DEVELOPMENT OF A VARIABLE FREQUENCY ARTIFICIAL LARYNX

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of

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To my Brother Vishwanath

To him, I owe my education, my life.

CERTIFICATE

This is to certify that the dissertation entitled "Development of a Variable Frequency Artificial Larynx" is the bonafide work in part fulfilment for M.Sc., Speech & Hearing, Carrying 100 marks of the student with Register Number: 19

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This is to certify that this dissertation has been prepared under my supervision and guidance.

S. S. Murty

GUIDE 21.5.74

D E C L A R A T I O N

This dissertation is ths result of my own study carried out under the guidance of Mr. S. S. Mury, Head of the Dapartment of Eleotronics, All India Institute of Speech & Hearing, and has not been submitted earlier at any University for any other Diploma or Degree.

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CHAPTER I

INTRODUCTION.

"All thoughts, feelings and action that may be embodied or suggested on vooal utterance, is expressed or appreciated through the medium of one or more of the following factors" (Brickson,1926; P.82-112). Erickson haa listed the basic factors of the human voice as pitch, volume and time.

"The one faculty which sets man apart from all living organisms, which makes him unique, is his ability to communicate, using his vocal tones for social interaction" (Fisher, 1966; P.3). Speech is a form of language that consists of sounds produced by utilising the flow of air exhaled from the lungs. "The act of speaking is a very specialised way of using the vooal mechanism. The act of speaking demand a combination of interaction of the mechanism of respiration, phonation, resonance and speech articulation" (Boone, 1971: P.17)

Speeoh is a means or method of evoking meaningful responses from somebody. When one analyses good speeoh, the speech that most adequately contributes to social interaction, it is discovered that it possesses certain characteristics. Each of these characteristics makes its peculiar contribution to the total impression. These important characteristics of speech are loudness, accent, style, voioe quality, articulation, stress, level of language and kind of language. "The peculiar contribution of all of the above characteristics of speech give rise to the final characteristic of speech, namely 'style', which is unique for each person" (N. P. Nataraja, 1972).

Larynx and the vooal cords are the vooal organs in the human beings. Voice, whioh is the vehicle of communication, can be defined as the laryngeal tone, and it is the result of the vibration of the vocal cords. However, there are some people whose larynx has to be surgically removed, because of carcinoma, of the larynx or for other reasons. If it may be said that speech is our most important characteristic, then it follows that the surgical removal of the larynx affects the most human part of us. The patient who has lost his larynx and who makes an otherwise satisfactory physical recovery presents a number of problems, that are always puzzling and sometimes discouraging. Baker (1954) states the situation suocintly: "The loss of the larynx in humans produces an oblitaration of the speech function that is unique because it is so complete. The absence of the phonating mechanism makes production of voice for speech impossible. More than this the surgical interaction of the upper airway also makes it difficult for the patient to produce those speech noises, which are important components of many speeoh sounds" (as quoted in Van Riper and Irwin, 1966).

There are two methods of rehabilitation of these patients:

1. Esophageal Speech and
2. Artificial larynx

Snidecor (1968) says 'by having developed the technique of esophageal speech, the speech therapist has greatly lessened the degree of disability incidental to the total removal of the larynx'. In the twentieth century and until a few years ago, surgeons and speech therapists were somewhat over-enthusiastic, concerning the relative numbers of persons who could learn esophageal speeoh. More recent and realistio studies indicate that from 12 to 33 percent of those surveyed could not or did not develop esophageal speech (American Cancer Society, 1951; Horn, 1962; Van Riper & Irwin, 1966; Greene, 1967; Snidecor, 1968). Greene (1964) has neatly summarized the factors, which render the acquisition of the esophageal speech, difficult or impossible. Some of them are poor post-operative results, damage to the nerve supply of the pharynx and tongue, old age, deafness and inability to monitor speech, low intelligence and real distaste for esophageal speech (Discussed in detail in Chapter II). Naturally for them the choice would be to use an artificial larynx. The presently available artificial larynges have many limitations. The chief among them is that the possibility of the pitch changing is limited. In none of these artificial larynges, is there provision to give the optimum frequency and to change the output intensity (discussed in detail in Chapter II). Snidecor (1968) says "along with over-optimism for the development of the esophaged speech, there developed an unwarranted critical attitude toward the artificial larynx. Greater tolerance, understanding and publicity might well have eased the way for those raluctant to use this aid". (P 199).

IMPORTANCE AND NEED FOR THE PRESENT STUDY

The major disadvantages of the presently available artificial larynges, are that, in all of them, the pitch range provided is limited. The best of the available artificial larynges, WE Type 5A, has a frequency range of an octave, from 100 to 200 Hz only, which is not sufficient to bring about normal inflectional and intonational change a in speech. With the above artificial larynx, there is no possibility of giving the optimum frequency of the patient. Giving his optimum frequenoy is important beoause at this level, the vocal tract of the patient gives the maximal response and it is hygienic to his remaining vocal mechanism. The present study aims to develop a variable frequency artificial larynx, which can be varied from 50 to 350 Hz.

Moreover, the output of the above artificial larynx is 75 dB at a distance of three feet between the speaker and the listener and there is no provision to change the output intensity of the device. But depending on the environmental conditions (background noise and the distance between the listener and the speaker) the changing of output intensity of the artifioial larynx is essential.

Another point of importance is that these available artificial larynges are too costly, particularly in Indiai situations, where people cannot afford its costs. Hence an artificial larynx at a much cheaper rate than the above, was felt essential.

About this WE type 5A artifioial larynx, Luchsinger (1965) says "a significant perfection of the eleotrolarynx has been met in this artifioial larynx". And we have seen that this best artifioial larynx has got so many limitations. Hence, a modification and development of another artificial larynx is required.

Shantha (1973) has shown that dyaphonic cases can be treated by way of the Isochronal Tone Stimulation Technique. She used an artificial larynx and a Beat Frequenoy Oscillator. But since Beat Frequency Oscillator is a costly instrument and not easily availabie, a substitute for this to feed the tones to the artificial larynx vibrator, is needed. A variable frequency artificial larynx, whioh this study aimed to develop, could be substituted for the Beat Frequency Oscillator and this would simplify the problem to a great extent.

This brief discussion is elaborated in the II Chapter expresses the importance and the need for carrying out this study.

DESIGN OBJECTIVES FOR AN ARTIFICIAL LARYNX

Before a choice can be made of a particular method of operation of an artificial larynx, there are number of acoustic and electronic circuit aspects of the problem to be considered. So far, no exhaustive survey of opinions of post laryngeotomised patients has been made to determine what would be an ideal type of artificial larynx. But from the standpoint of achieving normal speech and the concensue of some patients and Speech Pathologists is that an ideal device should have the following attributes:

1) Output speech 'quality' and pitch inflection like that of normal speech: An artificial larynx should have A wider pitch range than that provided at present (100 Hz to 200 Hz; WE type 5A) and that it should be variable, so that variations in stress, intonation and inflection, like in normal speech or which simulates normal speeoh, can be brought about. The optimum frequency of the patient should also be given so that whatever is remaining of the vocal tract of the patient gives the maximum response to the artificial larynx. To summarize, for the speech to sound natural, it should have pitoh inflection and like the normal voice, should have a suitable fundamental frequency accompanied by harmonics, that can be used to produce the various vowel sounds.,

2) Output speeoh volume of the artificial larynx ahould be equal to that of a normal speaker: For any communication to take place, signals of some kind must be transmitted from the sender to

the listener, that is, they must be strong enough to stimulate the listener. The artificial larynges available at present, are all limited in this respect. Even the WE Type 5A gives an output volume of 75 dB at a distance of three feet. In most of the situations, depending upon the background noise and the distance between the speaker and the listener, the output volume of this artificial larynx proves to be disadvantageous. The solution for this would be to provide a provision for varying the output, say from 60 to 110 dB, so that the patient can vary the output also, depending on the environmental conditions as is done by normal speakers.

3) They should be inexpensive and should have a low operating oost: It is particularly important in India, where the WE Type 5A costs about Rs. 650/- and hence a cheaper design is required. And for this electronic devioe, the battery power consumption should be kept to a minimum, in order to reduce costs of battery replacements. The manufacturing costs can be minimized by the use of commercially available transducers, transistors and other component parts.

4) Secondary to the above, but still of great importance to the user, the device should be inconapiquoua and hygeinic. It should be unobtrusive, without visible wires, tubes or other oppurteneraces and should be small in size.

3) It should be reliable with simple trouble-free operation for long periods of time. Simplicity of operation is very desirable, so that the subject requires only a minimum of training and as soon as possible gains the psyohological benefit of vocal communication with his family and others.

In addition the device should be as free as possible of mechanical difficulties necessitating service and repairs. The device should impede the paticnt as little aa possible in the use of his hands at work, play and, the activities of the daily living.

STATEMENT OF THE PROBLEM:

The problem of the present study then was to design a variable frequency artificial larynx, with a fundamental frequency which could be custom selected for each individual to match his optimum, and a rich supply of overtones. The problem was also to provide the patient with the provision of ohanging the output intensity of the artificial larynx. It was decided to develop such a variable frequency artificial larynx and check whether it would be used to train normal people in terms of using intonation and infectional pattern, dyaphonics and laryngectomes, if available.

LIMITATIONS 0F THE STUDY:

1. The study has to be limited because of want of time.
2. The study has to be limited because of the non-availability of the cases.

IMPLICATIONS OF THE STUDY:

1. This is a more versatile artificial larynx, than the WE Type 5A, because it has the provision for changing the frequency and intensity and has a wider frequency range. The optimum frequency of the patient can be custom selected for each patient with this artifioial larynx.

2. This is a useful instrument, particularly in India, as the production cost is very much less than the available artificial

larynges.

3. The variable frequency artificial larynx is useful in training the dysphonics, by the Isochronal Tone Stimulation Technique.

4. The intelligibility of the speech using this artificial larynx is very good. The oscillator interruptor provided hero was extremely useful in increasing the intelligibility of speech.

DEFINITIONS:

In the present study the following definitions have been used:

Pitch: Pitch is a Subjective auditory impression of the number of cycles per second of the oscillating waves and rare-factions. Even though pitch ia not a direct correlate of the frequency, it can be produced and measured in laboratory by means of different instruments.

Loudness: Loudness is, in general, the psychological correlate of the intensity; the term refers to the 'strength of sensation reoeived through the ears'. In the present study loudness has been taken as a direct correlate of the intensity, which oan be measured in terms of Sound Pressure Level, by using Sound Pressure Level Materr.

Optimum Frequency: Optimum Frequency is the fundamental frequency of the vocal cords whioh elicits the maximum responses of the vocal traot

$$OF = NF \times \frac{FFg}{NFg} \text{ where}$$

OF = Optimum frequency; NF = Natural frequency

NFg = Natural frequenoy of the good voice;

FFg = Fundamental frequency of thE good voice.

Intonation & Inflection: Intonation and inflection are two characteristics of normal speech, which go hand in hand with the pitch. Inflection ia referred to as the shift in pitch during the utterance of a syllable. It is accompanied by minute adjustments in length or tension of the folds which produce expressive pitch glides. Intonation is am exolusive term referring to pitch as a function of time and may be applied to a simple inflectional shift.

Stress & Accent: These are two other characteristics of speech. When certain words in a pollysyllabic words are given an extra stress, then it ia known as accent. Aocent ia primarily a matter of convention: it is concerned with oorrectiveness in word pronunciation. It refera to the relative stress of syllable in a word.

Isochronal Tone Stimulation: It ia A technique for correcting voice by eliciting Isochronal matching of the laryngeal tone to a selected tone produced by a vibrator; where the word 'Isochronal' means; taking place (vibrating) in the same time or at the same interval of time, with equal amplitude, as something else (According to Oxford English Dictionary).

Normal Speech: Normal speech is that which has proper intonation and inflection pattern, which ia important in conveying the proper meaning and which employs optimum frequency.

CHAPTER II

REVIEW OF LITERATURE

"Communication has long been recognized as one of the most fundamental components of human behavior" (Peterson, G.E., 1958). Mans primary method of communication is speech. Speech is the acoustic end product of the respiratory and masticatory apparatus.

Speech is a form of language that consists of sounds produced by utilizing the flow of air exhaled from the lungs. When one analyzes good speech, the speech that moat adequately contributes to social interaction, it ia discovered that it possesses oertain characteristics. Each of these characteristics makes its peculiar contribution to the total impression. These important characteristics are pitch, loudness, intonation and inflection, rhythm, voice quality, stress, accent, style, level of language and kind of language.

Voice is the vehicle of communication. Thus voice becomes the very basic factor of speech. Voice plays the musical accompaniment to speech, rendering it tuneful, pleasing, audible or coherent and it is an essential feature of communication.

One of the most important or most conspiquos characteristics of speeoh, that is, the voice quality of the speaker, which depends upon the patterning of the overtones and their intensities. The differing-sizes and shapes of the many resonating cavities within different human heads contribute to the quality.

The most important characteristic of speeoh, however, is pitch. For every voice there is a pitch level at which the voice is found to be comfortable or most effective and this is known as optimum pitch.

Intonation and inflection are two other characteristics of speech, which go hand in hand with pitch. Inflection is the shift in pitch during tho utterance of & syllable. There are times when it is appropriate to speak with a minimum of inflection, but a person who consistently talks on a monopitch will find his listener either irritated or asleep.

Loudneas is another important characteristic of speech. For verbal communication to occur signals of some kind must be transmitted, from the sender to the receiver, that is, they must be strong enough to stimulate the listener.

Stress and accent are two other characteristics of speech to be considered. When certain syllables in a pollysyllabic words are given an extra stress then it is known as accent. Accent is primarily a matter of convention; it is concerned with correctness in word pronunciation.

Projection is another characteristic of speech. It arises in part from a good voice mechanism, used properly. Projection is to make the voice easily audible to all listeners, without apparent expenditure of unnecessary effort. But mere loudness doea not of itself constitute projection. Failure to provide an adequate breath stream to activate the vocal banda with sufficient force may be a cause of poor projection. Good apaeoh must be more than clearly audible; it must be intelligible as well. Adequate projection contributes to both of these desired effects.

"The peouliar combination of all the above mentioned characteristics of speech give rise to the final charaoteristic of speech, namely style, which is unique for each person. Every individual has a style of speech, which is unique and this ia due to his peculiar combination of all tho characteristics of speech".(Nataraja, 1972).

Human beinga produce voice by making the vocal cords vibrate through the exhaled air from the lungs. A special problem of speech rehabilitation is presented by the case in which, because of cancer or other disease of the larynx, there has been a complete surgical removal of it. This operation is known as laryngectomy (Larynx - voioe box and 'eotomy' means cutting out and the patient who has undergone this is known as laryngeotomee. The patient is unable to use the breath for the phonation or even for whispered speech because the expired air no longer passes out through the mouth and nose, If it may said that speech is our most important characteristic, then it follows that this surgical removal of the larynx affects the most human part of us. The first laryngectomy operation was done by Bilroth in 1874.

Though the larynx is relatively small, it is complex in shape and structure and the problems produced by malignant tumors arising in the various parts of this organ differ greatly. The patient who has lost his larynx and who makes an otherwise satisfactory physical recovery, presents a number of associated problems, which are many times discouraging. Baker (1954) states the situation most succintly: "The loss of the larynx in humans produces an oblitaration of the speech function, that is unique because it is complete. The absence of the phonating mechanism makes production of vocal tones for impossible. More than this, tha surgical interaction of the upper - airway also makes it difficult for the patient to produce those speech noises which are important components of so many speech sounds". (As reported in Van Riper & Irwin, 1966).

The first symptom of the carcinomatic condition of the larynx is hoarseness (Van Riper & Irwin, 1966; Boone. D, 1971; Snidecor 1971).

To treat this symptom as a functional voice disorder would not only be futile but death dealing.

Complete recovery of the laryngeotomized patients can only be achieved by an operation which allows the restoration of the elementary functions of the larynx and permanent abolition of the tracheostoma. Various clinical and experimental procedures have been reported in the achievement of the above. They are:

1. Use of prosthesis
2. Surgioal reconstruction of a simplified but functionally adequate organ.
3. Transplantation of the larynx.

Arslam and Serafin (1972) report a technique of surgical reconstruction of a simplified but functionally adequate organ, in order to achieve the following three objectives:

1. Maintenance of respiration through nose and mouth,
2. Satisfactory swallowing without aspiration of food and saliva into the lower respiratory tract.
3. Restoration of spontaneous phonation using the pulmonary expiratory air stream.

In this operation, the trachea is raised by about 4 cm and is kept in this new position during the scarring period by means of various stichss fixing it to hypo-pharyngeal mucous membrane, to the epiglottis, to the body of tha hyoid bone, to the thyroid gland, to the external perichondrium of the larynx and by means of this, to the pharyngolaryngeal muscles and to the prelaryngeal muscles.

The 'neolarynx' obtained by this procedure is, therefore, made up of tha upper segment of tho trachea, of tho body of the epiglottis, over the opening by tho external laryngeal perichondrium with a lower constrictor muscle of the pharynx. It occupys exactly the space left empty by the removal of the larynx.

Phonation, respiration and deglutition are all restored completely with-in the first week after the operation. In all the patients phonation was characterized by a slightly sonorous emission, but this improved rapidly. In fact there was a marked increase in the fundamental tone of speech, in the intensity of emission and in the timbre.

Electroacoustic and speotrographio studies, comparing the neolarynx voice and the natural voice have been reported (Arslam, 1972; Arslan & Serafin, 1972). It was found in the neolarynx speech, the presence of a fundamental, 2 or 3 upper harmonics, and a regular arrangement of the vocal formants. Arslam and Rossi's (1972) study indicated greater resemblance between the neolarynx voice and normal voioe.

Transplantation of the larynx has been done on dogs and human being: (Ogura, Harvey, Mogi, Ueda and Ohyama, 1970; Work L.P. et. al, 1965; Lipidot, 1965; Silver, Liebort& Sam 1967).

Transplantation of the larynx consists of five factors. They are:

1. Technique of vascular reanastomosis of small vessels
2. Blood circulation.
3. Reinnervation
4. Pitch and sound production
5. Tissue typing.

The initial experiments with dogs have succeded. However, some of the technical and physiopathological problems are:

1. Misdirection of the regenerating nerve fibres
2. Reduction in the number of motor units

3. Tropical changes of the muscle figres
4. Retarded maturation of the neuromucular junction (Ogura, at. at., 1970).

In a study on seven dogs by Silver, Idebert and Sam (1967) only two dogs survived for two months. They report that the small size of the laryngeal blood vessels and the post-Oparative infection were the main problems.

Immunological accaptance of the donor larynx, matching of the donor and the recepient satisfactorily, finding, preserving and storing of the donor larynges remain as continuing problems. Work W.P. (1965) concludes that laryngeal transplantation is not possible to data, with present day surgical techniques and immunological and infection problems. Evoked phonation studies (Ueda, et. al. 1972) (unpublished article) showed that most of the treated dogs regained better functional control of the reinnervated vocal fold during voice production.

The speech therapist is called upon to help those who have had their larynx removed, learn to talk again. He is also called upon to counsel the patient pre-operativaly. The patient whose larynx is going to be removed should be told by the speech therapist about the post laryngectomy speech. There are many methods of rehabilitating the laryngeotomes. The two major approaches are (1) Recommending the esophageal speech and (2) Recommending the artificial larynx. (Rafer Tablel).

There are four types of alaryngeal speech available to the laryngectomes depending on the surgical result (Diedrich and Youngstorm, 1966; Simmons, 1971). The patient may learn Buccal speech, which requires trapping and compressing of air between the cheeks and the teeth and possibly between the tongue and the alveolar ridge (Diedrich and Youngstorm, 1966). This is difficult to learn and limited in its use as the intelligibility of the speech depends upon high air compression andexaggerated articulation (Simmons, 1971 and it is recommended as an adjunctive with most of tho patients (Luchsinger, 1965: Greene, 1968).

Another form of alaryngeal speech is known as pharyngeal speech which is produced by the air trapped in the meso or hypopharynx. It is not widely recommended because it lacks intelligibility, as the tongue is used both as a vibrator and articulator (Diedrich, 1966).

A third method of alaryngeal'speech production is known as gastric speech, which involves stomach as the new air chamber, and air is brought as true belch.

Alaryngeal Speech	**Artificial larynx**
1. Buccal speech 2. Pharyngeal speech 3. Gastric speeoh 4. Esophageal speeoh Methods of air intake: 1. Swallowing method 2. Inhalation method 3. Injection method: a) Glottal press b) Glossopharyngeal press **TABLE I** Showing the different types of rehabilitation procedures used with leryngectomee's.	1. PNEUMATIC ARTIFICIAL LARYNX: 1. Gottstein's Reed Larynx - 1900. 2. Bell Lab. Reed Larynx Type IA-1925. 3. WB Reed Larynx - 1926. 4. DSP - 8: Van Lunen 5. Riesz's Reed Larynx - 1930 6. Modification of the Bell Lab Reed Larynx By Martin in 1930. 7. Tokyo Artificial Larynx - 1971. **II. ELECTRO LARYNX:** A: Externally Applied: 1. Sonovox - 1942 2. Kett Mark I 3. Kett Mark III 4. Aurex Artificial Larynx 5. Bell Tel. Artificial Larynx - 1959 6. WE Type 5A Artificial larynx & 5B **B: Direct Activation of the oral Resonator:** 1. Ticchinni's reed type artificial larynx - 1955. 2. Cooper-Rand speech aid - 1958 C. Intra Oral Sound Source: 1. Oral Type Artificial Larynx -1959 2. Oral Vibrator - 1959 electronic 3. Pichler's Wireless Speech Aid -1961

However the major type of alaryngeal speech is known as esophageal speech. Esophageal speech, like normal speech, is based on a modulated air stream (Van Riper & Irwin, 1966). The air supply has been swallowed into the stomach, trapped in the upper portion of the esophagus. The modulations or vibrations seem, in most oases to be due to the action of the cricopharyngeal sphinoter, formed by the lowest fibres of the inferior conatrictor muscles. In place of the vocal cords he learns to use the esophageal sphinoter as a vibratory reed or pseudolottis, and the upper portion of the esophagus serves as an air reservoir or vicarious lung (Killanin, 1908; Morrison, 1931; Greene, 1964.; Van Riper and Irwin, 1966). With theoretical and factual evidence, Beck (1956) has shown that after laryngectomy, voice is produced with the esophagus as the source of air and with the vibration formerly produced by the vocal cords are now produced by the structures near the top of the esophagus. However various anatomical structures can be used as pseudoglottis. They are :

1. Between the base of the tongue and the posterior pharyngeal wall (Stetson, 1937).
2. Back of the tongue and the soft palate (Martin, 1950)
3. Between the contracted portion of the inferior conatrictor muscle.
4. Between the epiglottis and the two folds formed laterally from the muscles of the pharynx.
5. Between the folds of tha cricopharyngeua muscle.

