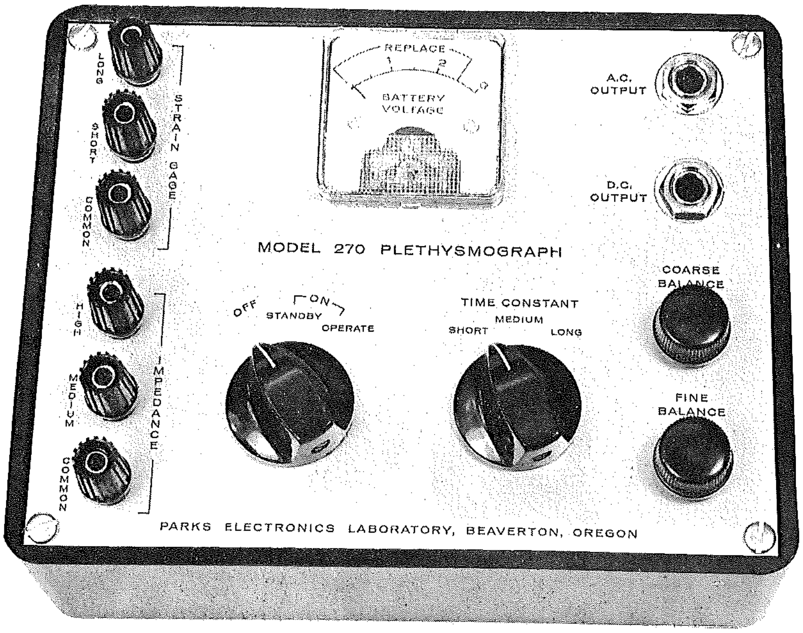
MODEL 270
PLETHYSMOGRAPH

PARKS ELECTRONICS LAB.
ROUTE 2, BOX 35 BEAVERTON, OREGON

A VERSATILE PLETHYSMOGRAPH FOR RESEARCH -- Model 270



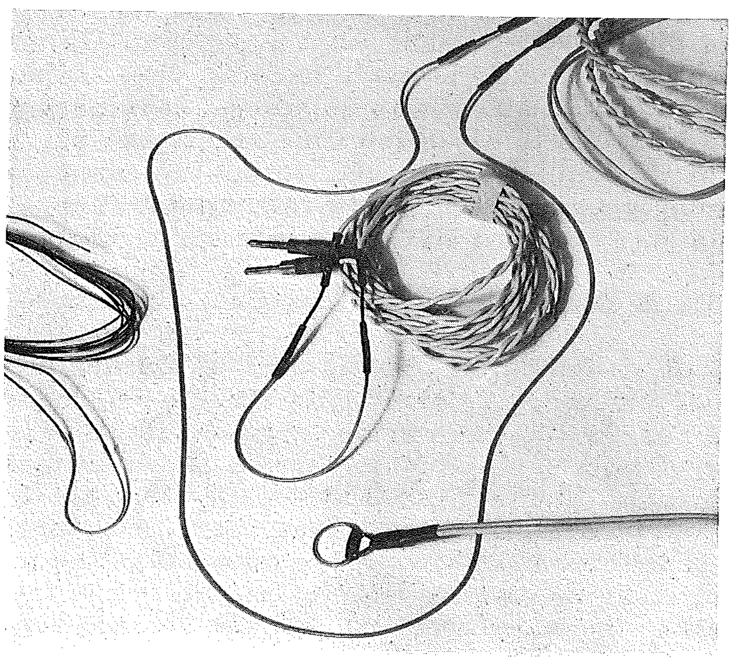
Price: $150
(less accessories)

Used to record small changes in the volume of digits, limbs, the chest, arteries and organs.

2 METHODS OF DETECTING VOLUME CHANGES

1. Impedance Method: Electrical impedance (resistance) of a digit, limb, artery, organ or tissue segment changes with blood volume. Hypodermic or surface electrodes may be used. An excellent method for studying time relationships in the cardiovascular system, making pulse-contour studies and taking systolic blood pressure measurements on animals (with the proper type cuff.)

2. Circumference Method: Uses highly elastic tubing filled with mercury. Resistance of the enclosed mercury column changes with its length. Unlike tubing filled with electrolytes, these gages are very quiet. Recordings are easily made quantitative in units of length.



Gages shown are priced from $3 to $7 each. They have a long shelf life.

Outside diameter of available gages is from .015 to .045 inch

Some typical mercury strain gages used in research and clinical studies.

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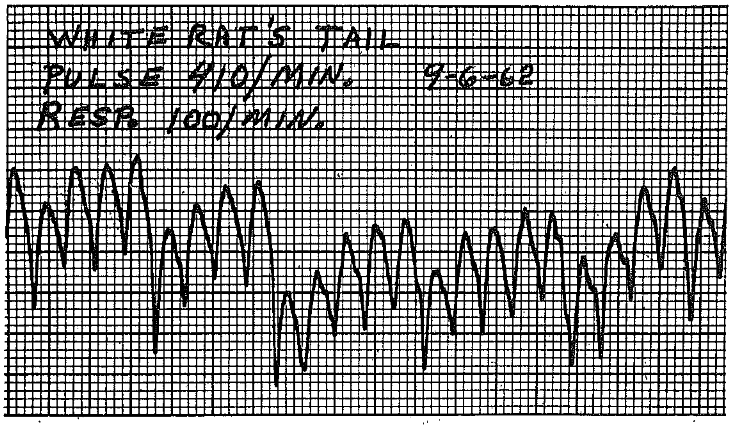
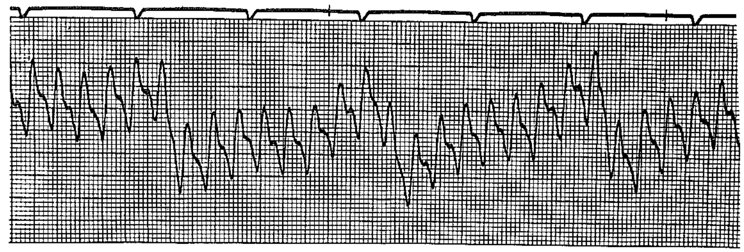
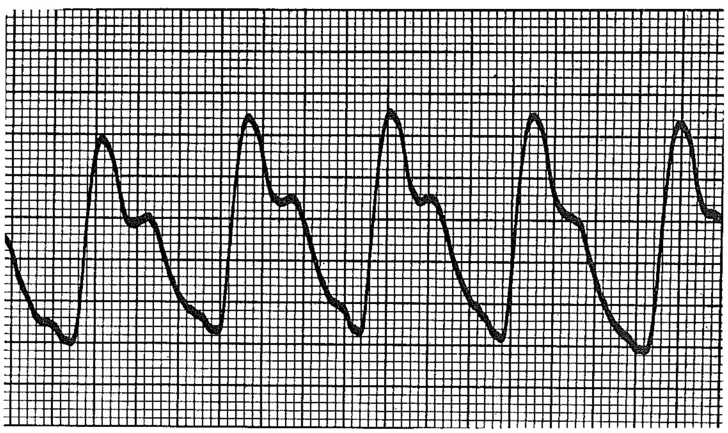
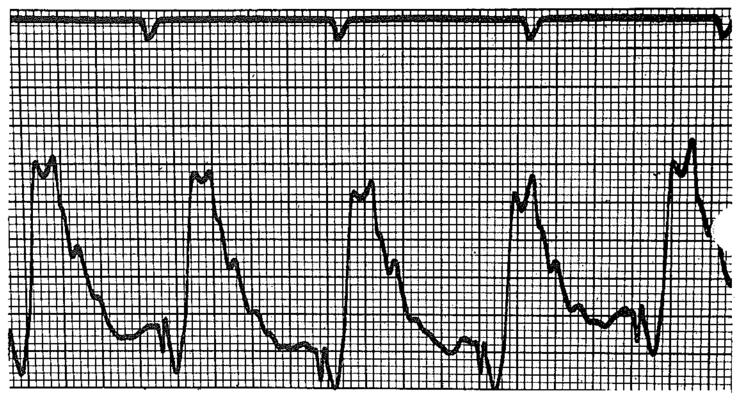
MERCURY STRAIN GAGE - A.C. Output. Left, below, gage is wrapped twice around the tail of an un-anesthetized but restrained white rat. Right, our smallest gage is sutured to the sclera of a rabbit. Eye muscles were cut so that only pulsations of the globe would be recorded. Lids were not touching the gage or wires to it. Changing the fluid pressure within the eye by means of a syringe modified the pulsations.







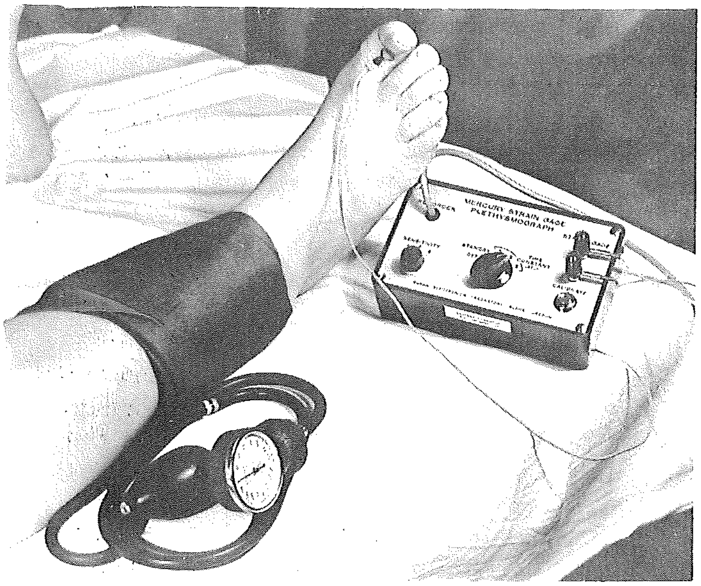


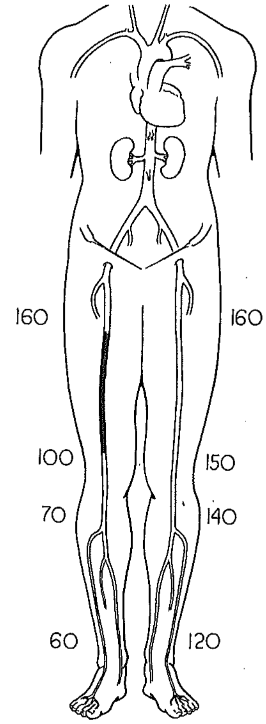
Left, above, a normal human digital pulse. Amplitude and amount of notching in the descending part of the wave vary considerably in the same individual from time to time and pulse contour becomes more rounded in obstructive disease. Right, above, mercury gage taped over the apex of the heart. Patient must hyperventilate and then stop breathing for a few seconds while the recording is made because chest expansion and contraction due to respiration interferes. This patient was standing. It is best to record the electrocardiogram simultaneously in order to establish time relationships. A.C. coupling is usually used for this type of recording. The A.C. output impedance of the Model 270 is in excess of 100,000 ohms and should be used with vacuum-tube input recorders with an input resistance of 10 megohms (standard EKG) to preserve a reasonably long time constant.

The Impedance Method of Pulse Detection

The electrical conductivity of a segment of tissue, such as a limb, finger, or length of artery changes with its blood volume. As blood fills a segment, its electrical resistance decreases slightly. Contact to the tissue is made by two surface or needle electrodes. Excellent pulse-volume waveforms can be obtained from small animals with tissue segments of less than one-half inch. Contact is always made along the length of an artery, never across it. Needles are inserted into the tissue near the artery, not in it. The impedance waveform is free of inertia and shows more detail than the mercury gage waveform. It is better suited to studying precise time relationships in the cardiovascular system because of the detail in the waveform and because surface electrodes can be placed anyplace on the body.

APPLICATIONS: Making systolic pressure measurements and recording changes in vasomotor tone.

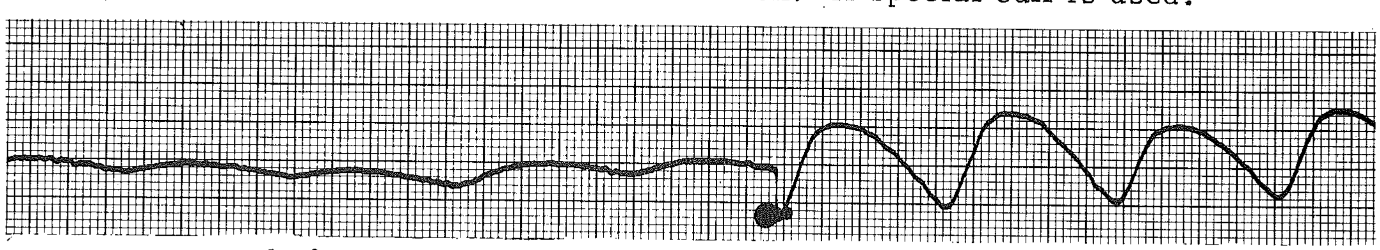




TOP LEFT: Our Model 250 Mercury Strain Gage Plethysmograph being used to make a blood pressure measurement at the ankle. Any of our plethysmographs can be used to do this. The pulse-volume sensing device is placed distal to the cuff. The cuff is inflated rapidly until pulsations disappear (above systolic pressure.) Then the cuff is deflated gradually until small pulsations appear. Cuff pressure at this point equals systolic blood pressure at the location of the cuff.

On cats, dogs, goats etc., that are anesthetized, the impedance method is used. Hypodermic needle electrodes are inserted into the tail distal to a premature infant size cuff. Surface electrodes may be used on un-anesthetized animals and infants who can be restrained or pacified. A big-toe size gage can be used on the wrist of an anesthetized infant to detect the pulse. The method of determining the systolic pressure is the same as that outlined above. Values obtained are reasonable and quite repeatable.

TOP RIGHT: Localizing arterial obstructions by the blood pressure gradient method. Systolic pressure is low distal to an obstruction. A special cuff is used.



before occlusion reactive hyperemia

GRAPH: The ability of peripheral vessels to dilate can be readily shown by simple methods. If a patient has an arterial obstruction and vascular surgery is considered, it is important to know whether or not the peripheral bed can accommodate the increased flow that would result from the surgery. A proven prognostic method is shown in the graph. The first pulses shown are very small and rounded. After this part of the recording was made, a cuff was inflated around the ankle and all blood flow was shut off for 5 minutes. This is not painful. The resultant tissue anoxia dilates vessels after cuff pressure is released and in this case pulsations increased in size by a considerable amount. When initial pulses are small, a 50% increase in pulse amplitude indicates a good distal bed. The rounded pulses which resulted are typical of those found in patients with an arterial obstruction, especially a high one.

RECORDING EQUIPMENT REQUIREMENTS----Model 270 Plethysmograph

The sensitivity and input characteristics of the recorder you will need for use with the Model 270 depends on what physiological phenomena you want to record. For digital pulses, a standard electrocardiograph works well. They have a deflection factor of 1 mv/cm and input resistance of 10 megohms or more. The electrocardiograph will record only pulsations, not gross volume changes.

For venous occlusion plethysmography, respiration or any other slow phenomena, a D.C. recording system is required. The electrocardiograph, though it may have a D.C. input, will not be satisfactory as a rule because of its low sensitivity on D.C. and the fast paper speed.

Chopper type D.C. amplifiers will usually work well with the D.C. output of the Model 270. The D.C. output impedance is about 5,000 ohms. We guarantee our Model 270 to be compatible with your recording equipment. If for any reason it is not, the plethysmograph may be returned and no charge will be made provided the instrument has not been damaged. The time constants in recording equipment used for electroencephalography may be too short to record adult pulse waves faithfully. Time constants in equipment for electromyography are much too short for use with this plethysmograph. Some recording equipment, such as that made by Grass instruments, can be used for plethysmography as well as encephalography. The specifications of the recorder should be examined. A time constant of 2 seconds would be about the minimum acceptable for recording human pulse contours.

Cable connections:

A cable with a plug to fit the patient cable receptacle of Sanborn, Burdick, Birtcher & Cambridge electrocardiographs (portable) will be supplied for $8 in lengths up to 4 ft. Longer lengths are not recommended. Wires with clips for use with the impedance method are 2 for $1 in lengths not over 6 ft.

GUARANTEE:

We guarantee the Model 270 against defective components and workmanship for two years from date of purchase. Damage caused by abuse and leaking batteries is not covered.

ORDERING REMINDERS:

1. Be sure you have a proper cable or can get one made.

2. The impedance method is very valuable for many applications, especially in timing cardiovascular events. Order the wires if you think you may want to try this method.

3. Gages don't last forever. Through accident they may be broken. We suggest you order at least two of each of the sizes you plan to use.

4. If you want to make systolic pressure measurements on the legs you will need a special leg cuff. The price of this cuff is $12.50.

5. If you are on the staff of a medical school or other research institution and need the instrument in a hurry, write, wire or phone for it. We will send you what you need and wait until the purchase order comes before billing.

6. Mail from the east is very slow--about 5 days for a letter. Send all bid invitations and correspondence by air mail.

Parks Electronics Laboratory

CARDIOVASCULAR INSTRUMENTATION

419 S. W. First Avenue
Beaverton, Oregon 97005
Phone (A/C 503) 644-7463

THE MERCURY STRAIN GAGE
(Whitney Gage)

The mercury strain gage is a length of highly elastic tubing filled with mercury. Contact is made to the ends of the mercury column by means of wires inserted into the ends of the tubing. As the tubing is stretched, the enclosed mercury column is lengthened and narrowed, increasing its electrical resistance. When tension is removed, the gage returns to its original length. The resistance increases linearly with length when the length changes are small compared to the unstretched length.

Characteristics of the mercury strain gage:

1. It is very quiet--doesn't generate noise like many other length transducers. The limit of its sensitivity has not yet been determined. We have made excellent noise-free recordings of the pulsatile changes in the eye of a rabbit (pulse & respiration) with our thinnest gage sutured to the sclera. The practical limitation in sensitivity is the movement of the subject. In pulse plethysmography, motion cannot be tolerated.

2. The gage is somewhat temperature sensitive, but this is very infrequently a problem. If you blow on the gage, its resistance will change temporarily. When its temperature returns to the former value, the resistance of the gage will be the same as before.

3. The shelf life of the mercury gage we make is from six months to over a year. We have been making them since late 1961 and have considerable experience with them. Latex gages are notoriously un-reliable both in use and on the shelf. The mercury-copper junction in the gage causes the latex to deteriorate. The silastic gages we make are far superior to latex types in reliability, elasticity and also cost much less.

4. The frequency response of the gage depends on the tension and dimensions of the gage. In our experience it has always been better than that required to measure physiological changes in humans and small animals.

5. The electrical resistance of the mercury gage is very low--less than one ohm for digital gages. For this reason it cannot be used in conventional bridges which are designed to work with resistances of 100 ohms or more. At present we make four plethysmographs for use with the mercury gage. All plethysmographs can be used with a standard office electrocardiograph. Our model 270 is the only one with a D.C. output.

APPLICATION NOTES:

1. The gage must be used under tension. It should be stretched by at least 10 or 20% of its unstretched length.

2. Respiration monitors need not encircle the chest. An 8 or 10 inch length stretched across the top of the chest will work well for relative measurements and timing.

3. A frequent application in experimental surgery is around the leg of a dog, just above the paw. An "open" gage is used and formed into a loop around the leg. A clamp is used at the junctions of the wire and the gage to keep tension constant on the gage. Wires to the gage are taped to the leg to minimize artifact caused by dangling wires.

4. The mercury strain gage is not a dependable monitoring tool when used on a digit because vasoconstriction frequently obliterates the digital pulse. Nevertheless, the mercury gage is often used in surgery. The impedance method of pulse detection is more reliable because it can be used farther up the limb. Using a cuff, systolic pressures as low as 20 mm. Hg. can be determined.

5. If you have a special application in mind, a letter or telephone call may save you a lot of time and trouble. We have several years experience with plethysmography and can pretty well judge what will and what won't work. Make a person-to-person call to Loren Parks, Area Code 503, 644-7463 (Beaverton, Oregon).

