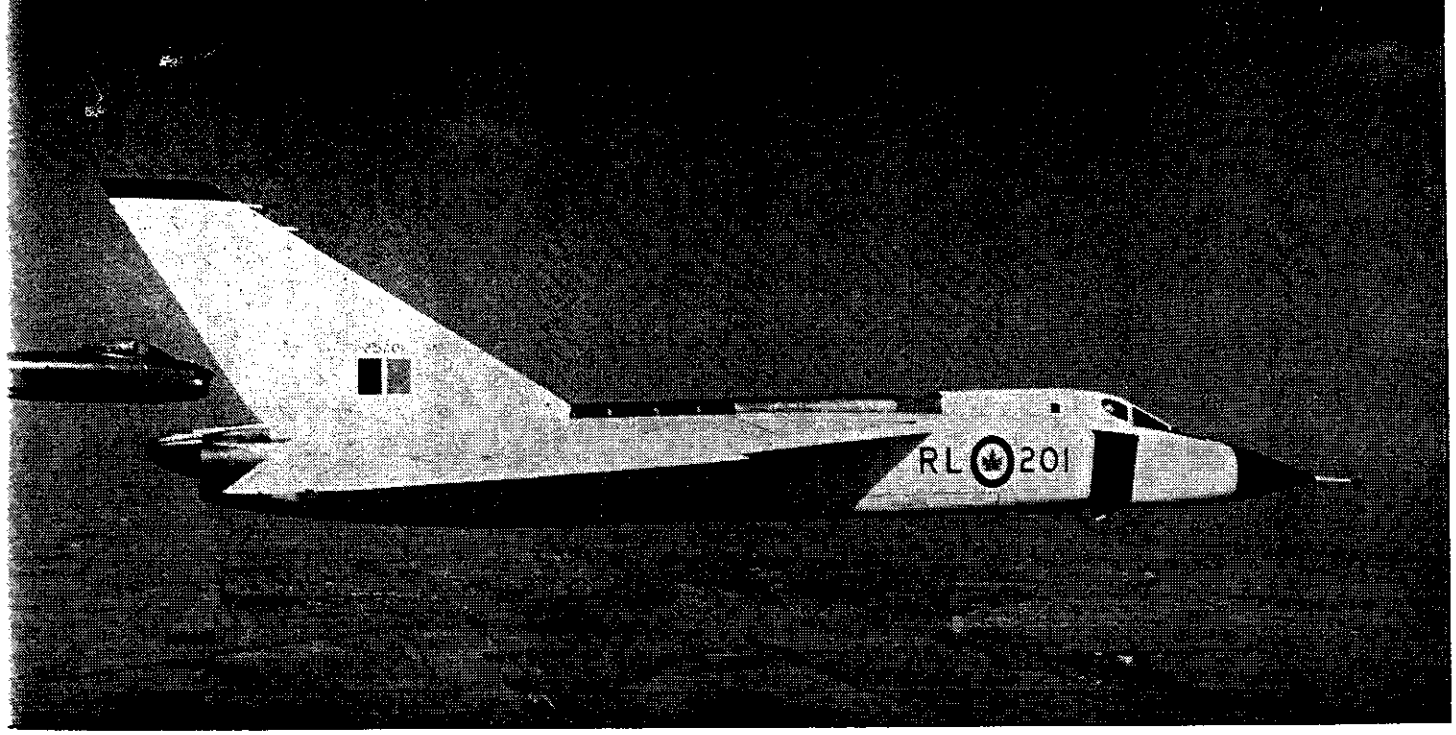

Automatic Flight Control in the Arrow

By JOHN H. BALDWIN*

THE AERONAUTICAL Division of Minneapolis-Honeywell Regulator Co. in Minneapolis, Minn., and Honeywell Controls Limited in Toronto are vitally concerned in development and production of the Electronic Weapon System for the Avro CF-105 Arrow. As sub-contractor to Avro Aircraft and associate prime contractors to Radio Corporation of America, these Honeywell divisions are engaged in the design and development of the flight control systems and instruments which will enable the Arrow to be the most advanced supersonic fighter aircraft of its type in the world.

Traditionally, Honeywell's Aero Division has been a leading North American supplier of Automatic Flight Control Ssystems for fighters and interceptors. The flight control equipment for the Arrow incorporates the latest techniques and components into a system specifically tailored for this aircraft. Thus, the resulting system will represent a unique product, tailored for the Arrow and designed to fulfil the operational requirements of the RCAF.