Tho last one seems to be the best one and it is formed between the 5th and 6th oervical vertebrae in esophageal speakers.

Each type of alaryngeal speech requires some method of getting air into the new air chamber (Simnons, 1971). There are three major methods of air intake, which are known as (1) Air swalowing, (2) Inhalation, and (3) the injection method. The last is the most commonly used technique. In learning esophageal speech the patient is taught to bring back the inhaled air, to produce the vocal tone and at the same time to articulate vowels.

There will always be patients who are unable to acquire esophageal speeoh by the above methods. Although Heaver & Arnold (1962) advocate the use of artificial vocal aids during the time the patient is learning esophageal speech, it is the general opinion that the too early introduction of them may discourage patients from learning to speak by natural means.

Sixty five percent of the laryngeotomee's learn to speak esophageal speech (Horn, 1962). This percentage varies from 50 to 75 percent (Gardner, 1951; Nessel, 1963) Van Riper & Irwin, 1966). However, not all can learn esophageal speech. Greene (1964) has neatly summarized the factors that canbe expected to render the acquisition of esophageal speech difficult or impossible.

1. A poor post operative result with formation of scar tissue which restricts facile dilation of the hypopharynx and cricopharyngeal sphinoter and stenosis of the esophagus (Levin, 1952).
2. Damage to the nerve supply to the pharynx and the tongue, by surgery, producing paralysis.
3. Old age and frailty accompanied by lack of drive to learn.
4. Deafness and inability to monitor speech (Levin, 1952; Lauder, 1968).
5. Low intelligence and inability to master the necessary new muscular co-ordinations.

6. Real distaste for esophageal speech and preference for an artificial vocal aid. There are a relatively few young people who by reason of physical or physiological weakness find it difficult or impractioal to learn esophageal speech, which is after all hard work, unless one might use the plosive method exclusively. The Artificial larynx may be a crutch and a very useful one. Those who suffer a severe mental depression may be encouraged and helped by an artificial larynx.
7. Suspected recurrence of the cancer, metastases and multiple lesions reoccur (Levin, 1952).
8. Complications arising after the operation such as, edema, infection, delay in healing, necrosis, etc (Parnell, 1968)

Another reason is that not all laryngectomees are able to develop esophaseal speech. "Despite the amount of knowledge regarding the esophngeal speech, which has accumulated in the past fifty years, one of the important questions which remains to be answered is why some individuals are able to learn to use the new vice without undue difficulty, while others, who appear equally well motivated, fail in their efforts to acquire it" (Finklebeiner, 1968).

The next mode of rehabilitation used with the laryngeotomees is that of artificial larynx. Recent and realistic studies indicate that 12 to 33 percent of those surveyed could not or did not develop esophageal speech (Snidecor, 1968).

Artificial larynx Berves the purpose of giving the patient, a substitute'built-in-voice' which is made to pass through the remaining of the vocal tract of the patient and then articulated in a normal manner.

The firat artificial lanax was conceived by Czermark and executed by Bruuk in 1859, fourteen years before the first laryngeotomy and approximately eighteen years after Raynaud reported what may be the case of esophageal speech (Luchsinger, 1965; Snidecor, 1968). It is an interesting coincidence that both this invention and the discovery of the physiologic phenomena of esophageal speech were made long before the first surgical attempts at laryngectomy. Czermark's patient presented complete laryngeal stenosis. The instrument was actuated by a read and driven from the tracheal stoma.

In 1873, Bilroth in Vienna accomplished the first successful total laryngectomy. His patient was fitted with an artificial larynx, which was unique in its complexity, for it oonsisted of three parts: a tracheal, a pharyngeal and a phonation oannula. The complexity of the instrument was in doubt justified by the fact that the operation of that day left a pharyngeal opening (Snidecor, 1968).

Basically all artificial larynges can ba divided into two types (Bangs, et. al 1946; Gardner and Harris, 1961; Hayes & Martin, 1963 Diedrich & Youngstorm, 1966).

1. Pneumatic artificial larynx (Refer Fig. 1 & 2)
2. Electric artificial larynx (Refer Photograph 1)

REED LARYNX

The first mechanical aid to artificial speech that has been devised was in the form of a snail chamber which oontained vibrating rubber bands or reed. These were activated from the air expelled from the stoma, the monotonous tone being transmitted by a tube into the mouth and vocaliaod there. In USA, the first of such devices (using rubber bands was manufactured by the Boll Laboratories in 1925 (Martin 1973). In 1929, a reed type of instrument was developed by that organisation and since 1930 it has been sold at the cost of

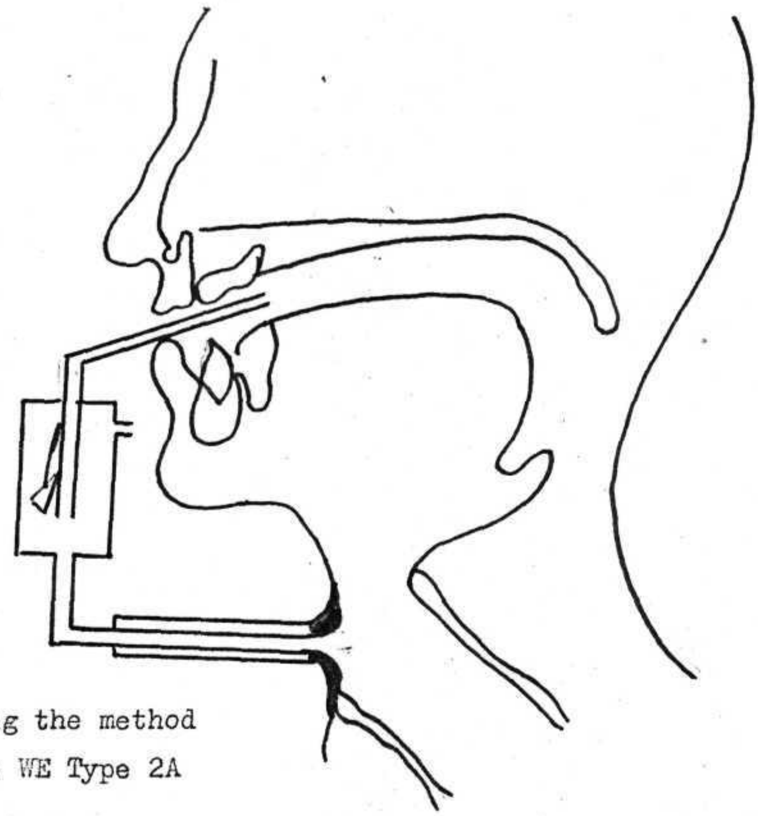


Figure 1 illustrating the method of operation of the WE Type 2A Artificial Larynx

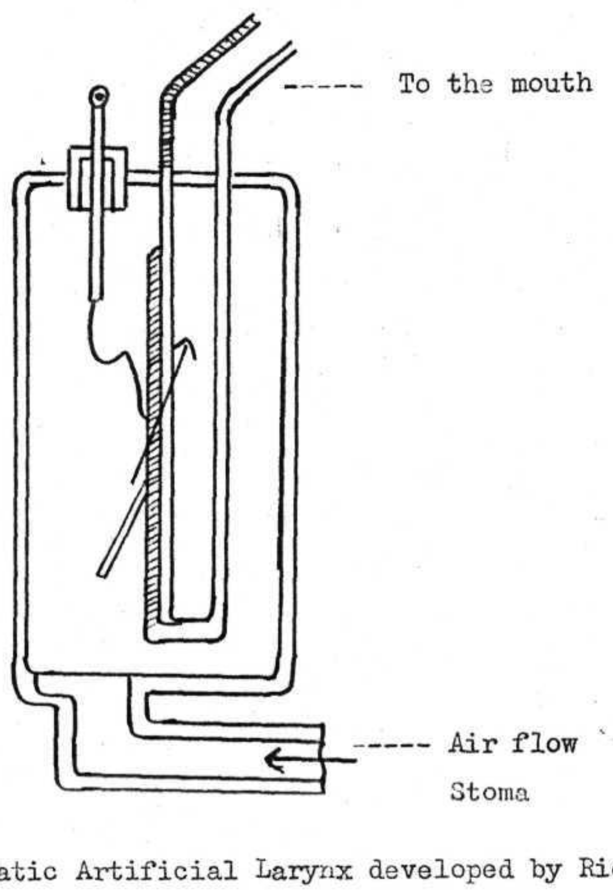
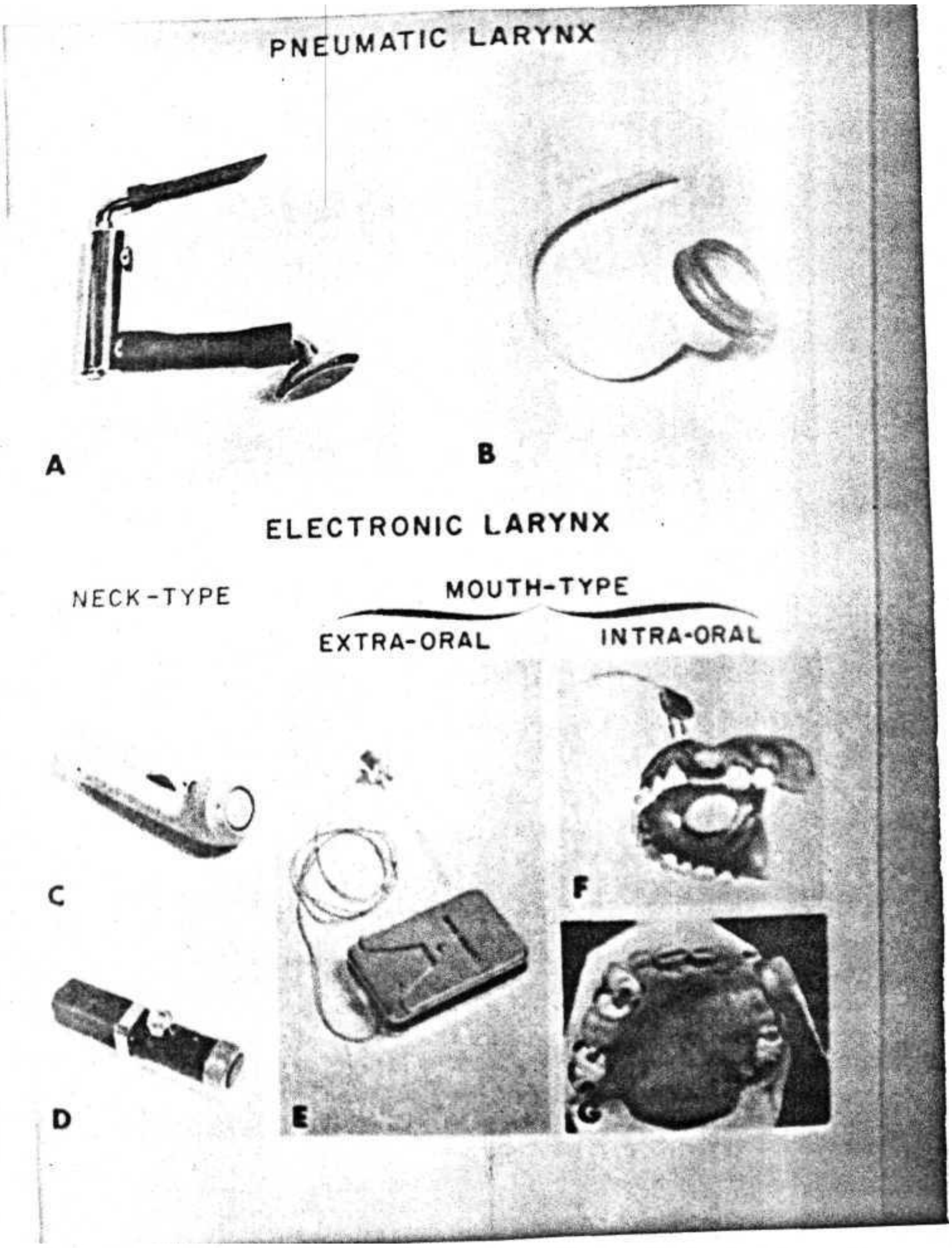


Figure 2 showing the Pneumatic Artificial Larynx developed by Riesz (1930)



PHOTOGRAPH 1

Showing the different types of artificial larynges.

A) WE Type 2A. B) Van Lunen DSP 8.

C) WE Type 5A. d) Kett Mark III.

E) Cooper Rand Aid. F) Tait's Oral Vibrator.

G) Pichler's Wireless Aid.

production. It was the only appliance for artificial speech available, until the invention of the Wright Electro larynx in 1942. This reed, larynx in the hands of a skilled speaker givea very good intelligibility (Snidecor, 1968), and according to a study by Hyman (1955) it is more pleasing to many ears than is esophageal speech. According to Snidecor (1968), there are two disadvantages: 1) The instrument is bulky and with its loop of tubing from neck to mouth, presents a strange appearance and 2) Unless carefully and regularly cleaned, unpleasant odors develop. The WE reed larynx is superseded by the new WE 5A and 5B, which will be discussed later.

The pneumatic type fits over or into the tracheal stoma and is activated by air from the lungs. It may require the attention of the laryngologist regarding the adaptation of the stem of the tracheostomy tube worn by the subject, if this type of fitting is to be used. One type, however, has a circular cup, that simply fits over the stoma.

The tone that substitutes for the voice is produced by forcing air past a vibrating reed. One end of the instrument is then held, in the mouth, so that the vibrated air is introduced well back into the mouth cavity, and is then articulated in the usual fashion. The advantages of this aid are: 1) it is cheaper, 2) it has a somewhat better quality (Martin, 1963), 3) it has the possibility of pitch change and differentiation between sonants and surds by air pressure changes. But it is more conspiquos and because mucous collects in it, it has to be taken apart and cleaned.

Through the efforts of Jewell, President of the Bell Telephone Laboratories in 1925, resulted in an instrument that employed, rubber bands streched in a manner to stimulate the vocal cords and was designated typo IA. Those rubber bands deteriorated rapidly and ware a source of considerable dissatisfaction. Consequently during 1929, a new artificial larynx, designated type 2A, was developed that incorporated several refinements including the substitution of a vibrating metallic reed for the elastic bands. The method of operation of the WE type 2A artificial larynx ia shown in Fig. 1. The metallic reed is connected by tubing to the stoma in the throat, so that the users breath can actuate the reed. The sound of the vibrating reed is conducted through another tube into the mouth and. this sound is used in the production of artificial speech sounds.

H. J. Van Lunen has described the development of a pneumatic artificial larynx, known as DSP 8. This relies upon the expulsion of air from the tracheal opening through a small round apparatus containing a diaphragm with a soft support ring which fits over the tracheal opening. A flap valve opens during the inspiration and closes during expiration. Air causes the membrane to vibrate and its tension can be adjusted by a screw to a higher or low pitoh. Vibrated air is then piped into the mouth by the tube attached to the apparatus, while the individual articulates on the artificially produced voice. This is a simple instrument and ia easily cleaned, and as it is made up of polythelene can be Boilod and sterilized (Reported in Greene, 1964).

Riesz (1930) has described the development of a Pneumatic artificial larynx (see Fig. 2). It consists of cyllindrical case divided into 2 compartments by a cyllindrioal partition having one flat side of which is covored with a sheet of rubber. Air can pass from one compartment to the other through an alongated hole, cut through the flat side of this partition. A thin reed of spring metal, clamped at one end, is hold in position over tha hole. As air is blown through this hole, it sets tho reed into vibration, which periodically varies the flow of air through the larynx and so superposes a train of sound waves on the steady flow of air.

In use the input tube of the artificial larynx is connected to the breathing of air by means of a rubber tube and a coupling pad hold against tha front of the neck. The sound generated by the steady flow of air from the lungs is introduced into the mouth through a flexible rubber tube. In speaking the speaker goes through a series of motions and muscular adjustments that are practically same as those used before the removal of the larynx. The action of the vocal cavities in converting the sound produced by the artificial, larynx into articulate speech, is identical with that when a normal larynx is used, with the exception that in the former case the sound is introduced into the mouth while normally it is introduced into the base of the pharynx. But this artificial larynx is unhygienic, unesthetic and the quality of the tone is not good.

The Dell System need type instrument was modified at the Memorial Hospital in 193O's by Martin, by discarding the complicated apparatus that had beenprovided for attachment to the tracheal stoma and substituting a funnel or bell shaped contrivance that could bo placed directly over the stoma. Though this device could have been used by any laryngectomae to produce intelligible speeoh, it was rejected by many asbaing unhygienic and unesthatic, since it was necessary to place the funnel over tho exposed Stoma and insert the attached rubber tube into the mouth while speaking.

Weinberg & Rickenna (1973) describe a recently developed Japanese made Pneumatic artificial larynx. This is known as Tokyo artificial larynx. Tokyo artificial larynx consists of a stoma cover, a vibratory mechanism and a sound conduction tube. The patient uses the Tokyo artificial larynx by placing the cover against the stoma, directing pulmonary air through a vibrator, to produce voice, and transmitting the pseudoglottal vocal sound into the vocal tract through a sound conduction tube placed in his mouth. The vibratory mechanism consists of a atrip of rubber placed over a stainless steel base and fastened to the base with a rubber band. The stoma cover and the base of the vibratory mechanism are made up of stainless steel, while the sound conduction tube is plastic. These materials permit easy cleaning and sterilisation. Moreover repair, adjustment are easy, becacuse the components can be taken apart by hand. The average fundamental frequency of speech with this device was 71 Hz. Speech intelligibility was 98 percent for consonants and 95 percent for vowels.

In his survey of the historical development in the perfection of the artificial larynx, Arnold (1960) distinguished five categories or principles of laryngeal substitutes (Arnold in Luchsinger 1965)-

1. EXTERNALLY APPLIED REED LARYNX:

In 1859, Czenaark devised the connection of the tracheostoma to a tube containing the vibrating reed and hence to the mouth. The reed instrument is best represented by the WE larynx developed in 1926. Although the prototype of artificial vibrators, it was highly successful (Snidecor, 1968) and now it is regarded obsolete and inefficient. (This has been discussed in detail earlier).

2. INTERNAL, REPLACEMENT OF THE,LARYNX:

Czerny (1870) and his followers replaced the missing larynx with a mechanical reconstruction of all laryngeal functions. These models of a truly artificial larynx included a movable metal epiglottis, a respiratory valve and a phonation mechanism, created by rubber bands or metal reeds. This typo of equipment became obsolete with Gluck's (1899, 1930: Gluck and Sorenson, 1913) modified laryngectomy; which obviated the greatest hazard in Bilroths original technique for laryngectomy, namely aspiration pneumonia.

3. EXTERNALLY APPLIED ELECTRIC SOUND GENERATOR:

In 1942, Greene introduced the first workable eleotrolarynx, which was developed by G. Wright from his battery powered buzzing device known as the Sonovox. Credit for conceiving suoh an instrument goes to Wright, who chanced to know that hecould articulate into speech, the buzzing sound of his electric razor which he held against his neck. Several forms of electric powered mechanical speech aids have been developed since Wright's invention. Rare in this, the sound of the buzzer is transmitted into the pharynx through the soft tissues of the neck through direct contact with the skin. The sound wave thus transferred into the pharyngeal cavity is then molded into speech sounds by the ordinary movements of the intact organs of articulation. There have several modifications including a rectifier operated from a 115 Volt A.C. main line, directly attached cell battery and finally a rechargeable battery. Improvement on the original bulky sonovox model has resulted in two well known types of commercially available artificial larynx. They are manufactured and distributed, by two Amarican Companies, Katt engineeing Corporation and Aurex Corporation.

The Kett Electro larynx has two types, Kett Mark I and Kett Mark III. The Kett Mark III is cordless and is especially to be recommended when the larynx is to be used under conditions of noise or when the patient is talking tc someone with nodorate hearing loss. It is a powerful instrument that also has tha advantage of being rechargeable. On the heavy side it should nevertheless be considered when conditions demand a relatively loud and intelligible instrument (Snideoor, 1968).

Aurex compact electrolarynx has self-contained unit battery in the handle of tha unit and it has a built-in volume control. The Aurex has been continually improved and ia highly favored by many laryngeotomees.

But all these instruments have some disadvantages, such as the monotonous buzz, the constant tone during operation and certain deficiencies in their frequency spectrum.