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MISCELLANEOUS AND GAGE ORDERING INFORMATION

QUANTITY: The cost of a gage is not only in labor and materials, but correspondence, invoicing, bidding, shipping and advertising. We have to sell at least two gages at a time to break even. All gages are made to order, so we can't really make them very efficiently. Therefore we ask that you order at least two gages at a time.

LIFE: Gages must be considered expendable. We guarantee them to arrive in good condition and to be free of manufacturing defects. They will give many months of service when not abused. Since Silastic is porous, the mercury is eventually oxidized and contact is erratic. A gage is most likely to break at the junction of the Silastic and the copper wires inserted into the ends of the tubing. To minimize puncture of the tubing at this junction, keep the tubing and wire straight at that point when the gage is under tension. A long, open gage is easily repaired by the user. A digital gage is more difficult to repair and should be attempted only in an emergency. Do not return gages to us for repair as they have no salvage value.

ALL SALES ARE FINAL: We do not guarantee the gage to do the job you want done or to work with your equipment. From experience we have learned we must have this policy to protect ourselves. People have attempted to return perfectly good gages simply because they were overconfident of their knowledge of electronics and use of their equipment. A returned gage is of no value to us. If you are not sure of equipment compatibility, write or phone. Of course we do guarantee that certain procedures with which we have had experience will work with these gages and with our equipment.

ORDERING INFORMATION: You must tell us exactly what you want. Order by the un-stretched length of material. The gage must be used under tension -- a 10 to 20% stretch. The preceding applies to "open" gages, ones not formed into a closed loop as a digital gage would be. Wires are flexible, vinyl covered. Standard lengths are either 4 or 6 feet and the price is the same for either of these lengths. For different lengths, add 25¢ per gage.

OPEN GAGE LENGTH - .015 x .040 material.

.015" x .040" tubing

less than one inch	$5.00
1 to 6" inclusive	4.00
over 6" to 12"	5.50
over 12" to 24"	7.00
over 24" to 40"	9.00

SPECIFY UN-STRETCHED LENGTH YOU DESIRE FROM ABOVE

.015 x .040 tubing is recommended for digits of adults, limbs, respiration and other applications where reliability is more important than extreme flexibility.

.012 x .025 tubing is used for a very sensitive, medium weight gage. Primary applications are in experimental surgery where the gage is sewn to the myocardium or around large vessels. Used on infants' limbs and fingers but with some difficulty. Reliability is not as good as with the heavier material. Add $1 per gage.

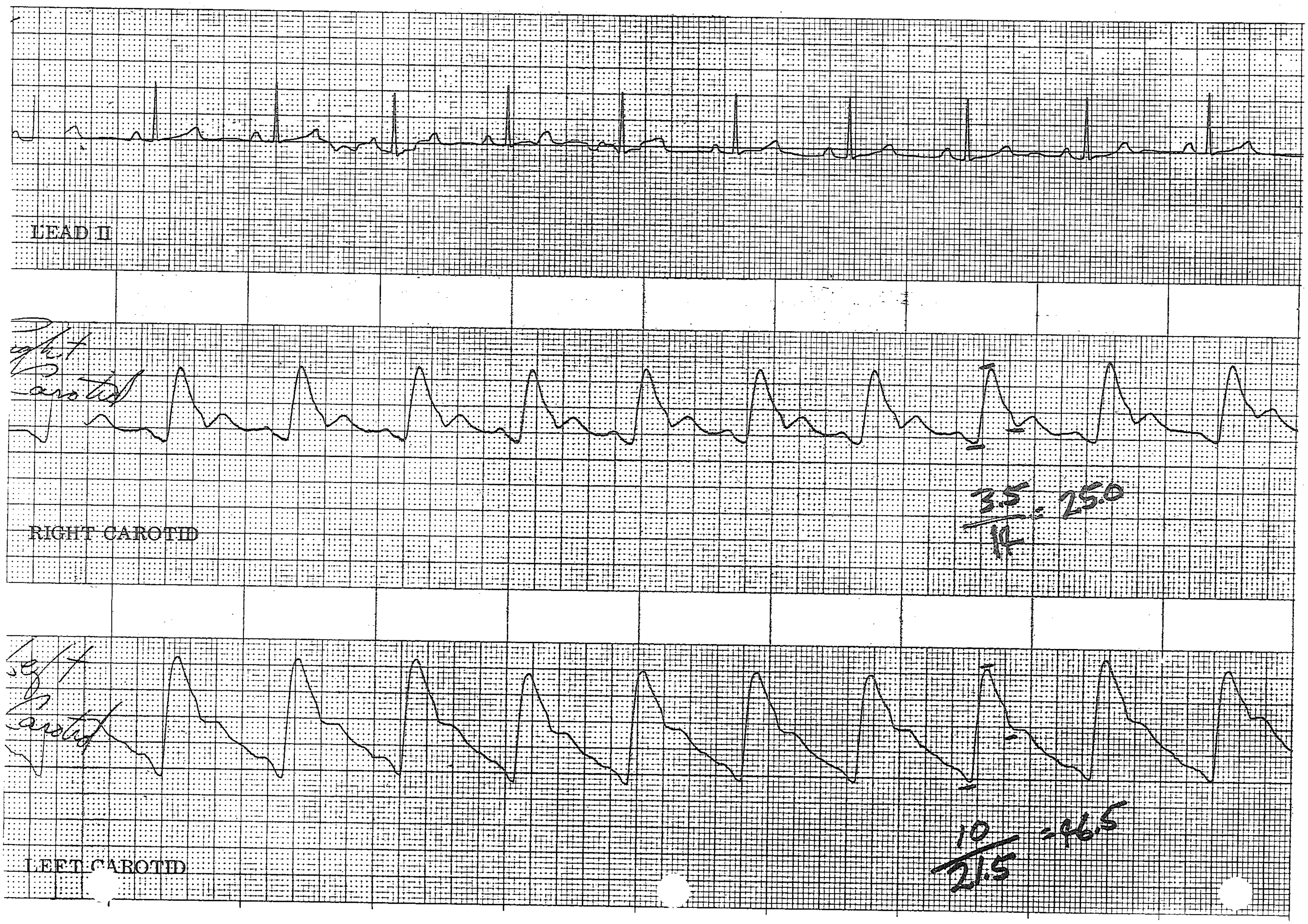
DIGITAL GAGES are made in a closed loop with .015 x .040 tubing. Flexible, vinyl-covered leads are approximately 3 feet long. All digital gages with standard lead length are $4.50 each. Add 25¢ each for lead lengths over 3 feet but under 10 feet. Long leads will cause a loss of sensitivity and are not recommended for general use. SPECIFY SIZE by telling us which digit you want the gages to fit on what size person. Example, big toe-large; fourth toe, adult male; index finger, 10 year old children. Or you may specify the unstretched diameter (not circumference). An assortment is often best because it is difficult to make one gage to fit everyone. On children, use the thumb if possible. Gages for very small fingers can obstruct venous return. Sometimes the smaller material is better.

PURCHASING DEPARTMENT: Prices above include postage and are firm through 1968. Shipment is normally within 4 working days of receipt of order. PLEASE send your orders air mail. If you want us to ship air mail, add 8¢ per gage.

ADDRESS CHANGE: Please use our new business address as shown below. (May, 1968)

PARKS ELECTRONICS LAB. 421 S.W. FIRST BEAVERTON, OREGON 97005
Area code 503 644-7463

TIMING CARDIOVASCULAR EVENTS---Use of the Impedance Plethysmograph and Surface Electrodes. Recordings shown on both sides of this sheet were made by Dr. Ernst Simonson, U. of Minn., with our Model 225.



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PLETHYSMOGRAPHY IN ANIMAL SURGERY

The plethysmograph is useful in a variety of ways in the field of experimental surgery. Most of the information we can furnish at this time is second hand.

A good method for monitoring the pulse on dogs uses a mercury strain gage wrapped just above the paw. The gage is an open type (not a digital gage) about 2.5 to 3 inches long. It is made of .015 x .045 tubing. The ends of the encircling gage are clamped together with a Mueller clip or some type of surgical clip. There must be tension on the gage. Wires to the gage are taped to the dogs leg to prevent pulling on the gage. The impedance method, using needle electrodes, can also be used but apparently there is a difficulty in gettin g the same pulse amplitude and shape if the needles are inadvertently pulled out and have to be re-inserted.

You can insert a needle into each thigh of an animal, using the impedance method, and get a pretty good size and fairly stable pulse waveform. The change is caused by pulsatile flow in the thighs to the bifurcation of the abdominal aorta. The amount of respiratory interference you get depends on the size of the animal, how you tie down the electrodes and wires, and the time constant you use. A cat is a fairly difficult animal to monitor because it is more troublesome to get the wires and electrodes secured to the leg, especially if it is covered with a lot of hair. You can make a good recording of respiration just by using poor electrode tie-down techniques and the way you drape the wires. The smaller the animal, the more respiration artifact you'll encounter. The shorter time constants minimize respiratory interference. If there is a slow speed on the recording device used, it is possible to obtain nice composite waveforms of pulse and respiration from which you can determine rate. An example is shown on the following page. Respiration influence is stronger on the forelegs and around the chest.

External carotid pulsations can be recorded from the scalp of animals and humans with the impedance method and surface or needle electrodes. Common carotid pulsations can be obtained by the impedance method on the neck but not too easily. A strain gage wrapped around the neck or part way around will sense pulsations. Internal carotid pulsations are of considerable interest but experimentation done to date has not been too productive. All has been done on humans. There are two ways of doing this that are legitimate and another method highly advertised but of questionable validity. One is the insertion of needle electrodes at two places distal to the branching of the carotids. Enough clinical work has not been done with this method to prove its practical value. Another is sensing of the pulsations of the ophthalmic artery by the movement of the eyes in their sockets. The problem in unanesthetized humans is eyelid twitter which interferes. With anesthetized humans or animals the technique may be successful. The questionable method we are mentioning but not promoting is the use of large electrodes on the scalp and at the base of the skull. Experimentation done at the U. of Minn. several years ago showed that pulsations in brain blood volume did not penetrate the cranium of a dog. While it is true that pulsations of the scalp are easily detected and that with occlusion of the common carotid or the bifurcation they are diminished, it is highly questionable that the placement of electrodes anyplace on the scalp will detect anything except blood flow from the external carotid.

Blood pressure measurements may be made on dogs, cats and even rats with proper procedures and cuffs. On dogs, needle electrodes are inserted about 3 inches apart along the length of the tail. Systolic pressure measurements are relatively easy to make on anesthetized animals. On rats, vasoconstriction may be a problem at times so the rats should be kept warm. Whether or not this is a problem in dogs too we do not know. It has not been encountered. It is possible a strain gage around the tail would work as a sensing device, and perhaps a better one. An open type gage should be wrapped around the tail, perhaps two or three times.

On internal organs there are two good methods. One is to use fish hooks for electrodes and the impedance method. Be sure there is no lacquer on the hooks so they will make good contact. Fish hooks stay in place well. You can solder small, limp wire to them and run the wire several feet without loss of signal. You cannot do this sort of thing with the low-resistance mercury strain gages. If you use needle electrodes near something that is physically moving with the pulse there is always the possibility that what is recorded is change in contact resistance caused by movement of the electrode as well as conductivity changes caused by blood volume change.

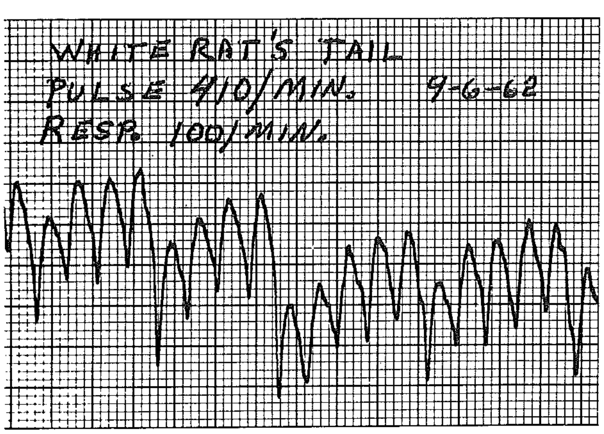
Changes in circumference can be recorded quantitatively or qualitatively by use of our smaller sizes of mercury gage sutured to the heart or around an artery or organ. The material size .012 x .025 is a good compromise between reliability and elasticity. The size .006 x 015 is far more compliant but the failure rate is higher because of the fragility of the gage. Also there has been a problem in obtaining tubing of this size without holes in the walls. If you want to use material of this size it is best that you write us, describing your application.

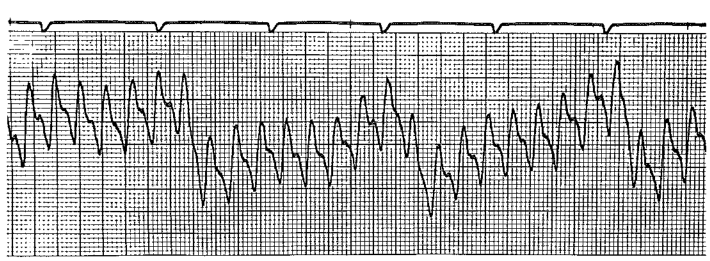
Respiration is easily monitored plethysmographically. If you're interested only in the rate, any of our plethysmographs used on the long time constant for larger animals will be satisfactory. If you want to show changes in tidal volume irrespective of rate then a D.C. (direct coupled) recording system is required. At present (Jan. 66) the Model 270 is the only plethysmograph we make that is direct coupled. All others are A.C. coupled. What this means is that your stylus will return to the center whether blood volume does or not. In other words, an A.C. coupled device, such as an electrocardiograph, is made for recording pulsatile changes of a relatively rapid nature. It is possible in some instances that the D.C. input on an electrocardiograph will have adequate sensitivity to record respiration. This would be of most interest to those of you with rack-mounted recording equipment with a variety of preamplifiers and multiple paper speeds. A D.C. input on an EKG preamp or electrocardiograph is usually 50 mv/cm rather than the 1 mv/cm at the patient cable input. If respiration recording is attempted, use the mercury gage over the abdomen or any part of the trunk that moves reliably and visibly with respiration. A gage need not encircle the trunk. On humans, the impedance method works best a few inches below the arm pits.

Examples of animal recordings:

In the graph to the left, a mercury strain gage of .015 x .040 material was wrapped twice around the tail of a white rat. The rat was restrained in a wire cage just large enough to admit him. The tail was outside the cage. The rat was not anesthetized or sedated. A recording such as this cannot be made unless the rat is perfectly still. It is necessary to wait until he is still before running the paper drive. It may be necessary to warm him to release vasomotor tone. In this case it was not. You will have to experiment with gage tension.

In the recording to the right, our gage of .005 x .015 material was sutured to the sclera of a rabbit. Eye muscles were cut so that only pulsations of the globe would be recorded and there would be a minimum of twitter. A local anesthetic was used. Lids were not touching the gage or wires to it. Changing the fluid pressure within the eye by means of a syringe changed the size of the pulses. Pulse and respiration rate can be easily measured on both graphs below.





How to say it:

Many people have trouble pronouncing impedance plethysmograph. They put the accent in the wrong place on impedance and they leave out the "th" sound in plethysmograph, substituting a "t" sound. Here are some phonetic aids.

im-pḗ-dance plĕ-thíz-mō-graph

What it isn't:

The name impedance plethysmograph which we apply to our instruments is not at all accurate but it is commonly accepted and understood. A plethysmograph should measure true volume in volume units. None of our plethysmographs do this. Also a plethysmograph should record. All our instruments are really accessories to recorders the user already has. And finally, when our instruments are used as directed, they are not graphing impedance for you at all. The graph is of conductance, the reciprocal of impedance. If we had you use them to record impedance variations, the pulse would look upside down to you and this would be confusing. This frank admission of deceit is for semanticists who sometimes take delight in pointing out how incorrectly we describe our instrument. They invariably pounce on the word plethysmograph and none yet has brought up the point that we are graphing conductance and not impedance.

How it works:

Most people we sell plethysmographs to just want to know which knobs to turn and where to hook it on the patient to get what they're after. This is probably the best approach for most people because in most cases there is really little to be gained by understanding the details of operation. A good set of operating rules will give you more results in less time than the finest explanation of principles that could be written.

We can't give a good set of rules to the doctor in research, the student and others with interests in very specialized applications. A little explanation for them may be in order. In the following paragraphs we assume you've heard of Ohm's law and are familiar with the terms voltage, current and resistance. The concept of impedance is a bit involved and is really not pertinent here. If you substitute the word resistance for impedance, your comprehension will be faster and in this case not appreciably inaccurate.

To start with, we will say that our impedance plethysmographs are used to measure extremely small changes in electrical resistance. Note the word c h a n g e s, not steady values. These small resistance changes are caused by changes in the blood volume of a tissue segment. Blood is a fairly good conducting fluid compared to other body tissue. The blood is the only variable for the type of resistance measurement we're making when technique is proper. Galvanic changes, the electrocardiogram, muscle action potentials, etc. are not recorded because of the nature of the circuit used.

Resistance changes in tissue segments caused by blood volume change vary from a few tenths of an ohm at most to a few thousandths of an ohm in vasoconstriction, disease, or in areas supplied by very small vessels. It is not practical to make such measurements with an ohmmeter or any other direct current measuring system. Measurements of tissue resistance are made with alternating current. Our plethysmographs use an a.c. current of approximately 30 kilocycles. We do not use a conventional Wheatstone Bridge circuit in any of our present instruments. Essentially, what we do is send a 30 kc. current through the tissue segment being studied and measure the a.c. voltage which appears across that tissue segment. When the current to the tissue is supplied by a high resistance source, the voltage across the tissue is proportional to the electrical resistance of the tissue and the electrode junctions. This is explained further on the following page.

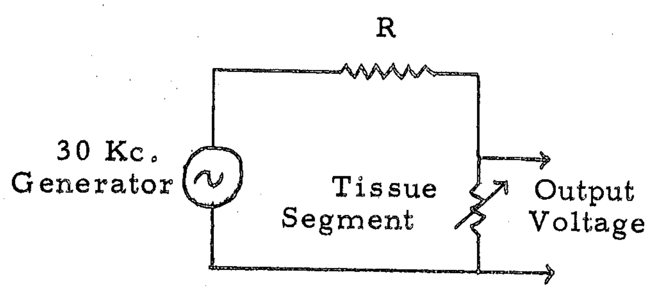


Fig. 1

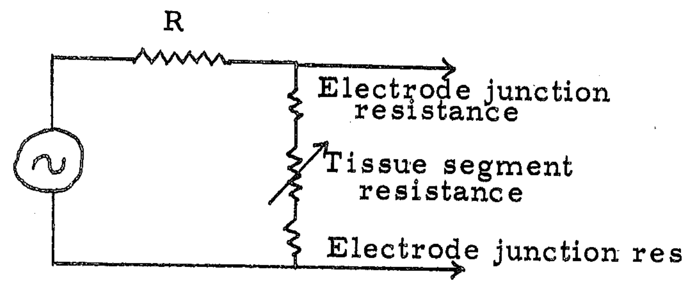


Fig. 2

In Fig. 1, if R is large compared with the resistance of the pulsating tissue segment, then the output voltage will vary directly with the resistance of the tissue segment. This relationship is very linear only if R is quite large so that the current in the loop is determined by R. As an example, consider R to be 10,000 ohms and the tissue resistance to be 100 ohms. If the tissue resistance changes by 10% to 110 ohms, the total resistance change of the entire loop is only 10 parts in 10,100 which is quite small and of no consequence. Since the actual resistance change of a pulsation is on the order of .1 ohm in many cases, the pulsatile change in resistance will not cause current in the loop to change with the pulse even though R is much lower, 1,000 ohms for example. In our plethysmographs to date, we use a capacitor with a reactance of about 1,000 ohms for R. (reactance is 1,000 ohms at 30 kc.) Using a reactance instead of a resistance gives the same effect but does not consume power which must be furnished by the generator (transistor oscillator) and ultimately the batteries. Our plethysmographs which display only pulsatile phenomena then can be relied upon to give a voltage output which is linearly related to the resistance change brought about by blood volume changes during the cardiac cycle. When gross changes of resistance in the tissue segment are to be recorded, a plethysmograph with a direct coupled output is used, such as our Model 270. Wide variations in impedance then may not be displayed linearly and the linearity of the total system should be checked by substituting known values of resistance for the tissue segment and plotting resistance versus output voltage. If the output voltage of the Model 270 does not change more than half a volt from zero center it can be assumed the recording will be quite linear. This covers about 99% of the applications for this instrument. In venous occlusion work the output change is so small the instrument can be considered quite linear. The relationship between blood volume change and resistance of the tissue segment is quite another thing and independent of the electrical function of the plethysmograph.