Heart of the Matter: The heart of an automatic flight control system is the damper, also known as the damping system. Modern, high performance aircraft designers have learned that it is possible to achieve exceptional performance only at some expense to the inherent stability of the airframe. Augmentation of this stability — to the point that the aircraft responds conventionally to commands — can be satisfactorily accomplished by adding an electro-mechanical damping system as part of the basic airframe.

The damping system introduces added commands to the control surfaces in a direction to stabilize flight. Since these commands are not detectable by the pilot they result in an airframe which responds to commands conventionally. Equivalent response could be achieved only be greatly increasing the size of the vertical stabilizer and other changes in the airframe design, these changes would result in loss of high-speed and high-altitude performance.

The damper system makes use of miniature gyros and accelerometers to sense aircraft motion, and commands compensating control surface action through precise hydraulic servo actuators. Since all of these components are designed and produced by Honeywell, true system compatibility results and consequently many expensive months of experimental flight testing are saved. Further compatibility is ensured by the fact that Honeywell also supplies the hydraulic control valves which work into the large control surface jacks. These control valves convert mechanical commands either from the pilot's control stick or from the damper servo actuators into hydraulic flow to position the control surface jacks.

Reliability: Since proper functioning of the damper system is so essential to the aircraft the utmost stress is placed on reliability in design. Two of the design concepts are worthy of mention:

(1) Proven components are used throughout after study is made to prevent misapplication, and

(2) Vacuum tubes are completely eliminated from the equipment. As a further precaution, an automatic feature is incorporated which detects malfunction and switches to a stand-by emergency damper system.

Although the damper is truly one element of the complete automatic flight-control system, the name Automatic Flight Control System (or AFCS) has been assigned to the components not contained in the damper. Again, full compatibility results from the fact that design of the AFCS is carried out by the same personnel who have designed the damper. One of the major functions of the AFCS is to

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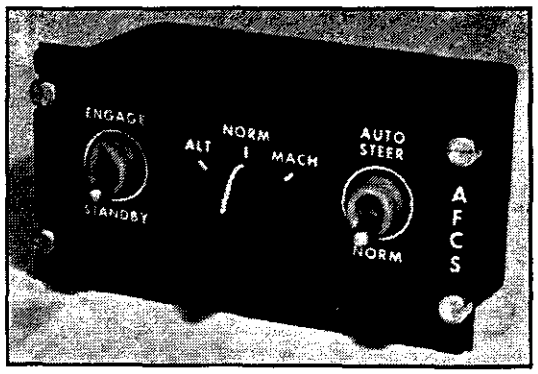
provide the tie-in between the radar system and the airframe to achieve completely automatic attack. Since the AFCS is being designed under subcontract to RCA, the radar designer, close liaison between the two companies ensures that the ultimate in performance it attained. Other features of the AFCS besides automatic attack are automatic constant altitude flight, automatic navigation tie-in, and "attitude hold" modes.

One of the major advantages which derives from the practice of designing a system for a specific aircraft is the saving in space, weight, and complexity derived from the integration of functions. Two examples of this concept are apparent in the central air data computer (CADC) and the vertical and heading reference systems (VHRS). The control air data computer, as its name implies, computes all of the information needed by the various users of air data in one central location; thus, altitude, true air speed, altitude difference, Mach number, etc. are but a few of the computed signals. More conventional aircraft have had as many as 30 individual or transducers located throughout the aircraft, many of them duplicating the functions of others located in unrelated equipments, but in the Arrow all of these computations are located in one unit thus saving duplication and complexity. The only air data computations not located in the CADC are those which are duplicated for reasons of increased reliability by redundancy.

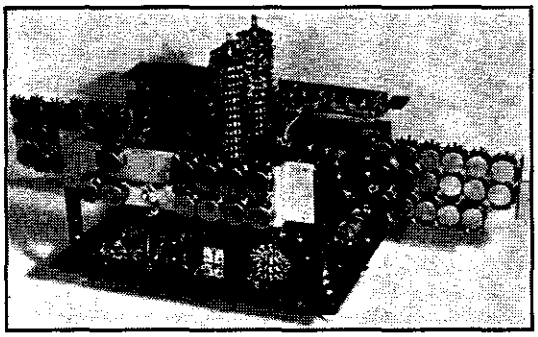
Eliminating Duplication: Similar logic is apparent in the vertical heading and reference system. In an aircraft such as the Arrow as many as 50 independent signals representing roll, pitch, or azimuth may be needed. Past aircraft have carried many duplicate sets of gyros to derive these signals.

