CTO initiated ESD. Figure 4.1.2 presents the on-line pump map for this run phase. The Hold points and the ESD point are also shown.

4.1.3.2 Pewee 2 Normal Restart Profile (CRT 24900-26120)

This test was performed to investigate the interactions between the "L", "H", "X" and "K" Systems and associated support systems

PEWEE 2 FACILITY
 TEST SERIES
 FEP-I 9/17/70

PEWEE 2 NORMAL PROFILE
 & SHUTDOWN #1
 CRT (15964 - 17945)
 ESD 17937.855

Figure 4.1.2

NRTO-R-0202

Enclosure (1)
 NRTO-M-28989

under simulated Pewee 2 normal restart profile and programmed shutdown operating conditions. The lines to the nozzle and moderator systems were not rewarmed after the preceeding test.

These operations included the establishment of ICG, ICL, and programmed profile operations to the Intermediate Power Hold. After the Intermediate Power Hold, a programmed shutdown was initiated to the Shutdown Hold. Twenty-six seconds after reaching the Shutdown Hold, the run was terminated by a CTO initiated ESD. The characteristics of the "X" System pressurization system were also determined for low GH_2 header pressure (~ 1200 psig) and high Dewar 3 ullages ($\sim 20\%$ liquid level). At the Intermediate Power Hold, the Flow Controller Trim capability was checked by increasing and decreasing the flow by 1 lb/sec. Figure 4.1.3 is the on-line pump map for this run. The predicted shutdown hold point, intermediate hold, full power hold and ESD point are also shown.

Prior to the establishment of the Initial Conditions Gas Hold (ICG), the following preparations were performed:

- a. Dewar 2 was pressurized to 60 psig.
- b. Dewars 4 and 5 were pressurized to 100 psig.
- c. The "K" System was chilled to K-6 using LH_2 from Dewar 5 only.
- d. Using the LH_2 cross-connect line, Dewar 3 was chilled and filled from Dewar 2.
- e. Two ullage bottles were put on-line in the Dewar 3 pressurization system.
- f. 100 psig was established at HP-60.
- g. The Ns Loop was set to control at $N_s=575$.
- h. The accumulator was put on-line with H-175 set at 20%.
- j. Section 1 of the TES was switched to ΔP control ($\text{HP-11D}=35$ psid).
- k. Water flow to the TES was established.
- m. B-15 and B-215 were initially set to 87% and 84% respectively the impedance for ICG.

The startup operation to the Intermediate Power Hold (IPH) for this phase was identical to that discussed in Section 4.1.3.1, except that B-15 was set to 55% when LH₂ flow was initiated from the "K" System. The fluid flow paths were also the same as in Section 4.1.3.1. After the Flow Controller Trim operations at the IPH, the CTO initiated a Program Shutdown to the Shutdown Hold point. After 26 seconds at the Shutdown Hold point, the profile run was terminated by a CTO initiated ESD.

4.1.4 Emergency Shutdown (ESD) and Cooldown Operations--FEP-I

During FEP-I, a total of seven emergency shutdowns and subsequent cooldown operations were conducted from simulated Pewee 2 Full Power Hold, Shutdown Hold, and Medium Power points. All the ESD's were manually initiated by the CTO after the initial conditions had been established by either program profile startups or by manual startups. The cooldown tests are described in conjunction with the ESD tests. Table 5.7.1.1 lists the system conditions just prior to each ESD, except those at the Shutdown Hold. These tests are discussed in the following sections.

4.1.4.1 ESD No. 1 From the Full Power Hold (CRT 17935-18340)

This test was performed to investigate the interactions of the accumulator, the "X" System, the "K" System, and the "G" System, and associated support systems under a simulated Pewee 2 Full Power Emergency Shutdown and cooldown operating conditions. The full power conditions for this test were established at the fourth Full Power Hold of the normal programmed profile test (Section 4.1.3.1). The accumulator pressure was 100 psi below the pump discharge pressure for this test. When steady-state conditions were established, the CTO manually initiated the ESD. The ESD point is shown in

Figure 4.1.2, the on-line pump map for this run. L-109 opened to 16% immediately after the ESD, and L-11 closed from 100% to 6.3% with no time delay. Approximately 28 seconds after shutdown, L-11 was closed from 6.3% to 0% by resetting the Emergency Shutdown Chain. Approximately 47 seconds after shutdown L-21 was closed, 75 seconds after shutdown X-3 was closed to terminate Dewar 3 flow. "K" System flow was throttled from about 10 lbs/sec to two lbs/sec in K-6 Flow Control; at this flow rate Dewar 5 was put on-line and Dewar 4 flow was terminated.

The "tank farm maneuver" was then initiated in the following manner. GH_2 Bottles #3, 5, 6, 7, and 8 were secured and Bottle #4 was put on-line at 1700 psig. After the G-3 Hold Closed was bypassed, K-6 was closed to terminate LH_2 flow. In G-3 Flow Control, 10 psig was established at KP-7 to remove LH_2 slowly from the propellant lines. When the temperatures at BT-15 and BT-215 started to increase, the GH_2 flow rate was increased to one lb/sec. At this time, the lower pressure GH_2 bottle (4) was secured and Bottles #3, 5, 6, 7, and 8 were put on-line again. G-3 was then closed and a GHe flow rate of three lbs/sec. was established using G-13 in Flow Control to simulate flow conditions during FROG installation on Pewee 2. When temperatures at B-15 and B-215 were in excess of 200°R , G-13 was closed, and the facility was put into a standby condition.

4.1.4.2 ESD No. 2 From the Full Power Hold (CRT 23905-24271)

This test was performed to investigate the interactions of the accumulator, "X" System, and "K" System under a simulated Pewee 2 Full Power ESD with L-109 opening to 15% instead of 16% as on ESD #1. The full power conditions for this run were established with a manual startup. The following steps were accomplished during the startup:

- a. Dewar 2 was pressurized to 60 psig.
- b. Dewars 4 and 5 were pressurized to 100 psig, K-1 was opened.
- c. Dewar 3 was filled to a level greater than 30%.
- d. 100 psig was established at HP-60.
- e. X-53/161 were switched to Pressure Control and 300 psig established in Dewar 3 with X-3 closed.
- f. The N_S controller was activated to control at an $N_S=575$.
- g. K-6, B-15 and B-215 were opened to chill the "K" System and main line.
- h. H-70 and H-75 were opened, H-175 was set to 20%.
- j. After the line was chilled, B-15 and B-215 were set to 55% and 38%, respectively, the simulated full power impedance settings.
- k. L-11 was opened and L-21 set to 20%.
- m. The TES (H-11) was switched to ΔP control (HP-11D=35 psid).
- n. In Flow Control, 30.1 lb/sec. was established at LF-10.
- o. X-3 was opened and X-103 was used to maintain the "X" System chill.
- p. B-15 and B-215 were adjusted when necessary to establish the simulated Pewee 2 Full Power Hold conditions.

When steady-state conditions had been attained, H-175 was opened to 26% to reduce the accumulator pressures approximately 140 psi below the pump discharge pressure. An ESD was manually initiated by the CTO. Figure 4.1.4 shows the on-line pump map for this run. L-109 opened immediately on shutdown to 15% and L-11 closed from 100% to 6.3% with no time delay. Approximately 13 seconds after the ESD, L-11 was closed from 6.3% to 0% by resetting of the ESD chain. L-21 was closed in about 22 seconds, and X-3 closed in 38 seconds. The "K" System flow was throttled from about 10 pps to 2 pps in K-6 flow control. The "K" System flow was then terminated and minimum GH_2 flow established. When BT-15 and BT-215 exceeded approximately 200°R, G-3 was closed and the facility put in a minimum secure.

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Enclosure (2)
NRTO-M-23777

4.1.4.3 ESD No. 3 From the Shutdown Hold (CRT 26115-26715)

This test was performed to investigate the interactions of the "L" System and the "K" System during a simulated Pewee Normal Shutdown and Cooldown, from the Shutdown Hold with the "K" System operational. The Shutdown Hold conditions for this test were established for this test as discussed in Section 4.1.3.2. After the Shutdown Hold conditions were obtained, the "X" System was taken off-line by closing X-3 and X-203. The CTO then initiated a manual ESD, and cooldown flow was initiated through the "K" System. L-11 was closed in about 15 seconds by resetting the ESD chain, and L-21 was closed in about 30 seconds.

After the maximum "K" System flow of about 9.6 lbs/sec had stabilized, K-6 was switched to Flow Control and flow steps of 5 pps, 4 pps, 3 pps, 2 pps and 1.5 pps established. An attempt was made to establish 1.0 pps, but the flow controller was unstable below about 1.25 pps. K-6 was then switched to Position Control in an unsuccessful attempt to establish 1.0 pps. K-6 was then closed and minimum GH_2 established using G-3 in Flow Control. When BT-15 and BT-215 were greater than 200°R, B-15 and B-215 were closed.

Dewar 4 was then refilled from Dewar 2 using the dewar cross-connect system. The GH_2 bottle #4 was then secured and the GH_2 header repressurized using Bottles #3, 5, 6, 7, and 8; and the facility put in a minimum secure.

4.1.4.4 ESD No. 4 From the Full Power Hold (CRT 29386-29593)

This test was performed to investigate the ESD transients from the simulated Pewee 2 full power operating point with the accumulator at the pump discharge pressure. The full power conditions for this

run were established in Manual Control as described in Section 4.1.4.2. When full power conditions had been established, H-175 was closed to increase the accumulator to the pump discharge pressure. After conditions stabilized, a CTO manually initiated ESD was produced. Figure 4.1.5 shows the on-line pump map for this run. L-109 opened to 15% immediately on shutdown and L-11 closed from 100% to 6.3% with no time delay. L-11 was completely closed in 12 seconds by resting the shutdown chain. L-21 was closed in 17 seconds, and X-3 in 21 seconds after the ESD. The "K" System flow was then throttled to two lbs/sec. and then closed in Position Control. Minimum GH_2 flow was established in G-3 Flow Control and the facility closed in a minimum secure.

4.1.4.5 ESD No. 5 From the Medium Power ($T_{FE}=2500^\circ\text{R}$) Point (CRT 41726-41966)

This test was performed to determine the accumulator "X" System and "K" System performance following an ESD from the simulated medium power point ($T_{FE}=2500^\circ\text{R}$), with the accumulator at the pump discharge pressure. The medium power conditions for this run were established in Manual Control. The following steps were accomplished during the startup:

- a. Dewar 1 was pressurized to 60 psig.
- b. Dewars 4 and 5 were pressurized to 100 psig, K-2 was opened.
- c. Dewar 3 was filled to a level greater than 30%.
- d. 100 psig was established at HP-60.
- e. X-53/161 were switched to Pressure Control and 107 psig established in Dewar 3 with X-3 closed.
- f. The N_S controller was activated to control at an $N_S=575$.
- g. K-6, B-15 and B-215 were opened to chill the "K" System and main line.
- h. H-70 and H-75 were opened, H-175 was set to 20%.
- j. After the line was chilled, B-15 and B-215 were set to 57%

PEWEE 2 FACILITY
TEST SERIES
FEP-I 9/17/70
PEWEE 2 SHUTDOWN #4
H-175 CLOSED
CRT (29386 - 29550)
ESD 29541.843
Figure 4.1.5

and 35%, respectively.

- k. L-11 was opened and L-21 set to 20%.
- m. The TES (H-11) was switched to ΔP control (HP-11D=35 psid).
- n. In Flow Control, 19.7 lbs/sec. was established at LF-10.
- o. X-3 was opened and X-103 was used to maintain the "X" System chill.
- p. B-15 and B-215 were adjusted when necessary to establish the simulated Pewee 2 Medium Power Hold.

After steady-state conditions were established, H-175 was closed to raise the accumulator pressure to the pump discharge pressure. When conditions stabilized, a manual ESD was initiated by the CTO. Figure 4.1.6 presents the on-line pump map for this test. On the ESD, L-109 opened immediately to 15% and L-11 closed from 100% to 6.3% with no time delay. L-11 was completely closed 11.5 seconds after the ESD by resetting the shutdown chain. L-21 was closed in 29.5 seconds and X-3 was closed in 42.5 seconds. When the "K" System reached maximum stable flow of about 9.6 pps, K-6 was switched to Position Control and closed, and minimum GH_2 flow established. B-15 and B-215 were closed when their inlet temperatures were above 200°R and the facility placed in a minimum secure.

4.1.4.6 ESD No. 6 From the Full Power Hold (CRT 43480-43935)

This test was performed to investigate the system performance following an ESD from the simulated Pewee 2 full power point with L-11 throttled to provide a 100 psi drop across the valve at a flow rate of 24.1 pps. The startup for this test was accomplished manually. The following steps were accomplished:

- a. Dewar 1 was pressurized to 60 psig.
- b. Dewars 4 and 5 were pressurized to 100 psig, K-2 was opened.
- c. Dewar 3 was filled to a level greater than 30%.

- d. 100 psig was established at HP-60.
- e. X-53/161 were switched to Pressure Control and 300 psig established in Dewar 3 with X-3 closed.
- f. The N_2 controller was activated to control at an $N_2=575$.
- g. K-6, B-15 and B-215 were opened to chill the "K" System and main line.
- h. H-70 and H-75 were opened, H-175 was set to 20% to operate the accumulator approximately 100 psi below the pump discharge pressure at full power.
- j. B-15 and B-215 were set to 55% and 38% respectively.
- k. L-11 was opened and L-21 set to 20%.
- m. The TES (H-11) was switched to ΔP control (HP-11D=35 psid).
- n. In Flow Control, 30.1 lbs/sec. was established at LF-10.
- o. X-3 was opened and X-103 used to maintain the "X" System chill.
- p. B-15 and B-215 were adjusted to establish Pewee 2 FPH.
- q. L-11 was then slowly closed to establish 100 psid across the valve (37%).

When stable conditions were obtained, the CTO initiated a manual ESD. Figure 4.1.7 is the on-line pump map for this run. On ESD, L-109 immediately opened to 15% and L-11 closed from 37% to 6.3% with no time delay. L-11 was closed in 14 seconds by resetting the ESD chain. L-21 and X-3 were closed in 31 and 36 seconds, respectively. The "K" System flow was then throttled to 2 pps in K-6 Flow Control. K-6 was then closed in Position Control and minimum GH_2 established in G-3 Flow Control. The LH_2 was expelled from the lines and the facility put in a minimum secure.

4.1.4.7 ESD No. 7 From the Full Power Hold (CRT 45300-45514)

This test was performed to determine the effect on the system performance of a full open failure of L-109 upon a CTO initiated ESD

from simulated Pewee 2 full power operating conditions. The startup phase for this run was the same as discussed in Section 4.1.4.6, except that L-11 was left 100% open and H-175 was closed at the Full Power Hold to raise the accumulator pressure to the pump discharge pressure. After the system had stabilized, the CTO initiated a manual ESD. Figure 4.1.8 is the on-line pump map for this run. On ESD, L-109 opened immediately to 100% and L-11 then closed to 6.3% with no time delay. L-11 was closed in 15 seconds by resetting the ESD chain. L-21 and X-3 were closed 32 and 37 seconds, respectively, after the ESD. The "K" System flow was then reduced to 2 pps in K-6 Flow Control.

LH₂ flow was then terminated and the LH₂ expelled with minimum GH₂ via G-3. The facility was then placed in a minimum secure.

4.1.5 Mark 35 Duration (CRT 32265-35093) (CRT 38275-39402)

The Mark 35 duration run was conducted to complete two hours of pump operation at or above the Pewee 2 full power operating conditions. Figures 4.1.9 and 4.1.10 are the on-line pump maps for the duration runs.

During the standby period prior to this run phase, the L-11 controller was switched at the R-CP to provide control for L-90. A constant closed command was given to L-11. The flow path was from Dewar 2 through L-2, L-3, the pump, L-90, L-91 and L-92 into Dewar 1. The following sequence of operations was performed.

- a. 60 psig was established in Dewar 2
- b. L-90 was opened.
- c. 100 psig was established at HP-60
- d. L-109 was switched to N_S control with the controller set for an N_S=575.

MARK 35 TURBOPUMP MAP

50 PSIG DEWAR PRESSURE
4.49 lb/ft³ PUMP DISCHARGE
DENSITY

P D T 9/30/68

PEWEE 2 FACILITY

TEST SERIES

FEP-I 9/17/70

PEWEE 2 SHUTDOWN #7

L-109 OPEN to 100%

ON SHUTDOWN

CRT (45300 - 45450)

ESD 45442.963

Figure 4.1.8

NRTO-R-0202

- e. L-191 was used to chill the recirculation line.
- f. L-111 was set to 2%.
- g. L-90 was set to 20%.
- h. L-92 was opened.
- j. L-161 was used to maintain Dewar 1 pressure between 50-60 psig.
- k. Using Speed Control, the CTO established 23,500 rpm.

After approximately 2700 seconds of operating time at 23,500 rpm, the LH_2 available in Dewar 2 had decreased to 30,000 pounds. Zero speed was demanded by the CTO and all systems were put in a standby condition.

The liquid hydrogen was transferred from Dewar 1 to Dewar 2 by closing L-3, Opening L-1 and venting Dewar 2 to a pressure less than Dewar 1. After the liquid transfer was completed L-1 was closed and L-3 was opened in preparation for the completion of the duration run.

The sequence listed above was repeated and approximately 1000 seconds of additional operational time at 23,500 rpm was accomplished. The total run time of this pump at speeds greater than 23,000 rpm was accomplished. The total run time of this pump at speeds greater than 23,000 rpm was slightly over 7200 seconds.

A liquid hydrogen transfer from Dewar 1 to 2 was accomplished. The controller output was switched from L-90 to L-11 and the systems put in standby.

4.1.6

Secure

Upon completion of the Emergency Shutdown #7 (See Section 4.1.4.7), the turbopump would not rotate with L-109 open. A secure operation of the Test Cell was begun. This included the following:

- a. Venting of Dewars 1, 2, 3, 4, and 5.
- b. Warmup of all liquid hydrogen lines with gaseous hydrogen.
- c. Purge of all hydrogen lines with gaseous helium.
- d. Secure of the thermal spray system and venting of the hot water tank.
- e. Establishing a helium block pressure in all hydrogen lines.
- f. Venting of high pressure gas headers.

The Facilities Remote Team was admitted to the area. The MCS's and control valves were switched to Test Cell Control and Control Room Operations were terminated for FEP-1.

4.2 FACILITY EXPERIMENTAL PLAN II

The operations and operating conditions described herein for FEP-II were based on the pre-test requirements given in NRTO-R-0199 and as modified based on data reviews conducted during run day activities. The test facility and test flow car configuration that existed during FEP-II were as referenced in Section 3.0. A detailed chronology of FEP-II is presented in Appendix "B".

4.2.1 Preoperational Phase (CRT 03600-13850)

The preoperational phase was initiated with the transfer of valves and systems to CP Control. Valves in the areas to be inerted were exercised. After the correct operation of the shutdown chain was verified, the inerting of the Flow Control Room, Pump Room and High Pressure Room was commenced. The remaining valves were exercised, and voltage and zero pressure calibrations were performed. After the forward area was cleared of all personnel, the GHe, GH₂, and GN₂ headers were pressurized. The initial chilldown of the "X", "K" and "L" Systems to X-3, K-6, L-11 and L-21, respectively, were then started. The initial chilldowns included a cryogenic soak period. During the cryogenic soak, the water system was set up to

provide 35 psig at WP-45. After the cryogenic soak in the "L" System the overspeed trip check was performed.

4.2.2 Turbopump Green Run (CRT 14595-15046)

This test was performed to provide an initial checkout of the turbopump installed for FEP-II near the Pewee 2 operating point, and to check out the Specific Speed Controller. In addition, a calibration of L-109 was performed. The LH_2 flow path for this test was from Dewar 2 through the turbopump and out L-109 and L-111. L-11, L-90, H-11 and H-75/70 were maintained closed throughout this run phase and the turbopump was powered through H-53/H-60 using gaseous hydrogen from the tank farm. The turbopump used for FEP-I was a Rocketdyne Mark 35 Pump (SN-R002R-3) and a Rocketdyne Mark 25 Turbine (SN-R005R).

The initial conditions for this run phase were:

- a. GH_2 header was pressurized with all the tank farm bottles.
- b. Dewar 2 was pressurized to 60 psig.
- c. 400 psig was established at HP-60 using GH_2 from the tank farm.
- d. The N_s Loop was set to control at $N_s=650$.
- e. L-111 was opened to 44%.

Figure 4.2.1 presents the on-line pump map for this run phase. The predicted pump operating conditions corresponding to Pewee 2 operations at SDH, IPH and FPH are also shown. In Speed Control, the CTO established 23,500 rpm at an $N_s=700$. Short holds were performed at 10,000 rpm, 15,000 rpm, and 20,000 rpm to evaluate pump operating characteristics. After a short hold at 23,500 rpm the N_s was increased to 900 using L-109 in N_s Control. L-109 position was increased to 10% by closing L-111 to 40%. A step response measurement was made on the N_s Loop. Using L-109 in N_s Control, the N_s was again decreased to approximately 700. L-109 was 7% open for an N_s of 730. Zero speed was then demanded to

terminate this run phase.

4.2.3 Pewee 2 Normal Profile Operation(s)

The Pewee 2 Normal Profile Operations performed during FEP-II included establishment of Initial Condition Gas (ICG), Initial Condition Liquid (ICL) and Run Program Operations. Two normal profile operating tests were performed during FEP-II as described in the following sections.

4.2.3.1 Pewee 2 Normal Profile Test No. 1 (CRT 16850-18890)

This test was performed to investigate the interactions between the "L", "H", "X" and "K" Systems and associated support systems under simulated Pewee 2 normal profile operating conditions. These operations included the establishment of the Initial Condition Gas (ICG), the Initial Condition Liquid (ICL) and programmed profile operations. The programmed profile included the Intermediate Power Hold, the Full Power Holds, the Shutdown Holds and a programmed shutdown after the third Full Power Hold with L-11 100% open. Prior to the programmed operations, the H-11 position and ΔP control mode characteristics were investigated with the pump in Flow Bias Control.

The normal profile during FEP-II differed from that of FEP-I in that L-11 was programmed into a block at the 37% position. This profile was also conducted with the accumulator at line pressure (H-175 was closed).

The fluid flow paths for this test were: (1) from the GH_2 storage vessels through G-3 and K-7/21 to the simulated nozzle and moderator impedance valves B-15/215, respectively, for ICG; (2) from Dewar 5 through K-6 and K-7/21 to the simulated nozzle and moderator

impedance valve B-15/215, respectively, when conditions stabilized L-21 was opened for ICL; and (3) from Dewar 2 through the turbopump and L-11/21 to the simulated nozzle and moderator system impedance valves B-15/215, respectively, for the Pewee 2 normal profile operation. The DDP-116 generated programmed profiles are presented in Section 5.3.3.

Prior to the establishment of the Initial Conditions Gas Hold (ICG), the following preparations were performed:

- a. Dewar 2 was pressurized to 60 psig.
- b. Dewars 4 and 5 were pressurized to 100 psig.
- c. The "K" System was chilled to K-6 using LH_2 from Dewar 5 only.
- d. Using the LH_2 cross-connect line, Dewar 3 was chilled and filled from Dewar 2.
- e. Two ullage bottles were put on-line in the Dewar 3 pressurization system.
- f. 100 psig was established at HP-60.
- g. The N_2 Loop was set to control at $N_s=575$.
- h. The accumulator was put on line by opening H-70/75.
- j. Section 1 of the TES was switched to ΔP control ($\Delta P=30$ psid)
- k. Water flow was established to the TES.
- m. B-15 and B-215 were set to 95% and 72%, respectively.

In G-3 Flow Control, 120 psig at KP-7 was established.

After K-6 was opened to its 35% clamp, G-3 was closed. The Hold Closed was activated. This initiated LH_2 flow from the "K" System through K-6. When B-15 and B-215 were chilled, B-15 and B-215 were set to 55% and 38% respectively. The K-6 block was inserted and removed.

After the Dewar 3 final chill, X-53/X-161 was switched to Pressure

Program and X-3 was opened. L-111 was opened to 32% and switched to Program. L-11 was then switched to Program (0% demand). H-60 was switched to Flow Program (0 lbs/sec at LF-10 demand). Using Flow Bias, the turbopump was started to establish 165 psig at HP-541. The TES bootstrap operation was accomplished by this time to provide turbine drive and Dewar 2 pressurization gas from the TES. H-11 was switched to Position Control and 50 psid was established at HP-11D. H-11 was then slowly opened to 100%. 30 psid was then established at HP-11D and H-11 was switched to ΔP control. When conditions were stable, L-21 was opened to 30%, the L-21 block inserted and closed to 18.5% (ICL).

With the Loss of Flow inputs ($\dot{w}$'s: LV-12 and LV-25) to the Shutdown Chain active, the CTO switched to Run for the programmed ramp to the Intermediate Power Hold (IPH). L-11 was programmed open and L-111 was programmed closed. The $\dot{w}/N$ input to the Shutdown Chain was activated at 18,000 rpm. After a 10 second hold at the IPH, the programmer was switched to Run for the ramp to the first Full Power Hold (FPH #1). At FPH #1, B-15 and B-215 and L-21 were adjusted to establish approximate Pewee 2 operating conditions.

After approximately 110 seconds of the FPH #1, the programmer was switched to Run for the ramp to the first Shutdown Hold (SDH #1). As HP-60 decreased to 200 psig, it was maintained during the Shutdown Holds, using H-53 in Pressure Control. This was done to evaluate the TES and pump operation at the Shutdown Hold with a constant turbine supply pressure of 200 psig. At 18,000 rpm, the $\dot{w}/N$ input was bypassed. SDH #1 was a programmed 10-second hold at an LF-10 flow rate of approximately 12 lbs/sec. At the end of SDH #1, the programmer started the ramp to FPH #2. At 18,000 rpm, the $\dot{w}/N$ input was activated. After a 60 second hold at FPH #2, the programmer was switched to Run for the ramp to SDH #2. At 18,000 rpm, the $\dot{w}/N$ input was bypassed. When LF-10 was

20 lbs/sec., H-175 was opened to supply warm gas to the accumulator from the TES during the shutdown. SDH #2 was a programmed 30-second hold. At the end of SDH #2, the programmer started the ramp to FPH #3 and H-175 was closed by the FLO Operator.

The $\dot{w}/N$ input was again activated at 18,000 rpm.

At FPH #3, H-11 was switched to Position Control and opened to 100%. K-6 was closed to simulate loss of the "K" System. After 120 seconds at the FPH #3, the CTO then switched to Program Shutdown. At 18,000 rpm, the $\dot{w}/N$ input was bypassed. When LF-10 decreased to 20 lbs/sec., H-75 was closed and H-175 was opened. X-53/161 was switched from Program to Pressure Control to maintain XP-61 at 100 psig. At the Shutdown Hold, the L-11 Hold Open command was bypassed and the following valves were switched to Override:

L-11 Delay	X-53/161	H-11
L-109	H-101	H-142

L-109 was switched to Position Control and closed, L-11 was switched to Position Control, and L-21 was opened to 100%. The CTO then terminated the profile run by initiating an Emergency Shutdown. Figure 4.2.2 is the on-line pump map for this run. Section 4.2.4.1 discusses the operations for the ESD from the Shutdown Hold.

4.2.3.2 Pewee 2 Normal Restart Profile (CRT 37380-39015)

This test was performed to investigate the interactions between the "L", "K", "X" and "H" Systems under a simulated Pewee 2 normal restart profile with H-11 100% open. Flow-loop step response measurements were also taken at the FPH #1 and the Shutdown Hold conditions.

The profile operations consisted of establishing the ICL, the Intermediate Power Hold, two Full Power Holds, and the Shutdown

Hold. Prior to the establishment of the Initial Condition Liquid, the following preparations were performed:

- a. Dewar 2 was pressurized to 60 psig.
- b. Dewars 4 and 5 were pressurized to 100 psig, K-2 was opened.
- c. Dewar 3 was filled to a level greater than 30%.
- d. The step (-2 volts) was patched to the Flow Loop.
- e. 100 psig was established at HP-60.
- f. The N_g controller was activated to control at an $N_g=575$.
- g. H-70 and H-75 were opened, H-175 was set to 17.5%.
- h. B-15 and B-215 were set to 56% and 38% respectively.
- j. K-6, B-15 and B-215 were opened to chill the "K" System and main line.
- k. X-53/101 were switched to Program Pressure Control.
- m. X-3 was opened.
- n. H-11 was opened in Position Control.
- o. The turbopump was started in Flow Bias and L-21 opened to 20%.

With the $\Delta\dot{w}$'s active and when BT-15 and BT-215 indicated 50°R, Run was selected. The "K" System was then isolated by closing K-6, since it was not required. The $\dot{w}/N$ was activated at 18,000 rpm. After a 10-second hold at the Intermediate Power Hold, the program was switched to run. At the Full Power Hold, the step response measurements were introduced into the Flow Controller, and then the step was set for +.8 volts. The program was then switched to Run and the response measurements taken again at the Shutdown Hold. The program was switched to Run again to establish the second Full Power Hold. The profile run was then terminated by a CTO manually initiated ESD. Figure 4.2.3 is the on-line pump map for this run.

4.2.4

Emergency Shutdowns(ESD) and Cooldown Operations - FEP-II

During FEP-II, a total of eight Emergency Shutdowns and subsequent cooldown operations were conducted from simulated Pewee 2 Full Power Hold, Shutdown Hold, and Medium Power points. All the ESD's were

manually initiated by the CTO after the initial conditions had been established by either program profile startups or by manual startups. The cooldown tests are described in conjunction with the ESD tests. Table 5.5.1.4 lists the system conditions just prior to each ESD, except those at the Shutdown Hold. These tests are discussed in the following sections.

4.2.4.1 Shutdown No. 1 from the Shutdown Hold (CRT 18375-18890)

This test was performed to investigate system interactions for simulated Pewee 2 Shutdown and Cooldown operations from the Shutdown Hold without the "K" System Operational. The "K" System was made inoperable during the third Full Power Hold of the first profile test by closing K-6 in Position Control and a programmed shutdown selected. When XP-61 decreased to 100 psig, X-53/161 was switched to Pressure Control and XP-61 maintained at 100 psig. At an LF-10 flow of 20 lb/sec., H-75 was closed and H-175 opened to remove the accumulator upon shutdown. After the Shutdown Hold was reached, L-11 Hold Open was bypassed and put in Position Control. L-11, L-109, X-53/161, H-101, H-11, and H-142 were then removed from the shutdown chain by switching them to Override. L-21 was then opened to 100%. After a hold of 120 seconds, the ESD was initiated by the CTO. Figure 4.2.2 shows the on-line pump map for this run. The moderator and main line flows were then supplied by the "X" System until X-3 was closed 50 seconds after the ESD. An LF-10 flow of 4.1 pps was then provided from Dewar 3 via L-11 and L-21. An attempt was made to throttle the LF-10 to 3 pps without much success. The flow was throttled to about 3.8 pps before it went unstable. Two flow pulses were then made using L-11 and L-21 to establish between 2-4 pps at LF-10. L-11 and L-21 were closed terminating the pulse cooling exercise. G-3 was used to warm the main line. When BT-15 and BT-215 exceeded 200°R, B-15 and B-215 were closed and the facility was put into a standby condition.

4.2.4.2 Shutdown No. 2 From the Full Power Hold (CRT 20150-20570)

This test was performed to investigate the accumulator "H", "L", "K" and "X" System interaction following an ESD from simulated Pewee 2 full power operating conditions with L-11 open to the 37% block installed prior to FEP-II. The effects of delaying the valve movement in the closed direction .45 seconds were also investigated.

The initial Full Power Conditions for this test were established manually. The steps accomplished during the startup were:

- a. Dewar 2 was pressurized to 60 psig.
- b. Dewars 4 and 5 were pressurized to 100 psig, K-1 was opened.
- c. Dewar 3 was filled to a level greater than 30%.
- d. 100 psig was established at HP-60.
- e. The L-11 delay was activated.
- f. X-53/161 were switched to Pressure Control and 300 psig established in Dewar 3 with X-3 closed.
- f. The N_g controller was activated to control at an N_g=575.
- h. K-6, B-15 and B-215 were opened to chill the "K" System and main line.
- j. H-70 and H-75 were opened, H-175 was set to 20%.
- k. B-15 and B-215 were set to 55% and 38% respectively.
- m. L-11 was opened to 37% and L-21 set to 20%.
- n. The TES (H-11) was switched to ΔP control (HP-11D=30 psid).
- o. In Flow Control, 30.1 lbs/sec. was established at LF-10.
- p. X-3 was opened and X-103 used to maintain the "X" System chill.
- q. B-15 and B-215 were adjusted when necessary to establish Pewee 2 FPH.

After the full power conditions were established, H-175 was adjusted until the accumulator was 55 psi below the pump discharge pressure. The CTO then initiated an ESD. Figure 4.2.4 is the on-line pump map for this run.

After the ESD, L-109 opened to 15% immediately and L-11 closed from 37% to 6.3% after a .45 second delay. L-11 was closed 14 seconds after the ESD by resetting the shutdown chain. L-21 and X-3 were closed 41 seconds and 50 seconds, respectively, after the shutdown. After maximum "K" System flow was established at about 9.6 pps, K-6 was closed in Position Control. The LH₂ was then expelled using G-3 to establish minimum GH₂ flow, and the facility placed in a minimum secure.

4.2.4.3 Shutdown No. 3 From the Full Power Hold (CRT 22000-22500)

This test was performed to investigate the accumulator, "L", "K", "X" and "H" Systems interaction following an ESD from simulated Pewee 2 full power operating conditions with the accumulator at the pump discharge pressure, L-11 at 37%, and the L-11 delay active. The initial full power conditions for this test were established manually as described in Section 4.2.4.2, except that H-175 was closed, L-21 was opened to 18.6%, and B-15 was set to 55.6%.

After stable conditions were obtained at the full power operating point, the CTO initiated the ESD. Figure 4.2.5 is the on-line pump map for this run. L-109 opened to 15% immediately and L-11 closed from 37% to 6.3% after a .45 second delay. L-11 was closed 13 seconds after the ESD by resetting the shutdown chain. L-21 was closed 39 seconds after ESD and X-3 closed 44 seconds after the ESD. When "K" System maximum flow was established of 9.6 pps, K-6 was closed and minimum GH₂ flow established. When the LH₂ was expelled, the facility was placed in a minimum secure.

4.2.4.4 Shutdown No. 4 From the Full Power Hold (CRT 28300-28500)

This test was performed to investigate the "L", "X", "H" and "K"

Systems interaction following an ESD from simulated Pewee 2 full power operating conditions without the accumulator on-line. The initial conditions for this run were established manually as described in Section 4.2.4.2, except that "K" System flow was from Dewar 4, H-175 was closed, L-21 was opened to 18.6%, and B-15 was set to 55.6%. After full power conditions were established, H-70 and H-75 were closed and H-175 opened to remove the accumulator from the system. When conditions stabilized, the CTO pushed the ESD button. Figure 4.2.6 shows the on-line pump map for this test. After the ESD, L-109 opened to 15% immediately and L-11 closed from 37% to 6.3% after a .45 second time delay. L-11 was then closed in 11 seconds. L-21 was closed in 27 seconds and X-3 was closed in 31 seconds. Maximum "K" System flow was established and K-6 was closed. Minimum GH_2 flow was then established and the facility placed in a minimum secure.

4.2.4.5 Shutdown No. 5 From the Medium Power Point ($T_{FE}=2500^\circ\text{R}$) (CRT 29600-29700)

This test was performed to investigate the "L", "X", "H" and "K" Systems interaction following an ESD from simulated Pewee 2 medium power ($T_{FE}=2500^\circ\text{R}$) operating conditions without the accumulator on-line. The initial conditions for this run were established manually as described in Section 4.2.4.2, except that "K" System flow was from Dewar 4, Dewar 3 was pressurized to 187 psig, H-175 was closed, L-21 was opened to 18.6%, B-15 was set to 55.6%, and the LF-10 flow was 19.7 lbs/sec. After medium power conditions were established, H-70 and H-75 were closed and H-175 opened to remove the accumulator system. After stable conditions were established, the CTO pushed the ESD button. Figure 4.2.7 is the on-line pump map for this run.

After the ESD, L-109 opened to 15% immediately and L-11 closed from 37% to 6.3% after a .45 second time delay. L-11 was fully closed

in 12 seconds by resetting the shutdown chain. L-21 was closed 25 seconds after the ESD and X-3 was closed 27 seconds after the ESD. K-6 was then closed after the maximum "K" System flow of 9.6 pps was established. Then minimum GH_2 flow was established via G-3 and the facility placed in a minimum secure.

4.2.4.6 Shutdown No. 6 From the Full Power Hold (CRT 30800-31180)

This test was performed to investigate the accumulator, "L", "X", "H" and "K" Systems interaction following an ESD from simulated Pewee 2 full power operating conditions with a cold accumulator at pump discharge pressure. The test was also performed to conduct fill operation of Dewar 5 from Dewar 2 using the dewar cross-connect system. The initial conditions for this run were established manually as described in Section 4.2.4.2, except that "K" System flow was from Dewar 4. H-70 and H-175 were closed, L-21 was opened to 19%, and B-15 was set to 56%. After full power conditions were established, H-175 was cycled in an attempt to chill the accumulator. The accumulator temperature was lowered to about 315°R prior to the ESD. H-175 was then set to 16% and the pulsed ESD was initiated. Figure 4.2.8 is the on-line pump map for this run. L-109 opened to 15% immediately on ESD and L-11 closed from 37% to 6.3% after a .45 second time delay. H-175 was not closed by the shutdown chain. L-11 was completely closed 12 seconds later by resetting the shutdown chain. L-21 was closed 19 seconds after the ESD and X-3 closed 20 seconds after the ESD. After maximum "K" System flow was established, K-6 was closed and minimum GH_2 flow established. The facility was then placed in a minimum secure and Dewar 5 was refilled from Dewar 2 using the dewar cross-connect system.

4.2.4.6 Shutdown No. 7 From the Full Power Hold (CRT 32850-33150)

This test was performed to investigate the accumulator, "L", "K",

"X", and "H" Systems interaction following an ESD from simulated Pewee 2 full power operating conditions with H-11 remaining at 100% after the ESD. The test was also run to perform pseudorandom noise measurements of the Flow Loop.

The initial conditions for this test were established manually as described in Section 4.2.4.2, except that "K" System flow was from Dewar 2, H-175 was opened to 16%, B-15 was set to 56%, and L-21 was opened to 30% and the block inserted, and then the valve set at 20%. After the full hold conditions were established, the pseudorandom measurements were taken on the Flow Loop. Then the L-21 block was checked by lowering L-21 against the block. L-21 was then reset to 20% and the block removed. H-11 was then switched to Position Control and opened to 100%. H-11 was then switched to Override so it would not be closed by the ESD chain; and the CTO pushed the ESD button. Figure 4.2.9 is the on-line pump map for this test.

Upon ESD, L-109 opened to 15% immediately and L-11 closed from 37% to 6.3% after a .45 second time delay. H-11 remained 100% open. L-11 was closed 10 seconds after the ESD by resetting the shutdown chain. L-21 was closed 22 seconds after the ESD and X-3 was closed 23 seconds after the ESD. After the "K" System maximum flow was established, K-6 was closed and minimum GH_2 flow established. The facility was then placed in a minimum secure.

4.2.4.8 Shutdown No. 8 From the Full Power Hold (CRT 38760-39015)

This test was performed to investigate the accumulator, "L", "X" and "H" Systems interaction following an ESD from simulated Pewee 2 full power operating conditions with H-11 initially at 100%, and with no L-11 time delay. The initial conditions for this test

were established programmed operations as described in Section 4.2.3.2. The "K" System was not on-line for the ESD.

After stable full power conditions were obtained, the CTO initiated the ESD. Figure 4.2.3 is the on-line pump map for this test. After ESD, L-109 opened to 15% immediately and L-11 closed from 37% to 6.3% with no time delay. H-11 went closed. L-11 was completely closed 12 seconds after the ESD by resetting the shutdown chain. I-21 was closed 25 seconds after the ESD and X-3 was closed 29 seconds after the ESD. Then minimum GH_2 flow was established and the facility placed in a minimum secure.

4.2.5 L-109 Calibration (CRT 34700-35150)

This test was performed to calibrate L-109 to its blocked position of 17%. Figure 4.2.10 is the on-line pump map for this run. For this phase, gaseous hydrogen to drive the turbine was supplied from the tank farm. H-53 was used to establish 400 psig at HP-60. After the system final chill, the N_s controller was activated to control at an $N_s=700$. L-111 was opened to 22%. In Speed Control, a pump speed of 23,500 rpm was established. At this point the N_s controller had opened L-109 to approximately 12%. The N_s was then increased to 860 with L-109 at 15%. L-111 position was decreased to 10%. L-109 was held at 15% by its electrical clamp; therefore, the N_s dropped to 800. L-109 was then switched to Position Control and opened to its mechanical stop at approximately 17%. L-111 position was further decreased to 5% to maintain the N_s below 900 as L-109 was opened. L-109 position was slowly decreased to establish an N_s of 700. L-109 was switched to N_s Control and the pump speed was decreased to zero. The system was put in a standby condition.

Pewee 2 Facility Test Series
 FEP-II 10/8/70
 L-109 Calibration
 CRT (34700-35150)

Figure 4.2.10

4.2.6

Secure

With the completion of the restart profile operation and Shutdown #8, all planned operations had been accomplished. The test cell was secured in the same manner as outlined in Section 4.1.6 and Control Room Operations were terminated for FEP-II.

5.0 TEST RESULTS

5.1 SYSTEM STEADY STATE DATA

The facility system state point data is presented in this section for the ICG, ICL, IPH, MPH, FPH, and SDH conditions established during FEP-I and FEP-II.

The test system changes made between FEP-I and FEP-II, which affect the system performance presented herein, consisted of the removal of the impedance orifice installed in the test flow car main line, and the installation of a mechanical block on L-11. The details of these reconfigurations are given in Section 3.0.

Table 5.1.1 compares the system steady-state data with the predicted performance at the Initial Condition Gas (ICG) conditions established during FEP-I and FEP-II. The predicted system parameters shown in Table 5.1.1 were obtained from the FEP-I Test Description (NRTO-R-0193) for FEP-I, and from the Pewee 2 Reactor Test Requirements document (N-1689R), dated November, 1970 for FEP-II. The facility system operating condition corresponding to ICG is a total GH_2 flow rate of 2 lb/sec. through G-3 to the Pewee 2 reactor nozzle through K-7 and to the Pewee 2 reactor manifold through K-21. The planned facility operation after establishment of ICG was to increase the GH_2 flow rate as required to obtain 120 psig at KP-7. As shown in Table 5.1.1 for FEP-I, a KP-7 pressure of 120 psig was obtained when 2 lb/sec. was established at GF-4 so the planned increase in GH_2 flow rate was not required for FEP-I. During FEP-II, a KP-7 pressure of 120 psig was established without first establishing 2 pps. As shown in Table 5.1.1 for FEP-II, a K-7 pressure of 120 psig resulted in a flow rate of 2.3 lb/sec. at GF-4. During FEP-I, the nozzle simulator valve (B-15) and the moderator simulator valve (B-215) were adjusted to obtain the predicted nozzle inlet and moderator inlet pressures at

TABLE 5.1.1
FACILITY PARAMETERS AT ICG

CONTROL ROOM TIME	-	SECONDS	FEP-I 15749	PREDICTED ICG	FEP-II 16955*	PREDICTED ICG
GH ₂ Header Pressure		psig	QP-30 2307	--	2255	--
G-3 Inlet Pressure		psig	GP-2 2305	--	2250	--
GF-4 Inlet Pressure		psig	GP-4 193.7	--	230	--
GH ₂ Venturi ΔP		psid	GP-4D 77.4	--	90	--
GH ₂ Flowrate		lb/sec	GF-4 1.94	2.0	2.30	2.0
GH ₂ Supply Valve Position		%	GR-3 17.96	--	20	--
LH ₂ Supply Pressure		psig	KP-5 100	--	100	--
LH ₂ Control Valve Position		%	KR-6 36.4	--	36.4	--
K-System Pressure		psig	KP-7 122	--	120	--
Cart Interface Pressure		psig	LP-12 118	--	120	--
Nozzle Torus Pressure		psig	BP-15 71.5	66	97	74
Moderator Torus Pressure		psig	BP-215 88.6	87	95	68
Nozzle Simulator Valve Position		%	BR-15 87	94	95	94
Moderator Simulator Valve Position		%	BR-215 84	72	71.5	72

*Post-ICG, i.e. 120 psig at KP-7

BP-15 and BP-215, respectively. For the FEP-II tests, the simulator valves were set based on the predicted valves using valve calibration data obtained during FEP-I and were not adjusted during the gas flow phase of the run.

Table 5.1.2 presents the system steady-state data for the pre-ICL and the ICL conditions established during FEP-I and FEP-II. The facility system operating conditions corresponding to pre-ICL are those that exist after stable LH_2 temperatures conditions are obtained with all flow from the "K" System after the closure of G-3. The reactor nozzle and moderator flows are provided through K-7 and K-21, respectively. At the pre-ICL conditions, the turbopump is operated in Flow Bias (Speed) Control with 165 psig established at the pump discharge with L-111 open to the initial program demand of 32%. The ICL condition is obtained after L-21 is opened to a pre-determined position and the reactor moderator flow is supplied from the "L" System only. The turbopump Flow Bias demand is not changed when L-21 is opened. As planned, the simulator valves were set to the predicted Full Power Hold conditions for the pre-ICL and ICL holds.

Table 5.1.3 presents the test system steady-state performance data for the Intermediate Power Hold (IPH), the Full Power Hold (FPH), the Shutdown Hold (SDH), and the Medium Power Hold (MPH) established during FEP-I and FEP-II. The facility system operating conditions at these holds consist of the turbopump in Program Flow Control with total reactor flow demand set for the corresponding Pewee 2 hold condition. The simulator valves and L-21 were adjusted at FPH and MPH conditions only to obtain the predicted inlet pressures and flows for the nozzle and moderator.

