

Oct. 11, 1949.

Filed May 13, 1944

H. D. GIFFEN
APPARATUS FOR TRANSMITTING CHANGES
IN GAUGE CONDITIONS

2,484,218

4 Sheets-Sheet 1

Fig. 1

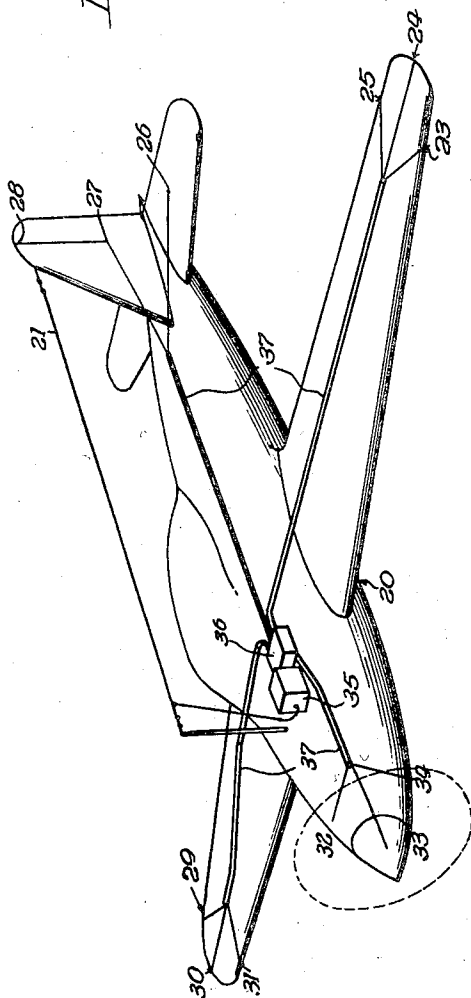
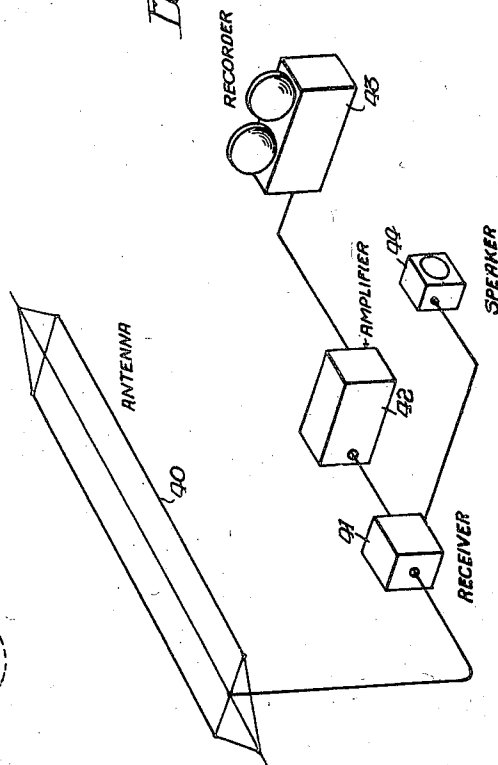


