250 KHZ Electrical Impedance Pneumograph

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An Electrical impedance Pneumograph working with a sinewave frequency of 250 KHZ is described. The authors find that chest impendance changes in the ratio of 0.0375 : 1 compared to d. c. skin resistance between the electrodes. The bridge arm balancing elements VR1 and C8 provide direct reading of resistive and capacitive components of chest impedance. The instrument has not been compared with a spirometer. Nevertheless, its linearity of output with change in volumetric resistance of the chest has been shown.

Commonly used methods for remote recording of respiration in human subjects employ a chest band with electromagnatic sensor, sealed air containing tube around the chest wtih pressure transducer, flow rate sensor in an intake flow meter and a thermister close to the nostril that responds to expiratory gas temperature. The first two methods are not adequate for use with subjects in Decompression Chamber if dynamics of the chest volume are to be studied during rapid changes of pressure simulating sudden pressurisation failures in aircraft with pressurised cabins. The flow meter sensor does not also give this information. The thermister transducer has a lag in response in addition to its responses to environmental temperatures. As early as 1959 Goldenshon and Zablow used the technique of electrical impedance plethysmography for remote recording of respiration in human subjects. They used two electrodes placed over the two wrists with 10 KHZ current between them. Geddes (1962) described a two electrode system carrying 50 KHZ current across the chest. Their method made it possible to record both respiration and ECG from the same pair of electrodes. Using a low torque potentiometer with spirometer they showed that electrical impedance plethysmogram of the chest recorded with electrodes was surprisingly faithful to the spirogram records. Allison et al (1964) used a four electrode system to study volumetric dynamics of the chest more exhaustively.

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The principle behind this simple method of recording respiration using two electrodes carrying low voltag higa frequency across the chest is that the high frequency current between two electrodes passes over the chest, through the chest and through the organs in the chest along collateral paths in addition to following straight paths between the two electrodes. A change in chest volume whether due to costal movement or diaphragmatic effects this volume and the impedance seen by the electrodes undergoes a change in direct proportion to changes in volumes This impedance (Z) is composed of resistive and capacitive elements in parallel. This paper describes a circuit (Fig. 1) developed at this Centre for remote recording of respiration from subjects undergoing Decompression Chamber runs.

CIRCUIT DIAGRAM OF ELECTIRICAL IMPEDANCE PNEUMOGRAPH

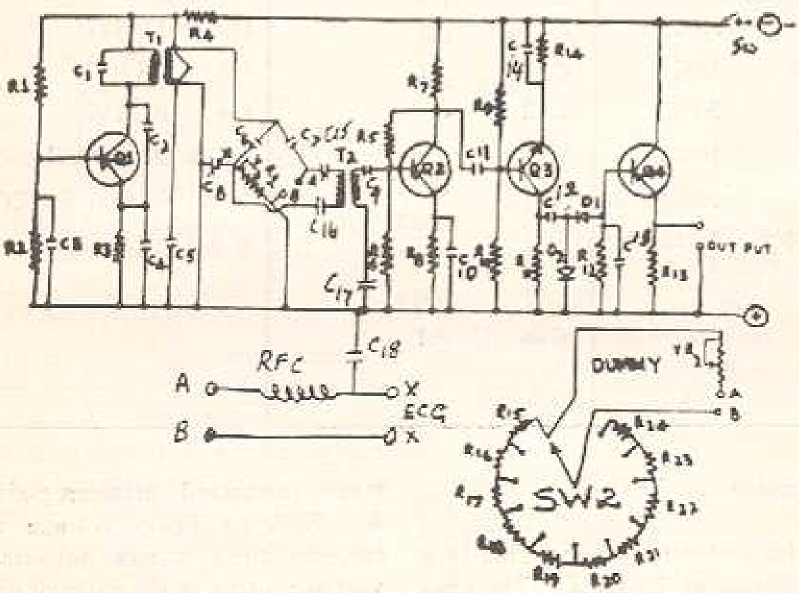

Fig. 1

LIST OF COMPONENTS

Resistors		Capacitors		Other Components	
R1	3K	C1	2' 0PF	T1	JAYCO M.W. OSC
R2	1.5K	C2	.002	T2	Output I, F. T. (Transistor Type) 455 KC/S.
R3	1K	C3	.01		
R4	100Ohm	C4	01		
R5	3.3K	C5	1uf	SW1	ON/OFF Switch
R6	10K	C6	.047	SW2	11 Pole Rotary Switch
R7	4.7K	C7	.047	VR1	500 Ohms
R8	1K	C8	0–500PF variable with shaft	VR2	500 Ohms
R9	3.3K	C9	1uf	Q1	AF 114
R10	39K	C10	.33	Q2	AF 117
R11	10K	C11	.01	Q3	2N 917
R12	500K	C12	.1	Q4	BC 157
R13	10K	C13	.1	D1 & D2	OA81
R14	500Ohms	C14	.1	X X	Output for ECG
R15 to R24	1 Ohm	C15	0047	R F C	15 mh
		C16	0047		
		C17	0022		
		C18	0.1		