Table 5.1.4 compares the test system steady-state performance data with the predicted performance at the Pewee 2 Full Power operating conditions established proceeding the Shutdown #3 of FEP-II. The predicted system parameters given in Table 5.1.4 were obtained from

TABLE 5.1.2
FACILITY PARAMETERS AT PRE-ICL AND ICL

FEP-I, II, HOLD CONDITION CONTROL ROOM TIME - SECONDS			PRE-ICL -I 25790	PRE-ICL-II 17370	ICL-I 16173	ICL-II 17520
K-System Pressure	psig	KP-5	101	101	101	101
K-6 Stem Position	%	KR-6	36.6	36.4	36.6	36.4
K-System Flow Rate	lb/sec	KF-5	7.4	6.7	7.0	6.9
System Pressure	psig	KP-7	90	93	91	92
Pump Flow Rate	lb/sec	HF-550	12.6	12.9	14.0	13.7
Pump Discharge Pressure	psig	HP-541	166	165	153	155
Total Propellant Flow Rate	lb/sec	LF-10	11.4	10.9	11.8	12.6
H-60 Inlet Pressure	psig	HP-60	138.6	161	91	188
H-60 Stem Position	%	HR-60	14.45	12.2	19.7	10.5
Turbine Inlet Pressure	psig	HP-67	16.7	15.5	15.6	15.1
Facility Main Line Interface Press.	psig	LP-12	87.4	91	88.4	91
Facility Mod. Line Interface Press.	psig	LP-25	81.5	84	142	130
L-21 Differential Pressure	psig	LP-21D	86.7	82	11	25
L-21 Stem Position	%	LR-21	0	0	17.8	19.6
Moderator System Flow Rate	lb/sec	LF-25	.79	.50	1.3	2.2
Nozzle Simulator Pressure	psig	BP-15	79	89	78	88
Nozzle Simulator Valve Position	%	BR-15	55	54.4	58.3	54.2
Moderator Simulator Pressure	psig	BP-215	81	83	140	126
Moderator Simulator Valve Position	%	BR-215	38	37.6	37.9	37.4
L-111 Position	%	LR-111	34	33.6	34	33.7
Turbopump Speed	~rpm	HQ- 50	8880	8470	8540	8450
H-11 ΔP	psid	HP-11D	17.4	0	56.4	0
Nozzle Simulator Temperature	°R	BT-15N	48.5	50	49.8	45.7
Moderator Simulator Temperature	°R	BT-215	51.2	51.5	57.2	52.1
Main Line Flow	lb/sec	BF-13C	-	7.1	-	7.7

TABLE 5.1.3
FACILITY PARAMETERS DURING PEWEE 2 POWER PROFILE HOLD CONDITIONS
FEP-I and FEP-II

FEP-I & FEP-II HOLD CONDITION		IPH ₁	IPH ₂	FPH ₁	FPH ₂	SDH ₁	SDH ₂	MPH ₁ [*]	MPH ₂ [*]
CONTROL ROOM TIME-SEC		26019	17598	17500	17720	26100	17805	41904	29620
Pump Flow rate-lb/sec	HF-550	31.4	30.9	35.3	34.4	13.2	13.0	23.2	22.3
Pump Discharge Pressure - psig	HP-541	756	768	912	890	154	155	416	419
Total Propellant Flowrate - lb/sec	LF-10	26.8	26.9	29.9	30.1	12.0	12.5	20.2	20.0
H-60 Inlet Pressure - psig	HF-60	718	730	848	848	116	177	381	385
H-60 Stem Position - %	HR-60	12.1	11.8	12.7	12.1	16.1	11.3	12.5	12.3
Turbine Inlet Pressure - psig	HP-67	99.8	99	127	121	14.8	15	49.7	49
Cart Interface Pressure - psig	LP-12	755	694	906	792	153	140	418	379
L-21 Differential Pressure - psid	LP-21D	202	168	228	222	38	32	79	90
L-21 Stem Position - %	LR-21	19.6	19.6	19.6	19.5	19.8	19.9	19.2	18.4
Moderator Flowrate - lb/sec	LF-25	5.5	5.6	6.0	6.0	2.5	2.5	3.8	3.9
Nozzle Torus Pressure - psig	BP-15	644	666	763	757	131	135	354	363
Moderator Torus Pressure - psig	BP-215	541	590	664	652	112	120	334	326
B-15 Stem Position - %	BR-15	54.4	54.6	55.5	55.6	53.9	55.6	54.7	54.6
B-215 Stem Position - %	BR-215	38.0	37.5	37.2	38.2	38.3	38.0	34.3	35.5
Cart Orifice ΔP - psid	BP-14D	86	-	108	-	17	-	51.4	-
Turbopump Speed - rpm	HQ-550	21,530	21,340	23,870	23,200	8,390	8,300	15,580	15,490
L-11 Stem Position- %	LR-11	99	37.3	99	37.4	99	37.5	99	37.3
L-11 ΔP - psid	LP-11D	0	77.6	0	98	1.3	20	0	45.5
Turbopump Specific Speed	N _S	659	642	668	654	750	780	681	667

*These points were established in TOTAL FLOW CONTROL with CTO demanded flow instead of program demand.

NRTD-R-0202

TABLE 5.1.4

FACILITY PARAMETERS AT PEWEE 2 FULL POWER HOLD
(CRT 20405 sec. FEP-II)

DESCRIPTION		PREDICTED	EXPERIMENTAL
<u>Facility System Flow Rates-lb/sec</u>			
Turbopump	HF-550c	32.7	34.5
Total Propellant Line	LF-10	30.1	29.9
Moderator Line	LF-25	(6.0)	5.8
Main Propellant Line	BF-13	(24.1)	24.1
Turbine	$\dot{V}_t$	2.3	2.4
Turbine Energy Source	HF-10	2.7	2.7
<u>Facility System Pressures - psia</u>			
Pump Inlet	HP-511	-	72.7
Pump Discharge	HP-541	908	915
Main Propellant Line	LP-10	-	914
Accumulator	HP-71	(808)	822
Inlet Turbine Control Valve	HP-60	-	875
Turbine Inlet	HP-67	129	135
Nozzle Torus	BP-15	(774)	781
Moderator Torus	BP-215	(644)	626
L-11 ΔP	LP-11D	100	100
L-21 ΔP	LP-21D	-	276
H-11 ΔP	HP-11D	-	31
Main Line Filter ΔP	LP-13D	-	~0
Moderator Line Filter ΔP	LP-25D	-	5.5
Main Line Interface	LP-12	-	817
Moderator Line Interface	LP-25	-	630
<u>Facility System Temperatures - °R</u>			
Pump Inlet	HT-511	38	38.5
Pump Discharge	HT-541	=	48.7
Nozzle Torus	BT-15	48.6	51.5
Moderator Torus	BT-215	-	52.9
Accumulator	HT-71	-	565
Turbine Inlet	HT-60	=	633
<u>Facility Control Valve Positions - %</u>			
TES Inlet Valve	HR-11	-	11.4
Turbine Control Valve	HR-60	12	12.0
Moderator Supply Valve	LR-21	20	18.6
Main Propellant Line Valve	LR-11	37	37.3
LH ₂ Bypass Valve	LR-109	0	0
Accumulator Vent Valve	HR-175	-	17.6
Nozzle Simulator Valve	BR-15	59	55.6
Moderator Simulator Valve	BR-215	38	38.0
<u>Facility Miscellaneous</u>			
Turbopump Speed - rpm	HQ-550/ 550A	23,000	23,340
Specific Speed	N _s	628	652
Reactor Inlet Enthalpy Btu/lb	H	-61	-50

() Required Pewee 2 Operating Conditions

the Pewee 2 Reactor Test Requirements document (N-1689R), dated November, 1970, except for the simulator valve positions which were predicted based on FEP-I calibration data.

A significant difference between the predicted and measured system steady-state parameters is in the turbopump flow rate which results in a slightly higher pump speed. Sources of possible leakage were investigated, and it was determined that the line material (LT-109) and line fluid (LT-110) temperatures downstream of L-109 remained near LH₂ temperatures throughout all run phases of FEP-I and FEP-II. Assuming that all leakage is through L-109, then the leakage rate based on a system flow balance at Pewee 2 FPH conditions is 1.6 lbs/sec. which would correspond to an effective flow area of 0.04 in².

5.2 VALVE CALIBRATION DATA

5.2.1 L-21 Calibration

Valve L-21 was calibrated during FEP-I at flow conditions corresponding to the Full Power Hold for Pewee 2. Prior to the Emergency Shutdown of the first run profile, the stem position of L-21 was varied from 10% to 100%, and returned to its normal position of 20%.

The equation for determining C_v for a valve flowing a measured weight flow rate of liquid is given below:

$$C_v = \frac{56.82 \times \dot{w}}{\sqrt{\rho \times \Delta P}}$$

For L-21

$\dot{w}$ = LF-25 lb/sec
 ρ = density of LH₂ at LP-25 and LT-25N
 and ΔP = LP-21D.

Figure 5.2.1 displays the C_v versus stem position relationship determined during Facility Experimental Plan I and the limited range of data obtained during EP-III of the LH_2 Jet Pump Test Series. The curve agrees well with the ETL water calibration data obtained in July, 1967.

After Emergency Shutdown #7 in FEP-2, the L-21 mechanical block was inserted and the valve was closed to a minimum position with full hydraulic pressure actuating the valve. At CRT 32957 seconds, the following data was observed:

LR-21 = 14.74%
 LP-21D = 351 psid
 LF-25 = 5.25 lbs/second
 LP-10 = 936 psia
 LT-10N = 49.70R

Calculated ρ valve = 4.42 lbs/ft³

C_v of L-21 = 7.6

minimum effective area = 0.20 inches² at 14.7% stem position.

5.2.2 H-60 Calibration

During the Mark 35 turbopump checkout, (FEP-I and FEP-II), the GH_2 tank farm was used to supply the turbine flow rate. A 400 psig pressure upstream of the turbine control valve H-60 was established and maintained so that the valve would open to approximately 30% at a pump speed of 24,000 rpm.

L-21 STEM POSITION
VERSUS C_v
PEWEE 2 FEP-I & II
Figure 5 2.1

The flow of GH_2 through the valve was always sonic, so the following equation was used for calculating the valve C_v :

$$C_v = \frac{38 \dot{w}_t \sqrt{\text{HT-60}}}{0.14 \times (\text{HP-60} + 13.0)}$$

A method for determining the turbine gas flow rate utilizes the steady-state condition that turbine work is equal to pump work. That is, the change in enthalpy of the turbine fluid times the turbine flow rate is equal to the change in enthalpy of the pump fluid times the pump flow rate. Thus, with the correct pump flow rate and the computed enthalpy changes in both turbine and pump fluids the flow rate of GH_2 to the turbine can be calculated. During Facility Experimental Plan I, however, the turbine exit gas temperature fell below the lower range of the thermocouple prior to achieving a pump speed of 24,000 rpm and turbine fluid exit enthalpy could not be determined. Consequently, the effective area was computed only for valve stem positions up to 13%, using enthalpy balance technique. A correlation of turbine gas flow rate ($\dot{w}_t$) and turbine inlet pressure (HP-67) for the Mark 25 turbine, had been developed previously (Reference N-4-2609). The flow rate of GH_2 through H-60 and the valve C_v was computed using the HP-67 and $\dot{w}_t$ correlation for a range of valve stem positions of 10 to 27%.

Prior to FEP-2 the turbine exhaust temperature thermocouple HT-581 was rescaled to include temperatures as low as 300°R. The Mark 35 turbopump installed specifically for FEP-2 was also subjected to a Green Run using the GH_2 tank farm to power the turbine. Again, H-60 effective area versus turbine flow rate data was calculated and the C_v was determined by the change in enthalpy technique for a range of stem positions of 9 to 24%. The data and calculations for FEP-I and FEP-II are presented in Tables 5.2.2.1 and 5.2.2.2. Figure 5.2.2 shows the close agreement of the three sets of data for the small plug of H-60 installed for the Pewee 2 Reactor Test Series.

TABLE 5.2.2.1

CALIBRATION OF H-60 PLUG - PEWEE 2 FEP-1

CRT		<u>41890</u>	<u>12520</u>	<u>12553</u>	<u>16260</u>	<u>12550</u>	<u>12600</u>	<u>12618</u>	<u>12666</u>	<u>12745</u>
HF-550	lb/sec	23.3	16.35	19.65	30.9	-	-	-	-	-
HP-541	psia	429	217	315	637	-	-	-	-	-
HT-541	°R	43	43.2	43.7	45.9	-	-	-	-	-
p disch	lb/ft ³	4.394	4.26	4.35	4.41	-	-	-	-	-
h disch	B/lb	-83.2	-88	-84.5	-70	-	-	-	-	-
$\dot{w}_p$ corr	lb/sec	22.8	15.5	19.04	30.3	-	-	-	-	-
HP-511	psia	73	73	73	72.4	-	-	-	-	-
HT-511	°R	39.3	40.6	40.2	39.6	-	-	-	-	-
h inlet	B/lb	-101.7	-98.5	-99.5	-101	-	-	-	-	-
HP-67	psia	62.6	35.4	49.6	96.3	47.3	72.5	99	131	140
HT-60	°R	610	540	542	604	541	542	542	540	536
h _{inlet}	B/lb	2052	1801	1805	2030	-	-	-	-	-
HP-581	psia	15.9	14.5	14.6	16.0	-	-	-	-	-
HT-581	°R	497	483	460	454	-	-	-	-	-
h _{exit}	B/lb	1647	1597	1515	1493	-	-	-	-	-
$\dot{w}_t^*$	lb/sec	1.04	.72	.985	1.15	.81*	1.27*	1.75*	2.34*	2.50*
HP-60	psia	396	385	382	578	384	378	373	382	383
C _v (1)		17.6	11.8	16.3	20.2	13.3	21.2	29.6	38.6	41.0
HR-60	%	12.6	7.5	10.2	13.4	10.0	15	20	25.2	27

*turbine flow rate determined using the HP-67- $\dot{w}_t$ correlation

$$\dot{w}_t = \frac{(\text{HP-67}+13)-34}{45.33}$$

TABLE 5.2.2.2

CALIBRATION OF H-60 PLUG--PEWEE 2, FEP-2

CRT	UNITS	14660	14574	14726	14732	14754	14761	14783
HF-550	lb/sec	19.97	24.36	27.44	29.39	31.98	33.86	36.59
HQ-550	rpm	12050	15019	17109	18681	20293	21719	23584
HP-60 _a	psia	380	375	371	367	360	358	350
HT-60	°R	527	528	529	529	529	528	528
HR-60	o/o	9.1	12.5	15.2	18.1	21.1	24.5	29.3
HP-67	psia	42.8	60	74.4	88.6	104	118	143
HP-581	psia	14.8	15.1	15.3	15.8	16.2	16.7	17.6
HT-581	°R	455	429	410	398	384	375	361
HP-541	psia	253	374	470	555	660	745	896
HT-541	lb/ft ³	43.1	44.1	45.2	46.0	46.7	47.3	48.6
odisch	B/lb	4.295	4.249	4.342	4.356	4.390	4.417	4.449
hdisch	psia	-87.45	-81.9	-76.5	-72.3	-67.8	-64.1	-56.8
HP-511	psia	73	73	73	73	73	73	72
HT-511	°R	40	40	40	40	40	40	39
h inlet	B/lb	-100	-100	-100	-100	-100	-100	-102
HF-550c	lb/sec	19.10	23.05	26.54	28.51	31.27	33.31	36.26
h _t in	B/lb	1755	1759	1762	1762	1762	1760	1760
h _t ex	B/lb	1497	1404	1336	1296	1230	1202	1148
h _p	B/lb	12.5	18.1	23.5	27.7	32.2	35.9	45.2
h _t	B/lb	258	355	426	466	532	558	612
w _t	lb/sec	.825	1.18	1.46	1.70	1.89	2.14	2.68
C _v		15.2	19.6	24.6	28.8	32.8	37.3	47.7
A _{eff}	in ²	.40	.52	.65	.76	.86	.98	1.26

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5.2.3 L-109 and L-111 Calibration

The Emergency Shutdown from Pewee 2 Full Power Hold conditions in which L-109 opened to 100% resulted in damage to the Mark 35 turbopump. Consequently, to eliminate any possibility of L-109 failing open to 100%, a mechanical block was installed by Rocketdyne which prevents valve L-109 from opening beyond 17%. The L-109 valve mapping exercise conducted during FEP-II caused the valve to open controllably to 17%, and the experimental data displayed in Table No. 5.2.3 has been analyzed to determine the valve effective area--stem position relationship. Figure 5.2.3.1 presents the effective area calculated for various L-109 valve configurations used in three recent test series. Valve serial No. 8900852 with the mechanical block will be used throughout the Pewee 2 Reactor Test Series.

Since the flow path was divided between L-109 and L-111 during the valve calibration exercise, some useful data on the calibration of L-111 at small stem positions was obtained, and the effective area is shown in Figure 5.2.3.2. The data agrees well with the previous data.

5.2.4 L-11 Calibration

For all the run phases of FEP-II, valve L-11 was opened to the maximum position permitted by its mechanical block. The propellant system data from FEP-I was analyzed and the stem position corresponding to 100 psi pressure drop at 24.1 lbs/second LH_2 flow rate was calculated to be 37%. At CRT 20400 seconds during FEP-II, the following data was observed:

	LF-10	=	30 lbs/second
	LF-25	=	5.83 lbs/second
calculated	$\dot{w}$ L-11	=	24.17 lbs/second
	LP-11D	=	100.8 psid
	LR-11	=	37.3%
	LP-10	=	916 psia
	LT-10N	=	48.75°R
calculated	density	=	4.45 lbs/ft ³
	C_v	=	64.8
	Effective area	=	1.71 in ²

TABLE 5.2.3, PART 1

L-109 CALIBRATION

PEWEE 2, FEP-I & II

<u>CRT</u>		<u>*13188</u>	<u>*13197</u>	<u>*13264</u>	<u>34700</u>	<u>34742</u>	<u>34825</u>	<u>35014</u>
HQ-550	rpm	-	-	-	23600	23600	23600	23600
HF-550	lb/sec	28.37	25.36	21.73	36.35	37.42	39.89	42.53
HP-541a	psia	691	553	395	891	873	783	699
HT-541	°R	46.6	44.9	43.1	49.4	49.26	48.3	47.85
p disch	lb/ft ³	4.41	4.40	4.38	4.416	4.412	4.403	4.376
HF-550c	lb/sec	27.86	24.85	21.27	35.75	36.77	39.12	41.45
LR-111	%	-	-	-	22.07	18.06	12.13	4.9
LR-109	%	8.1	8.9	9.5	11.23	12.84	15.13	17.33
LF-10	lb/sec	19.05	16.96	14.62	16.40	13.80	9.53	3.28
WL-109	lb/sec	8.81	7.89	6.58	19.35	22.97	29.59	38.17
C _v		9.15	9.20	9.14	17.66	21.19	28.87	39.58
A _{eff}	in ²	.24	.242	.240	.465	.558	.760	1.042
C _v L-111		-	-	-	14.96	12.73	9.30	3.40

*FEP-I DATA

TABLE 5.2.3, PART 2

L-109 CALIBRATION

PEWEE 2, FEP-I & II

<u>CRT</u>		<u>34693</u>	<u>34730</u>	<u>34750</u>	<u>34853</u>	<u>34938</u>	<u>35010</u>
HQ-550	rpm	23500	23600	23600	23550	23600	23680
HF-550	lb/sec	36.71	36.47	39.16	41.72	42.28	42.16
HP-541a	psia	890	889	820	734	708	700
HT-541	°R	49.3	49.4	48.6	48.10	48.0	47.9
p disch	lb/ft ³	4.420	4.416	4.411	4.385	4.375	4.374
HF-550c	lb/sec	36.14	35.87	38.47	40.74	41.20	41.07
LR-111	%	22.07	18.02	18.06	11.69	8.0	5.0
LR-109	%	11.42	12.57	13.77	15.57	16.5	17.16
LF-10	lb/sec	16.84	14.19	13.45	8.80	5.70	2.55
WL-109	lb/sec	19.30	21.68	25.02	31.94	35.50	38.52
C _v		17.61	19.81	23.87	32.28	36.58	39.93
Aeff	in ²	.464	.521	.628	.849	.963	1.05
C _v L-111		15.37	12.96	12.81	8.89	5.87	2.64

5.3 NORMAL PROFILE OPERATING CHARACTERISTICS

The Pewee 2 normal profile operations including establishment of Initial Condition Gas (ICG), Initial Condition Liquid (ICL), and run program operations were performed during FEP-I and FEP-II, as discussed in Section 4.0. The significant aspects of these operations are described in the following sections. The accumulator performance during run program phase is discussed in Section 5.7.

5.3.1 ICG To ICL

The facility system operating procedure planned for establishment of ICG and ICL conditions for Pewee 2 was to (1) establish a total GH_2 flow of 2 lb/sec. (GF-4) using G-3 to the reactor nozzle through K-7 and to the reactor moderator through K-21; (2) establish 120 psig at KP-7 using G-3 in order to maintain KC-1006 closed with K-6 open; (3) to establish "K" System LH_2 flow to the reactor nozzle through K-7 and the reactor manifold through K-21 by closure of G-3 in Position Control; and (4) to open L-21 to transfer the moderator flow from the "K" System to the "L" System when stable temperature conditions were obtained.

The initial condition gas state point was established during FEP-I. A flow rate of 2 lbs/sec GH_2 from the tank farm through valve G-3 and flow venturi GF-4 resulted in a pressure of 120 psig at KP-7. The planned procedure to increase the GH_2 flow rate in order to establish 120 psig at KP-7 was not required.

During FEP-I, valve G-3 was closed from 17% open in two seconds initiating the line chilldown operation. This procedure for accomplishing the chilldown of the line from K-6 to the Flow Cart differed from the method used during Pewee 1 in that the Mixing Chamber downstream of K-6 was not used to gradually cool the GH_2 to LH_2 . The ambient temperature

line gradually cooled as LH_2 flowed into it and the chilldown of the line upstream of valve B-15 proceeded uniformly and with small pressure fluctuations.

Figure 5.3.1.1 exhibits the chilldown of the temperature probe BT-15 as LH_2 from the "K" System flowed through the propellant line and B-15 and B-215. The rapid closure of G-3 produced a negative pressure spike of approximately 41 psi at BP-15 and 55 psi at BP-215, but the variation of propellant line pressure during the remainder of chilldown operation was only ± 10 psi from the steady state value of 100 psig.

The Initial Condition Gas state point was established at Control Room time 16955 seconds during FEP-II. The procedure used during FEP-II was to establish a KP-7 pressure of 120 psig using G-3 without stopping at 2 pps. As shown previously in Table 5.1.1, the GF-4 flow rate at trim condition was 2.55 lb/sec. GH_2 .

Figure 5.3.1.2 displays the chilldown operation performed during FEP-II. Valve G-3 was closed in 22 seconds, and the initial 40 psi pressure spike observed on FEP-I was eliminated. The chill of both BT-15 and BT-215 occurred uniformly with only slight pressure fluctuations.

The chilldown of the "K" System line and the propellant and moderator supply lines without the Mixing Chamber was accomplished in almost the same time intervals during FEP-I and FEP-II. For the first run day BT-15N was chilled in 237 seconds and BT-215N was chilled in 270 seconds. On the second run day BT-15N was chilled in 220 seconds and BT-215N was chilled in 250 seconds.

For FEP-I, the Initial Condition Liquid state point was established at Control Room time of 16140 seconds. LH_2 flow to valve B-215 was supplied by the "K" System. As planned for FEP-I, the vent valve L-121

PROPELLANT
LINE CHILLDOWN
USING "K" SYSTEM
PEWEE 2 FEP-I
FIGURE 5.3.1.1

MODERATOR AND PROPELLANT
LINE CHILLDOWN FOR PEWEE 2
FEP-II - Figure 5.3.1.2

was not used and the chill of the line to L-21 was accomplished through valve L-111 only. When L-21 was opened at 16070 seconds, a significant bubble of GH_2 flowed downstream to B-215. The highest temperature at BT-215 was 125°R and the time required to exhaust it beyond BT-215 was 70 seconds, after L-21 was opened as shown in Figure 5.3.1.3

During FEP-II, the chill of the "L" System was performed using both L-121 and L-111. L-121 was closed about 800 seconds before L-21 was opened. When L-21 was opened in order to achieve the ICL condition, a much smaller gas bubble than that which occurred during FEP-I flowed down the line to valve B-215. The highest temperature at BT-215N was 71°R , and the time required to exhaust it beyond BT-215 was 60 seconds after L-21 was opened. It was observed that switching the flow of LH_2 to valve B-215 from the "K" System to the "L" System (turbopump), a gas bubble originated in the system whether L-121 was used for chillover or not. For the Pewee 2 Reactor Test Series, a possible propellant system malfunction could be avoided by having valve L-121 mechanically blocked closed and accept the larger gas bubble flowing to the moderator system prior to attaining the Initial Condition Liquid operating point.

5.3.2 Flow Bias Operating Characteristics

Prior to the first programmed startup to one full power hold conditions of FEP-I, the turbopump was operated in flow bias control at approximately 8500 rpm and developed a discharge pressure of 165 psig. Several related procedural steps were initiated after flow bias was established and their effect on the propellant feed system is significant. Initially, the hydrogen gas to the turbine was supplied by the tank farm through valve H-53. The TES inlet valve, H-11, was switched to ΔP control (first 50 psid then later 30 psid) and opened to initiate the bootstrap operation. When the discharge pressure of the TES exceeded 100 psig, the tank farm

"K" SYSTEM
BUBBLE DURING
FIRST ICL
PEWEE 2 FEP-I
FIGURE 5.3.1.3

supply valve H-53 was closed and the turbopump was operated with hydrogen from the TES. At low system flow rates and pressure, the TES has often produced oscillations in the discharge pressure, and during Pewee 2 FEP-I, the oscillations affected the stem position of the turbine control valve H-60 as well as pump discharge pressure HP-541. (With the speed control loop a constant pump speed was maintained, however). Figure 5.3.2.1 exhibits the slightly divergent behavior of the oscillations of TES discharge pressure and H-60 stem position just prior to activating the startup programs. Figure 5.3.2.2 displays similar oscillations in the propellant feed system during the second normal profile startup of FEP-I, however, the duration of the second flow bias was much shorter than the first. It is apparent from Figures 5.3.2.1 and 5.3.2.2, that there is negligible difference in TES behavior when the ΔP control is 30 rather than 50 psid.

During Pewee 2 FEP-II, the flow bias portion of the startup procedure was altered to evaluate the following possible modes for operating the TES:

- (a) H-11 in ΔP control
- (b) H-11 in position control, and
- (c) H-11 full open.

The turbopump was started on tank farm gas and TES bootstrap was accomplished at a TES discharge pressure of 100 psig. The TES inlet valve H-11 was switched to ΔP control. Thereafter, it was switched to position control and the valve was manually adjusted to develop a 50 psi drop. Figure 5.3.2.3 illustrates the system oscillation that occurred until H-11 was opened to 100%. Then the variation in TES discharge pressure and valve stem position disappeared and the propellant feed system operated stable. When H-11 was closed sufficiently to produce a 30 psi drop and switched to ΔP control, the usual oscillations of the TES reappeared. The oscillation in the differential pressure across the TES inlet valve HP-11D during this exercise is shown in Figure 5.3.2.4.

AP Control @ 50 psid

TES OPERATION IN
 BOOTSTRAP PRIOR TO
 THE RESTART
 PROFILE PEWEE 2
 FEP-1
 FIGURE 5.3.2.2

AP Control = 30 psia

-98-

PRESSURE - PSIA

% - COLLISION RATE

START CONTROL ROOM TIME 25792

NON TIME - SECONDS

TES PERFORMANCE
DURING H-11
EXPERIMENT
PEWEE 2 FEP-II
FIGURE 5.3.2.3

DIFFERENTIAL PRESSURE ACROSS
TES INLET VALVE DURING FIRST
STARTUP - FEWEE 2 FEB-II
Figure 5.3.2.4

The final normal profile startup of Pewee 2 FEP-II was accomplished with valve H-11 open to 100% throughout the entire sequence. Figure 5.3.2.5 presents the non-oscillatory behavior of the propellant feed system during flow bias operation of the turbopump after the TES had been bootstrapped. The sharp increase in TES discharge pressure and pump discharge pressure is the result of the computer generated startup programs driving the pump toward the intermediate power hold condition.

TES PERFORMANCE
DURING START-UP
H-11 @ 100%
PEWEE 2 FEP-II
FIGURE 5.3.2.5

CONTROL ROOM TIME - SECONDS

5.3.3 Startup Program Operation

The first run profile of Facility Experimental Plan I programmed the total propellant line flow rate and Dewar 3 pressure to the intermediate Power Hold, the Full Power Hold and Shutdown Hold operating conditions with no major problems. The flow to the reactor simulator valve B-15 was initiated by the simultaneous closing of L-111 and opening of L-11. Even though the actual valve positions differed slightly from the desired profile as shown in Figure 5.3.3.1, the effect on system performance was minimal. Figure 5.3.3.2 illustrates the variation in propellant line flowrate of 10.8 to 13.5 lbs/sec before flow cross-over was achieved and the sharp pressure increase from 80 psig to pump discharge pressure in the line leading to B-15.

Another complete startup procedure was conducted later in the day and the same computer-generated run profiles were used. However, the lines were probably chilled better and the positions of the terminal valves were altered so a slightly different system performance occurred. Figure 5.3.3.3 displays the actual and desired L-11 and L-111 stem position profiles. The actual Dewar 3 pressure lagged behind the programmed demand even though X-53 was 100% open. The conditions of low Dewar 3 liquid level and low GH_2 header pressure were planned as part of this run phase. This experiment is discussed in more detail in Section 5.11.3.

Figure 5.3.3.4 indicates that the total propellant flowrate was higher on the second startup ranging from 12.4 to 13.6 lbs/sec. The pressure increase at BP-15 as L-11 was opened was not as great as before rising to only 135 psig during the second restart activity.

COMPARISON OF
 DESIRED VERSUS
 ACTUAL PRESSURE &
 VALVE POSITIONS
 PEWEE 2 FEB-1
 FIGURE 5.3.3.1

STAR POSITION - PSIC
 PRESSURE - PSIC

START CONTROL ROOM TIME 1617A

PEWEE 2 FEB-1
FIGURE 5.3.3.2

COMPARISON OF
ACTUAL VERSUS
DESIRED PRESSURE
& VALVE POSITIONS
DURING
RESTART PROFILE
PEWEE 2 FEP-I
FIGURE 5.3.3.3

MAIN LINE & MOD-
 ERATOR FLOWRATES
 & PRESSURES DUR-
 ING RESTART PRO-
 FILE PEWEE 2 FEB-1
 FIGURE 5.3.3.4

The startup profile from a Shutdown Hold condition was also studied. Since the computer generated only two programs during this time, a comparison of actual and demanded LF-10 and XP-61 values is presented in Figure 5.3.3.5. The agreement between the generated profiles and the response of the system was very good.

During Pewee 2 FEP-2, a normal programmed startup was conducted with most of the computer-generated profiles unaltered from FEP-1. Two significant physical changes existed in the propellant supply system for FEP-2; the first was a mechanical stop on valve L-11 at 37.3%, and the second was the removal of the restrictive orifice on the Pewee 2 Flow Cart. As a result of the modification to L-11, the opening profile for the valve was also modified for FEP-2. The program for opening L-11 extended the time required to open the valve to 35% and also reduced the rate of opening the valve against the stop to approximately 1% per second compared to 20% per second during FEP-1. Figure 5.3.3.6 exhibits the actual and desired valve profiles for the first programmed startup of FEP-2 and includes the actual and programmed Dewar 3 pressure. Figure 5.3.3.7, displaying the propellant and moderator supply line flowrates and pressure, can be compared to Figure 5.3.3.2 which presents the same parameters during the FEP-1 programmed startup. Removing the Flow Cart orifice and closing down B-15 slightly, resulted in a higher pressure at BP-15 during FEP-2. A larger opening of L-21 caused a greater flowrate of LH₂ at LF-25 and a higher pressure was produced at BP-215. The slight differences in pressure at B-15 and B-215 during the startup of both FEP-1 and FEP 2 are not significant since the actual opening of both valves represented Full Power Hold conditions rather than the startup impedance.

DEWAR 3 PRESSURE
 & MAIN LINE FLOW-
 RATE DURING RE-
 START
 PEWEE 2 FEP-1
 FIGURE 5.3.3.5

-1609-

COMPARISON OF
ACTUAL VERSUS
DESIRED DEWAR
3 PRESSURE, L-11
POSITION & L-111
POSITION
PEWEE 2 FEB-II
FIGURE 5.3.3.6

MAIN LINE & MOD-
ERATOR FLOWRATES
& PRESSURES DUR-
ING FIRST START-UP
PEWEE 2 FEB-17
FIGURE 5.3.3.7

5.4 NORMAL SHUTDOWN AND COOLDOWN OPERATING CHARACTERISTICS

5.4.1 Cooldown Using the K System

The normal programmed shutdown and cooldown operations were evaluated in several runs during FEP-I and FEP-II. Run #4 of FEP-I was terminated by a programmed shutdown from Full Power conditions. After 26 seconds at the shutdown hold, the CTO initiated an Emergency Shutdown.

Figure 5.4.1.1 shows the decrease of BP-15 and BP-215 during the programmed shutdown, following the ESD. The minor increase in BT-15 and BT-215 following the ESD were caused by warm fluid coming from the K-System through K-7 and K-21.

Following an ESD from the shutdown hold, the coolant flow to both the main and moderator lines is supplied from the K-System. The maximum flow capability and control characteristics of K-6 are discussed in Section 5.10.5.

After the minimum flow controllable with K-6 is greater than that required to cool the reactor, pulse cooling will be initiated. Section 5.4.2 describes the simulated pulse cooling, line purging, and FROG installation, also evaluated during FEP-I.

5.4.2 Simulated Pulse Coolant and FROG Installation (FEP-I)

Following Shutdown No.3, of Facility Experimental Plan 1 (FEP-I), the pulse cooling operations were practiced. After completion of the continuous LH₂ flow steps, K-6 was closed and N-430 was opened to supply a helium purge flow of approximately 46 scfm with 16 psig upstream of N-430. After 70 seconds K-6 was partially opened to provide a flow pulse of 1.5 lb/sec. A second pulse was performed following 90 seconds of helium purging. Each pulse was maintained for 60 seconds at an indicated flow rate of 1.5 lb/sec.

For the Pewee 2 test, the FROG will be installed as soon as the reactor decay power has decreased to the level where the duration is 50 seconds between LH_2 pulses. Then the lines will be carefully purged of LH_2 and 3 lb/sec of helium will be established to cool the reactor and to purge oxygen from the FROG system. Figure 5.4.2.1 shows that the helium flow from N-430 is not adequate to purge the LH_2 from the main and moderator lines. Nearly 60 seconds elapsed following termination of the LH_2 pulse until BT-15 increased above the saturation temperature. LT-12 and LT-25 still indicated the presence of some LH_2 at the end of the 60 second and 90 second periods.

Following Shutdown No. 1 of FEP-I, the use of G-3 to purge the lines prior to installation of the FROG was evaluated. In order to minimize the effects of a G-3 fail-open malfunction, it had been proposed to perform this operation with a reduced hydrogen supply pressure. During the pre-operational phase, GH_2 storage bottle No. 4 was lowered to 1690 psig. This bottle was then isolated by closing Q4 and the run phase commenced using bottles #3, 5, 6, 7 and 8. After emergency shutdown No. 2, the low pressure bottle was put on line while the continuous LH_2 coolant flow was supplied through K-6. The transfer was accomplished by first closing valves Q3, 5, 6, 7 and 8, and then opening Q-204 to slowly bring bottle #4 on line. When the header pressure was stable, Q-4 was opened. The complete transfer was accomplished in 28 seconds. The header pressure, QP-30, was 1770 psig after the transfer. For the Pewee 2 experimental plans a lower header pressure could be established prior to the run phase by venting the gas in one bottle at the completion of the pre-operational phase.

After the reduced GH_2 header pressure was established, K-6 was closed and G-3 was carefully opened to begin purging LH_2 from the lines. G-3 was opened in Flow Control to increase the pressure at KP-7 to

PULSE COOLING &

N-430 PURGING

PEWEE 2 FEP-I

FIGURE 5.4.2.1

10 psig. When KT-7, BT-15 and BT-215 began to increase, the GH_2 flow rate was slowly increased to 1 lb/sec, a flowrate adequate to cool the reactor indefinitely. The time that elapsed from the closing of K-6 until 1 lb/sec was established was 60 seconds. However, since some GH_2 was flowing during most of this operation it would be very unlikely that the Pewee 2 reactor core temperatures would reach their limit. When the line temperatures exceeded 250 degree R, G-3 was closed and the desired flow of 3 lb/sec of helium was established through G-13. Figure 5.4.2.2 shows that the effect of the complete transition on system behavior was very minor. Thus, the procedure appears to be satisfactory for the reactor test.

5.4.3 Cooldown Using the "X" and "L" System

If the K-System were to become inoperative during the Pewee 2 tests, the L-System could be used to provide coolant flow after the reactor is shutdown. The coolant flow rate would be controlled with L-11 and L-21. Following Run #1, the normal profile run, of FEP-II this contingency operation was evaluated.

After the full power operating conditions were established, the K-System was declared inoperative and K-6 was closed. A programmed shutdown was then initiated. During the ramp down to the shutdown hold, the following operations were performed to prepare the facility for the contingency cooldown operations:

1. When XP-61 decreased to 100 psig, X-53/X-161 was switched from program to Pressure Control to maintain the capability of supplying coolant flow from Dewar 3 following shutdown.
2. When LF-10 was approximately 20 lb/sec, the accumulator was no longer required for Emergency Shutdown protection so H-75 was closed and H-175 was opened.

3. When the turbopump speed decreased to 18,000 rpm, the $\dot{w}/n$ input to the emergency shutdown chain was bypassed to prevent an unnecessary shutdown.

After the shutdown hold was reached, the following additional operations were performed:

1. L-11 hold-open was bypassed and Position Control was selected.
2. L-11, L-109, X-53/X-161, H-101, H-11, and H-142 were switched to override to prevent their changing position on shutdown.
3. L-21 was opened from 20 to 100% to provide a maximum opening for flow after shutdown. The moderator flow rate, LF-25, increased from 2.5 lb/sec to 2.8 lb/sec when the valve was opened.

After 120 seconds had elapsed at the Shutdown Hold, an Emergency Shutdown was initiated by the CTO. Both the moderator and main line flows were supplied by Dewar 3 until X-3 was closed. L-11 and L-21 were then operated in Position Control to attempt to control the flow rates as required for reactor cooldown operations. Figures 5.4.3.1, 5.4.3.2 and 5.4.3.3 and Table 5.4.3 summarize the system performance during these operations.

Following the emergency shutdown, the turbopump was left in on free-wheeling condition with the latches disengaged. Based on Mark 25 experience, the resistance to flow through the pump is believed to be less when the pump is free to rotate than when the pump is restrained by the latches. The scaling of the pump discharge transducer, 0-1500 psi, prevents an accurate determination of the pressure drop through the pump, but it appears to be less than 5 psig. The maximum pump speed during this period was 1500 rpm.

TABLE 5.4.3.1
L SYSTEM COOLDOWN
K SYSTEM
INOPERATIVE

NRFO-R-0202

VALVE POSITION - %
PRESSURE - PSIG $\times 10^{-1}$

Table 5.4.3.3
L-System Cooldown
K-System Inoperative

SYSTEM PERFORMANCE DURING "L" SYSTEM
COOLDOWN OPERATIONS

<u>CRT</u>	<u>LR-11</u>	<u>BF-13</u>	<u>LR-21</u>	<u>LF-25</u>	<u>W^{TOTAL}</u>	<u>COMMENTS</u>
18377	-	-	-	-	-	ESD from the Shutdown Hold.
18405	37.3%	5.9 $\frac{\text{lb}}{\text{sec.}}$	100%	1.7 $\frac{\text{lb}}{\text{sec}}$	7.6 $\frac{\text{lb}}{\text{sec}}$	Flow supplied by "X" System.
18425	37.3	-	100	-	-	X-3 Closed.
18490	37.3	3.5	51.2	0.58	4.1	Reduced L-21 position.
18530	37.2	3.5	100	0.58	4.1	Maximum flow from "L" System.
18580	5.6	3.1	32.5	0.55	3.7	Minimum controllable flow with L-11.
18660	35.7	3.2	24.5	0.55	3.8	Minimum controllable flow with L-21.
18755	28.9	-	22.0	-	-	First pulse.
18855	29.6	-	27.6	-	-	Second pulse.

Table 5.4.3

As soon as the emergency shutdown occurred, the flow in the "L" System stopped. There were no vents open because L-109 and H-101 were not opened by the ESD chain. The "X" System pressure was high enough to block any flow into the main and moderator lines from the "L" System. LT-2 immediately began to increase indicating warming of the fluid trapped in the line. Even when flow was resumed through L-11 and L-21, this temperature continued to increase and exceeded the fluid saturation temperature about three minutes after the shutdown. The flow through L-11 and L-21 was not sufficient to keep the dewar discharge line chilled. Therefore, some portion of the system probably experienced two-phase flow.

L-11 and L-21 were partially closed in order to attempt to control the main line and moderator line flow rates at lower values. As shown in Table 5.4.3 and Figure 5.4.3.2, only minor reductions in flow rates (i.e. less than .5 pps at LF-10) could be made until the flow rate became unstable. However, BP-15 and BP-215 as shown in Figure 5.4.3.1 were quite stable during these operations. If this contingency cooldown procedure is required, the inlet pressure AP-101 and AP-196 and the reactor temperatures probably could be used to monitor the reductions of flow rates before the pulse cooling operation is initiated.

Two attempts at pulse cooling were made in which L-11 and L-21 were partially opened. It is not possible to accurately determine the flow rates since the fluid in the lines had been partially purged with helium flow through N-430 prior to each pulse. The indicated flow at LF-10 was successfully adjusted between two to four lb/sec as specified in the checklist. The stability of BP-15 and BP-215 during these pulses as shown in Figure 5.4.3.1 indicates that this procedure is satisfactory.

During the startup to Full Power conditions, L-251 was closed after the turbopump bootstrap operation was achieved. GH_2 required to maintain the pressure in Dewar 2 was then supplied by the TES. When the emergency shutdown was performed, the supply of GH_2 was eliminated; therefore, the dewar pressure began to slowly decrease. After about five minutes, L-53 was switched to Position Control, L-251 was opened and L-53 in Pressure Control was used to re-establish 60 psig at LP-62. During this period, LP-62 had decreased to 55 psig. While this decrease in pressure did not noticeably effect the L-System flow rate, L-251 should be opened as soon as possible following the shutdown.

When the pulse cooling phase was begun, H-101 was opened to 20% to prevent over-pressurization of the lines due to boiloff of LH_2 trapped between pulses. The flow through this valve did not interfere with the two pulses performed through L-11 and L-21.

5.5 EMERGENCY SHUTDOWN AND COOLDOWN OPERATING CHARACTERISTICS

5.5.1 Emergency Shutdown Operating Conditions

The emergency shutdowns (ESD) performed during the FEP Test Series were initiated by the CTO at system flow and pressure conditions corresponding to Pewee 2 Reactor Operations at fuel exit temperatures of 4400°R (FPH), 2500°F (MPH), and 800°R (SDH). The CTO initiated ESD performed from the Shutdown Holds (SDH) are discussed in Section 5.4.

The emergency shutdown tests were performed during the FEP Test Series in order to establish a system that would be acceptable for Pewee 2 Reactor Power Testing. The criterion for acceptability established for the FEP tests was that the initial pressure dip at BP-15 would be less than 70 psi for CTO initiated ESD from simulated Pewee 2 Full Power Operating Conditions. The Pewee 2 system operating conditions that were to be established proceeding ESD from MPH and FPH are given in Table 5.5.1.1.

The system operating conditions proceeding the EST test were achieved by adjustment of B-215, B-15, L-21 and LF-10 flow demand.

