Prepared this for Bill Davidson

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The following report summarizes the H-1 Rocket Engine design features for the various SATURN vehicles. Present plans call for engine design changes to be made in blocks where possible to simplify documentation, design coordination, and spare part availability. These engine blocks will coincide with the SATURN missile blocks where possible and the following description is broken down accordingly.

1. SA-T VEHICLE

The SA-T vehicle utilizes R&D engines H-1001 through H-1009 which are not capable of flight operation in the SATURN booster. These engines are delivered to a nominal 165,000 pounds of thrust and will be tested at this level until modifications can be made. Jupiter type gimbal blocks are used which make these engines approximately one inch shorter in overall length than the SA-1 and subsequent engines. Instrumentation for static testing will be incorporated on each individual engine and a hot firing will be performed on the single engine test stand prior to cluster installation. In addition, engine H-1010 is a SA-1 type engine which is to be delivered to Test Lab for single engine R&D testing. The following breakdown briefly outlines the design features for the SA-T Inboard and Outboard engines.

A. INBOARD

Engines H-1002 through H-1005 do not incorporate turbine exhaust aspirators and are programmed for inboard positions on the cluster. For initial testing, these engines will retain the straight turbine exhaust duct with no heat exchanger installed. Inboard engine exhaust ducts and heat exchangers will be added later however. Shortened outriggers are used on the inboard engines to allow the installation of compartment walls. A further reduction in outrigger size is planned to allow more access area to the installed engine.

B. OUTBOARD

Engines H-1006 through H-1009 will have the exhaust aspirator and functional heat exchangers installed at Rocketdyne prior to engine delivery. (See DCR #1). These engines will be used for the cluster outboard positions but will not be gimbaled during the initial test phase. Hydraulic systems will be installed later and complete Booster gimbal tests performed.

2. BLOCK I VEHICLES (SA-1 THROUGH SA-3)

Approximately 35 engines will be required for the first three flight vehicles. These engines will be delivered at a nominal 165,000 pound thrust level which will realize a booster thrust of 1,320,000 pounds. These engines are designed for an individual thrust of 188,000 pounds each but have been downrated to realize greater

DD FORM 1 FEB 50 96 REPLACES NME FORM 96, 1 OCT 48. WHICH MAY BE USED reliability. About one half of these engines will incorporate a Modification kit while at Rocketdyne for Outboard engine application. All engines are designed with the capability of conversion to either outboard or inboard configuration if necessary. The following system and component breakdown lists the various features of this block of engines.

A. THRUST CHAMBER & RELATED HARDWARE

(1) A new gimbal assembly is incorporated on this block of engines which is designed for flight loads. This assembly also has less mechanical tolerances and the additional strength makes the Block I and subsequent engines one inch longer than the SA-T engines. In addition a screw type adjustment is incorporated which allows one quarter inch gimbal point movement in any direction from the geometric thrust vector pierce point. The gimbal assembly is capable of 10 degree deflections normal to the gimbal block axes and is designed with upper studs to allow engine assembly and removal without disassembly. (See DCR #2).

(2) The LOX Dome and Inlet Elbow have been integrated to eliminate the joint, seal and connecting bolts. Serrated edges are incorporated to mate with the new gimbal assembly.

(3) An improved method of positively anchoring the thrust chamber fuel injector screen has been requested. (See DCR # 16).

(4) Lugs are provided on each chamber to accomodate the attachment of removable outriggers. For the gimbaled Outboard engines the outriggers will be provided by Rocketdyne as a part of the Outboard Modification Kit. (See DCR # 19A). On the Inboard engines it is planned to install shortened outriggers at ABMA.

(5) Lugs will be provided on all chambers to allow the attachment of accessory panels. (See DCR #23). On the Outboard engines, one set of these lugs will be used to attach the hydraulic package on the side of the chamber toward the turbopump accessory pad. The complete hydraulic system will be installed at ABMA. On the Inboard engines, which do not require a hydraulic system, both sets of lugs will be used to accomodate instrumentation panels which will be installed at ABMA.

