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SUBJECT A DESCRIPTION AND SOME OPERATING NOTES RELATING TO REHEATED DERWENT VIII ENGINES IN METEOR VT-196

PREPARED BY E.L. Smith and H.S. Fowler

ISSUED TO Internal
Flight Research
RCAF (W/C Bridgland)

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1.0 INTRODUCTION

The following memorandum has been written primarily for pilots and technical personnel who will be dealing with the reheated Derwent VIII engines in the Meteor VT-196. A description of the reheat system is given, following by some operating notes.

Readers desiring more information are referred to references 1 to 4 which describe the test bed development.

2.0 DESCRIPTION

2.1 Reheat Principle

A reheat system or afterburner is essentially a ram jet attached to the turbine outlet of a turbojet engine. Its functions are: to slow down the exhaust gases by means of a diffuser (to reduce the pressure losses associated with heat addition), to increase the energy of the gases by burning additional fuel, and, finally, to expand the gases through a propelling nozzle to create an increased rearward momentum. Since the jet velocity is dependant on the temperature of the exhaust gases, the reheat system gives an increased velocity; hence an increased rearward momentum, and consequently, an increased forward reaction or thrust on the engine supports.

Normally a variable area propelling nozzle is fitted to accommodate the increased volume of the exhaust gases associated with increased temperature. For reasons of simplicity, however, the initial tests on the VT-196 will be done with fixed oversize propelling nozzles.

2.2 Mechanical Construction

Figure 1 shows the layout of the reheat system.

The diffuser section, which attaches directly to the exhaust unit of the engine, is fabricated from 18 gauge Inconel sheet and is insulated with a Refrasil blanket.

The flame-holder and pilot zone fuel ring (which fix the position of the reheat flame front) are located in the diffuser exit. Four radial pins carry the flame-holder and allow for thermal expansion. Two of these pins are in the form of electric ignition plugs and project into the flame holder to ignite the reheat fuel. The flame-holder material is stainless steel, type 327.

In addition to the pilot zone fuel supply at the flame-holder, there are three main fuel nozzles, made of Inconel, which project radially inward through the turbine stator shroud and which spray the main reheat fuel directly on the rotating turbine blading. The primary objective of this arrangement is to cool the turbine blades.

The combustion duct follows the diffuser and simply supplies sufficient volume to allow the reheat fuel to be burned before the exhaust gases leave the system. 20-gauge Inconel is used for the combustion duct. Reinforcing stringers of stainless steel are mounted on the outside of the combustion duct and also serve as spacers to position the 26-gauge stainless steel insulating shroud. The reheat system supports which are in the form of four Inconel brackets, are mounted in the combustion duct.

The aft end of the reheat system is composed of an inner propelling nozzle which is formed from 16-gauge Inconel and an outer ejector nozzle also made of Inconel, which serves to suck cooling air through the annular gap between the combustion duct and the insulating shroud.

2.3 Reheat Fuel Control System

The control system fitted to the VT-196 is for research flying only; a single lever fully automatic system for operational flying is under development. However, the present system is simple and will deliver any required degree of reheat up to the maximum allowable.

Figure 2 shows the layout of the control system.

The tank pump supplies fuel to both engine and reheat via a common low pressure cock. Reheat fuel is carried to the high pressure pump which delivers fuel (at about 300 lb/in^2 pressure at ground level) to the air/fuel ratio control unit. This unit acts on the servo piston of the pump to keep a constant reheat temperature for any reheat throttle setting.

When not reheating the Burner shut-off cock (A) is closed and the by-pass shut-off cock (B) is open (i.e. switch C is "off"). Fuel therefore bypasses, going back to pump inlet and also to tank. The return to tank allows fresh fuel to enter the system continually to assist in pump cooling.

Before reheat can be lighted the engine throttles must be near the full rpm position to close the reheat master switch. To start reheat, switch D (reheat ignition) is moved to "on" to set the igniter sparking, and switch C (reheat fuel) is moved to "on" causing cocks A and B to reverse. The fuel now stops by-passing and flows to the pilot zone spray ring and to the main fuel nozzles. The pilot flame lights and ignites the main spray at the flame holder. Switch D is then switched "off" to save the ignition coils.

To increase reheat the reheat throttle is advanced.

To shut off reheat, the reheat throttle is closed, and then switch C is moved to "off", de-energizing the two solenoid cocks A and B and by-passing the reheat fuel. In emergency, reheat is

shut off quickly by moving switch C to "off" directly, closing the throttle afterward.

As mentioned previously, the air/fuel ratio control unit maintains a constant reheat temperature (i.e., a constant air/fuel ratio for a given reheat throttle setting). Thus as the engine air flow alters with varying flight speed or altitude, the reheat fuel flow is modulated accordingly. This is accomplished by supplying compressor delivery pressure (which is approximately proportional to engine air flow) via the reheat throttle valve to the control unit which, in turn, acts on the pump servo making the appropriate adjustments to reheat fuel flow. It will be noted that the reheat throttle simply alters the air pressure which the flow control unit senses.

3.0 OPERATING NOTES

3.1 General Handling

The Derwent VIII with the oversize nozzles fitted on the present system develops about 80 percent of normal thrust for a standard Meteor tail-pipe. Thus fairly reasonable take-off performance is maintained for the reheat-off case. With a similar installation, Rolls-Royce reported a take-off run of 1600 yards at an all up weight of 16,500 pounds for a grass-surfaced runway.