The emergency shutdown tests performed during FEP-I consisted of 5 ESD's from Pewee 2 FPH conditions and one ESD from Pewee 2 MPH conditions. Table 5.5.1.2 presents a summary of selected system conditions preceding and subsequent to the ESD tests performed during FEP-I. The data presented in this table were taken from the DDP-116 listings, the calcomp plots, and post-run wideband tape playback on CEC. The pressure dip data presented in Table 5.5.1.2 were taken from CEC playback charts, except as noted. The ESD event times were taken from the on-line CEC charts. Table 5.5.1.3 presents the event times for facility valve actions, pressure dips and other significant events. The event times correspond to the elapsed time

TABLE 5.5.1.1
 DESIRED PEWEE 2 SYSTEM OPERATING CONDITION
 PRECEEDING ESD TESTS

Parameter	Full Power Hold $T_{FE} = 4400^{\circ}R$	Medium Power Hold $T_{FE} = 2500^{\circ}R$
Simulated Nozzle Inlet Pressure (BP-015), PSIG	761	357
Simulated Moderator Inlet Pressure (BP-215), PSIG	631	325
Simulated Moderator Inlet Flow (LF025), PPS	6.0	3.7
Simulated Total Reactor Flow (LF-10), PPS	30.1	19.7

TABLE 5.5.1.2 P11 F P I SUMMARY OF SYSTEMS PARAMETERS PRECEDING AND SUBSEQUENT TO EMERGENCY SHUTDOWN

		<u>F E P - I</u>					
TEST		FEP- I	FEP- I	FEP- I	FEP- I	FEP- I	FEP- I
RUN NO.		Run 2	Run 3	Run 5	Run 8	Run 9	Run 10
Simulated Reactor Conditions		FPH	FPH	FPH	T _e = 2500° R	FPH	FPH
CRT at ESD		17,937.855	24,192.805	29,541.83	41,905.545	43,877.12	45,442.963
*Accumulator ΔP	HP-541 - HP-71	+78.8 (100)	+121.9 (143)	-24.1 (0)	-17.6 (0)	+80.6 (102)	-22.0 (0)
Accumulator Pressure	HP-71	841.5	779.3	933.4	433.6	842.6	942.3
Accumulator Temperature	HT-71	584.9	570.3	564.1	547.3	584.6	575.1
Pump Speed	HQ-550	23,925	23,876	24,140	15,625	24,063	24,063
Pump Discharge Pressure	HP-541	920.3	901.2	909.3	416.0	923.2	920.3
TES Inlet Pressure	HP-1	906.2	902.3	912.1	423.3	919.9	920.4
Main Line Pressure	LP-10	916.9	899.4	909.6	421.1	923.9	919.2
Pump Flow	HF-550	35.5	35.8	35.9	23.2	35.7	35.3
TES Flow	HF-10	5.7	5.4	4.9	3.1	5.3	4.4
Main Line Flow	LF-10	29.9	30.4	31.0	20.1	30.4	30.9
Simulated Nozzle Flow	BF-13	23.9	24.4	25.1	16.3	24.4	24.9
Simulated Moderator Flow	LF-25	6.0	6.0	6.0	3.8	6.1	6.1
*L-11 Position	LR-11	98.5	98.6%	98.6%	98.7%	36.9%	98.6%
L-11 Position After ESD	LR-11	6.6%	6.3%	6.4%	6.4%	6.4%	6.3%
L-11 Delay Time		.030	.030	.030	.030	.010	.030
L-11 Differential Pressure	LP-11D	0	0	0.1	0.2	103.5	0
H-11 Position	HR-11	9.1%	11.3%	10.8%	5.6%	12.0%	11.0%
H-11 Position After ESD	HR-11	0	0	0	0	0	0%
H-60 Position	HR-60	12.8%	12.6%	12.8%	12.6%	12.6%	12.6%
H-60 Position After ESD	HR-60	0	0	0	0	0	0
*H-175 Position	HR-175	16.5%	25.8%	0	0	19.3%	0
H-175 Position After ESD	HR-175	0	0	0	0	0	0
H-70 Position	HR-70	0	0	0	0	0	0
H-75 Position	HR-75	0	0	0	0	0	0
H-101 Position	HR-101	0	0	0	0	0	0
H-101 Position After ESD	HR-101	10.2%	10.1%	10.1%	10.2%	10.2%	10.0%
H-142 Position	HR-142	0	0	0	0	0	0
H-142 Position After ESD	HR-142	100	100	100	100	100	100
L-109 Position	LR-109	0	0	0	0	0	0
*L-109 Position After ESD	LR-109	15.9%	14.9%	14.9%	14.8%	14.8%	100%
L-21 Position	LR-21	19.5%	20.0%	19.4%	19.2%	19.6%	19.5%
H-180 Position	HR-180	C	C	C	C	C	C
H-180 Position After ESD	HR-180	0	0	0	0	0	0
Pressure Upstream of Flow Cart Orifice	BP-13	900.9	885.7	896.2	414.3	806.1	907.0
Simulated Nozzle Pressure	BP-15	772.9	754.6	757.3	355.0	671.6	771.5
Simulated Nozzle Pressure (Close Coupled)	BP-14	N/A	N/A	N/A	N/A	N/A	N/A
Flow Cart Orifice Differential Pressure	BP-14D	109.3	111.6	119.4	50.8	114.3	115.2
Simulated Moderator Pressure	BP-215	675.8	664.1	667.5	355.2	671.1	658.4
B-15 Position	BR-15	55.2%	55.9%	56.5%	54.7%	57.5%	55.9%
B-215 Position	BR-215	37.4%	37.9%	37.4%	34.3%	37.6%	37.9%
Initial Pressure Dip After ESD	BP-14	N/A	N/A	N/A	N/A	N/A	N/A
Initial Pressure Dip After ESD	BP-15	143	125	75	35	60	185
Initial Pressure Dip After ESD	HP-541	83	68	73	45	60	165

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TABLE 5.5.1.3 EMERGENCY SHUTDOWN EVENT TABLE (FEP-I)

TEST	FEP-I Run 2	FEP-I Run 3	FEP-I Run 5	FEP-I Run 8	FEP-I Run 9	FEP-I Run 10
ESD TIME	17937.855	24192.805	29541.845	41905.545	43877.123	45442.965
SIMULATED REACTOR CONDITIONS	Full Power	Full Power	Full Power	T _{fe} = 2500°R	Full Power	Full Power
H-60 Starts to Close	.005 sec.	.005 sec.	.005 sec.	.005 sec.	.005 sec.	.005 sec.
H-60 Closes	.040 sec.	.040 sec.	.040 sec.	.040 sec.	.040 sec.	.040 sec.
L-109 Starts to Open	.01 sec.	.015 sec.	.02 sec.	.018 sec.	.015 sec.	.018 sec.
L-109 Opens	.035 sec.	.030 sec.	.035 sec.	.030 sec.	.030 sec.	.080 @ 100%
HP-541 Starts to Drop	930 @ .030 sec.	915 @ .020 sec.	928 @ .020 sec.	412 @ .020 sec.	930 @ .020 sec.	930 @ .020 sec.
HP-541 Dips to	847 @ .030 sec.	847 @ .030 sec.	855 @ .030 sec.	367 @ .030 sec.	870 @ .030 sec.	765 @ .030 sec.
HP-71 Starts to Drop	.10 sec.	.14 sec.	.020 sec.	.040 sec.	.10 sec.	.020 sec.
LP-10 Starts to Drop	915 .041 sec.	893 .040 sec.	900 .040 sec.	413 .040 sec.	923 .040 sec.	930 .040 sec.
LP-10 Dips to	855 @ .052 sec.	840 @ .051 sec.	867 @ .050 sec.	390 @ .050 sec.	867 @ .050 sec.	843 @ .052 sec.
LP-11D Increases/Decreases	Decreases @ .040 sec.	Decreases .040 sec.	Decreases .040 sec.	Decreases @ .040 sec.	Increases .020 sec.	Decreases .040 sec.
L-11 Starts to Close	.030 sec.	.030 sec.	.030 sec.	.030 sec.	.010 sec.	.030 sec.
L-11 Reaches 6.3%	.70 sec.	.70 sec.	.70 sec.	.70 sec.	.25 sec.	.70 sec.
BP-14 Starts to Drop	NA	NA	NA	NA	NA	NA
BP-14 Dips to (1st Dip)	NA	NA	NA	NA	NA	NA
BP-14 Dips to (2nd Dip)	NA	NA	NA	NA	NA	NA
BP-14 Dips to (3rd Dip)	NA	NA	NA	NA	NA	NA
BP-15 Starts to Drop	773 .060 sec.	755 .060 sec.	760 .060 sec.	350 .060 sec.	671 .035 sec.	775 .060 sec.
BP-15 Dips to (1st Dip)	630 @ .078 sec.	630 @ .078 sec.	685 @ .070 sec.	315 @ .075 sec.	650 @ .062 sec.	590 @ .083 sec.
BP-15 Dips to (2nd Dip)	630 @ .125 sec.	615 @ .130 sec.	690 @ .105 sec.	320 @ .115 sec.	605 @ .080 sec.	615 @ .115 sec.
BP-15 Dips to (3rd Dip)	630 @ .160 sec.	580 @ .170 sec.	687 @ .140 sec.	320 @ .155 sec.	590 @ .092 sec.	660 @ .150 sec.
HR-11 Starts to Close	.005 sec.	.005 sec.	.005 sec.	.005 sec.	.005 sec.	.005 sec.
HR-11 Closed	.020 sec.	.020 sec.	.020 sec.	.020 sec.	.020 sec.	.020 sec.
HR-101 Starts to Open	NA	NA	NA	NA	NA	NA
HR-101 Open to 10%	NA	NA	NA	NA	NA	NA
HR-142 Starts to Open	NA	NA	NA	NA	NA	NA
HR-142 Open	NA	NA	NA	NA	NA	NA
HR-175 Starts to Close	.01 sec.	.01 sec.	Closed During	Closed During	.01 sec.	Closed During
HR-175 Closed	.03 sec.	.03 sec.	the ESD	the ESD	.03 sec.	the ESD
X-System Flow - Moderator Line	3 sec.	3 sec.	4 sec.	1.5 sec.	4 sec.	4 sec.
K-System Flow - Main Line	3.5 sec.	3 sec.	3 sec.	1.5 sec.	3 sec.	3 sec.
Warm Fluid LT10	3 sec.	4 sec.	3 sec.	6.5 sec.	4 sec.	3.5 sec.
Back Flow L-21	5 sec.	5 sec.	6 sec.	3.5 sec.	6 sec.	6.0 sec.
Backflow - LT10 Decreases	15 sec.	13 sec.	13 sec.	13.5 sec.	14 sec.	15 sec.
L-11 Closed	28 sec.	13 sec.	12 sec.	11.5 sec.	14 sec.	15 sec.
L-21 Closed	47 sec.	22 sec.	17 sec.	29.5 sec.	31 sec.	32 sec.
X-3 Closed	75 sec.	38 sec.	21 sec.	42.5 sec.	36 sec.	37 sec.

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N/A - NOT APPLICABLE
 NA - NOT AVAILABLE
 ESD AT T = 0 SECONDS
 WIDE BAND DATA USED WHERE AVAILABLE

after the ESD event time. The data presented in this table were taken from the Calcomp plots, on-line Sanborn Charts, and post-run wideband tape playbacks, on CEC charts. The pressure dip data and event times less than 0.5 second were taken from the CEC playback charts except as noted.

The referenced Pewee 2 system established prior to FEP-I included an impedance orifice installed on the Test Car to produce an 100 psi pressure drop at main-line LH_2 flow of 24.1 pps. The automatic facility valve actions that were planned to occur upon a CTO initiated ESD for the referenced Pewee 2 system established prior to FEP-I are; full closure of H-60, H-53, H-70, H-175, H-11, X-53 and X-161 without a demand time delay; full opening of H-180 without demand time delay; H-101 open to 10% after a 0.5 sec. demand time delay; L-109 opening to pre-determined position without demand time delay; and closure of L-11 from nominal 100% to 6.3% without a demand time delay. The significant operator action to be taken after ESD were to fully close L-11, L-21 and X-3. Tables 5.5.1.2 and 5.5.1.3 show that these actions occurred for all FEP-I ESD tests except for Run #9 where L-11 was closed from 37% to 6.3% without a demand time delay. This run was planned on FEP-I run day to evaluate the effect of this change on the pressure dip observed at BP-15 upon ESD from simulated Pewee 2 Full Power Operating Conditions.

The emergency shutdown tests performed during FEP-II consisted of six (6) ESD from Pewee 2 FPH conditions and one ESD from Pewee 2 MPH conditions. Tables 5.5.1.4 and 5.5.1.5 present the system conditions and event times for the ESD tests performed during FEP-II. The referenced Pewee 2 system established for FEP-II was the same as that for FEP-I except that: (1) the test car orifice installed for FEP-I was removed for FEP-II, (2) L-11 was provided with a mechanical maximum position block to produce, with the hold open circuit active, a 100 psi pressure drop at LP11D at an

TABLE 1.1. PEP-II UTILITY OF SYSTEMS PARAMETERS PRIOR TO AND SUBSEQUENT TO EMERGENCY SHUTDOWN

TEST RUN NO. Simulated Reactor Conditions CRT at ESD	FEP-II Run 3 FPH 0,405.0	FEP-II Run 4 FPH 22,140.770	FEP-II Run 5 FPH 23,403.146	FEP-II Run 6 T ₁ 2500°R T ₂ 29,624.993	FEP-II Run 7 FPH 31,146.63	FEP-II Run 8 FPH 33,062.614	FEP-II Run 10 FPH 38,763.900
*Accumulator ΔP	+93.0 (5)	+93.1 (0)	No Accumulator	No Accumulator	+186. (148)	+73.2 (35)	+72.5 (34)
Accumulator Pressure	808.6	361.7	0	0	730.9	817.4	829.4
Accumulator Temperature	564.5	520.5	440.9	446.6	464.0	555.8	562.4
Pump Speed	23,398	23,379	23,554	15,518	23,710	23,438	23,584
Pump Discharge Pressure	901.6	892.3	912.9	420.4	918.1	890.6	901.9
TES Inlet Pressure	904.8	999.8	915.9	426.3	915.4	888.1	898.4
Main Line Pressure	900.5	899.0	910.4	422.6	916.9	888.0	901.2
Pump Flow	34.9	35.1	35.3	23.1	35.7	35.6	35.4
TES Flow	4.9	4.6	4.9	3.2	5.1	5.0	5.3
Main Line Flow	30.0	30.5	30.4	19.9	30.6	30.6	30.1
Simulated Nozzle Flow	24.1	24.8	24.7	16.0	24.7	24.9	24.2
Simulated Moderator Flow	5.9	5.8	5.8	3.9	5.9	5.7	5.9
*L-11 Position	37.4%	37.3%	37.3%	37.3%	37.3%	37.3%	37.3%
L-11 Position After ESD	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%	6.25%
L-11 Delay Time	.426	.430	.425	.430	.430	.430	.050
L-11 Differential Pressure	100.5	103	102.2	44.4	101.5	102.7	96.7
H-11 Position	11.4%	10.6%	11.0%	5.3%	11.4%	100%	100%
H-11 Position After ESD	0%	0%	0%	0%	0%	100%	0%
H-60 Position	12.1%	12.2%	12.0%	12.4%	11.9%	12%	11.9%
H-60 Position After ESD	0	0	0	0	0	0	0
*H-175 Position	17.6%	0%	100%	100%	16.1%	15.8%	15.9%
H-175 Position After ESD	0%	0%	100%	100%	16.1%	0%	0%
H-70 Position	0	0	C	C	0	0	0
H-75 Position	0	0	C	C	0	0	0
H-101 Position	0%	0	0	0	0%	0	0
H-101 Position After ESD	10.3%	10.2%	9.6%	10.2%	9.5%	10.1%	10.2%
H-142 Position	0	0	0	0	0	0	0
H-142 Position After ESD	95%	95%	95%	95%	95%	95%	95%
L-109 Position	0%	0%	0%	0%	0%	.2%	0%
*L-109 Position After ESD	14.6%	14.9%	14.7%	14.6%	14.6%	14.6%	14.8%
L-21 Position	18.6%	18.3%	18.3%	18.4%	18.6%	18%	19.1%
H-180 Position	C	C	C	C	C	C	C
H-180 Position After ESD	0	0	0	0	0	0	0
Pressure Upstream of Flow Cart Orifice							
Simulated Nozzle Pressure	788.8	785.6	794.4	373.3	803.2	772.0	793.0
Simulated Nozzle Pressure (Close Coupled)	768.1	763.2	773.9	263.5	782.7	753.2	771.7
Flow Cart Orifice Differential Pressure	755.0	752	765	335	765	735	750
Simulated Moderator Pressure	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B-15 Position	612.5	626.4	650.1	325.4	629.9	627.9	644.5
B-215 Position	55.6%	56.1%	56.1%	54.3%	55.9%	56.5%	55.6%
	23.0%	27.5%	37.4	35.5%	37.9%	36.9%	37.8%
Initial Pressure Dip After ESD	55	52	61	30	60	65	60
Initial Pressure Dip After ESD	60	60	60	35	65	65	65
Initial Pressure Dip After ESD	61	61	61	35	67	67	67

BI 5.515 TIGLEY SHUTDOWN WNF TABLE (F P-II)

TEST	FEP-II Run 5	P-I Run 5	FEP-II Run 6	FEP-II Run 6	FEP-II Run 7	FEP-II Run 8	FEP-II Run 10
TIME	28403.146	28403.146	29624.978	29624.978	31146.63	33062.614	38763.900
SIMULATED REACTOR CONDITIONS	Full Power	Full Power	Full Power	T _{fe} =2500°R	Full Power	Full Power	Full Power
H-60 Starts to Close	.00 sec.	.005 sec.	.005 sec.	.005 sec.	.005 sec.	.005 sec.	.005 sec.
H-60 Closes	.00 sec.	.00 sec.	.040 sec.	.040 sec.	.040 sec.	.040 sec.	.040 sec.
L-109 Starts to Open	.015 sec.	.015 sec.	.015 sec.	.015 sec.	.020 sec.	.015 sec.	.015 sec.
L-109 Opens	.030 sec.	.030 sec.	.030 sec.	.030 sec.	.035 sec.	.030 sec.	.030 sec.
HP-541 Starts to Drop	90% @ .021 sec.	90% @ .020 sec.	913 @ .020 sec.	507 @ .020 sec.	900 @ .021 sec.	882 @ .021 sec.	882 @ .021 sec.
HP-541 Dips to	352 @ .035 sec.	352 @ .031 sec.	358 @ .030 sec.	461 @ .030 sec.	846 @ .035 sec.	815 @ .030 sec.	821 @ .035 sec.
HP-71 Starts to Drop	.100 sec.	.03 sec.	Zero psi in Accumulator	Zero psi in Accumulator	.17 sec.	.09 sec.	.100 sec.
LP-10 Starts to Drop	870 @ .040 sec.	970 @ .045 sec.	377.5 @ .041 sec.	382.5 @ .038 sec.	885 @ .042 sec.	858 @ .040 sec.	870 @ .043 sec.
LP-10 Dips to	810 @ .053 sec.	910 @ .054 sec.	925.0 @ .053 sec.	360 @ .050 sec.	828 @ .052 sec.	802.5 @ .054 sec.	820.5 @ .053 sec.
LP-11D Increases/Decreases	Decreases @ .040 sec.	Decreases @ .040 sec.	Decreases @ .040 sec.	Decreases @ .040 sec.	Decreases @ .040 sec.	Decreases @ .040 sec.	Decreases @ .045 sec.
L-11 Starts to Close	.426 sec.	.430 sec.	.425 sec.	.430 sec.	.430 sec.	.430 sec.	.050 sec.
L-11 Reaches 6.3%	.675 sec.	.685 sec.	.685 sec.	.670 sec.	.680 sec.	.690 sec.	.330 sec.
BP-14 Starts to Drop	755 @ .048 sec.	752 @ .055 sec.	765 @ .059 sec.	335 @ .061 sec.	765 @ .062 sec.	735 @ .054 sec.	750 @ .056 sec.
B-14 Dips to (1st Dip)	700 @ .077 sec.	700 @ .079 sec.	700 @ .084 sec.	305 @ .077 sec.	705 @ .081	670 @ .077 sec.	690 @ .83 sec.
BP-14 Dips to (2nd Dip)	660 @ .118 sec.	700 @ .110 sec.	N/A	N/A	N/A	N/A	N/A
BP-14 Dips to (3rd Dip)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BP-15 Starts to Drop	730 @ .060 sec.	770 @ .060 sec.	780 @ .067 sec.	360 @ .067 sec.	790 @ .070 sec.	760 @ .062 sec.	780 @ .060 sec.
BP-15 Dips to (1st Dip)	720 @ .074 sec.	710 @ .075 sec.	720 @ .080 sec.	325 @ .082 sec.	725 @ .082 sec.	695 @ .075 sec.	715 @ .080 sec.
FP-15 Dips to (2nd Dip)	690 @ .120 sec.	720 @ .115 sec.	680 @ .135 sec.	310 @ .138 sec.	---	690 @ .113 sec.	680 @ .120 sec.
BP-15 Dips to (3rd Dip)	692 @ .144 sec.	705 @ .144 sec.	N/A	N/A	---	N/A	N/A
HR-11 Starts to Close	.001 sec.	.001 sec.	.001 sec.	.02 sec.	.04 sec.	At 100% During	.05 sec.
HR-11 Close!	.04 sec.	.004 sec.	.004 sec.	.08 sec.	.07 sec.	for ESD	.08 sec.
HR-101 Starts to Open	.44 sec.	.43 sec.	.43 sec.	.45 sec.	.42 sec.	.42 sec.	.64 sec.
HR-101 Open to 10%	.49 sec.	.50 sec.	.48 sec.	.50 sec.	.49 sec.	.49 sec.	.70 sec.
HR-142 Starts to Open	.02 sec.	.02 sec.	.02 sec.	.025 sec.	.04 sec.	.03 sec.	.03 sec.
HR-142 Open	.24 sec.	.25 sec.	.28 sec.	.23 sec.	.24 sec.	.24 sec.	.25 sec.
HR-175 Starts to Close	.01 sec.	Close! During	Stayed @ 100%	Stayed @ 100%	Stayed at	.01 sec.	.01 sec.
HR-175 Closed	.04 sec.	the ESD	During ESD	During ESD	16% During ESD	.04 sec.	.04 sec.
X-system Flow - Moderator Line 3 sec.		3 sec.	1 sec.	1 sec.	2 sec.	2 sec.	3 sec.
X-system Flow - Main Line 3 sec.		2 sec.	2 sec.	2 sec.	2 sec.	2 sec.	NA
Warr Fluid LTIO 4 sec.		4 sec.	N/A	N/A	9 sec. (only 55°R)	4 sec.	4 sec.
Beck Flow L-21 5 sec.		5 sec.	2 sec.	2 sec.	3 sec.	4 sec.	6 sec.
Backflow - LTIO Decreases 14 sec.		13 sec.	N/A	N/A	12 sec.	11 sec.	12 sec.
L-11 Closed 14 sec.		13 sec.	11 sec.	12 sec.	12 sec.	10 sec.	12 sec.
L-21 Closed 41 sec.		39 sec.	27 sec.	25 sec.	19 sec.	22 sec.	25 sec.
A-3 Closed 50 sec.		44 sec.	31 sec.	27 sec.	20 sec.	23 sec.	29 sec.

N/A - NOT APPLICABLE
NA NOT AVAILABLE
ESD AT T = 0 SECONDS
WIDE BAND DATA USED WHERE AVAILABLE

LH₂ flow rate of 24.1 pps, (3) L-11 was provided with a demand time delay so that it would not start to close until a nominal 0.45 seconds after the ESD event, and (4) L-109 was provided with a mechanical maximum position block to prevent it opening beyond an effective flow area of 1.05 in².

5.5.2

System Performance during ESD

This section describes the effects of operating conditions on the system performance characteristics during the emergency shutdown test performed during FEP-I and FEP-II.

A close coupled pressure transducer (BP-14W) was installed near BP-15 in the FEP-II test flow car main line in order to evaluate the effect of pressure transducer sensor line length on the pressure oscillations observed at BP-15. Appendix A gives the sensor line data for all significant pressure measurements used for evaluation of ESD transient characteristics. Figure 5.5.2.1 is a plot of BP-15W and BP-14W as a function of time for Run 3 of FEP-II. Both transducers indicate that the first minimum occurred about .075 seconds after the ESD and that the magnitude of the drop was 60 psi. It is noted that the min. line ringing indicated by BP-15W after the first pressure oscillation is not indicated by BP-14W. This secondary ringing may be due to the BP-15W impulse tubing and not present in the propellant line. However, the magnitude and timing of the first pressure dip do appear, based on BP-15, to be true indications of the propellant line pressure.

It was expected that the orifice, installed in the test flow car main line prior to FEP-I, would have an attenuating effect on the line ringing at the simulated nozzle inlet from the propellant ESD. Fig. 5.5.2.2 shows BP-13 and BP-15 for Run 3 of FEP-I and Run 3 of FEP-II as a function of time after the ESD. BP-13 is the pressure tap upstream of the car orifice. It is seen that the orifice did not attenuate

RUN #3
FEP-I W/Orifice
L-11 @100%
@ ESD

RUN #3
FEP-II W/O Orifice
L-11 @37%
@ ESD

CART ORIFICE
EFFECTS PEWEE 2
FEP-I & II
FIGURE 5.5.2.2

the line ringing during FEP-I. The magnitude and frequency of the pressure dips at BP-13 and BP-15 are the same. BP-13 and BP-15 are also shown without the orifice in the line for comparison. It is again seen that the magnitude of the dips and the frequency at BP-13 and BP-15 are the same. The difference in the magnitudes of the dips between FEP-I and II are due to L-11 throttling which is discussed below.

The effect of L-11 initial position on the line ringing at BP-15W is shown in Figure 5.5.2.3. BP-15W is plotted as a function of time for Run #4 of FEP-II and Run 5 of FEP-I. During both runs the accumulator was at line pressure and L-109 opened to 15% on shutdown. During Run #4 of FEP-I the valve was initially 100% open. It is seen that the magnitude and frequency of the dips at BP-15 are smaller with L-11 initially at 37%. The magnitude of the first dip is about 60 psi with the valve throttled versus about 75 psi with the valve at 100%.

The effect of L-11 closing time delays on the pressure response at BP-15 following ESD was investigated during the FEP's. Figure 5.5.2.4 shows the BP-15W pressure and LR-11 position for ESD's with L-11 moving closed from an initial position of 37% to 6.3% within .020 seconds, .050 seconds, and .425 seconds after the ESD. The time required for L-11 to start to close is dependent on which mode of control the valve is in at the ESD. During Run 3 of FEP-II, the valve was against its 37% block with the hold open and delay active. Under these conditions, L-11 started to close in .425 seconds after the ESD. For Run 10 of FEP-II, the valve was against the 37% block with the hold open active but without the L-11 delay active. The valve started closed in .050 seconds after the ESD. For Run 9 of FEP-I, the valve was in position control at 37% without the hold open or the L-11 delay active. The valve started closed in .020 seconds after the ESD. It is seen for Run 9 that the pressure at

BP-15W begins to decrease in a ramp fashion within .040 seconds after the ESD. This pressure decrease is due to the closure of L-11 since the valve starts to close before the time required for the pressure wave, which is developed at the pump discharge, to reach either LP-10 or BP-15W locations. The pressure wave develops at the pump discharge about .020 seconds after the ESD indication and then requires an additional .035 to .040 seconds to travel from the pump to the BP-15W transducer. Assuming that the wave travels at sonic velocity (4000 fps) from the pump to BP-15W yields a calculated transverse time of .033 seconds which agrees rather well with the test data of .035 to .040 seconds. The movement of L-11 on Run 9 of FEP-I causes the pressure decay at BP-15W to be smoother than for the other runs. However, if the magnitude of the first pressure dip is compared with the steady-state pressure prior to the ESD, it is seen that the pressure dips for all three runs are about 60 to 65 psi. The closure of L-11 from 37% without a demand delay time results in a faster decay profile at BP-15 without significant improvement in the magnitude of the initial pressure dip. The acceptability of faster pressure decay is not considered in this analysis.

The effect of accumulator pressure conditions on the pressure response at BP-15 following ESD was investigated during the FEP's for L-11 at 100% and at 37%. Figure 5.5.2.5 shows the BP-15W pressure as a function of time for the runs studied. With L-11 at 100%, ESD's were performed with the accumulator at line pressure (H-175 closed) and with the accumulator 143 psi below line pressure (H-175 partially open). It is seen that with the accumulator at line pressure the first dip was about 75 psi and that with the accumulator at 143 psi below line pressure, the first dip was about 125 psi. With L-11 at 37%, tests were run with the accumulator at line pressure, 55 psi below line pressure, and with no accumulator. It is seen from Figure 5.5.2.5 that for these runs the first minimum was not affected by the accumulator pressure and that the first dip

was about 60 psi for all three runs. The pressure decay at BP-15 is faster without the accumulator on-line. The acceptability of the faster decay at BP-15 is not considered in this analysis.

The effect on the system performance of L-109 opening upon ESD was investigated during FEP-I. Figure 5.5.2.6 shows the turbopump parameters (i.e. pump speed, flow, and discharge pressure) and Figure 5.5.2.7 shows the pressure at BP-15W as a function of time for L-109 position after an ESD of 15%, 16% and 100%. As expected, the pressure oscillations at BP-15W are greater for larger L-109 openings on ESD. For opens of 15%, 16% and 100%, the first pressure dips at BP-15W are; respectively, 125 psi, 143 psi, and 185 psi. Figure 5.5.2.6 shows that when L-109 opened to 100%, the pump discharge pressure went to zero in about 0.12 seconds and that the indicated pump flow increased to a maximum of about 70 pps in 0.15 seconds after the ESD. The maximum pump discharge pressure decay rate for this shutdown was about 16,000 psi/sec. This planned test resulted in damage to the Mark 35 pump as discussed in Section 5.3.4.

The effect of H-11 at 100% on the system performance during an ESD was investigated during FEP-II. Run 8 of FEP-II was essentially the same as Run 3 except that during Run 8, H-11 was opened to 100% and allowed to remain open during the ESD. Figure 5.5.2.8 shows BP-15W as a function of time for Runs 3 and 8. From this figure, it is seen that H-11 remaining open at 100% causes the magnitude of the first pressure dip to increase by about 5 psi.

The TES performance during these two tests is shown in Figures 5.5.2.9 and 5.5.2.10. Figure 5.5.2.9 compares the TES inlet pressure (HP-1), the inlet temperature (HT-1), the outlet temperature (HT-12) and the outlet pressure (HP-43), for these runs. It also shows the H-11, H-142, and H-101 valve positions for these runs.

1. Run #10 - L-109 to 100%
 2. Run #2 - L-109 to 16%
 3. Run #3 - L-109 to 15%

L-109 OPENING
 EFFECTS ON PUMP
 PARAMETERS
 PEWEE 2 FEP-1
 FIGURE 5.5.2.6

L-109 EFFECTS
ON BP-15W PEWEE 2
FEP-1
FIGURE 5.5.2.7

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Figure 5.5.2.10 shows a comparison of the main line pressure (LP-10) and the TES inlet pressure (HP-1). Also shown is the differential pressure (HP-10D) across the TES flow venturi (HF-10). From Figure 5.5.2.9, it is seen that the TES inlet and outlet temperatures were not affected by H-11 remaining 100% open. The TES inlet pressure decays more rapidly when H-11 is left open, since it has a flow path at the discharge of the TES through H-142 and H-180. However, it is seen from Figure 5.5.2.10 that the flow through the TES is not from the accumulator and main line until about one (1) second after the shutdown. This is the time required for HP-1 to drop below LP-10. At this time the check valve HC-2001 opens, which closed almost immediately after the ESD, since the main line pressure decays more rapidly than the TES inlet pressure. When HC-2001 opens, the main line pressure has decayed by about 350 psi so that the flow path through the TES section due to the accumulator blowdown is limited to a maximum flow of about 8 pps for less than a second. These flows are not sufficient to effect the TES discharge temperature.

The effect of this on the pressure profile to the nozzle and moderator system is shown in Figure 5.5.2.11. The simulated nozzle inlet pressure (BP-15) and the simulated moderator inlet pressure (BP-215) are compared for Runs 3 and 8. From Figure 5.5.2.11 it is seen that there is a minimal effect on the moderator system since the pressure BP-215 decays to 300 psig in about 2.5 seconds for both runs. This is the pressure at which the X-System begins flowing to the moderator system. It is also seen, however, that the effect on the pressure decay at the simulated nozzle inlet BP-15 is minimal. The nozzle pressure decays to 100 psig in about two seconds with H-11 100% open, as compared to about 2.5 seconds when H-11 closes. The 100 psig level is when the K-System begins to flow to the main line.

CTO initiated emergency shutdown from simulated Pewee 2 Full Power conditions are shown in Figure 5.5.2.12 and 5.5.2.13. Presented

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TYPICAL SHUTDOWN-
NO ACCUMULATOR
RUN # 5 FEP-II
PEWEE 2
FIGURE 5.5.2.13

as function of time are the pump discharge pressure (HP-541W), the main line pressure (LP-10W), the simulated nozzle pressure (BP-15W), L-109 position and H-60 position. Figure 5.5.2.12 shows the behavior of the selected parameters for Run 3 of FEP-II which was performed with the accumulator at a nominal 100 psi below line pressure similar to that planned for Pewee 2. From this figure it is seen that the pump discharge pressure (HP-541W) does not remain below the main line pressure (LP-10) between 0.050 and .130 seconds after the ESD. This could indicate that the pump discharge check valve does not finally close until .130 seconds after the ESD and that the pump is still supplying fluid to the system during this time interval of the shutdown. , however, that there are still some unresolved problems in the HP-541 wide-band data and that it has been linearly corrected to the DDP-116 steady-state data before the ESD. The pressure dip at the simulated nozzle for this run is 60 psi at .075 seconds after the ESD. From this figure it is seen that the L-109 opening rate on shutdown was about 380% per second and that the H-60 average closing rate from 12% was about 480% per second. However, the initial closing rate (12% to 6%) was about 1500% per second. The slew rate of H-60 on shutdown is 3000% per second when closed from 100% . The slower closing rate of the valve under 6% is due to the snubbing effect of the valve actuator.

Figure 5.5.2.13 shows the behavior of selected parameters for Run 5 of FEP-II which was performed without the accumulator on line. It is seen in this case that the pump discharge pressure (HP-541W) does not remain below the main line pressure (LP-10) after 0.045 seconds after the ESD. This indicates that the pump is supplying fluid to the system downstream of the pump discharge valve through the time interval shown.

In summary, the Emergency Shutdown Tests performed during FEP-II have shown that the nozzle inlet initial pressure dip criteria can be met for CTO initiated ESD's with L-11 initially at 37% independent of accumulator operating conditions, L-11 delay times, and the H-11 opening.

5.5.3 Cooldown System Interactions

This section discusses the interactions between the cooldown systems following emergency shutdowns from simulated Pewee 2 full power and medium power hold conditions performed during FEP-II. The facility operating conditions preceeding and following these emergency shutdowns are similar to those planned for the Pewee 2 reactor power tests. Since the position of the reactor nozzle and moderator simulator valves were not changed from the pre-ESD condition, the indicated impedance of the reactor nozzle and moderator were not simulated throughout the post-ESD operations.

Figures 5.5.3.1 and 5.5.3.2 show the transient behavior of selected system parameters following the ESD performed during Run #3 from simulated Pewee 2 full power conditions. The sequence of events and their effects are summarized below.

1. When LP-25 decreased below XP-2, flow began from the X-System through X-3 into the moderator line. The initial flow from the X-System through LF-25 to the moderator line was 4.0 lb/sec. As shown in Figure 5.5.3.2, the temperature behavior at BT-215 indicates good LH₂ conditions existed upstream X-3 preceeding the shutdown.
2. When LP-12 decreased to less than 100 psig, flow began from the K-System through K-7 into the main line downstream of L-11. The flow rate measured by KF-5 increased to 4.5 lb/sec but then dropped to 2.9 lb/sec as the temperature at BT-15 began to increase. As shown in Figure 5.5.3.2, LT-12 began to increase before LT-10, the increase in temperature at BT-015 is thought to be due to warm fluid that existed between K-7 and KC-1007. The increase of LT-10 shown in Figure 5.5.3.2 is due to the accumulator which was maintained near the main line pressure prior to the ESD.

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3. When LP-10 decreased to less than LP-25, flow began from the X-System back through L-21 into the main line upstream L-11. This event is shown in Figures 5.5.3.1 and 5.5.3.2 when Lp-21D goes to zero. After this event, until L-11 was closed, the main line flow downstream L-11 was supplied by both the X and K Systems.
4. When L-11 was closed by the CTO at 13 seconds of the ESD, the K-System flow increased since it ~~was~~ the only source of flow to the main line. The stability of BP-15 shown in Figure 5.5.3.1 at this event indicates that the main line flow downstream of L-11 was not effected by this event.
5. The closure of L-21 by the CTO at 43 seconds of the ESD had no significant effect on the moderator line flow.
6. When X-3 was closed by the CTO at 51 seconds after shutdown, flow began from the K-System through K-21 into the moderator line. The event had no significant effect on the main line flow which was supplied by the K-System through K-7. The increase in temperature at BT-215 occurring after X-3 was closed is thought to be due to warm fluid that existed in the K-21 line.

After X-3 was closed, the facility was in the normal cooldown configuration with both main and moderator line flows being supplied by the K-System. The subsequent cooldown operations are discussed in Section 5.4.

Figures 5.5.3.3 and 5.5.3.4 shows the transient behavior of selected system parameters following the ESD performed during Run #5 from simulated Pewee 2 medium power conditions. For this run, the accumulator was maintained off-line. The sequence of events and their effects are similar to those discussed for the ESD from full power conditions.

COOLDOWN
CHARACTERISTICS
FOLLOWING ESD
FROM 2500°R
PEWEE 2 FEP-II
RUN #6

FIGURE 5.5.3.3

TEMPERATURE - °R

TIME - SECONDS

COOLDOWN
CHARACTERISTICS
FOLLOWING ESD
FROM 2500° R
PEWEE 2 FEP II
RUN #6
FIGURE 5.5.3.4

5.6

TES HEAT TRANSFER PERFORMANCE

Experimental steady-state data on the TES heat exchanger operating for long duration tests is useful for predicting future operating conditions of the TES.

Due to an insufficient record of TES performance data, an investigation of valid long duration run steady-state data was made. In addition to the Pewee 2 FEP-I duration run, other previous pump duration runs were also analyzed.

During the one hour pump duration run of FEP-I, the TES vaporized 2.7 lbs/sec LH_2 using various flowrates of hot water. Even though the hydrogen flowrate was constant, the hot water flowrate was slowly reduced and the corresponding change in gas and water exit temperatures was observed. Figure 5.6.1 displays the actual discharge temperatures of GH_2 and water

In a previous test, Mark 35 checkout test, March 19, 1969, the TES was used to simulate the operating conditions of HEX-1 for the Nuclear Furnace Facility. In that test, a constant flowrate of six lbs/sec LH_2 was vaporized with warm water (117°F). The water flowrate was continuously adjusted from 1350 to 1000 gpm. The experimental data is shown in Figure 5.6.2. These experimental data points have been analyzed for Q , the total heating rate between both fluids, the actual long mean temperature difference and U , the overall heat transfer coefficient according to the equation:

$$Q = UA\text{-LMTD}$$

where A of the inner surface of the TES is 342 ft^2 .

Figure 5.6.3 presents the values of U and LMTD calculated from the experimental data of Figures 5.6.1 and 5.6.2.

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TES PERFORMANCE
DURING MARK 35
CHECKOUT AND
DURATION TESTS
PEWEE 2 FEP-1
FIGURE 4.6.3

The normal mode of operating the TES is to maintain a constant water flow rate and increase hydrogen flowrate, to a desired value. The design point of 12.5 lbs/sec hydrogen was tested successfully during Phoebus 2A tests. That data and other related steady-state data of the TES while flowing 200°F water have been analyzed for overall heat transfer coefficient and log mean temperature difference and the trend of the calculated values are shown in Figure 5.6.4. These curves are useful for predicting the exit temperature of any hydrogen flowrate and water flowrate (exceeding 800 gpm) assuming that sufficient time has elapsed (5 minutes) to achieve a steady-operating condition.

TES OVERALL HEAT
 TRANSFER
 COEFFICIENT VERSUS
 HYDROGEN FLOWRATE
 PEWEE 2 FEP-I
 FIGURE 5.6.4

LOG MEAN TEMPERATURE DIFFERENCE - °R
 OVERALL HEAT TRANSFER COEFFICIENT - BTU/FT²-HR-°R

H₂O FLOW - 800 - 1500 GPM
 H₂O T_{inlet} - 200°F

$$* = \frac{(G \times \Delta t) m_p}{A_{TES} \times LMTD}$$

HYDROGEN FLOW RATE - LBS/SEC.

5.7 ACCUMULATOR OPERATING CHARACTERISTICS

During the various run phases of FEP-I and II, the gas accumulator was either operated with H-175 closed or H-175 partly open during normal profile operations in order to evaluate effects on accumulator pressures and temperatures. The partly open position of H-175 was that required to obtain a nominal accumulator pressure 100 psi below line pressure during Pewee 2 FPH conditions. For FEP-I, the accumulator pressure, HP-71, followed the pump discharge pressure with an -80 ± 10 psi difference during the first programmed startup to Pewee 2 Full Power Hold. Prior to the startup, the accumulator vent valve, H-175, was opened to 16%. During the ramp down to the Shutdown Hold, valve H-175 remained open at 16% and the accumulator pressure followed the pump discharge pressure with an approximate difference of -50 psi.

For the second programmed startup to the Pewee 2 Intermediate Power Hold, the vent valve stem position was increased to 19%. The accumulator pressure increased uniformly with pump discharge pressure and remained at an -80 ± 10 psi pressure differential with HP-541. As illustrated in Figure 5.7.1, no variation in accumulator pressurization occurred between the first and second programmed startup of FEP-I even though the position of H-175 varied from 16 to 19%. On the down ramp of the power profile, the relationship of accumulator pressure and pump discharge pressure when H-175 is open to 16% agrees well with the data shown in Figure 5.7.1.

For FEP-II, the accumulator vent valve was closed during the down ramp to shutdown hold point and the behavior of the accumulator is illustrated in Figure 5.7.2. The accumulator pressure, HP-71, remained very nearly equal to the pump discharge pressure, HP-541; but on the down ramp, the warm gas volume expanded beyond HT-74 to HT-75.

ACCUMULATOR GAS BURBLE AT SHUTDOWN HOLD

FIG 5.7.2

As shown in Figure 5.7.2, LT-10N did not indicate the presence of any warm fluid; but a temperature increase occurred at HT-001 indicating that the warm fluid from the accumulator was swept toward the TES and not toward the main propellant line. With the pump increasing the inlet pressure to the accumulator during the re-start operation, both HT-75 and HT-001 became rechilled to LH_2 temperature. Shortly thereafter, the accumulator vent valve was re-opened and the inlet temperature, HT-75, remained chilled during the next profile.

During FEP-II, several additional operations were performed on the gas accumulator to gain greater understanding of its operating characteristics. The vent valve, H-175, was closed as the propellant supply system ramped up to the Pewee 2 Full Power Hold condition. The difference in accumulator and line pressure, HP-541 and HP-71, was zero psid for the entire startup profile.

At the shutdown hold condition (CRT = 17970 seconds), valve H-175 was opened to 100% to warm the gas in the accumulator. The temperature of the gas volume, HT-71, increased from 460 to 540°R in approximately 50 seconds, whereas the accumulator gas discharge temperature, HT-74, increased from 390 to 490°R in the same interval. Thus, at shutdown hold operating conditions, opening H-175 resulted in a temperature rise of the gas in the accumulator of approximately 80°R.

The first run profile of FEP-2 was conducted with vent valve H-175 closed. The FPH condition was maintained for about two minutes and the accumulator gas temperature remained greater than 525°R.

An experiment of chilling the gas in the accumulator at full power operating conditions was also conducted during FEP-2. Vent valve H-175 was opened to 100% nine times for periods of 4 to 8 seconds and the lowest gas temperature achieved was 325°R. The first vent valve opening decreased the gas temperature to 350°R and the remaining eight valve openings only lowered the gas temperature another 25°R. Each time valve H-175 was opened to 100%, the accumulator pressure, HP-71, decreased to zero psig.

The rate of temperature and pressure increase in the gas accumulator was also observed during the nine cycles of H-175. From a chilled temperature of 325 to 350°R, the gas temperature increased at a rate of 5° per second after H-175 was closed. Similarly, from zero pressure in the accumulator, the pressure increased at a rate of approximately 15 to 20 psi per second after closing H-175.

5.8 TURBOPUMP PERFORMANCE

5.8.1 Operating History

The turbopump assembly used during Pewee 2, FEP-I consisted of a Rocketdyne Mark 35 pump (S.N. ROD2R-2) and a Mark 25 turbine (S.N. ROO5R). The pump assembly operated satisfactorily for two hours and 40 minutes during this test, and for one hour and 39 minutes, the turbopump ran at or above Pewee 2 Full Power operating condition.

Nine run phases were successfully completed during FEP-I, including a 60 minute duration run at Pewee 2 Full Power operating conditions. The pump failed to windmill after the completion of "L-109 Failure Full Open Test" when LH_2 at Dewar pressure flowed through L-109 set at 17.5 open. The Facility Experimental Plan was terminated at this time to investigate whether or not the pump could be rotated. After several unsuccessful attempts to rotate the pump, the investigation was ceased and control room operation was secured.

The total operating time history on the Mark 35 pump (SN-ROO2R-2) during Pewee 2 FEP-I and the Mark 35 Test EP-V is outlined below.

TEST	OPERATING SPEEDS VERSUS TIME	TOTAL ACCUMULATED OPERATING TIME
Mark 35 Test EP-V (3-9-70)	$\geq 23,000$ rpm - 28 min.	48 min.
Pewee 2, FEP-I (9-17-70)	7,500 - 8,500 rpm - 4 min.	-
	9,500 - 10,500 rpm - 2 min.	-
	11,500 - 12,500 rpm - 1.5 min.	-
	14,500 - 15,500 rpm - 10 min.	-
	17,500 - 18,500 rpm - 1.5 min.	-
	19,500 - 20,500 rpm - 6 min.	-
	$\geq 23,000$ rpm - 2 hrs. & 7 min.	2 hrs. & 40 min.
TOTAL TIME		3 hrs. & 28 min.

The two hours and seven minutes of operating time accumulated on the Mark 35 pump (SN R002R-2) at or above Pewee 2 full power operating conditions fulfills the two hour endurance test.

Prior to FEP-II, the Mark 35 pump (SN-R002R-2) was removed from Test Cell "C" and shipped to Rocketdyne, Canoga Park for disassembly and inspection. A Mark 35 pump (SN-R001R-3) was installed in Test Cell "C" for Pewee 2, FEP-II. The Rocketdyne Mark 25 turbine, Serial Number (SN-R005R) used during FEP-I was also used during FEP-II. The pump assembly operated satisfactorily for one hour and 28 minutes during FEP-II, of which 38 minutes were at or above Pewee 2 full power operating conditions.

Ten run phases were successfully completed during FEP-II with no variation in the pumping system performance.

The total operating history for the Mark 35 pump (SN-R001R-3) is outlined below.

TEST		OPERATING SPEEDS VERSUS TIME	TOTAL ACCUMULATED OPERATING TIME
Pewee 2, FEP-II (10-8-70)	7,500	- 8,500 rpm - 7 min.	-
	9,500	- 10,500 rpm - 1.5 min.	-
	11,500	- 12,500 rpm - 1 min.	-
	14,500	- 15,500 rpm - 3 min.	-
	19,500	- 20,500 rpm - 6 min.	-
		≥ 23,000 rpm - 38 min.	-
TOTAL TIME			1 hr. & 26 min.

The total operating history on the Mark 25 turbine (SN-R005R) is outlined below.

TEST	DATE	OPERATING TIME AT ≥ 23,000 rpm	TOTAL ACCUMULATED OPERATING TIME
Phoebus-2 EP-III			
Shutdown Studies		36 min.	36 min.
Phoebus-2A EP-III	6-8-68	-	26.7 min.
Phoebus-2A EP-IV	6-26-68	32 min.	32 min.
Phoebus-2A EP-V	7-18-68	16 min.	38.7 min.
Pewee 2 FEP-I	9-17-70	1 hr. & 40 min.	2 hrs. & 39 min.
Pewee 2 FEP-II	10-8-70	38 min.	1 hr. & 27 min.
TOTAL TIME		3 hrs. & 42 min.	6 hrs. & 19 min.

5.8.2

Pump Head-Rise Performance

The data obtained during Pewee 2, FEP-I and FEP-II was used to determine the head-flow characteristic for the Mark 35 pumps Serial Number (SN-R002R-2 and SN-R001R-3). Figure 5.8.2.1 presents the head-flow characteristic for both pumps used during FEP-I and FEP-II.

The Rocketdyne Turbine flowmeter Serial Number SN-7136525 is the same meter used for the Pewee 1 Reactor Test Series. The calibration curve for this flowmeter is presented in the Pewee 1 Final Test Report, LASL J-17-001-69 and the same calibration factor has been incorporated in the determination of the total pump flow rate.

The turbine flowmeter is a Potter type flowmeter built by Rocketdyne. As the flowmeter rotates, the magnetic pickup produces a number of pulse signals per second. The calibration factor used for both Pewee 1 and 2 is 1.455 pulses per gallon.

At the predicted full power operating point for the Pewee 1 reactor, the pump discharge density was estimated to be 4.49 lbs/ft³ and for convenience that value is still used as the reference discharge density.

The full range of the turbine flowmeter is 0 to 100 lbs/second LH₂; therefore, the number of pulses per second from the turbine flowmeter corresponding to 100 lbs/second is:

$$\frac{(100 \text{ lb/sec})(7.4805 \text{ gal/ft}^3)(1.435 \text{ pulse/gal})}{4.49 \text{ lbs/ft}^3} = 242.4 \text{ pulse/sec}$$

It should be pointed out that no change in either pump discharge density or turbine flowmeter calibration factor is included in the determination of total pump flow rate as it varies from 0 to 100 lbs/second.

The measurement Q/N, gpm/rpm, is computed by the following equation:

$$Q/N = \frac{(60 \times 7.4805)}{4.49} \frac{\text{HF-550}}{\text{HQ-500}} \frac{\text{gpm sec}}{\text{lbs}} \frac{(\text{lbs/sec})}{(\text{rpm})}$$

The head rise developed across the pump is calculated from the following propellant feed system parameters:

$$\Delta H = \frac{(\text{HP-541} - \text{HP-511}) \times 144 \text{ ft}}{1/2 (\rho_{\text{in}} + \rho_{\text{out}})}$$

where the inlet density $\rho_{\text{in}} = \phi$ (HP-541, HP-511) and outlet density $\rho_{\text{out}} = \phi$ (HP-541, HP-511).

The experimental data which was recorded during FEP-II and used to calculate the $\Delta H/N^2$ values corresponding to various Q/N operating points for the Mark 35 pump Serial Number (SN-ROOLR-3)

are presented in Table 5.8.2.1 below:

	CRT		14789	14828	14879	14850	14915	14775
HF-550	lbs/sec		36.71	38.64	41.33	39.69	41.98	36.03
HQ-550	rpm		23625	23625	23632	23612	23632	23637
HP-541	psig		883.2	824.3	714.8	794.6	713.6	882.9
HT-541	OR		48.7	47.95	47.0	47.6	47.0	48.8
p out	lbs/ft ³		4.42	4.43	4.42	4.43	4.42	4.42
HP-511	psig		61.6	60.2	60.0	60.15	59.7	60.0
HT-511	OR		38.8	39.2	38.4	38.6	38.55	38.9
p in	lbs/ft ³		4.355	4.33	4.365	4.355	4.36	4.34
Q/N x 10 ⁻¹	$\frac{\text{gpm}}{\text{rpm}}$		1.55	1.63	1.74	1.68	1.77	1.52
N _s			693	750	872	783	880	686
ΔP	psid		821.6	764.1	654.8	734.5	654	822.9
ΔH	FT		26965	25121	21466	24079	21452	27054
ΔH/N ² x 10 ⁻⁵	$\frac{\text{ft}}{\text{rpm}}$		4.83	4.50	3.84	4.32	3.84	4.84

The above data is for speeds greater than 23000 rpm.

MARK 35 PARAMETERS
DURING PEWEE 2 FEP-II

TABLE 5.8.2.1

5.8.3 Forward Bearing ΔP Variation

On the Mark 35 turbopump, the differential pressure across the forward bearing produces a flow of coolant for the bearings. A measure of this differential pressure at various pump operating speeds and specific speeds has been obtained by subtracting the inducer discharge pressure HP-512 from the inducer static or discharge pressure HP-514.