Fig. 2



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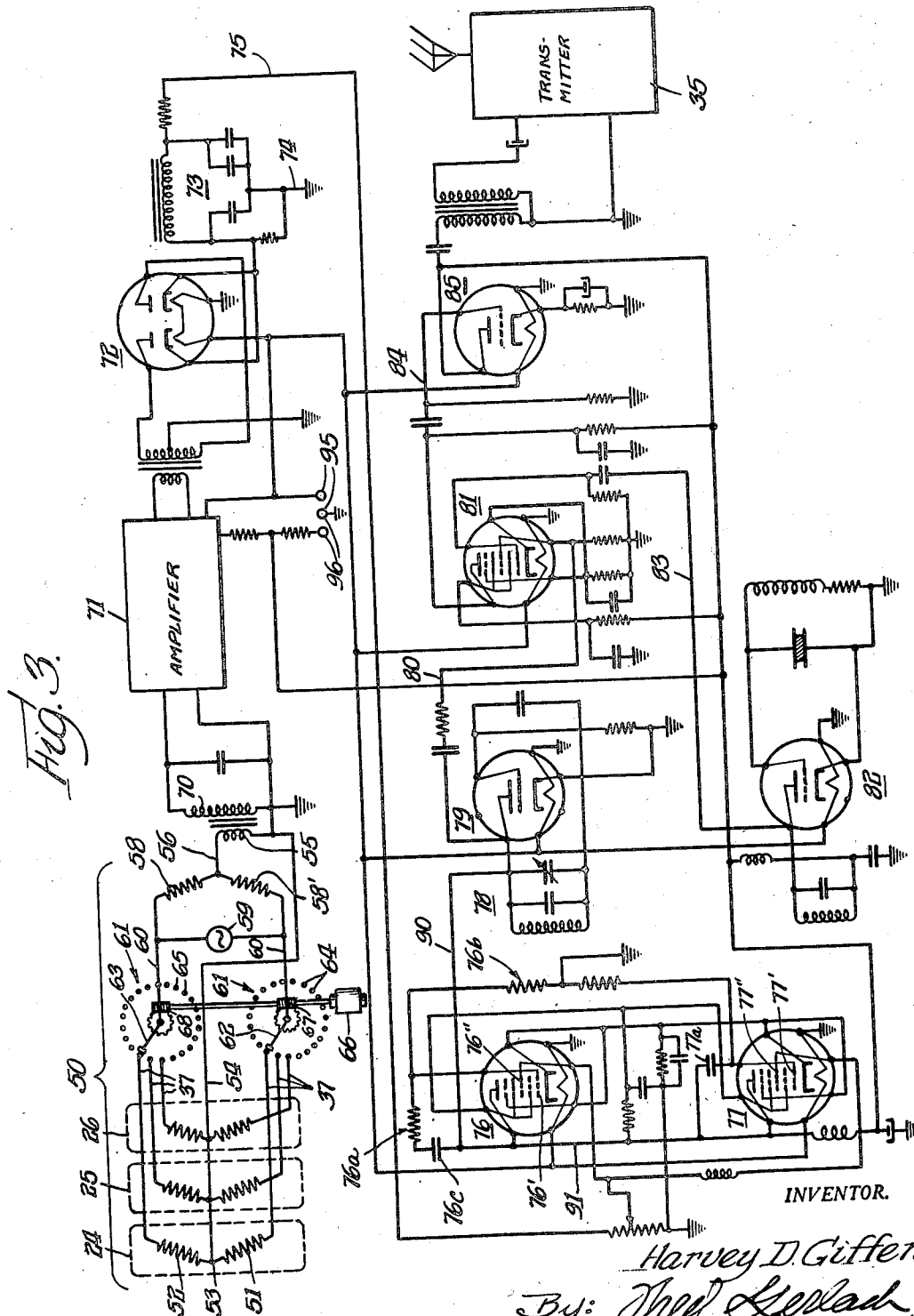
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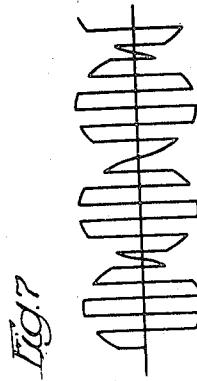
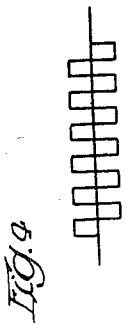
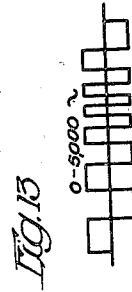
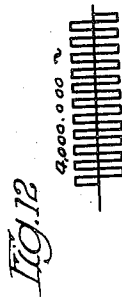
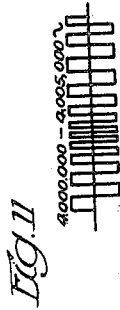
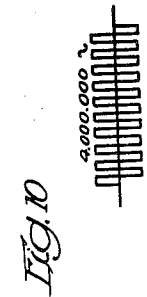
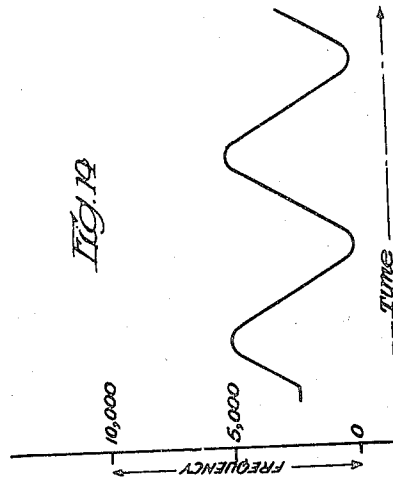
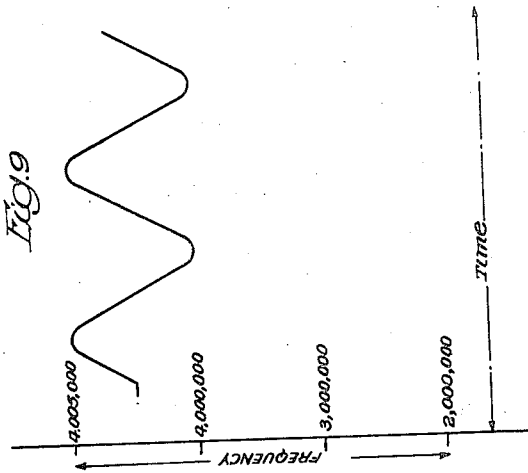
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Fig. 15

