SECTION C, PHYSICAL SCIENCES

Rocket-Borne Instrumentation Equipment for Ionic Conductivity Studies in the Upper Atmosphere[1]

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Measurements of ion density and mobility may be made by using electrical conductivity measurements in a freely flowing gaseous medium between two polarized electrodes of known geometry. Measurements of this kind have been made during rocket and balloon flights. This paper describes the instrumentation payloads provided for two Aerobee-100 rockets which were launched in November, 1960, at Fort Churchill, Manitoba, Canada.

Each payload comprised: a nose cone instrumentation rack which accommodated all of the airborne electronic equipment, together with the control circuits; two cylindrical Gerdien condensers, which were constructed and mounted on the forward tips of the nose skins. Control circuitry for the launching operations also was built.

NOSE RACK

Two nose racks were built in accordance with a standard design furnished by the National Aeronautics and Space Administration (NASA). The configuration of the two nose racks may be seen by referring to Fig. 1. The nose racks were constructed of 0.840-inch diameter, 0.109-inch wall tubular aluminum, and 0.093-inch aluminum sheet.

The rack design consisted essentially of four vertical corner structural members with six shelves mounted within the structure to support the payload electronic equipment. Special provisions were made for housing an AN/DRW-3 range safety fuel-cut-off receiver and its associated batteries. An AN/DPN-41 radar beacon and its associated power supply and batteries were mounted in the nose rack. An AN/DKT-7 telemetering transmitter was located on special structural brackets at the lower portion of the nose rack. This transmitter, which weighed 20 pounds, required rather sturdy mechanical support. The telemetering transmitter batteries were located on a shelf above the transmitter as pictured in Fig. 1. These batteries also supplied the power for the beacon power supply. The topmost shelf of the nose rack was used for mounting the electrometer and operational amplifiers, together with the battery power control relays. The mercury batteries for supplying power to the electrometer and operational amplifiers were located on the second shelf, and were contained in four phenolic battery cases. A longitudinal accelerometer was mounted in the middle of one of the shelves in the nose rack. This accelerometer was used to give information concerning rocket performance and to aid in calculating trajectory information. Also contained in the nose rack were three conversion circuit modules, which were used to convert the outputs of the Alphatron pressure gages to usable signals for supplying pressure information to the telemetry transmitter. Another circuit module was a small box containing a reed-switch oscillating circuit which was used to actuate periodically a shorting switch across the electrodes of the two Gerdien condensers. A Schonstedt type RAM-3 Magnetic Aspect Sensor, mounted as shown, was used in determining rocket spin performance.

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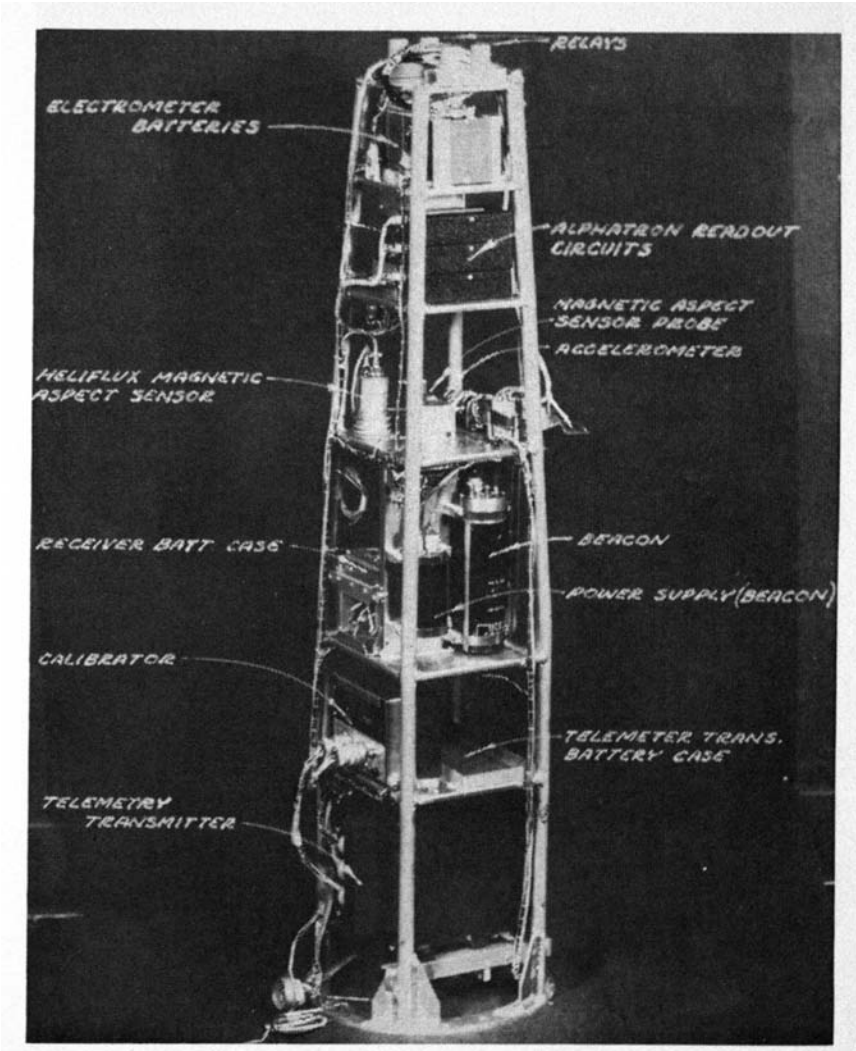