The two pressure transducers are scaled 0 to 500 psi and the observed difference between the two pressures is usually less than 20 psi. Nevertheless, the data shown in Figure 5.8.3.1 indicates a trend that for a wide operating range of the pump, the differential pressure is zero or so slight that coolant flow through the forward bearing probably does not exist.

In Figure 5.8.3.2, the estimated region of Mark 35 turbopump operation which results in negligible forward bearing coolant flow is compared with Pewee 2 pump operating points to show which Pewee 2 turbopump operating conditions would have low coolant flows to the forward bearing.

5.8.4 Mark 35 Pump Damage

The disassembly and inspection of the Mark 35 Pump SN R002R-2, in September 1970 after Pewee 2, FEP-I revealed two areas of internal damage. The outboard forward bearing cage was heavily worn, and the forward rub surface of the balance piston and its accompanying rub ring were severely damaged.

Ns.

550

600

650

700

750

800

850

FORWARD BEARING ΔP (HP-514 - HP-512)

20

16

12

8

4

0

-4

23,500 RPM

15-15,500 RPM

8500 RPM

FORWARD BEARING ΔP VS N_s AT VARIOUS SPEED

PEWEE 2 FEP I

MK 35 SN R002R-2

Figure 5.8.3.1

PEWEE 2 PUMP OPERATING LINE WITH RESPECT TO
REGION OF LOW FORWARD BEARING ΔP
FIGURE 5.8.3.2

5.8.4.1 Bearing Cage Wear

The forward bearing cage wear observed on the Mark 35 pump, SN R002R-2, was similar to that observed on previous pumps. When the pump, SN R001R-2, was disassembled at Rocketdyne in June of 1970 in preparation for the Pewee 2 FEP-II, the outboard forward bearing indicated severe wear. This pump had been used in the LH₂ Jet Pump tests and had ingested much warmer fluid than usual. It was the opinion of Rocketdyne and NRDS personnel that the warm inlet fluid had not properly cooled the bearing, thus causing excessive wear.

The Mark 35 Pump, SN R001R-3, (refurbished SN R001R-2) was used for Pewee 2 FEP-II. It ran for approximately 37 minutes at speeds greater than 23,00 rpm. The Mark 35 pump, SN R--2R-2, will be refurbished and installed for EP-I and EP-II of the Pewee 2 series. The estimated run time above 23,000 rpm for these two EP's will be approximately 90 minutes. To eliminate the possibility of forward bearing wear, the Mark 35 Pump, SN R001R-3, used on Pewee 2 FEP-II, will be re-installed for EP-III. The additional cycles planned for EP-III will give a total run time of slightly more than one hour on SN R001R-3 at speeds greater than 23,000 rpm.

5.8.4.2 Balance Piston Damage

The final emergency shutdown of FEP-I caused severe damage to the forward rub surface of the balance piston and its rub ring. The opening of L-109 to 100% on shutdown caused the pump discharge pressure to decrease faster than the balance piston cavity and sump pressures, thereby shifting the pump rotor forward approximately .006 inches. This caused the forward surface of the balance piston to rub against the forward rub ring. After disassembly, it was noted that the silver plating on the rub ring was worn off and

pieces of silver were lodged between the edge of the balance piston and the pump housing.

Subsequent inspection at Rocketdyne revealed that approximately .080 inch was shaved off the balance piston. As part of the refurbishment operation, a new, thicker rub ring was machined and silver plated.

5.9 HIGH PRESSURE LH₂ COOLDOWN SYSTEM

The performance characteristics of the Dewar 3 system for the various modes of operation planned in the Pewee 2 reactor test series have been determined in FEP-1 and FEP-2. The constant flow of LH₂ Dewar 3 for chilling the discharge line will lower the level of LH₂ to approximately 20%, and refilling the dewar from the cross-connect line is planned. The performance of the discharge line and cross-connect line chilldown, maintenance, and Dewar 3 refill operations are discussed in the following paragraphs.

5.9.1 Initial Chilldown of the Cross-Connect Line

During FEP-I and II, Dewar 3 was filled several times from Dewar 2 by flowing LH₂ through the Cross-Connect System. This system was initially chilled by first flowing through vent valve L-351 until LT-351 was less than 100°R.

Valve X-353 was then opened to complete the chilldown of the system. The fluid temperature decreased to 48°R, the saturation temperature, and remained there unchanged. It was decided that this temperature represented an adequate chill of the system for the subsequent operation of filling Dewar 3 and chilling the discharge line through X-103/X-203. The time required to chill XT-353 to 48°R was 4.5 minutes.

5.9.2 Chill Maintenance and Rechill

When the Dewar 3 initial fill and chilldown of FEP-I was completed, X-303 was closed. The cross-connect line was opened all the way to Dewar 2, but no LH₂ was supplied to maintain a system chill. During FEP-I, the system remained in this condition for approximately 50 minutes, until the third Full Power Hold of the Normal Profile Test (Run #2). At that time, X-353 was opened to 100% to rechill the line in preparation for the Dewar 3 refill experiment at the next shutdown.

hold. In 20 seconds XT-353 decreased from 490°R to 148°R. However, the temperature remained at this level for another 75 seconds, then rapidly dropped to less than 50°R. It was learned during FEP-II that the time required for rechill could be reduced by also opening L-351 until LT-351 was chilled.

5.9.3 Initial Chillydown of Dewar 3 Discharge Line

The initial chillydown of the "X" system and filling of Dewar 3 during FEP-I was accomplished by flowing LH₂ from Dewar 2 through the Cross-Connect System. The Dewar 3 discharge line was chilled by opening X-1, X-103, and X-203. The criteria for an adequate initial chill of the discharge line is that XT-812 and XT-821 are less than 200°R. The time required for the complete operation after the cross-connect system was chilled was 32 minutes. For the filling operation, X-171 was opened; the dewar level slowly increased, and the dewar was completely filled at the end of the chillydown period.

5.9.4 Chill Maintenance During Program Operations

The chill of the X-System discharge line shall be maintained through the Pewee 2 tests by flow of LH₂ through X-203, and, if necessary, by intermittent pulses through X-103. The original plan was to reduce Dewar 3 pressure to 0 psig on each of the shutdown holds. This operation would greatly reduce the flow of LH₂ through X-203. The effect upon the chill of the discharge line was evaluated during the first profile test of FEP-I, and the results of this test are shown in Figure 5.9.4.1. As planned for the Pewee 2 reactor test, the first shutdown lasted 10 seconds. The second shutdown hold lasted 30 seconds. During the third shutdown, a Dewar 3 refill operation was performed. During the programmed restarts following each of these holds, the discharge temperatures of XT-2 and XT-3 were rechilled below the saturation temperature within 30 seconds. This is

CONTROL ROOM TIME - SECONDS

CHILL MAINTENANCE
OF "X" SYSTEM

PEWEE 2 FEP-1

FIGURE 5.9.4.1

NRTO-R-0202

approximately one-half of the time required for the programmed facility parameters to reach the full power operating conditions. Valve X-103 was not used during this test.

The criterion given in the Pewee 2 RTR for chill maintenance of the line is that the entropy be maintained less than 3 BTU/lb-°R which corresponds to 52°R at 100 psig and 55°R at 300 psig. As shown in Figure 5.9.4.1, the flow through X-203 maintained XT-2/3 less than 52°R at pressures greater than 100 psig.

5.9.5 Cross-Connect System Flow Capability During Dewar 3 Refill

A refill of Dewar 3 was performed during the first programmed profile test of FEP-I. The cross-connect system was rechilled prior to the operation by flowing through X-353. The Dewar 3 pressure at XP-61 was approximately 10 psig while LH₂ was supplied to Dewar 3 through X-303. X-161 was in program control and was 50 to 100% open throughout the transfer. As discussed in para. 5.9.7, the flow rate through the cross-connect system was estimated to be 7.6 lbs/sec. This compares well with a previous estimate of between 6.5 and 10 lbs/sec, determined from earlier experimental data.

5.9.6 Dewar 3 Pressurization and Venting During Program Operations

Figures 5.9.6.1 and 5.9.6.2 show the results of programming the Dewar 3 pressure XP-61 during FEP-I. The first programmed operation, shown in Figure 5.9.6.1, was performed with high header pressure

DEWAR 3 PRESSURE
PROFILE FEP-I
NORMAL PEWEE
PROFILE
FIGURE 5.9.6.1

DEWAR 3 PRESSURE
PROFILE FEP-I
RESTART & PROGRAM
SHUTDOWN

FIGURE 5.9.6.2

and a liquid level greater than 75% in Dewar 3. This combination of high supply pressure and low gas ullage imposed a minimum requirement on the flow capacity of both the pressurization and venting systems. The actual Dewar 3 pressure profile achieved was very close to the desired profile.

Figure 5.9.6.2 shows the results of a programmed operation conducted with less than 1200 psig supply pressure and less than 20% liquid in Dewar 3. These conditions are more severe for the pressurization and venting system than any to be expected during the reactor tests. This run was terminated as planned by a programmed shutdown from the Intermediate Power Hold. The pressurization and venting rates were the same as required for a complete run. The actual pressure lagged the demand for the first 25 seconds because the initial demanded pressure increase rate of 10 psi/sec could not be achieved with the low supply pressure. Valve X-53 opened to 100% during this period, but could not supply the necessary flow rate. After 10 seconds, the required pressure profile ramp was 3 psi/sec and the flow through X-53 was sufficient to match XP-61 to the pressure demand. The higher pressure rate was demanded only during the first 10 seconds of the initial startup profile. The Dewar 3 pressure reached within 10 psi of the demanded pressure at 140 psig. Since Dewar 3 is not required for an emergency shutdown during the initial period, the lag in pressure experienced is not significant.

During both tests of the programmed operations of FEP-I, the flow through X-161 was sufficient to vent the dewar, as desired, to less than 100 psig. Below that pressure, the actual pressure lagged the demand. However, Dewar 3 will no longer be functional at that time, since the K-System at a pressure of 100 psig will serve as the primary cooldown system. Therefore, this lag in pressure is also of no consequence.

5.9.7 Dewar 3 Refill Characteristics

Fluid usage predictions for the Pewee 2 power run indicate that it may be necessary to transfer LH_2 from Dewar 1 or 2 into Dewar 3 during one or more of the shutdown holds. As part of the planned operation of FHP-I, a refill operation was performed during Shutdown Hold No. 3 of the first programmed profile run. At the preceding Full Power Hold, the dewar level was lowered to 20% level by flowing through X-103, and the cross-connect line was chilled through X-353. When the dewar pressure was reduced to less than 60 psig, X-303 was opened to begin the refill operation. After approximately 90 seconds, X-303 was closed and the programmed run was resumed. The test was concluded with an Emergency Shutdown from Full Power Hold No. 4.

The level measurement data recorded with the carbon resistor system (XX001) cannot be used to evaluate the filling operation. The discrepancies in this data are discussed in Section 5.15.2.

There was, however, good correlation between several of the Rosemount probes, as shown in Figure 5.9.7.1. At the start of the operation, XT-714 indicated a gas temperature; therefore, the level was between 10 and 20%. However, this measurement indicated LH_2 5 seconds after X-303 was opened. After another 25 seconds, XT-724 (30%) also indicated the presence of LH_2 . When the dewar was subsequently repressurized, XT-724 quickly increased above the saturation temperature. Other Rosemount probes higher in the dewar exhibited a similar reduction during refilling, followed by an increase during pressurization. The magnitude of this reduction was a function of the position of the probes in the dewar. The action of XT-724 indicates that while the filling operation is in progress the level measurements probably are not valid. When the dewar is repressurized, however, the Rosemounts again give reliable indications. In previous tests, the carbon resistors also gave fallacious readings during the filling process but did not return to normal for several minutes after the dewar was

ROSEMOUNT PROBE
INDICATIONS DURING
DEWAR 3 REFILL

PEWEE 2 FEP-I

FIGURE 5.9.7.1

pressurized. Therefore, the existing Dewar 3 Rosemounts are more useful as level indicators because of their more rapid recovery.

In order to estimate the amount of LH_2 transferred into Dewar 3, a number of assumptions have to be made. Table 5.9.7.1 summarizes the analyses and assumptions. It is estimated that 611 pounds were transferred into Dewar 3 during the 80 second refill period. The approximate flow rate was 7.6 lbs/sec. As reported in an earlier test report, LASL J-17-125-70, "Pewee 2 Shutdown Studies, EP-II and Ep-III," flow rate was estimated to be between 6.5 and 10 lbs/sec.

TABLE 5.9.7.1

DEWAR 3 REFILL INVENTORY ANALYSIS

<u>CRT</u>		<u>LH₂</u> <u>Usage</u>	<u>Dewar 3</u> <u>Inventory</u>
17385	XT-714 indicates gas as level is lowered by flow through X-103.	---	962 lbs
17385 to 395	X-103 still open. Flow rate to 24 lbs/sec.	240 lbs	722
17395 to 545	Dewar 3 pressure maintained at 300 psig. Flow through X-203 assumed to be 0.74 lb/sec.	111	611
17545 to 595	Dewar 3 vented. Average flow through X-203 assumed to be 0.37 lb/sec.	19	592
17595 to 675	Refill operation (W lbs. added).	W	592 + W
17675 to 745	Dewar 3 repressurized. Average flow through X-203 assumed to be 0.37 lb/sec.	26	566 + W
17745 to 940	Full Power Hold #4. Flow rate through X-203 assumed to be 0.74 lb/sec.	144	422 + W
17940 to 955	Emergency Shutdown. Flow from X-System estimated to be 4.7 lb/sec.	71	351 + W
17955	XT-714 increase indicating level is 20%	---	962

$$351 + W = 962$$

$$W = 611 \text{ lbs}$$

5.9.8 X-103/X-203 Flow Capability

It is not possible to verify the flow capability of the X-203 vent line, since there were no extended periods at full power conditions during FEP-I or FEP-II. This flow was measured during the Jet Pump Test series. Los Alamos report J-17-017-70 states that the flow rate was 0.74 lb/sec, with 300 psig in Dewar 3.

Prior to the FEP-I refilling operation discussed in para. 5.9.7, the dewar level was reduced by flowing through X-103 with the dewar pressurized to 293 psig. Figure 5.9.8.1 shows the behavior of the level instrumentation during this operation. There was good agreement between the DDP-116 XXI and the Rosemount probes. The combined flow rate through X-103/203 based on level changes indicated by Rosemount probes was 24 lb/sec. Assuming 0.7 lb/sec was flowing through X-203, the C_v of X-103 was 37 when the valve was 100% open.

DEWAR 3
BLOWDOWN WITH
X-103, PEWEE 2

5.9.9 Dewar 3 Level Instrumentation

It was determined from the NRX A-6 and Phoebus 2A reactor test series that carbon resistor level measurement, XX-1, in Dewar 3 could not be used during refilling through X-303. It was thought that the turbulence of LH_2 and cold gas within the dewar produced level indications considerably higher than the actual liquid level. This did not pose a serious problem, since the filling was performed prior to starting the run. The level indication does return to normal within a few minutes following completion of the filling operation. However, it is expected that refilling will be required during the Pewee 2 full power run profile.

Prior to FWP-I the carbon resistor rake was reoriented in an attempt to correct this problem. From experimental data it was observed that the change was only partially successful. As discussed in para. 5.9.7, the Rosemount level probes are also affected by the refilling turbulence. They do, however, return to normal immediately following the operation.

5.10 LOW PRESSURE LH₂ COOLDOWN SYSTEM PERFORMANCE

5.10.1 Initial Chillydown

The "K" System was initially chilled by flowing LH₂ through K-106 first from Dewar 4 and then from Dewar 5. During FEP-I this operation required 383 seconds after K-106 was opened. The system was then allowed to soak with K-1 and K-2 closed and K-106 set to a minimum position to release the fluid boil-off. No specific time was used for the soaking period since other concurrent operations determined the start of the run phase. This initial chillydown consumed 1500 pounds of LH₂ from Dewar 4 and 1000 pounds from Dewar 5.

5.10.2 Chill Maintenance

The Pewee 2 RTR requires that the "K" System fluid temperatures be maintained less than 52°R throughout the run. Past experience has shown that if KT-5 is kept less than 45°R, this criterion is satisfied throughout the line.

During the programmed and manual startups of FEP-I and II, the "K" System was used to provide flow to chill the main line through B-15 and the moderator line through B-215. This procedure provided a thorough chill of the "K" System prior to starting the run. When the turbopump was started and L-11 and L-21 were opened, the "K" System flow was terminated by higher pressure in the main and moderator lines. Through the remainder of each run profile, the chill of the "K" System was maintained by flowing approximately 2 lb/sec through K-107. The best evaluation of this procedure is Normal Profile Test of FEP-I. A constant flow rate of 2.3 lbs/sec was maintained for 11 minutes. At the end of this period KT-1, 5, and 7 were 41, 43 and 45°R, respectively.

The condition of the chill of the system was monitored in the Control Room by observing KT-5 and KT-1. The Control Room meter scaling precluded monitoring KT-7. Prior to the reactor tests this meter will be rescaled and the flow rate can probably be reduced. Occasionally in other runs it was necessary to open K-107 further, but the fluid required for these intermittent higher chilldown flow rates is not considered significant.

5.10.3 Dewar 4 to 5 Transfer Effects (FEP-I)

Only one of the "K" System dewars will be on line during the Pewee 2 Full Power tests. If both K-1 and K-2 were open, considerably more LH₂ would be required to maintain the chill of the discharge lines.

If the LH₂ level in the "on-line" dewar becomes low it will be necessary to change dewars and establish flow from the other one. It is expected that this would be necessary only late in the LH₂ phase of cooldown operations.

A test was performed during FEP-I to evaluate the effect on the system when performing such a transfer. Following Shutdown No. 1, the KF-5 flow rate was set to 2.2 lb/sec with K-6 in Flow Control, Dewar 4 on-line, and valve K-1 open. Dewar 5 was also pressurized to 100 psig but K-2 was closed. The K-2 line was not adequately chilled having been rechilled approximately 47 minutes earlier. To perform the transfer, K-2 was first opened and then K-1 was closed. The effect upon various system parameters is shown in Figure 5.10.1. KT-5 was chilled below the fluid saturation temperature in 25 seconds following the closure of K-1. A slow increase occurred at KT-5 but the test was terminated before a stable condition was achieved. The total increase was only 1°R, and since KT-1 was well chilled at this time this should not produce any significant effects.

TRANSITION FROM
DEWAR 4 TO DEWAR 5
DURING COOLDOWN
PEWEE 2 FEB-1
FIGURE 5.10.1

The results of this test indicated that the transfer between Dewar 4 and 5 can be made without interfering with the reactor cooldown.

5.10.4 K-System Refill from Cross-Connect Line

Following Shutdown #6 of FEP-II, the Cross-Connect System was used to transfer LH_2 from Dewar 2 to Dewar 5. This operation might be required during the cooldown phase of the Pewee 2 reactor test. Liquid hydrogen flowed from Dewar 2 through L-330, X-301, and K-302 into Dewar 5. Dewar 2 was pressurized to 60 psig. K-162, the vent valve on Dewar 5, was used to maintain KP62 at 40 psig. This pressure was later reduced to 25 psig when it became apparent that the filling rate was inadequate. The results of this test are shown in Table 5.10.4. The filling rate was approximately 4 lb/sec. with a pressure differential between Dewar 2 and Dewar 5 of 35 psid.

Since initial flow rate may also have been limited by an incomplete chill of the transfer line, it is recommended that the line be chilled through L-351 and X-353 prior to beginning the transfer operation.

Table 5.10.4
Transfer of LH_2 from Dewar 2 to Dewar 5 (FEP-II)

<u>CRT</u>	<u>KP-62</u>	<u>KL-2</u>	
31382	42.3 psig	18.4 K lbs	K-302 opened
31400	41.7	18.3	
31450	41.1	18.5	
31500	40.4	18.5	
31550	30.2	18.7	
31600	29.4	18.9	
31650	23.7	19.1	
31689	23.8	19.3	K-302 closed

5.10.5 K-System Flow Control Capability

Following the various emergency shutdown tests, K-6 remained open to its clamp (at 36%) until L-11, L-21 and X-3 were closed. The maximum flow capability of this system measured during FEP-II was a total of 9.6 lbs/sec with 7.8 lbs/sec being supplied to the main line. Table 5.10.5 tabulates the system parameters at these maximum flow conditions.

The planned procedure for Pewee 2 cooldown is to switch K-6 to Flow Control and reduce the flow to 5.0 lb/sec and then subsequently to lower flow rates until the minimum controllable rate is reached. During FEP-I, 17 seconds were required to close K-6 sufficiently to reduce the flow rate to 5.0 lb/sec. Subsequent flow rates of 4, 3, 2 and 1.5 were set without difficulty. The time required to make each of these changes was only three to five seconds. The system performance during each of these steps is shown in Figure 5.10.5.1 and Table 5.10.5. When an attempt was made to reduce the flow rate further, however, the flow controller became unstable at about 1.25 lb/sec.

K-6 FLOW CONTROL
CAPABILITY
PEWEE 2 FEP-1
FIGURE 5.10.5.1

EUGENE DIETZGEN CO
NATLNUAEUGENE DIETZGEN GRAPH PAPER
10 X 10 PER INCH

N

DIFFERENTIAL PRESSURE - psid x 2
STEM POSITION - %

CRT	KR-6	KP-5D	KP-5	KP-7	BR-15	BP-15	BT-15	BR-215	BP-215	BT-215
26135 (FEP-I)	37	40	9.4	87.2	53.6	74.2	45.6	38.1	73.5	46.8
26150	37	35	8.8	87.4	53.6	74.7	45.0	38.1	74.9	47.2
26195	6.4	12.5	5.2	51.3	53.6	42.2	44.4	38.1	40.5	46.3
26219	4.9	8.5	4.3	36.1	53.6	29.5	(44.0)	38.1	29.0	(44.9)
26231	3.0	4.2	3.0	34.7	53.6	30.3	(44.6)	38.1	25.4	(43.1)
26244	2.0	2.0	2.1	31.5	53.6	28.6	(44.3)	38.1	22.2	(43.0)
26264	1.0	1.0	1.5	31.3	53.6	27.8	(44.2)	38.1	22.4	(42.7)
33079 (FEP-II)	36.3	28	7.8 (1)	88.8	56.1	85.4	47.1	N/A	N/A	N/A
33101	36.1	42.3	9.6 (2)	85.4	56.1	81.3	46.1	36.8	75.2	49.8

(1) Flow to main line only. L-11 closed

(2) Combined flow to main and moderator lines. L-11, L-21 and X-3 closed.

(T) Saturated Temperature Condition.

"K" SYSTEM FLOW CAPABILITY TEST RESULTS

TABLE 5.10.5

5.11 Thermal Spray System Performance

Heated water from the process water tank was routed through three sections of the TES using the small bypass valves; but only one section was supplied the nominal 1200 gpm flow rate. The total flow rate of heated water was approximately one and a half times the amount required to convert liquid hydrogen to near ambient GH_2 for driving the Mark 25 turbine. A total flow rate of 1200 gpm from the TES will satisfy the thermal spray system requirements. During FEP-I a GN_2 pressure of 50 psig was maintained in the water tank throughout the run. The pressure control valve W-148 maintained the thermal spray system pressure downstream of the TES at 36 psig. Throughout FEP-II, the process water system was operated in a similar mode.

The Thermal Spray System as designed for Pewee 2, FEP-I and FEP-II distributed the TES water effluent over the surfaces of Dewar 1 and 2, Test Cell Building roof, Dewar 3, Tank Farm, Cryogenic Line and Nuclear Furnace System components to prevent overheating from the propellant flare.

The total thermal spray flow rate was 1350 gpm. The specific distribution of water through the thermal spray system will not be reported since the system will be modified to the same nozzle configuration used for the Pewee 1 Reactor Test Series. A subsystem test will be conducted to verify proper thermal spray coverage of surfaces exposed to the reactor plume.

Figure 5.11.1 presents the environmental temperature at Test Cell "C" during the first 45 minutes of the 60 minute duration run. The top two curves are for structures which received no thermal spray during the run. These curves show a variation of temperature which correlates with the hydrogen flow rate. The highest temperature occurred at the

ENVIRONMENTAL
TEMPERATURES
PEWE 2 FEB-I
FIGURE 5.11.1

NRTO-R-0202

motor drive building and the temperature reached $\sim 130^{\circ}\text{F}$ near the end of the 45 minute duration run. The two lower temperatures in Figure 5.11.1 demonstrate that the thermal spray to the more forward areas was adequate. The test cell building roof and Dewar 2 skin temperature were not plotted since both temperatures remained less than 140°F throughout the duration run.

5.12 FLOW CAR SYSTEM PERFORMANCE

For FEP-I and II, the Pewee 2 Reactor was simulated by a Flow Car with two analog control valves located at the termination of the main propellant line and the moderator supply line. The main propellant line on the Flow Car also included a 2.56 inch diameter venturi, BF-13, and a sharp-edged orifice (for FEP-I only).

5.12.1 BF-14 Orifice Performance

The 1.685 inch diameter orifice was designed to develop a 100 psi pressure loss in the piping system when flowing 24.1 pounds per second. This sharp-edged orifice was installed in the main propellant line to attenuate the pressure oscillations originating from the turbopump as a result of an Emergency Shutdown. Figure 5.12.1 displays the system pressure loss as indicated by BP-14D (pipe taps) versus the flow rate of LH_2 through the main propellant line to valve B-15. The measured pressure drop was 112 psid at a flow rate of 24.1 pounds per second.

5.12.2 Flow Car Line Impedance Data

The experimental pressure drop-flow rate data for the Flow Car has often been overlooked in the analysis of data during Facility Check-out runs. But, in order to verify the startup programs intended for the reactor car assembly, the impedance of the propellant and moderator lines are usually accounted for in the determination of the positions of terminal valves B-15 and B-215. At Control Room Time 16529 seconds during the Full Power Hold, the following data was observed or calculated:

$$\begin{aligned}
 (\text{LP-12})-(\text{BP-15}) &= 143 \text{ psid} & (\text{LP-25})-(\text{BP-215}) &= 19 \text{ psid} \\
 \text{BP-14D} &= 109 \text{ psid} & \text{LF-25} &= 5.96 \text{ lbs/sec} \\
 \text{Net } \Delta P &= 34 \text{ psid} & \rho \text{ LF-25} &= 4.2 \text{ lbs/ft}^3 \\
 \text{BF-13} &= 24.07 \text{ lbs/sec} \\
 (\text{LF-10-LF-25}) & & & \\
 \rho \text{ BF-13} &= 4.40 \text{ lbs/ft}^3 \\
 \left(\frac{K}{A^2}\right) &= .026 \text{ inch}^{-4} & \left(\frac{K}{A^2}\right) &= .25 \text{ inch}^{-4}
 \end{aligned}$$

The value of $\left(\frac{K}{A^2}\right)$ has been derived from:

$$\dot{w} = .667 A(\text{pipe}) \sqrt{\frac{g \rho \Delta P}{K}}$$

$$\left(\frac{K}{A^2}\right) = \frac{g \rho \Delta P}{2.24 \dot{w}^2}$$

where A is inches²

ρ is lbs/in³

ΔP is lbs/in²

g is in/sec²

& $\dot{w}$ is lbs/sec

5.12.3 B-15 and B-215 Mapping Data

Very limited experimental data of valve effective area versus stem position was obtained during FEP-I, since the same position for each valve was used for all liquid hydrogen operating conditions. Valve B-15 was operated over a range of 54 to 58% and B-215 was operated over a range of 35 to 38%. The respective range of C_v for each valve is 23 to 27 for B-15 and 5.8 to 6.6 for B-215. These C_v values are lower than the values as determined by water calibration.

5.12.4 Pewee 2 Flow Cart Venturi Flow Rate

Prior to Pewee 2 FEP-II, an equation for the Flow Cart venturi BF-13 was developed for the DDP-116 digital computer. For the 2.56 inch diameter venturi with three-inch diameter inlet and discharge ducts, the ideal equation for a liquid flow rate is:

$$\dot{w} = 3.827 \sqrt{\rho \times BP-13D}$$

The variation in liquid hydrogen density as line pressure is increased to 800 psig has been estimated with the following equation:

$$\rho_{BF-13} = 4.426 + .0000923 (BP-13+13.0)$$

Combining these two relations yields an equation for the computed flow rate at BF-13 requiring only two pressure measurements from the Pewee 2 Flow Cart:

$$\dot{w}_{BF-13} = \sqrt{[64.819 + .00135 (BP-13+13.0)] \rho_{BF-13} D}$$

The Flow Cart venturi was actually installed in a three-inch diameter propellant line with 3 x 4 in. reducers at each end of the venturi. As shown in Figure 5.12.4, the actual flow rate is about 8% less than that computed by the equation. Experimental data from Pewee 2 FEP-II, and Pewee 1 tests have been analyzed and the corrected flow coefficient for this venturi is given in the following flow rate equation:

$$\dot{w}_{BF-13} = 3.606 \sqrt{\rho \times BP-13D}$$

5.13 FLUID UTILIZATION

5.13.1 Summary of Fluids Used

The actual fluids used for FEP-I and FEP-II were monitored carefully during each run day, since the estimates of fluid usage predicted almost complete consumption of LH₂ in Dewar 2 and GH₂ in the tank farm.

The quantity of LH_2 in Dewar 2 prior to FEP-I and FEP-II was 260,000 pounds and 210,000 pounds respectively; and all but 40,000 and 35,000 pounds were used on the two run days. During FEP-I, all the available LH_2 was consolidated into Dewar 1 in order to finish the pump duration run and the remainder of the test phases.

With the capability to remotely supply the Process Water Tank with additional 200⁰F water, the amount of hot water remaining in the tank at the end of each run day was greater than 50%.

Even though long test phases which required powering the Mark 35 turbopump with tank farm gas were accomplished in both FEP-I and FEP-II, the actual GH_2 usage for each run day amounted to only 2/3 of the available quantity stored. Thus, the fluid which influenced the number of tests conducted in both FEP-I and FEP-II was the liquid hydrogen stored in Dewar 2.

5.13.2 Incremental Fluid Utilization

The following table (5.13.1) presents the actual usage of fluids during major test phases of FEP-I and FEP-II. Refilling any vessel with fluid during the run day (for example Dewar 3) is denoted with a plus sign, and the actual recorded usage of fluids is indicated with a negative sign.

Run Phase	Dewar 1 lbs	Dewar 2 lbs	Dewar 3 lbs	Dewar 4 lbs	Dewar 5 lbs	GHe lbs	GH ₂ lbs	GN ₂ lbs	Inerting GN ₂ -lbs	Hot Water gallons
Initial Inventory	6,000	260,000	4,250	27,500	30,000	6,250	11,300	102,600	57,600	225,000
End of Pre-Op Phase	-0	-10,000	+500	-2,500	-0	-250	-800	-400	-10,800	-1,000
End of Green Run	-0	-30,000	-0	-1,200	-1,300	-0	-1,800	-600	-0	-6,000
End of Normal Profile Run	-0	-55,000	-4,500	-6,600	-1,800	-0	-1,600	-1,400	-1,600	-64,000
										+23,000*
End of Restart & Two Shutdowns	-0	-35,000		-7,300	-4,000	-0	-1,700	-1,000	-7,600	-33,000
		+55,000**								+42,000*
End of Duration Run	+27,900	-133,000	+3,800	-300	-100	-0	-1,000	-1,400	-0	-5,000
End of Three More Shutdowns	+8,400	-43,000	-3,500	-0	-9,800	-0	-1,200	-0	-2,000	-56,000
<u>Secure Operation</u>										
Inventory After Secure	42,300	9,000	550	9,600	13,000	6,000	4,000	97,800	19,200	125,000
Actual Fluids Used	---	215,000	8,000	18,000	17,000	~300	7,300	5,000	38,400	165,000

*Added 65,000 gallons of hot water to Process Water Tank remotely during FEP-I
 **Transferred available LH₂ into one Dewar to complete Duration Run and FEP-I.

PEWEE 2 FEP-II ACTUAL FLUID UTILIZATION

Initial Inventory	39,000	210,000	4,700	30,000	30,800	6,300	10,860	92,000	56,000	225,000
End of Pre-Op Phase	-0	-10,000	-0	-3,000	-300	-0	-1,320	-2,800	-16,800	-5,000
End of Green Run	-0	-25,000	-0	-2,000	-0	-0	-1,560	-0	-1,200	-5,000
End of Normal Profile Run	-0	-35,000	-2,400	-0	-1,300	-0	-960	-1,800	-4,400	-60,000
			+2,300							+35,000
End of Six Shutdowns	-0	-65,000	-1,900	-0	-14,500	-0	-1,620	-400	-14,000	-40,000
L-109 Calibration	-0	-22,000	-0	-0	-0	-0	-1,800	-0	-1,000	-1,000
End Profile Run	-0	-18,000	-2,400	-0	-3,400	-0	-300	-600	-1,000	-14,000
Secure	-0	-0	-0	-0	-0	-600	-240	-1,000	-0	-5,000
Inventory After Secure	39,000	35,000	440	25,000	11,300	5,700	3,060	85,400	17,600	130,000
Actual Fluids Used	---	175,000	6,700	5,000	19,500	600	7,200	6,600	38,400	185,000

*Remotely added 35,000 gallons of hot water to Process Water Tank

PEWEE 2 FEP-I ACTUAL FLUID UTILIZATION

TABLE 5.13.1

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5.14

CONTROL SYSTEM PERFORMANCE

The facility control systems which were originally planned to be used for the Pewee 2 reactor tests included the (1) TES ΔP Control, (2) Reactor Total Flow Control, (3) turbopump Speed Control, (4) Pump Specific Speed Control, (5) K-6 Total Flow Control, (6) G-3 Flow Control, (7) G-13 Flow Control, (8) H-53 Pressure Control, (9) Dewar 3 Pressurization Control, (10) Dewars 1 and 2 Pressurization Control, (11) Dewars 4 and 5 Pressurization Control, and (12) Process Water Tank Pressurization Control.

These facility control systems were used to perform the required operations during the Pewee 2 Integrated Facility Test Series. The transfer functions for the controllers used during the FEP tests are given in Appendix A. The operational performance of these control systems during the FEP tests proved satisfactory, except for the Pump Specific Speed controller which was changed after FEP-I and checked out during the FEP-II tests.

The FEP-I control experiments consisted of pseudorandom, step, and sinusoidal tests on the Reactor Total Flow Loop; and step and sinusoidal tests on the Speed loop. These tests were performed at facility operating conditions corresponding to those required for Pewee 2 Full Power Operations. The control system inputs and initial conditions used during these tests are given in Table 5.14.1.

The FEP-II control experiments consisted of step response measurements on the Specific Speed Loop and Reactor Total Flow Loop. The pseudorandom tests performed during FEP-I were repeated during FEP-II since the special zero suppressed channels had not been patched to the narrow band data system during FEP-I.

CONTROLS EXPERIMENTS

PEWEE 2 FEP I

<u>LOOP</u>	<u>INPUTS</u>
FLOW	A) Pseudorandom Input Amplitude: ± 0.5 lb/sec Switching Frequency: 50 Chain Length: 1023 Time: 60 seconds B) Frequency Response Amplitude: ± 1 lb/sec Frequencies: 0.063, 0.1, 0.16, 0.25, 0.4, 0.63, 1, 1.6, 2.5, 4 and 6.3 Hz
SPEED	A) Frequency Response Amplitude: ± 400 rpm Frequencies: Same as above

INITIAL CONDITIONS FOR THE ABOVE TESTS

FLOW	29.7 lb/sec
SPEED	23,630 rpm

TABLE 5.14.1

The TES ΔP , Reactor Total Flow, Pump Speed, Pump Specific Speed control system performance are discussed in the following sections.

5.14.1 TES ΔP Control

The TES was operated in ΔP Control during the Pewee 2 Normal Profile operations conducted during FEP-I. The ΔP demand was set for 50 psid on the first normal profile run of FEP-I, but was changed to 30 psid on the second normal profile run of FEP-I in an attempt to increase the available inlet pressure to H-60 and reduce the apparent tendency of the system to fall out of bootstrap during Flow Bias operations. However, this change did not have any effect on the apparent tendency to fall out of bootstrap.

The TES pressure oscillations observed in ΔP Control are discussed in Section 5.3.2. The TES ΔP controller attempted to correct for the ΔP change across H-11 but was not able to do so. As discussed in Section 5.3.2, the TES pressure oscillations ceased when H-11 was opened to 100% in Position Control. As discussed in Section 5.3.2, the speed controller was able to maintain stable pump operating conditions when the turbopump was operated in Flow Bias control even though oscillations were occurring in the TES with H-11 in ΔP Control. It is expected that satisfactory Pewee 2 normal profile operations could be achieved with the TES ΔP controller, although it is planned to operate with H-11 set at 12% in Position Control during the Pewee 2 reactor tests.

5.14.2 Pump Specific Speed Control

The Specific Speed Controller exhibited ringing when perturbed by noise spikes in L-109 valve position when the turbopump was operated in Specific Speed Control during the FEP-I turbopump checkout run. Analysis of the HF-550 pump flow and HQ-550 pump RPM data revealed clear signals.

The Specific Speed controller gain was changed by -6 db to FEP-II.

A step response test was performed during the FEP-II turbopump check-out run on the Ns Controller to evaluate the effect of the 6 db gain reduction on Ns loop. The initial conditions and input signal parameters are given in Table 5.14.2.1. A reproduction of the CRS data traces shown in Figure 5.14.2.1. The step response on FEP-II revealed that the gain reduction eliminated the ringing yet retained adequate Ns response.

5.14.3 Pump Speed Control

Frequency response tests on the Speed Controller were performed during FEP-I. The initial conditions and input signals were given in Table 5.14.1. The results of the frequency response tests and the Nichols plot are given in Table 5.14.3.1 and Figure 5.14.3.1, respectively. The remaining related data is listed in Table 5.14.3.2.

The pump speed controller is considered satisfactory to support the Pewee 2 reactor tests based on the FEP-I and -II tests.

5.14.4 Total Reactor Flow Control

The turbopump was operated in Total Reactor Flow Control during the FEP-I and FEP-II Pewee 2 normal profile operations.

During FEP-I, frequency response measurements were made with the turbopump operated in Total Reactor Flow Control at facility operating conditions corresponding to Pewee 2 Full Power operations. The initial conditions and input signals are given in Table 5.4.1. The results of the frequency response tests are given in Table 5.14.4.1 and other

Loop	Ns
Initial Condition	L-109 at 10% Ns Control at 880 RPM = 23,500 Green Run
Inputs	0.3V Step in Ns Demand

FIGURE 5.14.2.1

FIGURE 5.14.2.1

RPM CONTROLLER RESPONSE

FREQUENCY CPS	db	RPM/RPM ϕ	<u>RPM</u> HR-60 db	<u>RPM</u> % ϕ	<u>LF-10</u> RPM db	<u>Lb/Sec</u> RPM ϕ
.063	0	0	+60	-67	-60	-22
.1	-.2	-9	+56	-36	-60.5	-27
.16	-1.3	-12	+56	-29	-64	-11
.25	-1.4	-9	+57	-32	-64	+23
.4	-1.5	-17	+56	-46	-62	0
.63	-1.5	-23	+54	-68	-60.5	0
1.0	-1.5	-32	+50	-72	-60	-15
1.6	-1.5	-52	-	-	-60.5	+11
2.5	-2.5	-81	-	-	-	-
4.0	-6.9	-137	-	-	-	-
6.3	-13.3	-180	+33	-135	-	-

TABLE 5.14.3.1

RPM RESPONSE DATA FEP I

FREQUENCY CPS	RPM OSC ^D ø	RPM M ø	HC-60 % ø	HR-60 % ø	LF-10 Lb/Sec ø	HF-550 Lb/Sec ø
.063	804 0	814 0°	0.72 +65	.96 +67	.81 -22	2.07 +25
.10	804 0	782 -9	0.1 +27	1.2 +27	.71 -36	2.58 +5
.16	804 0	695 -12	0.9 +17	1.1 +17	.45 -23	2.65 0
.25	804 0	685 -9	0.8 +14	.96 +23	.45 +14	2.43 -9
.40	804 0	672 -17	0.9 +35	1.08 +29	.51 -17	2.84 -9
.63	804 0	672 -23	1.14 +55	1.38 +45	.61 -23	2.95 -18
1.0	804 0	672 -32	1.74 +47	2.04 +40	.64 -47	3.06 -47
1.6	790 0	660 -52	2.67 +41	- -	.61 -41	3.1 -81
2.5	790 0	590 -81	- -	- -	- -	2.7 -135
4.0	790 0	360 -137	- -	- -	- -	1.62 -230
6.3	780 0	168 -180	3.4 0	3.9 -45	- -	0.36 -315

TABLE 5.14.3.2

FLOW CONTROLLER RESPONSE

FREQUENCY CPS	FLO/FLO		LF-10 Lb/sec	
	db	ϕ	HR-60 db	ϕ
.063	-.8	-63	+1	-100
.1	-4.8	-65	-5	-65
.16	-14.2	-93	-8.3	-26
.25	-16.2	-45	-7.5	-18
.4	-15.5	-36	-5.2	-22
.63	-14.1	-45	-	-
1.0	-12.8	-43	-	-
1.6	-11	-50	-	-
2.5	-13.5	-117	-	-

TABLE 5.14.4.1

related data is given in Table 5.14.4.2. Figure 5.14.4.1 shows the frequency response data plotted on a Nichols chart.

During FEP-II, step response test was performed with the turbopump operated in Total Reactor Flow Control at facility operating conditions corresponding to Pewee 2 full power hold and shutdown hold conditions but with H-11 full open in Position Control. The conditions and input parameters for these tests are listed in Table 5.14.4.3. Figures 5.14.4.2 and 5.14.4.3 show reproduction of the CRS data traces for the step response test performed at the full power hold and shutdown hold, respectively. Satisfactory loop response was obtained with no overshoot or ringing. The response was one second faster under these conditions than the response measured during FEP-I, five seconds versus six seconds. A small flow oscillation was evident during this shutdown hold and is believed to be due to having H-11 full open. The oscillation was 4.5 CPS and 0.3% (0.15 lbs/sec) peak amplitude.

FLOW RESPONSE DATA FEP I

FREQUENCY CPS	$\dot{w}_D$ PP OSC		LF-10		HC-60		HR-60		RPM		HF-550	
	Lb/Sec	ϕ	Lb/Sec	ϕ	%	ϕ	%	ϕ	RPM	ϕ	Lb/Sec	ϕ
.063	1	0°	.92	-63	.72	+34	.81	+37	815	-27	2.3	0
.1	1	0°	.57	-65	.93	0	1.02	0	768	-52	2.7	-32
.16	1	0°	.19	-93	.45	-41	.51	-38	540	-70	1.2	-64
.25	.99	0°	.15	-45	.3	-27	.36	-27	252	-63	.81	-63
.40	.99	0°	.16	-36	.24	-14	.3	-14	144	-57	.57	-57
.63	.99	0°	.19	-45	-	-	-	-	-	-	-	-
1.0	.99	0°	.22	-45	-	-	-	-	-	-	-	-
1.6	.99	0°	.27	-50	-	-	-	-	-	-	-	-
2.5	.99	0°	.21	-177	-	-	-	-	-	-	-	-

TABLE 5.14.4.2

Loop	Flow	Flow
Initial Condition	Full Power Hold H-11 at 100%	Shutdown Hold H-11 at 100%
Inputs	2V Step Decrease in Flow Demand ($\Delta 1$ #/Sec)	0.8V Step Increase in Flow Demand ($\Delta 0.4$ #/Sec)

Table 5.14.4.3

FIGURE 5.14.4.2

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FIGURE 5.14.4.3

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5.15 INSTRUMENTATION AND DATA SYSTEM PERFORMANCE

The following sections provides a discussion of the performance of Test Cell "C" instrumentation and data system which were used for both FEP-I and FEP-II.

5.15.1 Instrumentation

The instrumentation system performed satisfactorily during FEP-I and FEP-II. The instrumentation used during FEP-I and FEP-II was as given on the As-Run Pewee 2 FEP-I and Pewee 2 FEP-II channel lists. The following significant anomalies occurred.

HP-541 W produced erroneous pressure amplitude data during FEP-II. When compared with the related channel, SHP-541. The wide band channel exhibited an error of approximately 15% of full scale. This discrepancy is due to the temperature sensitivity of the pressure transducer which is flush-mounted on the LH₂ discharge line. A temperature compensated transducer is not available; therefore, the uncompensated one will continue to be used for Pewee 2.

The radial accelerometer for the turbine, HA-514, exhibited a dc offset during FEP-I. Consequently, it was removed from the VCD turbopump vibration input to the shutdown chain. Subsequent to FEP-I, the transducer and signal conditioner were checked and found to be satisfactory. The cable from the transducer to the signal conditioner was replaced, in that liquid air dripping on it may have caused it to be in error. This action corrected the problem for FEP-II.

The TES exit gas temperature channels, HT-012 and HT-032, were under-ranged during FEP-I for Mark 35 turbopump operation. At low turbine gas flow rates, the TES hydrogen gas exit temperature exceeds the 35-590°R range for these channels.

The accumulator check valve AP channel, HP-76D, became erratic during both FEP-I and II. Even though the pressure transducer was scaled 0-500 psid, the transducer may have been over-ranged during the run phases. A small hole discovered in the tubing on the low pressure side of the transducer might have caused the transducer to be subjected to full pump discharge pressure. For EP-I of Pewee 2 Reactor Test Series, a 0-1000 psid pressure transducer scaled to a 0-500 psid range will be installed.

Early in the run phase of FEP-I, channel BP-13D failed and indicated full scale throughout the day. Subsequent investigation revealed that the transducer was damaged. Prior to FEP-II, the differential pressure transducer was replaced and functioned properly during the entire test.

5.15.2 Data System Anomalies

The recording, processing and presentation of the data from the CEC recorders and the DDP-116 experienced no anomalies during FEP-I. Except for inadvertently switching two Sanborn channel titles on the run day setup, there were no anomalies in the Sanborn system.

A review of the 257 channels printed as Cal-Comp plots revealed that four channels were noisy, i.e., greater than 2% of full scale fluctuations. Three hydrogen gas temperature channels

were off-scale but the processing of the off-scale data was correct.

For FEP-II, no anomalies existed in the CEC, DDP-116 and Sanborn system data processing operation. As before, an analysis of 288 channels printed as Cal-Comp plots was conducted and, for almost the entire test, only five channels exhibited noise greater than 2% of full scale. For the last run phase, however, the data acquisition system began to introduce noise onto the magnetic tape. An investigation of the digitized tape for this portion of FEP-II showed that it was very noisy, consequently, all the subsequent processing generated noisy Cal-Comp plots. The output of the multiplexers for the last run was recorded in a faulty manner, either the tape was faulty or the recording heads were unclean. Additional checkout of this system is underway to verify that proper system operation will be assured for Pewee 2 EP-I.

During the data analysis effort following FEP-I, it was discovered that the Cal-Comp plot for Dewar 3 liquid level, XX-001, did not agree with the DDP-116 output data. Examination of the data reduction program which converts the input voltage signal to output data in engineering units, revealed an error in the corresponding Dewar 3 volume-to-voltage conversion values. The program has been corrected and channel XX-001 will indicate more accurately for Pewee 2 EP-I.

Severe oscillations in the Cal-Comp plot data were observed during transient periods of system operation. The other sources of data did not indicate such fluctuations. A parabolic interpolative sub-routine used to adjust the processed data to a common base of Control Room Time was not correctly processing the data.