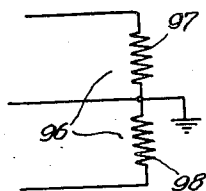


Fig. 16

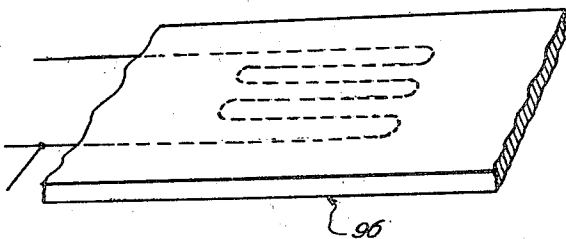


Fig. 17

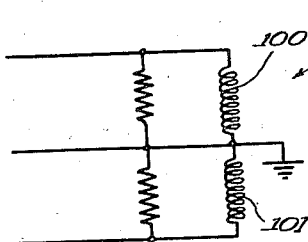


Fig. 18

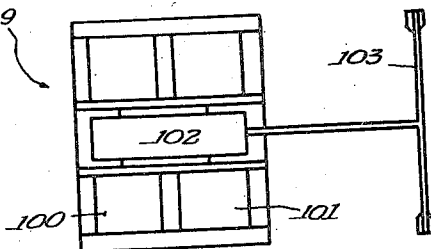
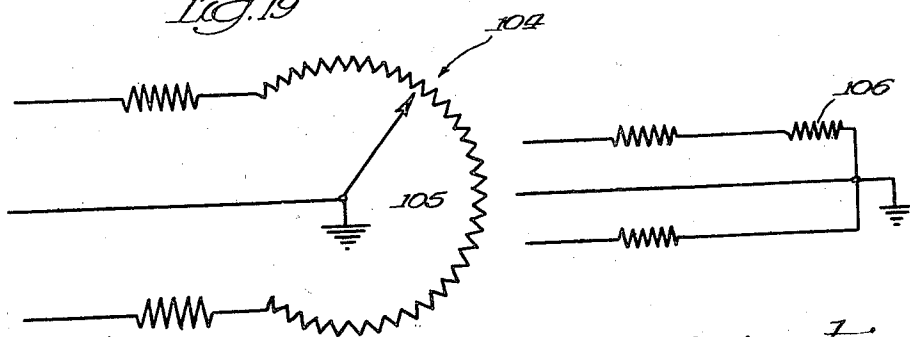


Fig. 19



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UNITED STATES PATENT OFFICE

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Application May 13, 1944, Serial No. 535,481

10 Claims. (Cl. 177—351)

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This invention relates to the transmission of signals indicative of changes which occur in different parts of a movable device, as, for example, an aeroplane, while it is undergoing such changes at rapid rates. This application is a continuation in part of my prior application Serial No. 458,224, filed September 14, 1942, and now abandoned.

The general object of the invention is to provide a new and improved apparatus for producing signals representing such changes.

Another object is to provide a new and improved apparatus for producing signals indicative of flight and stress data of aeroplanes in flight, such as airspeed, acceleration, strain measurements, control angles, etc., with a high degree of accuracy.