Figure 1. Aerobee Payload Assembly

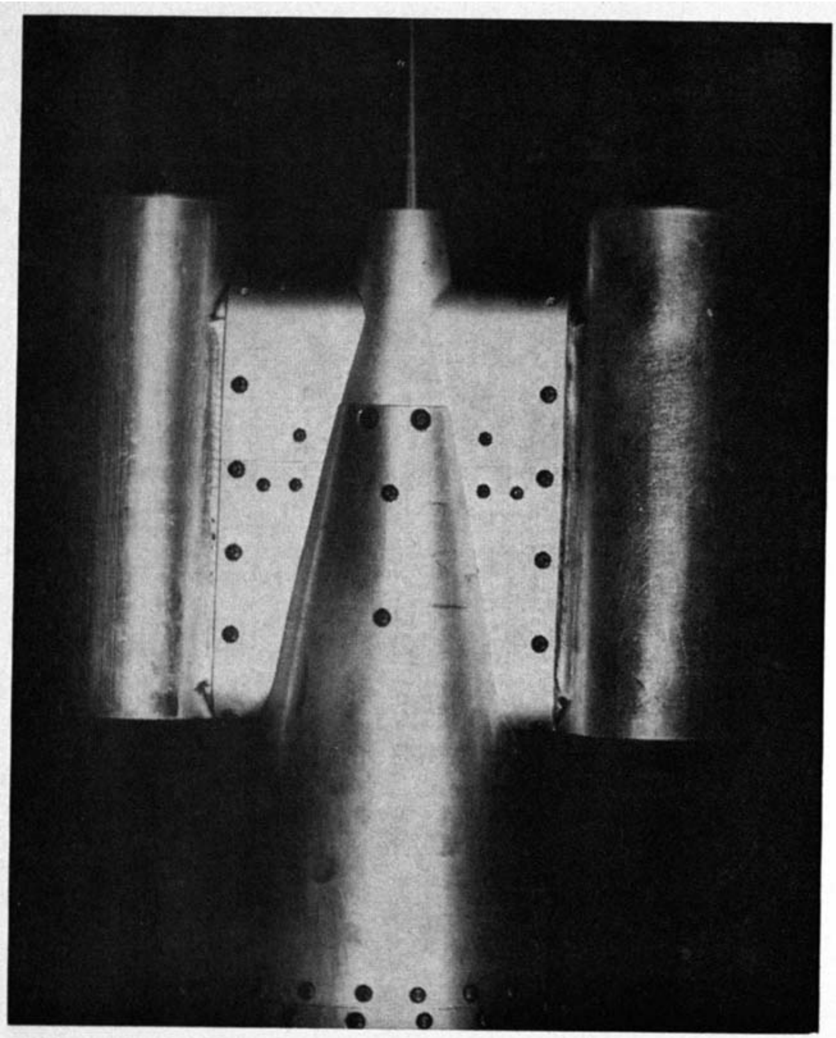

Figure 2. Aerobee Nose Tip With Gerdien Condensers

NOSE SKIN

The nose skins for the two Aerobee-100 rockets, NASA 1.01 and NASA 1.02, were supplied by NASA. Nose tip assemblies for the two nose skins were constructed. These assemblies each consisted of the two Gerdien condensers (Fig. 2), two Alphatron pressure gages, and two reed switches. Each condenser is constructed of an outer cylinder of aluminum, which is used to support and electrostatically shield the conductivity measuring electrodes mounted within. A cylindrical flourosint insulator was mounted immediately within the outer aluminum cylinder. A cylindrical two-inch diameter stainless steel outer electrode was mounted within the flourosint. A ⅞-inch diameter stainless steel inner electrode was supported on a ¼-inch diameter stem. The insulation resistance between the stem which supports the inner electrode and ground was maintained at a value greater than 10^{14} ohms. This high value of resistance was necessary in order to prevent loading the inputs of the electrometer amplifiers, which had resistances in the order of 10^{11} ohms.

In order to interpret accurately the data for the ionic-conductivity and ion-density experiment, it was necessary that the pressure within the Gerdien condensers be known. NASA supplied radio-active Alphatron pressure gages. These gages are Alphatron Type 0716, manufactured by NRC Equipment Corporation, Newton-Highlands, Massachusetts. These units came supplied with calibration curves and the calibration was checked at NASA. A third Alphatron was located in the main body of the Aerobee-100 for reference purposes.

The Alphatron pressure gages are small electronic devices mounted within a case the size and shape of a 6L6 metal vacuum tube. The pressure gages consist basically of a radioactive ionization chamber which uses tritium as the radioactive source, and a blocking oscillator whose output frequency is a function of the ionization chamber current. A pressure input tube is available at the ends of each of the Alphatron gages, and this tubular input connection was connected to the inner surfaces of the cylindrical Gerdien condensers. The two Alphatron pressure gages in the nose tip were mounted in a crossed configuration in order to use the available space.

