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Messrs. J.C. Floyd, R.F. Lindley.
M.A. Pesando.
CURTISS-WRIGHT RAMJETS.

Two Curtiss-Wright representatives, W.J. Mann and P. Nierenberg, visited Avro on Nov. 29, 1957, to discuss the possibility of using their ramjets on the Long Range Arrow. During the course of the meeting it was revealed that Curtiss-Wright have some 34" ramjets, which were produced for the ill-fated Navaho project, available as off-the-shelf items. These units have been paid for by USAF and, if satisfactory, may be obtained for our use. The meeting was somewhat restricted by Security, i.e. Curtiss-Wright was not cleared to reveal the ramjet information necessary for a detailed design and performance study.

1. Installation - the major design items discussed were:

   (a) Fuel carrying capacity of ramjet. The method employed by Curtiss-Wright involved the placement of fuel bags aft of the flame holders. It was recommended by Curtiss-Wright that this method be employed in the tail pipe portion.

   (b) An umbrella-type collapsible intake fairing was provided to close the intake during the time the ramjets are non-operative. However, it was mentioned that an intake closing frequency of 20 cps is in the preliminary specification stage. This feature would permit the selective use of ramjets, during flight.

   (c) The Curtiss-Wright representative suggested that the cooling of adjacent ramjet structure to ambient conditions can be easily achieved. Also a heat sink can be 'incorporated' to the incoming ramjet fuel.

   (d) The problem of mounting twin ramjets may be somewhat difficult, for the ramjet buzz is a prevailing problem.

   Finally a variety of operating points of the proposed Long Range Arrow performance was given to Mr. Nierenberg so that he can present us with optimum detailed ramjet performance and installation data.

2. **Ramjet Features and Performance**

Mr. Wiesenberg was able to give some leading particulars of a 35 inch diameter ramjet equipped to carry 1000 lb. of fuel in a collapsible bag in the duct aft of the flameholders. A further supply of about 650 lb. of fuel of which 600 lb. is JP4 is carried in an annular skin tank and in the centrebody, to be burned in the ramjet. The fuel contained in the centrebody is aluminum-tri-ethyl and is pyroforic, i.e. it will spontaneously ignite in a quite tenuous oxygen-containing atmosphere. Its excellent burning characteristics have made possible the burning of a mixture of 15% by weight of this fuel in JP4 at pressures down to $\frac{1}{4}$ lb. per square inch. Both specific gravity and heating value of aluminum-tri-ethyl are close to that of JP4. The present cost is $5.00 per lb.

While being used as a fuel tank the intake is closed off by an umbrella of meshing plates and the exit is plugged by a conical body which is fixed to the centrebody of the ramjet by a long rod. The rear fairing is jettisoned when the tank fuel has been used through breaking the rod by an explosive charge. Presumably the empty bag is either jettisoned before or burned on light up.

The design point of this 35 inch ramjet is as follows:

$M_D = 2.0$ @ 60,000 ft.

Propulsive thrust = 2400 lb. (convergent nozzle). (External drag of ramjet has been taken into account in this thrust.)

SFC = 3.5 lb./lb.hr. using JP4

Peak Drag Coefficients

(a) As a fuel tank $C_D = .55$ @ $M = 1.4$

(b) As a thrusting ramjet $C_D = .275$ @ $M = 1.3$

The empty weight of the engine is 560 lb.

ORIGINAL SIGNED BY
M. A. PESANDO

M.A. Pesando,
Chief Project Research Engineer.

cc: Mr. J.A. Chamberlin.

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