Figure 1 is over-simplified for explanation purposes. The voltage across the tissue segment is amplified and rectified and then condenser coupled to the output in pulse-type plethysmographs (models 3-H, 3-H-MSG, 202 and A.C. Output of 270). In addition it is not possible to measure the voltage across the tissue segment alone when only two electrodes are used. The electrical contact to the tissue is imperfect and the resistance of the two electrode junctions must be included (Fig. 2.) Any movement of the electrodes will vary the electrode junction resistance and this is recorded along with variations in the tissue resistance. Junction resistance changes from movement are often much larger than tissue changes and completely obliterate the desired pulsations. Therefore electrode junction resistances must be kept constant. When you consider that a resistance change of .05 ohm in 150 ohms causes a deflection of two centimeters (2 mv.) on an electrocardiograph you can understand why an extremely small resistance change is enough to spoil a recording. With good techniques you can record pulsations of arterial segments only a few millimeters long. The impedance method is the most sensitive and versatile method of detecting pulsations due to blood volume change. For this reason it is especially useful in place of a stethoscope to make systolic pressure determinations in surgery. Any of our impedance plethysmographs can be used for this purpose with surface or needle electrodes. In surgery, needle electrodes into the muscle surrounding the artery work best. The black wire or common electrode should be connected closest to the body trunk to minimize disturbance from the surgeon's contact with the patient. Tissue segment resistance changes with respiration in small animals and on the forearm of humans. Using a shorter time constant will discriminate against volume changes due to respiration but there will be some sacrifice in the fidelity of the pulse volume waveform.

Types of electrodes: (a) Needles

Ordinary hypodermic needles make quite good contact with tissue. The more surface area in contact with the tissue the better. It is not necessary to insert the needles into the artery, but they must be inserted into the tissue along the length of the artery. Just under the skin is usually satisfactory, but the closer you can get to the artery the more detail you will have in the waveform. The inertia-free nature of the impedance plethysmogram makes it very valuable for studies of pulse-propagation time and other time-related events. When the needles are inserted at the right place, you will note that the pulse has a very rapid upstroke and that there is a sharp change between the run-off portion of the previous wave and the arrival of the leading edge of the following pulse. Wherever there is a narrowing of the vessel, as in arterial obstructive disease, the change will not be so pronounced. In severe disease it may be quite smooth. A short time constant is usually used for this type work because it stabilizes the base line and sharp changes in the waveform contour are not appreciably attenuated.

One disadvantage of needle electrodes is that they tend to fall out. you can use a very small Mueller clip on your lead wire to make contact with the needle fitting. Then tape the fitting and the wire down to the patient. If someone rubs against the wire, the needle contact will be disturbed and distort the recording. Be sure the limb is at heart level or slightly elevated. Sharp changes in volume used in timing studies are better seen with the limb slightly elevated. When the limb is in a dependent position venous pooling apparently occurs and wave contour is seriously altered.

Needle electrodes are useful in making systolic pressure measurements on the tail of a dog or cat. A premature size blood pressure cuff is placed proximal to the needle electrodes which are inserted along the length of the tail. When you can record a reasonable size pulse, inflate the cuff rapidly to a pressure beyond that where systolic pressure should be . Then deflate the cuff slowly until the pulse is just visible on the recording. Cuff pressure then is approximately equal to arterial pressure in the tail. We say approximately because it is hard to prove that the pressure in the tail is actually as measured. Nevertheless, values are reasonable and repeatable. The shortcoming is in the cuff method, not in the plethysmograph. Anatomical hiding of the artery is a disadvantage when you try to use the animal's leg for a measurement. This method does not work on a rat. It does work on the arm of a monkey. It is assumed here that the animal is anesthetized

If you are monitoring an anesthetized animal with needle electrodes and observing the amplitude of the recorded pulsation, be especially careful that the electrodes are well anchored. If the needle falls out and you immediately replace it, you may not get the same amplitude or contour on your recording. A mercury gage wrapped around the leg gives better reproducibility.

It is not necessary to use a short segment of artery for impedance plethysmography. You can insert needles into the thighs of a dog--one in each-- and get a very large and perhaps more stable waveform. The current path is then through the iliacs to the bifurcation of the abdominal aorta. Needles can be placed almost anywhere and you will get some kind of waveform. Knowing what you have can be a problem though. If you can record the ECG simultaneously you will be able to better correlate the plethysmogram with the cardiac cycle. Occasionally with needle electrodes you will record a mirror image of the pulse. We do not know what causes this. All you can do is insert the needles someplace else.

In the liver, kidney, etc. fish hooks can be used in place of needles if they are well cleaned so they are free of lacquer or varnish. Their big advantage is that they stay in place better and don't require special anchoring provided you use quite limp wire to make contact with them.

Types of electrodes: (b) Surface

Contact to tissue may be made by means of electrodes placed on the surface of the skin. The 30 kc. current passes through the skin under the electrode, through the tissue segment between the electrodes and up to the other electrode. Current distribution is not uniform. Most current will be carried by paths of least electrical resistance and probably a major part of it flows through the arteries and veins. The pulsation of the artery is so large that it will be the only pulsation recorded. The electrical resistance of the skin is relatively high, especially dry skin and that of dark skinned people. It is best to scrape the skin with the edge of a tongue depressor or electrode and produce an erythema if possible. A thin coating of paste should remain and the electrode twisted on the skin until the paste thoroughly wets it. Many people have false ideas about making contact to the skin. Good contact is more important for getting good impedance plethysmograms than it is for getting electrocardiograms. We want you to have success with our plethysmographs and will tell you the proper ways to make contact.

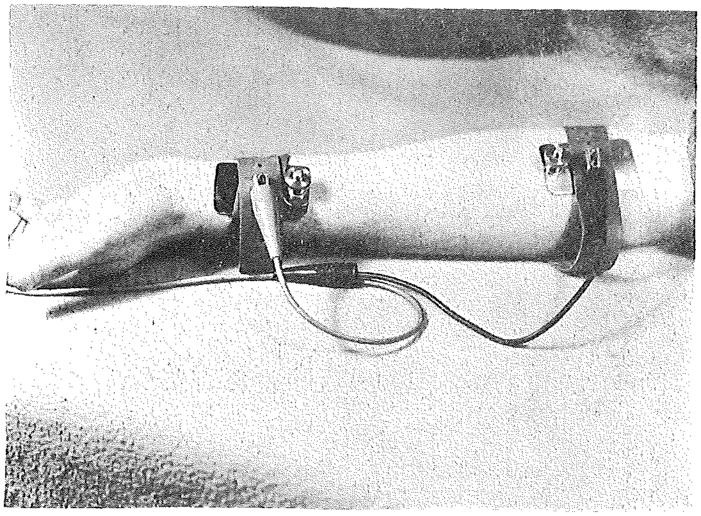
1. You may clean the skin with alcohol or ether before applying paste if you wish, but it isn't necessary. You <u>must</u> use paste. Do <u>not</u> try to get by without it.

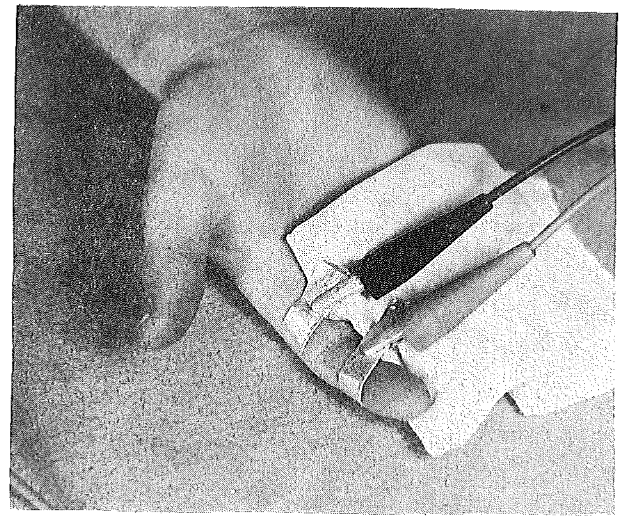
2. There are a number of electrode contact preparations on the market which are sold as "modern" preparations to replace "old-fashioned" paste. They have lots of appeal and you can often get by with them in electrocardiography, though they are the source of lots of a-c interference and base-line instability because of their poor contact. The electrical contact they make with tissue is so bad it can't be compared to a good paste contact. If you use them in place of the proper paste for electrode contact you are asking for trouble. Base-line instability is the symptom of poor electrode contact and movement.

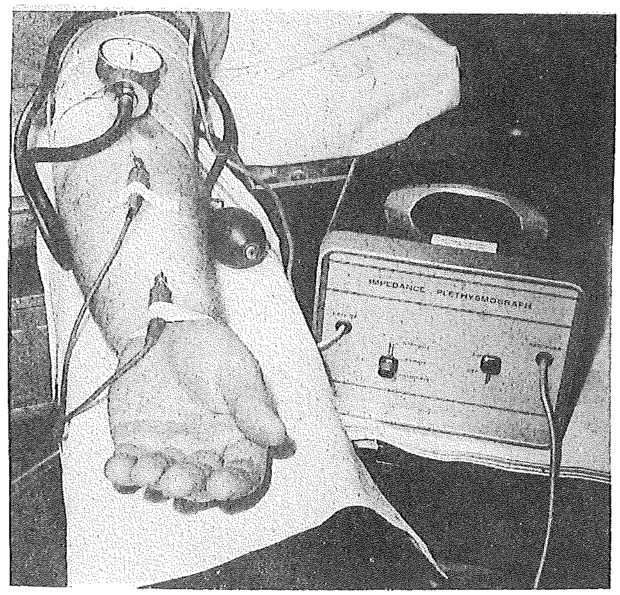
3. Proper paste is gray and gritty and has high conductivity. Unfortunately good EKG pastes are not readily available. The "modern" preparations such as creams and other forms of contact material distributed by reputable electrocardiograph manufacturers at present are not good but may work in some instances. We buy a good paste (Holland-Rantos) which you may buy from us at $1 a tube. Some pastes made for electro-shock and EEG are good. Good pastes are gritty and abrade the skin when rubbed. They contain salt and are hard and crumbly on drying. Paste will dry around the edges of the electrodes in time and will need to be replaced. Things like K-Y jelly and other lubricants should not be used as they are non-conductive.

Electrodes can be made of almost any metal. Ordinary EKG electrodes are fine. The suction ones can be used in some cases if they don't gradually lose their suction, causing erratic contact. Whatever type electrode you use, it must be attached or propped so that it does not move with respiration. Tissue volume can change considerably from respiration and activities of the sympathetic nervous system. Pulse amplitude can easily increase by a factor of 20 from constriction to dilation of peripheral arteries.

On the digits and on the limbs of animals it is more convenient to use bands of wire or flat metal. The more area you have in contact with the skin the better. Don't slop the paste on the skin between the electrodes because the current would tend to follow the paste rather than go down through the skin. Aluminum baking foil can be folded into 3 or 4 thicknesses and wrapped around the limb of an animal or a human digit. Use a Mueller clip or other spring-loaded device to clamp ends of the band together. Do not get the clips in the paste. Do not obstruct venous return. The mass of the clip and the wire should be small. The wire should be limp and supported a short distance from the digit. Dental matrix material is made of .002" stainless steel and in various widths. It is inexpensive and readily available from dental supply houses. The 3/8" width works well on digits. Wrap it around the base of any two toes. Usually you leave a toe between the two to which the bands are applied (for insulation.) The recording will be of the filling of the artery between the toes. This method is superior to the mercury gage method in cases of severe disease or intense vasoconstriction because the path is through larger vessels and those not so subject to constriction as ones at the tip of the digit. An old tooth brush can be used to spread the paste. You can get by with sloppier techniques in pasting if you prop the foot, the wires and have proper tension on the band. This takes some practice but those who have used both methods prefer the impedence method.







The upper left photo shows use of ordinary EKG electrodes on the surface of the skin. The skin beneath the electrodes is prepared by using a tongue depressor or edge of the electrode to rub electrode paste (not cream) into the skin, creating an erythema. The black wire is connected to the electrode closest to the body trunk. Only two surface electrodes are used for studying pulse waveforms or making blood pressure measurements on the legs. Electrodes placed on the lower leg (one just above the ankle, one a few inches below the knee) permit blood pressure measurements at sites above the electrodes. This method is good when there is obstruction below the knee and a satisfactory pulse at the toe cannot be obtained. While this method rarely fails to produce a usable pulse, it can fail in cases of obstruction of the trifurcation below the knee and poor collateral circulation. In such instances, the upper electrode is put just behind the knee and pressure measurements are made just above the knee and at the upper thigh.

In the photograph in the upper right corner, aluminum foil was folded 3 times to form bands which were placed around the fingers. Paste is used. Tremor of the digit is sometimes a problem with this method. It is often better to place the electrodes around the base of two fingers or toes. A piece of gauze may be placed between adjacent fingers for insulation. Another method is to place the electrodes on the second and fourth digit, using the third as an insulating barrier. This latter method is sometimes preferred by doctors making blood pressure measurements on the legs. They like it because if their patient has just come in from out of doors and his feet are cool, it is likely they can obtain a pulse without a vasodilating procedure because vessels between the toes are not so affected by vasoconstriction as the tip of the toes, where the mercury gage is used.

In the lower photograph, our former Model 3-H (replaced by Model 210) is being used with needle electrodes (only two) in surgery for monitoring and making blood pressure measurements. The arm should be at heart level or slightly above to assure good run-off and therefore a good pulsatile volume change.

SOME APPLICATIONS OF THE IMPEDANCE PLETHYSMOGRAPH

The impedance plethysmographs we make are designed for use with an electrocardiograph or cardioscope having a 5-pin patient cable receptacle. A double-circuit phone plug adapter can be used with research recorders having a 1 mv/cm input.

1. The impedance plethysmograph permits the recording of pulsatile changes in blood volume of an arm, leg, finger, toe, some internal organs and the tails of some animals. The recording is of pulse volume and varies directly with pulse pressure. It is the pulse you would feel with your fingers if your touch were sensitive enough.

The pulsation is not readily calibrated in ml. of blood flow or volume and we do not suggest or furnish material for such a calibration. The pulsation is readily calibrated in electrical units (ohms) by means of a calibrating switch on the panel. The ohmic calibration is especially useful where there are long time intervals between recordings. Use of the calibrating switch is described in the operating manual.

2. Systolic blood pressure can be determined on infants, adults in hypothermia, various parts of limbs, tail of a dog, etc. when the plethysmograph is used with a cuff. The determination is as accurate as the cuff method permits. The plethysmograph is used to detect the return of pulsations below the cuff when cuff pressure falls below systolic pressure. The impedance plethysmograph is by its nature the most reliable and sensitive instrument for this purpose. It will continue to record arterial pulsations, if at all present, long after digital plethysmographs have ceased functioning. It is especially valuable in surgery where systolic pressure may fall to very low levels. At very low pressures, the cuff method is inaccurate, but the impedance plethysmograph will accurately indicate when pulsations have returned and then a correction can be made for error in the cuff method. (Dept. Anes. U. of Ore Med. School.)

The reason the impedance method is best for this particular use is that the sensing of volume pulsation is made from a large segment of the forearm, not just the tip of a digit. The sensing current, which is imperceptible, follows the large arteries--- digs under muscle and fatty tissue. Vasoconstriction can obliterate a digital pulse unless a block is performed. Even then, the larger arterial pulsation present in the forearm is a better pulse indicator because its size makes it more stable if there is patient tremor or slight movements from other causes.

All pulse-detecting plethysmographs, being sensitive instruments, cannot tolerate much patient movement. The volume of a limb or digit changes with position and muscular activity. The forearm volume changes somewhat with respiration. When surface EKG electrodes are used, variations in electrode contact have so far made it impossible to monitor the effectiveness of external cardiac massage. To date (Jan. '62) we have not tried needle electrodes for this purpose.

(over)

The most stable monitoring waveform is obtained by connecting a sensing electrode to each ankle. The sensing current then flows through both legs, the iliacs and through the bifurcation of the abdominal aorta. Because of the size of these vessels, the pulsation is very large and more motion can be tolerated, especially if needle electrodes are used.

Hypodermic needle electrodes, rather than surface electrodes, are often used in surgery---two for sensing and one for a ground. All three are inserted into the forearm under the skin but not into the artery. One is placed just above the wrist and the other is placed anyplace a few inches or more proximal. The ground electrode is placed proximal to the two sensing electrodes. Its purpose is to isolate electrically the sensing circuit so intermittent touching of the patient will not upset the trace.

All plethysmographs we make are for recording pulses only and are not suited for recording very slow waves such as those encountered in venous occlusion plethysmography. A bypass operation cannot be monitored because the flow is not pulsatile.

3. In vascular disease, the impedance plethysmograph is used to evaluate circulation in the limbs. Ordinary surface-type EKG electrodes or thin bands of aluminum foil are used. Diagnosis is made from the size of the pulse and the shape. Waveforms recorded along the length of a limb above narrowed arteries are large and have a rapid upstroke, showing rapid filling of the artery. A dicrotic notch is usually present. Below the narrowing, waveform size is smaller and the filling (crest) time is much longer. The dicrotic notch is nearly always absent. Blood pressure at various parts of a limb can be accurately determined by the cuff method described in 2. The impedance plethysmograph will detect pulsatile flow in a limb if it is present at all. It is not as convenient to use on toes as our mercury strain gage plethysmograph, the transducer of which is a thin elastic tube filled with mercury which slips over the toe. With this instrument, candidates for sympathectomy are selected by the reactive hyperemia test with occlusion at the ankle for 5 to 10 minutes. Patients selected for sympathectomy show a 50% or more increase in pulse height following deflation of the cuff. (V.A. Hospital, Seattle) The impedance plethysmograph should also work with this test. It is used for the same purpose at other hospitals with a sympathetic block or other vasodilating technique. It is a much quicker and more reliable test than skin temperature change. The impedance plethysmograph shows arterial pulsations, and not capillary flow.

In the last three years of manufacturing plethysmographs and in research before that, we have done a number of specialized and interesting things with the impedance plethysmograph. We pretty well know in advance what will and what won't work or what the problems involved will be. If you have a special application in mind, please write and ask about its feasibility. As a general rule, difficulty arises when you try to get quantitative about blood volume or flow. Relative size measurements, precise time relationships and contours are easily made. For time relationships and contours as well as extreme sensitivity, the impedance method is without doubt the best.

The a.c. output impedance is high---over 100K ohms. It is meant for use into a vacuum tube grid circuit with an input resistance of at least .5 meg. The output is single ended. For use with an electrocardiograph, the plug which fits the patient cable receptacle on the electrocardiograph must be wired so that signal is fed into pin B (the in-phase grid on Lead I) and all other terminals are connected together and to ground. If a.c. interference is experienced, it may be necessary to connect a "common" terminal post on the plethysmograph to the metal frame of the electrocardiograph. There is sometimes a problem with Sanborn equipment using a single ended signal into their differential input and specific difficulties should be referred to us for remedies. Be aware of the fact that when you connect a "common" terminal on the plethysmograph to the frame of the electrocardiograph (which should be grounded) your patient is firmly grounded on the impedance mode and precautions against shock by other faulty electrical equipment and lamps should be taken. The plethysmograph itself is absolutely incapable of giving any shock. If the patient gets a tingle it is because electrical equipment used with the plethysmograph is not properly grounded.

