Nuclear Thermal Propulsion Ground Test History. H. P. Gerrish Jr, NASA Marshall Space Flight Center, ER20, Huntsville, AL 35812, harold.p.gerrish@nasa.gov

Abstract: Nuclear Thermal Propulsion (NTP) was started in ~1955 under the Atomic Energy Commission as project Rover and was assigned to Los Alamos National Laboratory. The Nevada Test Site was selected in 1956 and facility construction began in 1957. The KIWI-A was tested on July 1, 1959 for 5 minutes at 70MW. KIWI-A1 was tested on July 8, 1960 for 6 minutes at 85MW. KIWI-A3 was tested on October 10, 1960 for 5 minutes at 100MW.

The National Aeronautics and Space Administration (NASA) was formed in 1958. On August 31, 1960 the AEC and NASA established the Space Nuclear Propulsion Office and named Harold Finger as Director. Immediately following the formation of SNPO, contracts were awarded for the Reactor In Flight Test (RIFT), master plan for the Nuclear Rocket Engine Development Station (NRDS), and the Nuclear Engine for Rocket Vehicle Application (NERVA).

From December 7, 1961 to November 30, 1962, the KIWI-B1A, KIWI-B1B, and KIWI-B4A were tested at test cell A. The last two engines were only tested for several seconds before noticeable failure of the fuel elements. Harold Finger called a stop to any further hot fire testing until the problem was well understood. The KIWI-B4A cold flow test showed the problem to be related to fluid dynamics of hydrogen interstitial flow causing fuel element vibrations. President Kennedy visited the NTS one week after the KIWI-B4A failure and got to see the engine starting to be disassembled in the maintenance facility. The KIWI-B4D and KIWI-B4E were modified to not have the vibration problems and were tested in test cell C.

The NERVA NRX program started testing in early 1964 with NRX-A1 cold flow test series (unfueled graphite core), NRX-A2 and NRX-A3 power test series up to 1122 MW for 13 minutes. In March 1966, the NRX-EST (Engine System Test) was the first breadboard using flight functional relationship and total operating time of 116 minutes. The NRX-EST demonstrated the feasibility of a hot bleed cycle. The NRX-A5 had multiple start-ups in May-June 1966 with 30.75 minutes accumulative operating time at or above 1GW. The NRX-A6 was tested in December 1969 and ran for 62 minutes at 1100 MW. Each engine had post-test examination and found various structure anomalies which were identified for correction and the fuel element corrosion rate was reduced.

The Phoebus series of research reactors began testing at test cell C, in June 1965 with Phoebus 1A. Phoebus 1A operated for 10.5 minutes at 1100 MW before unexpected loss of propellant and leading to an engine breakdown. Phoebus 1B ran for 30 minutes in February of 1967. Phoebus 2A was the highest steady state reactor built at 5GW. Phoebus 2A ran for 12 minutes at 4100 MW demonstrating sufficient power is available.

The Peewee test bed reactor was tested November-December 1968 in test cell C for 40 minutes at 500MW with overall performance close to pre-run predictions. The XE’ engine was the only engine tested with close to a flight configuration and fired downward into a diffuser at the Engine Test Stand (ETS) in 1969. The XE’ was 1100 MW and had ~28 start-ups. The nuclear furnace NF-1 was operated at 44 MW with multiple test runs at 90 minutes in the summer of 1972. The NF-1 was the last NTP reactor tested.

The Rover/NERVA program was cancelled in 1973. However, before cancellation, a lot of other engineering work was conducted by Aerojet on a 75, 000 lbf prototype flight engine and by Los Alamos on a ~16,000 lbf “Small Engine” nuclear rocket design.

The ground test history of NTP at the NRDS also offers many lessons learned on how best to setup, operate, emergency shutdown, and post-test examine NTP engines. The reactor and engine maintenance and disassembly facilities were used for assembly and inspection of radioactive engines after testing. Most reactor/engines were run at test cell A or test cell C with open air exhaust. The Rover/NERVA program became aware of a new environmental regulation that would restrict the amount of radioactive particulates allowed to be release in open air and successfully demonstrated a scrubber concept with the NF-1. The ETS stand was the only one with a high altitude test chamber used for XE’. The ETS and other test cells showed the effects the engine’s radiation had on the facility materials and instrumentation as well as side effects the ground test facility has back on the engine operation. The breakdown of Phoebus 1A at test cell C showed how the site was cleaned up and back to operation for five more engines before the program was cancelled.