For Pewee 2 EP-I, this sub-routine will not be operational; however, another technique for identifying the time of each channel recording will be employed. For FEP-I, the pump discharge pressure wide band channel, HP-541 W, was not recorded on FM tape. During the R-1 day setup checklist, this channel operated properly. After FEP-I was completed, this malfunction was corrected for FEP-II. The fault was assigned to either the signal conditioning or recording processes.

APPENDIX A

TEST FACILITY SYSTEM ENGINEERING DATA

APPENDIX A

TEST FACILITY SYSTEM ENGINEERING DATA

A.1 Turbopump Assemblies

The turbopump Assemblies used during FEP-I and FEP-II and the corresponding operating histories are as described in Section 5.8.

A.2 Main and Moderator Line Terminal Filters

The LM-2018 filter element installed in the main supply line preceding FEP-I was provided with a 81.5 psid (-423°F) rated burst disc.

The LM-2028 filter element installed in the moderator supply line preceding FEP-I was provided with a 73 psid (-423°F) rated burst disc.

A.3 System Controllers

The transfer functions for the process System Controllers used during FEP-I and FEP-II are given in Table A.3.1.

It is to be noted that the only change in the system controllers between FEP-I and FEP-II was for the Specific Speed (N_s) controller. The reason for this change is discussed in Section 5.14.

A.4 DDP-116 Generated Program Demands

The program demand profiles that were generated by the DDP-116 for FEP-I and FEP-II are given in Table A.4.1 and A.4.2, respectively. The program demand profiles used during FEP-I and FEP-II provided for Dewar 3 pressure, total reactor flow rate, L-111 position and L-11 position. It is to be noted the most significant change in

APPENDIX A

TABLE A-3.1

SYSTEM CONTROLLER TRANSFER FUNCTIONS USED FOR FEP-I AND FEP-II

Pump Speed (RPM)	$\frac{\delta X_T}{\delta N_E} = \frac{.004 (s + 1)}{s (\frac{s}{100} + 1)}$	$\frac{\%}{\text{RPM}} - \text{Sec}$
Total Reactor Flow	$\frac{\delta N_D}{\delta \dot{V}_E} = \frac{464 (\frac{s}{3} + 1)}{s}$	$\frac{\text{RPM} - \text{Sec}}{\text{lbs/Sec}}$
Pump Specific Speed (N_S)	$\frac{\delta X_{LHBV}}{K\delta N - \delta \dot{W}_P} = \frac{1.5 (\frac{s}{16} + 1)}{s (\frac{s}{100} + 1)}$	$\frac{\%}{\text{lbs/Sec}} - \text{Sec}$
FEP-I		
FEP-II	$\frac{\delta X_{LHBV}}{K\delta N - \delta \dot{W}_P} = \frac{0.75 (\frac{s}{16} + 1)}{s (\frac{s}{100} + 1)}$	$\frac{\%}{\text{lbs/Sec}} - \text{Sec}$
K-6 Total Flow	$\frac{\delta X_6}{\delta \dot{W}_E} = \frac{(\frac{s}{10} + 1)}{s}$	$\frac{\%}{\text{lbs/Sec}} - \text{Sec}$
G-3 Flow	$\frac{\delta X_3}{\delta \dot{W}_E} = \frac{26 (\frac{s}{22} + 1)}{s (\frac{s}{1900} + 1)}$	$\frac{\%}{\text{lbs/Sec}} - \text{Sec}$
G-13 Flow	$\frac{\delta X_{13}}{\delta \dot{W}_E} = \frac{15 (\frac{s}{14} + 1)}{s (\frac{s}{2140} + 1)}$	$\frac{\%}{\text{lbs/Sec}} - \text{Sec}$
H-53 Pressure	$\frac{\delta X_{53}}{\delta \text{HP-60}_E} = .08 \frac{\%}{\text{PSI}}$	
Dewars 1 and 2 Pressure	$\frac{\delta X_{53}}{\delta P_E} = 10 \frac{\%}{\text{PSI}}$	

APPENDIX A

TABLE A-3.1 (CONT.)

SYSTEM CONTROLLED TRANSFER FUNCTIONS USED FOR FEP-I AND FEP-II

Dewars 4 and 5
Pressure

$$\frac{\delta X_{53}}{\delta P_E} = \frac{6.6}{\left(\frac{s}{200} + 1\right)} \quad \frac{\%}{\text{PSI}}$$

Dewar 3
Pressure

$$\frac{\delta X_{53}}{\delta P_E} = \frac{-\delta X_{161}}{\delta P_E} = \frac{8\left(\frac{s}{10.3} + 1\right)}{\left(\frac{s}{.53} + 1\right)} \quad \frac{\%}{\text{PSI}}$$

TES ΔP

$$\frac{\delta X_{HE}}{\delta P_E} = \frac{.059 \left(\frac{s}{.63} + 1\right)}{s \left(\frac{s}{10} + 1\right)} \quad \frac{\% - \text{sec}}{\text{psi}}$$

APPENDIX A

Time (Seconds)	Hold	Flow Rate (lb/sec)	Dewar 3 Pressure (psig)	L-11 Position (%)	L-111 Position (%)
0	ICL	0	0	0	32
3				8	12
6				20	
10		12.0	100	100	0
*60	IPH	27.0	250		
*70	FPH #1	30.1	300		
125			0		
140	SDH #1	12.0	0		
150	SDH #1	12.0	0		
*210	FPH #2	30.1	300		
265			0		
280	SDH #2	12.0	0		
310	SDH #2	12.0	0		
*370	FPH #3	30.1	300		
425			0		
440	SDH #3	12.0	0		
450	SDH #3	12.0	0		
*510	FPH #4	30.1	300		

* Automatic Hold

RUN PROFILE DEMANDS
 PEWEE 2 FEP-I
 TABLE A.4.1

APPENDIX A

Time (Seconds)	Hold	Flow Rate (lb/sec)	Dewar 3 Pressure (psig)	L-11 Position (%)	L-111 Position (%)
0	ICL	0	0	0	32
3				8	12
6				20	
10		12.0	100	35	0
26				100	
*60	IPH	27.0	250		
*70	FPH #1	30.1	300		
125					
140	SDH #1	12.0	0		
150	SDH #1	12.0	0		
*210	FPH #2	30.1	300		
265			0		
280	SDH #2	12.0	0		
290	SDH #2	12.0	0		
*350	FPH #3	30.1	300		
405			0		
420	SDH #3	12.0	0		
430	SDH #3	12.0	0		
*490	FPH #4	30.1	300		

*Automatic Hold

RUN PROFILE DEMANDS
PEWEE 2 FEP-II
TABLE A.4.2

APPENDIX A

the program profile between FEP-I and FEP-II was for L-11. This change was made to obtain a slower opening rate against the mechanical block installed for L-11 which limits its maximum opening to 17.3%.

The Programmed Shutdown Profiles consisted of (1) a decrease in total reactor flow rate program demand from the level at the time of Program Shutdown initiation to 12 lbs/sec at -0.25 lbs/sec/sec and (2) a decrease in Dewar 3 pressure program demand from the level at the time of Program Shutdown initiation to 0 psig in the time interval required to achieve a flow rate of 12 lbs/sec.

A.5

Data and Instrumentation

The Test Flow Car and Test Facility instrumentation is that given in the "As Run" Pewee 2 FEP-I channel list dated September 17, 1970, and the "As Run" Pewee 2 FEP-II channel list dated October 8, 1970.

The Multiplex, Wide Band, Sanborn and CEC Data available from FEP-I and FEP-II are given in the above referenced documents.

The equations used for DDP-116 computation are given in Table A.5.1.

A.6

Emergency Shutdown Chain

The Emergency Shutdown Chain inputs and resulting valve actions used during FEP-I and FEP-II were as given in Table A.6.1.

The valve actions shown are those used for the referenced Pewee 2 Emergency Shutdown System during FEP-II. The alternate valve actions used during FEP-I and FEP-II are discussed in Section 4.0 and 5.5.

APPENDIX A

<u>Display</u>	<u>Equation</u>
Q/N	100 (HF-550)/HQ-550
BF-13	(LF-10)-(LF-25)
BF-13C	$\sqrt{[64.819+.00135(BP-13+13)] (BP-13D)}$
LF-10	$\sqrt{[97.09+.00245(LP-010-13)] (\frac{LP-010D+LP-510D}{2})}$
N _S	$\frac{(HQ-550) \sqrt{100 (HF-550)}}{[32.07(HP-541)-32.90(HP-511)]^{\frac{3}{4}}}$
LF-25	$\sqrt{[6.104+.00010 (LP-025+13)] (LP-25D)}$
D/C	HP-541/HP-522
C/S	HP-522/HP-523
DP-1	(HP-514 + 100) - (HP-512)

DDP-116 COMPUTATIONS
PEWEE 2 FEP-I & FEP-II

TABLE A.5.1

APPENDIX A

TABLE A-6.1

EMERGENCY SHUTDOWN CHAIN INPUTS AND VALVE ACTIONS

PARAMETERS	CHAIN INPUTS		NOMINAL OPERATING POINT	CONSOLE ALARM SETTING	PCD LIMIT
	CHANNEL	TYPE			
Boiler Inlet Pressure	HP-67	High	120 psig (max.)	145 psig	225 psig
Turbine Inlet Temperature ⁽¹⁾	HT-60	Low	520°R (min.)	425°R	400°R
Turbopump Speed	HQ-590/H -590A	High	24,000 (max.)	1000 rpm below OST Setting	30,000 rpm (max.)
Pump Inlet Pressure ⁽¹⁾	HP-511	Low	50-60 psig	40 psig	33 psig
Pump Inlet Temperature ⁽¹⁾	HT-511	High	41°R (max.)	N/A	43°R
Pump Discharge Pressure ⁽¹⁾	HP-541	High	990 psig (max.)	1100 psig	1500 psig
Servo Hydraulic Pressure	JP-101/JP-201	Low	3000 psig (min.)	2400 psig	1600 psig
W/K	-	Low	N _S =575 (min.)	N/A	N _S =550
Nozzle Feed Line Pressure Change	LV-12	Step	N/A	N/A	± 100 psi
Vibration Cutoff #1 ⁽¹⁾ (Turbine Radial)	HA-514	High		N/A	50g Peak to Peak
Moderator Feed Line Pressure Change	LV-25	Step	N/A	N/A	± 100 psi
Dewar 1 Pressure ⁽¹⁾	LP-61	High	40-50 psig	60 psig	65 psig (Recir- culation only)
Loss of Critical Power at CP or TCC	-	-	-	-	Loss

(1) NOT PLANNED TO BE ACTIVE FOR PEWEE 2 REACTOR EP II/III

APPENDIX A

TABLE A-6.1 (CONT.)

EMERGENCY SHUTDOWN CHAIN INPUTS AND VALVE ACTIONS

CHAIN INPUTS

VALVE	ACTION
H-60	Close
H-53	Close
H-101	Open to 10% after 0.5 sec. delay
H-11/21/31	Close
H-142	Open
H-180	Open
H-70	Close
H-175	Close
L-109	Open to 15%
L-11	Close from 37% to 6.3% (0.2-in^2) after a 0.45 sec. delay.
X-53	Close
X-161	Close

APPENDIX A

The nozzle and moderator feed line pressure change circuits will trip the ESD chain when two out of three pressure signals indicate either a ± 100 psi step change or when the circuit output voltage (e_o) reaches five volts in accordance with following equation for a ramp.

$$e_o = 20 \times (1 - e^{-0.5 t})$$

e_o = output voltage

x = pressure ramp rate in volts/second

t = duration of ramp in seconds

A.7 Valve Holding Circuits

The following analog valves were provided with holding circuits during Pewee 2 FEP-I and FEP-II.

L-11	Hold Open and Hold Closed	G-13	Hold Closed
L-111	Hold Closed	X-53	Hold Closed
H-101	Hold Closed	X-103	Hold Closed
H-142	Hold Closed	X-153	Hold Closed
K-107	Hold Closed	X-161	Hold Closed
G-3	Hold Closed		

A.8 Electrical Clamps

The following valves were provided with electrical clamps during Pewee 2 FEP-I and FEP-II.

For FEP-I, L-109 was provided with a valve electrical clamp which prevented L-109 from opening beyond 16.5% (corresponding to an effective flow area of 0.94 in^2). For FEP-II, the clamp setting was reduced to 15.0% for an effective flow area of 0.84 in^2 .

APPENDIX A

K-6 was provided with a valve electrical clamp which prevented K-6 from opening beyond 35% (corresponding to a C_v of 80).

H-60 was provided with a valve electrical clamp which prevented H-60 from opening beyond 55%.

A.9

Mechanical Blocks

A mechanical block was installed on L-11 after FEP-I which prevents the valve from opening beyond 37.3%. A mechanical block was installed on L-109 after FEP-I which prevents the valve from opening beyond 17.3%. L-21 was provided with a remote insertable mechanical block after FEP-I which prevents the valve from closing less than 14.7% with the block in place and the valve operating under full hydraulic pressure. K-6 was also provided with a remote insertable mechanical block which prevents the valve from closing less than 6% with the block in place.

A.10

Flow Meter and Orifice Devices and Restriction

The flow meter and orifice devices used during Pewee 2 FEP-I and FEP-II are presented in Table A.10.1.

A.11

Analog Control Valves

The analog control valves and the corresponding manufacturer quoted C_v and trim used during Pewee 2 FEP-I and FEP-II are presented in Table A.11.1. The manufacturer quoted C_v are equal to or less than the actual C_v determined by test.

MEASUREMENTS	ELEMENT	TYPE	SIZE	TRANSDUCER RANGE	CHANNEL RANGE	FLOW RATE EQUATION	SERIAL OR DWG NUMBER
LH ₂ Main Line Flow Rate	LF-10	Venturi	3.0"	0-25 psid	0-50 lb/sec	4.72/0LP-10D	56Y-117403
LH ₂ Pump Discharge Flow Rate	HF-550	Turbine	6.0"	0-10 volts	0-100 lb/sec	242.3 pulses/sec for 100 lbs/sec	S/N 7136525
TES LH ₂ Flow Rate	HF-10	Venturi	1.485"	0-25 psid	0-12.5 lb/sec	2.5/HP-10D	56Y-117138
	HF-30	Venturi	1.485"	0-25 psid	0-12.5 lb/sec	2.5/HP-30D	56Y-117138
Total Water Flow Rate	WF-11	Magnetic Flow Meter	6.0"	---	0-1500 gpm	---	6610-00158/4
	WF-31	Magnetic Flow Meter	6.0"	---	0-1500 gpm	---	6610-00158/2
Moderator Flow Rate	LF-25	Venturi	1.5"	0-15 psid	0-10.0 lb/sec	1.188/0LP-25D	56Y-117417
Cart Main Flow Rate	HF-13	Venturi	2.56"	0-25 psid	0-40 lb/sec	3.827/0BP-13D	56Y-117301
GH ₂ Flow Rate	GF-4	Venturi	1.45"	0-1500 psig	0-15 lb/sec	.010 (GP-4+13)	56Y-117403
GHe Flow Rate	GF-14	Venturi	1.20"	0-1500 psig	0-15 lb/sec	.010 (GP-13+13)	39720
K-System LH ₂ Flow Rate	KF-5	Venturi	1.147"	0-50 psid	0-10.5 lb/sec	1.482/KP-5D	(Not Assigned)
FLOW Cart Restrictive Orifice (FEP-I Only)	BP-14D	Orifice	1.1685"	0-150 psid	0-100 psid at 23.7 lb/sec		65Y-143221B
Recirculation Line	LO-2091A	Orifice	1.273"	N/A	N/A	N/A	1440043

FLOW METER AND ORIFICE DATA
PEWEE 2 FEP-I AND FEP-II

TABLE A-10.1

APPENDIX A

Valve No.	Labeled Plug Trim & C _V	Valve No.	Labeled Plug Trim & C _V
H-11	76 Linear	G-3	19 Equal %
H-31	76 Linear	G-13	76 Equal %
H-53	50 Linear	L-11	1500 Special
H-60	50 Linear	L-21	76 Equal %
H-101	35 Equal %	L-53	35 Linear
H-142	130 Linear	L-111	250 Equal %
H-175	35 Equal %	L-121	35 Linear
K-6	850 Special	L-109	(5.5 in. Butterfly)
K-53	50 Equal %	W-53	35 Equal %
K-103	46 Equal %	W-148	195 Semi-throttle
K-106	110 Equal %	X-53	7.6 Equal %
K-107	76 Equal %	X-103	46 Equal %
B-15	110 Equal %	X-153	35 Equal %
B-215	46 Equal %	X-161	110 Equal %
		X-353	12 Equal %

ANALOG CONTROL VALVES
PEWEE 2 FEP-I & FEP-II

TABLE A.11.1

A.12 Moog Servo Valve

The moog servo valves associated with the analog control valves used during Pewee 2 FEP-I and FEP-II are presented in Table A.12.1.

A.13 Pressure Transducer Sensor Line Data

The physical data pertinent to various pressure transducer sensor lines used during Pewee 2 FEP-I and FEP-II is presented in Table A.13.1.

VALVE	SERVO S/N	SERVO SIZE	SERVO MODEL
H-60	207	25 gpm	72-101
L-109	8	25 gpm	72-191
L-11	23	60 gpm	72-103
L-21	405	25 gpm	72-101
K-6	40	60 gpm	72-103
B-15	58	25 gpm	72-101-3
B-215	2001	10 gpm	73-103F
L-111	259	25 gpm	72-101
L-90	407	25 gpm	72-101

MOOG SERVO DATA

PEWEE 2

FEP-I & FEP-II

TABLE A.12.1

APPENDIX A

CHANNEL NO.	CHANNEL	TRANSDUCER	TRANSDUCER	LINE	LINE	TRANSDUCER	TRANSDUCER	TRANSDUCER	NO. OF								
PARAMETER	TITLE	TYPE	MAX. CAL-psig	ELEMENT ORIENTATION	INSULATION	TUBING TAP LOCATION	PORT ORIENTATION	TUBE LENGTH etc.	length Inches	Size	# of valves	Expans. Loops	90° Bend	45° Bend	Tee's Straight	Tee's thru Branch	
LP-25	Pressure Upstream of LF-25	S.G.	2000	Horizontal	foam	≈ 8' upstream of LM2028 inlet Noise filter 1/8" tube 48" long With 3 45°	45° from top		132	1/4"	2		10	1	0	1	
BP-13	Pressure Upstream of Cart Venturi	S.G.	1000	Vertical	foam	37" downstream of elbow from shadow wall	Westside		244	1/4	1	4 of 10"	0	7	7	1	0
BP-13D	Propellant Delta P. BF-13 Cart Venturi	S.G.	25 psid	Vertical	High foam	37" downstream of elbow from shadow wall	Westside		248	1/4	1		0	8	6	0	0
				Vertical	Low	44" downstream of elbow from shadow wall	Westside		271	1/4	1		0	9	8	0	0
LP-90	High Pressure Upstream of L-90	S.G.	2000	Vertical	vacuum jacketed	12" upstream of L-90 inlet flange	Westside		129	1/4	1		1	5	1	0	1
BP-14D	Pewee 2 Flow Car Orifice (FEP-I only)	S.G.	150 psid	Horizontal	High foam	8" upstream of Marman flange	bottom		295	1/4	1		0	9	3	0	0
					Low	25 1/2" downstream of flange (Marman)	bottom		298	1/4	1		0	7	3	0	0
BP-15	Reactor Simulator Upstream Pressure	S.G.	1000	Vertical	foam	6" upstream of B-15 inlet flange	Southside		275	1/4	1		0	12	6	0	0
BP-215	Moderator Simulator Upstream Pressure	S.G.	1000 psid	Vertical	None	5 1/2" upstream of B-15 inlet flange (L)	Northside		260	1/4	1		0	17	0	0	0
BP-14	Close coupled Propellant Line Pressure (FEP-II only)	S.G.	1000 psig	Horizontal	None	43" Upstream of B-15 Inlet Flange	Bottom		29	1/4"	1		0	2	0	0	0

TABLE A.13.1
PRESSURE TRANSDUCER SENER LINE DATA
PEWEE II FEP-I&II
PART 1

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TABLE A.13.1
PRESSURE TRANSDUCER SENER LINE DATA
PEWEE II FEP-1&II
PART 1

APPENDIX A

CHANNEL NO. PARAMETER	CHANNEL TITLE	TRANSDUCER TYPE	TRANSDUCER RANGE	LINE ELEMENT ORIENTATION	LINE INSULATION	TRANSDUCER TUBING TAP LOCATION	TRANSDUCER PORT ORIENTATION	TRANSDUCER			NO. OF				
								TUBE LENGTH etc. Inches	Size	# of valves	Expans. Loop	90° Bends	45° Bends	Tee's Straight	Tee's thru Branch
HP-541	No. 1 Pump Discharge Pressure	S.G.	1500	Horizontal	foam	1' downstream HF-550 downstream flange	TOP	72	1/4	1		5	1	0	0
LP-13D	Main Propellant Line Final Filter Delta P LM-2028	S.G.		Horizontal	High	45" upstream of filter outlet flange	TOP	102	1/4	2	1	2	4	0	1
				Horizontal	Low	12" downstream of filter outlet flange	Bottom 45°	116	1/4	1	0	4	4	0	0
HP-1	Tee LH ₂ Supply Pressure	S.G.	2000	Horizontal	vacuum jacketed	1' upstream of relief valve line (HS-2001)	TOP	151	1/4	1	0	9	1	0	0
LP-10	Pressure Upstream Of Discharge Venturi	S.G.	1500	Horizontal	vacuum jacketed	31" downstream of LF-10 inlet flange	TOP	147" /	1/4" /	2		7	0	0	2
LP-10D	Discharge Venturi Delta P	S.G.	25 psid	Horizontal	High	31" downstream of LF-10 inlet flange	TOP	83"	1/4	2	1	4	0	0	1
				Horizontal	vacuum jacketed Low	46" downstream of LF-10 inlet flange	TOP	74	1/4 /	2	1	4	0	0	0
LP-11D	Diff. Pressure Upstream LF-10/ Downstream L-11	S.G.	500 psid	Horizontal	High	31" downstream of LF-10 inlet flange	TOP	510" /	1/4" /	2	1	11	4	1	0
				Horizontal	vacuum jacketed Low	57" upstream of LM-2018 filter inlet	TOP	66	1/4" /	2	0	3	1	1	0
LP-12	Nozzle Supply Pressure	S.G.	2000	Horizontal	vacuum jacketed	57" upstream of LM-2018 filter inlet	TOP	69 /	1/4" /	2	0	4	1	0	1

TABLE A.13.1
PRESSURE TRANSDUCER
SENER LINE DATA
PEWEE II FEP-I&II
PART 2

NRTO-R-0202

APPENDIX B

CHRONOLOGY, FEP-I

September 17, 1970

CHRONOLOGY FOR PEWEE 2 INTEGRATED FACILITY

TEST SERIES, FEP-II

October 8, 1970

APPENDIX B

CHRONOLOGY

FACILITY EXPERIMENTAL PLAN I

SEPTEMBER 17, 1970

I. PREOPERATIONAL PHASE

- A. SETUP CHECKLISTS RECEIVED APPROVED; STATUS BOARD CLEARED.
- B. REPORT ON TEST CELL PERSONNEL.
- C. CHECK THE CONTROL ROOM NET.
- D. REQUIRED SYSTEMS AND VALVES SWITCHED TO CP CONTROL.
- E. EXERCISE THE VALVES IN THE FLOW CONTROL ROOM, PUMP ROOM, AND HIGH PRESSURE ROOM.
- F. CHECK THE SHUTDOWN CHAIN.
- G. BEGIN INERTING THE TEST CELL.
 - 04564 Turn off the fans.
 - 04581 Close Q-113.
 - 04590 Pressurize the room inerting header (Bottles #13, 14, 15 and 16). QP-50 indicates 2440 psig.
 - 04663 Begin inerting the test cell.
- H. EXERCISE THE REMAINING VALVES AND CHECK THE PROPELLANT FLARE.
- I. PERFORM A VOLTAGE CALIBRATION.
 - 07011-07111 Calibration interval.
 - 07449-07575 Rowley zero pressure calibration interval.
- J. CLEAR THE REMOTE TEAM FROM THE TEST CELL AREA.

II. HEADER PRESSURIZATION, X-SYSTEM CHILLDOWN

- A. PRESSURIZE THE HEADERS.
 - 07810 Report on inerting.
 - 07815 Open K-50 and K-153.
 - 07838 Open L-153, L-50, L-251 and H-50.
 - 07861 Open G-11.
 - 07869 Open X-50 and X-153.
 - 07878 Open W-50.
 - 07883 Open G-50.
 - 07890 Close all the bottle purge valves.
 - 07902 Close Q-150.
 - 07909 Pressurize the helium header (Bottle #2). QP-20 indicates 2390 psig.

APPENDIX B

07946 Pressurize the hydrogen header (Bottle #4).
QP-30 indicates 3230 psig.
08023 Pressurize the nitrogen header (Bottles #9 and 10).
QP-40 indicates 3180 psig.

B. PROCEED WITH THE X-SYSTEM INITIAL CHILLDOWN.

08131 Turn on the propellant flare pulser.
08139 Open K-7 and K-21.
08147 Open N-430.
08157 Open B-15 and B-215.
08172 In G-13 FLOW Control, establish 1 lb/sec GHe.
08214 At the end of the 30 second timer, Close B-15 & B-215.
08222 Switch G-13 to POSITION Control and Close.
08230 Close N-430.
08234 Pulser Off.
08290 Close L-262 and L-153.
08311 Open L-62.
08317 Select Dewar 2 PRESSURE Feedback.
08324 In L-53 PRESSURE Control, establish 60 psig in Dewar 2.
08338 Close X-405 and X-261.
08348 Open L-330 and L-351.
08368 Open L-302.
08460 LT-351 indicates 100°R, Open X-353.
08469 Open L-331.
08478 Close L-351.
08494 Open X-171.
08610 XT-353 is less than 44°R, Open X-303.
08613 Close X-353.
08620 Open X-1, X-103 and X-203.
10510 XT-812 and XT-821 are less than 200°R, Close X-103.
10513 Use X-303, X-171 and X-103 as required to chill the X-System.

III. INITIAL CHILLDOWN OF K- AND L-SYSTEMS

This section will accomplish (a) the pressurization of Dewars 4 and 5 and the initial chilldown of the K-System to K-6 and (b) the initial chilldown of the L-System to L-11 and L-21.

A. PROCEED WITH THE K-SYSTEM PRESSURIZATION, CHILLDOWN AND SOAK.

08698 Open K-3.
08714 Close K-153, K-261 and K-262.
08764 Open K-61 and K-62.
08780 Select Dewars 4 and 5 auction feedback.
08786 In K-53 PRESSURE Control, establish 100 psig in Dewars 4 and 5.
08799 Open K-1.
08809 Use K-106 to chill KT-106.
09182 KT-106 is chilled, set K-106 to minimum.
09188 Close K-1 and start a 600 second timer.
09197 Switch K-53 to POSITION Control and Close.
09205 Close K-61 and K-62.
09213 Open K-153.

APPENDIX B

B. PROCEED WITH THE L-SYSTEM CHILLDOWN AND SOAK.

09091	Turn on the lube oil pump.
09104	Open L-3.
09124	Open L-2.
09135	Close H-460 and H-461.
09142	Use H-101 to chill HT-101.
09146	Use L-111 to chill LT-111.
09888	Use L-109 to chill the pump.
10141	The pump is chilled, close L-109.
10158	Release the pump latch.
10164	Start a 900 second timer.
10171	Report status of Dewar 3 chillover. XT-812 is 240°R.
10466	Switch L-53 to POSITION Control and Close.
10470	Close L-62.
10475	Open L-153.

IV. WATER SYSTEM SETUP AND OVERSPEED TRIP CHECK

A. PROCEED WITH THE SETUP OF THE WATER SYSTEM.

10229	Verify that W-153 is Closed.
10239	Open W-1, W-11, W-45, W-49, W-100, W-211, W-221 and W-231.
10309	Use W-53 to establish 35 psig at WP-45.
10370	Turn on the water flow meter power.
10383	Close W-11, W-100, W-211, W-221 and W-231.

B. PROCEED WITH THE CHECK OF THE SPEED INPUTS TO THE SHUTDOWN CHAIN.

11124	Set the overspeed trip pot to 65 divisions.									
11135	Bypass all the inputs to the shutdown chain.									
11139	Switch the shutdown valves to Override.									
11145	Open L-109 to trip Overspeeds #1 and 2.									
11275	Close L-109.									
11287	Report the following data:									
	<table border="0" style="margin-left: 40px;"> <tr> <td>a. Dewar Level:</td> <td>1</td> <td>2</td> </tr> <tr> <td>Reflectometer</td> <td>5.8 K#</td> <td>250 K#</td> </tr> <tr> <td>Staircase</td> <td>5.8 K#</td> <td>232 K#</td> </tr> </table>	a. Dewar Level:	1	2	Reflectometer	5.8 K#	250 K#	Staircase	5.8 K#	232 K#
a. Dewar Level:	1	2								
Reflectometer	5.8 K#	250 K#								
Staircase	5.8 K#	232 K#								
	<table border="0" style="margin-left: 40px;"> <tr> <td>b. 0% Temperature</td> <td>37°R</td> <td>37.5°R</td> </tr> <tr> <td>10% Temperature</td> <td>54+°R</td> <td>37.5°R</td> </tr> </table>	b. 0% Temperature	37°R	37.5°R	10% Temperature	54+°R	37.5°R			
b. 0% Temperature	37°R	37.5°R								
10% Temperature	54+°R	37.5°R								
11328	Report the following data:									
	<table border="0" style="margin-left: 40px;"> <tr><td>QP-20 is 1860 psig.</td></tr> <tr><td>QP-30 is 1690 psig.</td></tr> <tr><td>QP-40 is 3150 psig.</td></tr> <tr><td>QP-50 is 1980 psig.</td></tr> </table>	QP-20 is 1860 psig.	QP-30 is 1690 psig.	QP-40 is 3150 psig.	QP-50 is 1980 psig.					
QP-20 is 1860 psig.										
QP-30 is 1690 psig.										
QP-40 is 3150 psig.										
QP-50 is 1980 psig.										

APPENDIX B

11354 Report the following data:

a. Dewar Level:	4	5
Reflectometer	25 K#	30 K#
Staircase	21 K#	26 K#
0% Temperature	38.1°R	38.6°R

11392 Report the hot water tank level: 224 K gallons.

11396 Report the Dewar 3 level: 97-99%.

11412 Report the Test Cell "C" elevated water tank level: 150+ K gallons.

11539 Close Q-4.

11557 Pressurize the hydrogen header with (Bottles #3, 5, 6, 7 and 8). QP-30 indicates 3450 psig.

V. TURBOPUMP CHECKOUT

A. PROCEED WITH THE TURBOPUMP CHECKOUT.

11848 Set the overspeed trip pot to 695 divisions (25,500 rpm).

11882 Set the $\frac{W}{N}$ trip to 260 divisions (Ns = 550).

11890 Close L-153.

11906 Open L-62.

11912 In L-53 PRESSURE Control, establish 60 psig in Dewar 2.

11918 Set the following VCD values:

Turbine Radial	6 pulses in 50 msec
50 g's peak-to-peak	Low Pass Filter

11927 Activate the following inputs to the emergency shutdown chain:

VCD #1	Overspeed #1
HP-67	Overspeed #2
HT-60	JP-101/JP-201
HP-511	Loss of Critical Power
HP-541	

11954 Switch the following valves to Normal:

L-109	H-180/H-53
H-60	H-101
Shutdown Servo	

11969 Close H-180.

11979 In H-53 PRESSURE Control, establish and maintain 400 psig at HP-60.

12009 Use L-109 to chill the pump.

12139 Use H-101 to chill HT-101.

12144 Use L-111 to chill LT-111.

12199 In Ns Control, set the pot to 655 divisions (Ns is 700).

12383 Turn on the tapes.

APPENDIX B

12387	Set L-111 to 36% (ns is 550).
12397	Open the water bypass valves.
12412	Close H-101.
12428	In SPEED Control, establish 23,500 rpm.
12470	Speed is 6000 rpm.
12478	Speed is 7000 rpm; Ns is 800.
12488	Activate HT-511.
12505	Activate #/N.
12511	Speed is 10,000 rpm.
12534	Increase speed.
12564	Speed is 15,000 rpm.
12590	Increase speed.
12620	Speed is 20,000 rpm; Ns is 700; HF-550 is 30 lb/sec.
12648	Increase speed.
12672	Speed is 23,500 rpm; Ns is 700; HF-550 is 36 lb/sec; L-109 is controlling.
12696	In SPEED Control, slowly decrease the Ns to 575.
12749	Ns is 650.
12768	L-109 is 6%.
12785	L-109 is 4%; Ns is 650.
12797	Hold.
12855	L-109 is 3%.
12874	QP-30 is 2910 psig.
12895	Increase the Ns to 700.
12928	Hold. Ns is 650.
12948	L-111 is 36%.
12954	Decrease L-111 to 33%.
12982	L-111 is 33%; Ns is 670; LF-10 is 23 lb/sec; L-109 is 8.5%.
13005	Decrease Ns.
13021	Ns is 630.
13038	L-109 is between 5 and 10%.
13045	Hold. Ns is 640; QP-30 is 2650 psig.
13065	Decrease L-111 to 30%; Increase Ns to 700.
13088	Ns is 670.
13110	L-111 is 30%; QP-30 is 2560 psig.
13119	Ns is 660.
13142	Lube oil pressure is 230 psig and decreasing.
13151	Ns is between 600 and 650.
13157	Decrease speed along an Ns is 650.
13166	In SPEED Control, slowly decrease the speed to 15,000 rpm.
13190	Speed is 20,000 rpm.
13205	L-109 is 8%.
13211	Speed is 15,000; L-109 is 8%; Ns is 645.
13243	Increase Ns to 700.
13250	QP-30 is 2400 psig.
13263	Ns is 670.
13271	Demand zero speed along an Ns of 670.
13284	Speed is 10,000 rpm.
13287	Bypass #/N.
13292	Bypass HT-511.
13299	At zero speed, switch H-60 to POSITION Control and Close.
13302	Switch H-53 to POSITION Control and Close.
13306	Open H-180.

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13311	Close L-111.
13316	Set H-101 to minimum setting.
13319	Close W-211, W-221 and W-231.
13322	Turn data tapes Off.
13325	Switch L-109 to POSITION Control and Close.
13330	Switch L-153 to POSITION Control and Close.
13333	Close L-62.
13339	Open L-153.
13346	Bypass all the inputs to the shutdown chain.
13355	Switch the shutdown valves to Override.
13360	Minimum secure is established.

VI. PEWEE 2 NORMAL PROFILE OPERATION

A. PROCEED WITH THE PEWEE 2 PROFILE.

15006	Report status of Dewar 3 chilldown and Dewar 3 level.												
	<table border="0"> <tr> <td>XT-2</td> <td>is</td> <td>82°R.</td> </tr> <tr> <td>X-103</td> <td>is</td> <td>Closed.</td> </tr> <tr> <td>X-203</td> <td>is</td> <td>Open.</td> </tr> <tr> <td>Level</td> <td>is</td> <td>greater than 97%.</td> </tr> </table>	XT-2	is	82°R.	X-103	is	Closed.	X-203	is	Open.	Level	is	greater than 97%.
XT-2	is	82°R.											
X-103	is	Closed.											
X-203	is	Open.											
Level	is	greater than 97%.											
15021	Close L-153.												
15037	Open L-62.												
15044	In L-53 PRESSURE Control, establish 60 psig in Dewar 2.												
15053	Close K-153.												
15060	Open K-61 and K-62.												
15071	Select Dewar 4 and 5 Auction Pressure Feedback.												
15079	In K-53 PRESSURE Control, establish 100 psig in Dewars 4 and 5.												
15110	Open K-2.												
15121	Open K-106.												
15152	Reset the programmer.												
15157	Set the $\frac{W}{N}$ pot to 260 divisions (Ns is 550).												
15164	Set the following VCD values:												
	<table border="0"> <tr> <td>Turbine Radial</td> <td>6 pulses in 50 msec</td> </tr> <tr> <td>50 g's peak-to-peak</td> <td>Low Pass Filter</td> </tr> </table>	Turbine Radial	6 pulses in 50 msec	50 g's peak-to-peak	Low Pass Filter								
Turbine Radial	6 pulses in 50 msec												
50 g's peak-to-peak	Low Pass Filter												
15171	Patch the noise generator to the Flow Loop.												
15190	Set the oscillator amplitude to 1 volt.												
15195	Set the step to -1.0 volt.												
15197	Set the noise generator as follows:												
	<table border="0"> <tr> <td>Amplitude</td> <td>is</td> <td>0.5 lb/sec</td> </tr> <tr> <td>Switching Frequency</td> <td>is</td> <td>50</td> </tr> <tr> <td>Chain Length</td> <td>is</td> <td>1023</td> </tr> </table>	Amplitude	is	0.5 lb/sec	Switching Frequency	is	50	Chain Length	is	1023			
Amplitude	is	0.5 lb/sec											
Switching Frequency	is	50											
Chain Length	is	1023											

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15198 Patch the step.
 15203 Open X-303.
 15242 KT-2 is 40°R, Open K-1 and Close K-2.
 15246 KT-1 and KT-106 are 45°R, set K-106 at a minimum.
 15270 Close G-103.
 15276 Open G-1.
 15292 Activate H-142, Hold Closed.
 15298 Activate G-13, Hold Closed.
 15305 Close X-153 and activate, Hold Closed.
 15312 Open X-17, X-18 and X-61.
 15350 Set the overspeed trip pot to 785 divisions (30,000 rpm).
 15359 Activate the following inputs to the Emergency Shutdown Chain:

VCD #1	Overspeed #1
HP-67	Overspeed #2
HT-60	JP-101/JP-201
HP-511-Lo	Loss of Critical Power
HP-541	

15381 Switch the following valves to Normal:

X-53/X-161	H-60
H-70	Shutdown Servo
H-175	H-142
L-109	H-180/H-53
H-11	H-101

15413 Close H-180.
 15421 In H-53 PRESSURE Control, establish 100 psig at HP-60.
 15437 Use L-109 to chill the pump.
 15512 Use H-101 to chill HT-101.
 15519 Use L-111 to chill LT-111.
 15529 Turn on the tapes.
 15538 Open the water bypass valves.
 15568 Open H-70 and H-75.
 15578 Open H-175 to 17%.
 15590 Switch H-11 to ΔP control.
 15601 Turn on the reactor flare pulser.
 15623 Open W-11, W-100 and W-316.
 15653 Open G-427.
 15660 Open B-15 to 94% and B-215 to 72%.
 15671 Open N-430.
 15690 In G-3 Flow Control, establish 2 lb/sec GH_2 .
 15694 Close N-430.
 15706 Turn off the pulser.
 15712 Using B-15 and B-215, establish 66 psig at BP-15 and 87 psig at BP-215 (ICG).

APPENDIX B

15754	In G-3 FLOW Control, establish 120 psig at KP-7.															
15760	Use K-106 to chill KT-106.															
15777	Open K-6 to the 35% clamp.															
15786	Close K-106.															
15795	Switch G-3 to POSITION Control and Close. Activate the Hold Closed.															
15814	Open X-103.															
15858	BT-15 and BT-215 are chilled to 150°R, set:															
	B-15 to 59% B-215 to 38%															
15875	XT-2 is less than 47 R, close X-103. Activate the Hold Closed.															
15883	Switch X-53/X-161 to PROGRAM PRESSURE Control.															
15886	Close X-171.															
15890	Open X-3.															
15897	Open L-111 to 32% and switch to PROGRAM.															
15928	Switch L-11 to PROGRAM.															
15932	Switch L-11 to Normal.															
15940	Switch to Ns Control.															
15944	Close H-101 and activate Hold Closed.															
15950	Zero the Flow Bias.															
15954	Switch to Flow PROGRAM.															
15964	Use Flow Bias to establish 1650 psig at HP-541.															
16042	HP-60 exceeds 100 psig, Close H-53, and L-251.															
16060	Slowly Open L-21 to 18.5%															
16068	Close X-303.															
16072	Activate ΔP inputs.															
16170	Activate HT-511.															
16174	Switch to Run.															
16180	When KF-5 indicates zero, use K-107 to maintain 45°R at KT-7.															
16189	L-111 is Closed, activate the Hold Closed.															
16203	L-11 is Open, activate the L-11 Hold Open.															
16210	LF-10 is 20 lb/sec; Speed is 15,000 rpm; Ns is 750.															
16224	Zero flow bias.															
16230	Activate $\dot{W}/N$.															
16237	Intermediate Power Hold:															
	<table border="0"> <tr> <td>LF-25</td> <td>is</td> <td>5 lb/sec</td> </tr> <tr> <td>BP-15</td> <td>is</td> <td>500 psig</td> </tr> <tr> <td>BP-215</td> <td>is</td> <td>380 psig</td> </tr> <tr> <td>Pdish</td> <td>is</td> <td>620 psig</td> </tr> <tr> <td>Ns</td> <td>is</td> <td>710</td> </tr> </table>	LF-25	is	5 lb/sec	BP-15	is	500 psig	BP-215	is	380 psig	Pdish	is	620 psig	Ns	is	710
LF-25	is	5 lb/sec														
BP-15	is	500 psig														
BP-215	is	380 psig														
Pdish	is	620 psig														
Ns	is	710														
16258	Switch to run.															
16271	Full power hold #1.															
16277	Establish Pewee 2 operating conditions.															
16309	Use H-175 to establish 100 psid at HP-76D.															
16326	Hydrogen leak in HKR															
16410	BP-215 is 620 psig; BP-15 is 760 psig; Total Flow is 29 lb/sec; Pdish is 900 psig; Ns is 665; LF-25 is 6 lb/sec; BF-13 is Off Scale.															

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16518 L-21 is 20%; B-15 is 55%; B-215 is 38%; BP-215 is 670
psig.
16535 High Speed data burst.
16574 Bypass $\Delta\theta$ input.
16583 Proceed with the psuedorandom noise experiment.
16648 Unpatch the noise generator from the Flow Loop.
16653 Patch the oscillator to the Flow Loop.
16660 Proceed with the frequency response measurement.
16784 Unpatch the oscillator from the Flow Loop.
16789 Patch the oscillator to the Speed Loop.
16794 Set the step to +1.0 volts.
16798 Switch to SPEED Control.
16804 Proceed with the frequency response measurement.
16913 Unpatch the oscillator from the Speed Loop.
16917 Switch to Flow Program.
16949 Activate $\Delta\theta$ inputs.
16955 Switch Run.
16987 Speed is 18,000 rpm, bypass θ/N .
17030 Shutdown Hold #1. (10 seconds).
17078 Speed is 18,000 rpm, activate θ/N .
17098 Full Power Hold #2.
17114 Switch to Run.
17143 Speed is 18,000 rpm, bypass θ/N .
17188 Shutdown Hole #2 (30 seconds).
17255 Speed is 18,000 rpm, activate θ/N .
17276 Full Power Hold #3.
17281 Dewar 3 level is greater than 60%.
17288 Bypass X-103, Hold Closed.
17295 Use X-103 to decrease Dewar 3 level to 20%.
17326 B-15 is 56%; B-215 is 37.5%.
17401 X-103 is Closed, activate the Hold Closed.
17410 BP-15 is 650 psig; BP-215 is 760 psig.
17417 Use X-353 to chill XT-353 to 47°R.
17440 Hydrogen leak in HPR.
17544 Switch to Run.
17573 Speed is 18,000 rpm, bypass θ/N .
17599 XP-61 is 60 psig, Close X-353 and Open X-303.
17612 Dewar 3 level is 30%.
17617 Shutdown Hole #3.
17619 Switch to Hold, and start a 90 second timer.
17674 Switch to Run.
17676 The CTO switched to Run, Close X-303.
17722 Speed is 18,000 rpm, activate θ/N .
17744 Full Power Hold #4.
17755 Slowly Open L-21 to 100%.
17802 L-21 is 100%.
17807 Slowly Close L-21 to 10%.
17855 L-21 is 10%, BP-215 is 430 psig.
17863 Slowly Open L-21 to 20%.
17875 L-21 is 20%.
17880 Re-establish Pewee 2 operating conditions.
BP-15 is 770 psig and BP-215 is 660 psig.

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17938	Push the Emergency Shutdown Button.
17946	Close K-107.
17951	Bypass HT-511, Δ /N and Δ W.
17956	Reset the Emergency Shutdown Chain (10 seconds);
	bypass L-11 Hold Open; start a 50 second timer.
17972	Bypass the H-101 Hold Close and set H-101 to a minimum.
17985	Close L-21.
18012	Close X-3 and X-203.
18018	Close H-75.
18022	Switch H-11 to POSITION Control and Close.
18029	In K-6 Flow Control, establish 2 lb/sec LH ₂ at KF-5.
18033	Switch X-53/161 to POSITION Control and Close.
18039	Close X-171.
18061	Open K-2.
18070	Close K-1.
18083	Close Q-3, Q-5, Q-6, Q-7 and Q-8.
18089	Open Q-204.
18108	QP-30 is stable, Open Q-4.
18111	Close Q-204.
18162	Bypass G-3 Hold Closed.
18167	Switch K-6 to POSITION Control and Close.
18173	In G-3 Flow Control, establish 10 psig at KP-7.
18217	BT-15 and BT-215 are starting to increase, establish
	1 lb/sec GH ₂ ; set B-15 to 94% and B-215 to 72%.
18235	Open Q-203, Q-205, Q-206, Q-207 and Q-208.
18241	Close Q-4.
18248	QP-30 is stable, Open Q-3, Q-5, Q-6, Q-7 and Q-8.
18270	Q-4 Bottle Pressure is 1700 psig.
18281	Close Q-203, Q-205, Q-206, Q-207 and Q-208.
18284	Bypass G-13 Hold Closed.
18289	Switch G-3 to POSITION Control and Close.
18297	In G-13 Flow Control, establish 3 lb/sec at GHe.
18304	Close W-11, W-100 and W-316.
18312	Close the Water Bypass valves.
18315	Close H-142.
18325	Turn on the flare pulser.
18339	BT-15 and BT -215 are greater than 250°R, Close B-15
	and B-215.
18351	Switch G-13 to POSITION Control and Close.
18356	Turn off the tapes.
18364	Close G-427.
18367	Close G-1.
18381	Open G-103.
18384	Open N-430.
18389	Close K-2.
18398	Set K-106 to a minimum.
18406	Switch L-53 to POSITION Control and Close.
18413	Close L-62.
18419	Open L-153 and L-251.
18429	Switch K-53 to POSITION Control and Close.
18435	Close K-61 and K-62.
18439	Open K-153.
18448	Bypass all the inputs to the Shutdown Chain.

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18456	Switch all the shutdown valves to Override.
18471	Switch L-11 to POSITION Control and Close; Bypass Hold Closed.
18475	Bypass H-142 Hold Closed.
18484	Bypass X-103 Hold Closed.
18493	Vent Dewar 3 to 60 psig.
18497	Unpatch the oscillator.
18504	Unpatch the step.
18508	Reset the programmer.
18511	Minimum secure established.