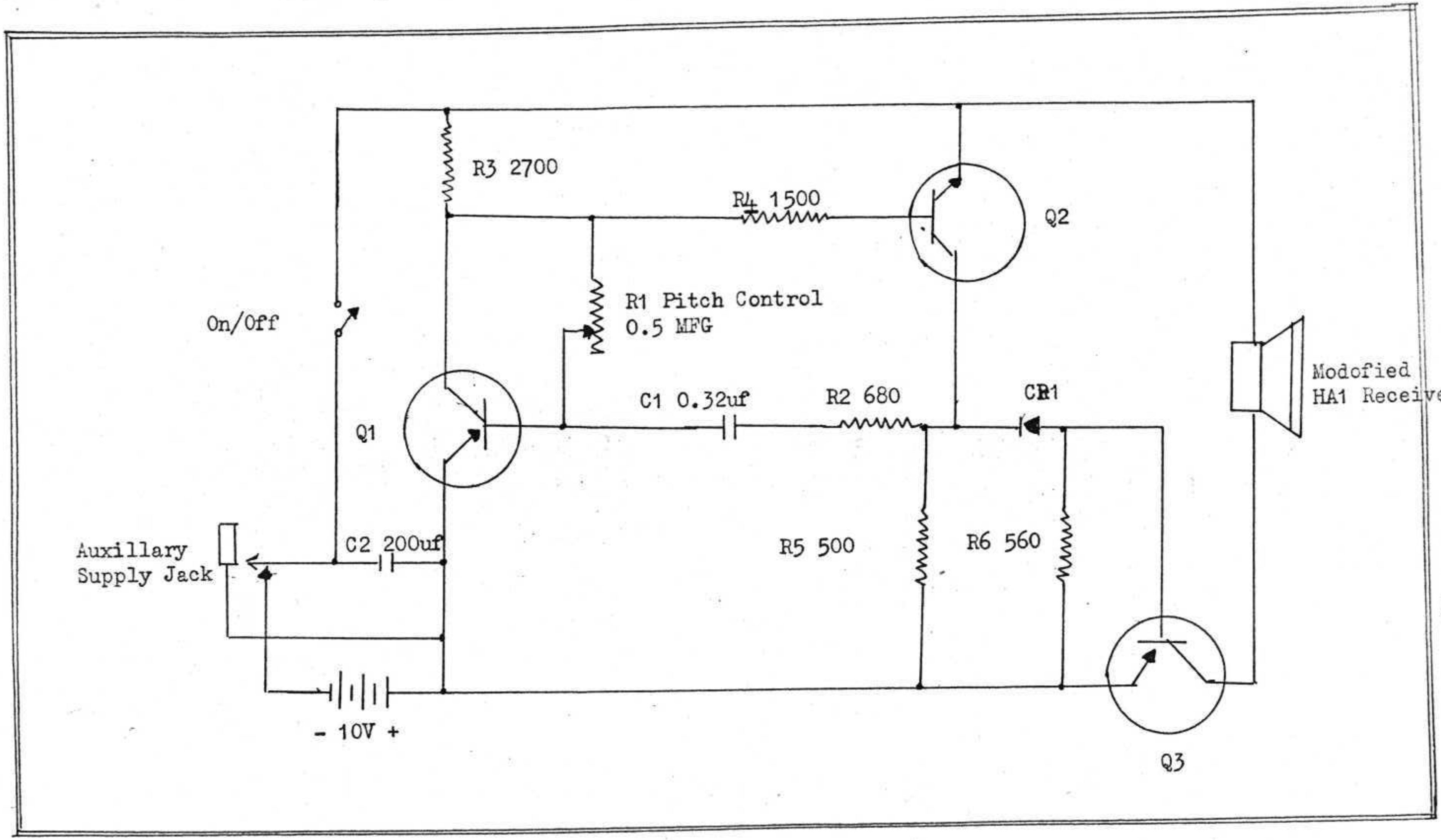
Barney, Haworth and Dunn (1959) have developed a new artificial larynx, which made use of transistors and miniaturised components to provide a voice for laryngectomees. This was subsequently known aa WE larynx, which was made in two models, one of relatively low pitch for men, designated 5A and one of higher pitch for woman, designated 5B. Both were stream-lined in shape, contoured to fit- the hand and include a battery switch and a pitch control knob which extended outside the housing. It included in one small hand held unit, a modified telephone receiver used as a vibrating driver that was held against the throat, a transistorised pulse ganerating circuit and a battery powered supply. When the pulae generator was switched on, vibrationa were transmitted through the throat wall into tha pharynx cavity and transformed into speech by the normal use of the articulatory structures. The authors claimed that the loudness of the speech obtained with this unit was comparable with that of a normal people speaking conversationally and speech was quite intelligible. However, they agreed that the speech so produced sounded somewhat mechanical. 'By the use of an easily operated inflection control, a degree of naturalness heretofore unobtained with other artificial larynges may be obtained with this' (Barney, et. al. 1959).

The transistor circuit is shown in Figure 3* It is essentially a two stage relaxation oscillator followed by a power stage that works into a transducer. The relaxation oscillator used a 'pnp' transistor Q1 and an 'npn' transistor Q2, ooupled together with regenerative feedback. The frequency of csoillation is determined by the pitch control resistance M, in combination with a capacitance Cl. The output of the relaxation osoillator appears across R5 as a aeries of short periodic pulses. The width of these pulses is determined by R2 and C1. The values given in the figure 3 give a pulse width of 0.0005 sec

The periodic pulses generated in the relaxation oscillator are transmitted through the semi conductor diode CR1, to the base of the power transistor Q3. The HA1 receiver is connected to the base of the power transistor and receives short periodic current pulse of about 0.45 amp. peak value at oscillation frequency.

The range of the oscillating frequency may be adjusted by changing the range of resistance R1, available in the pitch control rheostat to stimulate either a man's or woman's pitch range. For men the range is from 100 to 200 Hz and for women the range is from 200 to 400 Hz. This is an octave range in either case and 'is sufficient to duplicate the pitch inflection used in normal speech' (Barney et. al. 1959). The on/off switch and the pitch control rheostat are arranged so that the switch is closed at the lowest oscillating frequency and further movement of the control causes the frequency to increase. Two 5.2 volt batteries in series provide the necessary power to

FIGURE 3: SHOWS THE CIRCUIT DIAGRAM OF THE W.E. TYPE 5A ARTIFICIAL LARYNX



operate tho circuit.

Output volume measurements on subjects who have acquired a moderate amount of proficiency show SPL's on the vowel peaks of 70 to 75 dB's above 0.0002 microbar at a distance of 3 ft. from the speakers mouth. Though this is approximately normal conversational level, in in environment so noisy as to require a speaker to raise his voioe appreciably above the normal level, this volume would bring the speaker and the listener to shorter distances.

A quantitative estimate of whether the sound spectrum of the artificial voioe approximates that of the natural voice was made by comparing tho frequency spectra of 10 vowels spoken by a subject using first the now artificial larynx and then his natural voice. Haworth (196O) found that for some vocal sounds, the amplitudes of the higher frequencies dropped more rapidly in the natural voice than on the artificial voice, and for others it was opposite with a nearly even division. Haworth (1960) has oonoluded 'essentially thia means that the artificial tone souroe has a suitable spectrum'.

It has also been shown that the new artificial larynx is able to transmit sufficient power into the pharynx throughout the frequency spectrum to permit satisfactory development of the high amplitude regions of the vowel sounds (Barney, et. al. 1959). It has been indicated in the souroe spectrum of the natural voice are strongest at the lowest frequencies dropping in amplitude toward the high frequency noices at the ratio of about 9 dB per Octave (Haworth, 1960)-

The transistorised circuitry, carefully selected sound spectrum and manual control of volume and pitch modulation represent the major advantages of the above larynx (Luchsinger, 1965). Luchsinger (1865) concludes by saying 'a significant perfection of the electrio larynx has been met in this artificial larynx'. However, regarding the pitch of the artificial larynx, the pitch range provided ia only one octave, that is, from 100 to 200 cps and the authors claim that this is sufficient to duplicate the inflectional patterns found in normal speech, which is not true.

4. DIRBCT ACTIVATION OF THS ORAL RESONATOR:

Czermark's classical idea of leading the artificial sound directly into the oral cavity influenced the efforts of several investigators (Arnold 1960; Luchsinger, 1965). Numerous experiments were performed on the hope of realizing this idea in a practical manner.

Ticchioni of Italy produced a reed type Artificial larynx. In 1955, Tiochioni fitted a regular tobacco pipe with an electromagnetic vibrator, activated through a flexible cord by a battery powered pocket generator. The pipe is held in a simulated posture of pipe smoking and the hand that holds the pipe also controls the interruptor switch. Sound is thus introduced into the oral cavity as the carrier wave for articulated speech patterns. The advantages of this instrument are 1) it is easily cleaned, 2) easy to operate, 3) it is fairly inconspiquos and the disadvantages are 1) replacement of the batteries is difficult and 2) tone is not good (Martin, 1973).

Another model, the Cooper Rand speech aid works by direct oral activation. This was introduced in 1953 by the hand development Corporation. It consists of a hand operated oscillator, generated by a transistor battery. The electrical signal from the oscillator passes through a lead to a tone generator which is held in the other hand, and from which a plastic tube pipes Bound into the couth and on this it ia possible to articulate. The vibrator isheld in one hand and the other hand operates a volume control knob on the generator case. Thus this contraption has the disadvantage of occupying both the hands. Volume and pitch are adjustable and tone ia good. (Greene, 1964). but care must be taken not to let the tongue block the end of the transducer tube when speaking, as this interrupts the voice. The aged individual may find this reed unacceptable for esthetic reasons (Martin, 1973). According to Snidecor (1968) this Cooper Rand aid gives reasonable intelligibility and has a minimum amount of extraaneous noise.

5. INTRA ORAL SOUND SOURCE:

Cooper and Miller in 1959, invented an oral type of artificial larynx consisting of a small transducer affixed to a denture in the buccal area. It is connected by a fine wire that leads into the mouth from a transistorised circuit and battery in the patient's pocket. This mechanism is activated by a switoh that is secured in the arm pit. Another type of aid which also vibrates directly in the mouth is the oral vibrator developed by R. V. Tait (1959). "An upper dental prosthesis containing an electro-magnetically vibrated diaphragm is incorporated in an artificial palate. The dental plate is connected by a fine twin flex wire leading out of the mouth to a small battery operated audio oscillator, comparable in size to a, hearing aid and usually worn in a pocket. The dental applianoe is constructed as an upper denture for patients who normally wear one, or may ba held in position by the natural teeth in cases where no upper denture is worn".

*By pressing a small switch on the radio oscillator, the diaphragn in the mouth is caused to vibrate. The sound produced in this way may bo modulated into speech by normal speech movements of the oral musculature. The oscillator isprovided with a control whereby vibrations in pitch of voice may be obtained. The flex is detachable from the dental plate 30 that it need only be connected when the patient wishes to speak and is readily replaceable should breakage occur" (Snidecor, 1968).

With practice the patient can learn to use the oscillator switch to differentiate voiced and unvoiced speech sounds (Luchsinger, 1965). Snidecor (1968) says "The instrument has good intelligibility and a minimum of extranneous noise". All in all, the oral vibrator is relatively inconspiquos and a very promising development, but some would object to the use of wires that dangle from the mouth.

Luchsinger (1965) describes a further development of this by Pichler (1961), which was necessiated to overcome the objeotionable need for wires leading into mouth. Pichler (1961) has constructed a wireless speech aid. It consists of a microtransmitter loop worn under the patient's clothing. A 'speech contact' plug, built into the tracheal tube, serves as an impulse generator. The impulse waves are received in a miniature loud speaker, housed in an artificial denture over the upper jaw, which emits the audible sound waves. The essentially new goal of the device is to use the inborn phonorespiartory reflexes for the control of artificial phonation. The advantages of this artificial larynx has been listed by Luchsinger (1965). They are:

1) it is completely inconapiquos
2) it requires no manual operation;
3) it transmits the normal rhythm of speech and
4.) since it is devoid of mechanical parts, that have to be inserted into the mouth, it does not disturb the articulation

of consonants.

However, he has admitted that further technical improvements are necessary before the apparatus will be ready for standardized, production.

Then comes the highly debatable question of which mode of rehabilitation is more effective; esophageal speech or artificial larynx. Some of the factors which impede the development of esophageal speech have been discussed earlier. Usually in those situations, esophageal speech is not recommended. Now we shall see how effective esophageal speech will be.

Greene (1964) says "The esophageal speaker can become so fluent that strangers do not realize the true nature of the disability and may ask whether the patient has cold or laryngitis. This is a tribute indeed to the naturalness of the voice which upto this time no artificial larynx has been able to emulate".

It seems as though Greene is exaggerating the issue, for a number of studies have shown (Damate, 1950; Snidacor & Curry, 1959; Rollin, 1967; Shipp, 1967; Curry, 1968, Snidecor & Nichols, 1968; Snidecor, 1968) that even the superior esophageal speakers lie far below than normal speakers, with respect to frequency, rate of speech (in terms of number of word3 per minute) loudness, quality of the tone etc. And according to the criteria of C.G. Berlin (1963), which are indeed very simple, no esophageal speaker will be rated as good.

One of the best measures of efficiency in speech is rate in words per minute (Snidecor, 1968). Darley (1959) established rate norms of normals for a passage. His zero percentile was represented by 129 words per minute, 50th percentile by 166 words per minute and the 100th percentile by 222 words per minute. Franks (1939) found.

that critical listeners judge rate too rapid if it exceeds 185 words per minute and too slow if it is less than 140 words per minute. A previous study by Snidecor (1955) indicated a range of 108-137 words/minute with a median rate of 122.5 words per minute. Thus no speaker in this earlier study exceed Darley's 5th percentile and no speaker would be judged as adequately rapid by the Franke norms. The results of the Snideoor's study are shown in Table II. From this it is evident that only one speaker could achieve a rate of 153 words per minute (15th percentile) of Barley's study and within the limits of the satisfactory rate by Franke norms). Snidecor (1967) has also shown that speakers could often Speak as many words on one breath as normal speakers and more words than could the esophageal speaker on one breath stream.

TABLE II
GENERAL TEMPORAL RELATIONSHIPS
Esophageal Speakers

	1 M.W.	2 A	3 C	3 M	4 P	2 V	Normal speaker
1. Words/min	152	128	80	122	96	122	140-185
2. Syllables/min	210	183	117	168	147	168	203-265
3. Ratio of phonated to total time (%)	50.8	47.0	39.5	38.4	44.0	57.4	60-75
4. Count with one air-charge of breath	14	na**	na	na	na	na	40 est.
5. Duration of /a/ range (sec)	1.16 4.25	na	na	na	na	na	12.3-59.0
6. Duration of /a/mean of 10-12 trails(seo)	3.70	na	na	na	na	na	25.7
7 Repetition of /ba/	14						70 est.
8. Repetition of /ma/	15						70 ast.

* This and other folloiwing numerals on the horizontal represent the average rating of the esophageal speakers.

** Not available.

The ratio of phonated time to total time gives some measure of vocal efficiency. If the speaker has many or long pauses, his speech either will be unduly staccato or hesitant, thus distracting from the meaning (Snideoor, 1968). According to Black (1942) Hanley (1951) and Snideoor (1944) normal speakers phonate from 60 to 75 percent of the time during contonuos speech. The figure of 38.5 to 57.4 given in item 3, Table II is obviously well below that of normals.

The relative loudness of esophageal speech and the normal speech has been studied by Hyman (1955). His speakers included 8 who had normal voice and 8 who used esophageal speech. The peak intensity levels he reports, as approximate measure of their loudness ievels were 79 dB (normals) and 73 dB (esophageal speakers). A more recent study by Snideoor and Isshike (1965) shows that the normal speaker can sustain the vowel /a/ at the level of 95 dB, whereas only one esophageal speaker in Snidecor's study (1968) could produce the vowel /a/ at 85 dB level. Further the intensity increases and decreases for the esophageal speakers are rough (abrupt crescendos and gradual diminuendos). Van Den Berg, Moolennar-Bijl and Damste (1958) report the same value. And Nichols (1968) has shown this to be true on intensity profiles of broad band sonagrams. Evaluating the effective ness of esophageal speech, with respect to loudness, Nichols (1968) says "only the rare esophageal speaker can 'Turn UP the volume' of his voice so that he oan project to everyone in the room or in some busy place". Snidecor and Isshiki (1965) found that & normal speaker made smooth intensity changes which ranged upto 45 dB, whereas their superior esophageal speaker managed a range of 20 dB. Hyman (1955) puts this figure at 11 dB. Evaluating all these, Snidecor (1968) says "we oan see that potential intensity levels and variability are much less for the esophageal speaker than the normal speaker. The effecuency of the sound producing system, though surprisingly effective is less effective then for the normal speaker. The intensity modulating system is also less sensitive".

A Nichols (1968) concludes the issue by saying "finally consideration should be given to the relation between the actual magnitude of the voice as a function of the intelligibility. The intelligible voice need not be as loud as the unintelligible voice to be comfortable for the listener. Consequently an improvement in intelligibility may provide an apparent increase in loudness. The tendency of some speakers to finish words, sentences and phrases in a whisper, rather than charge more air behind the pseudoglottis, also has an effect on apparent loudness"(P.113). The pitch of the effective male eacphageal speaker is substantially lower than that of normal voice. Both the Damste (1958) data and Curry and Snidecor (l961) data reveal that mean frequency levels are about one octave below those for normal speakers. The Curry-Snidecor data reveals that superior esophageal speakers have a speaking range from 2.0 to 2.50 octaves with an 3D in tones of 2.30.

A spectrographic study of the esophageal voice by Arslam and Serafin (1972) showed the complete absence of regular succession of fundamentals and harmonics with a typical aspect of 'noise' even if there is a fairly regular arrangement of vocal formants.

Table III presents some physical measure of the frequency usage among alaryngeal speakers from studies of Damste (1953), Snidecor and Curry (1961), Shipp (1967) and Rollin (1967).

TABLE III

MEASUREMENTS 0F FUNDAMENTAL VOCAL FREQUENCY USAGE

	Damste (1958)	Snidecor & Curry (1961)	Shipp* (1967)	Rollin (1967)
Fundamental Frequency				
Mean(inHz)			94.38	65.6
Median (in Hz)	67.5	63.3	86.1	
SD(in tones)		2.3	2.56	
90% Range (in tones)		6.5	8.25	.
Highest frequency (in Hz)	(1357)	135.5		
Lowest frequency (in Hz)		17.2		

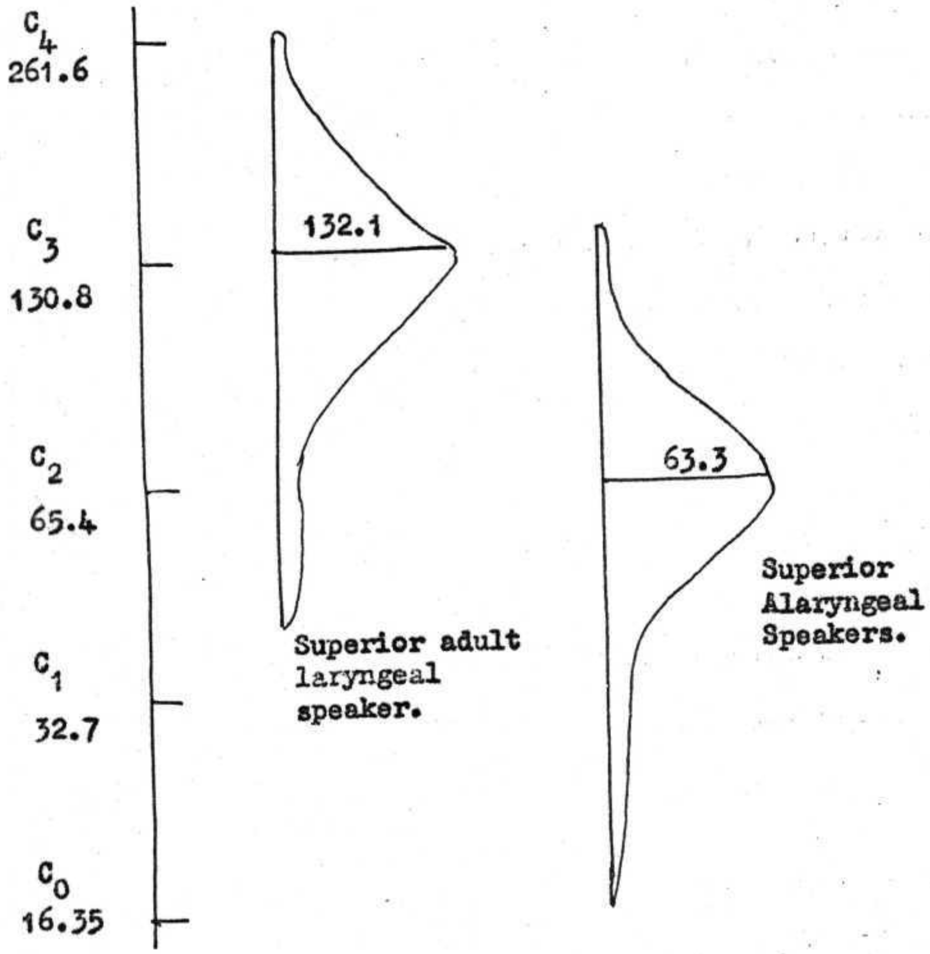
From Snidecor, 1968.

The combined data from Table III would appear to substantiate the conolusion from Snidecor& Curry (1961) that the mean froquency levels for most alaryngeal speakers is almost exactly one full octavs below the level for normal speakers. This is further evident from the Fig. 4.

Snidecor& Curry (1960) have described their experimental results with carefully selected alarygeal subjects judged to be reading a standard passage in a highly superior manner. The measurements of fundamental vocal frequency were obtained by utilising the phonophotographio technique described by Cowan (1936).

The fundamental frequency vocalizations of the alaryngaal speakers are produced in a frequency range which has special perception problems (Curry 1968). These rather obvious perceptual aspects of alaryngeal speech (that is, the 'pitch' aspects) have been considered by many authors. A passage from Van Den Berg (1954) is of particular importance. "The variations in pitch which can be produced by the patient are much United then those which caa be made in laryngeal speech.

FIGURE - 4



Distribution of frequencies measured for two groups of super speakers (From Snidecor 1968)

The reasons are obvious. In the larynx, we have a very complicated and delicate complex of muscles, which allow for compensatory mechanism, while in the pseudo larynx only one muscle is present".

With reference to quality or wave form information, spectrographic analysis of esophageal voice revealed that although the voice contains a noise component upto a high frequency region (6000 Hz), the harmonic components are still clear and easily distinguished from each other. When the voice is high in pitchy the noise component is relatively great and the pitch is unstable as noted in irregular 'vertical atraitions' of a wide band sonagram (Snidecor, 1968).

The voices of esophageal speakers are often hoarae, and they are frequently thought to have cold (Greene, 1968; Shrynek, 1957; Nichols 1968). Nichols (1968) has developed voice quality ratings of the Asai and esophageal voices, using paddock scales.

TABLE IV

VOICE QUALITY RATINGS FOR SPEAKERS USING THE ASAI ESOPHAGEAL VOICES.