When the impedance method is used, increasing volume will cause a negative going signal to appear at the output of the model 270. If the Lead Selector switch on the electrocardiograph is set to AVR, the pulse will appear upright as it should. When the mercury gage is used, increasing pulse volume will cause a positive going signal to appear at the output and the Lead Selector switch should be set to Lead I.

The a.c. output signal is shorted to ground in the Standby position of the OFF-ON switch. The Standby position protects the stylus of the electrocardiograph or other recorder from violent excursions resulting from movement of the patient or adjustment of electrodes.

The d.c. output is not shorted to ground in the Standby position. The d.c. jack is disconnected when there is a plug in the a.c. jack. You should not attempt to use the d.c. output of the plethysmograph into the patient cable receptacle of an electrocardiograph because you cannot determine when the d.c. output circuit is properly adjusted. The electrocardiograph is an a.c. coupled instrument and you cannot record anything but pulsatile changes in volume when the signal is inserted into the patient cable receptacle. While later model electrocardiographs may have a d.c. input jack, the d.c. sensitivity is about one fiftieth that of the a.c. or patient input. The lower sensitivity on d.c. and the fast paper speed limit the usefulness of the d.c. input considerably. It is definitely not suited for venous occlusion work with the Model 270 plethysmograph.

The TIME CONSTANT refers to the time required for the stylus to return to the base line when a step change in volume is detected. From the user's standpoint, the base line will wander less on the shorter time constant positions but the run-off of the human pulse wave will also appear to be faster than it really is. The upstroke on normal pulse waves will not be materially affected. Time Constant is an a.c. term and the above applies only to the a.c. output of the plethysmograph.

The actual output time constants of the Model 270 into an infinite impedance load are approximately 5 seconds, 1 second and .25 second. Most electrocardiographs have a three second time constant so the time constant of the entire recording system will be less than 3 seconds for the longest one and about .25 second for the shortest one.

The d.c. output is also single ended. The d.c. output impedance is about 5,000 ohms and is sufficiently low to drive most chopper type amplifiers. The voltage range of the d.c. output is approximately plus or minus one volt. The output circuit on d.c. is a transistor operating as an emitter follower with the emitter at ground and a total supply voltage of 3 volts d.c.

(next page)

Electrical Characteristics of the Model 270 Plethysmograph---continued

The sensitivity of the plethysmograph depends on the battery voltage, which is the major cause of drift. New batteries have more than 1.5 volts each so the meter will read slightly more than 3 volts on new batteries. Sensitivity will vary directly and linearly with battery voltage. Where long term stability is desired, a set of larger batteries should be used externally. The plastic case is shielded to minimize a.c. interference from stray electrostatic fields, so the instrument should be operated in its case. There is no shielding against magnetic fields so keep the plethysmograph away from transformers and motors when in use.

The Model 270 uses a carrier system and passive amplification. There is never any problem of phase-balancing the bridge because there is no bridge. The input terminals go to different taps on the input transformer. Digital gages and other low resistance ones should be used on SHORT so the system will balance on D.C. Bad gages or poor electrode contact on impedance terminals will also prevent you from attaining balance. The impedance connection marked HIGH is most likely to be used where contact is necessarily poor. Surface electrodes of standard electrocardiograph size and most needle electrodes will work best on the MEDIUM terminal. The COMMON terminal must also be used in either case.

This instrument is almost immune to electrical abuse. The most likely cause of damage will be from leaky flashlight batteries. When the meter indicates the battery voltage is under a volt, the batteries should be removed immediately as they are about to leak. You will get the best and most consistent performance from the instrument if battery voltage is above 2.5 volts.

LEAKPROOF BATTERIES ARE NOT LEAKPROOF. Buy only steel-jacketed batteries. Ordinary flashlight batteries are quite satisfactory. Alkaline batteries may give longer life and be desirable in some instances. Experience has shown that the primary cause of dead batteries is forgetfulness--not usage. It does not harm the instrument to turn it off and on frequently. It needs no warm up. It is better to turn it off more frequently than necessary than to leave it turned on for a week inadvertently.

Current drain of this instrument is approximately 18 ma. Batteries must make good contact in their brackets. Spring the ends of the bracket inward to increase pressure if necessary. The top end of the battery goes to the plus end of the bracket (stamped on the bottom of the bracket). If the meter reads full scale when you turn the instrument on, the batteries have been properly installed.

SERVICE: If you believe the instrument is in need of service, write us describing the type of recording you were attempting to make and enclose a sample of the recording. Word descriptions are very inadequate. These instruments by their nature are very reliable and we have several years experience with the basic circuits used. Most problems that arise are from misunderstandings about how to use the instrument and from incompatibility with certain types of recording equipment. Occasionally a cable is defective or has been improperly wired. When you suspect the instrument or a cable or incompatibility with your recorder, ask an electronics technician to try the instrument on recording equipment he has access to. It is very unlikely that a transistor in the instrument is bad. Any audio PNP transistor with low leakage and adequate collector dissipation and gain will work. We select transistors for lowest noise.

If you still have trouble, send the instrument to us WELL PACKED and we will repair it at no charge for two years from the date of purchase if the trouble is caused by a faulty part or defective manufacture. Damage done by someone trying to make a repair is not covered. Factory service for this type of instrument is best because very few technicians will understand the circuitry well enough to make a repair in a reasonable length of time. When we make the repair the instrument will be returned in like-new condition.

D.C. Output: The D.C. Output is used to display very slow changes in volume or length caused by sympathetic activity, venous occlusion, respiration etc. With a D.C. recording system you can calibrate your recording in units of length by simply laying the gage alongside a ruler and selecting appropriate sensitivity on your D.C. amplifier to give you the amount of deflection you want. With no connection to the plethysmograph, set the deflection factor of your D.C. recorder to about 50 mv/cm. and use the zero or balance controls on your D.C. amplifier to set the stylus to the reference position you desire. Do not touch the positioning or zero controls on your D.C. amplifier again. All subsequent positioning should be done with the plethysmograph after it is connec ted and the gages or impedance electrodes are attached.

As an example, assume you have a 10 inch mercury strain gage and you want to calibrate your recording so that it will record excursions between the limits of 12 and 13 inches. Set up your D.C. recorder as described above. Stretch the mercury gage to 12 inches and tape it so that it stays 12 inches (a yardstick works well.) Connect the wires from the gage to the strain gage terminals marked COMMON and LONG. Plug the connector from the recording device into the D.C. Output jack of the plethysmograph. Be sure the plug goes in all the way so that none of the barrel shows. Turn the left hand knob on the plethysmograph to OPERATE and note the reading on the meter. Battery voltage should not be in the REPLACE range. Adjust the coarse and fine balance on the plethysmograph to position the stylus to your reference line. When you pull the gage away from the yardstick, the recording stylus should deflect upward (positively.) Now stretch the gage along the ruler until it is 13 inches long. Adjust the sensitivity or deflection factor controls on the D.C. amplifier of your recorder until the stylus is at the position you want to show a 13" length. DO NOT TOUCH THE POSITIONING CONTROLS ON THE PLETHYSMOGRAPH OR THE RECORDER--they are used to set the base line or reference only. Now return the gage to a 12" length and see if the stylus goes back to the 12 inch reference point. It should. If it doesn't, repeat the procedure using the sensitivity or deflection factor setting you now know to be appropriate.

It is very difficult to give rules for setting this up because of the large variety of D.C. recording systems with which this instrument will be used. You may need to get some technical assistance to help you get started.

D.C. DRIFT: Wandering of the base line, if not caused by the recording system, may be caused by a number of things and it is necessary to first try to isolate the source of drift. Drift will be caused by the plethysmograph, characteristics of the animal tissue resistance (impedance) etc. You must realize that if you increase sensitivity enough you can find drift in any system---everything changes. What you really want to know is whether the drift is caused by equipment not working properly or whether it is a fault in technique. Here again, it is difficult to be definite. The following is meant as a guide.

Use the same sensitivity or deflection factor for the following test as you did when you encountered the drift. Lay the gage out on the table and zero your stylus by means of the positioning controls (coarse and fine balance) on the plethysmograph. Wait a while and see how much the stylus moves. If your gage is bad you won't be able to position the stylus to your reference point. Instead of the gage, you can use a 150 ohm wire-wound resistor between impedance terminals marked common and short. If the stylus does not drift appreciably, the drift was caused by physiological phenomena, problems in technique such as a sharp angle where the tubing comes out of the black sleeve, etc. If it does drift, the problem is with the plethysmograph batteries (most likely), the recorder, temperature changes of the gage caused by drafts or you're using a sensitivity too high for the nature of this plethysmograph. Short term stability should be a half millivolt or less. If long term stability is necessary, use large external batteries and stabilize the temperature of both the batteries and the plethysmograph. Be wary of lights warming the animal tissue and/or the gage. You will have more d.c. stability problems with impedance methods than with the mercury gage method because of the variations in junction resistances that are difficult to control when high sensitivity is used.

MONITORING AND EVALUATING RECONSTRUCTIVE SURGERY

One of the most important uses of the plethysmograph is as a monitor during and immediately after reconstructive surgery. It lets you know immediately whether or not an arterial pathway has been opened significantly and also permits you to follow recovery easily, inexpensively and objectively.

Assuming the patient has been adequately studied prior to surgery, the problem is to determine objectively whether or not circulation has been restored before the incision is sutured. The following procedure is used and reasons why are given.

1. After administration of the anesthetic and when the pressure and pulse rate have stabilized, make systolic pressure measurements of one arm and both ankles. A stethoscope can be used on the arm. Either type plethysmograph pick-up method can be used on the toes for pressure measurements at the ankles. These measurements are your reference or control. It is the relationship of the pressures that is important. As systemic pressure changes, the ratio of ankle to ankle and ankle to arm pressure should stay approximately the same except where surgical intervention makes a change. An ordinary arm cuff can be used to make all these measurements.

2. Pulsations may be recorded and kept in the record. Make note of sensitivity settings on the plethysmograph and recording device. As the operation progresses, vasoconstriction may significantly change the pulse amplitude, but blood pressure will remain about the same unless systemic pressure changes.

3. When the obstruction has been removed, make blood pressure measurements again. Dilate vessels in the foot by drugs or heat if necessary to make an accurate pressure measurement. Compare all three pressure readings with those you made previously. If arterial circulation has been improved, the ankle pressure reading on the operated leg should be increased with respect to the ankle pressure of the other leg and the arm. In some cases, the actual pressure may be equal to or less than that before surgery. Again, it is the relationship to the other pressures that is important. If there is a question, take pressures again or use a leg cuff (of the type we furnish) and make pressure measurements up the leg. A low pressure reading is reliable. Any measurement or technical error will result in a higher reading than should be obtained.

Watch for these technical and diagnostic errors:

a. Disregard pulse amplitude changes before and after surgery as being very significant. A day or two post-operative a comparison is more valid. During induction and surgery pulse amplitudes can vary over a 20 to 1 range. Slower heart rate increases pulse height.

b. The more information you have on the patient before surgery, the better off you are afterwards in borderline cases. If there is enough time, make one or more pressure measurements on each leg in addition to ankle pressure. Pressure measurements just below the knee are not too reliable because of anatomical hiding of the artery, but they can still be useful as controls. On pressure measurements above the ankle be sure the inflated part of the cuff is over the arteries and that any gap caused by the cuff not being long enough is on the lateral part of the leg. This is most important on high thigh measurements that are too high because the inflated part of the cuff does not encircle the limb. Occasionally with diabetics you will get unreasonable high pressures.

c. You cannot immediately evaluate the success of a sympathectomy with the plethysmograph. Up to 72 hours are required for the full effect to be realized. However, you can use the plethysmograph and a block to determine how much the patient can dilate.

end

ABOUT THE DIAGNOSTIC METHOD FOR ARTERIAL DISEASE

One purpose of our plethysmographs is to help you obtain objective data on a patient's peripheral arterial circulation. Most information is derived from systolic pressure measurements made at four places along the limb. Of all the diagnostic methods tried it has been found that blood pressure measurements show more about the location and severity of arterial obstructions than any method short of angiography. The value of blood pressure measurements in screening patients for possible surgery has been well established in studies of over 400 patients at the V.A. Hospital, Seattle. Many other V.A. Hospitals and medical schools use this method. The original work on this method was done by Dr. Travis Winsor. His work is published in The American Journal of the Medical Sciences, August, 1950. He used a different method of detecting the peripheral pulse and much more elaborate equipment than we manufacture. The method is the same.

The blood pressure gradient method is good and it is relatively simple. It requires some practice. It is not perfect. You cannot always get blood pressure measurements. Some patients have such extremely painful limbs they will not permit even the slight pressure of the strain gage around the toe, much less the pressure of a cuff on the ankle. Some patients cannot hold still because of psychosis or brain damage. Any patient who is co-operative can be studied with the mercury strain gage if he has any pulse at all in his toe after dilation. Patients without toe pulses (there are relatively few) can be studied with the impedance plethysmograph which can detect pulsations all the way up a limb.

Personal experience in studying numerous patients prior to angiography has caused me to ignore clinical signs that too many doctors use in arriving at a diagnosis. Cold feet, lack of palpable dorsalis pedis or posterior tibial pulse, lack of hair on the toes, thickened toenails, cyanotic toes, etc. are not at all reliable signs of arterial obstruction. It is blood pressure that is important.

As a doctor you probably want to know what the patient's arterial trouble is (if any) and whether or not he can be helped. Information which can be obtained by proper use of the plethysmograph permits you to quickly select those patients who can possibly be helped surgically and should have angiograms made. As a rule, these are patients who show low blood pressures in the thigh.

If blood pressures are normal in the thigh but are low below the knee then you'll probably consider other forms of treatment. With experience I think that you'll gain enough confidence in the plethysmographic diagnosis that you'll not suggest arteriograms on these patients unless you want to attempt opening the block by forcing a catheter thru it. If your patient has rest pain or ulcers the plethysmograph will determine for you how much the patient's vessels can dilate if a sympathectomy is done. It will also show how effective the sympathectomy was after 2 or 3 days have passed. Dilatation doesn't occur immediately after cutting the sympathetic chain.

A very important application of the plethysmograph is in making blood pressure measurements after reconstructive surgery---while the patient is still on the table. Many surgical failures are the result of technical accidents which could be corrected if caught in time. If blood pressure at the ankle of the operated leg does not rise substantially with respect to the ankle pressure of the other leg following removal of the obstruction, an obstruction is still present. Angiograms are made immediately and an attempt is made to clear the artery by use of suction, incision or reverse flushing.

This is about as much as we claim you can do with our plethysmographs in the field of arterial disease and using an ordinary electrocardiograph. Specific techniques and less common applications are given in the manual. I think you'll find the plethysmograph is a very valuable tool when used correctly.

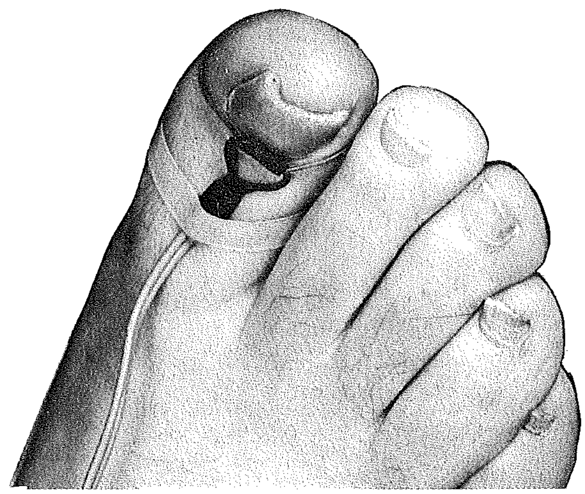
Loren Parks

Loren Parks

APPLYING THE MERCURY STRAIN GAGE

Proper placement of the gage is necessary to obtain a suitable size pulse. Even with proper placement there will be times when you cannot get a good pulse — when blood flow to the toe is seriously restricted and when the feet are cold.

The method of diagnosis outlined in this manual is based on pulsations near the tip of the digit. The gage should be placed so that the distal black sleeve is over the nail, usually near the base. To place the gage over the toe, grasp the elastic tubing with the thumb and forefingers of each hand and use your third fingers to stretch the gage into a circle. Don't stretch the gage any more than is necessary to slide it over the toe. DON'T ROLL THE GAGE ON. Rolling will interrupt or change the electrical characteristic of the mercury column in the gage and temporarily alter its sensitivity or make it inoperative.



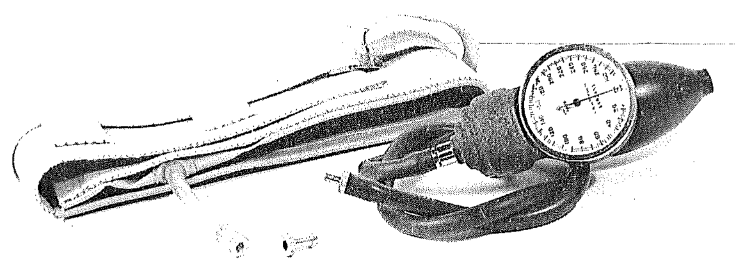
Tension should be uniform around the gage. There must be no sharp angle where the tubing enters the black sleeve because a sharp angle will interrupt the enclosed mercury column.

The gage is extremely sensitive to stretching — that's why it's called a strain gage. Accordingly, all changes in stretching should be caused by the digital pulse. Any change of tension on the wire connected to the gage would tend to stretch it and introduce unwanted waveforms superimposed on the pulse wave. To reduce erratic tension on the gage, it is necessary to tape the wire to the digit, preferably beyond the last flexible digital joint. In the photograph above, the tape is placed about 2/3 of the way around the toe — not tightly — so as to hold the wire but not obstruct venous flow. The tape can be placed farther toward the gage but should not be placed farther away from the gage. The wire can be taped again a few inches away with a little slack in the wire between the two pieces of tape. The second piece of tape helps relieve tension on the first piece caused by the weight of the wire. The wire to the gage should not hang free over the side of the bed. It should rest on the patient's leg or on the bed near the foot so there will be a minimum of tension on it. If there is tremor in the recording (something other than regular pulse waves) try different methods of taping or supporting the wire. It often helps to prop the foot. If the tremor occurs when you are making blood pressure measurements, make sure the tubing to the cuff is not rubbing the gage wire. Don't overlook the possibility of intentional tremor, especially where a disability compensation is concerned. A cold foot will have more tremor than a warm one and you may save time by having your patient lie down in a warm room with a heating pad or hot water bottle at his feet for ten minutes or so before you make your study. The quickest way to warm the feet is to soak them in a pan of warm water for a few minutes before beginning the study.

THE BLOOD PRESSURE CUFF

Having the right type of cuff for measurements is very important. At the ankle, an ordinary arm cuff has always been satisfactory. Just below the knee it may or may not give you an accurate measurement. It depends on the circumference of the leg. The important thing about cuffs seems to be that the inflatable part must go all the way around the leg. The cuff used by the doctors who developed this technique is shown below. The inflatable part is 4 x 16 inches. This cuff can be used at all four measuring points on the leg. To save time, some people use two or more cuffs at a time and switch the bulb and manometer. Some sphygmomanometers do not have a disconnect at the bag. A set of fittings, one of which is shown in the foreground, can be obtained inexpensively from any surgical supply house.

This cuff is a little bit short for measurements at the upper part of the leg, but this has not been a problem. The cuff may be obtained from Statham Instruments, Inc., 12401 West Olympic Boulevard, Los Angeles, California, 90064 for ~~$12.50~~ $13.50 each, or from us.