Circuit operation

Q1 with its associated components is a colpitts oscillator of 250KHZ. The peak to Peak voltage of the oscillations at its collector is 16 Volts. The signal is taken off this by low impedance secondary of T1 and fed to a bridge comprised of C6, C7 and VR1 at peak to peak voltage of 1.5 Volts. The remainder bridge arm completed by Z of the subject's chest when connected between points A and B. Peak to Peak Voltage across the subjects chest varies between .5 to 1 Volt according to the ratio of chest impedance to C7 reactance. C6 and C7 serve to block E C G signal from getting short circuited through the low impedance secondary of T1. C8 is variable 0-500 P.F. capacitor to neutrilise capacitive elements in the subject's chest that would otherwise make balancing of the bridge incomplete. Bridge output is taken to T2, a tiny 455 KHZ transistor set I.F.T. with untuned secondary. Q2 is an admittance feed back amplifier whose output is linear for input of peak to peak voltages expected for excursions of the chest. Q3 is a detector that is set at the mid point of its collector characteristic below the knee. D1 and D2 with R12 coupled to collector of Q3 through C12 has been found to improve linearity with rejection of low level noises. Output across R12 is taken directly to emitter follower Q4. C13 by passed the HF to ground. VR1 and C8 serve as a very useful function of enabling one to read off the resistive and reactive components of chest impedance.

Using this instrument we found that chest impedance (Z) varies from subject to subject, the size of electrodes used and the d. c. skin resistance between the electrodes. The impedance was 50 Ohms with silver or stainless steel electrodes of 5 Cm X 2.5 Cm with measured d c. skin resistance of 1K. The impedance was 230 ohms when 1 Cm dia circular cup electrodes were used. Since the value of d.c. skin resistance primarily depends upon technique of electrode application we found that A. C. chest resistance using this frequency was related to d. c. resistance in the ratio of 0.0375 : 1. For both sizes of electrodes used the capacitive element across the chest ranged between 200 and 500 PF. Complete balance was achieved with the adjustment of VR 1 and C8. The output of the instrument was measured for its linearity using a dummy resistance with 1 Ohm step change switch shown in circuit diagram. Using various values of dummy chest resistance, and as expected, we found that the d. c. level output of the instrument for one Ohm step calibration signals is linearly related to the ratio

$$\frac{r}{r + R + D}$$

where 'r' is the one Ohm step introduced, 'R' the lumped one Ohm steps already added, and 'D' the basic dummy chest resistance. Since the output of the instrument is sufficient for higher values of basic chest resistance (upto 500 Ohms) and is linear for the ratio stated above, the linearity of respiratory records was not affected for any values of trans chest a. c. resistance with in a range of 50 to 500 Ohms provided proper bridge balance was achieved in any particular case. When using this instrument, proper bridge balance means the following procedure :

(a) At full expiration adjust VR1 and C8 to get Zero output. Read the values of a.c. chest resistance from VR1 and capacitance from C8.

(b) Offset VR1 to a value lower than a.c chest resistance so as to read 0.2 volts on a good voltmeter connected to output points.

Results :

Graphs obtained on Grass model polygraph 7P1 are shown below.

Graph (Fig.) is taken with dummy chest resistance of 230 Ohms. As an illustration, this valuewas chosen to tally with the chest impedance of our subject with 1 Cm dia electrodes over 7th rib in mid axillary line. Fig. 2 compares the actual record from this subject with the dummy calibration. It is seen therefore that at full inspiration the chest volume resistance increases by 8 to 9 Ohms from the basic impedance at full expiration, Fig. 5 is the simultaneous record of ECG at higher paper speed when points A and B were also connected to ECG recorded through an RFC at point A. The RFC connection was necessary to block the 250 KHZ frequency from being lost through capacitances in the line running from the Decompression Chamber to ECG recorder.