	(Paddock scales) Harshness.	Breathiness	Hoarseness
Asai speakers:			
Male:			
one month	4.9	2.9	5.5
Three months	5.7	5.1	6.3
Four months	5.3	6.5	6.7
Female	6.1	6.5	6.6
Esophageal Speakers:			
Male 2 Beginner	6.3	2.0	6.7
Male 3 beginner	6.8	2.3	6.9
Male 4 Good	6.1	3.1	6.5
Male 5 good	6.3	2.9	6.8

From Snidecor, 1968.

From the Table IV it is evident that harshness ratings indicate a better vocal quality for the Asai voice. The hoarseness ratinga do not show clear cut differences. However, most striking is the fact of the growth of the breathineas ratinga for the male Asai speakers, over the months in which he has acquiring control over his voice and the female speakers breathineaa (Nichols,1968).

Niohols (1968) concludes by saying 'in a general senae, references to effectiveness have some relavance to the topic of voice quality. For example, Levin (1940) says that 'The quality of speech depends upon early training after the operation".

Coming to the effectiveness of artificial larynx, it is interesting to review the results of Hyman's (1955) study. He found, in comparing the voices of the artificial larynx, and esophageal speakers, that the artificial larynx speakers were always preferred. This study indicates that acoustically speeoh production by means of the artificial larynx was preferred over esophageal speech. Hyman says 'there is probably no significant difference in intelligibility between good speakers who employ the artificial larynx and esophageal speech'.

Hyman's study showed that the reed type artificial larynx was often louder than the normal voice under controlled conditions. However, according to Nichols, with the eleoctrolarynx, loudness is a matter of adjusting the power to an adequate level or trying a more powerful instrument. Barney, Haworth and Dunn (1959) studied this problem at length. The loudness of the artificial larynx they developed was felt adequate for conversational purposes although in situations in which the normal speaker would increase his intensit;

they advised that the speaker move closer to his listener. The vowel peaks with this instrument was 70 to 75 dB at a distance of three feet from the speakers mouth.

The loudness of the esophageal speech is so low sometimes that amplification becomes necessary (Greene and Watson, 1967) Bird H.M. 1965). Bird's amplification system includes a amplifier-loudspeaker unit. Greene and Watson (1967) say that all esophageal speakers will find amplification useful.

Greene (1967) reports that artificial larynges should be tried by a client for each speaker has different needs. She writes 'after extensive experimentation we retain the WE Type 5, the Aurex Neovox and the Dutch DSP 8, By far the most successful and popular is the Aurex".

Nichols (1968) is of the opinion that probably in terms of the general effectiveness of the voice the artificial larynx is so considerably derogated in the literature. Further he continues "A Common theme is the monotonous, meochanical, metallic voice produoed by the reed type instrument. Electronic larynges produoed in the 1960's have considerably better timbre. However, the monotony remains in most instruments; in others, the buzz of the carrier frequency may detract from the quality and may mask the speech of the user".

Saku Y (1954), by means of a frequency analyzer, made comparative studies of normal and artificial larynx speech and concluded that "these showed reductions in overtones in the speech of the artificial larynx, as well as indistinctiveness from the formants". The author believes that this may be one of the reasons that voice with the artificial larynx is not clear and sounds like a monotone.

The experiments of the Barney, Haworth and Dunn (1959) show that the introduction of tha vocal source into the articulatory system in the pharynx produces & batter voice than the same source introduced into the oral cavity. They uae this evidence to justify the use of the throat tissue vibration principle in the WE Type 5 electric larynx. A atudy by Wallaoh (1960) confirmed that a throat vibrator artificial larynx, an Aurex compact, was both more intelligible and more preferred', than a mouth vibrator, a Cooper Rand electro larynx. However, WE type 5 was not included in this comparison. Greene's (1967) report of the clinically established preferenoe for the Aurex Neovox, a throat vibrator, has already bsen mentioned. Barney, Haworth and Dunn (1959) did a series of comparisons between vowels produced by speakers using his normal voice and while using the artificial larynx. Certain of the vowels had too much power in the upper harmonics, others too little. The experimenters concluded that the spectrum of the vibrator was, on the average, adequate as a source of harmonica of vowel production.

Schonaurl (1962) says that the limitations of WE Type 5 artificial larynx are due to the reduction of the 'resonance cavity' because of the anatomical alterations following surgery, the thickness of the external layer of the neck, an uneven surface for the application of the sound head and the limit of loudness.

Hyman's (1955) study of the esophageal speech and air driven artificial larynx deals at seven point with listener preferences. In a series of paired comparisons, the artificial speakers were chosen as 'more pleasant to listen to' then the esophageal speakers, in every case. However, the judgement of the quality, may logically depend upon the criteria, other than the perception of quality per se. For example, it has been found by McCrowsky and Mulligan(1963) that the artificial larynx is more intelligible than esophageal speech to the naive listeners. The opposite was true for listeners who had training in speech rehabilitation (Speech Pathologists and students in training). The latter result was also noted by Shames, Font and. Mathwes (1963).

Taking all of the factors into consideration, i.e., loudness, quality, intelligibility etc., it can be said that the artificial larynx is a more effective mode of communication than eaophageal speech. One failure of the artificial larynx is the failure to produce the harmonic atructures of all vowels. Snidecor (1968) says "along with the overoptimism for the development of the esophageal speech, there developed an unwarranted critical attitude toward the artificial larynx".

Those who advocate esophageal apeech, claim that it has a better voice quality than the artificial larynx (Greene, 1964; Luchainger, 1965; Van Riper and Irwin, 1966; Snidecor, et. al., 1968) Further they think that the use of this instrument is an unnecessary crutch and interferes with the development of esophageal speech. Hymen (1955) says that people who start out with artificial larynx will generally be poor speakers. Here it is interesting to see Greene's statement: "The advantages of esophageal speech are so great that every patient must be encouraged to persevere for some months in learning the new skill before giving up the attempt".

Broadnitz (1962) asks therapists not to recommend an artificial larynx until we are sure that the patient can not learn eaophageal speech. He says early introduction of the artificial larynx diminishes the motivation of the patient to learn eaophageal voice. Furr (1968) agrees with Broadnitz.

Edelman (1967) also recommends that artificial larynx should not be introduced during the immedite post operative period. The reasons he gives are that the pattern of air intake is not the same indeed for esophageal speech and if the greater part of the communication efforts are dependent on a button instead of on the oo-ordinated movements of the oral musculature, that person will establish bad habit patterns for voice production which are opposed to those needed for esophageal voice.

Those who oppose the use of artificial larynx assert that the instrument has too many limitations, not the least of which is the unacceptable sound it makes.

The factors which impede in the development of esophageal speech have been discussed earlier (Page). And also it is known that many laryngactomee's do not learn esophageal speech. Usually in these situations an artificial larynx is recommended.

In a recent study of 3366 laryngectomees, Horn found that only 64% spoke with esophageal speech. Gardner and Harris (1961) reported that 40% of all laryngeotomees never acquire intelligible speech and an artificial aid should be recommended for them. Putney (1953) found in a survey of 446 laryngectomees that 38% failed to develop an useful voice. Martin (1963) says "Despite optimistic claims (sometimes as high as 80%), I would estimate that less than 1/2 of all laryngeotomees ever acquire a reasonably adequate and socially acceptable esophageal voice, that i3, better than'indiffierent", "poor", 'offensive' or 'absent'.

Lueders (1956) maintains that approximately 1/3 of all patients do not loam to speak and that based en his judgement of some patients who consider themselves able esophageal speakers, the proficiency of the remaining 2/3 might be questioned.

Kallen (1934) reports of the acute depression which often interferes with speech progress."A pathologic reactive depression is the usual sequela to the doctor's dictum that the larynx is cancerous and that it has to be removed at once: and that natural speech will no longer be possible". (Heaver and Arnold, 1962: as quoted in Greene, 1964). And even after the operation, when the patient can't speak, however effective our counseling may be, this depression will persist. For this reason Heaver & Arnold (1962) advocate the use of artificial larynx until the esophageal voice is mastered. Lueders (1956) states further: "The psychological importance of an early return or communicative ability should be considered, speech being the most important social function, should be restored to the patient as soon as possible. The psychological effect of enforced silence during a protracted learning period for the esophageal speech is the building up of resentments and frustrations that tend to make the patient uncooperative. It is perhaps better to offer him the help of electrolarynx, with which he can atleast satisfy his all important sense of speech". Another paragraph from Lauder (1968) is interesting: "Many speech pathologists, physicians, laryngectomees and paramedical specialists claim that the early economic balance is a necessity for the new laryngectomees; that esophageal speech can be developed later when the patient has recovered from this traumatic experience". They assert that the instrument is much more understandable then the esophageal voice and it enables the user to communicate much sooner and more effectively, particularly in situations involving emotional stress or more volume then is normally possible with esophageal voice is required.

In a questionaire study De Beule and Damste (1972) have shown that 50% of the laryngectomees learnt speaking through an artificial larynx. They also say that only 5% of the artificial larynx speakers did not learn to speak with it.

In comparing esophageal speech with eleotro larynx speech, Martin (1963) asserted that the eleotrolarynx voice tends to be of uniform quality; that it is far rasping in tone than many otherwise acceptable esophageal voices and furthermore, that it always devoid of intake burps, facial grimaces and concomitant forced expulsion of air from the stoma. Martin (1963) claims that even the best esophageal voice is monotonous and somewhat hoarse. He also has a difinite opinion as to when the electrolarynx should be introduced to the laryngeotomee. He states "furthermore, contrary to the pronouncement of many esophageal voice teachers, resorting to such a device promptly after operation, in my experience, does not preclude or discourage the patient from latter efforts to the attainment of esophageal speech, nor does it lessen the chance of ultimate success in that endeavor. It can serve, however, as a stop-gap, in all the cases and give the laryngectomee an unprejudiced eventual choice between the two methods. Also it makes it possible that use of either one as a supplement to the other, depending upon the requirement of tha occasion. Elimination of any unnecessary delay in aohieving a practical means of communication transcends any and all other considerations".

No research has yet shown that an artificial larynx precludes or slows down thelearning of esophageal speech (Diedrich, 1966; Grant, 1963: as reported in Lauder 1968). Further Diedrich (1966) continues: "it might show that the artificial larynx as a means of communication, the clinician should feel rewarded that he has provided a means by this was accomplished and not feel guilty that ho was unable to teach tha person esophageal speech. It was a decision for the client to make, not the clinician". And the advocates of the artificial larynx claim that the use of the artificial larynx need not interfere with the development of the esophageal speech, so long as the patient's teacher perseveres in teaching tha proper technique for esophageal voice.

Diedrich (1966) says that articulation skill is an additional speech benefit which might occur from the use of the artificial larynx during the immediate post-operative period. The user of the artificial larynx must articulate precisely or the speech will be unintelligible. He must learn, for example, to make voiceless consonant sounds with intrapharyngeal air pressure and not with pulmonary air. Tho learner of esophageal phonation must also learn to articulate voiceless sounds in a like manner. Clinical observation indicates that the laryngeotomees learn to articulate well if they had successfully used the artificial larynx before acquiring esophageal speech.

Another secondary benefit of good articulation ia its influence on air intake precision in articulation. This movement aids in the injection process especially during the syllable pulse of plosives and sibilants, Because of these possible speech gains through the use of the artificial larynx, it is suggested that the esophageal speech learning period can bo shortened, not lengthened. (Diedrich 1966).

Laupher (1968) says that artificial larynx is no deterrent to the learning of effective esophageal speech. In fact it may be an aid in as much as it permits the person to keep his communication alive, to return sooner to his job: it helps keep his morable high and tension low and this helps establish a favourable climate for learning esophageal speach.

Summers (1973) says that electrolarynx can also bo beneficial and useful for thosa patients who have temporary tracheostomies, in whom the primary problem is the inability to phonate.

The entire subject was summarized by Diedrich & Youngstorm (1966) who say: "The philosophy with which the speech clinician should maintain does not appear to simple division between esophageal speech or artificial larynx. They are not mutually exclusive. The question is not which method is better, but which methods are best, not only for any given patient but also for any given time, within the rehabilitation time. What may be appropriate just after surgery may not be appropriate in a ysar; what is adequate speech at home may not be adequate at work. Also the clinician's method of choice may not be in harmony with the wishes of the patient. Herein, he has a professional ethic which should not be ignored - the patient must have freedom of choice after he has been provided with the best available information about his problem".

Pitch plays a very important role in speech. There is a great amount of variation of pitch from individual to individual. However, in the gamut of pitch scales of each individual subject there ia one level atleast (usually 2 in adult males) at which the chambers of mouth, throat and chest have a relatively high potential, for the resonance of the laryngeal tone. That is, there is a pitch level at which the individual phonate most efficiently and makes tha loudest tone possible, with the least expenditure of energy - a pitch at which the greater amount of energy carried in the air column is transmitted into sound waves (West 1968).

Apart from this the individual uses his own pitch level which is known as habitual pitoh level,makes considerable variations from this general level, which breaks the monotony of the speech and also gives the intended emotional as well as cannotative meaning, if it is used property.

According to Wolbert, variation in pitoh in speech are mainly instrumental in the expression of logical aspect of meaning. They also contribute; signifioantly in the expression of emotional meaning. Lynch found by experimentation that both experienced and the inexperienced speakers use the widest inflections for anger and the narrowest for grief.

According to Fry, for the comprehension of speech, not only discrimination of consonants are neoessary, but also cues like stress and inflectional patterns, the melody of the language are neoessary, which are compared against the fixed patterns that have been learned. Stress, intonation and inflection are the words which denote the variations in pitch continued with the other attributes of voice like loudness and time.

Wincle (Reported in Greene 1964) has shown that stress in speech is dependent upon increase in breath force or a fuller use of resonance. Inflection ia accompanied by minute adjustments in lengths or tension of the folds which produce expressive pitch glides. The moaning of speech is utterly dependent upon tho factors of stress, pitch or pace, which are conceived intellectually as a rhythmic quence of events or coherence of what would otherwise be the utterence of a disconnected series of vowels and consonants.

Fairbanks defining intonation and stress in the light of the knowledge gained in the acoustic laboratory states that intonation is an exclusive term referring to pitch as a function of time and may be applied to a simple inflection or tolong term variations in phrases over numerous inflectional shifts (Greene, 1968). Fairbanks in defining rhythm in speech as a 'pattern of vocal change', says that 'it is inherent in speech to be rhythmatic' or draws attention to the need for regular ventilation or breathing pattern which underlie pause, stress, rate, pitch or intensity. Accent refers to the relative stress on syllable in a word. Accent also plays an important role in speech.

"One of the most important and most conspiquos characteristic of speech is the voice quality of the speaker" (Nataraja, 1972). When the voice becomes disordered the implication to communication is immense. The abnormal voice can be a serious handicap and embarassment to the speaker, if he is aware of the effects on the listener. More than this the vocal hygiene of the patient will be disturbed. Perkins (1971) while evaluating optimum phonation says that the dominant criteria for the Speech Pathologist is vocal hygiene.

"Most of the therapies of voice disorders are based on the belief that a person has an optimum pitch, at which the voice will be of a good quality and will have maximum intensity with minimum expenditure on energy and they concern mainly with altering the habitual pitch level or making the patient to use optimum pitch". (N.P. Nataraja, 1972).

Shantha (1973) in her study of treating the voice disorders by the Isochronal Tone Stimulation Technique found that this technique was effective with a majority of voico disorders. By changing the pitch and by providing optimum frequency she could treat voice problems such as 'puberphonia', 'nasality', 'hoarseness' etc

The instruments which Shantha used in this technique were a Beat Frequency Oscillator and the vibrator of the WE Type 5A artificial larynx. The vibrator was kept at the neck region tuned to the case's optimum frequency first. They were asked to match their voice to the frequency of the vibrator. Next the vibrator frequency was changed toward optimum frequency, step by step, following the progressive approximation technique. During the matching procedure cases were guided by the appearances and disappearances of beats, i.e., when the laryngeal tone and the tone through the vibrator differed slightly (within 10 cps) they resulted in beats. The cases were instructed first to match for the disappearances of beats, thus achieving the desired frequency at each stage till the optimum frequency of the case was achieved.

Since the Beat Frequency Oscillator is a very costly instrument and not easily obtainable a substitute for this to feed the tones through the vibrator becomes essential. For this it is hoped that, a variable frequency artificial larynx, the development of which this study aims, can be used.

Here it is aimed to develop a variable frequency artificial larynx, so that depending upon the optimum frequency of the individual patient the frequency of the artificial larynx can be changed and thus the patient can be given the optimum frequency and the needed harmonics to bring about the inflectional patterns found in normal speech. Hataraja (1972) has developed a method of locating tha optimum frequency objectively, where he defined optimum frequency operationally as the fundamental frequency of tho voice, which elicits tho maximum response of the vocal tract. Aa Perkins (1971) states the main goal of Speech Pathologists is to maintain vocal hygiene. Host of the times maximum realisation of tha acoustical and esthetic goals is achieved when the voice is produced efficiently, therefore effectively, therefore hygienically - (Perkins 1971). Perkins (1971) continues: The specification of the optimal function is quite different fron the specification of the normal; optimum is boat, normal is average. Thus the clinician by giving the optimum frequency is making the case to use the best voice, which is hygienic to his vocal mechanism (N.P. Nataraja and H.Jayarama, 1974)

CHAPTER III

METHODOLOGY

The aim of the study was to develop a variable frequency artificial larynx with a pitch range of 50 to 350 Hz. It was also intended to provide provision for ohanging the output intensity of the artificial larynx.

The Block Diagram of such an artificial larynx is shown in Figure.5.

TEST ROOM;

All the experiments were carried out in the Electronics Laboratory of the All India Institute of Speech & Hearing. Frequency and intensity measurements and recordings were carried out in the Electro acoustic room, a room which is an ordinary room set apart for such work and equipped for such work.

EXPERIMENT - 1

STUDYING THE INFLECTION PATTERNS IN NORMALS:

Five good speakers wore selected from the population of the Institute (those who had experience in dramas as actors and those who were using optimum frequency). Good speakers were selected, because it was assumed that they would have good intonation patterns The age range of the subjects selected were from 21 to 35 years.

The instruments used were:

1. Condenser microphone
2. Sound pressure level meter with an octave filter set
3. Stroboscope
4. Tacho Unit.

These instruments were arranged as shoen in Figure 6

FIGURE 5: BLOCK DIAGRAM OF THE VARIABLE FREQUENCY ARTIFICIAL LARYNX DEVELOPED

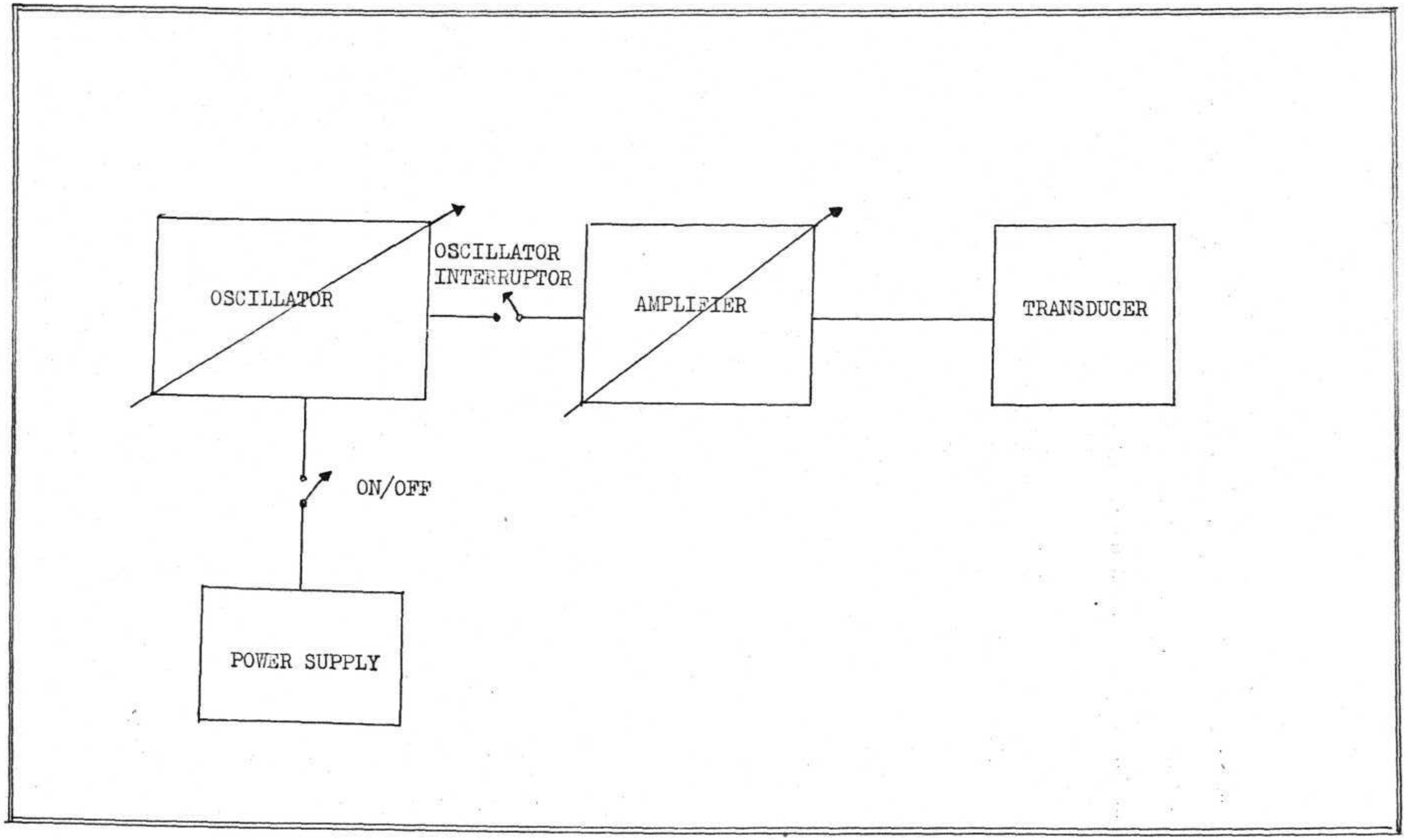
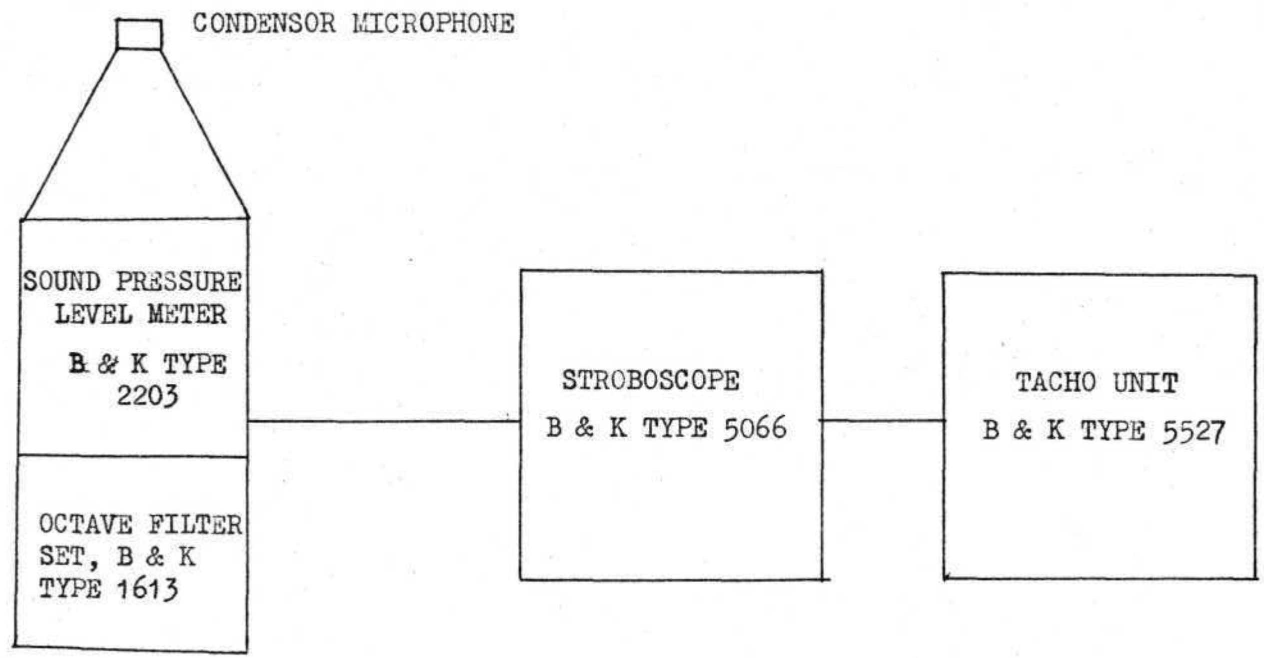


FIGURE 6: SCHEMATIC ARRANGEMENT OF THE INSTRUMENTS USED FOR FINDING THE SPEAKING FUNDAMENTAL FREQUENCY



Three sentences were selected. The sentences selected were all marked with respect to pitch levels. For example,

naa mane gho kti:ni

1. Low pitch level
2. Normal pitch
3. High pitch level

. Falling pitch

. Rising pitch

The sentences selected were;

1.naa.:mane:ghokti:ni.