It is possible that other cuffs will work as well. The Baum thigh cuff gives accurate readings. Its disadvantage is that it is so wide you can't make measurements at two places above the knee. It is also hard to wrap because the taper of the leg and width of the cuff combine to make the cuff want to spiral down the leg rather than wrap around in a tight, single band

Some amputation-type cuffs may work. Whatever type cuff you use, you should try it on people with normal arteries and with varying circumferences of the leg at the crotch. You want to put the cuff as high as you can get it. Systolic pressure should drop about 10 points with each measurement as you move the cuff lower. This is a rule of thumb. Just below the knee the measurement seems to be less reliable, apparently from an anatomical protection of the artery on some people. Pressure differences between successive cuff positions on people with mild or severe disease may be from 0 to 15 or 20 points in symptom-free regions. Sometimes a reverse gradient is found across the knee. It has been found empirically that pressure differences of at least 30 mm. are required to be an indication of a significant occlusion.

You should keep this point in mind about cuff error — it always makes pressure readings too high and never, in our experience, has it made any measurement too low. In other words, a low pressure measurement can be relied upon. Pressure at the upper thigh normally runs 20 or more points above arm pressure.

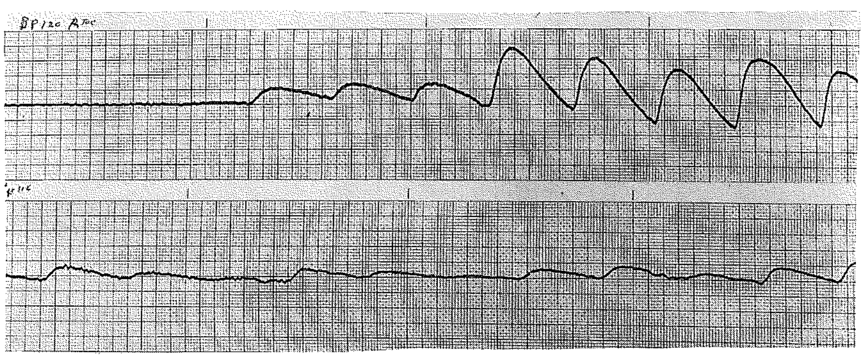
With proper cuffs we have encountered several cases of unreasonably high leg pressures where there was obvious distal disease. In one case the big toe of a diabetic had been amputated a few days previously, but other toes had quite normal pulse shapes. We have not had such an experience with atherosclerosis in a non diabetic patient. But others with end-artery disease have shown normal pulses in obviously diseased (ulcerated) toes.

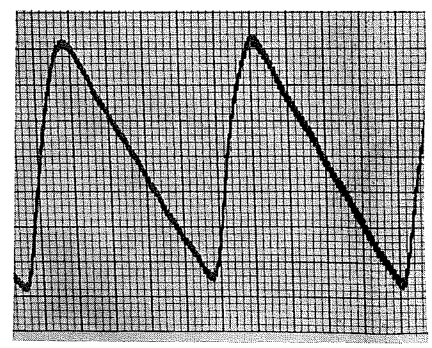
MAKING THE BLOOD PRESSURE MEASUREMENT --- TECHNIQUES MSG

The waveforms shown below are typical of those you will get from patients with moderate involvement. This patient had an obstruction in the iliac artery of his left leg that caused his left ankle pressure to be about 70 mm. and caused him pain on exercise. These waveforms are of his better leg. Blood pressure at the ankle was 120 mm. and there was no pain.

The upper left graph shows a straight line where the cuff was being deflated but cuff pressure was still higher than arterial pressure. It appears from this graph that when the first pulse appeared the valve to the cuff was locked shut until it was certain that the pulse was of arterial origin and not an artifact. This method is highly recommended on patients with more severe disease or tremor. After three pulses the cuff was deflated rapidly to a lower pressure and pulse size increased. Note that there is a rounding to the top of these pulses. Rounding is typical of restricted arterial flow which in this case was caused by the cuff.

Contrast these rounded peaks with the sharp peaks on the waves taken from the same toe after the cuff was deflated completely -- graph to right.



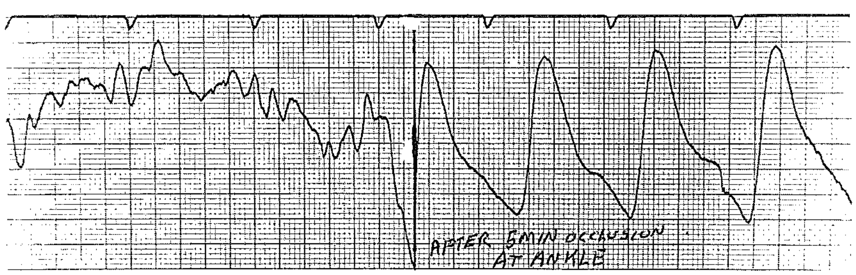


On the lower part of the picture to the left (made on the same limb) you can see small pulse waves coming and going in the base line. This means cuff pressure and arterial pressure are very close. Respiration affects systolic pressure and with certain parts of the respiratory cycle systolic pressure is high enough to force blood under the cuff and into the toe. At other parts of the cycle arterial flow is completely obstructed. There is no point in trying to obtain a blood pressure measurement closer than 5 mm. as it isn't meaningful. It also isn't necessary to get a nice looking graph like the one in the upper left to get a valid pressure reading. Some patients just can't hold still enough to give you a steady baseline. If you allow the pressure in the cuff to drop at 10 point intervals and then examine for a regular pulsation you are less likely to get an invalid reading. If you get no pulse at 90 mm., for example, but you do get a pulse at 80, record the reading as 85. You can't miss it much and you'll save a lot of time. Another thing you can do to save time is watch the pulse disappear when you pump up the cuff and note the approximate pressure so you will know when to go slowly on deflating the cuff. You can also make an approximate measurement the first time, release all pressure for a few seconds to restore circulation, and then make a second measurement more carefully. Getting consistent pressures on patients with irregular heart beats is more difficult because systolic pressure varies so much from beat to beat. If only one beat out of three is a big one use the cuff in a locked position for several seconds at 10 mm. pressure intervals until you see an occasional beat come through.

VASOCONSTRICTION IN A NORMAL LIMB

The photograph below shows rather dramatically what you will encounter in a normal limb under certain conditions. I performed the reactive hyperemia test on myself just to see what it felt like. I wrapped the cuff around my ankle and put the gage on my big toe. I did not tape it and you can see the tremor in the trace. My feet were cold, as they usually are, because I stand when I work and the cement floor is cold. After recording a few inches of tremor (no pulse obtainable) I pumped up the cuff well beyond systolic pressure at the ankle and locked it shut for 5 minutes. I watched the manometer to make certain pressure stayed high enough to shut off all blood flow. I felt only pressure at the ankle and there was a numb feeling. There was no pain. After 5 minutes I released all cuff pressure, waited about 30 seconds, and started the recorder. Considerable vasodilatation had occurred and pulses were large with normal contour. Note that even though the gage was not taped, tremor was gone. You will find the same thing on some of your patients that I have shown below--cold, clammy feet and even a blueness in the toenails--but normal digital pulses and ankle pressures when vasomotor tone is released. Vasoconstriction may again reduce the size of the pulse within a few minutes. You may find you get a longer lasting vasodilatation if you have the patient immerse his feet in a basin of quite warm water for a few minutes.

If you have warmed the patient's feet quite well and you still cannot get a pulse and you know the gage is working (tap the toe lightly and watch for stylus deflection) then you are justified in concluding there is an arterial obstruction of some type. The limiting factor in the detection of small pulses is tremor. The plethysmograph can easily be made more sensitive but it would not significantly help you in making a diagnosis. Proper taping of the gage, wires to it, and propping of the foot minimize tremor.



VASOCONSTRICTION IN SURGERY

The mercury strain gage plethysmograph is not recommended for use in surgery. The reason is that vasoconstriction may be very pronounced and render the instrument useless unless a vasodilating drug is used. The gage is useful in animal surgery, especially on dogs where the gage is wrapped just above the paw. Certain anesthetics almost obliterate peripheral pulses in animals and cause tremor. For general surgical monitoring and for making systolic pressure measurements down to 20 mm. Hg., the impedance plethysmographic method is preferred. The reason is that it can be used where arteries are larger and not so subject to vasoconstriction.

SYMPATHECTOMY

You might think that the mercury strain gage plethysmograph would indicate the cutting through of all sympathetic fibers to a limb in a lumbar sympathectomy because all vasomotor tone would be instantly released. Unfortunately, vasodilatation requires up to 72 hours. However, you can predict response to a sympathectomy by using the plethysmograph and a nerve block or even hot water. It will show you very well the amount of vasodilatation that can be obtained. Then after sympathectomy you can compare peripheral pulses with those obtained from nerve block. Also you can see if sympathetic tone is returning after a period of several months or years by again attempting vasodilatation.

PLETHYSMOGRAPHIC STUDY 4-7-64 No Significant Obstruction Found

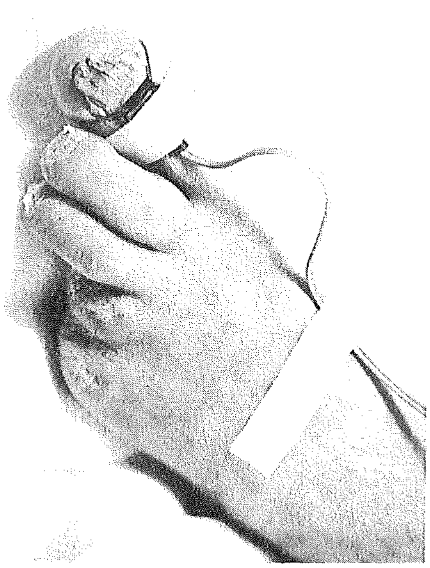
This patient was admitted to the county hospital on the basis of his complaint of pain in the right leg which was not correlated with exercise. Two years previously an embolus had been removed from the iliac artery on his left side and the repair made with an autogenous vein graft.

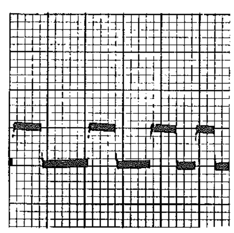
Physical signs were very thickened toenails on both feet and a deep indentation in the left heel, apparently the site of a previous ulcer.

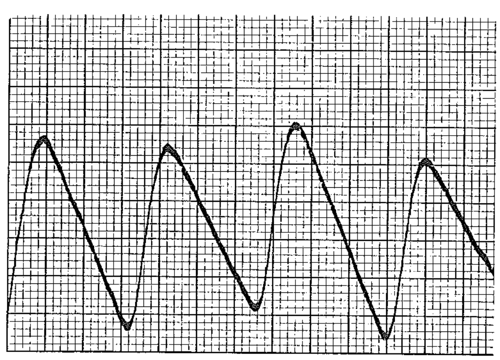
The gage is shown applied to his left big toe in the photo below. Pulses obtained were so large the electrocardiograph sensitivity had to be reduced 50% in order to record the entire pulse on the paper. In the photo below the half standard calibration of the electrocardiograph and a few pulses from the left big toe are shown.

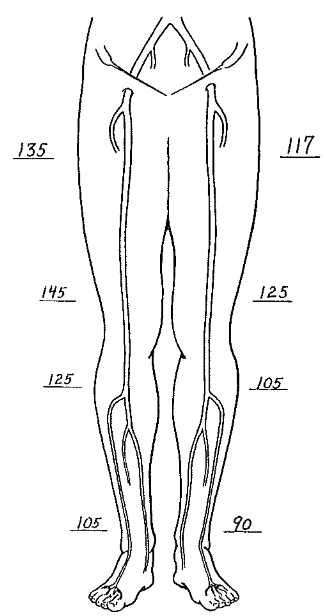
Pulse height in itself is not a good indicator of whether or not there is an obstruction. A patient with a superficial femoral or iliac obstruction can have quite large pulses, but they are rounded on top. When pulses are large and also have a sharp point at the top and bottom (like those in the photograph) then it is quite certain that the large arteries of the leg are sufficiently open that they are not the cause of the patient's symptoms.

Blood pressure measurement at the left ankle was 90 mm. This is not too good a sign as it is in the region where there may or may not be an obstruction. Refer now to the chart below and note the pressures obtained with the use of the plethysmograph. These pressures do not follow the "normal" pressure gradient of 10 mm. between each measuring site. On the left, the ankle to below knee gradient is 15 mm., certainly not very significant. The gradient across the right knee is 20 mm., approaching the 30 mm. gradient considered significant. But in the measurement between upper thigh and above the knee on the right leg there is a reverse gradient. This means that there is probably a measurement error caused by technique or the patient's anatomy. A reverse gradient is not uncommon. When systolic pressure readings such as those shown on this patient are inconsistent, measurements can be repeated or others taken at a slightly different level.









SYSTOLIC PRESSURE

This information has been written for the technician who will be using the plethysmograph. Using the strain gage plethysmograph is quite simple, but if you're confronted with all the techniques and precautions at once it can look pretty complicated.

We suggest you scan this information, look over the examples of patient studies and get a general idea of what is in the manual. Don't attempt to understand everything before trying the instrument out. Take it little by little, experimenting with your own thumb or finger pulse or that of an associate until you feel familiar with the plethysmograph. Don't attempt to learn use of the instrument on a patient. You may have a fairly difficult one to study or one without peripheral pulses and you won't be sure of your technique. When you do study patients, questions will come to mind and we have attempted to answer a number of them for you.

Many people don't realize that there is a tremendous variation in the pulse of a digit on an individual during the day, especially when the weather is chilly. There is also a tremendous variation in the pulse of different individuals who are seemingly in the same temperature environment and have had sufficient time to reach an equilibrium.

In demonstrating the mercury strain gage plethysmograph at staff meetings and at medical conventions, we are very careful to make sure there is someone available for demonstration who has a good finger pulse. We first show the interested party the pulse on our "plant" and then transfer the gage to the digit of the interested doctor. This shows him very forcefully, if he is vasoconstricted, what variations there are in normals.

Vasoconstriction can obliterate the digital pulse just as severe disease can. Without a pulse, you can't make a systolic blood pressure measurement with the plethysmograph and your electrocardiograph. Since blood pressure measurement of the extremities is the most important feature of the plethysmograph it is pretty essential to have a pulse in the digit. Getting a pulse is usually not a problem if you know how to release vasomotor tone. Techniques for doing this are covered in the following pages of this section and elsewhere in the manual.

DETERMINING BRACHIAL PRESSURE AND RECORDING THE FINGER PULSE

The reason you need to take brachial pressure is that in the plethysmographic study you are comparing pressure in the arm with pressures in the leg. Only systolic pressure is measured because it is easy to determine it fairly accurately on nearly all diseased limbs.

First, feel the patient's fingers and see if they are warm. If they aren't, then they probably don't have a very good pulse. The easiest way to increase the size of the pulse is to have the patient soak his hands in warm water for 2 or 3 minutes.

Next, wrap the arm cuff above the elbow and have the patient lie down. Carefully place the strain gage around the patient's thumb or forefinger, depending on the size of the gage. The gage must be under tension to work properly. Dont' roll the gage on. Sharp fingernails can cut the gage so be especially careful. The base of the nail should be covered by the joint in the circular part of the gage. Put a piece of tape around the brown enameled wire right next to the gage to keep the weight of the wire from pulling on the gage.

Roll up a small towel and place it under the patient's palm so that the weight of the hand doesn't rest on the finger tips. The purpose is to keep the finger with the gage on it as motionless as possible. Take systolic pressure with the stethoscope if you wish and then take it with the plethysmograph by noting the cuff pressure when pulsations reappear as you deflate the cuff. There are some variations in systolic pressure with time and some with a reaction from the cuff, so systolic pressure determined by the two different methods may not agree closely. The concern here is not to know the pressure exactly but to know what you measure with the plethysmograph. This is because the relationship between arm and leg pressures when measured by the same method is the important thing.

Don't be concerned if you can't get repeatability of 2 or 3 mm. because these differences are not significant in diagnosis. An error in measurement of 5 mm. or less is not going to be significant so to save time you can drop cuff pressures in 10 mm. increments and lock it to see if a pulse is present. As an example, if there is no pulse at 140 mm. but a fair sized one at 130, call the pressure reading 135 mm.

Either before or after you have made your brachial systolic pressure measurement you should record a short strip of the patient's finger pulse with no pressure in the cuff. The pulses you select to tape or staple to the study chart should have their tops and bottoms on about the same horizontal level. In other words, pick out a pulse sequence where there isn't a lot of up and down movement of the baseline. For quite interference free pulses, have the patient take a couple of deep breaths and then exhale and stop breathing for a few seconds while you record. The reason you record the pulse is to give the doctor a record of what the patient's unobstructed arterial pulse looks like and how big it is. The presence or absence of the dicrotic wave (notching on the down stroke) in the toe pulse is only significant if there is a dicrotic wave in the finger pulse. On most elderly patients the finger pulse will have a sharp peak and only a very small inflection on the down stroke.

While systolic pressure in the extremities is the important thing, there may be times when the doctor would like some other supporting objective evidence. The size and shape of pulses at the finger and on the toes may be helpful. Whenever you pick out a pulse to put on the chart, make certain it is a "typical" pulse and not one that has a notch in it that none of the others have.

THE REACTIVE HYPEREMIA TEST

You might wonder why this test is done next instead of taking pressures on the legs. There is a very good reason for this which will be apparent to you after you've studied a few patients. A lot of people, normal and otherwise, have cold feet a lot of the time. If you put the strain gage on their toes you may just get a quivering line and no discernible regular pulse. Unless they have severe disease, they are merely vasoconstricted and you will have to dilate their vessels to get a pulse. Dilatation can be accomplished with drugs, whiskey, a pan of warm water for soaking the feet and a number of other methods. The vasodilating test commonly used with the plethysmograph is called the reactive hyperemia test. To perform it, wrap an arm or leg cuff around the patient's ankle, record a bit of his pulse (or lack of pulse) and then pump up the cuff to a pressure well above his arm pressure and lock the valve shut for 5 minutes or more. Make sure the cuff doesn't leak by watching pressure. The patient will only feel pressure unless he has pain at rest, swelling or ulcers. If he feels pain, vasodilatation should be attempted by soaking the feet in warm water or by heat from a lamp, water bottle, hair dryer, etc. After 5 minutes of occlusion, release pressure completely.

Make a recording of the toe pulse before you inflate the cuff. Reduce sensitivity of the plethysmograph or electrocardiograph so the pulse is no more than 2 large divisions high. If you can't get a pulse that large even with maximum sensitivity it will not invalidate the test in any way. If you cannot get any pulse at all be sure the gage is working by tapping the toe while you watch the stylus for a response. BE SURE TO MAKE A NOTE OF THE SENSITIVITY OF THE SYSTEM — whether or not plethysmograph sensitivity was reduced or electrocardiograph sensitivity reduced and how much approximately. If the stylus wanders badly it is because the patient is moving slightly or flexing his toe or the wire to the gage isn't taped down properly. It often helps to put something to the side of the patient's foot to prop it so he can relax all his leg muscles. Use whatever method you can except warming the foot to get a better pulse and use the best ones you obtain for the chart. The reason you don't want the pulse too large on the chart is that vasodilation may make the pulse so large it goes clear off the sides of the paper.

Now inflate the cuff around the ankle until pressure is high enough to shut off all flow or until it is higher than brachial pressure by 20 or 30 mm. A quiver may remain which is not a pulse, but due to motion. Leave the cuff inflated for at least 5 minutes and as long as 10. You must watch the pressure in the cuff because if the air leaks out and the pressure drops low enough to let blood circulate, a lot of the usefulness of the test is lost. The plethysmograph may be left turned on or it may be turned off during this test.

After the 5 min. (or more) occlusion, deflate the cuff completely and watch the pulses on the electrocardiograph. Usually they start small and get larger over a period of 30 seconds to 2 or 3 minutes. You can record 2 or 3 pulses every few seconds until you are sure pulse size has reached its peak and is getting smaller. Save the largest pulses for mounting on the chart. If you have to reduce the sensitivity of the plethysmograph or electrocardiograph to keep the pulse on the paper, be sure you note that on the recording as well as on the study chart. It would be a serious error to fail to record sensitivity or to fail to record it properly. The difference in the size of the pulse before and after ankle occlusion is quite important in determining the adequacy of the blood vessels in the foot. Also be sure you record which foot the recording was made from and how long the occlusion lasted.