(6) Attaching lugs will be located on each thrust chamber for mounting heat exchangers as required. (See DCR #9A). Heat exchanger attaching struts will be installed as a part of the Outboard Modification Kit.

(7) A two inch channel will be located near the thrust chamber nozzle exit to meet Inboard engine flame deflector sealing requirements if necessary. (See DCR #10).

B. IGNITION SYSTEM

(1) The hypergol container assembly will be designed to prevent interference with the Outboard suction lines and will receive either a six or nine cubic inch hypergol cartridge. (See DCR # 15). This feature will also be incorporated on SA-T engines to prevent interference during gimbaling tests.

(2) Triethylaluminum is presently being considered as the hypergolic fluid. A backup system capability is being provided to insure satisfactory ignition. Pyrotechnic squibs can be installed in thrust chambers if required.

C. TURBOPUMP AND MOUNT

(1) Lower LOX pump NPSH requirements are anticipated with impeller and inducer redesign. This redesign provides cut back impeller vanes and a thick blade medium lead inducer. Also a stepped labyrinth wear ring has been incorporated to provide increased radial clearance and reduce interference problems.

(2) The material of the fuel and LOX volutes and the gearbox has been changed to tens-50 T-6 aluminum, a high strength alloy, to permit reliable operation at uprated levels. Also the LOX adapter flange to volute thru bolts are of K Monel to provide increased strength.

(3) Design of the seals at both pump adapter flange to volute areas has been changed to reduce leakage. On the LOX side, an asbestos rubber gasket replaces the flexitallic gasket and an "O" ring between the washer and flange replaces the crush gasket at the bolt seal. On the fuel side, an "O" ring replaces the large flat gasket and the bolts have been modified to eliminate the washers and relocates the "O" ring on the bolt grip.

(4) Modification of the turbine includes welding the turbine manifold to bearing housing joint which eliminates the skinner seal, and redesign of the upper exhaust duct flange to eliminate the internal back-up ring.

(5) A new one piece gearbox manifold casting will be incorporated with a Marman flange drain line connection. The lubricant drain line will be provided by Rocketdyne on the Outboard engines. (See DCR #19, sheet 2).

(6) A new forward pump mount (forged) will be incorporated to withstand flight loads. In addition the fittings for this mount will incorporate a special design to allow the attachment of a lifting device. This device will allow vertical removal and installation at the Static Test Stand or Launch Site as required.

D. TURBINE EXHAUST SYSTEM

(1) The complete turbine exhaust system for the Outboard engines will be installed by Rocketdyne including the ABMA furnished heat exchanger. (See DCR # 19A). The engines programmed for Inboard positions will be delivered with no turbine exhaust system but will be acceptance tested to a standard exhaust system back pressure. The exhaust system for the Inboard engines will be installed at ABMA during SATURN assembly

(2) The heat exchanger inlet and outlet flanges incorporate a 24 hole bolt pattern on SA-1 for the Outboard engines. To obtain a better seal, a 36 hole bolt pattern is used starting on SA-2 and subsequent. All Inboard engine exhaust systems (SA-1 and subsequent)will utilize the 36 hole bolt pattern.

E. GAS GENERATOR AND CONTROLS SYSTEM

(1) The turbine spinner initiators will require high voltage (500 volts) for firing as a safety feature. (See DCR #28).

(2) It has been requested that a heater be incorporated on the turbine spinners to insure reliability at low temperatures during standby. (See DCR #20).

(3) Flowmeter provisions have been deleted from the bootstrap lines to reduce the number of connections. Flowrates can be determined by other means. (See DCR #4).

(4) A quick disconnect has been incorporated into the fuel bootstrap line to facilitate draining. The connection will also be used for filling the thrust chamber with fuel if necessary for start and for flushing and purging the jacket. (See DCR # 13).