The Arrow contains one central gyro system which provides these signals to all users by means of two centrally located repeaters. Use of miniature components in the gyro platform and its associated units will result in the most precise reference system for interceptor use known today.

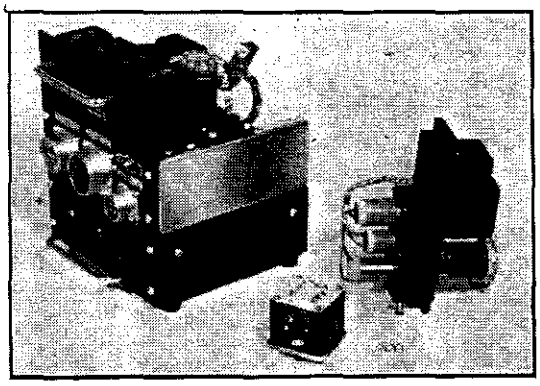
Both the CADC and the VHRS are being designed by Honeywell for the Avro Arrow. Signals from these systems will be used by the AFCS, the radar and computers, the navigation system, and the flight instruments, and



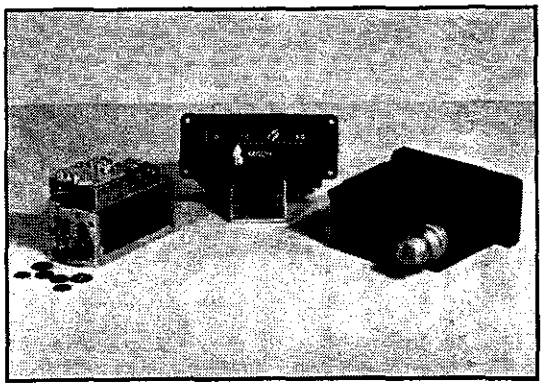
Function selector panel includes switches for engaging and for tying AFCS to RCA nav system, and pickle button for selecting Mach or altitude hold modes.



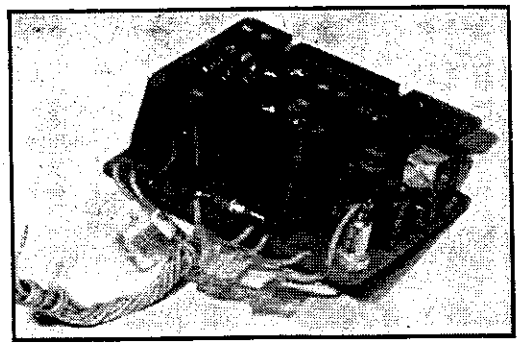
Rear view of damper test equipment pack open for maintenance. All 105's flight and navigation systems will operate through damper.



Stabilization repeater breadboard model is one of two servo repeaters for stabilization loop of reference platform. Repeaters will be housed in platform computer.



New rectangular Mach indicator with three independent pointers shows actual Mach, command Mach and Mach limit. Unit is hermetically sealed and integrally lighted.



Summing amplifier breadboard model shows compactness of precision amplifier used to torque Honeywell gyros in reference platform.

so continuous liaison is maintained with the designers of these systems to ensure compatibility.

Some of the flight instruments for the Arrow represent the latest concepts derived by the "human engineers". Displays of information to the pilot have been carefully studied and simulated in order to determine the best presentations which will allow quick reading with fewest mistakes.

Changing Shapes: Even though circular instruments are the easiest to build they are not always the best from a human engineering viewpoint, especially if many similarly shaped instruments displaying different information are grouped at random. Thus, in the Arrow, the instrument panel design is being considered as a whole to determine the best location of instruments as well as the best shape. Fuel quantity gages and exhaust gas temperature indicators of conventional Honeywell design are used. However, the Mach indicator has been specified to be rectangular and so one of the first linear-scale flight instruments is being designed. Similarly, the flight director/attitude indicator (the basic blind flying instrument) is being designed in a square shape.

Since both of these instruments receive signals from the CADC and/or the VHRSystem their compatability is assured.

Additional airborne devices designed by Honeywell for the Arrow are the thermistor level system and the center of gravity control system. These systems provide automatic control of the fuel drainage sequence so that the pilot need not concern himself with selecting fuel tanks during flight. The systems also inform the pilot of the condition of his fuel system at any time.

Elimination of all vacuum tubes and their replacement by transistors and magnetic amplifiers has greatly increased reliability.