The reactive hyperemia test is a vasodilating test. It is used at this point in the procedure because it dilates the vessels in the toe and makes it easier to take blood pressure measurements on the leg because the pulses are bigger. The doctor wants to know if the patient is capable of dilating and if so, how much. Often you will see patients who have practically no pulse before the test who respond so much that you can't keep the pulse on the paper without reducing sensitivity. These people are vasoconstricted and frequently have no serious impairment of flow from arterial obstructions.

Next, take the blood pressure at the ankle, just as you did on the arm. If the patient has small, rounded pulses even after vasodilation you will probably have to use the longest time constant. If the patient has very large pulses you can use a shorter time constant. Some patients again vasoconstrict within a few minutes after the occlusion, in fact so soon you may not have time to get all your high level pressure measurements. You can dilate them again by the same method or you can have them soak their feet in a pail of warm water. They will probably stay dilated longer with warm water.

Actually, it doesn't matter too much which method you use to dilate vessels in the foot as long as you record pulses before and afterward. The advantage of the occlusion method is that it has been determined that if pulse amplitude increases by 50% there is adequate run off to support the additional flow which might be provided by surgical treatment of the arteries.

The time constant has to do with the recording of slow changes such as those caused by respiration, sympathetic activity, speed of recovery from big stylus excursions caused by movement, etc. A short time constant, such as .2 or .5, would make the base line more stable but would not give a true picture of a slow, rounded pulse. It would make the descending part of the wave fall more rapidly than the patients pulse volume actually falls. So if the pulse is big, has a rapid upstroke and you are just interested in making blood pressure measurements, use the .2 or .5 position. The one or two second position is a good compromise between stability and accurate recording of the pulse volume wave. If you want the most faithful reproduction of the pulses at the toes you may have to use the 5 second position in order to determine blood pressure. The shorter time constants reduce the size of the slow, rounded waves. The size of the recorded wave is not nearly as significant as you might think. It is pressure that is important.

PRESSURES UP THE LEG

If systolic pressure at the ankle is lower than brachial pressure, and especially if it is 30 or 40 mm. lower, you will want to take pressures up the leg to localize the obstruction. It is presumed here that the reactive hyperemia test has just been done and that there is a reasonably good size recorded pulse.

The first place you take blood pressure above the ankle is just below the knee. If there is no obstruction between that point and the ankle, the pressure will be the same or 10 to 20 mm. higher than at the ankle. A pressure of 10 mm. of mercury higher is the usual thing. If it is 30 points or more higher, either obstructive disease is present below the knee or there is a cuff error due to improper cuff size for the size of the limb or to anatomical abnormalities. Use of an arm cuff at this point always makes the pressure measurements too high, never too low, if they are wrong. On very thin limbs they may be reasonably accurate. If you make certain the part of the cuff which inflates is over the center and back part of the leg and that any gap in the inflatable part of the cuff surrounding the leg is toward the top and outside of the leg, your measurements will be more correct. Arterial obstructions frequently occur right below the knee and therefore under the cuff. Arteries may be so hardened they won't compress to completely shut off the blood when the cuff is inflated. When an obstruction is right under a cuff, the size of the recorded pulse does not increase greatly with pressure changes in the cuff of 10 mm. In such cases you should shut off the cuff at 5 or 10 mm pressure intervals and mark on the recording what cuff pressure is beside the recorded pulse wave. This will help you or the doctor to determine at what pressure the pulse gets significantly larger and is more likely to be the true pressure--at least as true as you can get. You can make another measurement with the cuff between the knee and the ankle.

Above the knee you must use a special cuff--one like that shown elsewhere in this manual. The important thing is to have the part that inflates go completely around the leg. The cuff now made by Statham Instruments is the one used by the doctors who developed the technique. It has an inflated part about 5" x 17" and can be used with standard sphygmomanometers and adapters from your surgical supply dealer. We can supply both the cuff and adapters for $13.50, our cost.

The upper thigh measurement is made by putting the cuff just as high as you can get it. Put the ends of the cuff toward the outside of the leg. The cuff described above is not long enough for some patients at the upper thigh, but if pressure measurements are low, they are reliable.

IRREGULAR HEART RHYTHMS make systolic pressure determinations a little more difficult because the size of the pulse varies so much from beat to beat. All you can do is deflate the cuff quite slowly in the region of systolic pressure, make two or more determinations and average them out. End.

USING THE MODEL 270 WITH AN ELECTROCARDIOGRAPH

The Model 270 Plethysmograph was designed for use with research-type recording equipment commonly found in medical schools and the larger hospitals. These instruments have features the ordinary electrocardiograph does not have. Therefore certain compromises in performance of the total system must be made when an electrocardiograph channel is used as the recorder. As an example, most modern multi-channel recorders used in research have high-impedance d.c. inputs with deflection factors of 1 mv/cm. This provides adequate sensitivity for venous occlusion studies with the Model 270. The portable or not-so-portable electrocardiographs frequently have a d.c. input, but 50 millivolts of signal is required to deflect the stylus 1 cm. The Model 270 cannot provide this much signal except perhaps from respiration gages where there is considerable stretching of the gage. Even if more signal output were available the result would not be satisfactory because the paper speed would most likely be too fast. Those who have access to recorders with proper paper speed and have only the low-sensitivity d.c. input mentioned may purchase or construct a d.c. amplifier with an input impedance of at least 5,000 ohms and a gain of about 50 and low drift.

Research recording instruments also have a wide range of attenuation available to accommodate input signals from fractions of a millivolt to hundreds of millivolts. An electro cardiograph is designed to work with inputs of about 1 to 5 millivolts. The range of attenuation provided by its "sensitivity" control is quite limited. Since there is no attenuation available on the Model 270 you may find that pulses obtained from normal digits are so large that the recording stylus of the electrocardiograph runs off both the top and the bottom of the recording paper. Some electrocardiographs (Sanborn) have fixed sensitivity settings which may be adequate to reduce the size of the recorded wave. Others may have a 1/2 V position (Birtcher) which can be used. Others have only a sensitivity control which may or may not be adequate. Whenever the sensitivity is too high for proper recording, the input to the 270 may be mismatched to reduce sensitivity. As an example, digital gages are normally connected between the COMMON and SHORT terminals. If they are connected between COMMON and LONG instead, you will find the output signal is reduced considerably. The impedance method inputs can be mismatched in the same manner by use of the HIGH input instead of MEDIUM.

A.C. interference has two causes which will be discussed... improper connection and magnetic fields.

1. The Model 270 has an a.c. output (the one you use with electrocardiographs) which is both high-impedance and single ended. An electrocardiograph has high-impedance inputs, two of them, called differential. One of these inputs must be connected to ground, the other to the output of the Model 270. The input of the electrocardiograph for which our accessory cables are wired is the one which gives a positive (upward) deflection of the stylus for a positive-going voltage applied to the input when the Lead Selector switch is in the Lead I position. Under these circumstances a digital pulse recorded by the strain gage method will deflect the stylus upward on increasing blood volume. With the impedance method the deflection will be downward on increasing volume. A different position of the Lead Selector switch will make it upright.

(over)

Possibilities of trouble are as follows:

a. You have had your own connecting cable made and it isn't made right.
b. We furnished the cable and inadvertently forgot to ground the ring on the phone plug which grounds the un-used input on the ECG. Our cables are made to mate with receptacles which automatically take care of this grounding at the proper place, but the switching-type connector used in the 270 makes it necessary to modify our standard cable.
c. The cable is defective because a wire has broken, usually at one of the connectors.

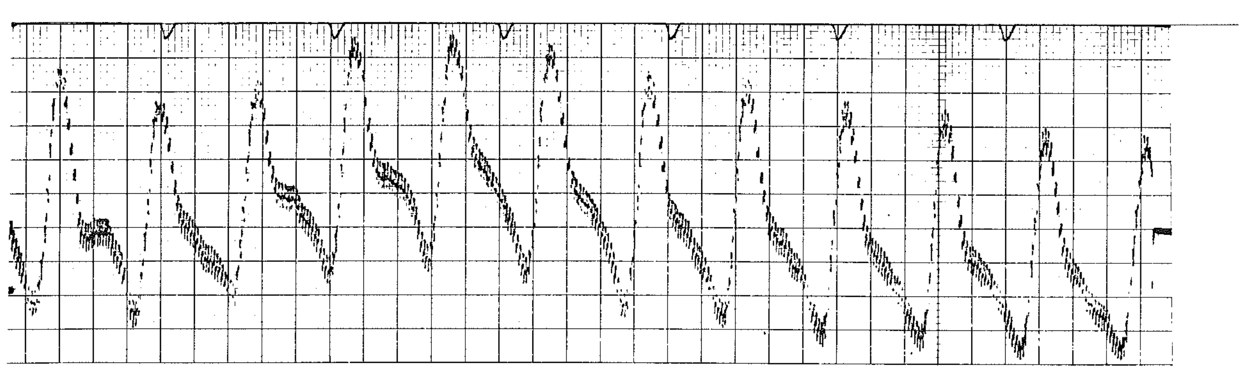
2. The second cause of a.c. interference is magnetic fields. These fields exist around wires carrying a.c. current, such as power cords or even wiring in the walls. They are especially strong around transformers. The metal cabinet of the electrocardiograph is quite ineffective with regard to shielding these fields. The only practical remedy is to keep away from them. This means that your output cable between the plethysmograph and the recorder should be positioned away from the recorder and electric wires. It also means that the Model 270 itself should not be near the recorder--not next to it anyway. A distance of 2 feet or so is usually adequate. There is no reason not to put it on the bed with the patient during studies.

3. The power plug to the electrocardiograph needs to be reversed in the wall outlet (old-style machines) or the power line reversing switch on the EKG itself needs to be switched.

4. Long cables between the plethysmograph and the recorder can be a cause of interference. The a.c. output impedance of the plethysmograph is high and cable shielding is not perfect. With longer cables the possibility of the induction of 60 cycle currents by stray magnetic fields is increased. We prefer to keep cables between 3 and 6 feet long.

5. Improper grounding of equipment can also cause trouble. Any external ground, if used, should be made to the metal frame of the recording instrument and not the plethysmograph. With most electrocardiographs produced within the last few years an external ground is not necessary.

The graph shows a.c. interference. This type of interference is distinguished by a rather large band which follows the pulse wave.



THE MOST COMMON CAUSES OF FAILURE TO ACHIEVE SATISFACTORY RESULTS FROM THE USE OF THIS INSTRUMENT IN DIGITAL PLETHYSMOGRAPHY

1. Batteries are weak or dead because the plethysmograph was left in the STANDBY position (ON) instead of turning the knob to OFF. Frequently, when the mistake is discovered a day or two later, the instrument is turned to OFF. Then when you want to use it, the batteries are weak or dead. If you find that an instrument has been left turned ON inadvertently, leave a note with it stating that you found it turned on and the batteries may be dead. Replacement flashlite batteries cost only 40¢ and should be kept on hand.

2. Strain gage is not being placed on the digit properly. It has been rolled on or there is a sharp angle where the elastic gage enters the black tubing. Sometimes people put the gage proximal to the nail. This is not correct on humans. It should be placed just at the base of the nail.

3. The tubing to the blood pressure cuff is rubbing against the wire to the strain gage, causing erratic movement of the EKG machine stylus. Gage wire is not properly taped to the toe & foot.

4. The strain gage is broken, either from defective manufacture or improper handling. In general, the life of the gage depends on how it is handled. But with time (6 months to 2 years) it can go bad. If the gage is defective or if the mercury column is interrupted (see 2 above) touching the toe will not deflect the stylus. If the stylus does deflect when the toe is touched, it is very unlikely the gage is at fault. Of course, if the batteries are dead there will be little or no deflection even though the gage is good. Re-position the gage on the toe and try the "touch" test again.

5. Patient is vasoconstricted and there is no detectable pulse. Many people do not realize how completely vasoconstriction reduces pulsatile blood flow. To determine systolic pressure you must have a pulse. If the patient does not have a pulse you must attempt to release vasomotor tone by warming the foot or creating a reactive hyperemia by shutting off all blood to the foot (with the cuff) for five minutes or more, then releasing cuff pressure. You must watch cuff pressure during the reactive hyperemia test to be certain it stays well above the patient's systolic pressure. Leakage of blood thru the arteries during the occlusion period will prevent vasodilatation. If you fail on the first test and suspect cuff leakage, try again.

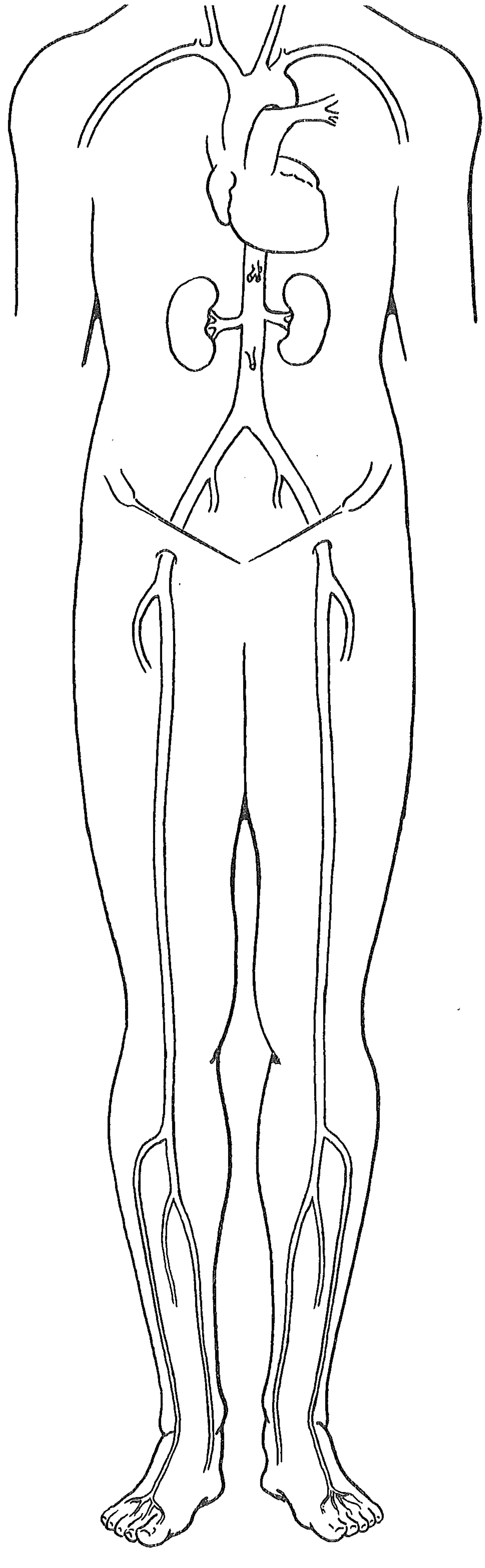
6. The patient does not have a detectable digital pulse because of arterial disease. Obstruction at the trifurcation below the knee is often involved in such cases. If you attempt to learn the use of the plethysmograph on people with obvious severe disease, you are making a mistake. You cannot be sure you are doing the right things and you cannot be sure your instruments are working properly. You should perform the procedures on normals first----some with warm feet and some with cold feet. A little bit of actual experience will make the rather loosely organized instructions in this manual much more meaningful.

WHEN YOU WILL FAIL THROUGH FAULT OF THE METHOD

1. If there is no digital pulse, you can't detect one by use of any instrument. Lack of a digital pulse occurs in advanced disease where toes are purple or the foot is swollen and red. Some patients with cyanotic toes that feel clammy are merely vasoconstricted. If you are sure the patient is not vasoconstricted, try a different toe or use the impedance method between the bases of the first and third toes. If this fails you must use a pulse-detection method farther up the leg such as a calf gage or impedance electrodes at the ankle or above. Sometimes a patient won't hold still because he is in pain or because he doesn't want you to find out he is a malingerer.

(over)

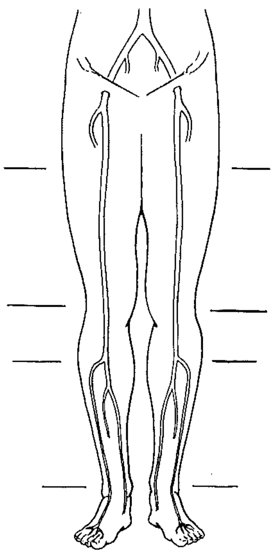
2. Sometimes cuff pressures are unreasonably high. This is most likely to occur at the upper thigh on large patients. Be sure the inflated part of the cuff is toward the inside. The cuff we buy and re-sell is a little shorter than it should be but we have no choice at present. At other points on the leg, high pressures may be caused by anatomical hiding of the artery, especially just below the knee. Arterial rigidity will also cause abnormally high pressures. This is most frequently encountered in diabetics. A pressure reading that is too high is questionable. One that is too low can be relied upon. If the "end point" is not sharp (no sharp demarcation between no flow and pulsatile flow) you may have the cuff right over the obstruction. This occurs sometimes just above the knee. If you doubt the validity of a measurement, make it again or move the cuff and make it again. Deflate the cuff 10 mm. at a time and observe the recording until you are sure a small pulse is present. Then add 5 mm. to your cuff pressure. You can't be far wrong, and an error of 5 mm. is not significant. Stopping the fall of cuff pressure every 10 mm. is a great help in obtaining difficult pressure measurements. An aneroid manometer works best.



Plethysmographic study of ______________________________ Age ___ No. _____

Patient of Dr. __________ Referred by Dr. __________ Date ______________

Examination performed by ____________________



Finger pulse waveform at sensitivity setting of ________.

Attach sample of finger pulse waveform over this area.

Brachial pressure ___/___ mm.

REACTIVE HYPEREMIA TEST

Right ankle occlusion time: ____ min.

Pulse before occlusion.	Pulse after occlusion.
Sens. _____	Sens. _____

Left ankle occlusion time: ____ min.

Pulse before occlusion.	Pulse after occlusion.
Sens. _____	Sens. _____

Make systolic pressure measurements along the legs either before or after the reactive hyperemia test and record results on drawing above.

Sens. refers to the sensitivity setting of the plethysmograph (if any) or any sensitivity adjustment you may make on the electrocardiograph such as going to 1/2 standard, 1/2 V, etc.

The Mercury Strain Gage---How it fails in time and how to make temporary repairs.

The mercury strain gages we make use silastic tubing. Silastic is far superior to rubber in its resistance to decomposition. After several years of using silastic mercury strain gages, none have failed that we know of from chemical changes in the silastic. But in time gages do fail. Some last a year or two. Some probably last less than that. Gages must be considered expendable items.

FAILURE FROM MECHANICAL ABUSE If the gage is stretched beyond its elastic limit it breaks. Frequently it breaks where it has been inadvertently nicked with a knife or sharp fingernail. Other times it pulls off the wire stuffed into its ends. Too much pressure at the junction of the mercury and the copper wire can cause the wire to penetrate the side of the tubing. In normal use the latter condition is unlikely, but it can occur if gages are positioned with pliers, hemostats, thumb forceps, etc.