In order to convert the output of the Alphatron pressure gages to a usable voltage for the telemetry input, the following circuit was designed. It consisted basically of a binary counter chain which divided the output from the Alphatron pressure gages by a factor of 16. By mixing the output of the first binary stage with the output of the fourth binary stage, a readout voltage function was obtained which could be applied to a telemetry channel.

Mounted within the nose tip assembly was a solenoid which enveloped two reed-type switches. The solenoid was energized with a pulse of current occurring at one-second intervals, and this energy closed the two reed switches which provided short circuits across the electrodes of the Gerdien condensers. The Gerdien condenser, after being discharged by the momentary short circuit, was allowed to recharge at a rate which was a function of the conductivity and ion density conditions being encountered.

The lower portion of each nose skin was equipped with a battery access door. This door was made available so that the battery pack for the AN/DRW-3 receiver could be changed without disassembly of the nose cone. The door was also available for connecting the AN/DPS-41 beacon antenna coax while assembling the nose skin to the rocket.

PAYLOAD EQUIPMENT ON ROCKET BODY

A third Alphatron pressure gage was mounted between the oxidizer and fuel tanks on the main body of the Aerobee-100. An access door was available between the two tanks for mounting the Alphatron assembly. This Alphatron pressure gage was used as a reference pressure gage for interpreting the information from the two gages mounted in the nose tip of the rocket, which read the pressure within the Gerdien-condenser cylinders. As was used for the nose tip Alphatrons, an octal socket was connected to the base of the lower Alphatron for providing power and bringing out the PRF information to the Alphatron readout circuits, then to the telemetry.

The Aerobee-100 rocket has a fuel-mixing valve which is controlled by chamber pressure. A Bourns Laboratory linear-motion potentiometer was mounted to the side of the cylinder which actuated the fuel-mixing valves. This potentiometer was mechanically coupled to the piston which moved the two valves and was used to provide a DC voltage to the rocket monitor channel of the telemetry. The position of the valve could be monitored, and its position could be distinctly indicated at times before launch, during sustainer thrust, and after burnout.

ELECTRICAL DESCRIPTION OF PAYLOAD

The primary purpose of the complete electrical payload is to support the ionic conductivity and ion density experiment. A brief description of the electrical circuits of the payload equipment is given in the following paragraphs.