The complexity of equipment necessary for the interceptor mission makes the problem of locating a malfunction a difficult one, and yet long turnaround time cannot be permitted for purposes of trouble shooting. Considerable effort has, therefore, been expanded in the design of ground test equipment which will speed the location and correction of faults. Ground test equipment which can be quickly connected to the aircraft and which will then indicate satisfactory or unsatisfactory performance of each subsystem followed by indication of the location of the fault has been designed. This equipment is being delivered concurrently with the flight test models of the airborne equipment so that it will undergo equivalent field trials to prove its worth. The importance of this ground test equipment cannot be underestimated when the problems of mobilizing for defense in the face of a shortage of technical personnel is considered. The high cost of the modern aircraft, the high level of training of modern aircrews, and the need for speed in the interception of an attacking force will not permit long delays for the locations of a faulty resistor.

Canadian Contribution

THE AERONAUTICAL Division of Honeywell Controls Limited in Toronto is undertaking an important part of the Integrated Electronic Weapon System program for the CF-105 Avro Arrow. Present effort consists of design engineering and engineering liaison but as the Arrow approaches operational status all departments of the Aero Division will become involved. The 200-man division includes production, repair field service engineering, functions. All departments have been engaged in work for the Canadian aeronautical industry, with particular emphasis on the Avro CF-100. Instruments and flight controls are being manufactured and maintained by the organization, thus providing the skill and experience necessary to perform the same functions on the Avro Arrow in the future.

Most of the effort in the Engineering department is engaged on projects for the Avro Arrow. About 30% of the original design by Minneapolis-Honeywell is being carried out by Canadian engineers and technicians in Toronto. This department has been expanded to include 100 people of which 80 are on Arrow projects.

Experience Gained: From a description on these projects it will be seen that the range of experience being gained by these Canadian engineers will be invaluable in the growth of an independent aeronautical industry in Canada. Initially, many of the projects were conceived in Minneapolis and were staffed by Canadian engineers on loan. All personnel have now returned to Toronto and the design is contributing in close liaison with Minneapolis engineers. In this way, the Canadian company has taken full responsibility for much of the original design and yet is making use of the long experience of the Minneapolis operation.

The Mach indicator is typical of the design and development projects being undertaken. The selection of a rectillinear display was made by human engineers in the Aero Research Department in Minneapolis. Canadian engineers took over when requirements were specified and are now at the stage of fabricating developmental protoypes. The choice of a rectilinear presentation required that many problems be solved not previously encountered in the design of circular instruments, thus, major advances in integral lighting, hermetic sealing, and servo drives for linear scales have been made. The instrument will contain three servo driven pointers of extremely high positioning accuracy, and will be powered by transistor-mag-amp hybrid amplifiers.

Several parts of the vertical and heading reference system are also being designed in Canada. In particular, the erection computer for the platform and the extremely precise transistor amplifiers for the platform gyros are now under design. Fast-acting accurate servo repeaters necessary to eliminate duplication of gyro systems on the aircraft

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in the wrong direction.

Commented Ron idly indicating the dust cloud: "That's the flying instructor."

We watched as the tired old car returned at a sedate rate of knots, mission successful. The haggard face of a young-old-man peered wanly out at us. Instructing is a tough racket at any time, but imagine having to sprint for the old jalop every little while to herd your students around the airfield!

Summing up our impressions on the Champion Tri-Traveler, the writer feels that for the price, ($6,475 Canadian, sales tax included), this aircraft is all right. It seems particularly suited to the flying school or club role. Easy to learn, docile in flight, an exceptionally low landing speed, all combine to make it a good aircraft for the beginner.

ARROW FLIGHT CONTROL

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are being designed in Toronto.

Ground Test: All of the ground test equipment for Honeywell designed systems is being designed in Toronto. The first models of the ground test equipment for the damper have been delivered and are undergoing field trials. The purpose of this equipment is to ensure that all of the flight equipment is operating properly before take-off. Rather than penalize the take-off weight of the aircraft by incorporating comprehensive self-checking features in the flight equipment, portable units of ground test equipment have been designed. These units may be quickly attached to the aircraft for daily inspection and will indicate whether or not the flight system is operating properly. If not, a further unit may be used to isolate quickly which of the flight equipment is faulty, so that quick repairs can be effected by replacement.