2. adu: bahala chennāāgide

3. ni bengal rige h gti:yāā

As the speaking fundamantal frequency could not be measured using the available instruments, it was planned to measure the frequency at the beginning, medial and final positions of the sentence, as the subjects were asked to prolong the vowels. The corresponding frequencies were measured directly on the Tacho unit.

This experiment was carried out to have an idea of how much of frequency variation from the level of optimum frequency should be made to convey the given meaning and also how much of frequency range should be provided in the artificial larynx.

EXPERIMENT 2

CONSTRUCTION OF A VARIABLE FREQUENCY ARTIFICIAL LARYNX:

A) Sound Source & the Variable Frequency Oscillator:

In the present study, a sinusoidal wave which equals the optimum frequency of the case is selected as a sound source. The sinusoidal wave consists of higher harmonics to obtain the quality of normal speech.

The varuiable frequency oscillator concists or a simple Hartley oscillator circuit. The frequency variation is achieved by simple circuit modification. The higher harmonics were obtained by modifying the negative bias. The stability of the oscillator frequency is achieved by Using appropriate ratio of R1 and R2. The circuit diagram of the oscillator is shown in Figure 7. The frequency range of the osoillator is 50 to 350 Hz. The output of the oscillator over the entire range was measured by using a AC Milli Volt Meter, Philips type GM 6012.

The oscillator output characteristics for different frequencies (Harmonics) were measured by using AF Analyzer, Bruel and Kjaer, Type 2107 and Level Recorder, Brual and Kjaer, Type 2305.

Oscillator Interruptor:

A power interruptor was introduced in the oscillator circuit to stop tho power to the circuit.

Frequency Analysis:

The oscillator output, for different frequencies was fed to an AF Analyzer as a direct input. The AF Analyzer was connected to the Level Recorder by means of a flexible shaft for automatic analysis. The output of the AF analyzer was fed to the Level Recorder (See Figure 8). After making the preliminary adjustments, the signal was analysed in the following bands:

20 Hz to 63 Hz
63 Hz to 200 Hz
200 Hz to 630 Hz
630 Hz to 2000 Hz
2000 Hz to 6300 Hz

Tho frequency analysis recording was obtained on the recording

FIGURE 7 : CIRCUIT DIAGRAM OF THE VARIABLE FREQUENCY OSCILLATOR DEVELOPED

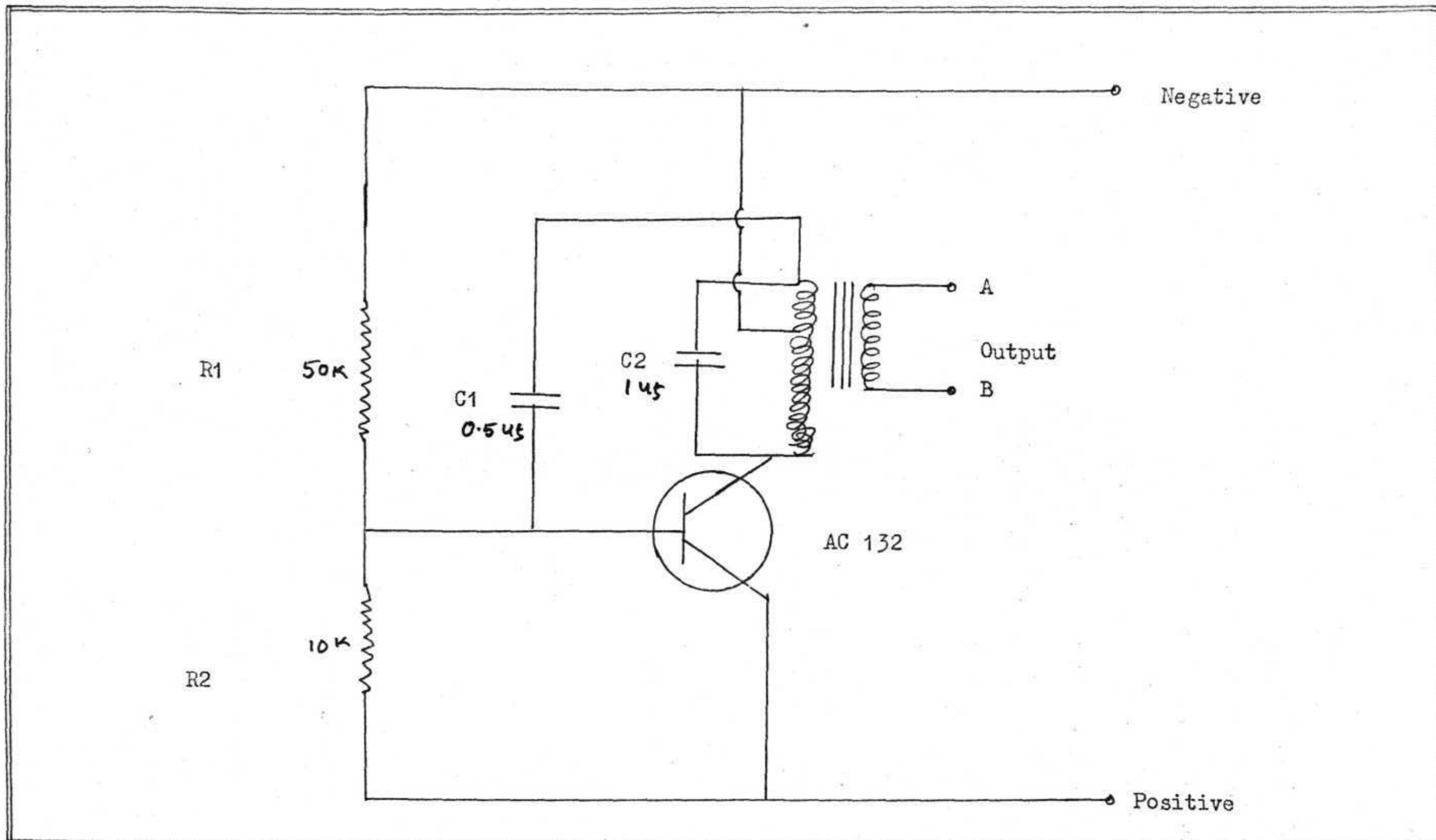
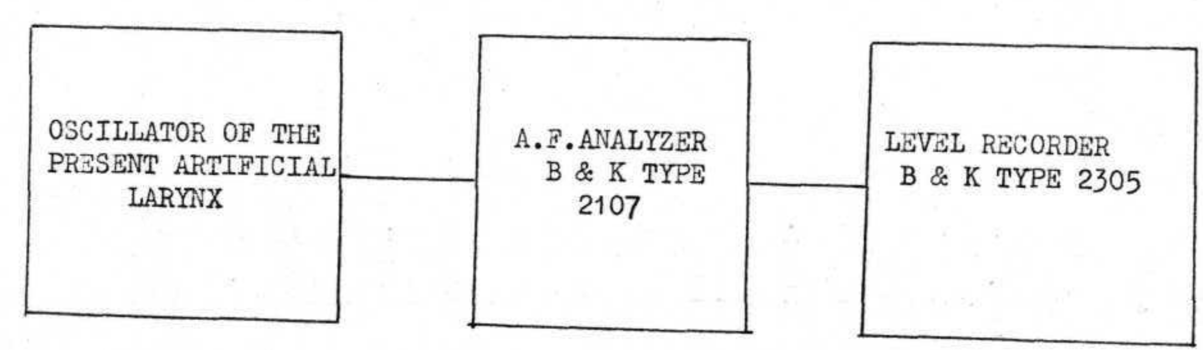


FIGURE 8: SCHEMATIC ARRANGEMENT OF THE INSTRUMENTS USED FOR THE FREQUENCY ANALYSIS OF THE VARIABLE FREQUENCY OSCILLATOR



paper of the level recorder.

Frequency analysis of the acoustio output of the transducer used in the present study was also analyzed as described above. Here the output of the transducer at different frequencies were fed to the AP Analyzer (Type 2107) through a condenser microphone, keeping the transducer at a constant distance from the condensor microphone. As above, the signal was analyzed in five bands, from 20 Hz to 6300 Hz.

The frequency analysis of the output of the WE Type 5A artificial larynx transducer using that circuit was done in two ways.

1. Feeding a oonstant frequency signal of 125 Hz from the Beat Frequency Oscillator.
2. The actual osoillator output of the WE Type 5A artificial larynx, keeping the pitch control knob at the minimum and the maximum positions. The frequency analysis was done in the same way as above.

Also frequency analysis of the normal human voioe, when the subject phonated /a/ was carried out as described above. First his optimum frequency was found out and the subject was asked to phonate at that level keeping the intensity constant aa far as possible. The tacho unit was used as a clue in maintaining the same pitch level.

In a similar way the frequenoy analysis of the transducer output was carriad out. The same subject selected in the above experiment was selected again. The frequency of the present artificial larynx was fixed at the optimum value of the subject and the transducer output was resonated through the vocal tract in the vowel /a/ position. The results were analyzed.

B) Amplifier Circuit:

The amplifier circuit used to drive the transducer consists of two stages:

1) Voltage amplifier, and
2) Power amplifier.

The voltage amplifier consists of a single transformer coupled amplifier. The power amplifier oonsists of a single stage power transistor circuit. The voltage and the power amplifiers are coupled through a potentiometer to control the intensity of the transducer. The transducer is directly connected to the collector circuit of the poster transistor. The circuit diagram of the amplifier developed is shown in Figure:9.

The amplifier is directly coupled with the oscillator circuit (Refer: Figure 10).

The frequency and power characteristics of the amplifier were measured by using the AF Watt Meter, Radart Type 930-A, AF Generator Philips TypeGM 2308. The arrangements of instruments to measure the frequency and power characteristics of the amplifier developed is shown in the Figure 11.

A constant voltage of 0.1 volts, for range of frequencies 50 Hz to 4 K Hz, from the AF Generator waa fed as input to the amplifier. The gain control of the amplifier was placed little above middle value. The output of the amplifier was fed to the AF Watt Meter and the power output was obtained for different frequencies.

The power consumption of the whole circuit (both oscillator & amplifier) was measured using 2 multi-meters (Goerz Electronics, Unigor Type 4P).

FIGURE 9 : CIRCUIT DIAGRAM OF THE AMPLIFIER DEVELOPED TO BE COUPLED WITH THE VARIABLE FREQUENCY OSCILLATOR

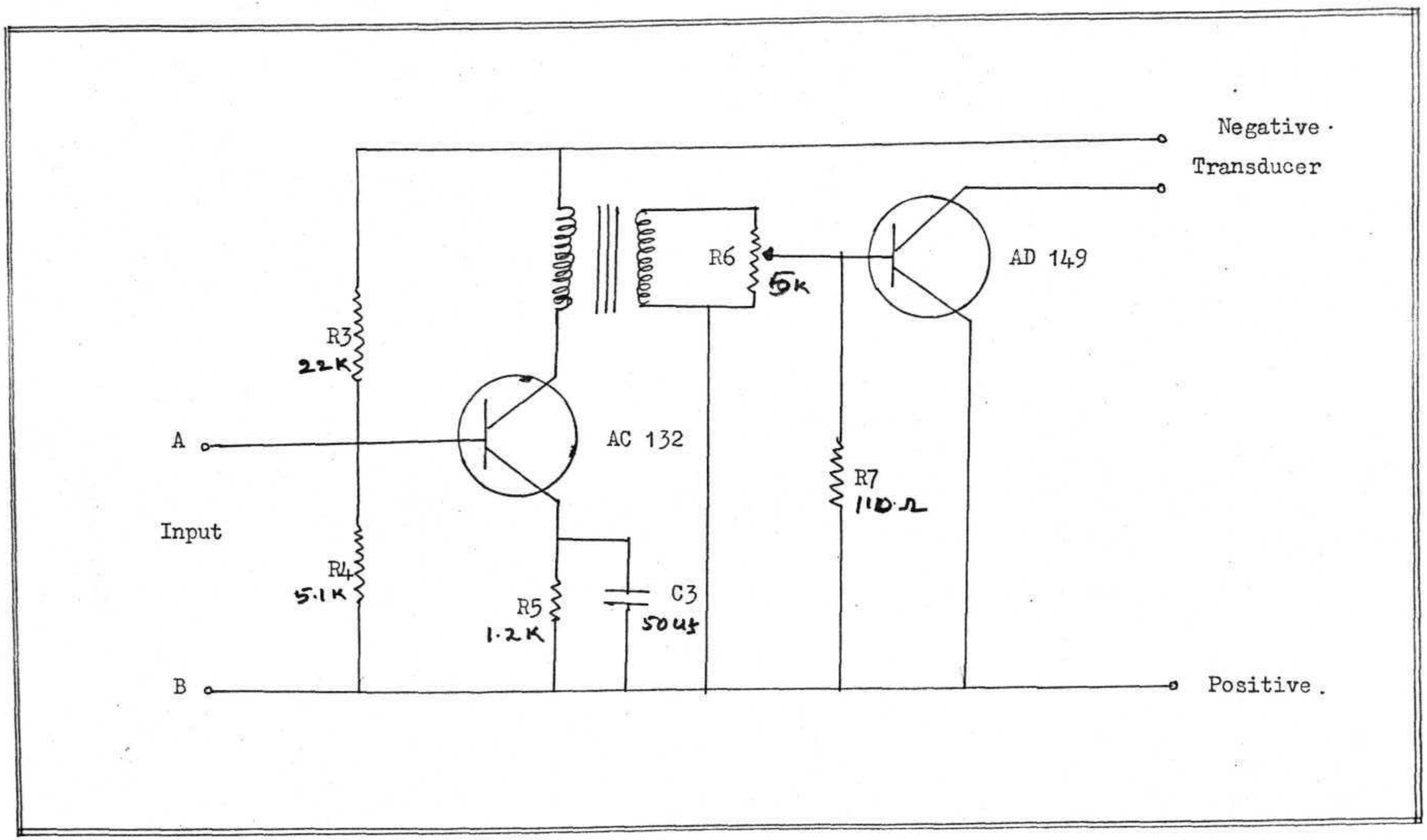


FIGURE 10 : CIRCUIT DIAGRAM OF THE VARIABLE FREQUENCY ARTIFICIAL LARYNX DEVELOPED

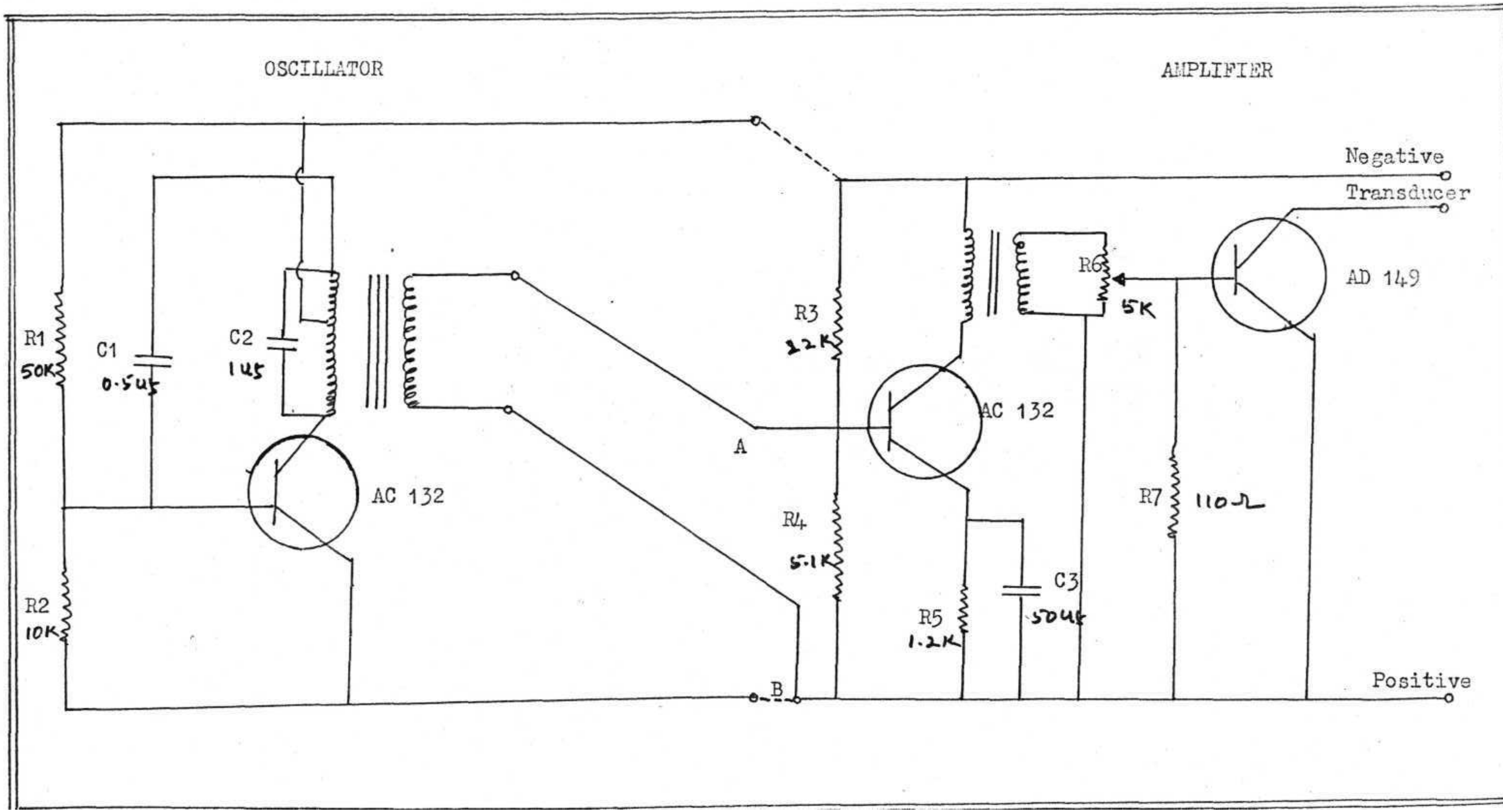
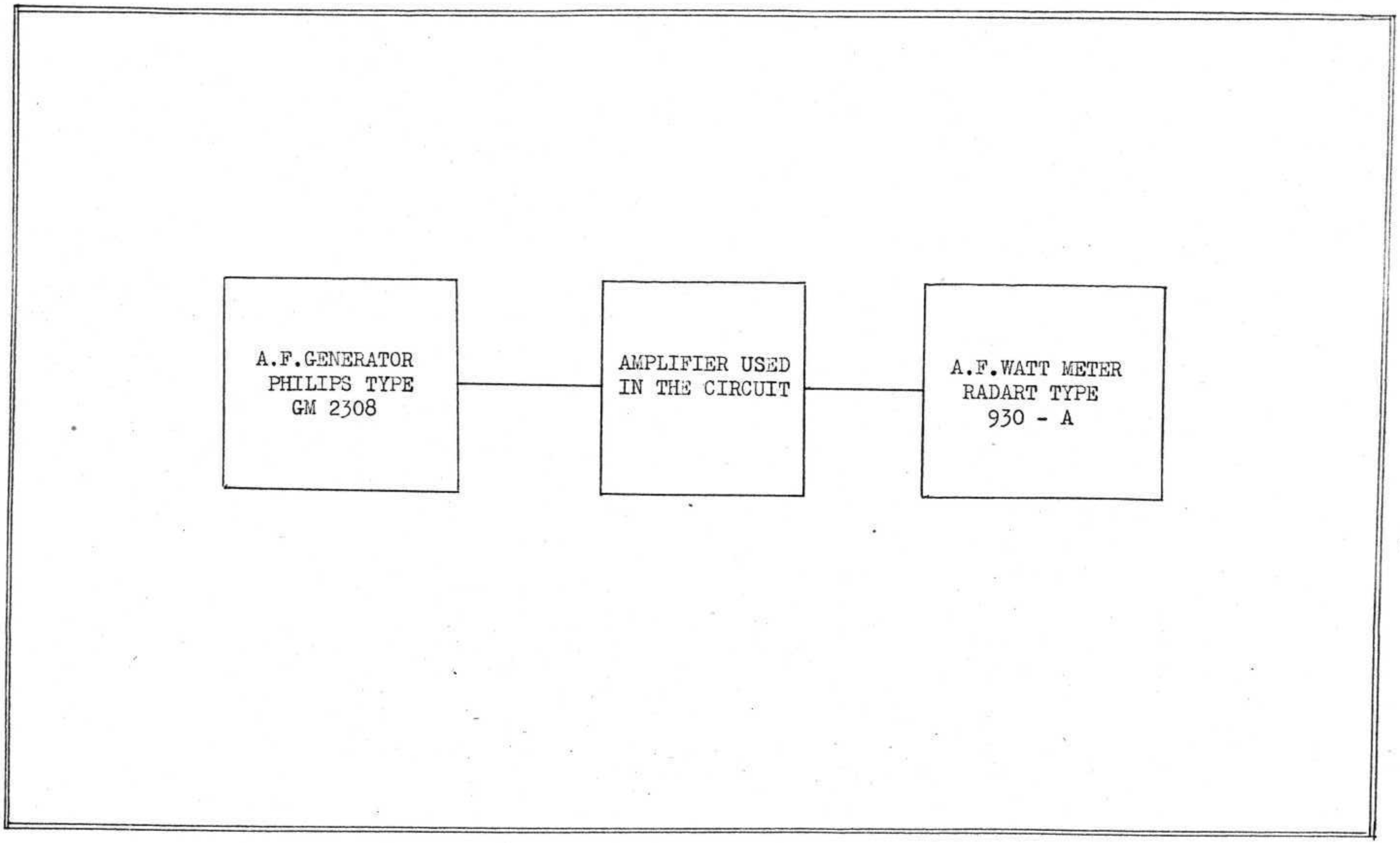


FIGURE 11: SCHEMATIC ARRANGEMENT OF THE INSTRUMENTS USED FOR THE ANALYSIS OF THE FREQUENCY AND POWER CHARACTERISTICS OF THE AMPLIFIER DEVELOPED



Intensity Control:

To control the output of the transducer, a potentiometer of 5 K ohm value was introduced in between the Voltage and power amplifier stage. This potentiomater gives linear rise and decrease in intensity.