VII. PEWEE-2 EMERGENCY SHUTDOWN #1 FROM FULL POWER CONDITIONS.

A. PROCEED WITH THE PEWEE 2 SHUTDOWN TEST.

22966	Repressurize the water tank to 50 psig.										
23093	Dewar 3 level indicates 60%.										
23102	Verify that L-2 is open.										
23104	Close L-153.										
23125	Open L-62.										
23129	In L-53 PRESSURE Control, establish 60 psig in Dewar 2.										
23143	Close K-153.										
23149	Open K-61 and K-62.										
23164	In K-53 PRESSURE Control, establish 100 psig in Dewars 4 and 5.										
23201	Open K-1.										
23210	Use K-106 to chill KT-1 and KT-106.										
23220	Open L-331.										
23228	Use X-353 to chill XT-353.										
23240	Close X-353.										
23245	Open X-103.										
23263	Open X-303.										
23280	Close L-331.										
23290	Set X-353 to a minimum.										
23298	KT-1 and KT-106 are chilled, set K-106 to a minimum.										
23324	Set the following VCD values:										
	<table border="0"> <tr> <td>Turbine Radial</td> <td>6 pulses in 50 msec</td> </tr> <tr> <td>50 g's peak-to-peak</td> <td>Low Pass Filter</td> </tr> </table>	Turbine Radial	6 pulses in 50 msec	50 g's peak-to-peak	Low Pass Filter						
Turbine Radial	6 pulses in 50 msec										
50 g's peak-to-peak	Low Pass Filter										
23336	Set the Φ/N pot to 260 divisions (Ns is 550).										
23342	Activate the G-3 Hold Closed.										
23351	Close G-103.										
23357	Open G-1.										
23374	Set the Overspeed trip pot to 785 divisions (30,000 rpm).										
23384	Activate the following inputs to the Shutdown Chain:										
	<table border="0"> <tr> <td>VCD #1</td> <td>Overspeed #1</td> </tr> <tr> <td>HP-67</td> <td>Overspeed #2</td> </tr> <tr> <td>HT-60</td> <td>JP-101/JP-201</td> </tr> <tr> <td>HP-511-Lo</td> <td>Loss of Critical Power</td> </tr> <tr> <td>HP-541</td> <td></td> </tr> </table>	VCD #1	Overspeed #1	HP-67	Overspeed #2	HT-60	JP-101/JP-201	HP-511-Lo	Loss of Critical Power	HP-541	
VCD #1	Overspeed #1										
HP-67	Overspeed #2										
HT-60	JP-101/JP-201										
HP-511-Lo	Loss of Critical Power										
HP-541											

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23410 Switch the following valves to Normal:

L-11	H-180/H-53
L-109	X-53/X-161
H-11	H-175
H-60	H-70
Shutdown Servo	H-101
H-142	

23448 Close H-180.

23457 In H-53 PRESSURE Control, establish 100 psig at HP-60.

23469 Set ΔP Control pot to 60 divisions.

23491 Use L-109 to chill the pump.

23532 Use H-101 to chill HT-101.

23591 Use L-111 to chill IT-111.

23604 Report status of Dewar 3:

XT-2	is	47°R
Level	is	60%
X-103	is	Closed
X-171	is	Open

23621 Use X-103 to maintain XT-2 less than 55°R.

23625 Close X-303.

23637 Close L-331.

23640 Open X-353.

23648 Close X-171.

23657 In X-53/161 PRESSURE Control, establish 300 psig in Dewar 3.

23661 Verify X-3 is Closed.

23667 Open W-211, W-221, and W-231.

23692 In Ns Control, set the pot to 405 divisions (Ns is 575).

23703 Turn on the tapes.

23706 Open G-427.

23717 Open W-11, W-100 and W-316.

23751 Open N-430.

23756 Open B-15 and B-215.

23769 Open K-6 to the clamp.

23773 Close K-106.

23781 Close N-430.

23790 Use K-107 to maintain a chill at KT-107 after switching to Run.

23800 Open H-70, H-75 and H-175 to 20%.

23831 BT-15 and BT-215 are chilled, set B-15 to 55% and B-215 to 38%.

23842 Open L-11 and L-21 to 20%.

23873 Actuate L-11 Hold Open.

23878 Switch H-11 to ΔP Control.

23897 Close H-101.

23905 In Flow Control, establish 30.1 lb/sec at LF-10.

23926 Use K-107 to maintain a chill at KT-7.

23969 Activate HT-511.

23996 Speed is 18,000 rpm, activate $\frac{R}{N}$.

23999 HP-60 exceeds 200 psig, Close L-251 and H-53.

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24023	Speed is 24,000 rpm.
24049	Ns is 700.
24064	Open X-3.
24084	Use B-15 and B-215 to establish Pewee 2 operating conditions.
24096	Use H-175 to establish 100 psid at HP-76D.
24130	Speed is 24,000 rpm; BP-15 is 750 psig; BP-215 is 660 psig.
24193	Push the Emergency Shutdown Button.
24201	Close K-107.
24204	Bypass HT-511 and W/N.
24207	Reset the Emergency Shutdown Chain (10 seconds); bypass L-11, Hold Open and start a 30 second timer.
24211	Set H-101 to a minimum.
24225	Close L-21 (30 seconds).
24228	Close X-3 and X-203.
24240	In K-6 Flow Control, establish 2 lb/sec at KF-5.
24262	Switch K-6 to POSITION Control and Close.
24267	Bypass G-3 Hold Close.
24271	In G-3 Flow Control, establish minimum GH ₂ .
24274	Set K-106 to a minimum.
24280	Close H-75.
24300	Close W-11, W-100 and W-316.
24305	Switch H-11 to POSITION Control and Close.
24309	Close H-142.
24329	Close the water bypass valves.
24335	Turn off the tapes.
24339	Switch L-53 to POSITION Control and Close.
24344	Close L-62.
24350	Open L-153 and L-251.
24362	Bypass all the inputs to the Shutdown Chain.
24371	Switch all the shutdown valves to Override.
24375	Switch G-3 to POSITION Control and Close.
24381	BT-15 and BT-215 are 250°R, Close B-15 and B-215.
24385	Close G-427.
24390	Close G-1.
24403	Open G-103.
24408	Open N-430.
24415	Close K-1.
24424	Open X-171 and X-203.
24436	Switch K-53 to POSITION Control and Close.
24443	Close K-61 and K-62.
24450	Open K-153.
24455	Minimum secure established.

VIII. PEWEE 2 NORMAL RESTART PROFILE

A. Proceed with the Pewee 2 Restart Profile.

24597	Dewar 3 level is greater than 40%.
24929	Close Q-3, Q-5, Q-6, Q-7 and Q-8.
24941	Open Q-204.
24961	QP-30 is stable, Open Q-4.

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24964	Close Q-204.										
24969	Close L-153.										
24985	Open L-62.										
24992	In L-53 PRESSURE Control establish 60 psig in Dewar 2.										
25056	Close K-153.										
25064	Open K-61 and K-62.										
25074	Select Dewar 4 and 5 Auction Feedback.										
25080	In K-53 PRESSURE Control establish 100 psig in Dewar 4 and 5.										
25101	Open K-2.										
25106	Open K-106.										
25150	Reset the programmer.										
25158	Set the ω/N pot to 260 division (Ns is 550).										
25161	Set the following VCD valves:										
	<table border="0"> <tbody> <tr> <td>Turbine Radial</td> <td>6 pulses in 50 msec</td> </tr> <tr> <td>50 g's peak-to-peak</td> <td>Low Pass Filter</td> </tr> </tbody> </table>	Turbine Radial	6 pulses in 50 msec	50 g's peak-to-peak	Low Pass Filter						
Turbine Radial	6 pulses in 50 msec										
50 g's peak-to-peak	Low Pass Filter										
25170	Close G-103.										
25175	Open G-1.										
25181	Activate H-142, Hold Closed.										
25190	KT-2 and KT-106 are chilled, K-106 is at a minimum.										
25195	Activate G-13, Hold Closed.										
25203	Activate X-153, Hold Closed.										
25212	Set the Overspeed Trip pot to 785 division (30,000 rpm).										
25217	Activate the following inputs to the Shutdown Chain.										
	<table border="0"> <tbody> <tr> <td>VCD #1</td> <td>Overspeed #1</td> </tr> <tr> <td>HP-67</td> <td>Overspeed #2</td> </tr> <tr> <td>HT-60</td> <td>JP-101/JP-201</td> </tr> <tr> <td>HP-511-Lo</td> <td>Loss of Critical Power</td> </tr> <tr> <td>HP-541</td> <td></td> </tr> </tbody> </table>	VCD #1	Overspeed #1	HP-67	Overspeed #2	HT-60	JP-101/JP-201	HP-511-Lo	Loss of Critical Power	HP-541	
VCD #1	Overspeed #1										
HP-67	Overspeed #2										
HT-60	JP-101/JP-201										
HP-511-Lo	Loss of Critical Power										
HP-541											
25243	Switch the following valves to Normal:										
	<table border="0"> <tbody> <tr> <td>L-109</td> <td>H-180/H-53</td> </tr> <tr> <td>H-60</td> <td>H-101</td> </tr> <tr> <td>H-11</td> <td>H-142</td> </tr> <tr> <td>Shutdown Servo</td> <td>H-175</td> </tr> <tr> <td>H-70</td> <td>X-53/X-161</td> </tr> </tbody> </table>	L-109	H-180/H-53	H-60	H-101	H-11	H-142	Shutdown Servo	H-175	H-70	X-53/X-161
L-109	H-180/H-53										
H-60	H-101										
H-11	H-142										
Shutdown Servo	H-175										
H-70	X-53/X-161										
25272	Close H-180.										
25279	In H-53 PRESSURE Control, establish 100 psig at HP-60.										
25294	Use L-109 to chill the pump.										
25356	Use H-101 to chill HT-101.										
25364	Use L-111 to chill LT-111.										
25369	Open H-70, H-75 and H-175 to 20%.										
25383	Open W-211, W-221 and W-231.										
25408	Turn on the tapes.										
25427	Switch H-11 to ΔP Control.										
25433	Turn on the Reactor Flare Pulser.										
25440	Open W-11, W-100 and W-316.										
25444	Open G-427.										

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25473 Open B-15 to 87% and B-215 to 80%.
 25477 Open N-430.
 25496 In G-3 FLOW Control, establish 2 lb/sec GH₂.
 25504 Close N-430.
 25508 Turn Off the pulser.
 25518 Using B-15 and B-215, establish 66 psig at BP-15 and 87 psig at BP-215 (ICG).
 25542 In G-3 FLOW Control, establish 120 psig at KP-7.
 25548 Use K-106 to chill KT-106.
 25555 Open K-6 to the 35% clamp.
 25560 QP-30 is 1300 psig.
 25566 Close K-106.
 25572 Switch G-3 to POSITION Control and Close. Activate the Hold Closed.
 25591 Open X-103.
 25599 BT-15 and BT-215 are chilled to 150°R, set B-15 to 55% and B-215 to 38%.
 25610 XT-2 is less than 47R, Close X-103. Activate the Hold Closed.
 25639 Switch X-53/X-161 to PROGRAM PRESSURE Control.
 25642 Close X-171.
 25660 Open X-3.
 25666 Open L-111 to 32% and switch to PROGRAM.
 25690 In Ns Control, set the pot to 405 divisions (Ns is 575).
 25708 Activate HT-511.
 25712 Switch L-11 to PROGRAM.
 25717 Switch L-11 to Normal.
 25722 Close H-101 and activate Hold Closed.
 25745 Zero the Flow Bias.
 25749 Switch to FLOW PROGRAM.
 25760 Use FLOW Bias to establish 165 psig at HP-541.
 25790 HP-60 exceeds 100 psig, Close L-251 and H-53.
 25801 Slowly Open L-21 to 20%.
 25821 Verify X-303 is Closed.
 25827 Activate Δ#.
 25855 Switch to Run.
 25875 L-11 is Open, activate the L-11 Hold Open.
 25879 When L-111 is Closed, activate the Hold Closed.
 25901 At Flow Crossover Zero Flow Bias.
 25909 Speed is 18,000 rpm, activate #/N.
 25916 Intermediate Power Hold. Ns is 700; BP-15 is 600 psig; BP-215 is 500 psig; Flow is 26 lb/sec.
 25960 XP-61 is 240 psig.
 25974 Use Flow Trim to increase flow by 1 lb/sec to 27 lb/sec.
 25989 Flow is 27 lb/sec.
 25995 Remove 1 lb/sec Flow Trim.
 26007 Flow is 26 lb/sec; BP-15 is 640 psig; BP-215 is 540 psig.
 26019 Initiate Program Shutdown.
 26036 Speed is 18,000 rpm, bypass #/N.
 26080 Shutdown Hold, start a 20 second timer.
 26084 Close X-3 and X-203.
 26116 Push the Emergency Shutdown Button.

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26121	Close K-107.
26123	Bypass HT-511, $\Delta\bar{w}$.
26128	Reset the Emergency Shutdown Chain (10 seconds).
26132	Bypass the H-101 Hold Closed and set H-101 to a minimum.
26146	Close L-21.
26151	Close H-75.
26155	Switch H-11 to POSITION Control and Close.
26164	In K-6 FLOW Control establish 5 lb/sec at KF-5.
26170	Switch X-53/161 to POSITION Control and Close.
26173	Open X-171.
26183	Close W-11, W-211, W-221 and W-231.
26190	Open W-311 to 50%.
26210	In K-6 FLOW Control establish:
26217	4 lb/sec at KF-5.
26228	3 lb/sec at KF-5.
26239	2 lb/sec at KF-5.
26258	1.5 lb/sec at KF-5.
26280	1.2 lb/sec is unstable.
26296	1.0 lb/sec at KF-5.
26299	Switch K-6 to POSITION Control and Close.
26301	Open N-430.
26366	Establish 1.5 lb/sec at KF-5 with K-6 in FLOW Control.
26428	Switch K-6 to POSITION Control and Close.
26519	Establish 1.5 lb/sec at KF-5 with K-6 in FLOW Control.
26536	Bypass G-3 Hold Closed.
26583	Switch K-6 to POSITION Control and Close.
26587	In G-3 Flow Control establish minimum GH_2 .
26597	Close W-100, W-311 and W-316.
26643	Close K-2.
26648	Set K-106 to a minimum
26658	Switch K-53 to POSITION Control and Close.
26665	Close K-61 and K-62.
26674	Open K-153.
26693	Turn the tapes off
26702	Switch L-53 to POSITION Control and Close.
26708	Close L-62.
26713	BT-15 and BT-215 are greater than 250°R, Close B-15 and B-215.
26715	Switch G-3 to POSITION Control and Close.
26721	Close G-427.
26727	Open L-153.
26736	Bypass all the inputs to the Shutdown Chain.
26745	Switch all Shutdown valves to Override.
26755	Switch L-111 to POSITION Control and Close; Bypass the Hold Close.
26765	Close H-142 and Bypass H-142 Hold Close.
26770	Close G-1.
26787	Open G-103.
26793	Bypass X-103, Hold Close.
26796	Reset the Programmer.
26799	Close Q-4; QP-30 is 910 psig.
26813	Open Q-203, Q-205, Q-206, Q-207 and Q-208.

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26845 QP-30 is stable; Open Q-3, Q-5, Q-6, Q-7 and Q-8.
26850 Close Q-203, Q-205, Q-206, Q-207 and Q-208.
26862 QP-30 is 1890 psig.
26870 Minimum secure is established.

IX. PEWEE 2 EMERGENCY SHUTDOWN #2 FROM FULL POWER CONDITIONS

During this phase, an Emergency Shutdown will be performed from Pewee 2 full power hold operating conditions. The accumulator, the K-System, and Dewar 3 will be on-line. L-109 will be commanded to 100% upon shutdown.

A. Proceed with the Pewee 2 Shutdown Test.

28144 Repressurize the water tank. WP-1 is 50 psig.
28327 Dewar 3 level is between 30 and 40%.
28337 Open L-2.
28342 Close L-153.
28361 Open L-62.
28367 In L-53 PRESSURE Control, establish 60 psig in Dewar 2.
28375 Close K-153.
28382 Open K-61 and K-62.
28395 In K-53 PRESSURE Control, establish 100 psig in
Dewars 4 and 5.
28408 Open K-1.
28416 Use K-106 to chill KT-1 and KT-106.
28435 Close X-353 and verify that X-303 is Closed.
28454 Open X-103.
28470 Set the following VCD values:

Turbine Radial	6 pulses in 50 msec
50 g's peak-to-peak	Low Pass Filter

28480 Set the ω/N pot to 260 divisions (Ns is 550).
28485 Activate the G-3 Hold Closed.
28490 Close G-103.
28497 Open G-1.
28514 KT-1 and KT-106 are chilled, set K-106 to a minimum.
28522 Set the Overspeed trip pot to 785 divisions (30,000 rpm).
28526 Activate the following inputs to the Shutdown Chain:

VCD #1	Overspeed #1
HP-67	Overspeed #2
HT-60	JP-101/JP-201
HP-511 -Lo	Loss of Critical Power
HP-541	

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28551 Switch the following valves to Normal:

L-11	H-180/H-53
L-109	X-53/X-161
H-11	H-175
H-60	H-70
Shutdown Servo	H-70
H-142	H-101

28581 Close H-180

28590 In H-53 PRESSURE Control, establish 100 psig at HP-60.

28603 Use L-109 to chill the pump.

28701 Use H-101 to chill HT-101.

28710 Use L-111 to chill LT-111 and maintain a chill at LT-10.

28718 Report status of Dewar 3.

XT-2	is	85°R.
X-103	is	Open.
X-203	is	Closed.
X-171	is	Open.
Level	is	between 30 and 40%.

28741 Use X-103 to maintain XT-2 less than 55°R.

28750 Close X-353.

28752 Open X-303.

28848 XT-2 is less than 47°R, Close X-103.

28865 Close X-303.

28876 Close X-171.

28887 In X-53/161 PRESSURE Control, establish 300 psig in Dewar 3.

28893 Open W-211, W-221 and W-231.

28940 Close W-211, W-221 and W-231.

29135 Open W-211, W-221 and W-231.

29142 Turn on the tapes.

29147 Open G-427.

29159 Open W-11, W-100 and W-316.

29277 Open N-430.

29282 Open B-15 and B-215.

29285 Open K-6 to the clamp.

29291 Close K-106.

29298 Close N-430.

29309 Open H-70, H-75 and H-175 to 20%.

29327 BT-15 and BT-215 are chilled, set B-15 to 55% and B-215 to 38%.

29338 Close L-111.

29346 Open L-11 and L-21 to 20%.

29363 Switch H-11 to ΔP Control.

29374 Close H-101.

29380 In Ns Control, set the pot to 405 divisions (Ns is 575).

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29386 In FLOW Control, establish 30.1 lb/sec at LF-10.
 29402 Use K-107 to maintain a chill at KT-7.
 29433 Activate HT-511.
 29437 HP-60 exceeds 200 psig, Close L-251 and H-53.
 29446 Close H-175.
 29453 Speed is 18,000 rpm, activate W/N.
 29490 Open X-3.
 29497 Use B-15 and B-215 to establish Pewee 2 operating conditions.
 29522 BP-15 is 761 psig.
 29535 BP-215 is 670 psig.
 29542 Push the Emergency Shutdown Button and start a 30-second timer.
 29550 Close K-107.
 29553 Bypass HT-511 and W/N.
 29556 Reset the Emergency Shutdown Chain (10 seconds).
 29559 Set H-101 to a minimum.
 29561 Close L-21 (30 seconds).
 29564 Close X-3 and X-203.
 29573 In K-6 Flow Control, establish 5 lb/sec at KF-5.
 29593 Switch K-6 to POSITION Control and Close.
 29597 Bypass G-3, Hold Closed.
 29600 In G-3 Flow Control, establish minimum GH₂.
 29603 Set K-106 to a minimum.
 29606 Close H-75.
 29612 Close W-11, W-100 and W-316.
 29621 Switch H-11 to POSITION Control and Close.
 29626 Close H-142.
 29639 Close the water bypass valves.
 29642 Turn off the tapes.
 29649 Switch L-53 to POSITION Control and Close.
 29652 Close L-61.
 29657 Open L-153 and L-251.
 29664 Switch G-3 to POSITION Control and Close.
 29668 Bypass all the inputs to the Shutdown Chain.
 29676 Switch all the shutdown valves to Override.
 29687 Verify that B-15 and B-215 are Closed.
 29695 Close G-427.
 29698 Close G-1.
 29714 Open G-103.
 29718 Open N-430.
 29723 Close K-1.
 29732 Open X-171 and X-203.
 29742 Switch K-53 to POSITION Control and Close.
 29764 Close K-61 and K-62.
 29774 Open K-153.
 29799 Minimum secure established, Dewar 3 operation continuing.
 29890 Report the following data:

Dewar Level	4	5
Reflectometer	7.25 K#	21.8 K#
Staircase	7 K#	25 K#

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X. TRANSFER CONTROL TO L-90

30705	Open L-91.
30718	Close L-491.
30774	Command L-11 Closed.
30780	Transfer controller output to L-90.
30785	Select Recirculation.
31100	Use L-109 to chill the turbopump.
31137	Slowly Open L-90.
31141	Use L-191 to chill IT-191.
31161	Verify L-11 is at 0%.
31163	Monitor BP-15 and BP-215.
31271	Close L-90 to 10%.
31280	Close L-191.
31295	Controller transfer complete.

IX. MARK 35 DURATION TEST

A. PROCEED WITH THE DURATION TEST.

31764	Set the Overspeed Trip Pot to 670 divisions (25,500 rpm).
31788	Set the $\frac{W}{N}$ pot to 260 divisions (Ns is 550).
31791	Select Dewar 2 Pressure Feedback.
31794	Close L-153.
31809	Open L-62.
31815	In L-53 PRESSURE Control, establish 60 psig in Dewar 2.
31829	Set the following VCD values:

Pump Radial	6 pulses in 50 msec
50 g's peak-to-peak	Low Pass Filter

31840	Activate the following inputs to the Shutdown Chain:
-------	--

VCD #2	Overspeed #1
HP-67	Overspeed #2
HT-60	JP-101/JP-201
HP-511-Lo	Loss of Critical Power
HP-541	LP-61

31904	Close W-49.
31909	Close W-110.
31939	Switch the following valves to Normal:

L-109	H-142
H-11	H-180/H-53
H-60	H-101
Shutdown Servo	

31960	Open L-90.
31964	Close H-180.
31974	In H-53 PRESSURE Control, establish 100 psig at HP-60.
31989	Use L-109 to chill the pump.

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32031	Use H-101 to chill HT-101.
32039	Use L-111 to chill LT-111.
32044	Use L-191 to chill LT-191.
32100	Open W-211, W-221 and W-231.
32102	Turn on the tapes.
32122	Switch H-11 to ΔP Control.
32131	In Ns Control, set the Ns pot to 405 divisions (Ns is 575).
32137	Close H-101.
32143	Open L-111 to 2%. Monitor LT-111.
32147	Set L-90 to 20%.
32150	Open L-92.
32163	Open W-11 and W-100.
32178	Use L-161 to maintain 50-60 psig at LP-61.
32265	In SPEED Control, establish 23,500 rpm.
32307	Activate HT-511.
32312	Speed is 10,000 rpm; Ns is 750.
32319	Activate $\frac{W}{N}$.
32325	HP-60 exceeds 200 psig, Close L-251 and H-53.
32346	Speed is 20,000 rpm; Ns is 730.
32375	Turbopump endurance conditions established by CTO.
	Speed is 23,500 rpm; Ns is 690; HF-550 is 36 lb/sec.
32404	Turbopump endurance conditions established by CRT.
	Speed is 23,500 rpm; Ns is 690; HF-550 is 36 lb/sec.
32523	Speed is 23,500 rpm; Ns is 690; HF-550 is 36 lb/sec.
32790	Dewar 2 level is 115 K#.
33117	Dewar 2 level is 103 K#.
33156	Speed is 23,500 rpm; Ns is 690.
33498	Dewar 2 level is 90 K#.
33510	Speed is 23,500 rpm; Ns is 690; HF-550 is 36 lb/sec;
	Pdisch is 850 psig.
33930	Dewar 2 level is 75K#.
33956	Bypass VCD #2.
33960	Activate VCD #1.
33968	Speed is 23,500 rpm; Ns is 690; HF-550 is 36 lb/sec;
	Pdisch is 850 psig.
33995	Bypass VCD #1.
34131	Dewar 2 level is 70K#.
34140	Dewar 1 level is 45 K#.
34328	Lost pen on XP-61 (Z2R242B8).
34398	Elapsed time is 2000 sec.
34837	Dewar 2 level is 43 K#.
34851	HT-531 is 49°R; Tinlet is 600; Texh is 605°.
34883	H ₂ O level is 102 K gal.
35044	Demand zero speed.
35046	Timer stopped.
35081	Bypass HT-511 and $\frac{W}{N}$.
35092	Switch H-60 to POSITION Control and Close.
35097	Close L-92.
35121	Open H-180.
35124	Close L-161.
35130	Close L-111.
35135	Set H-101 to minimum setting.
35138	Close W-11 and W-100.
35143	Turn off the tapes.
35152	Switch L-109 to POSITION Control and Close.
35155	Switch H-11 to POSITION Control and Close.

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35164 Close the water bypass valves.
 35171 Switch L-53 to POSITION Control and Close.
 35175 Close L-62.
 35181 Open L-153 and L-251.
 35192 Bypass all the inputs to the Shutdown Chain.
 35201 Switch the shutdown valves to Override.
 35213 Minimum secure established.
 35290 Begin LH₂ transfer from Dewar 1 to Dewar 2.

XII. MARK 35 DURATION TEST CONTINUED

A. PROCEED WITH THE DURATION TEST.

37675 HT-511 < 80°; LP-3 is 10 psig; L-113 Closed; L-2 is Open.
 37698 Open L-3.
 37726 Set H-101 to a minimum.
 37747 Set the Overspeed Trip Pot to 670 divisions (25,500 rpm).
 37755 Set the $\frac{R}{N}$ pot to 260 divisions (Ns is 550).
 37761 Select Dewar 2 Pressure Feedback.
 37763 Close L-153.
 37783 Open L-62.
 37793 In L-53 PRESSURE Control, establish 60 psig in Dewar 2.
 37799 Set the following VCD values:

Pump Radial	6 pulses in 50 msec
50 g's peak-to-peak	Low Pass Filter

37813 Activate the following inputs to the Shutdown Chain:

VCD #2	HT-60
HP-67	HP-511-Lo

37828 Shutdown. HP-511 Lo in tripped condition.
 37846 Reset after bypassing inputs.
 37868 Activate the following inputs to the Shutdown Chain:

VCD #2	Overspeed #1
HP-67	Overspeed #2
HT-60	JP-101/JP-201
HP-511-Lo	Loss of Critical Power
HP-541	LP-61

37928 Switch the following valves to Normal:

L-109	H-142
H-11	H-180/H-53
H-60	H-101

Shutdown Servo

37950 60 psig in Dewar 2.
 37960 Open L-90.
 37963 Close H-180.
 37969 In H-53 PRESSURE Control, establish 100 psig at HP-60.
 37980 Use L-109 to chill the pump.
 38035 HT-511 is 47°R.
 38057 Use H-101 to chill HT-101.

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38063	Use L-111 to chill LT-111.
38066	Use L-191 to chill LT-191.
38158	Open W-211, W-221 and W-231.
38164	Turn on the tapes.
38169	Open H-70.
38174	Open H-75.
38179	Open H-175 to 20%.
38189	Switch H-11 to Δ P Control.
38196	In Ns Control, set the Ns pot to 405 divisions (Ns is 575)
38205	Close H-101.
38208	Open L-111 to 2%.
38216	Set L-90 to 20%.
38222	Open L-92.
38236	Open W-11 and W-100.
38247	Use L-161 to maintain 50-60 psig at LP-61.
38275	In SPEED Control, establish 23,500 rpm.
38292	Speed is 5000 rpm.
38305	Activate HT-511.
38311	Speed is 10,000 rpm; Ns is 800.
38316	Activate $\bar{W}$ /N.
38320	HP-60 exceeds 200 psig, Close L-251 and H-53.
38327	Close H-175.
38366	Turbopump endurance conditions established by CTO and TMR Speed is 23,500 rpm; Ns is 705; HF-550 is 36.5 lb/sec; Pdisch is 840 psig.
38393	HT-511 is 37°R; HT-541 is 49°R.
38461	Dewar 2 level is 80 K#.
38672	Speed is 23,500 rpm; Ns is 700; HF-550 is 36.5 lb/sec; Pdisch is 850 psig.
38688	Dewar 2 level is 74 K#.
39020	Dewar 2 level is 60 K#.
39056	Speed is 23,500 rpm; Ns is 700; HF-550 is 36.5 lb/sec; Pdisch is 850 psig.
39180	H ₂ O tank level is 140 K gal.
39275	Speed is 23,500 rpm; Ns is 695; HF-550 is 36.5 lb/sec; Pdisch is 850 psig.
39350	Demand zero speed.
39374	Close H-75.
39396	Bypass HT-511 and $\bar{W}$ /N.
39405	Switch H-60 to POSITION Control and Close.
39408	Open H-175.
39413	Close L-92.
39435	Open H-180.
39440	Close L-161.
39444	Close L-111.
39447	Set H-101 to minimum setting.
39472	Close W-11 and W-100.
39476	Turn off the tapes.
39484	Switch L-109 to POSITION Control and Close.
39489	Switch H-11 to POSITION Control and Close.
39495	Close the water bypass valves.
39500	Switch L-53 to POSITION Control and Close.
39507	Close L-62.
39516	Open L-153 and L-251.

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39524	Bypass all the inputs to the Shutdown Chain.
39536	Switch the shutdown valves to Override.
39548	Minimum secure established.
39599	Close L-90.
39610	Open L-191.
39621	Transfer controller output to L-11.
39942	Select Dewar 1 pressure feedback.
39978	Open L-3.
40018	Close L-153.
40036	Close L-161.
40094	Open L-61
40139	In L-53 pressure control, establish 60 psig in Dewar 1.
40206	HT-511 is 42°R.
40225	Use L-109 to chill the turbopump.
40272	Set B-15 to a minimum.
40286	Turn on the pulser.
40297	Open N-430.
40307	Slowly open L-11.
40316	Use B-15 to vent BP-15 to less than 60 psig.
40332	Verify L-90 at zero %.
40348	Close L-11.
40350	Set H-101 to a minimum.
40355	Use B-15 to maintain BP-15 at less than 100 psig.
40359	Select Accumulator.
40373	Close L-162.

XIII. PEWEE 2 EMERGENCY SHUTDOWN: TFE is 2500°R

A. PROCEED WITH THE PEWEE 2 SHUTDOWN TEST AT SIMULATED TFE = 2500°R.

40851	Verify that L-153 is Closed.
40858	Verify that Dewar 1 feedback is selected.
40864	Verify that L-61 is Open.
40867	Verify that L-53 is in PRESSURE Control, and 60 psig is established in Dewar 1.
40870	Close K-153.
40880	Open K-62.
40888	In K-53 PRESSURE Control, establish 100 psig in Dewars 4 and 5.
40904	Open K-1.
40911	Use K-106 to chill KT-1 and KT-106.
40926	Open L-331.
40932	Open X-203.
40937	Use X-353 to chill XT-353.
40975	Verify that X-3 is Closed.
40997	KT-2 and KT-106 are chilled, set K-106 to a minimum.
41079	Set the following VCD values:

Turbine Radial	6 pulses in 50 msec
50 g's peak-to-peak	Low Pass Filter

41091	Set the ϕ /N pot to 260 divisions.
41095	Activate G-3 Hold Closed.
41101	Close G-103.
41105	Open G-1.

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41131      Set the Overspeed trip pot to 530 divisions (20,000 rpm).
41235      XT-353 is less than 47°R, Open X-303 and Close X-353.
41245      Open X-103.
41264      Activate the following inputs to the Shutdown Chain:

```

VCD #1	Overspeed #1
HP-67	Overspeed #2
HT-60	JP-101/JP-201
HP-511-Lo	Loss of Critical Power
HP-541	

41291 Switch the following valves to Normal:

L-11	H-142
L-109	H-180/H-53
H-11	X-53/X-161
H-60	H-175
Shutdown Servo	H-70
	H-101