Not the least important of the programs being undertaken by Toronto Aero is the co-ordination of training and instruction manual preparation. The future of the Arrow as an operational aircraft depends upon the ability of RCAF personnel to maintain it as an effective flying weapon. Thus, early in the developmental program detailed plans are being made to ensure that technical skills and information will be ready when the RCAF takes delivery of the most modern interceptor in the world.

COMING EVENTS

June 9-10—Canadian Conference for Computing and Data Processing, University of Toronto.

June 14—Air Force Day across Canada.

June 15-19—Semi-Annual Meeting, American Soc. of Mechanical Engineers, Statler-Hilton Hotel, Detroit.

June 24-26—31st Meeting, Aviation Distributors & Mfrs. Assoc., Mt. Washington Hotel, Bretton Woods, N.H.

June 25-27—Air Transportation Conference, American Inst. of Electrical Engineers, Statler Hotel, Buffalo, N.Y.

July 8-11—IAS National Summer Meeting, Ambassador Hotel, Los Angeles, Calif.

July 26-August 16—Canadian National Soaring Championships, Brantford. Ont.

September 1-7—1958 SBAC Flying Display & Exhibition, Farnborough, England.

September 8-13—First International Congress, International Council of the Aeronautical Sciences, Palace Hotel, Madrid, Spain.

September 29-October 3—SAE National Aeronautic Meeting, Aeronautic Production Forum and Aircraft Engineering Display, Ambassador Hotel, Los Angeles, Calif.

October 7-8—CAI/IAS 1958 Joint Meeting, Chateau Laurier, Ottawa.

October 8-10—IRE 1958 Convention & Exposition, Automotive Bldg., Exhibition Park, Toronto.

October 17-19—COPA Annual Convention, St. Jovite, P.Q.

FAIREY CONVERSION

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the Navy from the USN in 1949. All had seen action in the Pacific during World War II. The RCN is retaining a number of Avengers, mainly for service with reserve squadrons.

Most of the ex-RCN machines so far sold to the civil market have gone to U.S. firms who plan to put them to work spraying and dusting.

June Completion: The Fairey conversion program was to be completed early this month so that the aircraft could take part in the spruce budworm operation in New Brunswick. In addition to the Avengers, there will be about 90 Stearmans, most of which work under sub-contract to Wheeler.

The conversion involves the installation of a bulky coffin-shaped spray tank which measures 13 ft. in length, 45 ins. in width and 35 ins. in depth, and has a capacity of 860 U.S. gallons. The tank is slung in the bomb bay and to make room about 900 pounds of equipment has been removed; this includes armament circuits, electronic gear and the bomb bay doors. Original fuel cells were left unchanged.

About three-quarters of the tank projects below the main fuselage, giving the Avenger even more of the appearance of a pregnant fish than it had before. The .125 in. thick welded steel tanks are held in place by nine steel straps. Each end of the individual straps is connected to turnbuckles on the sides. The tanks can be moved very quickly by disconnecting the filling points, jettison control and turnbuckles.

Under Pressure: Pressure for spraying comes from a hydraulic-driven two inch centrifugal 150 gpm pump, which is installed directly behind the tank. The spray booms under the wings have 25 nozzles each and are made of 1.25 in. steel pipe, each held in place by three V-struts.

The extra drag of the protruding spray tank and spray boom imposes a speed penalty of about 20 knots.

The Avenger sprayer has an average spraying run of about seven minutes at a rate of 120 gpm, but in an emergency, the whole load can be jettisoned in 20 seconds through a dump valve installed in the bottom of the tank.

Two prototypes for the Fairey Avenger sprayer were completed during March by the company's Pat Bay branch, near Victoria, on Vancouver Island. On completion, these two aircraft — both of which were earmarked for Skyway — were flown by Fairey test pilots to the Eastern Passage facility, where work on the other eleven machines was carried out. Prototype development was carried out at Pat Bay in order to make it more convenient to liaison with a U.S. firm on the west coast that had made a similar conversion last year.

Communications equipment, by Lear and Pye, includes VHF transceivers and HF receivers.

The versatility of the Avengers has led to their being suggested as possibly being suitable for commercial freight hauling in the north. It has been proposed that cargo could be snugged into the bomb bay in a cargo net. The spray tank could also be used to carry fuel and oil into areas where multi-engine aircraft are unable to operate.

They might also be useful in fighting forest fires. In the U.S., crop sprayers have often been used to provide an efficient fire break using a solution of sodium calcium borate (see "Firebrake . . . a New Tool for Forest Fire Control", *Aircraft*, February 1958).