Another object is to provide an apparatus for producing signals indicating changes in a plurality of detector devices or gauges by making separate signals for each gauge in such rapid sequence and by repeating such sequence signals at extremely short intervals of time so as to produce a substantially continuous series of signals which can then be analyzed to give a separate and substantially continuous record of the changes in each gauge.

Another object is to provide an apparatus for producing signals indicative of changes in gauges and utilizing a beat frequency oscillator, one component of which is caused to vary in pitch according to the stimuli being studied and providing an audio frequency signal suitable for transmission to a remote point.

Other objects and advantages will become readily apparent from the following description taken in connection with the accompanying drawings, in which:

Figure 1 is a perspective view of an aeroplane in flight equipped with the mobile part of a preferred form of the invention.

Figure 2 is a diagrammatic illustration of the ground part of the same form of the invention.

Figure 3 is a wiring diagram of the mobile part of the apparatus.

Figures 4 to 14, inclusive, are diagrammatic representations of the wave forms and variations in different parts of the apparatus.

Figures 15 to 20, inclusive, illustrate types of gauge devices that may be used in the apparatus.

While the invention is susceptible of embodiment in many different forms, I have shown in the drawings and shall herein describe in detail one embodiment, with the understanding that the present disclosure is to be considered as an

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exemplification of the principles of the invention and is not intended to limit the invention to the embodiment illustrated. The scope of the invention will be pointed out in the appended claims.

In the form of apparatus selected for purposes of illustration the invention is adapted to transmit in rapid sequence signals modulated by gauge devices located on various parts of an aeroplane. In Figure 1 there is illustrated an aeroplane 20 in flight. It is equipped with an antenna 21 and a radio transmitter 35. Gauge devices 23 to 34 are located on various parts of the aeroplane so as to be actuated individually by the parts or accessories with which they are associated. The radio transmitter may be the transmitter otherwise used for communication purposes. 36 indicates the major part of the mobile portion of the invention, and 37 indicates generally the leads or connecting wires running from the gauge devices to the part 36.

The ground part of the apparatus as illustrated in Figure 2 comprises an antenna 40, a receiver 41 of modulated audio frequency signals, an amplifier 42 and a recorder 43. The receiver, amplifier and recorder may be of more or less standard design. The recorder is herein shown as of the type which records the audio frequency signals on a film so that the film may be used conveniently with the type of analyzer disclosed in a co-pending application of Harvey D. Giffen, Serial No. 478,367, filed March 8, 1943, now Patent No. 2,380,231 dated July 10, 1945, and entitled Method of and apparatus for analyzing recorded data.

It is contemplated that other forms of recorders may be used, as, for example, those printing on a tape, etc. A monitor consisting of a speaker 44 is preferably connected to the receiver 41 for obtaining an audible signal for test or other purposes.

The exemplary form of the invention will now be described in more detail with reference to Figure 3.

Of the gauges indicated in Figure 1, numbers 24, 25 and 26 are shown in Figure 3. These gauges (and the others as well) are preferably of a resistance or reluctance type that can be connected in as two arms of a Wheatstone bridge 50. Thus the gauges have elements 51 and 52 connected together at 53. The common points of all of the gauges are connected together, and by a lead 54 are connected to one end of a coupling coil 55, the other end of which is connected by a lead 56 to the common mid-point

57 of a pair of resistances 58, 58' which form the other two arms of the A. C. bridge.

An alternating current generator 59 is connected across the outer ends of the resistances 58, 58'. A generator of any suitable frequency may be employed, the lower frequency limit being determined as a function of the duration of signals to be transmitted. In this connection, the generator frequency should be such that at least one complete frequency cycle of the generator will occur within the duration of the shortest signal impulse to be transmitted. The upper frequency limit is determined in accordance with various electrical factors, such as radiation characteristic, high frequency resistance of conductors, and the like; and the upper frequency limit may range anywhere from 4,000 to upwardly of 50,000 cycles per second. In practice, an optimum frequency of 1,000 cycles per second has been found to be adequate for practical purposes.