```
41319      Close H-180.
41327      In H-53 PRESSURE Control, establish 100 psig at HP-60.
41347      Set H-175 to 20%.
41358      Use L-109 to chill the pump.
41402      Use H-101 to chill HT-101.
41407      Use L-111 to chill LT-111.
41410      Report Dewar 3 status:
```

XT-2 is 40 and 65°R
X-103 is Open
X-171 is Open

41449 XT-2 is less than 47°R, Close X-103.
41455 Use X-103 to chill XT-2 to less than 47°R. Maintain
XT-2 less than 55°R.
41459 Close X-303.
41465 Close L-331.
41469 Open X-353.
41470 Use L-111 to maintain a chill at LT-10.
41479 Close X-171.
41484 Turn on the tapes.
41502 In X-53/161 PRESSURE Control, establish 187 psig in
Dewar 3.
41505 Open W-211, W-221 and W-231.
41568 Open G-427.
41575 Open W-11, W-100 and W-316.
41588 Dewar 3 level is 70%.
41602 Open B-15 and B-215.
41621 Open K-6 to the clamp.
41624 Close K-106.
41630 Close N-430.
41638 Open H-70, H-75 and H-175 to 20%.
41654 BT-15 and BT-215 are chilled to 150°R, set B-15 to
57% and B-215 to 35%.

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41676 Open L-11 and L-21 to 20%.
 41686 Close L-111.
 41702 Actuate L-11 Hold Open.
 41706 Switch H-11 to ΔP Control.
 41717 In Ns control set the pot to 405 divisions (Ns is 575).
 41719 Close H-101.
 41728 In FLOW Control, establish 19.7 #/sec at LF-10.
 41743 Use K-107 to maintain 45°R at KT-7.
 41757 Activate HT-511.
 41767 Close H-175.
 41775 Activate $\frac{W}{N}$.
 41778 HP-60 exceeds 200 psig, Close L-251 and H-53.
 41840 Open X-3.
 41861 Pewee 2 conditions at TFE is 2500°R established
 BP-15 is 350 psig; BP-215 is 330 psig.
 41868 Dewar 3 status is XT-2 is 45°R, X-103 is Open and Level
 is 60%.
 41905 Push the Emergency Shutdown Button.
 41910 Close K-107.
 41913 Bypass HT-511 and $\frac{W}{N}$.
 41917 Reset the Emergency Shutdown Chain (10 seconds).
 41921 Set H-101 to a minimum.
 41934 Close L-21 (30 seconds).
 41944 Close X-3 and X-203.
 41957 KF-5 indicates maximum flow, Close K-6, Flow is 8.2 lb/sec.
 41964 Bypass G-3, Hold Closed.
 41966 In G-3 FLOW Control, establish minimum GH₂.
 41970 Set K-106 to a minimum.
 41974 Close H-75.
 41980 Close W-11 and W-100.
 41987 Switch H-11 to POSITION Control and Close.
 41992 Close H-142.
 42007 Close the water bypass valves.
 42014 Turn off the tapes.
 42027 Switch L-53 to POSITION Control and Close.
 42031 Close L-62.
 42036 Open L-153 and L-251.
 42045 Close W-316.
 42049 Switch G-3 to POSITION Control and Close.
 42055 Bypass all the inputs to the Shutdown Chain.
 42063 Switch all the shutdown valves to Override.
 42070 BT-15 and BT-215 are 200°R, Close B-15 and B-215.
 42085 Close G-427.
 42087 Close G-1.
 42104 Open G-103.
 42109 Open N-430.
 42115 Close K-2.
 42121 Open X-171 and X-203.
 42131 Switch K-53 to POSITION Control and Close.
 42138 Close K-62.
 42143 Open K-153.
 42160 Minimum secure established.

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XIV. PEWEE 2 EMERGENCY SHUTDOWN #3

During this phase, an Emergency Shutdown will be performed from Pewee 2 full power hold operating conditions. The accumulator, the K-System, and Dewar 3 will be on-line. L-109 will be commanded to 100% upon shutdown.

A. PROCEED WITH THE PEWEE 2 SHUTDOWN TEST.

42930	Report Dewar 3 status:
	Level is 50%.
	XT-2 is 67°R.
	X-103 is Closed.
	X-203 is Open.
	X-171 is Closed.
42939	Verify that L-1 is Open.
42941	Close L-153.
42959	Open L-61.
42966	In L-53 PRESSURE Control, establish 60 psig in Dewar 1.
42975	QP-30 is 700 psig.
42981	Close K-153.
42988	Open K-62.
42998	In K-53 PRESSURE Control, establish 100 psig in Dewar 5.
43027	Open K-1.
43037	Use K-106 to chill KT-2 and KT-106.
43048	Verify that L-331 is Closed.
43051	Verify that X-353 is Open.
43057	Open X-103.
43070	KT-2 and KT-106 are chilled, set K-106 to a minimum.
43074	XT-2 is less than 47°R, Close X-103.
43076	Set the following VCD values:
	Turbine Radial 6 pulses in 50 msec
	50 g's peak-to-peak Low Pass Filter
43086	Set the $\frac{R}{N}$ pot to 260 divisions (Ns is 550).
43088	Activate the G-3 Hold Closed.
43093	Close G-103.
43099	Open G-1.
43106	Set the Overspeed trip pot to 785 divisions (30,000 rpm).
43121	Activate the following inputs to the Shutdown Chain:
	VCD #1 Overspeed #1
	HP-67 Overspeed #2
	HT-60 JP-101/JP-201
	HP-511-Lo Loss of Critical Power
	HP-541
43150	Switch the following valves to Normal:
	L-11 H-180/H-53
	L-109 X-53/X-161
	H-11 H-175
	H-60 H-70
	Shutdown Servo H-101
	H-142

APPENDIX B

43175	Close H-180.												
43184	In H-53 PRESSURE Control, establish 100 psig at HP-60.												
43197	Use L-109 to chill the pump.												
43252	Use H-101 to chill HT-101.												
43256	Use L-111 to chill LT-111.												
43261	Report status of Dewar 3:												
	<table border="0" style="margin-left: 100px;"> <tr> <td>XT-2</td> <td>is</td> <td>47°R.</td> </tr> <tr> <td>X-103</td> <td>is</td> <td>Closed.</td> </tr> <tr> <td>X-171</td> <td>is</td> <td>Closed.</td> </tr> <tr> <td>Level</td> <td>is</td> <td>50%.</td> </tr> </table>	XT-2	is	47°R.	X-103	is	Closed.	X-171	is	Closed.	Level	is	50%.
XT-2	is	47°R.											
X-103	is	Closed.											
X-171	is	Closed.											
Level	is	50%.											
43274	Use X-103 to maintain XT-2 less than 55°R.												
43284	In X-53/161 PRESSURE Control, establish 300 psig in Dewar 3.												
43325	Open W-211, W-221 and W-231.												
43330	Open G-427.												
43340	Turn on the tapes.												
43360	Open W-11, W-100 and W-316.												
43374	Open N-430.												
43377	Open B-15 and B-215.												
43385	Open K-6 to the clamp.												
43393	Close K-106.												
43396	Close N-430.												
43406	Open H-70, H-75 and H-175 to 20%.												
43418	BT-15 and BT-215 are chilled, set B-15 to 55% and B-215 to 38%.												
43434	Open L-11 and L-21 to 20%.												
43454	Switch H-11 to ΔP Control.												
43469	In Ns Control, set the pot. to 405 divisions (Ns is 575).												
43471	Close H-101.												
43479	Close L-111.												
43482	In FLOW Control, establish 30.1 lb/sec at LF-10.												
43496	Use K-107 to maintain a chill at KT-7.												
43531	Activate HT-511.												
43546	HP-60 exceeds 200 psig, Close L-25 and H-53.												
43557	Activate $\frac{W}{N}$.												
43598	Open X-3.												
43604	Use B-15 and B-215 to establish Pewee 2 operating conditions.												
43636	Use H-175 to establish 100 psid at HP-76D.												
43661	HP-76D is Pdisch; HP-71 is 170 psig.												
43711	Open H-175 to 20%.												
43724	BP-15 is 700 psig.												
43735	Adjust B-15 to obtain 660 psig at BP-15.												
43751	BP-15 is 660 psig.												
43775	Using L-11 establish 900 psig at HP-541.												
43786	L-11 is 70%.												
43819	L-11 is 45%.												
43831	Pdisch is 850 psig.												
43857	Pdisch is 900 psig.												
43877	Push the Emergency Shutdown Button and start a 30 second timer.												

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43883	Close K-107.
43887	Bypass HT-511 and W/N.
43892	Reset the Emergency Shutdown Chain (10 seconds).
	Bypass L-11, Hold Open.
43895	Set H-101 to a minimum.
43907	Close L-21 (30 seconds).
43911	Close X-3 and X-203.
43920	In K-6 Flow Control, establish 2 lb/sec at KF-5.
43927	Switch K-6 to POSITION Control and Close.
43931	Bypass G-3, Hold Closed.
43934	In G-3 Flow Control, establish minimum GH ₂ .
43940	Set K-106 to a minimum.
43945	Close H-75.
43952	Close W-11, W-100 and W-316.
43955	Switch H-11 to POSITION Control and Close.
43959	Close H-142.
43973	Close the water bypass valves.
43976	Turn off the tapes.
43982	Open W-316.
44002	Switch L-53 to POSITION Control and Close.
44006	Close L-61.
44013	Open L-153 and L-251.
44019	Bypass all the inputs to the Shutdown Chain.
44028	Switch all the shutdown valves to Override.
44030	BT-15 and BT-215 are 250°R, Close B-15 and B-215.
44033	Switch G-3 to POSITION Control and Close.
44038	Close G-427.
44045	Close W-316.
44059	Close G-1.
44073	Open G-103.
44078	Open N-430.
44083	Close K-2.
44093	Dewar 3 PRESSURE is 240 psig.
44105	Switch K-53 to POSITION Control and Close.
44137	Close K-62.
44145	Open K-153.
44150	Minimum secure established.
44324	Reset L-109 shutdown command to 100%.

XV. PEWEE 2 EMERGENCY SHUTDOWN: L-109 FAIL OPEN ON SHUTDOWN

A. PROCEED WITH THE PEWEE 2 SHUTDOWN TEST WITH L-109 FAIL OPEN ON SHUTDOWN.

44635	Report Dewar 3 status:									
	<table border="0" style="margin-left: 40px;"> <tr> <td>XT-2</td> <td>is</td> <td>55°R.</td> </tr> <tr> <td>XP-61</td> <td>is</td> <td>230 psig.</td> </tr> <tr> <td>Level</td> <td>is</td> <td>between 30 and 40%.</td> </tr> </table>	XT-2	is	55°R.	XP-61	is	230 psig.	Level	is	between 30 and 40%.
XT-2	is	55°R.								
XP-61	is	230 psig.								
Level	is	between 30 and 40%.								
44815	Close L-153, Dewar 1 level is 50 K#.									
44834	Open L-61.									
44840	In L-53 PRESSURE Control, establish 60 psig in Dewar 1.									
44862	Close K-153.									

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44869 44878 44893 44898 44911	<p>Open K-62.</p> <p>In K-53 PRESSURE Control, establish 100 psig in Dewar 5.</p> <p>Open K-2.</p> <p>Use K-106 to chill KT-2 and KT-106.</p> <p>Set the following VCD values:</p> <table border="0" style="margin-left: 100px;"> <tr> <td>Turbine Radial</td> <td>6 pulses in 50 msec</td> </tr> <tr> <td>50 g's peak-to-peak</td> <td>Low Pass Filter</td> </tr> </table>	Turbine Radial	6 pulses in 50 msec	50 g's peak-to-peak	Low Pass Filter														
Turbine Radial	6 pulses in 50 msec																		
50 g's peak-to-peak	Low Pass Filter																		
44919 44923 44928 44934 44941 44948	<p>Set the #/N pot to 260 divisions (Ns is 550).</p> <p>Activate the G-3 Hold Closed.</p> <p>Close G-103.</p> <p>Open G-1.</p> <p>Set the Overspeed trip pot to 785 divisions (30,000 rpm).</p> <p>Activate the following inputs to the Shutdown Chain:</p> <table border="0" style="margin-left: 100px;"> <tr> <td>VCD #1</td> <td>Overspeed #1</td> </tr> <tr> <td>HP-67</td> <td>Overspeed #2</td> </tr> <tr> <td>HT-60</td> <td>JP-101/JP-201</td> </tr> <tr> <td>HP-511-Lo</td> <td>Loss of Critical Power</td> </tr> <tr> <td>HP-541</td> <td></td> </tr> </table>	VCD #1	Overspeed #1	HP-67	Overspeed #2	HT-60	JP-101/JP-201	HP-511-Lo	Loss of Critical Power	HP-541									
VCD #1	Overspeed #1																		
HP-67	Overspeed #2																		
HT-60	JP-101/JP-201																		
HP-511-Lo	Loss of Critical Power																		
HP-541																			
44980	<p>Switch the following valves to Normal:</p> <table border="0" style="margin-left: 100px;"> <tr> <td>L-11</td> <td>H-180/H-53</td> </tr> <tr> <td>L-109</td> <td>X-53/X-161</td> </tr> <tr> <td>H-11</td> <td>H-175</td> </tr> <tr> <td>H-60</td> <td>H-70</td> </tr> <tr> <td>Shutdown Servo</td> <td>H-101</td> </tr> <tr> <td>H-142</td> <td></td> </tr> </table>	L-11	H-180/H-53	L-109	X-53/X-161	H-11	H-175	H-60	H-70	Shutdown Servo	H-101	H-142							
L-11	H-180/H-53																		
L-109	X-53/X-161																		
H-11	H-175																		
H-60	H-70																		
Shutdown Servo	H-101																		
H-142																			
45005 45012 45024 45042 45046 45057	<p>Close H-180.</p> <p>In H-53 PRESSURE Control, establish 100 psig at HP-60.</p> <p>Use L-109 to chill the pump.</p> <p>Use H-101 to chill HT-101.</p> <p>Use L-111 to chill LT-111.</p> <p>Report status Dewar 3:</p> <table border="0" style="margin-left: 100px;"> <tr> <td>Level</td> <td>is</td> <td>30%.</td> </tr> <tr> <td>XT-2</td> <td>is</td> <td>45°R.</td> </tr> <tr> <td>XP-61</td> <td>is</td> <td>190 psig.</td> </tr> <tr> <td>X-103</td> <td>is</td> <td>Closed.</td> </tr> <tr> <td>X-203</td> <td>is</td> <td>Open.</td> </tr> <tr> <td>X-171</td> <td>is</td> <td>Closed.</td> </tr> </table>	Level	is	30%.	XT-2	is	45°R.	XP-61	is	190 psig.	X-103	is	Closed.	X-203	is	Open.	X-171	is	Closed.
Level	is	30%.																	
XT-2	is	45°R.																	
XP-61	is	190 psig.																	
X-103	is	Closed.																	
X-203	is	Open.																	
X-171	is	Closed.																	
45081 45092 45095	<p>Use X-103 to maintain XT-2 less than 47°R.</p> <p>Verify that X-171 is Closed.</p> <p>In X-53/161 PRESSURE Control, establish 300 psig in Dewar 3.</p>																		

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45102 Open W-211, W-221 and W-231.
 45110 Turn on the tapes.
 45112 Open G-427.
 45126 Open W-11, W-100 and W-316.
 45136 Open N-430.
 45153 QP-30 is 550 psig.
 45159 Open B-15 and B-215.
 45169 Open K-6 to the clamp.
 45172 Close K-106.
 45180 Close N-430.
 45186 Open H-70, H-75 and H-175 to 20%.
 45202 BT-15 and BT-215 are chilled, set B-15 to 55% and B-215 to 38%.
 45217 In K-6 Flow Control reduce the Flow.
 45242 Flow is 1.8 lb/sec.
 45244 Open L-11 and L-21 to 20%.
 45268 Actuate L-11, Hold Open.
 45271 Switch H-11 to ΔP Control.
 45288 In Ns Control, set the pot to 405 divisions (Ns is 575).
 45292 Close H-101.
 45299 In FLOW Control, establish 30.1 lb/sec at LF-10.
 45313 Use K-107 to maintain a chill at KT-7.
 45330 Switch K-6 to POSITION Control and Close.
 45341 Activate HT-511.
 45347 HP-60 exceeds 200 psig, Close L-251 and H-53.
 45358 Close H-175.
 45360 Activate $\bar{W}/N$.
 45383 Open X-3.
 45421 Pewee 2 operating conditions established.
 45443 Push the Emergency Shutdown Button and start a 30 second timer.
 45450 Close K-107.
 45453 Bypass HT-511 and $\bar{W}/N$.
 45456 Reset the Emergency Shutdown Chain (10 seconds). Bypass L-11, Hold Open.
 45462 Set H-101 to a minimum.
 45475 Close L-21 (30 seconds).
 45479 Close X-3 and X-203.
 45487 In K-6 Flow Control, establish 2 lb/sec at KF-5.
 45505 Switch K-6 to POSITION Control and Close.
 45510 Bypass G-3 Hold Closed.
 45514 In G-3 Flow Control, establish minimum GH_2 .
 45516 Set K-106 to a minimum.
 45523 Close H-75.
 45529 Close W-11 and W-100.
 45533 Switch H-11 to POSITION Control and Close.
 45538 Close H-142.
 45550 Close the water bypass valves.
 45555 Turn off the tapes.
 45560 Switch L-53 to POSITION Control and Close.
 45563 Close L-61.
 45568 Open L-153 and L-251.
 45573 Bypass all the inputs to the Shutdown Chain.
 45578 Switch G-3 to POSITION Control and Close.
 45583 Switch all the shutdown valves to Override.

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45586 Close W-316.
 45596 BT-15 and BT-215 are 250°R, Close B-15 and B-215.
 45600 Close G-427.
 45605 Close G-1.
 45622 Open G-103.
 45628 Open N-430.
 45632 Close K-2.
 45655 XP-61 is 250 psig; Level is 20%.
 45698 Switch K-53 to POSITION Control and Close.
 45702 Close K-62.
 45707 Open K-153.
 45722 Reset L-109 shutdown command to 15%.
 45725 Minimum secure established.

XVI. PEWEE 2 SHUTDOWN TEST: H-60 FAIL CLOSED

A. PROCEED WITH THE H-60 FAIL CLOSED SHUTDOWN TEST.

47310 Report Dewar 3 status:

XP-61	is	230 psig.
Level	is	20%.
X-203	is	Closed.
X-103	is	Closed.
X-171	is	Closed.

47315 Close L-153.
 47330 Open L-61.
 47337 In L-53 PRESSURE Control, establish 60 psig in Dewar 1.
 47343 Close K-153.
 47355 Open K-62.
 47364 QP-30 is 530 psig.
 47371 In K-53 PRESSURE Control, establish 100 psig in
 Dewars 4 and 5.
 47393 Open K-2.
 47399 Use K-106 to chill KT-2 and KT-106.
 47407 Set the following VCD values:

Turbine Radial	6 pulses in 50 msec
50 g's peak-to-peak	Low Pass Filter

47420 Set the $\frac{W}{N}$ pot to 260 divisions (Ns is 550).
 47423 Activate G-3, Hold Closed.
 47435 Close G-103.
 47460 Open G-1.
 47465 Set the Overspeed trip pot to 785 divisions (30,000 rpm).
 47472 Activate the following inputs to the Shutdown Chain:

VCD #1	Overspeed #1
HP-67	Overspeed #2
HT-60	JP-101/JP-201
HP-511-Lo	Loss of Critical Power
HP-541	

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47501 Switch the following valves to Normal:

L-11	H-142
L-109	H-180/H-53
H-11	X-53/X-161
H-60	H-175
Shutdown Servo	H-70
	H-101

47525 Close H-180.

47546 Use L-109 to chill the pump.

47608 L-109 is Open to the clamp; no rotation.

47644 Close L-109.

47657 Open L-109.

47668 L-109 is Open to the clamp; no rotation.

47670 Open H-101.

47702 H-101 is 100%.

47720 "Button up the system."

47740 Standby condition.

47825 Begin Shutdown phase.

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CHRONOLOGY FOR PEWEE 2 INTEGRATED FACILITY TEST SERIES

FEP-II

OCTOBER 8, 1970

I. PRE-OPERATIONAL PHASE

- A. SETUP CHECKLISTS RECEIVED APPROVED; STATUS BOARD CLEARED.
- B. CHECK THE CONTROL ROOM NET.
- C. REQUIRED SYSTEMS SWITCHED TO CP CONTROL.
- D. EXERCISE THE VALVES IN THE FLOW CONTROL ROOM, PUMP ROOM, AND HIGH PRESSURE ROOM.
- E. CHECK THE SHUTDOWN CHAIN.
- F. BEGIN INERTING THE TEST CELL.

04878 Turn off the fans.
04886 Close Q-113.
04896 Pressurize the room inerting header (Bottles #13, 14, 15 & 16).
 QP-50 indicates 2390 psig.
04960 Begin inerting the test cell.

- G. EXERCISE THE REMAINING VALVES AND CHECK THE PROPELLANT FLARE.
- H. PERFORM A VOLTAGE CALIBRATION.

06231-06331 Calibration interval.

- J. PERFORM ZERO PRESSURE CALIBRATION.

06918-07940 Calibration interval.

II. HEADER, PRESSURIZATION, X-SYSTEM CHILLDOWN

- A. PRESSURIZE THE HEADERS.

07126 Report on inerting:
07137 Open K-50 and K-153.
07148 Open L-153, L-50, L-251 and H-50.
07173 Open G-11.
07180 Open X-50 and X-153.
07190 Open W-50.
07197 Open G-50.
07201 Close all the bottle purge valves.
07219 Close Q-150.
07229 Pressurize the helium header (Bottle #2).
 QP-20 indicates 3010 psig.
07270 Pressurize the hydrogen header (Bottles #3, 4, 5, 6, 7, & 8).
 QP-30 indicates 3290 psig.
07317 Pressurize the nitrogen header (Bottles #9 and 10).
 QP-40 indicates 3020 psig.

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B. PROCEED WITH THE X-SYSTEM INITIAL CHILLDOWN.

07411	Turn on the propellant flare pulser.
07428	Open K-7 and K-21.
07443	Open N-430.
07451	Open B-15 and B-215.
07469	In G-13 FLOW Control, establish 1 lb/sec GHe.
07506	At the end of the 30-second timer, Close B-15 and B-215.
07520	Switch G-13 to POSITION Control and Close.
07535	Close N-430.
07537	Pulser OFF.
07542	Close L-262 and L-153.
07566	Open L-62.
07572	Select Dewar 2 pressure feedback.
07578	In L-53 PRESSURE Control, establish 60 psig in Dewar 2.
07598	Close X-405 and X-261.
07608	Open L-330 and L-351.
07629	Open L-302.
07717	LT-351 indicates 100°R, Open X-353.
07722	Open L-331.
07733	Close L-351.
07751	Open X-171.
07923	XT-353 is less than 44°R, Open X-303.
07929	Close X-353.
07935	Open X-1, X-103, X-203.
09931	XT-812 and XT-821 are less than 200°R, Close X-103.
09935	Close X-303.
09947	Use X-303, X-171 and X-103 as required to chill the X-System.

III. INITIAL CHILLDOWN OF K AND L-SYSTEM

A. PROCEED WITH THE K-SYSTEM PRESSURIZATION, CHILLDOWN AND SOAK.

08022	Close K-402.
08033	Open K-3.
08041	Close K-153, K-262, and K-261.
08061	Open K-61 and K-62.
08077	Select Dewars 4 and 5 suction feedback.
08086	In K-53 PRESSURE Control, establish 100 psig in Dewars 4 and 5.
08099	Open K-1.
08188	Use K-106 to chill KT-106.
08660	KT-106 is chilled, set K-106 to minimum.
08667	Close K-1.
08690	Switch K-53 to POSITION Control and Close.
08704	Close K-61 and K-62.
08728	Open K-153.

B. PROCEED WITH THE L-SYSTEM CHILLDOWN AND SOAK.

08308	Turn on the lube oil pump.
08322	Open L-3.
08341	Open L-2.

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08348 Close H-460 and H-461.
 08381 Use H-101 to chill HT-101 and L-111 to chill LT-111.
 08386 Use L-121 to chill LT-121.
 09075 Use L-109 to chill the pump.
 09134 The pump is chilled, Close L-109.
 09143 Release the pump latch.
 09151 Start a 900-second timer.

IV. WATER SYSTEM SETUP AND OVERSPEED TRIP CHECK

A. PROCEED WITH THE SETUP OF THE WATER SYSTEM.

09243 Verify that W-153 is closed.
 09252 Open W-1, W-211, W-221, W-231, W-11, W-45, W-49, W-100.
 09347 Use W-53 to establish 35 psig at WP-45.
 09427 Turn on the water flow meter power.
 09462 Close W-11, W-211, W-221, W-231.
 10001 Bentley probes appear to be inoperative.
 10373 Pump speed is 1500 rpm.
 10435 Track at 10 ips.
 10441 Data at 10 ips.
 12250 Bentley CEC's HD-501 and HD-504 decreased to 1/3 gain (Greater span)
 12754 Pump speed is 500 rpm.
 12764 Track at 1 ips.
 12777 Data at 1 ips.
 13363 Lowered the scope gain on Bentley probes HD-501 and HD-504.

B. PROCEED WITH THE CHECK OF THE SPEED INPUTS TO THE SHUTDOWN CHAIN.

13460 Set the Overspeed Trip Pot to 65 divisions.
 13468 Bypass all the inputs to the Shutdown Chain and switch the shutdown valves to Override.
 13477 Open L-109 to trip Overspeed #1 and Overspeed #2.
 13600 Close L-109.
 13608 Report the following data:

<u>Dewar Level:</u>	<u>1</u>	<u>2</u>
Reflectometer	35K lbs.	200K lbs.
Staircase	29.9K lbs.	160K lbs.
0% Temperature	37°R	38°R
10% Temperature	37°R	38°R

13647 Report the following data:

QP-20 is 3010 psig.
 QP-30 is 2880 psig.
 QP-40 is 3000 psig.
 QP-50 is 1630 psig.

13669 Report the following data:

<u>Dewar Level:</u>	<u>4</u>	<u>5</u>
Reflectometer	27K lbs.	30.5K lbs.
Staircase	24K lbs.	29K lbs.
0% Temperature	38.1°R	38.5°R

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13705	Report the hot water tank level: 220 K gallons
13709	Report the Dewar 3 level: Greater than .99%.
13717	Report the Test Cell "C" Elevated Water Tank level: 150+ K gallons.
13850	HA-515B has 10% spikes (CEC).

V. TURBOPUMP GREEN RUN AND Ns CONTROLLER CHECKOUT

A. PROCEED WITH THE TURBOPUMP GREEN RUN AND Ns CONTROLLER CHECKOUT.

14307	Verify that the Ns controller is -6db from FEP-I.										
14045	Set the Overspeed Trip Pot to 785 divisions (30,000 rpm).										
14056	Set the $\frac{W}{N}$ trip to 255 divisions (Ns is 550).										
14072	Set the step to +.3 volts.										
14079	Patch the step to the Ns Loop.										
14083	Close L-153.										
14100	Open L-62.										
14107	In L-53 PRESSURE Control, establish 60 psig in Dewar 2.										
14113	Set the following VCD values:										
	<table border="0" style="width: 100%;"> <tr> <td style="width: 50%;">Turbine Radial</td> <td style="width: 50%;">6 pulses in 50 msec</td> </tr> <tr> <td>50 g's peak-to-peak</td> <td>Low Pass Filter</td> </tr> </table>	Turbine Radial	6 pulses in 50 msec	50 g's peak-to-peak	Low Pass Filter						
Turbine Radial	6 pulses in 50 msec										
50 g's peak-to-peak	Low Pass Filter										
14122	Activate the following inputs to the Emergency Shutdown Chain:										
	<table border="0" style="width: 100%;"> <tr> <td style="width: 50%;">VCD #1</td> <td style="width: 50%;">Overspeed #1</td> </tr> <tr> <td>HP-67</td> <td>Overspeed #2</td> </tr> <tr> <td>HT-60</td> <td>JP-101/JP-201</td> </tr> <tr> <td>HP-511 Low</td> <td>Loss of Critical Power</td> </tr> <tr> <td>HP-541</td> <td></td> </tr> </table>	VCD #1	Overspeed #1	HP-67	Overspeed #2	HT-60	JP-101/JP-201	HP-511 Low	Loss of Critical Power	HP-541	
VCD #1	Overspeed #1										
HP-67	Overspeed #2										
HT-60	JP-101/JP-201										
HP-511 Low	Loss of Critical Power										
HP-541											
14185	Switch the following valves to Normal:										
	<table border="0" style="width: 100%;"> <tr> <td style="width: 50%;">L-109</td> <td style="width: 50%;">H-180/H-53</td> </tr> <tr> <td>H-60</td> <td>H-101</td> </tr> </table>	L-109	H-180/H-53	H-60	H-101						
L-109	H-180/H-53										
H-60	H-101										
	Shutdown Servo										
14199	Close H-180.										
14208	In H-53 PRESSURE Control, establish 400 psig at HP-60.										
14225	Use L-109 to chill the pump.										
14351	In Ns Control, set the pot to 570 divisions (Ns is 650).										
14363	Use H-101 to chill HT-101.										
14365	Use L-111 to chill LT-111.										
14551	Turn on the tapes.										
14559	Set L-111 to 44%.										
14565	Open the water bypass valves.										
14589	Close H-101.										
14595	In SPEED Control, establish 23,500 rpm.										
14639	Speed is 10,000 rpm; Ns is 850.										
14659	Activate HT-511.										
14677	Speed is 15,000 rpm; Ns is 750.										
14736	Activate $\frac{W}{N}$										
14741	Speed is 20,000 rpm; Ns is 700.										
14771	Speed is 23,500 rpm; Ns is 695.										
14786	In Ns control use L-109 to establish an Ns of 900.										
14809	Ns is 690.										
14845	Ns is 780.										
14853	Ns is 800; L-109 is 6%.										

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14889 Ns is 880; L-109 is 8%.
14901 Use L-111 to establish an L-109 stem position of 10%.
14916 Small H₂ leak in the PMP room.
14925 L-111 is 40%; L-109 is 10%; Ns is 880; Speed is 23,500 rpm.
14934 Proceed with the step response measurement.
14944 Step in.
14949 Step out.
14953 In Ns control, use L-109 to establish an Ns of 700.
14991 Ns is 720.
14996 Demand zero speed.
15015 Bypass W/N at 18,000 rpm.
15036 Bypass HT-511.
15043 At zero speed, switch H-60 to POSITION Control and Close.
15046 Switch H-53 to POSITION Control and Close.
15049 Open H-180.
15053 Close L-111.
15058 Set H-101 to minimum setting.
15061 Close W-211, W-221, W-231.
15066 Switch L-109 to POSITION Control and Close.
15072 Switch L-53 to POSITION Control and Close.
15075 Close L-62.
15081 Open L-153.
15087 Bypass all the inputs to the Shutdown Chain and switch the shutdown valves to Override.

15101 Unpatch the step.
15105 Standby secure established.

VI. PEWEE 2 NORMAL PROFILE OPERATION

A. PROCEED WITH THE PEWEE 2 PROFILE

16061 Close L-153.
16067 Report status of Dewar 3 chilldown and Dewar 3 level. Dewar 3 is well chilled; X-303 and X-171 are closed; Dewar 3 is full.

16082 Open L-62.
16086 In L-53 PRESSURE Control establish 60 psig in Dewar 2.
16095 Close K-153.
16101 Open K-61 and K-62.
16115 Select Dewar 4 and 5 Auction Pressure Feedback.
16123 In K-53 PRESSURE Control, establish 100 psig in Dewars 4 and 5.
16148 Open K-2.
16157 Open K-106.
16245 KT-2 is 40°R open K-1 and close K-2.
16298 Reset the programmer.
16309 Set the W/N pot to 255 divisions (Ns is 550).
16317 Set the required VCD values.
16340 Verify that X-303 and X-171 are open.
16351 Filling Dewar 3.
16369 KT-1 and KT 106 are 45°R, set K-106 to a minimum.
16378 XT-2 is less than 47°R, close X-103.
Use X-103 to maintain XT-2 less than 47°R.

16382 Close G-103.
16389 Open G-1.
16414 Activate H-142 Hold Close.
16418 Activate G-13 Hold Close.
16426 Close X-153 and activate Hold Close.

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16435 Open X-17, X-18 and X-61.
 16451 Set the Overspeed Trip Pot to 785 divisions (30,000 rpm).
 16458 Activate the required inputs to the Emergency Shutdown Chain.
 16484 Switch the following valves to Normal

X-53/X-161	H-60
H-70	Shutdown Servo
H-175	H-142
L-109	H-180/H-53
H-11	H-101

16513 Close H-180.
 16522 In H-53 PRESSURE Control, establish 100 psig at HP-60.
 16530 Use L-109 to chill the pump.
 16631 In Ns Control, set the pot to 385 divisions (Ns is 575).
 16635 Use H-101 to chill HT-101.
 16638 Use L-111 to chill LT-111.
 16645 Use L-121 to chill LT-121.
 16723 Turn on the tapes.
 16726 Open the water bypass valves.
 16731 Open H-70 and H-75.
 16741 Switch H-11 to ΔP Control.
 16745 Turn on the reactor flare pulser.
 16752 Open W-11 and W-316.
 16759 Open G-427.
 16767 Open N-430.
 16777 Open B-15 to 94%; B-215 to 72%.
 16812 In G-3 FLOW Control, establish 120 psig at KP-7.
 16817 Close N-430.
 16823 Turn off the pulser.
 16860 BP-15 is 90 psig; BP-215 is 95 psig.
 16865 Use K-106 to chill KT-106.
 16918 Open K-6 to the 35% clamp and close K-106.
 16950 Switch G-3 to POSITION Control and slowly Close. Activate the Hold Closed.
 17021 BT-15 is chilled to 150°R, set B-15 to 55%.
 17047 BF-13 is 5 lb/sec.
 17067 BT-215 is chilled to 150°R, set B-215 to 38%.
 17088 Insert and remove the K-6 block.
 17119 When XT-2 is less than 47°R, close X-103. Activate the Hold Closed.
 17128 Switch X-53/X-161 to PROGRAM PRESSURE Control.
 17137 Close X-171.
 17159 Open X-3.
 17169 Open L-111 to 32% and switch to PROGRAM.
 17187 Switch L-11 to PROGRAM.
 17193 Switch L-11 Delay to NORMAL.
 17198 Close H-101 and activate Hold Closed.
 17205 Zero the Flow Bias.
 17208 Switch to FLOW PROGRAM.
 17217 Use Flow Bias to establish 165 psig at HP-541.
 17281 HP-60 exceeds 100 psig, close L-251, H-53.
 17290 Switch H-11 to POSITION Control.
 17300 Using H-11, establish 50 psid at HP-11D.

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17337 Slowly open H-11 to 100%.
 17340 Speed is 8000 rpm; H-60 is 15%.
 17370 Close H-11 to establish 30 psid at HP-11D.
 17420 Switch H-11 to ΔP Control.
 17425 In H-53 PRESSURE Control, establish 200 psig at HP-60.
 17436 Slowly open L-21 to 30%.
 17458 Insert the L-21 Block.
 17465 Set L-21 to 20%.
 17477 Activate the ΔP 's.
 17480 Close X-303.
 17514 H₂ in PMP Room N.W.
 17523 BT-15 and BT-215 are 50°R, switch to Run.
 17530 When KF-5 indicates zero, use K-107 to maintain 45°R at KT-7.
 17542 Activate HT-511.
 17548 L-111 is closed, activate the Hold Closed.
 17552 HP-60 exceeds 200 psig, switch H-53 to POSITION Control and Close.
 17555 At Flow Crossover, zero Flow Bias.
 17573 At 18,000 rpm, activate ΔP /N.
 17579 L-11 is 37% open, activate the L-11 HOLD OPEN.
 17584 Intermediate Power Hold: Ns is 660; LF-25 is 5.8 lb/sec; BF-13 is 23 lb/sec; HF-550 is 26 lb/sec.
 17597 Switch to run.
 17609 Full Power Hold #1.
 17649 H₂ in FCR, N.E. Corner.
 17679 Establish Pewee 2 operating conditions: LF-25 is 6.3 lb/sec; BP-215 is 640 psig; BP-15 is 750 psig; LF-10 is 29 lb/sec; BF-13 is 26 lb/sec; HF-550 is 35 lb/sec; speed is 22,500 rpm.
 17720 Switch to Run.
 17746 At 18,000 rpm, bypass ΔP /N.
 17786 HP-60 is 200 psig, switch H-53 to PRESSURE Control and maintain 200 psig.
 17790 Shutdown Hold #1. (10 seconds).
 17824 HP-60 exceeds 200 psig, switch H-53 to POSITION Control and Close.
 17842 At 18,000 rpm activate ΔP /N.
 17862 Full Power Hold #2: LF-25 is 6.3 lb/sec; LF-10 is 29.5 lb/sec; BF-13 is 26 lb/sec; BP-15 is 740 psig; BP-215 is 660 psig.
 17925 Switch to Run.
 17951 At 18,000 rpm, bypass ΔP /N.
 17965 LF-10 is 20 lb/sec, slowly Open H-175.
 17975 Ns is 650.
 17998 Shutdown Hold #2.
 18012 Report end of Shutdown Hold #2 and Close H-175.
 18045 At 18,000 rpm activate ΔP /N.
 18067 Full Power Hold #3.
 18071 Establish Pewee 2 operating conditions: BP-15 is 760 psig; BP-215 is 660 psig; BF-13 is 26 lb/sec; LF-10 is 29.5 lb/sec; HF-550 is 35 lb/sec.
 18094 Switch H-11 to POSITION Control.
 18102 Open H-11 to 100%.
 18153 Close K-6 and set K-106 to a minimum.
 18159 Close K-1.
 18175 BP-215 is 680 psig; BP-15 is 790 psig.

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18180 Switch to PROGRAM SHUTDOWN.
 18206 At 18,000 rpm, bypass Δ /N.
 18222 LF-10 is 20 lb/sec, Close H-75 and Open H-175.
 18234 XP-61 is 100 psig, switch X-53/X-161 to PRESSURE Control.
 Maintain 100 psig at XP-61.
 18253 Shutdown Hold.
 18258 Bypass L-11 Hold Open.
 18263 Switch the following valves to Override:

L-11 Delay	X-53/X-161	H-11
L-109	H-101	H-142

18286 Switch L-109 to POSITION Control and Close.
 18294 Switch L-11 to POSITION Control.
 18306 Open L-21 to 100%.
 18377 Push the Emergency Shutdown Button.
 18382 Upon Shutdown, bypass HT-511 and Δ 's, Open H-175 to 20%.
 18386 Reset the Emergency Shutdown Chain.
 18389 Switch H-11 to POSITION Control and Close.
 18399 Bypass H-101 Hold Close and set H-101 to a minimum; and maintain 200-300 psig at HP-1.
 18408 Dewar 3 level is 80%.
 18417 H₂ greater than 10% in PMP Room.
 18427 Close X-3 and X-203.
 18432 Remove L-21 Block.
 18440 Using L-11 and L-21 establish the following flow rates at LF-10:
 5 lb/sec; 4 lb/sec; 3 lb/sec; 2 lb/sec

18448 LF-10 is 2 lb/sec.
 18450 Switch X-53/161 to POSITION Control and Close.
 18460 L-11 is open to the block; L-21 is open.
 18470 LF-10 is 2 lb/sec; BF-13 is 3 lb/sec; .5 lb/sec at L-21;
 LF-25 is .5 lb/sec.
 18520 LF-25 is .75 lb/sec; BF-13 is 3.5 lb/sec.
 18580 LF-25 is 3.5 lb/sec.
 18610 BF-13 is 3 lb/sec; LF-25 is 1 lb/sec.
 18628 L-11 is 15%.
 18652 L-11 is 35%; LF-25 is .5 lb/sec.
 18670 Close L-11 and L-21.
 18676 Set H-101 to a minimum.
 18678 Close K-107.
 18687 Open N-430.
 18693 Switch L-53 to POSITION Control and Close.
 18698 Open L-251.
 18707 In L-53 PRESSURE Control, establish 60 psig in Dewar 2.
 18724 BT-15 and BT-215 are beginning to increase, Open L-11 and L-21 to establish 2 - 4 lbs/sec at LF-10.
 18733 Repeat Pulse cooling with L-11, L-21 as required.
 18742 LF-10 is 2.5 lb/sec; LF-25 is .5 lb/sec.
 18751 HT-511 is 41°R.
 18758 Open X-171 and X-203.
 18778 Close L-11, L-21.

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18844	L-11 is 30%; L-21 is 30%; LF-25 is .5 lb/sec; LF-10 is 2 lb/sec.
18864	Close L-11, L-21.
18868	Close H-142 and Bypass H-142 Hold Closed.
18873	Bypass G-13 Hold Closed.
18879	Bypass G-3 Hold Closed.
18888	In G-3 FLOW Control, establish minimum GH_2 flow.
18890	Turn off the tapes.
18924	Close W-11.
18948	Close the water bypass valves.
18978	Switch K-53 to POSITION Control and Close.
18987	Close K-61 and K-62.
19000	Open K-153.
19007	Switch L-53 to POSITION Control and Close.
19011	Close L-62.
19015	Open L-153.
19020	Bypass all inputs to the shutdown chain and switch all shutdown valves to Override.
19036	Switch L-11 to POSITION Control and Close.
19047	Bypass the X-103 HOLD CLOSED.
19054	Reset the Programmer.
19072	Switch G-3 to POSITION Control and Close.
19089	BT-15 and BT-215 are greater than 250°R , Close B-15 and B-215.
19092	Close G-427.
19095	Close W-316.
19102	Close G-1.
19122	Open G-103.
19130	Close N-430.
19143	Dewar 4 Reflectometer does not agree with Dewar 4 Staircase.
19167	Standby secure established.
19386	Vent 10 psig from water tank.

VII. PEWEE 2 SHUTDOWN TEST: ACCUMULATOR AT 100 PSID

A. PROCEED WITH THE PEWEE 2 SHUTDOWN TEST WITH THE ACCUMULATOR AT 100 PSI BELOW LINE PRESSURE.

19445	Close L-153.
19462	Open L-62.
19471	In L-53 PRESSURE Control, establish 60 psig in Dewar 2.
19476	Close K-153.
19486	WP-1 is 45 psig.
19495	Open K-61 and K-62.
19504	In K-53 PRESSURE Control, establish 100 psig in Dewars 4 and 5.
19519	Open K-1.
19529	Use K-106 to chill KT-1 and KT-106.
19555	Report Dewar 3 Status: XT-2 is 45°R ; X-303 is closed; Dewar 3 level is 80%.
19590	Set the required VCD values.
19607	Set the Φ/N pot to 255 division (Ns is 550).
19620	Set the Overspeed Trip Pot to 785 divisions (30,000 rpm).
19637	KT-1 and KT-106 are chilled, set K-106 to a minimum.
19643	Activate G-3 Hold Closed.

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19655	Close G-103.												
19660	Open G-1.												
19683	Activate the required inputs to the Shutdown Chain.												
19707	Switch the following valves to Normal:												
	<table border="0" style="width: 100%;"> <tr> <td>L-11 Delay</td> <td>H-142</td> </tr> <tr> <td>L-109</td> <td>H-180/H-53</td> </tr> <tr> <td>H-11</td> <td>X-53/X-161</td> </tr> <tr> <td>H-60</td> <td>H-175</td> </tr> <tr> <td>Shutdown Servo</td> <td>H-70</td> </tr> <tr> <td></td> <td>H-101</td> </tr> </table>	L-11 Delay	H-142	L-109	H-180/H-53	H-11	X-53/X-161	H-60	H-175	Shutdown Servo	H-70		H-101
L-11 Delay	H-142												
L-109	H-180/H-53												
H-11	X-53/X-161												
H-60	H-175												
Shutdown Servo	H-70												
	H-101												
19741	Close H-180.												
19748	In H-53 PRESSURE Control, establish 100 psig at HP-60.												
19752	Use L-109 to chill the pump.												
19831	In Ns Control, set the pot to 385 divisions (Ns is 575).												
19842	Use H-101 to chill HT-101.												
19845	Use L-111 to chill LT-111.												
19848	Use L-121 to chill LT-121.												
19854	Report Dewar 3 status: XT-2 is 45°R; Level is 80%; HT-511 is 41°R.												
19912	Use X-103 to chill XT-2 to less than 47°R.												
19914	Verify that X-303 is closed.												
19917	Close X-171.												
19926	In X-53/161 PRESSURE Control, establish 300 psig in Dewar 3.												
19929	Open W-211, W-221, W-231.												
19954	Open G-427.												
19957	Open W-11 and W-316.												
19977	Turn on the tapes.												
19980	Open N-430.												
19986	Open B-15 and B-215.												
19999	Open K-6 to the clamp.												
20019	Dewar 3 level is 70%.												
20025	Close K-106.												
20029	Close N-430.												
20039	Open H-70.												
20042	Open H-75.												
20045	Open H-175 to 20%.												
20057	BT-15 and BT-215 are chilled, set B-15 to 55% and B-215 to 38%.												
20066	Open L-11 to 37% and L-21 to 20%.												
20092	Activate the L-11 Hold Open.												
20095	Switch H-11 to Δ P Control.												
20103	Close H-101.												
20108	In FLOW Control, establish 30.1 lb/sec at LF-10.												
20128	Activate HT-511.												
20137	Use K-107 to maintain a chill at KT-107.												
20165	HP-60 exceeds 200 psig, Close L-251, H-53.												
20178	Activate Φ /N at 18000 rpm.												
20192	Open X-3.												
20291	Dewar 3 level is 60%.												
20370	Establish Pewee 2 Full Power operating conditions: BP-215 is 620 psig; BP-15 is 760 psig; LF-10 is 30.1 lb/sec.												

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20355	Lost HP-76D
20377	Using H-175, establish 100 psid between HP-71 and LP-10.
20405	Push the Emergency Shutdown Button
20408	Close K-107.
20411	Bypass HT-511 and W/N.
20416	Reset the Emergency Shutdown Chain.
20421	Bypass L-11 Hold Open.
20424	Set H-101 to a minimum.
20443	Close L-21.
20452	Close X-3 and X-203.
20466	Bypass G-3 Hold.Closed.
20472	KF-5 indicates maximum flow, close K-6.
20483	In G-3 FLOW Control, establish minimum GH ₂ .
20531	Switch H-11 to POSITION Control and Close.
20556	Set K-106 to a minimum.
20560	Close H-75.
20566	Close W-11.
20569	Turn off the tapes.
20577	Close H-142.
20585	Close the water bypass valves.
20593	Switch L-53 to POSITION Control and Close.
20597	Close L-62.
20606	Switch G-3 to POSITION Control and Close.
20607	BT-15 and BT-215 are 200°R, Close B-15 and B-215.
20610	Open L-153 and L-251.
20619	Bypass all the inputs to the Shutdown Chain and switch all the shutdown valves to Override.
20626	Close W-316.
20640	Close G-427.
20648	Close G-1.
20664	Open G-103.
20668	Open N-430.
20674	Close K-1.
20678	Open X-171 and X-203.
20689	Switch K-53 to POSITION Control and Close.
20696	Close K-61 and K-62.
20705	Open K-153.
20710	Standby secure established.

VIII. PEWEE 2 EMERGENCY SHUTDOWN: ACCUMULATOR AT LINE PRESSURE

A. PROCEED WITH THE PEWEE 2 SHUTDOWN TEST WITH THE ACCUMULATOR AT LINE PRESSURE.

20983	Report Dewar 3 Status: XT-2 is chilled; pressure is 170 psig; level is 50%.
21099	Close L-153.
21125	Open L-62.
21130	In L-53 PRESSURE Control, establish 60 psig in Dewar 2.
21133	Close K-153.
21140	Open K-61 and K-62.
21154	In K-53 PRESSURE Control, establish 100 psig in Dewars 4 and 5.
21161	Use X-353 to chill XT-353.
21179	Open K-1.
21184	Use K-106 to chill KT-1 and KT-106.
21210	Open L-351.

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21249 Close L-351.
 21263 Set the required VCD values.
 21281 XT-353 is less than 47°R Open X-303.
 21288 Close X-353.
 21299 Open X-103 and when XT-2 is less than 47°R, Close X-103.
 21304 KT-1 and KT-106 are chilled, set K-106 to a minimum.
 21306 Activate the G-3 Hold Closed.
 21315 Close G-103.
 21322 Open G-1.
 21347 Set the Φ /N pot to 255 divisions (Ns is 550).
 21351 Set the Overspeed trip pot to 785 divisions (30,000 rpm).
 21366 Activate the required inputs to the Shutdown Chain.
 21439 Switch the following valves to Normal:

L-11 Delay	H-180/H-53
L-109	X-53/X-161
H-11	H-70
H-60	H-101
Shutdown Servo	
H-142	

 21467 Close H-180.
 21474 In H-53 PRESSURE Control, establish 100 psig at HP-60.
 21479 Use L-109 to chill the pump.
 21585 In Ns Control, set the pot to 385 divisions (Ns is 575).
 21594 Use H-101 to chill HT-101.
 21597 Use L-111 to chill LT-111.
 21601 Use L-121 to chill LT-121.
 21612 Report status of Dewar 3: XT-2 is 45°R; level is 80%;
 X-303 is open.
 21661 Close X-303.
 21668 Close X-171.
 21676 In X-53/161 PRESSURE Control, establish 300 psig in Dewar 3.
 21679 Open W-211, W-221, W-231.
 21701 Turn on the tapes.
 21706 Open G-427.
 21709 Open W-11 and W-11 and W-316.
 21729 Open B-15 and B-215.
 21744 Open K-6 to the clamp.
 21747 Close K-106.
 21788 Close N-430.
 21792 Use K-107 to maintain a chill at KT-107.
 21798 Open H-70.
 21809 H₂ leak in FCR.
 21810 Open H-75.
 21815 Close H-175.
 21838 BT-15 and BT-215 are chilled, set B-15 to 55.6%; B-215 to 38%.
 21853 Open L-11 to 37%.
 21870 Hold:
 21900 Close L-11.
 21947 Open L-11 to 37%.
 21955 Open L-21 to 20%.
 21967 Actuate L-11 Hold Open.
 21971 Switch H-11 to Δ P Control.

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21978 Close H-101.
 21985 In FLOW Control, establish 30.1 lb/sec at LF-10.
 22003 Use K-107 to maintain a chill at KT-7.
 22019 Activate HT-511.
 22040 HP-60 exceeds 200 psig, Close L-251 and H-53.
 22048 10% H₂ in FCR.
 22055 Activate $\frac{W}{N}$ at 18,000 rpm.
 22065 Open X-3.
 22089 Use B-15 and B-215 to establish Pewee 2 operating conditions.
 $\frac{W}{N}$ LF-25 is 6; BT-215 is 630; LF-10 is 30 lb/sec; BP-15 is 760.
 22123 Report Dewar 3 status: chilled; level >70%.
 22141 On TD Command, push the Emergency Shutdown Button.
 22143 Close K-107.
 22146 Bypass HT-511 and $\frac{W}{N}$.
 22150 Reset the Emergency Shutdown Chain (10 seconds).
 22156 Bypass L-11 Hold Open.
 22158 Set H-101 to a minimum.
 22174 Close L-21 (30 seconds).
 22183 Close X-3 and X-203.
 22189 250 psig in Dewar 3.
 22193 Open X-161.
 22208 KF-5 indicates maximum flow, close K-6.
 22218 Bypass G-3 Hold Close.
 22221 In G-3 Flow Control, establish minimum GH₂.
 22228 Set K-106 to a minimum.
 22232 Close H-75.
 22236 Open H-175.
 22242 Close W-11.
 22245 Switch H-11 to POSITION Control and Close.
 22248 Close H-142.
 22260 Close the water bypass valves.
 22262 Turn off the tapes.
 22269 Switch L-53 to POSITION Control and Close.
 22272 Close L-62.
 22278 Open L-153 and L-251.
 22286 Bypass all the inputs to the Shutdown Chain and switch all the shutdown valves to Override.
 22305 BT-15 is 250°R, close B-15.
 22350 Switch G-3 to POSITION Control and Close.
 22357 BT-215 is 250°R, Close B-215.
 22359 Close G-427.
 22361 Close W-316.
 22364 Close G-1.
 22379 Open G-103.
 22383 Open N-430.
 22389 Close K-1.
 22406 Open X-171.
 22412 Close X-203.
 22420 Switch K-53 to POSITION Control and Close.
 22427 Close K-61 and K-62.
 22442 Re-entry to secure leak at X-103.
 22460 Open K-153.

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X. PEWEE 2 EMERGENCY SHUTDOWN WITH NO ACCUMULATOR

A. X-103 LEAK IS SEALED, PROCEED WITH THE PEWEE 2 SHUTDOWN TEST WITH NO ACCUMULATOR.

27444	Close L-153.										
27470	Open L-62.										
27476	In L-53 PRESSURE Control, establish 60 psig in Dewar 2.										
27481	Close K-153.										
27488	Open K-61 and K-62.										
27514	In K-53 PRESSURE Control, establish 100 psig in Dewars 4 and 5.										
27525	Open K-2.										
27537	Use K-106 to chill KT-2 and KT-106.										
27652	KT-2 and KT-106 are chilled, set K-106 to a minimum.										
27550	Report Dewar 3 status: level is greater than 90%; XT-2 is 45°R; X-353 is closed; X-303 is closed.										
27583	Set the required VCD values.										
27596	Set the W/N pot to 255 divisions (Ns is 550)										
27610	Set the Overspeed trip pot to 785 divisions (30,000 rpm).										
27618	Activate the required inputs to the Shutdown Chain.										
27652	KT-2 and KT-106 are chilled, set K-106 to a minimum.										
27665	Activate G-3 Hold Closed.										
27674	Verify X-153 Hold Close active; verify that X-161 is open.										
27682	Close G-103.										
27687	Open G-1.										
27710	Switch the following valves to Normal:										
	<table border="0" style="margin-left: 40px;"> <tr> <td>L-11 Delay</td> <td>H-142</td> </tr> <tr> <td>L-109</td> <td>H-180/H-53</td> </tr> <tr> <td>H-11</td> <td>X-53/X-161</td> </tr> <tr> <td>H-60</td> <td>H-101</td> </tr> <tr> <td>Shutdown Servo</td> <td></td> </tr> </table>	L-11 Delay	H-142	L-109	H-180/H-53	H-11	X-53/X-161	H-60	H-101	Shutdown Servo	
L-11 Delay	H-142										
L-109	H-180/H-53										
H-11	X-53/X-161										
H-60	H-101										
Shutdown Servo											
27738	Close H-180.										
27745	In H-53 PRESSURE Control, establish 100 psig at HP-60.										
27750	Use L-109 to chill the pump.										
27859	In Ns Control, set the pot to 385 divisions (Ns is 575).										
27866	Use H-101 to chill HT-101 and use L-111 to chill LT-111.										
27869	Use L-121 to chill LT-121.										
27874	Report Dewar 3 status. Level is greater than 90%; XT-2 is 45°R.										
27884	Use X-103 to chill XT-2 to less than 47°R. Maintain XT-2 less than 55°R.										
27923	Close X-303.										
27925	Close X-171.										
27929	Turn on the tapes.										
27938	In X-53/161 PRESSURE Control, establish 300 psig in Dewar 3.										
27942	Open W-211, W-221, and W-231.										
27947	Open G-427.										
27965	Open W-11 and W-316.										
27987	Open B-15 and B-215.										
28005	Open K-6 to the clamp and Close K-106.										
28031	Close N-430.										
28037	Open H-70.										

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28042 Open H-75.
 28050 Close H-175.
 28077 BT-15 and BT-215 are chilled to 150°R, set B-15 to 55.6% and B-215 to 38%.
 28081 Open L-11 to 37% and L-21 to 18.6%.
 28136 Actuate L-11 Hold Open.
 28140 Switch H-11 to ΔP Control.
 28149 Close H-101.
 28156 In FLOW Control, establish 30.1 lb/sec at LF-10.
 28173 Use K-107 to maintain 45°R at KT-7.
 28197 Activate HT-511.
 28207 HP-60 exceeds 200 psig, close L-251, H-53.
 28214 Activate W/N at 18,000 rpm.
 28221 Open X-3.
 28296 Establish Pewee 2 Full Power conditions.
 28329 Pewee 2 Full Power conditions established: LF-10 is 30.1 lb/sec; LF-25 is 6 lb/sec; NS is 650; BP-15 is 770 psig; BP-215 is 650 psig.
 28331 H₂ leak in PMP Room.
 28338 Close H-70 and H-75.
 28344 Open H-175.
 28355 Report Dewar 3 status: Level is 80%; KT-2 is 46°R.
 28408 Push the Emergency Shutdown Button.
 28410 Close K-107.
 28413 Bypass HT-511 and W/N.
 28416 Reset the Emergency Shutdown Chain.
 28423 Bypass L-11 Hold Open.
 28425 Set H-101 to a minimum.
 28432 Close L-21.
 28438 Close X-3 and X-203.
 28447 KF-5 indicates maximum flow of 9 lb/sec; close K-6.
 28461 Bypass G-3 Hold Closed.
 28466 In G-3 FLOW Control, establish minimum GH₂.
 28471 Set K-106 to a minimum.
 28478 Close W-11.
 28481 Switch H-11 to POSITION Control and Close.
 28484 Close H-142.
 28489 Close the water bypass valves.
 28497 Turn off the tapes.
 28503 Switch L-53 to POSITION Control and Close.
 28509 Close L-62.
 28516 Open L-153 and L-251.
 28520 Bypass all the inputs to the Shutdown Chain and switch all the shutdown valves to Override.
 28538 Switch G-3 to POSITION Control and Close.
 28546 BT-15 and BT-215 are 200°R, Close B-15 and B-215.
 28549 Close W-316.
 28553 Close G-427.
 28556 Close G-1.
 28569 Open G-103.
 28573 Open N-430.

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28577	Close K-2.
28588	Open X-171.
28594	Open X-203.
28600	Switch K-53 to POSITION Control and Close.
28605	Close K-61 and K-62.
28612	Open K-153.
28621	Standby secure established.

X. PEWEE 2 EMERGENCY SHUTDOWN: TFE IS 2500°R WITH NO ACCUMULATOR

A. PROCEED WITH THE PEWEE 2 SHUTDOWN TEST AT SIMULATED TFE IS 2500°R

28790	Report status of Dewar 3: level is greater than 70%;
	XT-2 is 50°R.
28816	Close L-153.
28826	Close K-153.
28834	Open L-62.
28840	In L-53 PRESSURE Control, establish 60 psig in Dewar 2.
28845	Open K-61 and K-62.
28860	In K-53 PRESSURE Control, establish 100 psig in Dewars 4 and 5.
28880	Open K-1 and K-2.
28885	Use K-106 to chill KT-2 and KT-106.
28897	Use X-103 to maintain XT-2 less than 47°R.
28906	Set the required VCD values.
28910	Set the W/N pot to 255 divisions (Ns is 550).
28916	Set the Overspeed trip pot to 785 divisions (30,000 rpm).
28924	Activate the required inputs to the Shutdown Chain.
28950	KT-1 and KT-106 are chilled, set K-106 to a minimum.
28956	Activate G-3 Hold Closed.
28961	Close G-103.
28966	Open G-1.
28981	Switch the required valves to Normal.
29004	Close H-180.
29015	In H-53 PRESSURE Control, establish 100 psig at HP-60.
29017	Use L-109 to chill the pump.
29148	In Ns Control, set the pot to 385 divisions (Ns is 575).
29161	Use H-101 to chill HT-101 and use L-111 to chill LT-111.
29164	Use L-121 to chill LT-121.
29168	Report Dewar 3 status: level is greater than 80%; XT-2 is 46°R.
29209	Close X-303.
29211	Close X-171.
29216	Turn on the tapes.
29224	In X-53/161 PRESSURE Control, establish 187 psig in Dewar 3.
29228	Open W-211, W-221, and W-231.
29232	Open G-427.
29251	Open W-11 and W-316.
29275	Open B-15 and B-215.
29291	Open K-6 to the clamp and Close K-106.
29311	Close N-430.
29336	Open H-70 and H-75.
29344	Close H-175.
29375	BT-15 and BT-215 are chilled to 150°R, set: B-15 to 55.6%;
	B-215 to 38%.

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29379 Open L-11 to 37%.
 29395 Open L-21 to 19%.
 29406 Activate L-11 Hold Open.
 29409 Switch H-11 to ΔP Control.
 29417 Close H-101.
 29423 In FLOW Control, establish 19.7 lb/sec at LF-10.
 29440 Use K-107 to maintain 45°R at KT-7.
 29460 Activate HT-511.
 29472 HP-60 exceeds 200 psig, Close L-251, H-53.
 29508 Open X-3.
 29511 Establish Pewee 2 conditions at TFE is 2500°R.
 29577 Pewee 2 conditions at TFE are 2500°R: LF-10 is 19.7 lb/sec;
 BP-15 is 360 psig; BP-215 is 320 psig.
 29582 Close H-70 and H-75.
 29596 Open H-175.
 29602 H₂ leak PMP Room.
 29625 Push the Emergency Shutdown Button.
 29627 Close K-107.
 29629 Bypass HT-511.
 29634 Reset the Emergency Shutdown Chain.
 29637 Bypass L-11 Hold Open.
 29641 Set H-101 to a minimum.
 29649 Close L-21.
 29651 Close X-3 and X-203.
 29659 KF-5 indicates maximum flow of 8.6 lb/sec, close K-6.
 29668 Bypass G-3 Hold Closed.
 29673 In G-3 FLOW Control, establish minimum GH₂ and set K-106
 to a minimum.
 29681 Close W-11.
 29685 Switch H-11 to POSITION Control and Close.
 29688 Close H-142.
 29699 Close the water bypass valves.
 29701 Turn off the tapes.
 29706 Switch L-53 to POSITION Control and Close.
 29710 Close L-62.
 29713 Switch G-3 to POSITION Control and Close.
 29718 Open L-153 and L-251.
 29725 Bypass all the inputs to the Shutdown Chain and switch all
 the shutdown valves to Override.
 29745 BT-15 and BT-215 are 200°R, Close B-15 and B-215.
 29750 Close G-427.
 29754 Close W-316.
 29760 Close G-1.
 29774 Open G-103.
 29779 Open N-430.
 29783 Close K-2.
 29790 Open X-171 and X-203.
 29799 Switch K-53 to POSITION Control and Close.
 29805 Close K-61 and K-62.
 29815 Open K-153.
 29818 Standby secure established.

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KI. PEWEE 2 EMERGENCY SHUTDOWN: ACCUMULATOR AT LINE PRESSURE AND ~200°R

A. PROCEED WITH THE PEWEE 2 SHUTDOWN TEST WITH THE ACCUMULATOR AT LINE PRESSURE AND ~200°R.

29946 Dewar 5 reflectometer is 23K lbs; staircase 19 K lbs.
