Automatic Flow Control

IN JET ENGINE FUEL SYSTEMS

By J. W. TOMLINSON

IT CAN BE said without contradiction that the fuel system of a jet engine is the most complex section of the entire power unit and the most difficult to understand. Like all other complicated mechanisms, the jet engine fuel system had a humble beginning.

Not many years ago, a system consisting of a single fuel pump, a barostat, a pressurizing valve, torch igniters, and a set of burners would suffice. With the tremendous increase in power, speed, and altitude, derived from present day engines, these now out of date systems would be hopelessly inadequate.

During the early days of jet development, the trend was to design separate units and connect up with external plumbing. With more and more units being added, fuel system designers resorted to incorporating several of these into one major assembly, called the Fuel Control Unit. While this had the advantage of cutting down the external plumbing, it added to the complexity of the system to all except the initiated. The reason for this article is to describe briefly in simple language how this major unit operates automatically to adjust the fuel flow to meet the changes in air/fuel requirements due to rapid changes in altitude and forward speed and during acceleration.

Anglo-American: One of the most used fuel control units in Canada today is the Lucas-Bendix type, made by Bendix under license to Lucas. This unit is used on the Orenda 8, 9, and 10 series, installed in the CF-100 and the Sabre 5.

The unit is designed to make use of the varying compressor inlet and outlet air pressures and the fuel pressures in the fuel system, to automatically schedule the fuel to the burners. This, like other automatic scheduling systems, relieves the pilot of continually having to manipulate the throttle lever during manoeuvres. The unit is designed also to protect the engine against overfueling during acceleration, with subsequent possible compressor "stall" and engine failure.

Three distinct assemblies are bolted together to form the unit, these are the throttling control (T.C.U.), the acceleration control (A.C.U.), and the low pressure filter (L.P.F.). The filter is placed in the middle, making it convenient to return servo bleed fuel to the low pressure side of the system without external plumbing.

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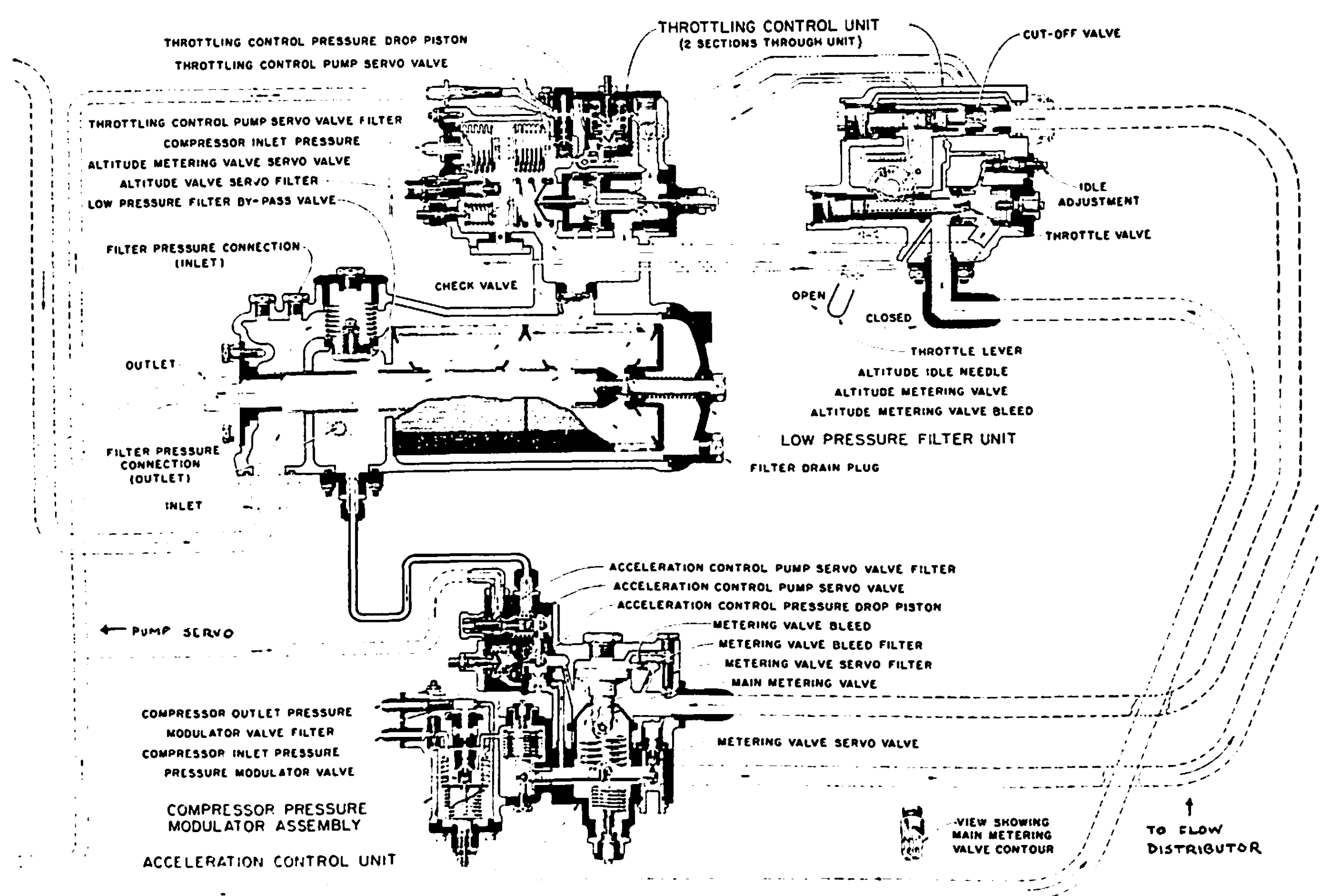
Below: A schematic of the TJS-2 Lucas-Bendix Fuel Control Unit.