It should be noted, however, that at temperatures below about 10°C, there is some tendency for the tail-pipes to buffet at full rpm (14,700) with reheat off. Thus it is advisable to take-off and climb with some reheat on. It will likely be found that the minimum reheat fuel flow will be adequate to suppress buffeting.

It will also be noted that there is an increased tendency for combustion rumble on starting when oversize nozzles are fitted. This may be suppressed by reducing the rate at which the high pressure cock is opened beyond the half-on position.

3.2 Lighting, Controlling and Shutting Off

Reheat will normally be lighted at 14,500 rpm, with reheat throttles closed; this is accomplished by moving the reheat ignition switch to "on" and then moving the reheat fuel switch to "on". There is a noticeable increase in thrust as reheat comes on. The reheat ignition switch is then moved to "off".

When lighting at altitude it will probably be necessary to open the reheat throttle slightly. Initially, lighting may be attempted at throttle openings up to half throttle. Experience with the system may indicate that larger reheat throttle openings are allowable. After an unsuccessful attempt to light, the reheat fuel switch should be switched "off" for 30 seconds to ventilate the reheat system.

When a light cannot be obtained with the above procedure, the engine rpm may be reduced to 13,500 rpm and lighting attempted again. The reheat throttle should not be opened beyond quarter throttle at reduced rpm.

The amount of reheat is controlled by the reheat throttle. As the reheat throttle is opened the jet pipe temperature will rise slowly since, as far as the engine is concerned, the application of reheat simply corresponds to a reduction in propelling nozzle area. Initially maximum allowable reheat fuel flow will be specified by a jet-pipe temperature limit of 680°C below 20,000 feet and 700°C above 20,000 feet. Later testing may be carried out at specified turbine pressure ratios or to altered jet-pipe temperature limits as further data is obtained from flight tests. However, an overriding maximum jet pipe temperature limit will always be given.

It will be noted that there is a slight drop in rpm as reheat is increased. Thus it is necessary to advance the engine throttle slightly to hold rpm constant as reheat is increased.

For a normal reheat shut-down, the reheat throttle will be closed and the reheat fuel switch moved to "off".

For a fast reheat shut-down, the reheat fuel switch may be moved to "off" immediately and the reheat throttle closed afterward.

It should be noted that it will be necessary to throttle the engine slightly as reheat is shut off to prevent overspeeding. This effect is associated with the governor rate and will become progressively greater as altitude is increased.

For a fast shut-down of the whole unit the engine throttles may be closed immediately thus opening the reheat master switch and shutting off reheat fuel. The high pressure and low pressure engine cocks may then be closed. The reheat fuel switch must be moved to "off" and the reheat throttle closed before starting up again.

It should be noted that reheat must always be switched off, either by moving the reheat fuel switch to "off" or by closing the engine throttles, before cutting the engine by closing the engine high pressure cock.

It should also be noted that the low pressure cock is common to both engine and reheat fuel systems. Hence to isolate the reheat system completely, it is necessary to stop the engine. However, closing the low pressure cock should only be done as an operational necessity since some damage to the fuel pumps may result.

3.3 Howling Combustion

Howling is a form of rough combustion which excites a high frequency (600 - 700 cycles/second) vibration in the exhaust gases. It is characterized by a distinct change in reheat noise and, while not damaging for short periods, it may, if allowed to continue at high fuel flows, cause fatigue and splitting of the tail-pipe skin.

This form of rough combustion has been eliminated on the test bed and it is predicted that the alteration in fuel distribution at altitude should be such as to suppress howling. However, a vibration indicator will be mounted on the reheat pipe and will light a warning light on the pilot's panel if howling occurs. Reheat should be switched off immediately if howling is encountered.

The stainless steel cooling shroud around the tail-pipe will serve to protect the nacelle structure in the event of damage to the reheat pipe due to howling.

4.0 SUMMARY OF OPERATING PROCEDURES

4.1 Starting Engine

Add the following items to normal pre-starting checks:

Reheat Ignition Switch - - - - - -	OFF
Reheat Fuel Switch - - - - - -	OFF
Reheat Throttle - - - - - - -	CLOSED

4.2 LIGHTING Reheat

Engine rpm - - - - - - - - - - - - -	14,500
Reheat Ignition Switch- - - - - - -	ON
Reheat fuel Switch- - - - - - - - -	ON
After light-up, Reheat Ignition -	OFF

4.3 Shutting Off Reheat

Reheat Throttle - - - - - - - - - -	CLOSE
Reheat Fuel Switch - - - - - - - -	OFF
Engine Throttle - - - - - - - - -	REDUCE - to prevent overspeeding

For faster shut-off:

Reheat Fuel Switch - - - - - - - -	OFF
Reheat Throttle - - - - - - - - -	CLOSE
Engine Throttle - - - - - - - - -	REDUCE

4.4 Shutting Off Both Reheat and Engine

Engine Throttle - - - - - - - - -	CLOSE
High Pressure Cock - - - - - - - -	CLOSE

Low Pressure Cock - - - - - - - CLOSE
Reheat Fuel Switch- - - - - - - OFF
Reheat Throttle - - - - - - - - CLOSE

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