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Fig. 3 Fig. 2

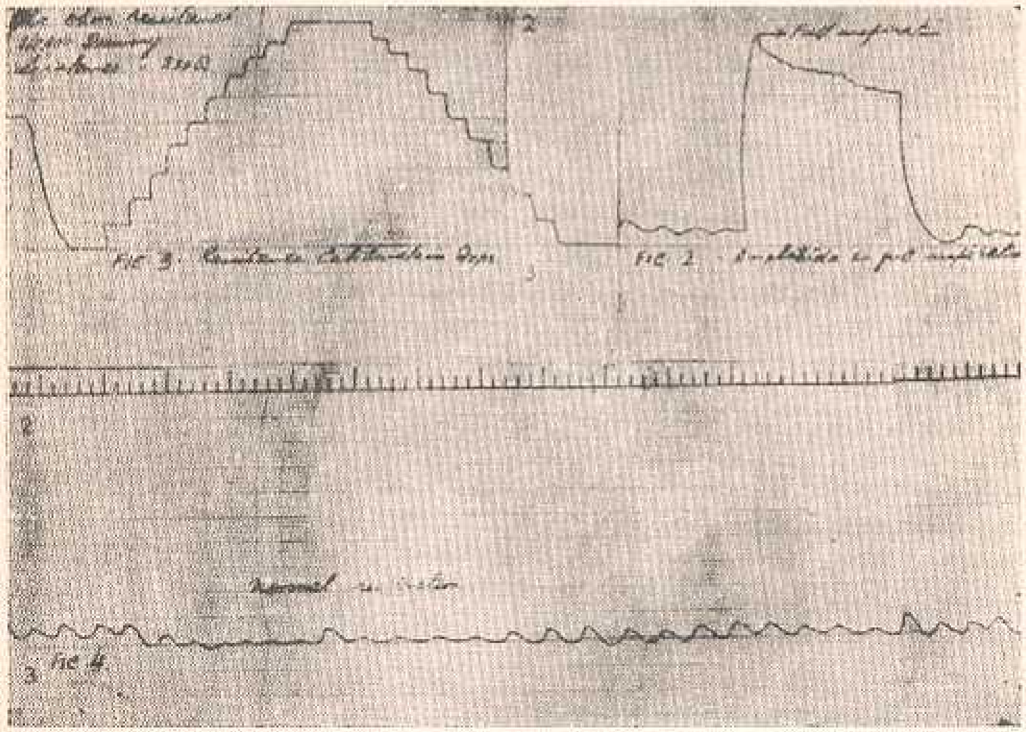

Fig. 4

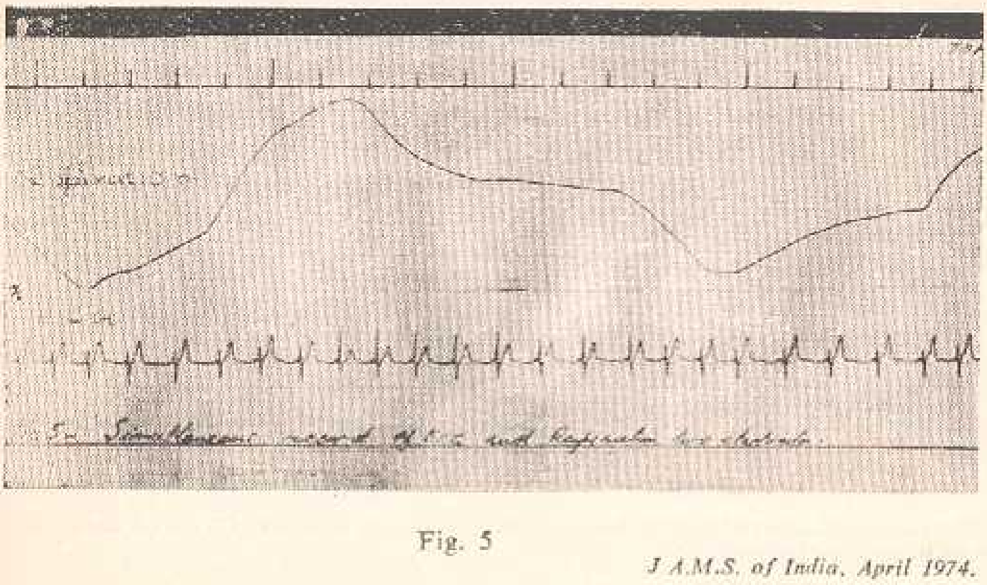

Fig. 5