The gauge devices are arranged to be connected, one at a time and in rapidly recurring sequence, as arms of the bridge circuit, by means of the leads 37, leads 60 and a switch mechanism 61. This switch mechanism is illustrated in Figure 3 as comprising a pair of rotating contact arms 62 and 63, the outer ends of which pass over and engage successively contacts 64 and 65 arranged annularly around the axes of rotation of the switch arms. The leads 37 from one end of each gauge are connected to the contacts 64 while the leads from the other end of each gauge are connected to the contacts 65. By rotating the arms in synchronism the gauges are connected individually and in predetermined sequence into the bridge circuit.

Normally, the arms of the switch mechanism are rotated synchronously at a constant rate by a motor 66 and suitable gearing 67 and 68, so that each gauge is connected in the bridge circuit with predetermined frequency, the length of time each switch device is closed being determined in part by the arcuate width of the rotating arms and in part by the speed of rotation of the arms. The number of switch contacts can be varied in accordance with the number of gauges it is desired shall be used, twenty-two being shown in Figure 3. With that number of contacts the switch arms are preferably rotated at a speed of approximately four revolutions per second, so each contact has a duration on the order of $\frac{1}{100}$ second.

A coil 70 is coupled to coil 55 and arranged to conduct the A. C. bridge carrier current from the generator 59, as modulated by successive gauges, to an amplifier indicated generally as 71, after which the amplified current is rectified in an electronic rectifier 72 and filtered in a filter 73. A lead 74 extends from the filter to ground, and a lead 75 is connected to injector grids of a pair of reactance tubes 76 and 77, one of which (76) acts as a variable capacity and the other (77) as a variable inductance in a variable oscillator circuit 78 embodying an oscillator tube 79. A lead 80 feeds the variable frequency from the oscillator 78 into a mixer tube 81 to which there is also fed a fixed frequency from a crystal controlled oscillator 82, by a lead 83. The variable frequency from the oscillator 78 and the fixed frequency from the oscillator 82 act to form a beat note of a frequency proportionate to the frequency change in oscillator 78. In a preferred form of the invention the fixed frequency oscillator 82 was tuned at 4,000,000 cycles and the oscillator 78 is also tuned

at 4,000,000 cycles when the bridge 50 is balanced, giving a zero beat. The gauges are preferably so constructed that in their condition of maximum unbalance they cause the oscillator 78 to change its range of oscillation to 4,005,000 cycles. When this frequency beats against the fixed frequency from the oscillator 82 there is produced a beat frequency of 5,000 cycles. Thus as a gauge varies it produces a frequency at 84, which varies between zero and 5,000 cycles in proportion to the magnitude of the stress or stimuli acting upon the gauge.

Tubes 76 and 77 are arranged in such a way that the oscillations of circuit 78 are fed back to the No. 1 grid of each tube by connections 90, 91. Thus grid 77' of tube 77 is fed through a small condenser 77^a and grid 76' of tube 76 through resistors 76^a and 76^b. Condenser 76^c is a blocking condenser to remove D. C. from the grid. This constitutes a phasing control of the oscillator circuit, which, in turn, is determined by the input capacities of the tubes. These input capacities vary with bias on the central control grid, so that the tubes will have the effect of an inductance tube 77 and a capacitance tube 76 in shunt with the coil-condenser combination of the oscillator, and these effective dimensions can be varied by the bias on the injector grids 76'' and 77'' respectively, of the "reactance" tubes 76 and 77.

This audio frequency beat is then passed through an amplifier 85 and can be transmitted by the radio transmitter 35 on the aeroplane, or by other suitable means, to a receiving and recording means such as that shown in Figure 2.

A power source 95 is provided for the filaments of the tubes, and a power source 96 to provide positive high voltage for the tubes.