C) Transducer:

In the present study, the transducer of the WE Larynx, Type SA, was used. This transducer handles a power of 400 milli watts. The mechanical impedance of the transducer matches with the impedence of the throat muscles, and also matches with the impedance of the amplifier developed.

D) Power Supply:

The D.C. Power required for the whole circuit is supplied by means of a 9 volts battery. The current drain through the circuit at the maximum was 200 milli amperes. The voltage was constant for a continuos operation of fifteen minutes. After fifteen minutes the drop in voltage was 0.1 volts, which was ineffective to the circuit in terms of quality and power output.

E) On/Off Switch:

A small on/off switch was introduced in the battery circuit to switch of tha power, whenever the instrument is not in use.

F) Mechanical Construction:

The whole oirouit was mounted on a 5 inch by 11/2" printed circuit board developed for this purpose. The printed circuit board was made taking a copper/ebonite board. The design of lay out of components was drawn on the copper side of the Board. Lines were drawn with white paint on the board where copper linings were required. Then the extra copper was dissolved by dipping the board in Forric Chloride solution. Suitable holes were made for mounting and soldering the components. Two knobs, one for ohanging the frequency and one for changing the intensity were provided. They were arranged on the body of the panel in such a way aa to enable the patient to operate the frequency knob with the thumb and the intensity variation knob with the forefinger. These two were arranged on the upper portion of the artificial larynx. Just above the frequency variation knob, on/off switch knob was provided. Below the intensity variation knob and in the lower portion of the artificial larynx, an oscillator interruptor was provided in such a way that the patient can operate it with his little finger. The panel of the artificial larynx is shown in Figure 12.

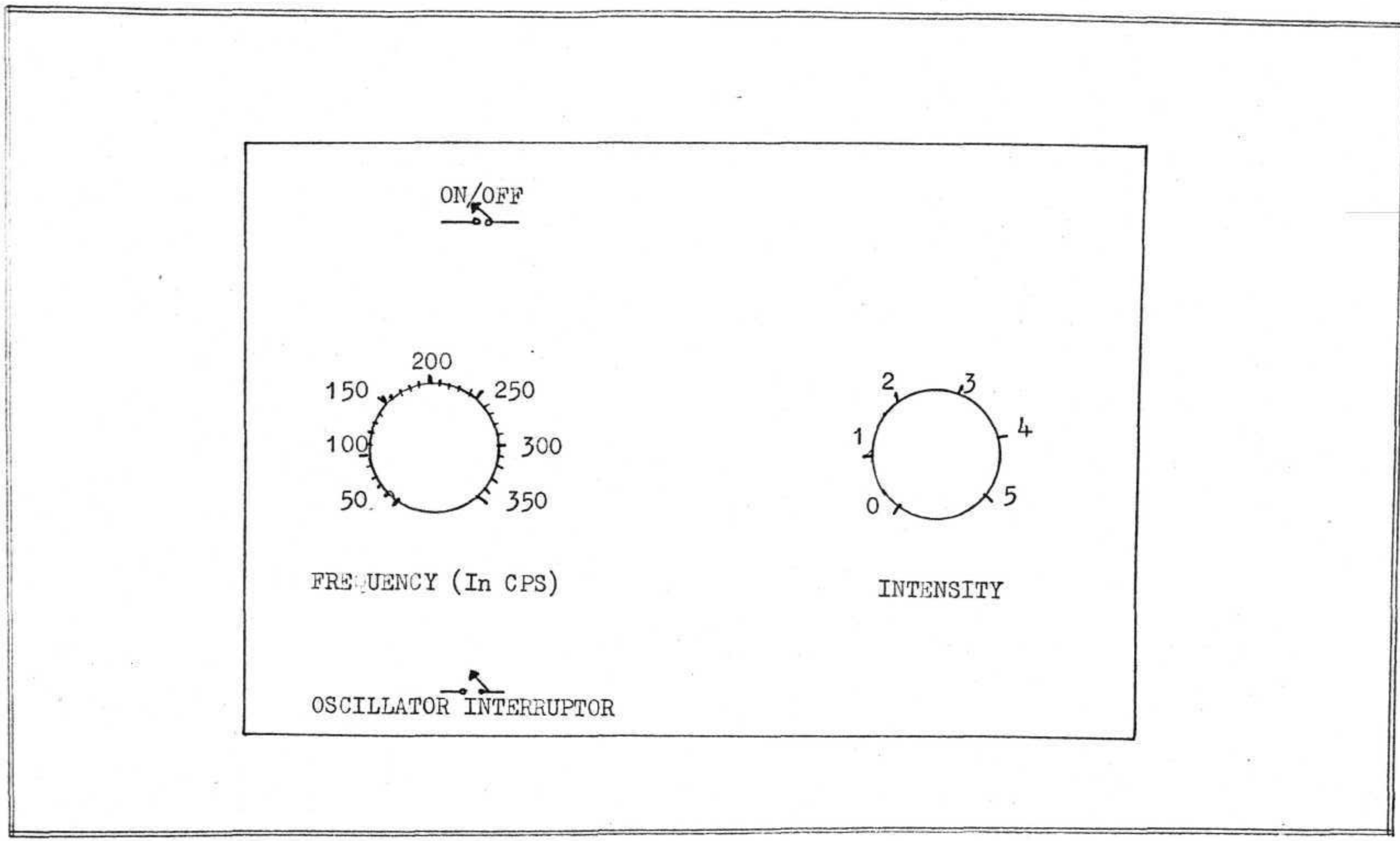
CALIBRATION OF THE FREQUENCY DIAL;

A knob with a fixed marking was connected to the shaft of the amplifier to change the frequency. Frequency valuea were marked on the body of the panel. The fixed mark on the knob ahowa the frequency of the oscillator, corresponding to the number on the body of the panel. Those markings wore made by measuring the actual frequency of the oscillator by using Frequency Counter, ITI Type 702.

CALIBRATION 0F THE INTENSITY DIAL:

The intensity dial was fixed to the same panel. The potentiometer shaft was provided with a fixed mark. Reference numbers on the panel were made with respect to the knob marking. The whole intensity range is divided into five levels on the grounds of the output of the vibrator in an open field. The intensity measurements were made by using a sound Pressure Level Meter, Brual & Kjaer, Type 2203.

FIGURE 12: PANEL OF THE ARTIFICIAL LARYNX WITH THE FREQUENCY AND INTENSITY CHANGING KNOBS



Tho intensity measurements were also made when the transducer was pressed against the throat. The intensity control was kept at the maximmn position and the condensor microphone was kept at a distance of 1 ft. The measurements wore carried out in the same way.

EXPERIMENT: 3

TRAINING NORMAL SPEAKERS TO ACHIEVE THE INTONATION PATTERN FOUND IN NORMAL SPEECH OR TO SIMULATES NORMAL SPEECH, USING THE ARTIFICIAL LARYNX

The following instrumentS wEre used:

1. Same as in experiment one.
2. Variable frequency artificial larynx (developed)

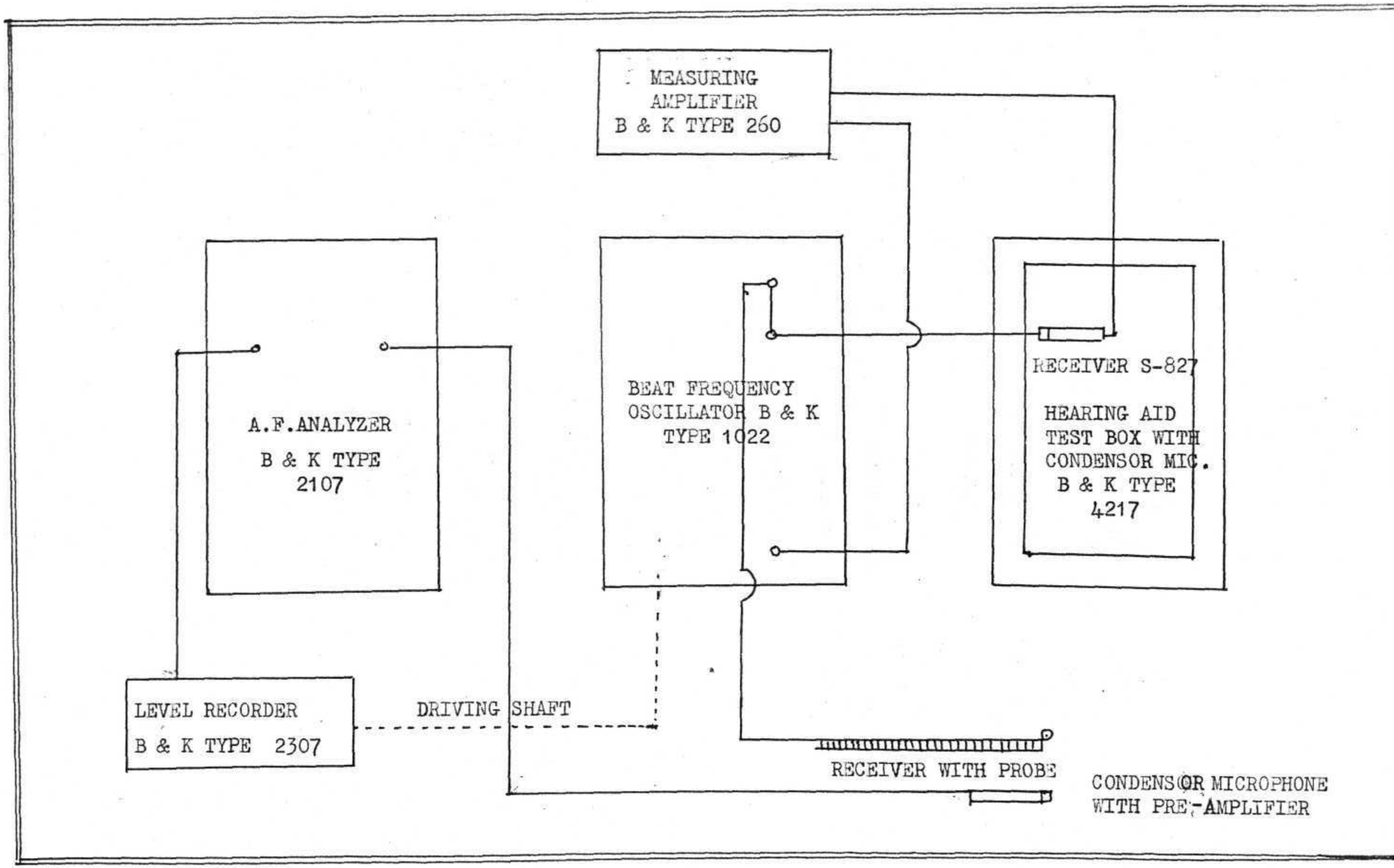
Sentences used were same aa in Experiment.1.

Five normal speakers were selected from the population of the Institute and their optimum frequencies were found out (using the method given by N.P.Uataraja, 1972,Refer Figure 13). Then the purpose and use of the different knoba of the present artificial larynx were explained to them in detail. They ware asked for any doubts they had about using the present artificial larynx.

Then the subjects were asked to dramatize the sentences seleCted in the earlier experiment, making necessary pitch variations. The speaking fundamental frequency WAS found as in experiment one.

Than the subjects were shown how to operate different knobs. Then the frequency knob was set at their optimum frequency level, and the subjects were asked to dramatize the sentences selected, using the artificial larynx, making necessary pitch variations. Tho speaking fundamental froquency, when using the artificial larynx, was found out in the same way.

FIGURE 13: SCHEMATIC ARRANGEMENT OF THE INSTRUMENTS USED FOR FINDING THE OPTIMUM FREQUENCY



EXPERIMENT 4

FINDING THE INTELLIGIBILITY OF THE SPEECH PRDUCED WITH THIS ARTIFICIAL LARYNX

Five subjects were selected from the population of the Institute. Some of them were there in the First and Third experiments also. Their optimum frequencies were found out. The output of the artificial larynx was kept at the middle value. The artificial larynx was set at that level for each subject and they were asked to speak spontaneously for two minutes, making necessary variations in frequency, from the level of the optimum frequency, and also they were asked to read a passage. At the same time the speech was recorded. The recorded material was later given to four judges who consisted of two trained Speech Pathologists to rate the intelligibility of the speech. They were asked to rate the intelligibility of speech on a. three point rating scale, in terms of 'poor', 'fair', or 'normal'.

EXPERIMENT 3

TRAINING; THE DYSPHONICS BY ISOCHRONAL TONE STIMULATION TECHNIQUE WITH THIS ARTIFICIAL LARYNX

Three cases who were coming to the Institute Clinic were selected. All of these cases were diagnosed clinically as 'high pitched voice with pitch breaks' by trained Speech Pathologists. Their optimum frequency was found out and by the Isochronal Tone Stimulation Technique (described by Shantha, Y.S., 1973) they were treated.

CHAPTER IV

In the present study the following instruments were used:

1. Condensor Microphone, Bruel & Kjaer, Type 4131
2. Sound Pressure Level Meter with Octave Filter Set, Bruel & Kjaer, Type 2203
3. Stroboscope, Bruel & Kjaer, Type 4911
4. Tacho Unit, Bruel & Kjaer, Type 5527
5. A.C. Milli Volt Meter, Philips, Type GM 6012/90
6. A.F. Analyzer, Bruel & Kjaer, Type 2107
7. Level Recorder, Bruel & Kjaer, Type 2305
8. A.F. Watt Meter, Radart Type 930-A
9. A.F. Generator, Philips, Type GM 2308
10. Frequency Counter, I.T.I. Type 702
11. Beat Frequency Oscillator, Bruel & Kjaer, Type 1022
12. Hearing Aid Test Box, Bruel & Kjaer, Typo 4217
13. Tape Recorder, Bush Type
14. Multi Meters, Unigor Type 4P. Goerz Electronics.

C0NDENSOR MICROPHONE. BRUEL & KJAER. TYPE 4131

The B & K one inch condensor microphones are designed for pre-oision sound pressure measurements. Their range of application covers the whole of the audible frequencies (20 Hz to 18 K Hz) and of pre-ssure levels (15 dB to 146 dB). Their most outstanding feature is excellent long term stability under a great range of environmental conditions and especially to their insensitivity to temparature varia-tions. They are, therefore, well suited for field measurements, though the accuracy of the calibration Hatches laboratory standard requirements.

The one inch microphones are of ths omnidirective type, with a relatively high sensitivity. They are designed for permanent exposure outside unless special precautions are taken.

This microphone always used with the SPL meter was used in the present study to measure intensity and was also Used in finding the speaking fundamental frequency and optimum frequency of the subjects.

SOUND PRESSURE LEVEL METER BRUEL & KJAER TYPE 2203 WIH AN OCTAVE: FILTER SET. BRUEL & KJAER TYPE 1613

The precision SPL Meter is a highly accurate instrument designed for outside use as well as for precise laboratory measurements.

SPL Meters are required to measure noise at different levels, spectra and waveforms under widely varying conditions of sound source distribution and reflections at the sound field boundaries. It consists of three weighting networks, called A, B, and C and covers a frequency range 20 to 20000 Hz within certain tolerances.

Type 2203 covers the range of 18 to 136 dB. Electronically the Instrument consists of the following main parts:

1. Condensor Microphone and source follower
2. Input aaplifier with input attenautors.
3. Weighting networks.
4. Output aaplifier with out attenuators.
5. Motor rectifier and indicating meter.
6. Power supply.

In the present study the instrument was used to find tho speaking fundamental frequency and also in all the intensity measurements.

STROBOSCOPE, BRUEL AND KJAER, TYPE 4911.

The Motion analyzer, type 4911, is designed for use in observing and measuing periodic mechanical phenomena such as mechanical resonances, vibrations, slip between machines. It is also useful for observing the functioning of the larynx and many other complicated mechanisms.

TACHO UNIT. BEUEL & KJAER. TYPE 5527

With the additional Tacho Unit, the number of the input pulses, as received from the stroboscope from some kind or triggering device, is measured and indicated in RPM.

In four speed ranges: 0-1000, 0-3000, 0-10000, 0-30000 RPM the spaed is simply read on the instrument without the need for the usual continuos readjustment to follow possible variations in speed.

The Tacho Unit is connected to the Stroboscope by a cable from the 'output f' socket, the saw tooth signal from which it is in eaact synchronism with the input pulses fed to the Stroboscope.

The unit normally obtains the necessary current supply via a second cable from the Stroboscope. Measuring accuracy of the instrument is $\pm$ 2%. It gives a direct reading of the fundamental frequency of the voice.

In the present study, thia instrument was used to find the speaking fundamental frequency of the subjects in experiments one and three.

BROADBAND A.C. MILLI VOLT METER. PHILIPS GM/6012/90

The Philips electronic voltmeter is suitable for measurement of alternating voltage3 from 0.1mV upto 300 V in the frequency range from 2 ops to 1 M cps.

The extensive measuring and frequency range makes the apparatus eminently suitable for voice in laboratories and electro-technical workshops. The instrument is indispensable for carrying out measurements in the audio and ultrasonic frequency range.

The instrument is equipped with scales calibrated both in volts and dB. For calibrating the meter, two voltages are available, viz., a voltago of 30 mV and a voltage of 10V. The built-in amplifier can also be used separately. If used as an amplifier, the amplification factor is 30-70.

The apparatus is suitable for connection to A.C.mains of 110, 125, 145, 200, 220 and 245 V. The power consumption is 55 Watt.

In the present study this instrument was used to find the output voltage of the oscillator, over the entire range.

AUDIO FREQUENCY ANALYZER. BRUEL & KJAER,TYPE 2107,.

This is an AC operated AF Analyzer of the constant percentage bandwidth type, It has been designed especially as a narrow band sound and vibration analyzer but may be U3ed for any kind of frequenoy analysis and distortion measurement within the specified frequency range.

The analyzer can also be used as a linear amplifier and a vaccum tube volt meter. In addition it is supplied with the weighting networks for sound level measurements, A, B, D, C, the characteristics of which are recommended in the IEC Publication.

The instrument is supplied with an output switch, by means of which the rectifier and the meter circuit can be switched to measure either the peak, the arithmetic average or the true RMS value of the input signal. To enable easy and accurate meter reading for both high and low frequency signals two different standardized meter damping of characteristics can be selected.

Electronically the analyzer consists if an input amplifier, a number of weighting networks, a selective amplifier section, and an output amplifier.

In the present study, this instrument was used for the oscillator frequency analysis and also for measuring the optimum frequency.

LEVEL RECORDS. BRUEL & KJAER. TYPE 2305

This level recorder has been designed for use in accurate recording of signal levels in the frequency range 2 Hz to 200000 Hz. Typical fields of application are the recording of the frequency response characteristics, reverbaration decay curves, noise and vibration levels, spectrograms and polar diagrams.

The operation of the recorder is based upon the Servo principle. When the magnitude of the voltage applied to the input terminals is changed, a current will flow through the driving coil of the writing system, thus moving the stylus, which is mechanically coupled to the range potentiometer. By the movement of the stylus the voltage delivered from the potentiometer to the input amplifier will be altered until a stable condition is regained. In this way it is possible to obtain recordings for different ranges of voltage variations by employing different ranges of potentiometers.

In the present study, the level recorder was used for measuring the optimum frequency and also for the frequency analysis of the oscillator.

A.F.METER. RADART TYPE. 930-A.

Tha Radart A.F, Watt Meter is an extremely useful and versatile instrument for measurements of unknown impedance and power levels in the audio frequency range.