 29959 Dewar 3 level is greater than 60%.
 30142 Close L-153.
 30146 Close K-153.
 30157 Open K-61 and K-62.
 30161 Open L-62.
 30166 In L-53 PRESSURE Control, establish 60 psig in Dewar 2.
 30175 In K-53 PRESSURE Control, establish 100 psig in Dewars 4 and 5.
 30194 Open K-2.
 30205 Use K-106 to chill KT-2 and KT-106.
 30213 Set the required VCD values.
 30216 Set the Φ/N pot to 255 divisions (Ns is 550).
 30224 Set the Overspeed trip pot to 785 divisions (30,000 rpm).
 30238 Open L-351.
 30243 KT-2 and KT-106 are chilled, set K-106 to a minimum.
 30252 Activate the G-3 Hold Closed.
 30258 Close G-103.
 30265 Open G-1.
 30271 Open X-353 to chill XT-353.
 30292 Close L-251.
 30315 Close X-353.
 30318 Activate the required inputs to the Shutdown Chain.
 30342 Switch the following valves to Normal:

L-11 Delay	H-180/H-53
L-109	X-53/X-161
H-11	H-70
H-60	H-101
Shutdown Servo	
H-142	

30365 Close H-180.
 30370 In H-53 PRESSURE Control, establish 100 psig at HP-60.
 30375 Use L-109 to chill the pump.
 30453 In Ns Control, set the pot to 385 divisions (Ns is 575).
 30465 Use H-101 to chill HT-101 and use L-111 to chill LT-111.
 30469 Use L-121 to chill LT-121.
 30477 Report status of Dewar 3: level is greater than 60%;
 XT-2 is 46°R.
 30504 Verify that X-303 is closed.
 30507 Close X-171.
 30516 In X-53/161 PRESSURE Control, establish 300 psig in Dewar 3.
 30518 Open W-211, W-221, and W-231.
 30522 Turn on the tapes.
 30527 Open G-427.
 30541 Open W-11 and W-316.
 30562 Open B-15 and B-215.
 30580 Open K-6 to the clamp and Close K-106.
 30610 Close N-430.

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30615 Use K-107 to maintain a chill at KT-107.
 30622 Open H-75.
 30628 Close H-175.
 30645 BT-15 is chilled, set B-15 to 56%.
 30653 BT-215 is chilled, set B-215 to 38%.
 30656 Open L-11 to 37% and L-21 to 19%.
 30689 Actuate L-11 Hold Open.
 30693 Switch H-11 to ΔP Control.
 30699 Close H-101.
 30707 In FLOW Control, establish 30.1 lb/sec at LF-10.
 30720 Use K-107 to maintain a chill at KT-7.
 30734 Activate HT-511.
 30752 HP-60 exceeds 200 psig, Close L-251, H-53.
 30756 Activate $\bar{w}/N$.
 30796 Use B-15 and B-215 to establish Pewee 2 operating conditions:
 $\bar{w}$ LF-25 is 6; BP-215 is 630; Ns is 650; speed is 23,500 rpm;
 $\bar{w}$ BF-13 is 24.1; BP-15 is 780; LF-10 is 30.

 30800 Open X-3.
 30823 Open and Close H-175 to obtain 200°R at HT-71 and set
 H-175 to 17.5%.
 30898 H₂ leak of 7% in PMP Room.
 31091 Report Dewar 3 status: Level is greater than 40%; XT-2 is 46°R.
 31149 Push the Emergency Shutdown Button.
 31150 Close K-107.
 31152 Bypass HT-511 and $\bar{w}/N$.
 31155 Reset the Emergency Shutdown Chain and bypass L-11 Hold Open.
 31158 Set H-101 to a minimum.
 31162 Close L-21.
 31165 Close X-3 and X-203.
 31173 KF-5 indicates maximum flow, Close K-6.
 31179 Bypass G-3 Hold Close.
 31182 In G-3 FLOW Control, establish minimum GH₂.
 31186 Set K-106 to a minimum.
 31189 Close H-75.
 31194 Open H-175.
 31200 Close W-11.
 31202 Switch H-11 to POSITION Control and Close.
 31204 Close H-142.
 31219 Close the water bypass valves.
 31226 Switch G-3 to POSITION Control and Close.
 31233 Close W-316.
 31237 Close G-427.
 31240 BT-15 and BT-215 are greater than 250°R, Close B-15, B-215.
 31245 Close K-2.
 31256 Switch K-53 to POSITION Control and Close.
 31261 Close K-61 and K-62.
 31270 Dewar 2 level is 97 K lbs.
 31281 Open K-153.
 31291 Use K-162 to establish and maintain 40 psig in Dewar 5.
 31299 Switch L-53 to POSITION Control and Close.
 31306 Open L-251.
 31310 Dewar 5 level is 16 K lbs. stair, (18K lbs Reflectometer).

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31322	In L-53 PRESSURE Control establish 60 psig in Dewar 2.
31348	Dewar 5 pressure is 60 psig.
31356	Open X-301
31382	Open K-302.
31402	KP-62 is 42 psig.
31488	Dewar 2 Reflectometer is 92 K lbs.
31518	Open K-162. Decrease Dewar 5 pressure to 30 psig.
31689	Close K-302.
31560	Dewar 2 Reflectometer is 90K lbs.
31602	Open K-162, decrease Dewar 5 pressure to 25 psig.
31623	Dewar 2 Reflectometer is 90K lbs.
31630	QP-30 is 1690 psig.
31641	Dewar 5 pressure is 23 psig.
31657	Dewar 3 level is greater than 40%.
31690	Close K-302.
31696	Close K-162.
31708	Close K-153.
31715	Select Dewar 4 Feedback.
31727	Select Dewar 5 Feedback.
31736	Open K-62.
31748	In K-53 PRESSURE Control, establish 100 psig in Dewar 5.
31800	Switch K-53 to POSITION Control and Close.
31808	Close K-61.
31817	Open K-153.
31824	Select Auction Feedback.
31828	Turn the tapes off.
31840	Switch L-53 to POSITION Control and Close.
31844	Close L-62.
31849	Open L-153.
31858	Bypass all the inputs to the Shutdown Chain and switch all Shutdown valves to Override.
31862	Close G-1.
31878	Open G-103.
31888	Standby Secure Established
31896	Dewar 3 pressure is 200 psig
31901	Open X-171
31905	Open X-203

XII. PEWEE 2 EMERGENCY SHUTDOWN: ACCUMULATOR AT 100 PSID BELOW LINE PRESSURE

A. PROCEED WITH THE PEWEE 2 SHUTDOWN TEST WITH THE ACCUMULATOR AT 100 PSID AND H-11 OPEN.

32034	Close L-153.
32038	Close K-153
32045	Open K-61 and K-62.
32052	Open L-62.
32060	In L-53 PRESSURE Control, establish 60 psig in Dewar 2
32067	In K-53 PRESSURE Control, establish 100 psig in Dewars 4 and 5.
32080	Open X-353 to chill XT-353.
32098	Open K-2
32111	Use K-106 to chill KT-2 and KT-106.
32128	Open X-161
32151	Set the required VCD values.
32161	Patch the generator to the flow loop.
32171	KT-2 and KT-106 are chilled, set K-106 to a minimum.
32171	Close X-161.
32180	Close X-353

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32188 XT-353 is less than 47° R Open X-303.
 32200 Use X-103 to maintain XT-2 less than 47° R
 32217 **Set the Generator: AMP is 0.5 lbs/sec; Freq. is 50;**
Chain Length is 1023.
 32230 Activate the G-3 Hold Closed.
 32236 Close G-103.
 32241 Open G-1
 32255 Set the Overspeed trip pot to 785 divisions (30,000 rpm).
 32260 Activate the required inputs to the shutdown chain.
 32286 Switch the following valves to Normal:
 L-11 Delay H-180/H-53
 L-109 X-53/X-161
 H-11 H-175
 H-60 H-70
 Shutdown Servo H-101
 H-142

 32316 Close H-180.
 32322 In H-53 PRESSURE Control, establish 100 psig at HP-60.
 32326 Use L-109 to chill the pump.
 32400 Use X-103 to maintain XT-2 less than 55° R.
 32402 Close X-303
 32417 In Ns Control, set the pot to 385 divisions (Ns is 575).
 32429 Use H-101 to chill HT-101 and use L-111 to chill LT-111.
 32433 Use L-121 to chill LT-121.
 32475 Close X-171.
 32485 In X-53/161 PRESSURE Control, establish 300 psig in Dewar 3.
 32487 Open W-211, W-221, W-231.
 32510 Turn on the tapes.
 32513 Open G-427.
 32521 Open W-11 and W-316.
 32540 Open B-15 and B-215.
 32550 Open K-6 to the clamp and Close K-106.
 32581 Close N-430.
 32586 Use K-107 to maintain a chill at KT-107.
 32588 Open H-70
 32593 Open H-75
 32601 Open H-175 to 17.5%.
 32616 BT-15 is chilled, set: B-15 to 56%.
 32623 BT-215 is chilled, set B-215 to 38%.
 32632 Open L-11 to 37%.
 32644 Open L-21 to 30%.
 32656 Insert the L-21 block and set L-21 to 19%.
 32677 Actuate L-11 Hold Open.
 32683 Switch H-11 to ΔP Control.
 32692 Close H-101
 32694 In FLOW Control, establish 30.1 lb./sec. at LF-10.
 32709 Use K-107 to maintain a chill at KT-7.
 32725 Activate HT-511.
 32734 HP-60 exceeds 200 psig, Close L-251, H-53.
 32742 H₂ leak at East Wall NE corner of FCR
 32749 Activate #/N at 18,000 RPM
 32759 Open X-3.
 32777 Use B-15 and B-215 to establish Pewee 2 operating conditions:
 ★ LF-25 is 5.8; BP-215 is 630; Speed is 24,000 RPM, BP-15 is 1750.
 32852 Verify that H-175 is set to 17.5%.
 32859 Proceed with the Pseudo-Random noise experiment.
 32890 Report Dewar 3 status; 34 Level is less than 60%; XT-2 is 47° R.

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32929 Close L-21 to the block.
32954 Open L-21 to 19%.
32971 BP-15 is 760 psig; LF-25 is 6 lb./sec.
32984 Remove the L-21 **block**.
33005 Switch H-11 to POSITION Control.
33012 Open H-11 to 100%.
33045 Switch H-11 to Override.
33062 Push the Emergency Shutdown Button.
33065 Close K-107.
33068 Bypass HT-511 and W/N
33071 Reset the Emergency Shutdown Chain (10 seconds) and bypass L-11 Hold
33075 Set H-101 to a minimum. Open.
33078 Close L-21
33084 Close X-3 and X-203.
33097 Switch H-11 to POSITION Control and Close.
33105 KF-5 indicates maximum flow, close K-6.
33113 Bypass G-3 Hold Close.
33116 In G-3 Flow Control, establish minimum GH_2 .
33119 Set K-106 to a minimum.
33122 Close H-75.
33126 Open H-175.
33131 Close W-11
33134 Close H-142.
33144 Close the water bypass valves.
33146 Turn off the tapes.
33152 Switch L-53 to POSITION Control and Close.
33159 Close L-62.
33164 Open L-153 and L-251.
33172 Bypass all the inputs to the Shutdown Chain and switch all the
shutdown valves to Override.
33176 Switch G-3 to POSITION CONTROL and Close.
33181 BT-15 and BT-215 are 250° R, Close: B-15 and B-215
33185 Close W-316.
33188 Close G-427.
33196 Close G-1.
33214 Open G-103.
33219 Open N-430.
33225 Close K-2.
33229 Open X-171 and X-203.
33235 Switch K-53 to POSITION Control and Close.
33243 Close K-61 and K-62.
33248 Unpatch the step
33256 Open K-153.
33280 Standby Secure Established.

XIII. L-109 CALIBRATION

A. PROCEED WITH THE L-109 CALIBRATION

34259 Vent BP-15
34279 Verify the Overspeed trip Pot is set to 785 divisions (30,000 rpm.).
34291 Set the W/N trip to 255 divisions (Ns is 550).
34293 Close L-153.
34311 Open L-62.
34319 In L-53 PRESSURE Control, establish 60 psig in Dewar 2.
34330 Set the required VCD values.
34338 Activate the required inputs to the Emergency Shutdown Chain.
34366 Switch the following valves to Normal: L-109, H-60, Shutdown
Servo, H-180/H-53, H-101 -55-

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34380 Close H-180.
 34387 In H-53 PRESSURE Control, establish 400 psig at HP-60.
 34397 Use L-109 to chill the pump.
 34424 H₂ leak of 5% in FCR.
 34479 In Ns Control, set the pot to 665 divisions (Ns **is** 700).
 34490 Use H-101 to chill HT-101 and use L-111 to chill LT-111.
 34543 Turn on the tapes.
 34548 Set L-111 to 22%.
 34553 Open the water bypass valves.
 34577 Close H-101.
 34583 In SPEED Control, establish 23,500 rpm.
 34616 Activate: HT-511
 34625 Speed is 10,000 RPM
 34644 Speed is 15,000 RPM
 34654 Speed is 18,000 RPM; Activate $\frac{W}{N}$
 34659 Ns is 700
 34680 Speed is 23,500 RPM; Ns is 690; L-109 is 12%
 34698 Use L-111 to establish an L-109 stem position of 13%.
 34725 Switch L-109 to Position Control.
 34735 Use L-109 to establish an Ns is 900.
 34758 Ns is 800.
 34769 Ns is 850; L-109 is at the clamp.
 34783 Ns is 860; L-109 is 15%.
 34793 Close L-111
 34826 L-111 is 10%; Ns is 800.
 34835 Opening L-109 thru the clamp.
 34862 Ns is 900
 34867 L-109 is 16% in TMR
 34879 Close L-111
 34902 L-111 is 7%.
 34910 Open L-109
 34927 Ns is 860
 34929 L-109 is 17%.
 34936 Ns is 900.
 34950 Ns is 900; L-109 is 16.5 in TMR.
 34964 Close L-111
 34978 L-111 is 5%; Ns is 875
 34987 Open L-109
 35005 Ns is 900
 35019 Use L-109 to establish an Ns is 700.
 35065 L-109 is 16%.
 35084 Ns is 870.
 35097 Ns is 830.
 35101 L-109 is 15%.
 35103 Ns is 800.
 35107 L-109 is 14%.
 35116 Switch to Ns Control.
 35120 Demand zero speed
 35137 Bypass $\frac{W}{N}$ at 18,000 RPM.
 35149 Bypass HT-511.
 35158 Switch H-60 to POSITION Control and Close.
 35160 Switch H-53 to POSITION Control and Close.
 35163 Open H-180.
 35168 Close L-111.
 35173 Set H-101 to minimum setting.
 35177 Close W-211, W-221, and W-231.

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35181 Switch L-109 to POSITION Control and Close.
 35187 Switch L-53 to POSITION Control and Close.
 35190 Close L-62.
 35195 Open L-153.
 35199 Bypass all the inputs to the Shutdown Chain and switch the
 shutdown valves to Override.
 35212 QP-30 is 1020 psig.
 35229 Dewar 2 level is 52K lbs.
 35237 H₂ Leak - 10% in PMP Room.
 35251 Minimum Secure Established.

IV. PEWEE 2 RESTART PROFILE OPERATION

A. PROCEED WITH THE PEWEE 2 RESTART PROFILE

37380 Report status of Dewar 3 chilldown and Dewar 3 level: XP-61 is
 10 psig; XT-2 is chilled; X-203 is open; X-103 is open; Level is
 greater than 70%.
 37444 Dewar 2 Level is 52K lbs.
 37451 QP-30 is 1060 psig.
 37565 Close L-153.
 37569 Close K-153.
 37576 Open K-61; K-62.
 37583 Open L-62.
 37590 In L-53 PRESSURE Control establish 60 psig in Dewar 2.
 37598 Select Dewar 4 and 5 Auction Pressure Feedback.
 37605 In K-53 PRESSURE Control, establish 100 psig. in Dewars 4 and 5.
 37624 Open K-2.
 37639 Open K-106.
 37646 Reset the Programmer.
 37652 Patch the step.
 37662 Set the step to -2.0 volts.
 37667 Patch the step to the flow loop.
 37686 Set the ω/N pot to 255 divisions (Ns is 550).
 37690 Set the required VCD values.
 37697 KT-1 and KT-106 are 45° R, set K-106 to a minimum.
 37710 Verify that X-203 is Open.
 37715 Verify that X-171 is Open
 37719 Verify that X-303 is Closed.
 37723 Close G-103.
 37729 Open G-1.
 37733 Set the Overspeed Trip Pot to 785 divisions (30,000 rpm).
 37745 Activate the required inputs to the Emergency Shutdown Chain.
 37771 Switch the following valves to Normal:
 X-53/X-161 H-60
 H-70 Shutdown Servo
 H-175 H-142
 L-109 H-180/H-53
 H-11 H-101

 37800 Close H-180.
 37807 In H-53 PRESSURE Control, establish 100 psig at HP-60.
 37810 Use L-109 to chill the pump.
 37824 HP-76D bad at Sanborn.
 37888 In Ns Control, set the pot to 385 divisions (Ns is 575).
 37895 Use H-101 to chill HT-101 and use L-111 to chill LT-111.
 37898 Use L-121 to chill LT-121.
 37958 Turn on the tapes.
 37961 Open the water bypass valves.
 37968 Open H-70

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37973 Open H-75.
 37985 Open H-175 to 17.5%.
 37997 Turn on the reactor flare pulser.
 38001 Open W-11 and W-316.
 38006 Open G-427.
 38011 Open N-430.
 38022 Open B-15 to 56% and B-215 to 38%.
 38029 Close N-430
 38036 Use K-106 to chill KT-106.
 38044 Open K-6 to the 35% clamp and close K-106.
 38077 XT-2 is less than 47° R, close X-103. Activate the Hold Closed.
 38094 Switch X-53/X-161 to PROGRAM PRESSURE Control.
 38097 Close X-171.
 38103 Open X-3.
 38107 XP-61 is 0 psig.
 38116 Open L-111 to 32% and switch to PROGRAM.
 38135 Switch L-11 Delay to NORMAL.
 38141 Open H-11.
 38152 Close H-101 and activate Hold Closed.
 38160 Switch L-11 to Program.
 38167 Zero the Flow Bias.
 38179 Switch to FLOW PROGRAM.
 38188 Use Flow Bias to establish 165 psig at HP-541.
 38249 HP-60 exceeds 100 psig, Close L-251, H-53
 38264 Open L-21 to 19%.
 38285 Activate the $\Delta \dot{w}$'s.
 38293 Close X-303.
 38344 BT-15 and BT-215 are 50° R, switch to Run.
 38359 KF-5 indicates zero, use K-107 to maintain 45°R at KT-7.
 38369 Close K-6.
 38371 At Flow Crossover, zero Flow Bias.
 38374 L-111 is closed, activate the Hold Closed.
 38399 At 18,000 rpm, activate $\dot{w}/N$.
 38402 L-11 is 37% open, activate the L-11 HOLD OPEN.
 38406 Intermediate Power Hold.
 38414 Switch to run.
 38426 Full Power Hold No. 1.
 38429 Establish Pewee 2 operating conditions.
 38441 Proceed with the step response measurement
 38477 Step In
 38488 Step Out
 38494 Set the step to +0.8 volts.
 38501 H₂ leak greater than 10% in FCR
 38511 Switch to Run
 38539 Bypass $\dot{w}/N$
 38585 At shutdown Hold; Switch to Hold
 38588 Proceed with the step response measurement.
 38603 Secure the K-System
 38613 Step In
 38624 Step Out
 38640 Switch to Run.
 38688 Activate $\dot{w}/N$
 38707 Full Power Hold
 38710 Use B-15 and B-215 to establish Pewee 2 operating conditions,
 $\dot{w}$ LF-10 is 30; $\dot{w}$ LF-25 is 6; BP-215 is 631; BP-15 is 761.
 38726 Report Dewar 3 status. XT-2 is chilled
 38743 Verify L-11 delay in Override.
 38746 Verify H-175 is 17.5%

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38764 Push the Emergency Shutdown Button.
38768 Bypass HT-511 and W/N.
38771 Reset the Emergency Shutdown Chain and bypass L-11 Hold Open.
38779 Set H-101 to a minimum.
38783 Close L-21
38791 Close X-3 and X-203
38795 Shutdown due to ΔW 's.
38805 KF-5 indicates maximum flow, close K-6.
38807 Bypass the ΔW 's.
38817 In G-3 Flow Control, establish minimum GH_2 .
38819 Bypass G-3 Hold Close.
38821 Set K-106 to a minimum.
38832 Close H-75.
38837 Open H-175.
38843 Close: W-11.
38850 Switch H-11 to POSITION Control and Close.
38859 Close H-142.
38867 Close the water bypass valves.
38869 Turn off the tapes
38878 Switch G-3 to POSITION Control and Close.
38883 Close W-316.
38886 Switch L-53 to POSITION Control and Close.
38892 Close L-62.
38897 Open L-153 and L-251.
38904 Bypass all the inputs to the Shutdown Chain and switch all the shutdown valves to Override.
38910 BT-15 and BT-215 are 250° R, Close: B-15 and B-215.
38918 Close G-427.
38925 Close G-1.
38936 Pulser Off.
38941 Open G-103.
38948 Open N-430.
38961 Verify K-1 and K-2 are closed.
38964 Open: X-171 and X-203.
38972 Switch K-53 to POSITION Control and Close.
38977 Close: K-61 and K-62.
38980 Open K-153.
39015 Standby secure established.

XIV. SHUTDOWN PHASE

39040 Begin Shutdown Phase.

NRTO-R-0202

APPENDIX C

LOSS OF POWER TESTS

APPENDIX C
LOSS OF POWER TESTS

A. INTRODUCTION

The loss of power tests were performed as a part of the Pewee 2 FEP-I dry run conducted on 9/16/70. The tests consisted of (1) operating the facility valves required for Pewee 2 test series with power supplied only from the diesel generator, and (2) operating the valves required for the cooldown of Pewee 2 with power supplied only from the emergency power buss.

B. TEST OBJECTIVES

The loss of power tests were performed to demonstrate the Test Cell "C" capability to provide sufficient power for the Pewee 2 Test Series and to verify that the valves, instrumentation, and systems failed in the manner expected.

The specific objectives were:

1. To verify that the diesel generators were capable of supplying the power necessary for the conduct of the Pewee 2 Test Series.
2. To verify that the loss of commercial power would not affect the test operations.
3. To verify that a reactor cooldown could be accomplished utilizing power from the emergency power buss.
4. To determine the behavior of the emergency shutdown chain and the shutdown valves upon loss of critical power.
5. To allow the control room operators to observe their consoles, as well as experience the effects of room lighting, communication net changes, and any other effects due to loss of the critical power buss.

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C. TEST DESCRIPTION

The loss of power test was performed with the operating team monitoring their normal run day position. There were also personnel monitoring the valve indications in the local control room at Test Cell "C".

In preparation for dropping the utility power at the test cell and the control point, and placing the critical power on the separate generators, the "Loss of Critical Power" input to the shutdown chain was activated and the valves on the shutdown chain were switched to Normal. This was done to see if any transients or other problems would occur that would initiate an inadvertent emergency shutdown. The shutdown valves were then placed in their expected Pewee 2 run positions. The test cell utility power and the control point computer room utility power was then dropped.

With the shutdown valves in Normal and the Loss of Critical Power input still active, the commercial portion of the critical power bus for both the CP and Test Cell "C" was dropped by opening breaker 1204 of Line B in NRDS Substation No. 1 at the CP Power House Area. Refer to Figure C.1 for a simplified single line electrical schematic. This then placed the entire critical bus power demand on the paralleled test cell and control point generators (No. 3 and No.2). Next, the interconnecting line (Line N) breaker was opened (Breaker 1201) to separate the two diesel generators. The standby generator (No.1) at the CP was not running. Then the shutdown valves were returned to override, and the Loss of Critical Power input to the shutdown chain was bypassed. Next, the normal exercising of all facility valves and systems which would not release high pressure gas was performed in a manner similar to all dry runs, except that the diesel generators were supplying the critical power bus.

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Figure C.1
UTILITY & CRITICAL POWER SYSTEM

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In preparation for the loss of critical power, all facility valves were placed by checklist in the position they were expected to be operating for a Pewee 2 full power hold; except for those valves which would release high pressure gas, LH₂ or water. Each console operator then completed a data sheet to record the position of each valve and the reading of each instrumentation channel. The valves on the shutdown chain were again placed in Normal, and the Loss of Critical Power input to the shutdown chain was activated. All control valves were left in position control. To minimize the transient on the diesel generators, the generators were paralleled, commercial critical power was restored in parallel with the two generators, and then the generators were removed from the line leaving the test cell and control point critical bus being supplied only by commercial power through breakers No. 1201 and No. 1204. The loss of critical power was then produced by opening breaker No. 1204 at NRDS Substation No. 1 in the CP area to simultaneously drop both the CP and TCC critical power bus. Each console operator then completed his data sheet to record the indicated valve positions and meter settings after the ESD.

Next, those valves that were operable from the emergency power system and were considered necessary for Pewee 2 cooldown or facility securing were cycled to verify that they were operable and controllable from the emergency power bus. Since all data systems were stopped when the critical power was dropped, the only recorded data after power failure was the stem position on the 11 analog valves on the shutdown chain which were recorded on the two special Sanborn recorders powered from a portable gasoline operated generator.

The commercial power was restored after about 25 minutes by closing breakers 1204 and 1201. Then the diesel generators were placed back in parallel load sharing with the commercial power and set to carry all but 50 KW or less of the critical power load, as is the normal mode of operation. Utility power was then restored to the CP and TCC and the various air conditioning systems

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restarted. After all systems were again operating, the shutdown valves were placee in override and all shutdown inputs were bypassed. Then all valves were returned to their normal secured position, and the MCS systems and control valves were switched to Forward Area Control, and the facility operations were returned to Status Board Control.

D. TEST RESULTS

1. Loss of Utility Power

The loss of the control point computer room and test cell utility power did not interact with the facility control room operation and, as expected, did not cause an emergency shutdown. Dropping the computer room utility power stopped the air conditioning for the computer room and DDP-116, although the circulation fans within the DDP-116 continued air flow; and no problem of overheating was even remotely approached while the DDP-116 continued to operate for approximately $2\frac{1}{2}$ hours until the air conditioner was restarted. Lighting for the computer room was lost when utility power was dropped, and the battery operated lights were minimal. There are two wall mounted battery operated lights, one centered on the west wall and one centered on the south wall, but this left the DDP-116 area in almost total darkness. The FAC room also lost its lights, but the single wall mounted battery light on the north wall provided adequate illumination to continue operations within the FAC room.

Dropping the test cell utility power resulted in loss of the air conditioning equipment for the Test Cell Building. The temperature increased from 72°F to 86°F during the $2\frac{1}{2}$ hours that the utility power was off. There were no reported instrumentation problems during this time.

2. Loss of Commercial Critical Power

The operations of dropping commercial critical power and separating the

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diesel generators did not cause any transients or other abnormal actions to produce an emergency shutdown.

By transferring the critical buss load from shared diesel/commercial to the diesel generators, and separating the interconnect line between the CP and Test Cell "C" generators a complete commercial power failure was simulated. In this configuration, the test cell generator was supplying a critical bus load of approximately 165 KW and the Control Point generator was supplying a critical bus load of approximately 160 KW.

The facility valves were then exercised successfully in the normal fashion for all dry runs. This verified the valve operability and correct position feedback information as confirmed from the indication in the LCR utilizing the power supplied.

Table I is a listing of all valves and systems that were operated during this Dry Run. The table lists some information about the valve and actuator as well as its control mode and position feedback console indication. It also shows the position to which the valve was exercised on critical power.

3. Loss of Critical Power

The dropping of the critical power of the test cell and control room did not result in any unexpected system or equipment operation. An emergency shutdown resulted due to the loss of critical power output to the shutdown chain and the emergency power systems picked up the necessary load as designed.

Table I also shows the position to which the valves were operated in preparation for dropping the critical power buss, any special circuits to which the valve may have been connected, and the position the valves were observed to have assumed after the critical power was dropped.

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The notation of SDC means the valve was on the Emergency Shutdown Chain, HO or HC means that the valve has a Hold Open or Hold Close circuit and A or N means the holding circuit was Active or Normal. The next column shows the valve failure open loss of critical ac power as determined by the local test of NRTO-G-0162 (performed on September 25, 1970) and reported by memorandum, NRTO-M-29143, dated September 28, 1970, H. P. Langer to J. W. Connell, subject: Digital Valve Failure Test Results, for the binary valves.

a. Air Conditioning System Effects

The control room air conditioning system stopped operating with loss of the critical power and produced an instant silence. There were no heating problems experienced in the control room during the 25 minutes that the air conditioning was off. The air conditioning at the test cell building and the CP computer room are discussed in Section D(1).

b. Lighting System Effects

Upon loss of critical power, the control room ceiling mounted emergency lights (incandescent type bulbs powered from the 60 battery cells connected in series to provide 130 vdc and located in the CP generator building) came on and operated satisfactorily as the regular fluorescent lights went out. The emergency light system provided very adequate lighting to conduct an orderly reactor shutdown. This same battery source also powered the emergency lights in the CP generator building and worked satisfactorily.

c. Communication System Effects

Following the loss of critical power, there was no noise or interruption of the control room operators' net or of the test director's net, or

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the FAC net between all stations including the POW, LCR, FAC, OPS, COM, TV Stations, as well as TMR and regular console operator locations. This verified that the communication system can transfer to and operate satisfactorily from the 12 vdc communication battery bank, which has 12 battery cells (six cells each in parallel) and then a backup bank of an additional 12 battery cells (six cells each in parallel), which is available in the CP basement battery room by manually transferring a knife blade switch. The audio quality of the operator net on emergency power was much better than normal because the control room air conditioning system stopped when critical power was dropped. It then became apparent that the background noise level of the air flow is very significant.

d. Instrumentation System Effects

After the critical power bus was dropped, operators recorded the valve positions as shown on Table I, and they recorded their console meter indications. Since there was no pressure in the gaseous headers or LH₂ dewars, many operating instrumentation channels did not indicate any pressure or temperatures different from ambient. The instrumentation channels that require signal conditioning and are necessary for use during cooldown under a loss of critical power conditions, obtain ac power from the supercritical bus for these signal conditioning amplifiers (Neff amplifiers). These channels are noted in the control room by three pieces of yellow tape around the outside molding of the meter face. The following 16 instrumentation channels are marked and exhibited valid (as far as could be determined from a non-flowing or non-pressurized system) meter indications:

CTO	-	LP-12
FLO	-	LP-61, LP-62
H2O	-	WP-1D
SER	-	JP-101, JP-202
ACLD	-	QP-20, QP-30, QP-40, KP-61, KP-62
CLD	-	GP-14, KF-5, GP-2, GF-4, KT-7

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The above facility channels which are displayed in the TMR are also marked with yellow tape on the edge of the meter face. Also the low pressure GHe header channel QP-401 was operable since it has a swept pot type pressure transducer and uses the same power supplier as the valve stem position. There are several console meter faces which are marked with yellow tape but are not powered from the supercritical buss for Pewee 2 testing; these markings will be corrected before Pewee 2 operations.

e. Analog Valve Console Position Indications

The analog valve and JBV stem position meters on the consoles remained operable after the loss of critical power indicating that the test cell Supercritical Power System was operating satisfactorily from the battery bank of 120 battery cells (60 cells each in parallel) and that the +22.5 vdc swept pot power supply and the -10 vdc zero suppression power supply were operable from the supercritical bus.

Some analog valves remained at their intermediate open positions, indicating that the Control Point Supercritical Power System was operating satisfactorily from the battery bank of 62 battery cells in series, and that the ± 15 vdc and ± 100 vdc amplifier and potentiometer reference power supplies were operable from this supercritical bus.

f. Binary Valve Console Lamp Indications (Motorola)

Following the loss of critical power, the console binary valve position indicator lamps, in general, stayed illuminated which indicates the control point 28 vdc battery system, which supplies power to the indicator lamps, was operating satisfactorily. Also operating was the Motorola System at the test cell, from its battery system, and the Motorola at the Control Point from its battery system, which supplies the logic to determine the binary valve limit switch positions.

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However, when the valves operable on the emergency buss were cycled, refer to Section D3i, some of the valves open and closed limit light indications did not function. Movement of the valves were verified at the LCR.

The Test Cell "C" 28 vdc power to the binary valve open or closed limit micro switches is wired into the LCR and to the Test Cell "C" Motorola transmitting unit; the Motorola is powered by 24 vdc with backup nickle-cadmium batteries within the Motorola cabinet. The open or closed indications are multiplexed and transmitted by long line to the CP Motorola unit to supply power to the appropriate console open or closed switch lamp.

Those valves which did not have proper open or closed limit switch indications at the operator's console in the Control Point were self-correcting when the critical power was restored. This tends to indicate that the Motorola System did have some anomalies and was not correctly sensing the change of some valve positions. This may be caused by the voltage level of the 28 vdc power system decreasing enough that the additional voltage drop in the lead wires to the valve limit switch and back to the LCR was less than the voltage required to actuate the relays of the Motorola transmitting unit in the LCR which is used to sense a change in the valve position. Section D3j discusses the voltage decay of emergency power system for the 25 minutes that it was used.

It should be noted that even though some of the binary valves operable on the emergency buss did not indicate changes of state at the console, that the valves did operate normally.

The valves have adjacent pressure or temperature indications which, under reactor cooldown conditions, help to determine if a valve is operating as commanded; therefore, the Motorola System may not be considered mandatory for reactor operations, but is still desirable.

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g. Data Recording System Effects

Upon loss of critical power, all the data recording systems ceased to function since they are not on the emergency power buss. In order to record the valve positions of the shutdown valves on loss of critical power, two special Sanborn recorders of eight channels each were powered by a portable gasoline generator. These recorders will not be used during the test series.

h. Emergency Shutdown System Effects

Prior to the loss of critical power, the following 13 valves were placed on the shutdown chain by switching them to NORMAL: L-11, L-109, H-11, H-31, H-53, H-60, H-70, H-101, H-142, H-175, H-180, X-53 and X-161. All of these valves except for H-70 and H-180, are analog valves with position feedback potentiometers, and they were set up to have their positions recorded on two special Sanborn recorders with eight channels each, which were operated by a small portable gasoline generator; and were, therefore, unaffected by the loss of critical power which stopped all other data recording systems. Before the critical power was dropped, the Loss of Critical Power input to shutdown chain was activated and the valves on the shutdown chain placed in their expected Pewee 2 operating position in position control. There were no recorded channels for the critical power voltage or for the emergency shutdown command signal; therefore, the time of these two events is not precisely known with respect to the valve positions of the 11 valves which are shown as Figures 2 and 3. None of the 11 valves were on the supercritical power buss.

Routine setup of the hydraulic analog valves prior to each Experimental Plan requires that the Moog servo valve mechanical bias adjustment be set to drive the analog valve to the desired position (open or closed) upon loss of ac power to the analog valve local controller. Normally,

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this is closed except for the pump bypass valve L-109. As can be seen from Figures C . 2 and C . 3, that five of the valves (H-11, H-31, H-60, H-175 and X-53) were positioned partly open, and then came further open different amounts and at different rates before all valves rapidly closed (L-109 opened) to their shutdown commanded positions. This "bounce" or "hop" of the valve before the shutdown command or the Moog mechanical bias control effect comes into play has been observed visually during past routine setups where the local ac power to the local controller is failed to check the setup of the mechanical bias. There is latitude in the mechanical bias adjustment to permit it to drive open or closed on ac failure; and, therefore, theoretically it could be adjusted to fail closed at any rate from infinity to a maximum for each given valve. In practice, the latitude is limited by the mechanical and electrical properties of the valve/controller system, so that a given setup cannot be depended upon to stay the same or be repeatable. This valve "hop" has been attributed to the non-uniform decrease of the ± 15 vdc that drives the operational amplifier, which is the valve position controller that maintains a zero error between the measured valve position and the demanded valve position. The ± 15 and -15 vdc are highly regulated, and very stable voltage sources derived from a power supply within each valve local control box which uses 110 vac critical or supercritical power. When the ac voltage is decreasing as in a power failure, the fields within the power supply do not collapse at equal rates to produce a uniform ± 15 and -15 vdc decrease and, therefore, cause an imbalance within the operational amplifier. This effect is of a random, unpredictable and unrepeatable nature.

If the start of the drifting open of H-60 is used as the time of actual "loss of critical power", then the shutdown chain Loss of

EMERGENCY SHUTDOWN VALVE POSITION TRACES DURING LOSS OF CRITICAL POWER

FIGURE C.3

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Critical Power input (IB-511 and IB-512) takes about 100 to 120 milliseconds to trip the shutdown chain. These two channels IB-511 for the CP and IB-512 for Test Cell "C" provide a signal to the shutdown comparator chassis and to the SER console alarm lights whenever there is sensed a loss of at least one phase of the three phase power supplied to the Rectomatic battery charger of the Supercritical Power System static inverter for either the test cell or the control point. Each channel has three closed relay contacts in series when there is sufficient voltage across each relay coil to energize the coil which is connected between a phase and neutral of the Rectomatic three phase ac input power. When the voltage across the relay coils decreases enough to cause one coil to de-energize and open the series connection, the SER console alarm light (Loss of Critical Power, CP; or Loss of Critical Power Test Cell) illuminates and a shutdown command is available to the shutdown chain. IB-511 is the test cell channel which senses the three-phase voltage downstream of Load Center No. 3 Circuit Breaker No. 5 in the test cell basement, while IB-512 is the control point channel which senses the three phase voltage downstream of Panel A14 Circuit Breaker No. 10 in the Control Point Battery Rooms. The CP wiring diagram is shown on EG&G drawing N4D-1790 and the Test Cell "C" diagram on drawing N4D-1861.

(1) L-11 Response

At the time of the loss of power test, it was planned to operate L-11 100% open with no shutdown delay and with the hold open active. Upon an ESD, L-11 would then go closed to 6.3% at a maximum slew rate of 170%/sec. The valve remains at 6.3% until closed by the CTO. When the ESD was caused by the loss of critical power, it is seen that L-11 closed initially at its normal velocity of 170%/sec until it reached approximately 70%. The closing rate then decreased to about 10%/sec until the valve was completely closed. The valve response during this time was due to the mechanical bias of the valve. It is also seen that the valve did not stop at the 6.3% position.

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Since this test was run, the L-11 normal operations has been changed to be 37% open with the hold open active during the run phase. A block is installed at the 37% opening. When an ESD occurs, the valve has been provided with a 0.45 second delay time after the ESD command before it goes to 6.3% at a nominal slew rate of 170%/sec. The valve then remains at 6.3% until closed by the CTO. To ensure that L-11 performs these required operations after all ESD, the valve will be placed on the emergency power buss.

(2) L-109 Response

At the time of this test, the L-109 response upon an ESD was to open to 15% with no delays at a slew rate of approximately 2500%/sec. There was an electrical clamp at that position. Upon loss of critical power, the L-109 initial response was as expected; at the emergency shutdown the valve opened to about 18% at a rate of approximately 2500%/sec, while the electrical clamp had been preset to about 16%. After about .05 seconds, the valve had closed from 18% to 13% at a rate of approximately 500%/sec, and then started opening again at a rate of approximately 180%/sec to the 54% position about .25 seconds after ESD, where it increased from 54% to 95% at a rate of 435%/sec.

It was determined that it was unexceptable for L-109 to fail 100% open on an ESD so the valve has been provided with a mechanical block at 17%. It was also determined from the FEP Test Series that L-109 should open to 15% on ESD. The electrical block has been changed to 15% for Pewee 2.

(3) H-11 and H-31 Response

The normal operation of the ESD chain is to close H-11 and H-31 at their maximum slew rate of about 1000 %/sec with no time delays.

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H-11 and H-31 were about 11 to 12% open before the loss of power test, and they "hopped" open to 3 to 4% a short time (about 40 to 50 milliseconds) after the loss of critical power before the shutdown chain command closed them at their maximum rate of approximately 1000%/sec. Their behavior was determined to be acceptable from the FEP-II test data.

(4) H-53 Response

The shutdown chain commands H-53 closed when an ESD is initiated. During the Pewee 2 power run, the valve will already be closed so the valve was closed prior to the loss of critical power.

After the power was dropped, its position trace came up about 1% at 220 milliseconds after the shutdown command. This was suspected to be caused from the actuation force being reduced on the valve plug after the operational amplifier power supply had decayed and only the Moog mechanical bias was holding the valve closed. GH_2 flow is over the plug on this valve, so any upstream pressure would tend to close H-53.

(5) H-60 Response

The ESD chain is to close H-60 at its maximum slew rate of about 3000 %/sec with no time delays when an ESD occurs. Following the loss of critical power, the valve H-60 started to "hop" open from its steady position of 13% to about 19% open at a rate of approximately 70%/sec before being driven closed at a rate of approximately 1400%/sec.

(6) H-70 Response

H-70 is command closed by the ESD chain. This is a binary valve so that the valve position was not recorded on the special sanborns;

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however, from Table 1 it is seen that the valve remained open upon the loss of critical power.

(7) H-142 Response

The TES discharge gas vent valve, H-142, is commanded 100% open at its maximum slew rate with no time delay following an ESD. H-142 was closed before the loss of power and at the time of the emergency shutdown command it started open, as required, at a rate of approximately 360%/sec but opened to only 75% at a time about 280 milliseconds after ESD. At this time the output from the operational amplifier apparently decreased to a level where the Moog mechanical bias adjustment took command and slowly closed the valve at a rate of approximately 15%/sec.

(8) H-101 Response

The ESD chain normally opens H-101 to 10% after a 0.5 second time delay. H-101 was closed throughout the loss of power test and did not move. The H-101 controller has a time delay of .5 seconds after shutdown before it would normally be commanded open. With the loss of power, this delay was active until the controller output decayed and the Moog bias just kept the valve closed.

(9) H-175 Response

H-175 is commanded closed upon initiation of an ESD by the shutdown chain. After the loss of critical power, H-175 came open the most during the "hop" before the shutdown command was received. It came open from 14% at a decreasing rate and tended to level off about 23% when the shutdown commanded it closed at a rate of approximately 1400%/sec.

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(10) H-180 Response

H-180 is closed during the run phase and the valve is commanded open upon an ESD. This is a binary vent valve and was not recorded on the special sanborn recorders. However, Table 1 indicates that the valve remained closed after the critical power was dropped.

(11) X-53 Response

X-53 is commanded closed upon initiation of an ESD at its maximum slew rate with no time delay. The valve was about 12% open before the loss of power test and "hopped" open 3 to 4% a short time (about 40 to 50 milliseconds) after the loss of critical power before the shutdown chain command closed it at its maximum rate of approximately 1000%/sec.

(12) X-161 Response

X-161 is commanded closed upon an ESD. The valve was closed prior to the loss of power and remained closed after the power was dropped.

1. Valves Operable After the Loss of Critical Power

While operating on the Emergency Power System, all valves that were planned to be used to shut down the facility and continue reactor cool-down were exercised one at a time. These valves are shown in Table I and a summary of the valves operation are shown as follows:

G-3	Operated satisfactorily
G-13	Operated satisfactorily
K-1	Cycled okay as verified from LCR, but no open indication at ACLD console

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K-2	Cycled okay as verified from LCR, but no closed indication at ACLD console.
K-3	Operated satisfactorily.
K-6	Operated satisfactorily to the 35% open clamp.
K-6 Block	Would not operate but the controls will be placed on supercritical power.
K-21	Cycled okay as verified from LCR, but no open indication on CLD console. The valve will be blocked open during Pewee 2.
K-53	Operated satisfactorily.
K-103	Operated satisfactorily.
K-106	Operated satisfactorily.
L-121	Was not operated and will be blocked closed for Pewee 2.
L-161	Operated satisfactorily.
L-162	Cycled okay as verified from LCR, but no open or closed indication at FLO console.
L-261	Cycled okay as verified from LCR, but no closed indication at FLO console.
L-262	Cycled okay as verified from LCR, but no open or closed indication at FLO console.
W-45	Cycled okay as verified from LCR, but no open indication at H2O console.
W-50	Cycled okay as verified from LCR, but no open light at H2O console.
W-53	Operated satisfactorily.
X-3	Operated satisfactorily.
X-153	Operated satisfactorily.
X-171	Operated satisfactorily.

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j. Emergency Power Bus and Decay Following Loss of Critical Power

After the critical power was dropped, the emergency power system operated satisfactorily for the approximately 25 minutes before the critical power was restored. During the loss of critical power, the backup -10 vdc zero suppression power supply was observed to have been tripped off by the power supply crossover network. After critical power was restored, this power supply was re-set from the CP and it operated satisfactorily. The reason for tripping off is not known.

The test cell supercritical bus operated at a load of approximately 1.86 KW. The battery voltage decreased as follows during the 25 minutes, starting at approximately 1407 hours.

Time Hours	Supercritical Bus		28 vdc	Bus	Motorola Batteries	
	TCC	CP*	TCC	CP	TCC	CP
1405	129	137	28.8	28	25.9	25
1410	116	126	25	27	25	25
1415	116	126	24	25.5	24.5	23
1420	116	126	23.8	25.5	24	23
1425	116	126	23.8	25.5	24	23
1430	116	126	23.8	25.5	24	23

* Data recorded from local test conducted Dec 2 1970

The supercritical bus at the test cell and the Control Point was connected to supply power to the systems presented in tables C.1 and C.2.

APPENDIX C

E. CONCLUSIONS

The objectives of the loss of power test were accomplished during this test. The operation of the facility valves was verified with the power supplied only from the diesel generator. The transfer of the power to the diesel generator was accomplished by dropping the utility and commercial critical power without any power transients which would cause an ESD. The facility systems and valves failure modes were determined upon the loss of critical power and these valves and systems on the emergency power lines were verified. Also, the entire Pewee 2 operating team was able to observe their console and system effects upon a critical power failure.

APPENDIX C

TABLE C.1

Test Cell Panel board "F" Supercritical Power Bus

<u>No.</u>	<u>Breaker Amps</u>	<u>Equipment</u>
1	5	W-45
2	5	L-161, L-261
3	5	G-23
4	5	L-162, L-262, L-91, L-491
5	5	N-1, N-61, N-161
6	5	N-50, Y-4
7	5	N-2, N-62, N-162
8	5	W-50
9	5	N-3, N-63, N-163
10	5	K-53
11	5	Y-13
12	5	Neutronics, in the Penthouse
13	5	N-221, D-12
14	5	8 Neff Amplifiers (JP-101, JP-201, LP-12, GP-4 QP-20, QP-40, QP-30, KP-5D)
15	5	W-4, D-14
16	5	8 Neff Amplifiers (KP-62, KT-7, GP-2, LP-61, LP-62, KP-61, GP-14, WP-1D)
17	5	W-204, D-114
18	5	8 Neff Amplifiers (8 reactor channels, not yet installed)
19	5	Y-111
20	5	8 Neff Amplifiers (8 reactor channels, not yet installed)
21	5	X-153
22	10	Spare
23	5	X-171, D-101
24	10	Primary +10.5 vdc strain gauge power supply
25	5	G-3

APPENDIX C
TABLE C.1 Continued

<u>No.</u>	<u>Breaker Amps</u>	<u>Equipment</u>
26	10	Backup +10.5 vdc strain gauge power supply
27	5	K-6
28	10	Primary +22.5 vdc swept pot power supply and -10 vdc zero suppression power supply
29	5	G-13
30	10	Backup +22.5 vdc swept pot power supply and -10 vdc zero suppression power supply
31	5	N-30, pump latch
32	5	Primary +300 vdc platinum resistance probe temperature transducer power supply
33	5	R-13, X-3, L-178
34	5	Backup +300 vdc platinum resistance probe temperature transducer power supply.
35	5	K-21, D-102
36	10	Spare
37	5	Y-10
38	5	Spare
39	5	Y-20
40	5	Spare

APPENDIX C

TABLE C.2

Control Point Panel Z2E016 Supercritical Power Bus

<u>Nb.</u>	<u>Breaker Amps</u>	<u>Equipment</u>
1	20	Primary +15vdc and -15vdc power supplies for controller amplifiers
2	20	Backup+15 vdc and -15 vdc power supplies for controller amplifiers.
3	20	Primary +100 vdc and -100 vdc power supplies for potentiometer reference.
4	20	Backup +100 vdc and -100 vdc power supplies for potentiometer reference.
5	20	Spare
6	20	Spare
7	20	Power to neutronics operator console in Panel Z2R017H.
8	20	Spare
9	20	Spare
10	20	Spare
11	20	Spare
12	20	Spare
13	20	Spare
14	20	Spare