(5) The uncooled gas generator combustor body will have propellant arrival controlled by a mechanically linked valve assembly rather than individual cracking valves. Development difficulties may preclude a retrofit of this item but it is highly desirable due to sequencing problems inherent to the presently designed valves.

(6) Individual control lines have been replaced by an integrated control line assembly. This welded assembly elinimates thirteen (13) connections as compared to the SA-T engines. In this new arrangement the main LOX valve opening is controlled by dynamic rather than static fuel pressure to prevent adverse temperature effects. An in-line quick disconnect connects the integrated line assembly to the Oronite blender to facilitate line drainage.

F. ELECTRICAL AND INSTRUMENTATION SYSTEM

(1) The electrical harness, as delivered on the engines, will be lengthened to meet ABMA installation requirements. (See DCR #29). This harness will probably require additional modification when ABMA network requirements are finalized.

(2) All instrumentation provisions have been incorporated to meet ABMA requirements with the exception of the Oronite Blender Piston travel indicator. (See DCR # 4).

(3) Position indicators will be installed on the main propellant valves, however retrofit or modification of the resistance will be required until the desired 2000 ohm resistance is introduced. (See DCR # 13A).

(4) A "Thrust O. K." indicator device will be selected and installed by ABMA. This indicator will monitor thrust chamber fuel injector manifold pressure to sense satisfactory combustion prior to liftoff and to initiate a individual cutoff signal in the event of a malfunction.

G. ENGINE SYSTEM

(1) A dry start engine starting sequence has been requested from Rocketdyne. (See DCR # 7). This sequence would delete the present requirement for pre-filling the thrust chamber jacket with fuel thus simplifying servicing procedures. In addition more stable transition with a reduction in oscillations is indicated. The automatic purge now required in conjuction with wet start will also be eliminated. The availability and development status of longer burning duration turbine spinners will dictate the feasibility of incorporating this feature.

(2) A special effort has been made to insure reliable seals and flange connections and prevent fluid leakages. This is especially necessary due to the engine compartment concept. All flange finishes, gasket and O-Rings have been designed to meet preliminary ABMA requirements with the exception of the joint between the turbine outlet and upper turbine exhaust duct. (See DCR # 3).

(3) The engine servicing connect points have been designed to meet ABMA requirements (See DCR #18). Twist type disconnects will be used on the engine to prevent possible inadvertant disconnection of couplings.

(4) Engine alignment procedures will be performed at ABMA where it is intended to pre-align the individual engines by adjusting the geometric thrust vector as close as possible to the gimbal point. The actuator (Outboard) and dummy strut (Inboard) lengths will be predetermined and then used during engine installation to meet cluster alignment requirements.

3. BLOCK II VEHICLES (SA-4 THROUGH SA-6)

Engine "X" design features and proposed changes have been considered by both ABMA and Rocketdyne to further improve engine simplicity and reliability. In general, this engine design should feature more complete interchangeability of components and Inboard/Outboard configurations. Purge, flush, and overboard drain requirements should be minimized and pre-run and post-run operational and facility requirements should incorporate further simplification. Reliability should be the prime goal and the reduction of components and connecting joints should be strongly considered to meet this goal. The nominal operating thrust of the delivered engines will be 188,000 pounds. If for some reason derated operation is necessary, only orifice changes should be required. Proposed system and component changes are listed in the following outline.

A. THRUST CHAMBER & RELATED HARDWARE

(1) A type 191 injector is proposed which will feature flush mounted igniter spray nozzles. The tapped hole in the center of the injector will be retained.

(2) The thrust chamber tubes may incorporate a "looped" configuration in the bell nozzle to facilitate exhaust gas disposal into the thrust chamber exhaust. It is hoped that the high impact velocity of the gases will more efficiently remove the fuel rich turbine exhaust gases. More complete engine interchangeability will also be realized with the standardized exhaust systems.

