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Mr. J.C. Floyd.

M.A. Pesando.

DISCUSSIONS ON RAMJETS WITH CURTISS-WRIGHT AT WOODRIDGE, N.J., JAN. 31, 1958.

Present

Avro Personnel: Messrs. M.A. Pesando
R.F. Marshall
W. Kuzyk
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Curtiss-Wright Personnel: Messrs. B. Nierenberg (Engineering Sales)
G.G. Brown (Assistant Chief Engineer)
J.W. McCrea (Chief Project Engineer)
R. Schaefer (" " ")
G. Christie (Div. Sales Manager)
N.J. Roller (Asst. Project Engineer)
R. Juntwait
W.J. Mann (Sales Mgr., Curtiss-Wright Canada)
E.L. Davies (Sales Engineer, C-W, Canada)

1. GENERAL

The conference commenced with a brief rundown on the history of the Curtiss-Wright ramjets. The 20", 34" and 48" ramjets were briefly discussed with respect to performance, hardware and application. Noteworthy is the Hydrocon which is a fuel flow metering device developed by Curtiss-Wright. This portion of the meeting was confidential and it was requested that visiting Avro personnel refrain from 'note taking'. Ramjet development commenced in 1946 at Curtiss-Wright, development times for the 20", 34" and 48" ramjets were 3, 6 and 4 years respectively.

2. ARROW 4

The second phase of the conference dealt with the ramjet application to the Arrow 4. A preliminary scheme was outlined on drawing RJD-7133. Four 34" ramjets podded in pairs were proposed. Two-dimensional intakes generating a double oblique shock were employed. Several proposals regarding the fuel carrying abilities of the pods were presented, viz,

- (a) 5000 lb. per aircraft in useable fillets and the section aft of the rear flame holders.
- (b) (a) plus 5000 lb. per aircraft in centre body, the exact methods not finalized.

2. ARROW 4 (cont'd.)

- (c) Area rule or bulging the pods provide 2000 lb. per aircraft additional fuel volume.

It is noteworthy that an attempt was made to utilize 'fillet volume' for the major portion of the fuel carrying capabilities of the pods. This feature is costly and deviates from the original scheme of flooding the ramjets.

Performance

A preliminary performance was estimated for one 34" ramjet, and is shown in the following table:

Mo	1.5	2.0	2.5	2.5	3.0
AH - ft.	40,000	40,000	40,000	80,000	80,000
F _n - lb.	2,998	7,634	16,164	2,238	3,180
SFC - lb/hp/lb.	3.46	2.41	2.84	3.00	3.20*
W _f - lb./hr.	10,370	18,400	45,900	6,710	10,170
η recovery max.	.945	.945	.875	.875	.750
η recovery opt.	.92	.94	.836	.807	.591

F_n, the net thrust, is defined as $F_n = \frac{W_5 V_5}{g} - \frac{W_0 V_0}{g} + A_5(P_5 - P_0)$

$$\text{and, } W_5 = W_a + W_f$$

$$W_a = .995 W_0 \text{ (ref. turbine accessories)}$$

F_e, the engine thrust is defined as

$$F_e = F_n - \text{cowl, friction, wake, additive drags.}$$

Drag

Some pod drag figures were quoted, and are as follows:

Mo	0.9	0.9	1.4	1.4
C _D cold	.25	.36	.52	.60 (based on po frontal are.
Condition	front and aft faired	front and aft faired	front faired only	front faired

The above data applies to the pods and excludes any pylon or wing effects. The aft end employed 8° boattailing which in effect reduced the base area by 25%.

* SFC not too good here, possible to optimize for efficient Mach number or to metal variable nozzle.

2. ARROW 4 (cont'd.)

Fuels

Recent developments indicated that up to 25% of aluminum tri-ethyl enriched JP4 or equivalent can be utilized to increase the operational limits of the ramjet engine.

Addenda

Viton A was utilized as the material for high temperature bearings seals. Tests at WADC showed satisfactory results up to 500°C and 500/700 psi (limits of test) provided the seal was not disassembled. The material can be obtained from several sources, one of which is Lineas Inc., State Rd. and Levick St., Philadelphia, Pa. This information, although remote from the main topic of the conference was recorded as useful possible data with respect to systems engineering of future Arrows.

3. TOUR OF FACILITIES

Immediately following luncheon a tour of the facilities progressed. Actual ramjet hardware was displayed, i.e. the 20", 34" and 48" skeleton. Curtiss-Wright ramjets have performed satisfactorily at up to 10 hours life associated with missiles. Curtiss-Wright envisaged no particular problem in extending this life to 100 hours as required for Arrow 4 use. After inspection of ramjets the impressive test facilities, peculiar to ramjet development were shown and described to the Avro group. It is interesting to note that the value of this test facility was of the order of \$17,000,000. Present capabilities of the facility are M⁴ and 85,000 ft. altitude. Development time for a new ramjet is estimated at 24 months by Curtiss-Wright.

4. FINAL DISCUSSION

The final discussion concerned the seriousness of the Arrow 4 proposal, i.e. the existence of a firm R.C.A.F. requirement. It was agreed that Curtiss-Wright personnel visit Avro in the next few weeks to discuss Arrow 4 policy prior to any presentation by Curtiss-Wright on ramjets to the R.C.A.F.

ORIGINAL SIGNED BY
M. A. PESANDO

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MAP/js

MARIO PESANDO'S REPORTS TO ME ON
SUBJECT OF LONG RANGE ARROW (MR4)
AND RAMJETS FOR SAME.