Gerdien Condensers and Amplifiers

The Gerdien condensers mounted at the nose tip of the rocket have been described previously. They are the devices used for ion collection. The ion currents from the Gerdien condensers are fed into the input connections of electrometer and operational amplifiers, pictured at the top of the rack in Fig. 1. The outer cylindrical electrode of one Gerdien condenser is connected to a negative 100-volt DC potential, while the other outer cylindrical electrode is connected to a positive 100-volt DC potential. By use of these opposite polarities, measurements may be made on both positive and negative ions. There are two electrometer amplifiers. One is a high-sensitivity amplifier and the other a low-sensitivity amplifier. There is also an operational amplifier for each electrometer amplifier, which has an output proportional to the slope or rate-of-change of the electrometer amplifier output. Each of the six amplifiers has an output that is fed into the AN/DKT-7 telemetry. Four relays and four battery packs are mounted near the electrometer amplifiers to provide power for both the operational and electrometer amplifiers. The four relays are energized by 28 volts DC, used to operate the AN/DKT-7 telemeter.

Reed Switch Circuits

In shunt with the two electrodes of each Gerdien condenser, there is a reed-type switch which has a high insulation resistance between its contacts when they are open. The contacts are closed approximately once each second in order to discharge the voltage which has developed across the condenser. The condenser is allowed to recharge at a rate determined by the ion density. The reed switches are closed by a solenoid connected in series with the base circuit of a unijunction transistor oscillator. This circuit is a conventional unijunction sawtooth generator utilizing a 2N491 unijunction transistor. As a capacitor is charged from the B+ source through a resistor, the voltage on the unijunction emitter is increased to such a point that current will flow from the emitter to the base mentioned. The unijunction is a negative resistance device and, as a result, the capacitor discharges almost completely. During the time that the capacitor is discharging, the solenoid surrounding the reed switches is energized and the reed switches close. The time required for the current pulse to occur again in the emitter circuit is determined by the resistance-capacitance time constant. There is a small resistor in series with the solenoid. The pulse voltage developed across this resistor is introduced into the telemetry system as a time-of-closure monitor in conjunction with the 28-volt battery monitor voltage. There is also provided a steady DC source voltage that may be controlled at the blockhouse for energizing the solenoid continuously while the rocket is in the tower. This will provide a continuous short circuit across the Gerdien condensers for calibration purposes.

AN/DKT-7 Telemeter

The AN/DKT-7 pulse-position telemeter transmitter was supplied by NASA. It consists basically of a five-kilocycle oscillator which is used for generating the reference pulses for each of the 15 channels. The five-kilocycle oscillator is used to synchronize a sawtooth generator that, in turn, drives a binary counter chain of four stages. The outputs of all halves of the four binary stages are used in various combinations to gate the transducer information being measured into one common data channel. This mixed data is fed into a sawtooth comparator, and is used to develop an output pulse which is positioned in time from its respective reference pulse in accordance with the voltage from the transducer source being measured. The sixteenth channel is used for a triple-pulse synchronizing signal. This synchronizing pulse signal is delayed 100 microseconds from its reference pulse and is used to synchronize the ground station equipment. The triple-pulse and the data pulses are mixed and are used to trigger a pulse modulator which, in turn, modulates the RF transmitter circuits. The antenna for the telemetering unit is mounted in a tail fin of the rocket. In flight, the transmitter operates from a 28-volt battery source for the dynamotor and a six-volt source for the filaments. The dynamotor supplies the remainder of the voltages for the transmitter. A relay is used within the telemeter for power control. This relay is connected for "external-internal" power operation and has a set of holding contacts for locking itself in the "internal" position. The fifteen channels of the telemetry transmitter were allocated for use as follows: six for the ionic conductivity experimental data; six for the radio-active pressure gage readings; one for the accelerometer; one for rocket performance monitoring, and one for battery voltage readout.

The fifteen transducer output voltages were fed into a calibration unit before being fed into the telemeter. The calibrator is a cam-operated set of switches which introduce known regulated voltages, in equal one-volt steps from zero to five volts, into each channel in sequence. While each channel is being calibrated, the transducer information is switched out by the cam-operated switches. A time-delay relay is incorporated in the calibrator motor circuit so that it will calibrate once each minute. A gage voltage source of five volts DC consists essentially of a zener diode used to control the output voltage of an emitter-follower. The gage voltage was also used for the longitudinal accelerometer and the fuel valve monitor circuit.

Control circuits for the telemetry transmitter were designed so that external DC power could be supplied in order to conserve battery life prior to launch. Monitor meters were available for the batteries and for transmitter radio frequency performance. Other minor control functions were included on the control panel for controlling the remainder of the payload equipment. Facilities were also available for recharging the payload batteries while the nose cone was assembled over the payload.