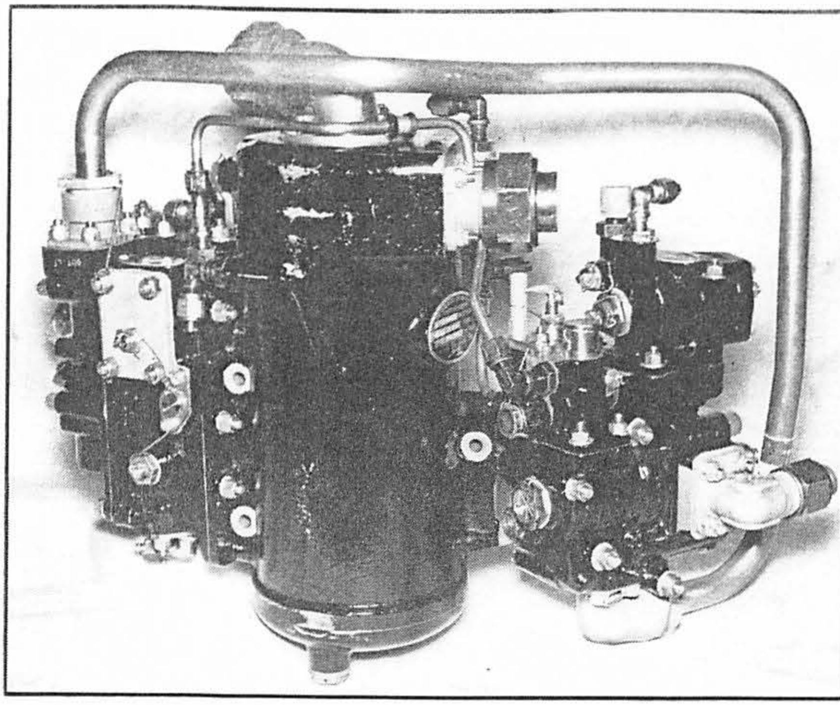


At the Start: During the starting cycle, fuel from the aircraft tanks enters the L.P.F. under boost pump pressure of approximately 25 psi, passing through the filter elements and on to the high pressure pumps. The pumps being mechanically driven by the engine, which has started to turn by means of the starter motor, begin to pump fuel at high pressure to the throttling control of the T.C.U.

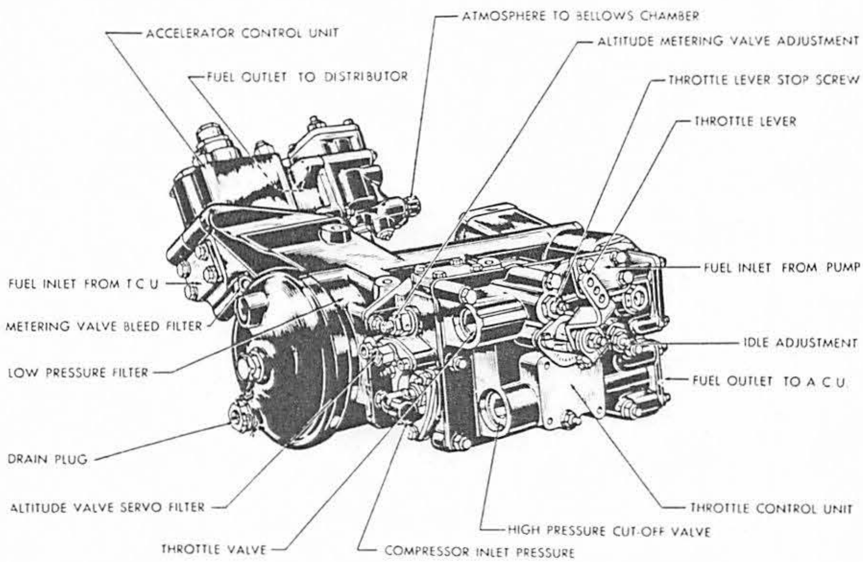
The pilot moves the throttle lever to the idling position and a small flow of H.P. fuel is passed through the throttle valve on to the burners. At the beginning, the H.P. fuel pumps are operating at full delivery, pumping far more fuel to the throttling control than is necessary for idling. This is immediately attended to by the pressure drop piston in the T.C.U., acting in the following manner. A small diameter passage inside the unit allows fuel to pass from the upstream side of the throttle valve to one side of the pressure drop piston. The fuel pressure from the downstream side of the throttle valve acts on the other side of the piston. As the pressure builds up on the upstream side of the throttle valve, due to the pump working at full delivery against the almost closed throttle valve, the increased pressure causes the pressure drop piston to move. This allows, through a rocker lever and half-ball valve assembly, servo fuel to bleed from the H.P. pump servo line to the L.P. filter of the F.C.U., thus reducing the pump delivery to that required for idling.