In Figures 4 to 14 are illustrated the wave forms of the different potentials or frequencies which exist in the different parts of the circuit of the exemplary form of the invention. As mentioned hereinbefore, the part 50 is fundamentally an A. C. bridge. The bridge carrier as supplied by the generator 59 is illustrated in Figure 4. The modulation by a gauge responding to a maximum stress is exemplified by Figure 5, and the modulated bridge carrier by Figure 6. Figure 7 shows the modulated bridge carrier after amplification in amplifier 71, preferably to a relatively high potential such as 50 volts, and Figure 8 the wave form after rectification at 72 and filtering at 73. The varying potential of Figure 8 is fed to the reactance tubes of oscillator 78 and causes the frequency in this oscillator to vary between 4,000,000 and 4,005,000 cycles as shown by the curve of Figure 9. The frequency of oscillator 78 with the bridge 50 in balance, which is therein taken as 4,000,000 cycles, is exemplified in Figure 10, and this frequency with the bridge unbalanced by a gauge under maximum stress is shown in Figure 11 wherein it varies from 4,000,000 to 4,005,000 due to the frequency modulation shown by the curve of Figure 9. The fixed frequency of the oscillator 82 is exemplified by Figure 12. When the variable frequency of Figure 11 (4,000,000 to 4,005,000 cycles) beats against the fixed frequency of oscillator 82 (4,000,000 cycles) the audio beat frequency of Figure 13 is obtained. This frequency may be pictured as in Figure 14 for comparison with Figure 9.

Thus as the gauge 24 varies between its normal and maximum conditions it produces an audio beat frequency (Figure 13) at 84 (Figure 3) which varies between zero and 5,000 cycles and is proportional to the magnitude of the stress or stimuli

acting upon the gauge. This makes available for transmission to a recording mechanism variable frequencies of constant amplitude.

The invention in the form disclosed is applicable to advantage in recording flight and/or stress data on an aeroplane operating under conditions which cause very rapid changes in the gauges located about the plane. For example, it is possible to obtain accurate recordings during a dive, wherein the stresses may change from normal to maximum in a few seconds. The invention is equally applicable to the production of signals indicating changes in a plurality of stationary gauge devices when it is desirable to transmit them over a single line or transmitter to a remote point.

If a record is desired of the changes in a gauge at a single detection station it is possible to obtain a continuous record by stopping the switch mechanism 61 to connect in the desired gauge, or by adjusting the switch mechanism manually to select the desired gauge. With the apparatus of Figure 3 otherwise in operation, the transmitter 35 will then broadcast an audio frequency signal which varies in frequency proportionally to changes in the gauge and which is of constant amplitude. The transmission of this signal is continuous, with the result that a continuous record can be obtained.

Generally, in obtaining data on an aeroplane it is desirable to record the changes occurring at a considerable number of detection stations. The particular form of the invention illustrated provides contacts on the switch mechanism 61 to accommodate twenty-two gauges. In using a plurality of gauges it is also desirable to obtain for each gauge a substantially continuous record. This is possible with the invention herein disclosed because of the high speed operation it permits with accurate results.

The rotating switch arms 62 and 63 are, in the preferred form of the invention, driven by the motor 60 at a speed of approximately 250 R. P. M. so that contact is made with all of the gauges each quarter second. Although the gauges are connected with the bridge circuit successively, the time for completing a cycle of operation is so small ($\frac{1}{4}$ second) that recordings are made from all the gauges substantially simultaneously. The switch arms and switch contacts may be of such arcuate widths as to provide contacts of approximately $\frac{1}{100}$ second duration. Recordings of such short duration are possible in part because of the large frequency swing (0 to 5000 cycles) provided by the apparatus for the audio frequency beat signals.

The gauges may be of various conventional types selected for the particular flight and physical stress characteristic under observation.

The gauges for detecting strains in various parts of the plane may, as shown in Figures 15 and 16, comprise conventional wire wound units 96 including an active portion 97 and an unstressed dummy portion 98 mounted on the same type of material, the active portion being responsive to the changes in strain of the associated part. The two portions of such a gauge are connected into opposite arms of a Wheatstone bridge as illustrated in Figure 3, so as to compensate for any temperature changes, either in the gauges or in the leads to the gauges.

A gauge for recording changes in air speed, as shown in Figures 17 and 18, may consist of a reluctance type unit 99 having two coils 100 and 101 for connection to the bridge circuit. This

unit may have an armature 102 moving in relation to the two coils thereof and coupled to a conventional air speed diaphragm 103.

