THIRD QUARTERLY TECHNICAL PROGRESS STATUS REPORT FOR DOE/NETL GAS GENERATOR TEST PROGRAM

7/31/01

CONTRACT STATUS

The following contract activities occurred during this report period:
1] CES submitted it's proposal to DCAA for it's audit of actual costs for the year 2000.

2] CES and AEROJET [sub-contractor for fabrication of platelets hardware] have entered into a letter contract [LC] and a Confidentiality Agreement to initiate work activities for fabrication of the Gas Generator platelet injectors for the NETL 10 Mw Gas Generator Test Program. Final definition of that contract activities is in work and should be completed by early August 2001.

3] CES and AEROJET [sub-contractor for testing] have entered into a letter contract [LC] and a Confidentiality Agreement to initiate work activities for the testing of the Gas Generator for the NETL 10 Mw Gas Generator Test Program utilizing the revised Test Plan dated May 2001. Finalization and definition of these contracts activities is in work and should be completed by early August 2001.

4] CES and TECMA [sub-contractor for fabrication of Gas Generator and ancillary hardware] have entered into a letter contract [LC] for fabricating all Gas Generator hardware and ancillary hardware except for the Gas Generator platelet hardware.

PROGRAM MANAGEMENT STATUS

The Test Plan dated June 2000, which had been approved by DOE/NETL for the 10 Mw Gas Generator Test Program has been updated and revised to reflect the Gas Generator finalized design and testing requirements. The new revised Test Plan dated May 2001, will be forwarded to NETL [Thomas J George] under separate cover. This revised Test Plan has been submitted to AEROJET [sub-contractor for testing] for their evaluation and updating of their proposal bid as required.

SCHEDULE STATUS

CES expects this Gas Generator 10 Mw Testing program could still be completed on or near the original scheduled completion date of 5/7/02 or within the late summer to early fall time frame. However a major hurdle to overcome in this testing phase of the program is the awarding to Aerojet of a number of U.S. Government high priority hot-fire testing programs for National security issues which may impact CES' 10 Mw Gas Generator testing program. Aerojet will not commit to meeting CES' testing schedule due to these U.S. Government high priority National security hot-fire testing programs. However, even with that condition, it is likely that CES' 10 Mw Gas Generator testing could be done by the July-August-September time frame. Additional evaluations and assessments of the testing phase of the program will be accomplished "real time" by both CES and Aerojet on an "on-going" basis. Revised testing schedules will be prepared during this next report period.

The scheduling conflicts are expected to be resolved by mid-August with a tentative testing schedule for the DOE/NETL 10 Mw Gas Generator Test Program showing both the best schedule completion date and the most realistic completion date. However in either case it appears that the program will be completed by next year in late summer or early fall. Based upon AEROJET's currently planned program scheduled testing dates, the completion date for the DOE/NETL 10 Mw Gas Generator Test Program testing could slip from 5/7/02 to 7/19/02.

SUBCONTRATOR ACTIVITIES

AEROJET [CES' subcontractor for fabrication of the platelet injectors] has begun the process for fabricating the Gas Generator Igniter platelet injectors. The platelet materials, for the Igniter platelet injectors, is already available so fabrication could begin.

TECHNICAL STATUS

DESIGN STATUS

Propellant Inlet Line Assemblies

No additional work has been performed on the Propellant Inlet Line Assemblies during this report period. Detailed drawings of the Propellant Inlet Line Assemblies will be released with the Final Assembly Drawing. A description of the Propellant Inlet and Outlet Line Assemblies is shown in **Figure 1.**

Igniter Assembly

The Igniter Assembly design is shown in **Figure 2.** As was reported in the previous Technical Progress Report, the Igniter Assembly Design is a spark initiated torch Igniter. The igniter is mounted from the back of the injector assembly into the center of the injector body using six [6] bolts. Photo-etched platelet washers direct the oxygen gas and methane gas in precise amounts towards the centrally located electrode. The combustion process propagates from the initial flame kernel throughout the torch chamber, ultimately igniting the main chamber flow. This type of igniter is well characterized through testing and is very reliable.

The Igniter Assembly design is being slightly modified to accommodate the availability of 3.5 inch diameter Monel-400 raw material bar stock. Both the housing and seal diameter have been slightly reduced in diameter. This will not affect the function or durability of the igniter.