The power delivered into any chosen load is measured by a sensitive rectifier voltmeter. Power levels in the range of 20/ uW to 10 W are read by the meter to a fair degree of accuracy, at very low as well as high frequencies.

The instrument essentially consists of an input, transformer would on a 'English Electric' strip would C core made of an misotropic magnetic alloy. It has a number of taps on the primary side to enable various impedances to be provided across the input terminals) The central taps and the symmetrical taps are brought out separately to provide facilities for balanced as well as unbalanced operation. A separate ground terminal has been provided for screening, if found necessary.

A switchable resistive matching pad is employed for transforming the necessary amount of power to the meter circuit.

In the present study, this instrument was used for analyzing the power & frequency characteristics of the amplifier developed.

A.F.GENERATOR. PHILIPS TYPE. GM 2308/90

This is a generator operating in the 0-16000 cps frequency range. It comprises of two oscillators, both variable in frequency one from 85 to 100 K cps and the other from 1000 to 101 K ops. The two osoillators output voltages are mixed, the resultant output signal frequency being variable between 0 to 16000 cps.

The generator output voltage can be derived from either of the two sets of output terminals (I and II).

The output I can be matched to various impedances: the voltage supplied to the load may be either earthed or free from earth. The output power can be varied continuously between O and 1 Watt.

Ths voltage available on output H can be adjusted accurately to any value between 0 and 25 V with the aid of a continuous control attenuator and a step attenuator.

The following are the examples of the different possibilities of application:

1. Measuring the sensitivity and the frequency of the audio amplifiers and loudspeakers.
2. Measuring with great accuracy small frequency deviations and frequency drift.
3. Measuring distortion and intermodulation in receivers, amplifiers and loudspeakers.
4. Accurate determination of the frequency of the electrical oscillators (with the aid of a onthode ray Oscilloscope).

In the present study, the generator was used to measure the fre- . quency and power characteristics of the amplifier. A constant voltage of 0.1 volts, from this instrument was fed to the amplifier and the output of the amplifier was in turn fed to the A.F. Watt Meter and the power output was obtained for different frequencies.

FREQUENCY COUNTER, ITI TYPE 702

The digital frequency counter, is a portable instrument designed to make direct frequency and period measurements, upto a frequency of 1 M Hz.

High accuracy in measurement is obtained by an internal crystal oscillator, which would be further improved by housing it in a temparature controlled from.

The frequency counter is completely transistorized to have low power consumption, low heat generation and portability. Plug in printed card construction is employed for ease of servicing and maintenance.

Measurements are displayed by 6mm characters illuminated by filament lamps arranged in a 'ladder' pattern.

The controls are very simple so that the counter can be operated by even semiskilled persons. Self check facility is provided.

The instrument may be operated from a mains supply of 230 volta, ± 50 cps A.C.

In the present study, the instrument waa used for the frequency calibration and for finding out the frequency range provided. The unknown signal was connected to the input sockets. After preliminary adjustments, the displayed readings were noted down.

BEAT FREQUENCY OSCILLATOR. BRUEL & KJAER. TYPE 1022

The beat frequency Oscillator is a precision signal generator, using solid state circuitry throughout. It covers the range 20 to 20000 Hz and is designed for acoustical,vibrational and electrical measurements.

The 1022 works on the heterodyne principle, using two high frequency oscillators one of which operates at a fixed frequency while the frequency of the other can be varied. The required audio-frequency is then obtained by mixing these frequencies to produce a beat frequency.

The instrument contains several features that aid experimental work. A regular stage is provided so that for instance constant sound pressure or vibration level may be maintained.

The output signal can be automatically frequency modulated by an internal generator to produce a warble tone for use during reverbaration measurements. Alternatively the output signal can be externally modulated to.allow wider choice of modulation frequency and frequency deviation.

The output attenuator has a range of 100 dB in 10 dB steps and the output impedance can be varied to give maximum power (2.5 W) in a load of 6 - 60 - 600 - or 6000 ohms.

The 1022 may be swept continuously through its frequency range by means of an external motor drive. Alternately, parts of the frequency range may be blocked with adjustable cams to suit any particular sweep program. If it is driven by the level recorder 2305, it can also be automatically synchronized with frequency calibrated paper.

Outputs of 100 - 120 K Hz variable and 120 K Hz fixed frequencies are available for use as control frequencies for the Heterodyne Slave filter 2020.

Remote control facilities are provided to start and stop the scanning and the oscillator and for instance to lift the pen on the Level Recorder when the oscillator is sweeping outside the frequency range of interest.

In the present study, the Beat Frequency Oscillator was used in finding the optimum frequency of the subjects.

HEARING AID TEST BOX. BRUEL & KJAER, TYPE 4217

This is an easily operated chamber for reproducible testing of all types of hearing aids in the frequency range 250 to 5000 Hz.

This consists of a miniature anechoic enclosure with a built-in loud speaker and a transistorized oscillator and amplified section. With the Bruel and Kjaer precision SPL meter and one inch condensor microphone, the set up is complete and ready for measurements.

In the present study, the instrument was used for finding the optimum frequency of the subjects. Here only the anechoic part of the hearing aid test box was used to keep the microphone and the speaker which were connected to the Beat Frequency Oscillator and measuring amplifier and the speaker to obtain a compressor voltage for the Beat Frequency Oscillator.

BUSH CASSETTE TAPE RECORDER. TYPE T.P.100

This is a compact cassette magnetic tape recorder and this works both on A.C. and D.C. of 6 volts. This recorder is provided with automatic gain control which provides a uniform recording. The response of the tape recorder is 10 Hz to 4 K Hz which galls within the speech range. The recorder was used in the present study, by using Philips C-90 Cassette, the samples were presented to judges using the same recorder for evaluation. To keep the speed constant the recorder was operated on mains (A.C. 230 Volts, 50 Hz).

MULTI METERS. UNIGOR TYPE 4P. GOERZ ELECTRONICS:

This is a sensitive multimeter used to measure voltage, current and Resistance. The sensitivity of the meter 100000 ohms/volt. In the present study two meters of the above type were used to measure voltage and current of the circuit. From the voltage and current rating the power drawn by the circuit was calculated using formula P = E x I.

CHAPTER V

ANALYSIS, RESULTS & DISCUSSI0N

Studying The Inflection Patterns in Normals:

The results of this experiment are shown in Table 5. The subjects speaking fundamental frequency was directly observed on the Tacho Unit, as the subjects prolonged the vowels at the beginning and end of the sentence. As the deflation of the Tacho Unit needle is not fast, it could easily be observed.

The optimum frequencies of the subjects wore almost same (120-130) The frequency range, for different subjeots, for different sentences, were almost same, except for 5 or 10 Hz differences. However, one subject on the first sentence reached a highest frequency of 330 Hz, which no other subject reached on the same sentence. All other subjeots reached a highest frequency of 250 Hz on this sentence. However, the meaning conveyed by the subject, who achieved this highest frequency of 330 Hz was in no way different from that of other subjects. A trained speech therapist observed for the differences in meaning, if any.

From table 5, it is seen that the discrepancy in frequency for different subjects, for different sentences, apart from the above one, is only 5 to 10 Hz. This may be due to the difference in their optimum frequency. All the subjects varied the frequency from the level of optimum frequency. The average drop from the level of optimum was 20 to 30 Hz below the optimum level, whereas it increased by 100 Hz to 205 Hz above the optimum level.

Table 5 shows that the lowest frequency reached was 100 Hz and the highest frequency was 330 Hz. So the pitch range of 50 Hz to 350 Hz provided in the present artificial larynx will be sufficient for the adult males to achieve the needed inflection and intonation pattern.

subject/ sentence	1 Min	Max	2 Min	Max	3 Min	Max	Optimum frequency
1	100	330	105	200	100	190	125
2	125	240	100	190	120	180	130
3	110	220	100	180	120	160	120
4	105	250	110	190	115	170	125
5	100	240	105	175	110	170	125

TABLE 5
Showing the Speaking Fundamental Frequency ranges of five subjects.

EXPERIMENT - 2

Construction of A Variable Frequency Artificial Larynx:

In the present study, a sinusoidal wave which equals the optimum frequency of the case was selected as a sound source.

The audio frequency oscillator used in this circuit is simple in it3 design and operation. The frequency was stabilised for the entire range of frequencies.

The variable frequency oscillator developed here consists of a simple Hartley Oscillator. It is easy to make a compact Weinsbridge oscillator in place of the present oscillator. However, in the present study, the Woinsbridge oscillator was not used because of the following reasons.

1. Non availability of low voltage lowcurrent bulbs, which act as negative feedback elements, in the Woinsbridge oscillator, to control the amplitude of the oscillations. For

this purpose, a 20 mA, 2.5 volts bulb was needed, And also a
vi variable condensor of a suitable value (300 pf) was not available.

2. Tho output of the weinsbridge oscillator is low. It needs atleast two or three stages of amplification to obtain enough signal strength to drive the amplifier. Since one of the design objectives here was to minimize the cost of the artificial larynx and also that it should be as miniaturised as possible, which may not be possible using the Weinsbridge oscillator.
3. Since a frequency range of 1:7 ratio can be easily obtained, an Hartley oscillator was used.

The frequency of the present oscillator is given by the Formula $f = 1/2\pi\ LC$. The values R1 and R2 provide necessary forward and reverso bias for the transistor. The necessary positive feedback is fed through the condensor C1 to the base of the transistor (AC 132). The transistor AC 132 used here is a general purpose low frequency transistor used as an oscillator or as an amplifier. The necessary frequency and harmonics were obtained by changing the negative bias (by changing the resistance R1). The necessary inductance value is obtained from the primary of a transformer. The necessary oapacitance was introduced by using ceramic condensor C2 , connected across the primary of the transformer. The tank circuit was connected as a load in the collector. The output of the oscillator was obtained from the secondary of tho transformer.

The frequency range of the oscillator was measured using a frequency counter and it was found that the oscillator gives a frequency range of 50 Us to 350 Hz. It was found that the frequency range was stable at fixed values, The output of the oscillator was measured with AC Milli volt mater mid it was found that the output varies from 1.9 volts to 2.1 volts. The variation is only 0.2 volts over the entire range of frequencies. And also this variation does not bring about any- large variation in power output of the transducer.

FREQUENCY ANALYSIS OF THE OSCILLATOR OUTPUT:

The oscillator output was fed to the AF Analyzer as a direct output and the output of the AF Analyzer was in turn fed to thelevel Recorder and the Analysis was made for the frequencies 100, 120, 130, 140, 150, 160, 170, 180, 190, 200, 225, 250, 275, 300, 325 and 350 cycles. The results of this frequenoy analysis is given in Table 6. It was found that at each of these frequencies, the fundamental tone and the harmonics in the frequency range of 63 to 200, 200 to 630, 630 to 2000 and 2000 to 6300 were observed:

Band/ freq- uency.	20-63	63-200	200 - 630	630 - 2000	2000 - 6300
100 Hz		100 Fo	200 Hz, 2nd harmonic	700 Hz to 900 Hz compo- nents with increasing intensity and components between 900 Hz and 1.2 K Hz with decreasing inter sity.	2K to 4K compo nents with de- creasing in- tensity
120 Hz		120 Fo	240 Hz,2nd Harmonic	700 Hz to 800 Hz compo- nents. 1K Max. peak. 1.8 K components.	Weak compo- nents.
130 Hz		130 Fo	2nd & 3rd Harmonics with incr- easing in- tensity.	4th and 8th harmonics 1.5 to 2K rich com- ponents.	weak compo- nents.

Band/ frequency.	20-63	63-200	200-630	630-2000	2000-6300
140HZ		140 Fo	2nd & 3rd Harmonics with increasing intensity. mild Peak at 630 Hz.	Maximum peak at 1150Hz	
150Hz		150 Fo	3rd harmonic	Harm, between 1150 Hz & 1300 Hz with increasing intensity.	4K components with increasin intensity
16OH2		160 Fo	3rd harmonio with componenta	1300 Hz to 1450 Hz harm, with increasing intensity,with components.	3K components
170Hz		170 Fo	2nd harmonic with components	Maximum peak at 1400 Hs	2.6 K components.
180Hz		180 Fo	2nd harmonio with components.	Maximum peak at 1500 Hz	2.1 K components.
190Hz		190 Fo	No componenta	740 Hz,4th Hamonic 925-1000 Hz harmonics with increasing intensity.	5K components
200Hz		No	3rd harmonic	1000 to 1100 Hz harmonics with Increasing intensity.	Ko components
225			225 Fo.2nd harmonic	Max. peak at 1150 Hz 700-15OO components.	No componenta
250Hz			250 Fo.	Third harmonic max. peak at 1300 Hz 1100 to 1500 components.	No components
275Hz			275 Fo.	maximum peak at 1400 Hz	4K components
300Hz			300 Fo. 2nd Harmonic.	maximum poak at 1600 Hz. 2K Components	No components
325Hz			325 Fo	2nd harmonic,5th Harmonic with max.intensity.	No components

FABLE 6

Showing the results of the Frequency Analysis of the Oscillator Output.

The intensity of the harmonica in the frequency range 2000-6300 Hs were found to be weak compared to the intensities in 200-630 Hz and 630-2000 Hz ranges. The general trend of the harmonics was decreasing with increase of frequency. The harmonic components were dear and easily distinguishable. Frequency analysis of 120, 130, 140, 170 and 180Hz showed clear peaks at 8th harmonic. Above frequencies 200 Hz clear peaks were observed at the 5th harmonics.

TRANSDUCER CHARACTERISTICS

The Characteristics of the Transducer for a Pure Tone:

The transducer used was connected to the Beat Frequency Oscillator and a fixed frequency of 125 Hz was fed. Moderate power was fed until the tone was audible from the vibrator. This audible tone was analyzed using the Condensor Microphone, AF Analyzer & Level Recorder. It was observed that the transducer produces harmonics upto 6 KHz of uniform intensity along with the fundamental tone of 125 Hz

Also the transducers acoustical output, with the original circuit (WE Type 5A) was analyzed at different positions of the Pitch Control Knob. At the minimum position of the pitch control knob the analysis reveals that the harmonic components are weak in intensity over a fundamental note and the intensity is falling with increase of frequency.

When the pitch control knob was placed at a higher position, it was found from the analysis that the harmonics were strong in intensity upto 6 KHz and the fall of intensity with increase of frequency is vary low.

This transducer's acoustical output was analyzed, using the circuit developed in the study. The analysis was made as mentioned above Analysis was made at only two frequencies - viz, 125 Hz and 150 Hz. This selection is only arbitrary. From the analysis it was found that the fundamental was at 125 Hz and tho tone was rich in harmonics and the frequency composition upto 6 KHz. The frequency components were more at 1K, 2K, 4K and 6K. The components were more at 1K and 2K were strong. Also similar analysis was made keeping the frequency at 150 Hz and similar results were obtained as with 125 Hz.

A comparison of the analysis of the /a/ using artificial larynx and natural voice was made. Table 7 gives the results of the comparison bettveen them. The results of the analysis show similar findings.

BANDS	Fundamental of 125 Hz	
	using artificial larynx	Using natural voice.
63 - 200	125 Hz Harmonic components at 200 Hz.	125 Hz Harmonics
200 - 630	250 Hz Harmonic 400 Hz components	250 Hz harmonios rich components between 300 to 630 Hz with increasing intensity
630 -2000	650 Hz Harmonic.Max. poak at 1K.	Maximum poak at 1K 1.4K components.
2000-6300	2.1K components decreasing intensity. 5K components.	Rich components between 2.2K to 5K decreasing intensity

TABLE 7
showing the results of tho frequency analysis of /a/ using artificial larynx and using natural voice.

OSCILLATOR INTERRUPTOR

A miniature noiseless mechanical switch was provided in the power supply circuit of the oscillator. This serves as a on/off device for the oscillator.

AMPLIFIER AND INTENSITY CONTROL

The amplifier consists of two stages:

1. A single stage voltage amplifier using a AC 132 transistor. The AC 132 was selected here as it is a general purpose low frequency voltage amplifier. The transistor was provided with forward and reverse biases by using suitable values of R3 and R4. Necessary stability was obtained by using suitable ratio of R3 and R4 of 4:1. The forward bias in the emitter circuit was provided by using R5 and bypass capacitor C3. The transformer was used in the collector circuit as a load. The input signal to the transistor was fed directly from the output of the oscillator as shown in Figure 10.

INTENSITY CONTROL

The input obtained from the secondary of the transformer of the voltage amplifier was fed to a 5K ohms logarithmic potentiometer. The variable amplified signal output from the oscillator was fed to the power amplifier. The potentiometer was calibrated, with respect to the output of the transducer. The transducer output was measured in free field condition keeping the SPL meter at a distance of one ft. The results of this experiment are shown in Table 8

Also the transducers output, when it was held pressed against the throat was also measured at a distance of one foot. The results of this are shown in Table 9.

From table 8 it is evident that the intensity can be varied over a 39.5 dB range in free field condition and from Table 9 it is evident that the output of the artificial larynx can be varied over a 33.5 dB range in actual use.

Rrequency in Hz.	Distance of 1 foot	
	Minimum intensity	Maximum intensity
50	70 dB	104 dB
100	72 dB	104 dB
150	74 dB	107 dB
200	74 dB	108 dB
250	72 dB	109 dB
300	77 dB	109.5 dB
350	73 dB	109 dB

TABLE 8 Showing the output of the Transducer measured at a distance of one foot in free field condition

Frequency in Hz.	Distance of 1 ft.	
	Minimum intensity	Maximum intensity.
too	56 dB	84 dB
130	58 dB	88.5 dB
200	53 dB	88 dB
250	58 dB	88 dB
300	55 dB	86 dB
350	55 dB	84 dB

TABLE 9 - Showing the Output of the transducer measured at a distance of 1 ft. when it was pressed against the throat.

POWER AMPLIFIER

The power amplifier consists of a single transistor stage, The translator used was AD 149. This is a general purpose power transistor used for most of the audio amplifiers at the output stages. The transducer was coupled directly in the collector circuit as shown in Figure 9.

The amplifier characteristics were measured by using AF generator and AF Watt meter. A constant output was given to the amplifier and the gain control of the amplifier was kept a little above the middle value. Table 11 gives the relationship between frequency and the power output of the amplifier. Graph 1 also shows the relationship between the power output Vs Frequency curves. From these two it was found that the amplifier gives & flat frequency response from 250 Hz to 700 Hz, with a little fall on frequencies below 150 Hz and above 1K. The fall is not very steep.

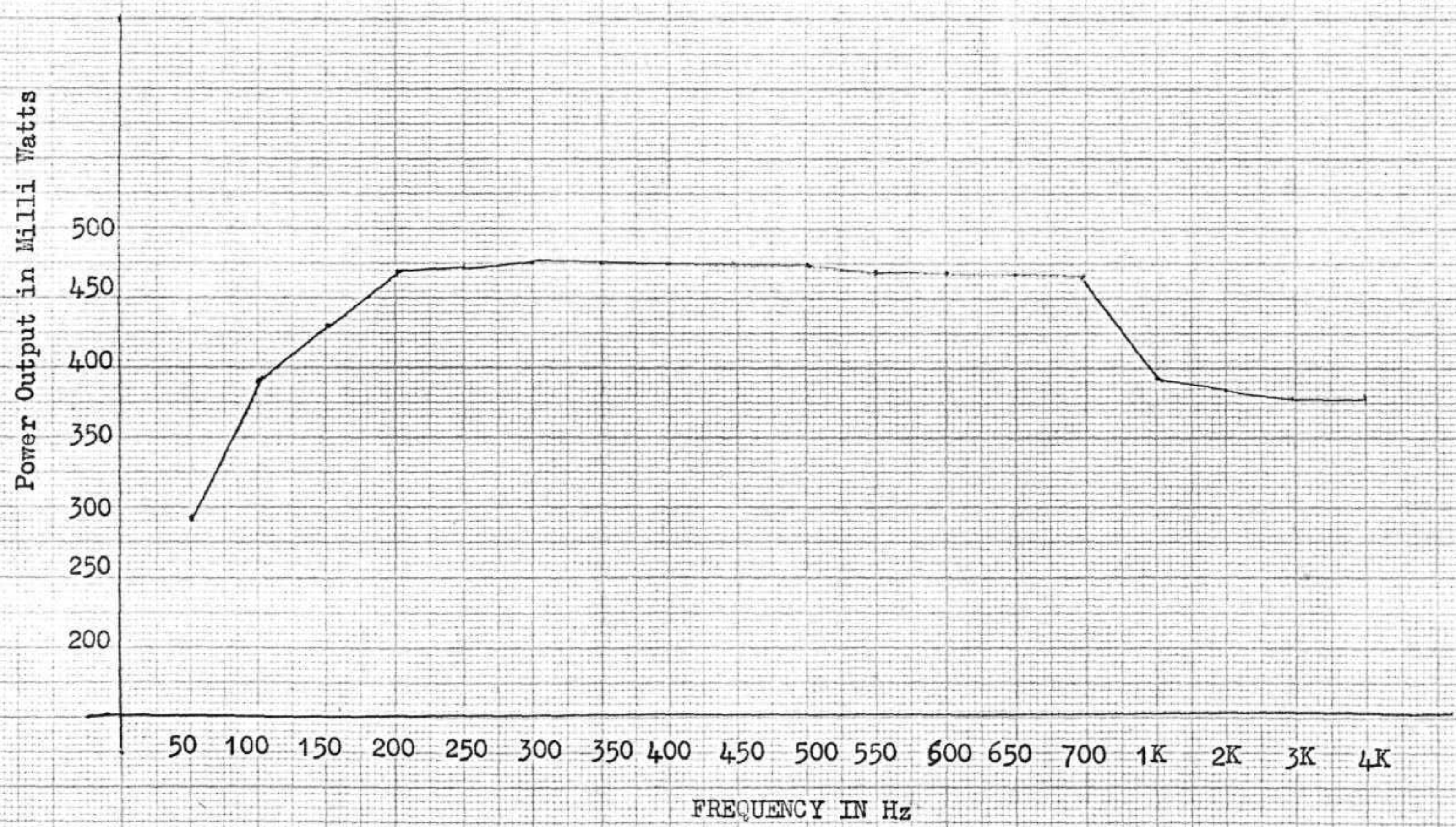
POWER SUPPLY

The power consumption of the whole circuit (both oscillator and amplifier) was measured using two multi-meters, at the level of the maximum gain of the amplifier. It was calculated from the formula P = E x I. The power consumption at maximum intensity was found to ba 500 milli watts at 125 Hz. It was observed that the voltage drop was very little after 15 minutes of use. It wa3 found to be 0.1 volt.