For recording acceleration it is possible to use a wire wound strain gauge, of the sort shown in Figures 15 and 16, actuated by a standard type of accelerometer. As shown in Figures 19 and 20, various types of resistance gauges may be employed for appropriate gauging purposes. For recording changes in angularity of elevators, rudders, flaps, and other relatively movable parts, a conventional potentiometer 104, as shown in Figure 19, may be linked to the elevator, rudder, flap, or other movable member, by drivingly connecting the movable arm 105 of the potentiometer to the movable member, the movement of which is to be indicated, recorded, or otherwise gauged. In such an arrangement the potentiometer forms the two arms of the bridge circuit.

As indicated in Figure 20, temperatures, as, for example, oil temperature, or air temperature, may be indicated, recorded, or otherwise gauged by means of a resistance type unit 106, responsive to the temperature to be measured, and connected in one of the arms of the bridge circuit; and it is obvious that numerous other conventional devices, adapted for employment in connection with Wheatstone bridge circuits of the sort illustrated in Figure 3, may be employed for gauging and applying any desired variable data upon the system forming the subject matter of the present invention.

In operating, the apparatus, when embodying a plurality of gauges, transmits in repeated and rapid sequence variable audio frequency signals which vary in accordance with the different gauges. As mentioned hereinbefore, these signals may be received in an apparatus as illustrated in Figure 2, then amplified, and recorded on a conventional 16 mm. film type sound recorder. Preferably, timing points are introduced into the signal by the switching device and are available for use in controlling the synchronizing of the film in a suitable power driven analyzer.

It is thought that the invention and its numerous attendant advantages will be fully understood from the foregoing description; and it is obvious that numerous changes may be made in the form, construction and arrangement of the several parts without departing from the spirit or scope of the invention, or sacrificing its attendant advantages, the form herein disclosed being a preferred embodiment for the purpose of demonstrating the invention; and we do not herein claim the patentable combination embodying particular features of the receiver and recorder mechanism, or the manner of operating the same, as claimed in a co-pending application Serial No. 549,440; nor the combination including particular features of the recording apparatus and the operation thereof, the same being claimed in a co-pending application Serial No. 549,441; nor the combination forming a telemetric system including a plurality of sending stations and the means of operating the same, as claimed in a co-pending application Serial No. 549,442 (now Patent No. 2,446,803, dated April 12, 1949); nor the combination embodying specific means for accomplishing the frequency variation of signal impulses in repeated succession and the manner of so operating a telemetric system, as claimed in a co-pending application Serial No. 549,443 (now Patent No. 2,446,804, dated April 12, 1949); the

present invention herein claimed residing in the combinations recited in the appended claims.

I claim:

1. An apparatus for producing signals indicating changes in characteristics of remote gauges comprising, in combination, a plurality of gauge devices each acting when operated to vary an electrical property thereof, a bridge circuit having at least one leg thereof open for the connection of a gauge device thereto, means for producing a carrier wave therefor, a high speed switching device operable during continuous movement thereof, successively to connect said gauge devices individually into the bridge circuit to effect modulation of said carrier wave for short periods of time, means acting on the carrier so as to leave a potential changing in proportion to the changes in the gauge device then connected through the switching device, and an oscillator means subjected to said potential to vary the frequency of the oscillations produced thereby.
2. An apparatus for producing signals indicating changes in a plurality of gauge devices comprising, in combination, gauge devices responsive to changes in the physical and flight characteristics and acting when operated to vary an electrical property thereof, a bridge circuit having at least one open leg for the connection of a gauge device thereto, means for producing an alternating bridge carrier wave, a switching device operable to connect said gauge devices individually to effect modulation of said carrier wave, rectifying and filtering means for removing the carrier so as to leave a potential changing in proportion to the change in the gauge device then connected through the switching device, and oscillator means subjected to said potential to produce oscillations varying in proportion to the changes in said potential.
3. In a system for producing signals substantially continuously from a plurality of detection stations on an aeroplane in flight, in combination, a detection device for each station each responding to changes occurring at its station, an A. C. bridge circuit having at least one leg open for the connection of a gauge device thereto, means for connecting said detection devices into said circuit individually in rapid and repeated sequence to vary an A. C. voltage in rapid and repeated sequence in accordance with said changes, and means for generating audio frequency signals varying in accordance with said modulated voltage.
4. In a system for producing signals substantially continuously from a plurality of detection stations on an aeroplane in flight, in combination, a two-element detection device for each station each responding to changes occurring at its station, an A. C. bridge circuit having two legs thereof open for the connection of said two-element devices therein, means for connecting said detection devices into the open legs of said circuit individually in rapid and repeated sequence to vary an A. C. voltage in rapid and repeated sequence in accordance with said changes, and means for generating audio frequency signals varying in accordance with said modulated voltage.
5. An apparatus for producing signals indicating changes in a plurality of physical and flight characteristics of an aircraft comprising, in combination, resistance gauge devices responsive to changes in the physical and flight characteristics under observation and acting, when operated, to vary the resistance thereof, an A. C. bridge circuit