Drawings of the photo-etched platelet washer details have been released for fabrication. Artwork is currently being generated for making master negatives. After being inspected, working negatives will be made from the artwork to fabricate the Nickel-200 platelets. The Nickel-200 platelet raw material stock has been acquired. Igniter Body detail drawings are in work and are approximately 90 % complete.

Injector Assemblies

The Injector Assembly design consists of the injector body with the option to employ three different injection patterns as discussed in the previous Technical Progress Report. The injector cross section is shown in **Figure 3**. Because we were unable to locate Inconel-625 raw material stock for the three-inch thick injector body it has been decided to use Monel-400 for the injector body, which is readily available. The material has been ordered to fabricate the injector bodies and the platelet injectors.

Monel-400 material has been used for many gaseous and liquid oxygen applications in the Aerospace Industry and although it is not quite as strong at elevated temperatures, it is considered more than adequate for this proposed application. We believe the Monel-400 material to be a satisfactory substitute. Monel-400 is basically a Nickel-Copper alloy and therefore should bond well with the Inconel-600 injector face platelets. However, because the Monel-400 is expected to have a lower bonding temperature requirement compared to the Inconel-600 platelets, the Inconel-600 platelets will be bonded separately and then bonded to the Monel-400 injector body. This particular bond combination has not been demonstrated in the past. We are therefore preparing a sub-scale three-inch diameter diffusion bond demonstration simulating injector land width and channel spacing to verify adequate bonding before committing the 10MW hardware.

Injection Patterns

As reported in the previous Technical Progress Report, many years of gaseous and liquid rocket engine development has shown the wisdom of having multiple injection patterns available for test evaluation. For this reason three different injection patterns have been proposed for the present test program. Each of the three patterns consists of 126 injection elements but each one differs in important ways. The first pattern is considered to be the most benign, the last pattern is considered the highest performing and possibly least benign. The injection element layout for the three patterns selected for test evaluation is shown in **Figure 4**. A description of each pattern follows:

The first pattern, i.e. **Pattern 'A'** consists of 126 like on like impinging elements to create a gaseous fan. To promote a benign atmosphere adjacent to the injector face the methane pairs impinge subsurface to the injector face whereas the oxygen pairs impinge further from the face above the methane orifices. This allows the fuel to be close to the injector face and locates the oxidizer further away from the face. The injector face is further protected by allowing 90% of the de-ionized water to weep through the injector face in such a manner as to approximate transpiration cooling. The remaining 10% of the available water is injected from the injector face as a film cooling around the periphery of the combustion chamber.

The second injection pattern, i.e. **Pattern 'B'** consists of 126 vortex elements. The methane gas and the oxygen gas as well as 11% of the available de-ionized water is injected tangentially in the pre-mix cups in such a manner as to create a hollow cone of mixed gas and de-ionized water. Because the de-ionized water is considerably more dense than the two gases the water will hug the wall of the swirl cup and thus protect the wall from possible erosion and remain underneath the burning gases as it exits from the face. The remainder of the face is protected with an additional 79% of the available de-ionized water. This water is ejected through additional vortex elements uniformly distributed across the injector face. These elements can be considered as micro-lawn sprinklers uniformly spaced across the injector face. The remaining 10% of the available water is injected from the injector face as a film cooling around the periphery of the combustion chamber.

The third injection pattern, i.e. **Pattern 'C'** also consists of 126 vortex elements, but the pre-mix cup configuration i.e. "dual vortex elements" is very different from the previous pattern elements in that it actually develops two adjacent swirls exiting from each pre-mix cup. In addition, the amount of de-ionized water injected into the dual swirl cup is 50% greater i.e. it is 22% of the available water. The remainder of the injector face is protected, by allowing 68% of the de-ionized water to weep through the injector face. This is accomplished in a similar manner as described for Pattern A. Pattern "C" however uses only 2/3 the amount of de-ionized water for transpiring through the face compared to Pattern "A". Again, the remaining 10% of the available water injected from the injector face is combustion chamber periphery film cooling.

The detailed engineering for all three injection patterns has been completed. The injector pattern drawings are being prepared for the art-work generation that is required to fabricate the individual platelets and will be called out on the final injector drawing assembly. Detailed injector drawings are in work. The Pattern "A" injector drawing has been completed. The remaining injector pattern drawings are approximately 80 % complete. Released drawings of all three [3] injection patterns will be available before the end of August 2001.