B. IGNITION SYSTEM

(1) Hypergol ignition of the thrust chamber propellants may possibly be deleted if the turbine is driven from tapped off thrust chamber gases. In this

arrangement thrust chamber ignition could be initiated by the turbine spinner.

C. TURBOPUMP AND MOUNT

(1) A reduction in LOX pump NPSH requirements is anticipated with the incorporation of a tapered LOX inducer with cut back blades and an increase in the LOX inlet diameter from 7 to 8 inches. An NPSH of 20 ft. at 165 K and 30 ft. at 188 K is indicated. The LOX impeller will be redesigned to provide ten blades. The fuel impeller will be redesigned to provide eight blades.

(2) LOX and fuel pump adapter flange redesign will integrate the diffuser vanes. This reduces fretting and chatter. LOX adapter flange short bolts have been increased from 13 to 26 to prevent bolt failures from over loading.

(3) Changes in the gearbox will provide increased strength and reliability at the 188 K thrust level. The face width of the intermediate and high speed gears will be increased, and larger roller bearings are planned for the intermediate shaft.

(4) Another gearbox change provides an internal lubrication system, with passages in the gearbox casting. This both reduces possible leakage areas and permits a cleaner turbopump configuration. The accessory pad will be mounted directly to the gearbox and the overspeed trip pad will be eliminated. The overspeed trip is replaced by a simpler magnetic speed counter mounted at the turbine.

(5) Turbine design changes include an increased number of bolts and an "O" ring seal at the turbine to volute mounting flange. This provides increased strength and reduces the possibility of lubricant leakage.

(6) The Oronite additive lube system will be deleted and fuel only will be used if tests results verify the reliability of this arrangement. A gearbox drain sump and accessory driven pump could possibly permit recirculation of lubricant back into the fuel pump inlet. Draining the lubricant into the turbine exhaust system is also being studied. The gear case internal pressure will be increased with this change which will require a change in seal design.

D. GAS GENERATOR AND CONTROLS SYSTEM

(1) To reduce components and simplify engine operation it is deemed highly desirable to eliminate the bi-propellant gas generator by operating the turbine from main thrust chamber gases. This feature was originally planned for the H-2 Rocket Engine which incorporated the Mark XIV Turbopump. Due to the proven reliability of the Mark III Turbopump and the additional design improvements that are being introduced it has been requested that H-1 engine "X" for SA-4 and subsequent incorporate the tap off turbine and less emphasis be placed on the Mark XIV Turbopump/H-2 combination.

E. ELECTRICAL AND INSTRUMENTATION SYSTEM

(1) It is hoped that the electrical cable arrangements, connectors, design, cable lengths and assembly techniques will be final enough to use the delivered electrical systems on the engines.

(2) Instrumentation requirements will probably be reduced and taps and bosses eliminated accordingly.

F. ENGINE SYSTEM

(1) In order to minimize re-firing of the engines due to component changes, it has been requested that the pressure drop across critical components be standardized. (See DCR # 8). As this request has not been met for SATURN Block I engines, every effort should be made to incorporate this feature on Engine "X" and subsequent.

(2) To reduce the possibility of having engine area fires due to propellant or hot gas leaks a complete analysis of all joints, seals, flanges, etc. is being made by ABMA. As a result of this analysis firm design improvement requests will be forthcoming to Rocketdyne.

(3) A study is being made to protect sensitive engine components from detrimental temperature effects by using individual component insulation. In addition, form fitted enclosures extending from the thrust chamber throat to the gimbal firewall are being considered for radiation protection with an integral fire fighting system.

(4) The presently designed hydraulic system will remain basically the same. Delivery by Rocketdyne is still being considered but looks unlikely.

(5) In conclusion, it is felt that Engine "X" for SA-4 and subsequent should incorporate the desirable features of the H-2 engine but retain the improved Mark III Turbopump design. This design should generally be the final package for use on subsequent SATURN Vehicles until such a time as considerably larger thrusts are required.

(6) If additional information is desired, contact D. L. Christensen, Ext. 6902.

(Distribution on next page)

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