- including one of said devices at a time, means for producing a carrier wave therefor, means including a motor-driven switching device operable during continuous movement thereof successively to connect said gauge devices individually into said bridge circuit to effect modulation of said carrier wave for periods of time on the order of $\frac{1}{100}$ second, means for amplifying the modulated carrier, and means for producing audio frequency signals, varying in accordance with said modulated carrier wave.
6. An apparatus for producing signals indicating changes in a plurality of physical and flight characteristics of an aircraft comprising, in combination, gauge devices responsive to changes in the physical and flight characteristics under observation and acting, when operated, to vary an electrical property thereof, an A. C. bridge circuit including one of said devices at a time, means for producing a carrier wave therefor, and means including a high speed motor-driven switching device operable during continuous movement thereof successively to connect said gauge devices individually into said bridge circuit to effect modulation of said carrier wave for periods of time on the order of $\frac{1}{100}$ second, means for amplifying the modulated carrier, and means for producing audio frequency signals, varying in accordance with said modulated carrier wave.
7. Signalling apparatus comprising bridge means forming one side of an electrical bridge, a plurality of gauge devices each comprising means having electrical characteristics that vary in response to variable conditions to be signalled, continuously and repeatedly rotatable switch means interconnected with said gauge devices and said bridge means for successively and cyclically connecting said gauge devices to form the other side of said electrical bridge, means for applying alternating electrical potential across said bridge whereby to deliver therefrom a carrier wave modulated, during successive intervals, in accordance with the electrical characteristics of said gauge devices, and means for transmitting a detectable signal corresponding with said modulated carrier wave.
8. Signalling apparatus comprising bridge means forming one side of an electrical bridge, a plurality of gauge devices each comprising means having electrical characteristics that vary in response to variable conditions to be signalled, continuously and repeatedly rotatable switch means interconnected with said gauge devices and said bridge means for successively and cyclically connecting said gauge devices to form the other side of said electrical bridge, means to drive said rotatable switch means at a speed to connect said gauge devices successively in said electrical bridge for periods of time each of the order of a fractional second, means for applying alternating electrical potential across said bridge whereby to deliver therefrom a carrier wave modulated, during successive intervals, in accordance with the electrical characteristics of said gauge devices, and means for transmitting a detectable signal corresponding with said modulated carrier wave.
9. Signalling apparatus comprising bridge means forming one side of an electrical bridge, a plurality of gauge devices each comprising means having electrical characteristics that vary in response to variable conditions to be signalled, continuously and repeatedly rotatable switch means interconnected with said gauge devices and said bridge means for successively and cyclically connecting said gauge devices to form the

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other side of said electrical bridge, means for applying alternating electrical potential across said bridge whereby to deliver therefrom a carrier wave modulated, during successive intervals, in accordance with the electrical characteristics of said gauge devices, and means for generating audio frequency signals varying, during successive intervals, in accordance with said modulated carrier wave.

10. Signalling apparatus comprising bridge means forming one side of an electrical bridge, a plurality of gauge devices, each comprising means having electrical characteristics that vary in response to variable conditions to be signalled, continuously and repeatedly rotatable switch means interconnected with said gauge devices and said bridge means for successively, rapidly and cyclically connecting said gauge devices to form the other side of said electrical bridge, means for applying alternating electrical potential across said bridge, whereby to deliver therefrom a carrier wave modulated, during successive intervals, in accordance with the electrical characteristics of said gauge devices, means for amplifying said

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carrier wave, means for producing audio frequency signals, varying in accordance with said modulated carrier wave, means for transmitting a corresponding detectable signal, and means for receiving said signal.

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