Frequency in Hz.	Power in Milli Watts
50	290
100	380
150	430
200	440
250	440
300	450
350	450
400	450
450	450
500	450
550	440
600	440
650	440
700	440
1K	390
2K	380
3K	370
4K	370

TABLE 10: Showing the relation between frequency & power output of the amplifier.

GRAHH SHOWING THE RELATION BETWEEN FREQUENCY
AND POWER OUTPUT OF THE AMPLIFIER.



An of/off switch was provided in between the battery and the instrument which facilitates to switch off the instrument whenever it is not in use.

EXPERIMENT. 3

"Training the Normal Speakers to Achieve the Intonation Pattern Found in Normal Speech or to Simulate the Normal Speech, using the Artificial Larynx"

All the five subjects selected, learned to speak using the artificial larynx, making use of all the knobs. All of them learned to speak well, using this artificial larynx within 24 hours. However, two subjects learned to talk with this instrument within two or three hours. The other three subjects had little difficulty using the frequency variation knob. Still, one subject after 24 hours of training and practice, could not properly use the frequency variation knob. Table 11 gives the results of this experiment:

Subjects/ sentence.	1		2		3	
	Min.	Max	Min.	Max.	Min.	Max.
1	120	300	110	170	120	170
2	120	220	115	180	135	175 ,
3	125	180	120	175	110	150
4	110	230	125	175	100	150
5	140	190	130	160	120	140

TABLE 11 - Showing the pitch variation achieved by the subjects using the present artificial larynx.

All the subjects had no difficulty in using the oscillator interruptor.

EXPERIMENT 4

"Finding the Intelligibility of the Speech with this Artificial larynx"

All the judges who evaluated the recorded speech, reported that the spacch was intelligible and good speech. Table 12 shows the ratings of four judges of the speech of five subjects. It also gives their individual opinion about the subject's speech:

sub-jects/ judges	1	2	3	4
1	Good speech in-telligible pro-longed littlo Can be easily heard.	Normal speech Intelligible	Very Near to normal Inte-lligible Good articulation Pitch varia-tion very near to normal.	Good speech arti-culation good in-telligibtiy Pitch variation very much similar to normal Little p longed Nasality observed.
2	Good speech Intelligible Prolonged Pitch varia-tion not completely normal.	Good speech Intelligible Little pro-longed Loudness enough.	Fair speech Intelligible Good articul-ation Pitch variation not normal but very near to normal.	Good speech Intelligible Good articulati Little prolonge
3	Good speech Intelligible Pitch varia-tion don't worry. As long as it communicates it is O.K.	Good speech Highly inte-lligible But some artifi-cially is there.	Fair speech Intelligible Good articu-lation. Little prolonged Pitch varia-tion not upto normal.	In between fair and normal cate-gory Intelligib. Articulation good Prolonged Pitch variation not upto normal.
	Good speech Intelligible	Fair Speech Intelligible	Intelligible Good articu-lation Good Speech Pitch variation O.K.	Good speech Pitch variation not normal
5	Intelligible Most of the times Mono-tonous.	Moderate sp-eech Intelli-gible Artifi-cial speech.	Intelligible Good Articu-lation Fair Speech Nono-tonyis there	Intelligible Good Articulation Monotonous Fair Speech

TABLE 12 - Showing the ratings of the subjects Speech produced with this Artificial Larynx

EXPERIMENT 5

Training the Dysphonics with this Lrtificial Larynx by the Isochronal Tone Stimulation Technique

This experiment was carried out on only one subject, because of the non-availability of cases. This case was diagnosed by Speech Pathologists as a case of 'high pitch' with pitch breaks'. His habitual frequency was 200 Hz and his optimum was 140 Hz. After 30 minutes of training, the subject could achieve a fundamental of 150 Hz, with no pitch breaks.

DISCUSSION

The results of the first experiment indicate that the frequency variation achieved in normal speech is from 100 Hz to 330 Hz. Since all the subjects selected in this study were good speakers, who were assumed to have good intonation patterns (they had some experience in dramas as actors, also) it can be said that the speaking fundamental frequency range may be even less than this inthe majority of the normal speakers.

The results of this experiment are contradictory to the findings of Barney, et. al. (1959) who say that a pitch range of 100 to 200 Hz is sufficient to duplicate the inflection pattern used in normal speech. In this study this experiment was carried out to have an idea of how much of frequency variation from the level of optimum should be made to convey the given meaning and also how much of frequency variation should be provided in the artificial larynx. Accordingly it was decided to provide a pitch range of 50 to 350 Hz, even if some speakers go beyond the range of 100 to 330 Hz observed in this experiment. The range provided here is more than that provided in the WE Type 5A, which provides a range of 100 to 200 Hz.

In the construction of the variablo frequency oscillator a sinusoidal wave with higher harmonics was taken as sound source, whereas in WE 'Type 5A, short periodic pulses from a relaxation oscillator were taken as sound source. Hero the frequency variation is continuos but can bo controlled also, but not so in the case of WE Type 5A. With this artificial larynx, a fundamental frequency can be custom selected for each individual to match his optimum, with a rich supply of overtones.

The optimum frequency of the laryngectomees can be found by Nataraja's (1972) method. Nataraja (1972) has found a relationship between the natural frequency of the vocal tract of the good speakers and the fundamental : frequency. He has found a relationship of 8:1 It is not known whether this relationship holds good with laryngectomee's, because of the observed difference in the vocal tract. In spite of this, by whatever method one can find the optimum frequency of the laryngectomee's, that optimum frequency could be provided with this artificial larynx. Furthermore, giving optimum frequencies to the laryngectomee's by Nataraja's method, will atleast be an approximation 60 the frequency of tho particular age group. It is better to give atleast this (that is tho frequency of a particular age group to which tho patient belongs) than giving him some other frequency.

This artificial larynx consists of a Hartley oscillator, the output of which is sufficient to drive the amplifier, with a single stage voltage and power amplification. In this oscillator, the frequency can be varied by changing the resistance R1 . It was found that tho output voltage of the oscillator varies from 1.9 to 2.1 volts, which does not bring any large variation in tho power output of the transducer and hence frequency is stabilized over the entire frequence range and at particular value.

Frequency analysis reveals that in each of the frequencies, the fundamental tone and the harmonics were clearly present. In most of the frequencies upto 180 Hz, fourth, fifth, sixth and eighth harmonics were found clearly and components upto 5K were observed. However, conspiquously at 200 Hz, the fundamental tone was not observed in the analysis. This may be because of some outside disturbance or some error in the analysis. Even though the fourth, fifth, sixty and eighth harmonics were found, the amplitude of tho harmonics, upto 180 Hz was maximum at the eighth harmonic. This is in support of Nataraja's finding that in the eighth harmonic of the fundamental, the vocal tract gives the maximum response in tho case of adult sales. Above 200 Hz the amplitude of the 5th harmonic was highest and this supports the finding of Shantha (1973) in case of females. This supports that optimum frequency for any particular individual can be given with this artificial larynx.

Further a comparison of the frequency analysis, for a fixed signal of 125 Hz, of the WE Type 5A artificial larynx and the present artificial larynx shows that tho tones produced by the present artificial larynx gives good harmonics. In the case of WE Type 5A artificial larynx, though it gives fundamental and components upto 6 KHs, the amplitude of the components decrease with increase in frequency. With the present larynx, it gives the fundamental and the second, fourth, fifty and the eighth harmonics, with tho maximum peak at 1000 Hz. Components upto 6.KHz were also observed. Components at 1K and 2K were stronger than others.

Analysis of the frequency characteristics of the optimum frequency (125 Hz) of a subjects was carried out in two ways:

1) When he was using natural voice.

2) When the tone was resonated through the vocal tract of the subject, fed from the artificial larynx.

The analysis revealed similar results for both and this is in support of theresults obtained when the oscillator output frequency (120 Hz) was analyzed. In all these conditions, similar components and harmonics were observed. But most important is that in all these conditions the maximum peak was at 1K. From this we can say that, the sound source used here gives almost same frequency spectrum as that of normal voice. Further it supports Nataraja's finding that the vocal tract gives maximum response at the frequency, which is the eighth harmonic of the fundmantal. It can be ooncluded here that the spectrum of the transducer tone is adequate as a source of harmonics for vowel production and that the voice of the artificial larynx has greater resemblance to normal voice. This also supports the fact that the harmonics in the source spectrum of the natural voice are strongest at the low frequencies dropping in amplitude toward the high frequencies and this is a further proof of the naturalness of the tone of the present artificial larynx. However, the analysis must be carried out at other frequencies and also more extensively, before any definite conclusion is reached.

The introduction of a minia-ture noiseless, mechanical switch as oscillator interruptor was found to be effective. By pressing this the subject can stop the transducer at any moment, either between words or phrases or sentences. This avoids the unnecessary vibrating sound produced by the transducer during the non-articulation period. This constant background bussing noise was attributed as the factor causing the unintellicibility of speech. As was found in experiment 4 the lessening of the continuos noise with this oscillator stop, helped to increase the intelligibility of the speech. Another advantage of this oscillator stop is power saving.

The input obtained from the secondary of the transformer was fed to a 5K ohms logarithmic potentiometer. By this it was possible to achieve an intensity variation over a range of 39.5 dB. The output of the artificial larynx was measured, both when the transducer sas kept in free field and when held pressed against the throat muscles. In the free field the lowest intensity was 70 dB and the highest was 109.5 dB. However, when pressed against the throat, the maximum output is only 88.5 dB and the minimum is 55 dB. Still, the patient can vary from 55 dB to 88.5 dB, over a range of 33.5 dB when in actual use. It was also observed that the new artificial larynx is able to transmit sufficient power into the pharynx throughout the frequency spectrum to permit satisfactory development of the high amplitude regions of the vowel sounds. It has been indicated that the harmonics in the source spectrum of the natural voice are strongest at the low frequencies dropping in amplitude toward the high frequencies.

This maximum output of 88.5 dB provided in the present artificial larynx, when pressed against the throat, is more than the peak intensity values of normals. Hyman (1950) reports the peak intensity values for normals as 79 dB. This is one advantage over the WE Type 5A artificial larynx, where the intensity is constant at 75 dB.

From the analysis of the amplifier characteristics it is evident that the amplifier given a flat frequency response from 250 to 700 Hz. From this it is clear that whatever the harmonics the transducer and the oscillator are giving is not because of the amplifier distortion.

P0WER SUPPLY

The instrument works on 9 volts D.C. From the analysis of the power consumption of the instrument, it was observed that the current drain through the whole cirouit at the maximum intensity was 200 milli-amperes. When compared to the WE Type 5A this figure is very high (22 milli-ampere in the case of WE Type 5A). It was also observed that the voltage was constant for a continuos operation of 15minutes. After 15 minutes tha drop in voltage was only 0.1 volts, which was found to be ineffective to produce any changes either in the oscillator circuit or in the amplifier, in terms of power output or quality. The battery was sufficient to drive the circuit for its normal operation for long duration.

Furthermore the consumption of the power by the circuit is lessencd by the oscillator interruptor.

TRANSDUCER

As said earlier, in the present study the transducer of the WE TypE 5A artificial larynx was used because of the following reasons:

1) It was readily available.
2) The constructors of this transducer have taken into consideration the impedance of the throat muscles and the tissues. This is important because the mechanical impedance of the throat muscles is 4000 times more than that of air and hence there will be a difference in the performance of the transducer when pressed against the throat. Barney, et. al., (1959) have made a number of modifications in the HA 1 receiver. in order to give a greater amplitude of vibration into the circuit.

This transducer handles a power of 400 milli watts and it also matches the impedance of the amplifier developed. As Barney, et. al. (1959) have found that the introduction of the tone the pharyngeal cavity gives good speech, in this study also it waa fo-llowed.

The whole circuit was mounted on a 5" x 1½" printed circuit board. For simplicity of operation a rectangular type of tube was used to house the artificial larynx. Outside this cyllinder (tube), a little below the transducer, the on/off switch was provided. Below thin switch the frequency variation knob was provided, so that the patients can easily operate it with their thumb. On the other side, the intensity variation knob was provided, so as to enable the patient to operate it with his forefinger. Below this the oscillator inte-rruptor was given. The patients can operate it with their little finger. The frequency variation knob was calibrated using frequency counter and the intensity variation knob was calibrated based on the transducers output in the free field. On the intensity variation knob 5 markings were made from 0 to 5 for convenience.

Most of the subjects selected for experiment three could be easily trained to use the present artificial larynx. Two of them needed 24 hours of training. Two of them could very well use this artificial larynx with only 3 hours of training and practice. However, one sub-ject, even after 24 h urs of practice would not effectively use the frequency variation knob. And those two subjects who had 24 hours of training, in the beginning had some problems with the proper manipu-lation of the frequency variation knob, that is in achieving the normal inflection patterns of Speech. For all these subjects, the tacho unit waa provided as a visual clue to achieve the frequency they had earlicr achieved while speaking. It is also possible that they might have used audition as one more clue. However, no particular reason is known and can be for the failure of one subject to achieve this Furthermore the results of the experiment 4 were essentially in agreement with the results obtained from this experiment. From the results of this experiment it is evident that the subjects can be trained to efficiently use this artificial larynx.

All the judges who evaluated the recorded speech samples of the subjects reported that the speech was intelligible. The twojudges (trained Speech Pathologists) reported of good articulation. According to their ratings, subjects 1 and 3 are best speakers, subjects 2 and 4 are good speakers, and subject 5 will come under fair category. Even this subject's speech was intelligible with good articulation, but the main problem was with frequency variation. The subjects one and three could achieve frequency variation which was very near to normal. This is further supported from the results of the experiment 3. Those subjects who achieved good frequency variation in experiment 3 were rated as good speakers by all the four judges here also and also the subject 5 who was rated as having 'fair' speech. From this it can be said that bias of the judges is not involved.

Here the speech of all the subjects was udged to be highly intelligible. This supports Hyman's (1955) finding that artificial larynx speech is always moro intelligible than esophageal speech and it was always preferred to esophageal speech. Barney, et. al. (1959) also say that speech of the artificial Iarynx will always be intelligible and the reason they give is that it might due to either,one) due to the frequency structure of the tone, or 2) duo to the introduction of the vibratory tone to the pharyngeal area. Howver, in all these studies, the speech was considered to be monotonous and tho constant buzzing was an irritating factor. In tho present study the observed good intelligibility of the speech may be because of either of the following factors or a combination of them:

1) Frequency composition of tho tone of the transducer and the oscillator, was very slow similar to tho normal voioe as has been indicated.
2) All the subjects were using their optimum frequency and made variations from this level
3) All the subjects varied the frequency in a manner approximately similar to the variations in normal speech.
4) All of them had good articulation.
5) All of them effectively used the oscillator interrupton, so that the con stant background buzzing was minimized.
6) The artificial larynx had sufficient output intensity.
7) All of them did prolong the speech a little.

All of the judges reported of prolongation of speech. All of them did prolong the vowels a little, but it was not so conspiquos. Perhaps the frequent use of the oscillator interruptor might have added to this. It is also interesting to find that one judge (trained speech pathologist) observed nasality in the speech of one of the subjects, who was actually the best speaker in that group.

From the results of the experiment 5, it was found that the dysphonics can be treated using this artificial larynx. However, this was not tried on many patients. Since the frequency can be changed from 50 Hz to 350 Hz, this artificial larynx can be used with all high and low pitched voice cases. It can also be used with all dysphonics ii our aim is to give the optimum frequency, since it is hygienic to our vocal mechanism. it can be conveniently used as a substitute to the Beat Frequency Oscillator, to treat the dysphonics by the Isochronal Tone Stimulation Technique.

All the design objectives, which were planned in the beginning, could be achieved in this study. A variable frequency oscillator could be constructed and with this a variation of 50 Hz to 350 Hz was obtained. The patients can be given the provision for changing the output intensity.

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CHAPTER VI

SUMMARY, CONCLUSIONS & RECOMMENDATIONS

The present study was concerned with the development of a variable frequency artificial larynx. The presently available artificial larynges have many disadvantages. Most important of them is that the provision given for varying the frequency in these devices is too limited and that the pitch range provided is too small. Of all the presently available artificial larynges, WE Type 5A is considered tobe the best aid, and even this best aid is not excluded from the above said disadvantages. Hence the development of a variable frequency artificial larynx was considered essential and was undertaken.

It was also planned to bring about the following modifications:

1) To provide the provision for giving the optimum frequency of the subjects. Giving this optimum frequency is essential, as the vocal tract gives the maximum response at this level and it is hygienic to the vocal mechanism. It results in good speech.
2) Providing the facility for changing the output of the artificial larynx.
3) The cost of the artificial larynx should also be minimized to the extent possible.

In order to bring about these modifications, the following design objectives were held in the beginning:

1) output speech quality and pitch inflection like that of normal speech.
2) Output space : volume of the artificial larynx should be equal to that of the normal speaker.

3) They should be inexpensive and should have a low operating cost. This is particularly important in India.
4) The device should be inconspicuous and hygienic.
5) It should be reliable with simple, trouble-free operation
6) The device should be as free as possible of mechanical difficulties necessitating service and repairs.

To achieve the first objective, the following modifications were brought about:

1) The pitch range provided was greater in this artificial larynx. This range will be sufficient to duplicate the pitch inflections used in normal speech (Results of the first experiment support this). The pitch range provided was 50 Hz to 350 Hz.
2) Possibility of selecting a suitable fundamental, with needed supply of overtones, for each individual to match his optimum frequency. This was easily achieved as the frequency variation is continuous from 50 Hz to 350 Hz, any value over this rnnge can be selected.
3) Providing the provision for frequency changing and that it should be continuous, but can be controlled also. For this purpose a variable frequency oscillator was constructed using a simple Hartley oscillator. Frequency variation was got in this circuit by varying the negative bias, that is by varying the resistance R1, as shown in Figure 10.
4) The frequency spectrum of the output of the artificial larynx should be similar to that of the normal voice. Analysis of the normal voice and the output of the artificial larynx, for a particular frequency shows that they are very similar. Frequency analysis of the artificial larynx output shows that

upto 180 Hz, it gives maximum peak at the 8th harmonic and above 200 Hz, it gives maximum peak at the 5th harmonic.

5) Providing an oscillator interruptor. By this the patient can stop the oscillator working, either between words or phrases or sontences. By this the speech was found to be extremely intelligible as it minimized the constant buzzing noise and it also served the purpose of saving the power.

To achieve the second objective, an amplifier, with a single stage voltage amplification and a single stage power amplification was built. The input obtained from the secondary of the transformer of the voltage amplifier waa fed to 5K ohms logarithmic potentiometer (R6) which gives linear raise and decrease in intensity. In the free field the intensity can bo varied from 70 dB to 109.5 dB, over a 39.5 dB range and when pressed against the throat a variation from 55 dB to 88. 5 dB, over a range of 33.5 dB. The peak intensity of 88.5 dB got when the transducer was pressed against the throat, is more than that of normals. It has been clearly shown that whatever the harmonics the oscillator and the transducer are producing, is not because of the amplifier distortion, as it gives a flat frequency response to all the frequencies.

To achieve the third objective, the manufacturing cost of the instrument was kept at minimum. This was made possible by the use of a commercially available transistors and other component parts.

The fourth, Fifth and sixth objectives were also achieved with this artificial larynx.

The study was also concerned with studying of the speech produced by normals and laryngectomees, using this artificial larynx. Use of this artificial larynx in Baking the dysphonics to achieve their optimum frequency by Isochronal Tone Stimulation Technique was also a part of the study. Laryngectomees could not be studied, as the oases were not available. The study was carried out on only one dysphonic (who was diagnosed as high pitched case with pitch breaks), by using the Isochronal Tone Stimulation Technique.

The speech intelligibility with this artificial larynx was found with normals and it was found that speech was extremely intelligible (as reported by judges). All of the subjects had. good articulation. They all could effectively use the oscillator interruptor, which was one of the important factors in the high intelligibility of the speech. One subject had difficulty in using the frequency variation knob, while others had no such difficulty. Subjects can be easily trained to use this artificial larynx.

CONCLUSIONS

1. A frequency range of 50 Hz to 350 Hz was provided in the artificial larynx.
2. The above variation in frequency of 50 Hz to 350 Hz is continuous but it can also be controlled.
3. With this range of 50 Hz to 350 Hz, a suitable fundamental for each individual, with a rich supply of overtones to match his optimum, can be selected instantaneously and make variations in speech from this level.
4. Frequency spectrum of the artificial larynx voice was almost completely similar to that of the normal voice.
5. The oscillator interruptor was very useful in increasing the intelligibility of the speech.

6. The artificial larynx gives an output of 70 to 109.5 dB in the free-field and 55 to 88.5 dB when pressed against the throat. The peak intensity levels were more than that of normals.

7. The patient3 can easily be trained to use this artificial larynx. Achieving frequency variation may be little difficult

8. The manufacturing cost of this artificial larynx is far below than that of presently available artificial larynges.

9. The equipment used in the Isochronal Tone Stimulation Technique has been simplified here.

RECOMMENDATIONS

1. Miniaturization of this artificial larynx canbe taken up.

2. This artificial larynx can be made to work on 1.5 volts D.C., by providing one or two stages of amplification.

3. The performance of this artificial larynx can be tested on laryngectomees.

4. Treating the dysphonics, using this artificial larynx, on a large sample, by the Isochronal Tone Stimulation Technique is most desirable.

5. Spectrographic analysis of thetone of this artificial larynx can be carried out.

6. A study of the inflection pattern of speech in normals will ba useful in training the laryngectomees to achieve good speech, using this artificial larynx.

7. Transducers of low cost (available in India) must be tried

as mechanical vibrators in this artificial larynx. In this respect, the scooter horns seem to be most promising.

8) An attempt oan be made to minimize the powor oonaumption of this artificial larynx.

9) Attempt must be made to achieve the same frequency components found in normal speech, in the artificial larynx also.

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