Magnetic Aspect Sensor

A Heliflux Magnetic Aspect Sensor was contained in the payload in order to obtain more information concerning rocket performance. This device is manufactured by the Schonstedt Engineering Company of Silver Springs, Maryland. It is a small device consisting of a cylindrical container and a pick-up probe. The circuit, which operates from a six-volt

100-milliampere battery, consists basically of a input voltage regulator, a five-kilocycle oscillator, a phase detector, and a rectifier for supplying an output voltage to the telemetry. The five-kilocycle signal is supplied to the sensing probe and, when the probe coil is saturated with an external magnetic flux, a second-harmonic voltage is generated. This voltage is fed back to the oscillator and compared with the original five-kilocycle source to generate an output signal which is a function of the strength of the external field. The output signal is fed into an AN/DKT-7 channel.

Accelerometer

A Giannini Controls Corporation accelerometer was used to obtain information on rocket performance and for trajectory information. This accelerometer was built with a winding of three segments. All segments give an output voltage ranging from zero to five volts. One segment performs over the range of 0 to 10G, the next segment from 10 to 20G, and the third segment from 0 to -10G. The voltage output of the accelerometer was fed into a telemetry channel input on the AN/DKT-7.

AN/DPN-41 Radar Beacon

An AN/DPN-41 beacon and its associated power supply were used for obtaining rocket trajectory information. Both the beacon and its power supply were mounted in a vertical position, as shown in Fig. 1. Power for the beacon power supply is obtained from the same 28-volt battery pack used for the telemetering transmitter. This battery pack consists of 20 cells of Yardney HR-5 Silver-cell batteries. The antenna for the S-Band beacon is of the small quadraloop type, and is mounted on the nose skin at a level approximately coinciding with the S-Band beacon.

AN/DRW-3 Range Safety Receiver

An AN/DRW-3 receiver was incorporated into the nose rack assembly in order to meet the range safety requirements of the firing range. This receiver was supplied by the Churchill facility. The receiver consists essentially of a super-heterodyne receiver with a detector output which is used to close a relay. This relay is connected in a circuit which applies voltage to an explosive primacord surrounding the main fuel line of the rocket motor. This fuel line could have been severed for range safety purposes, had it been decided that the rocket power should be interrupted. A battery pack containing all of the receiver batteries was made so that it could be removed through an access door in the nose skin. These batteries could be replaced at launch time; consequently, fresh batteries could be made available. A control panel, which could be used to supply external power from a power supply, was available. B+ voltage and current could be monitored on the panel along with the filament voltage. Meters were available on the control panel for monitoring the voltage from the rocket monitor which, in this case, is the fuel-valve position monitor.

Fuel Valve Monitor

As perviously described, the fuel valve monitor consists essentially of a Bourns Laboratory 2,000-ohm linear-motion potentiometer, rigidly attached to the outside wall of a cylinder whose piston actuates the fuel and oxidizer mixing valves for the rocket motor. The mixing valve piston acquires three positions during the performance of the motor. Since the shaft of the potentiometer is mechanically attached to the piston rod actuating the valves, the valve position may be monitored by reading the voltage which is tapped from the potentiometer output. The five-volt gage voltage is used as a voltage source for the fuel-valve monitor circuit. The output of the potentiometer is fed into a telemetry channel for rocket performance monitoring at the ground station. In addition to the fuel-valve position monitor circuit, the primacord wrapped around the fuel line for severence may be monitored by modifying the voltages of the valve position monitor circuit.

CONCLUSION

An aerodynamic study of the nose tip assembly, done by Aerojet General Corporation of Azusa, California, while the payloads for the two rockets were being constructed indicated that the structure would withstand any mechanical forces or frictional heating that it would encounter.

After the payloads were completed, they were subjected to a series of compatibility tests at Goddard Space Flight center. These tests were made to insure that each part of the equipment would perform satisfactorily without any unnecessary interference to other pieces of equipment. Following the compatibility tests, the rockets and payloads were shipped to Fort Churchill, Manitoba, Canada where they were assembled, tested and launched in November of 1960. Both rockets performed well, and all of the instrumentation appeared to perform satisfactorily. The telemetry information recorded appeared to be complete, with all channels carrying their proper information. NASA has the responsibility of reducing the data from the telemetry records for this project. At this time, their data reduction is not complete and no information is presently available concerning the results of the ionic conductivity experiment.