The automatic scheduling of fuel, whether it is for changes in altitude or forward speed, or for rapid accelerations, is all taken care of through this pump servo line which connects the F.C.U. to the pumps.

When the pilot opens the throttle from idling, the pressure on the downstream side of the throttle valve will drop in relation to the upstream pressure from the pumps. Since these pressures act on either side of the throttling control pressure drop piston, this change will cause the piston to move to keep the servo valve in the T.C.U. closed. With increasing pump speed, and the servo line sealed off in the T.C.U., the servo pressure will build up in the pumps, and move the pump servo pistons to increase delivery to meet the new throttle lever position. Thus a correct flow at a constant pressure is



Both photograph and drawing illustrate the Lucas-Bendix fuel control unit.



maintained to meet the full range of throttle openings.

Overspeed Control: When the maximum throttle opening is reached, the servo line is bled off inside the pump to prevent the pump over-speeding and increasing the rpm beyond the safe limit.

From the preceding paragraphs, it will be conceived that the pressure drop piston in the T.C.U., automatically controls the fuel pressure and pump delivery, through the pump servo line, to meet changes in throttle openings.

Adjustment for Altitude: Automatic adjustment must be made to compensate for changes in the air fuel ratio due to varying altitudes and forward speeds. This is taken care of by using the changing compressor inlet pressure to operate an altitude metering valve. A pipe line is taken from the air intake to the unit, feeding compressor inlet pressure into a bellows assembly.

As the forward speed of the aircraft increases, or the altitude decreases, the bellows expand through increased inlet pressure. This causes a lever attached to the bellows to move and permit the altitude metering valve servo valve in the T.C.U. to unseat, with subsequent bleeding off of fuel from the back of the altitude metering valve piston. This action permits the piston and attached valve to move and increase the orifice

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FUEL CONTROL

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around the tapered end of the valve, permitting more fuel to flow. This opening and closing of the servo valve and movement of the piston is taking place automatically while the pilot is flying the aircraft, thus the fuel flow is trimmed to suit the changing conditions of flight.

Acceleration Control: Still another adjustment has to be made, this is to control the fuel flow during acceleration, when there is a danger of overfueling at the early stages of throttle opening. This could cause a situation where the sudden increase in fuel burning results in the setting up of a back pressure at the rear end of the compressor, sufficient to damage the compressor blades. This condition is called "compressor stall" and is avoided by making use of the pressure differential across the compressor in conjunction with a pressure modulator. The modulator is a sub-assembly of the acceleration control unit (A.C.U.) containing a capsule stack, one section of which is open to compressor inlet pressure. A series of restrictors and a half-ball valve, modulate the compressor inlet and outlet pressures which are passed on to a second chamber containing a closed bellows assembly. When the modulated pressure is sufficiently high, the closed bellows contract to open the metering valve servo valve and bleed fuel from the back of the metering valve piston. This permits the metering valve to move to allow an increased flow of fuel, sufficient to accelerate the engine within the specified time limit and yet avoid overfueling at the critical engine speed.

The A.C.U. also contains a pressure drop piston and servo valve mechanism which bleeds the pump servo line to reduce pump delivery should the A.C.U. fuel inlet pressure get too high in relation to the outlet pressure.

The foregoing is only a very brief description of how the Lucas-Bendix flow control unit operates. However it should be sufficient to provide an insight into the subject without getting too involved.

PILOT'S NOTES

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remember not to commit that particular error himself. Cartoons, however, fail if they do not get the point over to the reader. Used with discretion, they are a useful attention-getter. Used freely they can reduce the book to an inferior type of comic strip.

When the manual has been drafted and the illustrations are in a sufficiently advanced stage of preparation, the contents of the book are agreed, paragraph by paragraph, with the company test pilots. This may be a lengthy procedure since opinions on operating techniques may vary widely, and test pilots, particularly when the weather is good, are busy people. Eventually agreement is reached with them and with other interested parties within the company and then a conference is called at which RCAF representatives go over the draft and make their comments and suggestions. A technique advocated by the aircraft manufacturer may not be agree-