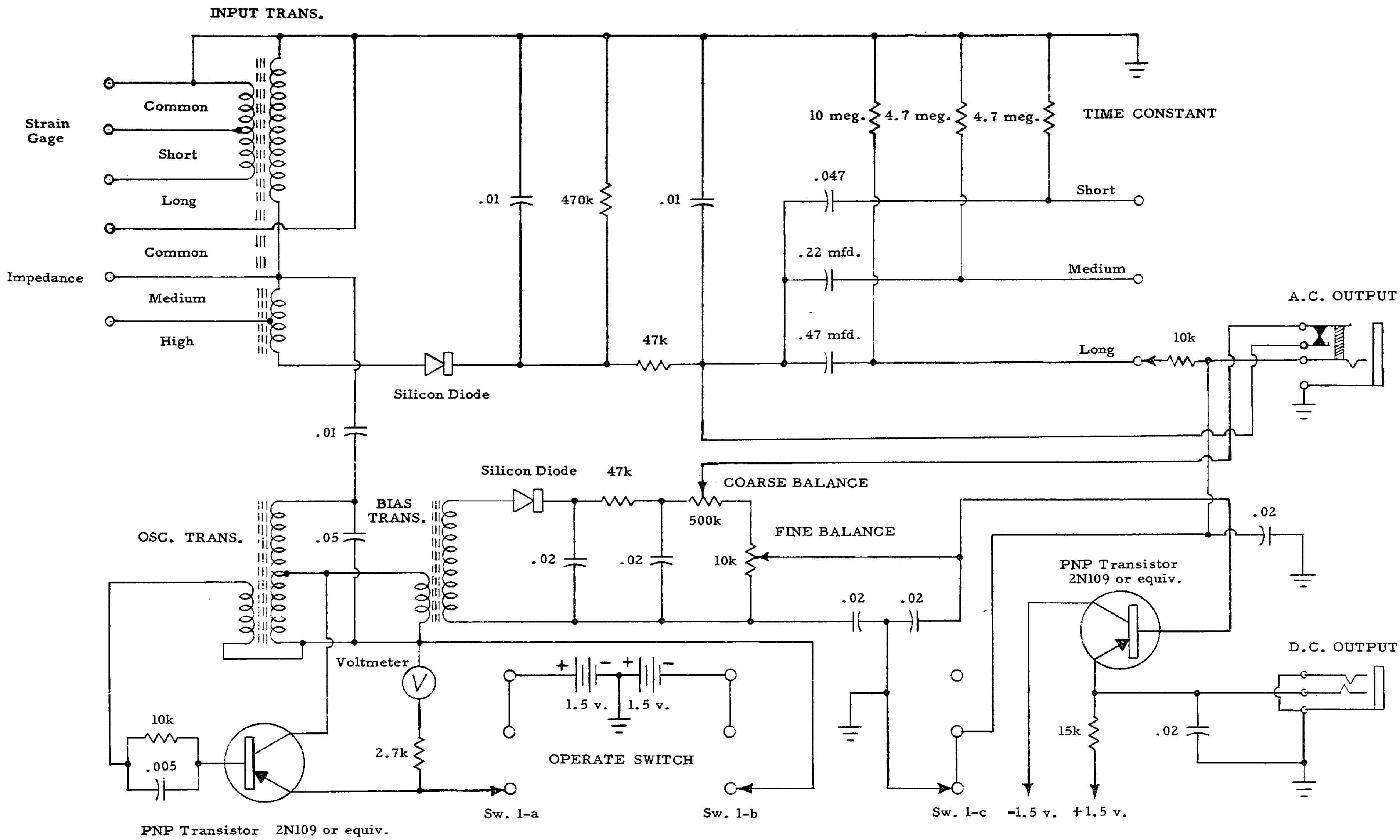
CHEMICAL FAILURE In time the mercury attacks the copper wire and you will see that the gage has a greenish tint to it. The green color doesn't mean the gage is inoperative and it doesn't mean the gage has been abused. This is the natural course of events. The electrical continuity of the gage is eventually broken and of course then it won't work. A gage may show continuity and be active when it is not stretched, but with stretching the continuity is broken. A gage that is perfectly good can have the same symptoms if it is not applied to the toe properly. There must not be a sharp bend at the points where the gage leaves the black sleeve.

You can sometimes extend the life of gages by the following techniques:

A gage that has not leaked mercury fails at the ends---at the junction of the mercury and the copper wire. Connect an ohmmeter or other continuity checker to the gage. An ohmmeter should be set to the R x 1 scale. Squeeze the center of the gage with your fingers in order to remove mercury from the center of the gage and pressurize the end. Frequently you'll find that the gage can be made to show continuity and that the continuity will remain when the pressure is released. Stretch the gage to see if continuity is broken. If it isn't, let well enough alone. Sometimes gages will continue to work with only this simple treatment. If reasonable stretching breaks continuity and you are willing to risk ruining the gage entirely, follow the procedure below.

Assume that you have diagnosed the trouble as failure of the junction at a particular end of the gage. Using a razor blade or sharp knife, carefully slit the black sleeve that covers the ends of the gage and remove it. It is very easy to also slit the silastic tubing, which of course you do not want to do. Next, hold the junction between the thumb and forefinger of your left hand. Hold the bare wire (solid, enameled) in your right hand and attempt to force it farther into the tubing. Some people with moist or weak hands cannot do this. If the gage slips in your left hand, use a small cloth one layer thick (a handkerchief) to give you additional friction. The purpose of this treatment is to pressurize the mercury within the gage. If successful the life of the gage will be extended considerably. It is easy to force mercury out of the tubing or force the wire through the side of the tubing so push steadily and straight. A digital gage is the most difficult to repair and of course will be smaller when you're finished. If you succeed, wrap the joint with tape at the point where the black tubing used to be, letting the tape overlap the mercury to wire junction a bit to protect it.

A long, open gage which has been broken or needs to be shortened is easily repaired or changed. Hold the open or cut end of the gage up against a strong light and see if you can see the mercury column move up and down as you stretch the gage. When you find where the end of the column is, stretch the gage and while keeping it stretched snip off the unfilled portion of the tubing and attempt to force the solid wire into the opening. If you release the tension on the tubing the mercury will come out. If you find a small air bubble near the end when you are finished the gage may not check good immediately but may check good later. Silastic is porous to air and if the mercury is under pressure the air may be forced out.



MODEL 270 PLETHYSMOGRAPH 6-63

PARKS ELECTRONICS LAB. ROUTE 2, BEAVERTON, OREGON

SERVICE NOTES ON THE MODEL 270 PLETHYSMOGRAPH

Jan. '69

As of Jan., 1969 there are about 600 model 270 plethysmographs in operation. We receive a unit for service about once every 3 months. They are pretty reliable instruments. Nevertheless, troubles sometimes occur and this page is written primarily for our foreign customers who would have considerable expense and delay in returning an instrument for repair. Here are some causes of trouble we have found.

1. The most common troubles you will find are not in the plethysmograph but in the strain gages or the cable between the plethysmograph and the recorder.

2. A.C. (mains or secteur) interference is caused by improper connection to the a.c. output jack. If you use a differential amplifier you must ground (earth) one of the inputs. Another cause is magnetic fields from transformers. Be sure the plethysmograph and the cable are away from the recorder or other equipment.

3. Binding posts (terminals on panel) loose or shorted to the panel.

4. Output transistor has failed. This affects d.c. output only. With 150 ohms between common and medium terminals (impedance) you should be able to set the d.c. output to zero with the coarse balance control set at about mid-position. The output transistor is a p-n-p silicon, selected for low noise.

5. Low sensitivity is usually caused by a short circuit between one of the binding posts and the panel (use an oscilloscope), a cup core is cracked (usually the oscillator or input transformer). Do not loosen the input transformer without good reason because it must make proper contact between cup and lid or sensitivity will be low. It is more or less resonant. Oscillator frequency should be about 30 kc. The oscillator transistor should be a low-frequency germanium type selected for low noise.

USE OF THE MERCURY STRAIN GAGE PLETHYSMOGRAPH BY SURGEONS AT THE VETERANS HOSPITAL, SEATTLE, WASHINGTON

A Bibliography

This list of references is furnished by Parks Electronics Laboratory of Beaverton, Oregon for the convenience of its customers. Much of the work done in the studies that follow utilized the Model 250 Plethysmograph we manufacture. Some of it was done using bridges built at the V.A. Hospital. No endorsement of plethysmographs made by Parks Electronics Laboratory by the Veterans Administration is to be implied.

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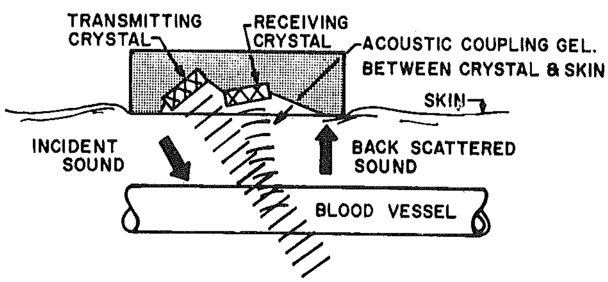
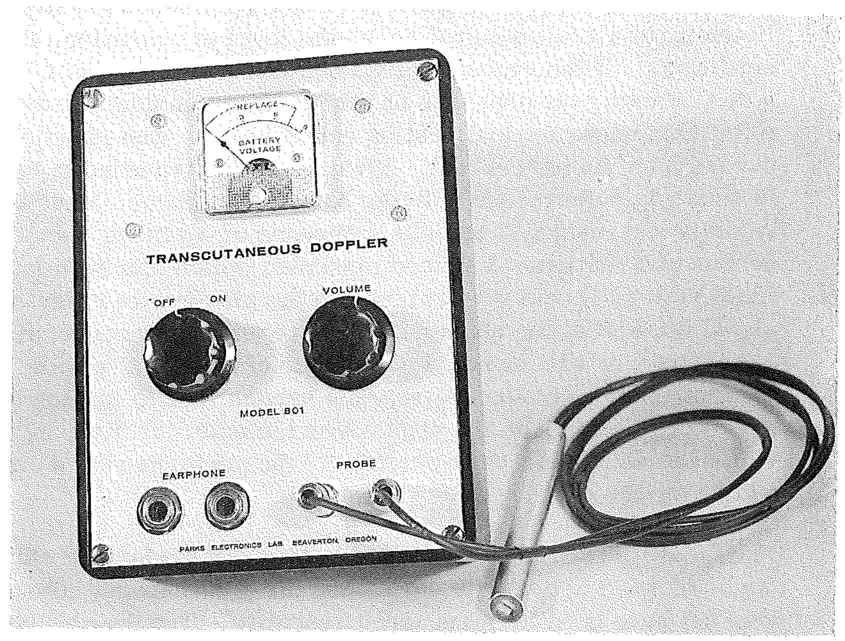
TRANSCUTANEOUS DOPPLER

ULTRASONIC BLOOD-VELOCITY DETECTOR

$250





This instrument is designed for the vascular surgeon. It permits him to determine the adequacy of blood flow through the arteries and veins of the limbs by permitting him to hear sounds correlated with blood movement. The sound obtained over the arteries is a hissing noise whose pitch varies with blood velocity. You can hear the variation in velocity with the cardiac cycle, evaluate the rapidity of the upstroke in the pulsatile wave, determine the presence or absence of the dicrotic notch and trace the major arteries along their course. Blood flow in the large vein on the back of the forearm sounds like a howling gale as it varies in velocity with respiration and other factors. All these sounds of diagnostic value are obtained quickly and easily from the surface of the skin. There is absolutely no pain associated with it. You use an aqueous gel to couple the ultrasound waves from the probe to the body tissue and back.

The probe we furnish for surgeons is meant for both deep and shallow work. We have compared the operation of our instrument with others on the market using a 5 MC. frequency and believe ours will let you find the deep arteries more easily and trace them farther down the leg. Since the ultrasonic beams are sharply focused, the probe must be designed for a certain depth range. We have made it perform best at the deeper levels, though it will still trace pulsatile arterial flow all down the arm, across the arteries of the hand and the fingers out to the finger tips. We use a frequency of approximately 10 Megacycles. Higher frequencies give greater Doppler effect and hence make it easier to hear low-velocity blood movement.

HOW IT WORKS: The principle of operation is the Doppler effect. Ultrasound energy at a repetition rate of about 10 million times per second is focused into the moving blood stream. The wavelength of the waves is so small that a portion of the transmitted energy is reflected from the individual blood particles. The energy reflected back to the surface and picked up by the receiving crystal is the same frequency as that being sent by the transmitting crystal when there is no blood movement. But with blood movement the frequency is slightly different, how different depending on the velocity. The difference between the transmitted and received frequencies is what is heard in the earphones. A higher velocity of blood movement causes a higher pitched sound than low-velocity movement. The cardiac cycle, including the dicrotic notch in the wave, is easily heard. The sound is not a squeal, but a hissing sound whose pitch varies. When the beam of ultrasound energy strikes vessels carrying both arterial and venous flow there is a steady low-pitched hiss with the hiss of a pulse superimposed. Though difficult to describe, once the sound is heard it is easily recognized.

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DIAGNOSING VENOUS DISEASE

With the Transcutaneous Doppler you can determine the patency of the deep venous system from the level of the posterior tibial vein at the ankle to the external iliac vein in the lower abdomen. This is accomplished by listening for the presence of the sounds of moving venous blood as they are normally heard adjacent to the major arterial supply to the leg. If the deep venous system is occluded, the venous sounds are not heard. In listening to a venous signal below the level of occlusion, the venous signal is usually continuous under resting conditions. If the venous signal does not change in pitch, indicating a change in velocity, as the patient takes a deep breath, the presence of venous hypertension is indicated. The venous signal at the level of the posterior tibial vein under normal resting conditions is often inaudible. In order to establish its patency, certain maneuvers must be carried out. First, with the transducer positioned over the posterior tibial artery, the foot is suddenly compressed with the hand. This forces blood out of the foot through the deep veins, increasing its velocity and making it audible. Absence of a venous signal with this maneuver is a positive indication of venous obstruction. A second maneuver which has been found useful is to manually compress the posterior tibial vein as it courses proximal to the pickup site at the ankle. Under normal conditions there is no venous signal elicited at the ankle with compression. However, if the posterior tibial vein is patent, a sudden surge of venous flow will be noted on release of the compression. If a venous flow signal should be elicited during the compression phase, retrograde venous flow is indicated, presumably secondary to valvular incompetence. It is possible to place the probe over the external iliac, common femoral, superficial femoral and popliteal veins and determine their patency by the performance of compression and release maneuvers, both above and below the probe.

OTHER POINTS: There is a good reason for preferring earphones over a speaker for diagnostic work. You can hear much better with earphones for two reasons. One is that a small loudspeaker in a small cabinet does not have good low-frequency response. The doppler shift is proportional to the velocity of blood flow, so low velocity flow produces low-pitched sounds. A set of hi-fi headphones will reproduce these sounds well, but a small speaker won't. Another reason for headphones is that the ear is very inefficient at hearing low-frequency sounds when higher-pitched sounds are present, such as noise from fans, air conditioners, speech and footsteps. The earphones limit what you hear to sounds associated with blood movement plus a small residual noise in the device. We have provided two earphone jacks so that two sets of headphones can be used. Two sets are essential for teaching or demonstration purposes.

There is no readout on this instrument, no means of connecting it to a recording device that will give you a graph. Think of it as a stethoscope for blood flow, one which gives you characteristic sounds for different flow rates and combinations of venous and arterial flow. The sounds are very easy to recognize, since venous flow is not pulsatile in the same way as arterial flow and can be easily stopped to leave the pure arterial sounds by simple means, such as clenching the fist. We think you'll be amazed at what you can hear, and how easy you find it to trace the important arteries and veins--at least this is the reaction we've gotten in our demonstrations.

PRECAUTIONS: The possibility of damage to delicate nerve endings by ultrasound energy exists. Therefore the probe should not be used on the eye or possibly in other areas where the focused beam might cause damage.

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Reprints of the above articles are available from Dr. D.E. Strandness, V.A. Hospital, Seattle, Wash. 98108

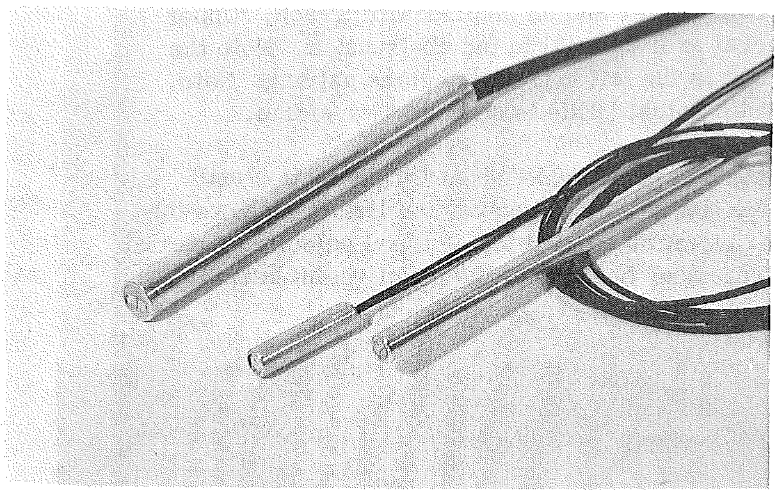
ORDERING INFORMATION: Price is $250 with one set of earphones, $270 with two sets. Add $2.50 for regular parcel post, $5 for air mail delivery. Terms net, 30 days. Price is firm thru 1967. 30 day return privilege if not satisfied. Shipment normally within 1 week of receipt of purchase order. Available for trial under some circumstances, but orders have priority on instruments in stock. If you have questions phone person-to-person Loren Parks, Area 503 644-7463.

PARKS ELECTRONICS LABORATORY 375 S.W. First Beaverton, Oregon 97005 U.S.A.

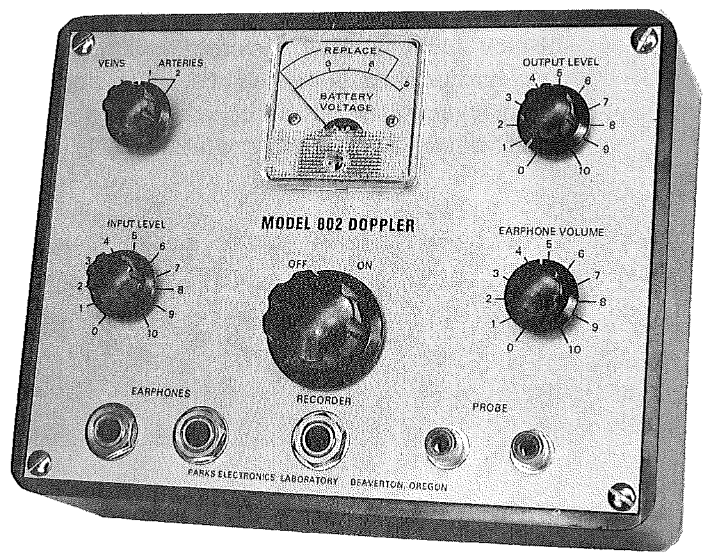
MODEL 802 DOPPLER

A TRANSCUTANEOUS BLOOD-VELOCITY DETECTOR FOR RECORDING OF ARTERIAL AND VENOUS BLOOD VELOCITY WAVEFORMS

$350 with 1 set of headphones



The uppermost probe is the one normally supplied with the instrument.



The Model 802 Doppler is a combination of our Model 801 and a zero-crossing detector which permits the recording of the frequency of the audible sounds obtained by the doppler effect from moving blood particles. A 10 MHz. beam of ultrasound is used. The voltage output of the instrument is proportional to the velocity of blood flow. At present we do not know that velocity can be measured quantitatively by transcutaneous methods. The value of the recording is that it shows rate of change of velocity. Abnormalities in arterial and venous velocities are apparent. The highly-focused beam permits you to examine individual arteries in the limbs from the attachment to the trunk as far as the tips of the digits. Certain manipulations of the limbs (compression and release) can diminish or augment venous velocity and prove of considerable diagnostic value.

The instrument is designed for use on the limbs but is often used on the neck and around the eyes for study of carotid artery disease. The possibility of damage to delicate nerve tissue from the ultrasonic beam exists and therefore the probe should not be pointed into such areas.

A selection of time constants (filtering) is furnished to give the desired degree of smoothness to the recorded waveforms. When the depth of the dicrotic notch must be accurately known a short time constant is used and a ragged trace results. In some arteries (radial, post. tibial) the blood velocity may fall to zero at the notch. Our directional doppler shows that at least sometimes the flow actually reverses for a short time following the notch. The Model 802 does not indicate direction of flow.

The Model 802 is designed to work into the d.c. input jack of an electrocardiograph or into any d.c. recording system with high input impedance and a 50 mv/cm deflection factor.

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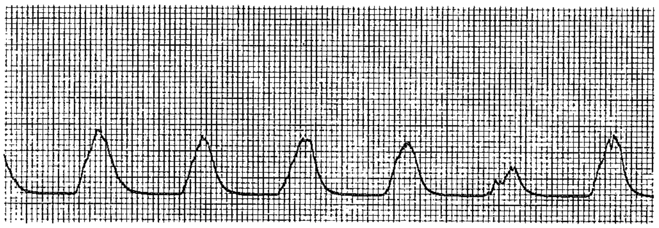
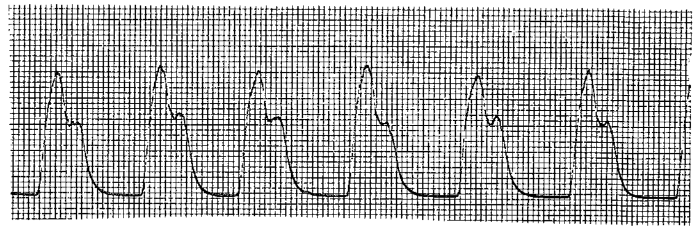
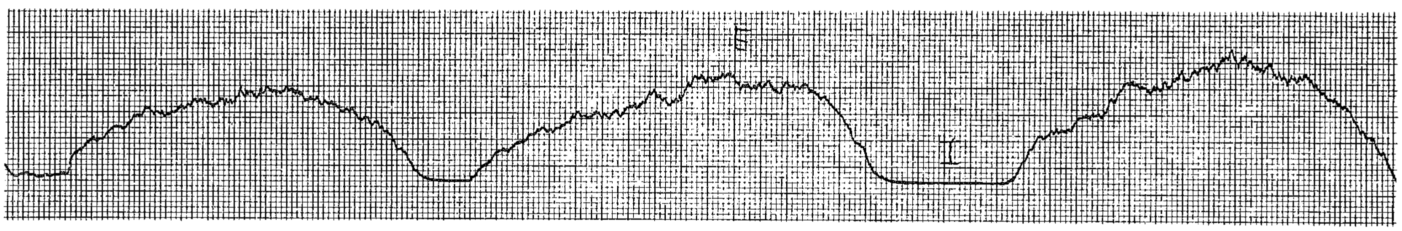




The recordings above and below were made with the 802 doppler and an electrocardiograph. Upper left is a velocity recording of a right superficial femoral artery distal to the obstruction. Note the slow upstroke and lack of a dicrotic notch. To the right is the left s.f. on the same patient. Note the larger waveform, the rapid upstroke and the dicrotic notch. This is a normal waveform.

Below, a recording of velocity in the right common femoral vein, same patient. Inspiration and expiration marks are shown. The zero-flow line is the flat bottom. A waveform like this shows the deep venous system is open because of the pronounced effect of respiration on blood velocity. Arterial and venous flow at the groin is easily separated and recorded because of the pencil-point beam width.



PRICE: $350 with 1 set of earphones, $370 with two sets. Jacks are provided for two sets of earphones because if you are instructing or demonstrating you cannot hold the probe still while changing headphones from one person to another. For group demonstration the Model 802 may be connected to a public address system or any small amplifier such as is used for phonographs or electric guitars.

The Model 802 is designed for use by vascular surgeons in private practice. It is meant for short diagnostic procedures with a single pencil - type probe. It is not suitable for use with a variety of probes because there are no tuning controls on the front panel. For best performance, a doppler instrument should be tuned to match each probe, and probes vary in both their frequency and reactive characteristics. When the Model 802 is tuned to its probe it operates as well or better than any doppler instrument we make. Four other models, including a directional doppler, are made for hospital and research use. The Model 802 is guaranteed for 1 year against defects in manufacture or failure of electrical components. The guarantee does not cover breakage or physical damage to the probe (which may be gas sterilized but not autoclaved). The probe should be considered an expendable item to be replaced every year or two, depending on usage. ($35). The Model 802 uses two 9-volt transistor radio batteries, available at drug, variety and hardware stores for about 85¢ each. Battery life is several hours if use is intermittent.

SERVICE: The doppler is a very specialized instrument. It should be serviced only at the factory. In the first year about 1 out of 50 instruments will fail and the failure is almost always in the probe. If you have not gotten at least 6 months service, the probe is replaced at no charge (provided failure was not caused by abuse).

We also make doppler blood-flow telemetry equipment for animals (Franklin-type), exercise EKG telemetry, heart rate monitors, mercury strain gage (whitney gage) plethysmographs and impedance plethysmographs. We also make a separate readout for our Model 801 Doppler.

For technical information, call person-to-person Loren Parks Area 503 644-7463

PARKS ELECTRONICS LABORATORY 421 S.W. FIRST BEAVERTON, OREGON 97005

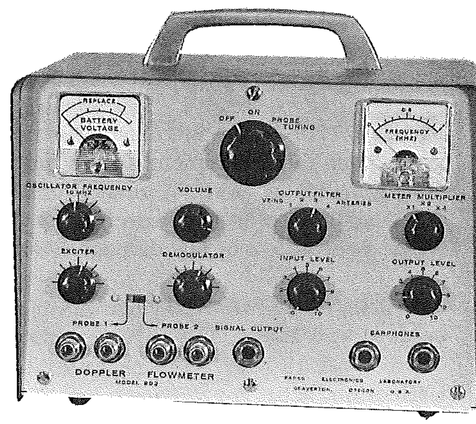
ULTRASONIC

DOPPLER FLOWMETER

MODEL 803

A DIAGNOSTIC AND MONITORING INSTRUMENT FOR
USE WITH SURFACE AND PERI-ARTERIAL PROBES

PRICE **$450**



1. Average relative blood velocity displayed on a panel meter.
2. Probes tuned by front-panel controls
3. Two probes can be used, with selection of either by a front-panel switch.
4. Probes may be gas sterilized for use directly on blood vessels.
5. Independent of power line--operates from flashlight cells.
6. Has output to permit recording of blood velocity curves.
7. Does NOT indicate direction of blood flow.

This instrument was designed for the anesthesiologist, though it will find application in a variety of other research fields. It does all the jobs our previous models 801 and 802 did and has the additional features of much longer battery life, switchable probes and a meter which indicates relative velocity, making the instrument independent of other recording instruments. This latter feature makes it especially useful for assessing average flow of a patient on a pump by sensing flow at the radial or brachial artery. ~~At present (March, 1969) the non-directional instruments have greater sensitivity than the directional ones and are to be preferred if the directional characteristic is not necessary.~~

REPORTED APPLICATIONS OF THE DOPPLER

1. Determining blood pressure of patients on a pump (using a cuff). The doppler is used to detect the return of flow when cuff pressure is lowered in the usual manner.
2. Determining systolic and diastolic pressures on patients in shock and on infants. Systolic and diastolic measurements in the twenties have been reported. Systolic pressures are determined with the transducer under the cuff or distal to it. Diastolic measurements are made by interpretation of characteristic sounds of wall motion, whereas systolic measurements are made from sounds resulting from the reflection of ultrasonic waves from moving blood particles.
3. Gas-sterilized probes are placed directly on the artery during surgery to determine flow characteristics.
4. Peri-arterial probes are used on animals for flow studies in the lab. We also make a blood flow telemetry system for animals.
5. Diagnosis of arterial and venous disease.

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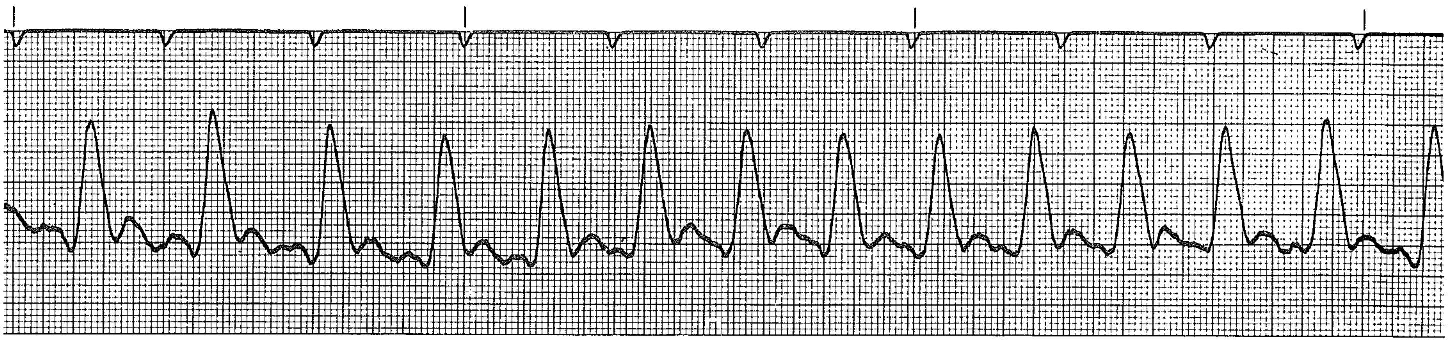

Blood velocity curves from the radial artery. Zero flow is at the bottom of the graph.

PRACTICAL PROBLEM: The beam width of the probes is approximately 3 to 4 mm. in our standard transcutaneous probes. This means that positioning is critical. For surgical monitoring you should be able to re-position the transducer easily.

PRECAUTIONS: The ultrasonic beam should not be aimed into the retina or other delicate tissue. On humans the instrument should not be used for more than a few minutes at a time in one spot, but discontinuously. A slight amount of heat is generated (power to the probe is 20 mw). In one case where the instrument was inadvertently left on and gel dried out, a superficial burn was noted on an infant. We are not aware of any damage having been done to anyone other than the above.

TECHNICAL INFORMATION: The instrument is designed for 10 MHz. probes but with re-tuning can be used at 8 MHz. The zero-crossing detector (frequency to voltage converter) is linear from 300 Hz. to over 15 KHz. The recorder should be d.c. coupled with a high-impedance (1 megohm) input. Deflection factor for venous work should be 50 mv/cm or better and for arterial work 100 mv/cm or better. Batteries are 8 medium size (size "C") flashlight cells. Current drain is 20 ma. A separate amplifier and speaker can be used for group demonstrations. Mechanical vibration problems prevent the incorporation of a good fidelity speaker in the cabinet. We can provide a suitable amplifier and speaker if necessary.

REFERENCES:

Application of a transcutaneous doppler flowmeter in evaluation of occlusive arterial disease. Surgery, Gynecology & Obstetrics May, 1966 pp. 1039-1045 Strandness, et al.

Ultrasonic flow detection, a useful technic in the evaluation of peripheral vascular disease. Am. Jour. Surg. Vol. 113 pp. 311-320 March 1967 Strandness, et al.

The ultrasonic velocity detector in a clinical study of venous disease. Archives of Surgery Vol. 97 July, 1968 pp. 75-80 Sumner et al.

A doppler ultrasound method for diagnosing lower extremity venous disease Surgery, Gynecology & Obstetrics Aug. 1968 P. 339 Sigel et al.

Comparison of clinical and doppler ultrasound evaluation of confirmed lower extremity venous disease Surgery, July 1968 pp. 332-338 Sigel et al.

Obtain reprints on the first three from Dr. Strandness, V.A. Hospital, Seattle, Wash. 98108.
Reprints on the last two from Dr. Bernard Sigel, V.A. Hospital, Philadelphia, Penna. 19104.

AVAILABLE PROBES: Standard pencil type probes (3/8" diam.), flat disc probes (beam perpendicular to the plane of the probe) and flat probes with crystals mounted at 30 degrees (radial artery) are available at $35 each. Peri-arterial probes in sizes to fit vessels of 3 mm to 27 mm. diameter are $35 to $50 each, depending on size. Write for information.

PRICE: $450 f.o.b. Beaverton, Ore. Includes 1 set stereo earphones, one of our standard surface probes of your choice (pencil, flat, radial), operating manual and diagram. Guaranteed for 1 year against part failure or manufacturing defects except for probes which must be considered expendable. Instrument must be returned to us for service (U.S. & Canada) or to our representatives in Europe. Weight (without batteries) is 4 lbs.

PARKS ELECTRONICS LABORATORY 375 S.W. FIRST BEAVERTON, OREGON 97005 U.S.A.
Telephone (person-to-person for technical information) Loren Parks Area 503 644-7463

DIRECTIONAL DOPPLER FLOWMETER

MODEL 805

$700

The Model 805 is an ultrasonic (10 MHz) type blood flowmeter whose output is proportional to blood velocity. Its ability to discriminate between directions of flow and to present each direction on a separate channel for analysis is its outstanding feature. A composite flow signal can also be obtained. Relative velocity and directional characteristics of flow can be obtained from the surface of the skin. On adults, flow studies are limited to the limbs, digits, neck and facial areas. Penetration to the aorta is not possible. On small children useful information may sometimes be obtained through the chest wall. The ultrasonic beam should not be aimed into the retina or into other sensitive tissue.

Other Features:

Probes available for transcutaneous work include a pencil-type probe, a flat probe with the ultrasound beam perpendicular to the plane of the probe, and a flat probe with the beam making a 30 degree angle to the skin (radial artery probe.) All may be gas sterilized. The sterilized pencil probe is often used in surgery after arterial repair. Peri-arterial probes for vessels from 3 mm. to 27 mm. in diameter are also available in a variety of sizes. Write or call for information about these probes. Probe prices range from $35 to $50 each.

All controls for tuning are on the front panel. A selection of filtering time constants permits selection of the desired degree of smoothing of the recorded wave. A precision attenuator allows the Model 805 to be used with a large variety of d.c. recording instruments. We recommend that the recorder have a high input impedance (1 megohm) and a deflection factor of 50 mv/cm for venous work. It can be less sensitive for arterial work. The d.c. input on most electrocardiographs is suitable for clinical work.

The Model 805 operates from self-contained flashlight cells, available everywhere.

PRICE: $700 f.o.b. Beaverton, Oregon. Includes one set of earphones and your choice of 1 transcutaneous probe mentioned above. Outside the U.S. we suggest you purchase your earphones locally, making the price $675. The instrument weighs 4 pounds without batteries. Guarantee of 1 year covers the instrument but not probes, which must be considered expendable.

PARKS ELECTRONICS LABORATORY 375 S.W. FIRST BEAVERTON, OREGON 97005 U.S.A.
For technical information, phone (person-to-person) Loren Parks Area 503 644-7463

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EXAMPLES OF DIRECTIONAL CHARACTERISTIC

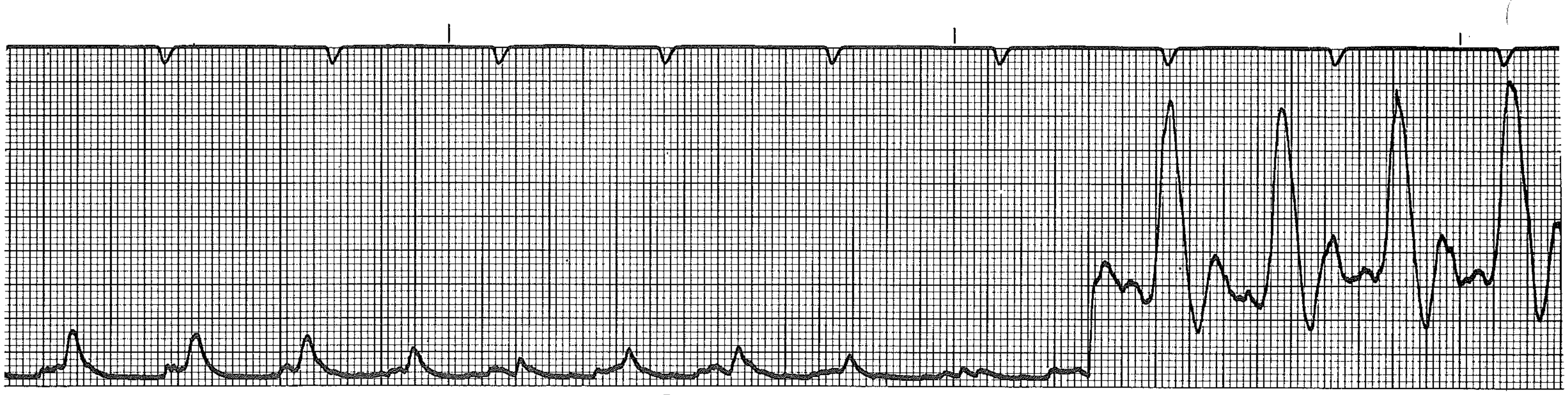
The recordings below were obtained from the radial artery, transcutaneously.

A. Pencil probe is pointed upstream, Signal Output switch in A position (flow toward probe).
B. Pencil probe in same position but Signal output switch in B position (flow away from probe).

C. Probe position changed, pointing downstream toward hand. Signal Output switch in A position, (flow toward probe). A small reverse-flow wave is seen. The size of this wave varies with hand temperature and other factors. If the distal bed is wide open it is not seen at all. If the fist is clenched it is larger.
D. Probe position still downstream, Signal Output switch in B position.

Variations in wave size are due to differences in the angle at which the ultrasound beam enters the blood stream (comparison of A and D). The bottom line of the graph is the zero flow line.

A. TOWARD PROBE — B. AWAY FROM Probe



C. PROBE POINTED TOWARD HAND - FLOW TOWARD PROBE — D. FLOW AWAY FROM PROBE

REFERENCES:

Application of a transcutaneous doppler flowmeter in evaluation of occlusive arterial disease. Surgery, Gynecology & Obstetrics May, 1966 pp. 1039-1045 Strandness, et al.

Ultrasonic flow detection, a useful technic in the evaluation of peripheral vascular disease. Am. Jour. Surg. Vol. 113 pp. 311-320 March 1967 Strandness, et al.

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DIRECTIONAL DOPPLER

FOR

VASCULAR SURGEONS

MODEL 806

$850

The Model 806 Directional Doppler includes all the best features of our models 803 and 805. In addition, two meters on the front panel indicate the direction of flow and the relative flow velocity.

Flow velocity recordings may be made on any recorder with a high input impedance and a 100 mv/cm deflection factor. The d.c. input of an electrocardiograph channel is satisfactory. Provisions are made for insertion of a frequency calibration so that, for example, you know that a deflection of 2 cm on your recorder is equivalent to a doppler shift of 2 kilohertz at 10 MHz. Please understand that quantitative flow measurements cannot be made through the skin unless the inside diameter of the vessel is known. Therefore the indication on the meters can only mean relative flow and even that only when the angle at which the ultrasonic beam intercepts the vessel is constant. The ultrasonic beam must enter the vessel at some angle other than 90 degrees in order for the direction discrimination to operate, at least 15 degrees off perpendicular. When the beam intersects an artery and a vein, some flow will be indicated on both channels.

The instrument may be tuned to match a variety of probe shapes provided their operating frequency is in the vicinity of 10 MHz. For special applications we can modify any of our dopplers to operate at other popular frequencies such as 5 or 8 MHz.

The audio output is normally heard in stereo earphones, and a true stereo effect is obtained. Changes in flow direction may be detected by a noticeable shift in sound to the opposite ear. In other words, flow in one direction is heard in one ear, the other direction in the other ear. The difference is only in phase so to obtain this effect the user must have fairly equal hearing ability in both ears.

The instrument operates from ordinary flashlight batteries. For group demonstrations we make a speaker with built-on transistor amplifier and flashlight battery pack. Adequate for all but large auditoriums. Price is $80. Of course the stereo effect is lost with a single amplifier and speaker but even with two amplifiers and speakers the effect is not nearly as good as with earphones.

PRICE: $850, f.o.b. Beaverton, Ore., U.S.A. Includes one set of stereo earphones and one probe of your choice, either pencil-shaped probe or plastic probes for blood pressure measurements or radial artery flow. Extra probes are $35 each. We recommend you purchase all probes at the same time so we can furnish a matched set and thus minimize re-tuning as probes are switched. Extra stereo earphones are $25 and we strongly recommend you get an extra set for demonstrations. These are SONY DR-6A. Includes two cables to fit most recorders. If you are going to use a Sanborn electrocardiograph, please give the model as the cable needed may be different. Instrument weight (without batteries) is 7 1/4 lbs.

For technical information, call person-to-person Loren Parks Area 503 644-7463.

PARKS ELECTRONICS LAB. 12770 S.W. FIRST, BEAVERTON, OREGON 97005