B.P. INSTRUMENT

1.0.0 INTRODUCTION

The field of medical instrumentation is by no means new . But with the advancement of science and technology, more effective, improved and sophisticated measuring devices are continuously made available to the user. Thus it becomes a necessary for the user to apprise himself about the lates technology from time to time.

Biomedical instrumentation can generally be classified into the major types : clinical and research. Clinical instrumentation is basically devoted to the diagnosis, care and treatment of patients, whereas, research instrumentation is used primarily in the search of new knowledge pertaining to the various systems that compose the human organism.

The major function of the clinical instrumentation is the measurement of physiological variables. A variable is any quantity whose value changes with time. A variable associated with the physiological process of body is called a physiological variable. Examples of physiological variables used in clinical medicine are body temperature, the electrical activity of heart (ECG), arterial blood pressure, and respiratory airflows.

Here, we will take up in detail the engineering methods and the development of instrumentation regarding the measurement of blood pressure. As one of the physiological variables that can be quite readily measured, blood pressure in considered a good indicator of the status of the cardiovascular system. A history of BP measurement has saved many persons from dangerous diseases and also in reducing deaths from heart attack and heart disease. To keep check on the abnormal behavior of BP, its measurement has become an essential practice by doctors.

Blood pressure is defined as the force exerted by the blood against the walls of the blood vessels and is measured in millimeters of mercury (mm Hg) above atmospheric pressure. Arterial blood pressure is the lateral pressure (or force exerted by the blood on a unit area) on the arterial wall and this pressure constantly changes over the course of the cardiac cycle.

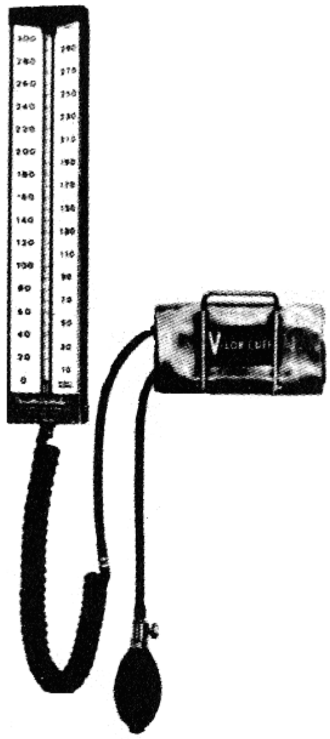
Though measuring BP is a continuous process, it is common practice to measure the highest pressure and the lowest pressure in this cycle. The highest pressure is the systolic blood pressure which is produced by contraction of the heart, the lowest pressure is the diastolic blood pressure which is the pressure between heart beats. A typical or normal BP is expressed as 120/80 mm Hg, where 120 is the systolic pressure and 80 is the diastolic pressure.

2.0.0 MEASUREMENT OF BLOOD PRESSURE

BP can be measured by either direct or indirect methods :

2.1.0 INDIRECT MEASUREMENTS

In routine clinical tests, BP is usually measured by means of an indirect method using a sphygmomanometer and stethoscope. The name is derived from the Greek word, sphygmos, meaning pulse. This method is easy to use and can be automated. The sphygmometer measures BP by balancing air pressure against the pressure of blood in the artery. The sphygmomanometer consists of an inflatable pressure cuff which is wrapped around the patients upper arm and connected to a mercury type manometer or to a pressure gauge. A wall mounted sphygmomanometer is shown in figure-1 (a) and a portable unit is shown in figure-. 1 (b).



Fifure 1 (a)

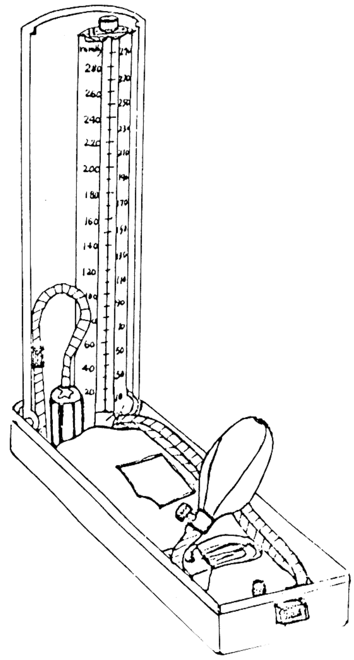


Figure 1 (b)

The cuff consists of a rubber blabber inside an inelastic fabric covering that can be wrapped around the upper arm and fastened with either hooks or a Velcro fastener. The cuff is normally inflated manually with a rubber bulb and deflated slowly through a needle valve. Air is pumped by rubber bulb in to the cuff until blood flow in the artery is stopped, as determined by a stethoscope applied to the lower part of the arm. As air is slowly released, arterial pressure exceeds cuff pressure and a sound of renewed blood flow, known as " **Korotkoff sound**" can be heard via the stethoscope. The manometer reading at which this sound is first heard is recorded as the **systolic pressure**. As the cuff pressure is further reduced, the sound generally increases in intensity until, when the cuff if nearly deflated, the artery is no longer squeezed and blood flow is normal. At this point, the “Korotkoff Sound” will cease. The point at which the “Korotkoff Sound” is muffled usually just before it ceases is generally taken as the **diastolic pressure**.

The sphygmomanometer technique is an ausculatory method, i.e. it depends upon the operator recognizing the occurrence and disappearance of “Korotkoff Sound” and correlating them with cuff pressure.

An alternative method, called the palpatory method, is except that the physician identifies the flow of blood in the artery by feeling the pulse of the patient downstream from the cuff instead of listening for the Korotkoff sound. Although systolic pressure can easily be measured by the palpatory method, diastolic pressure is much more difficult to identify. For this reason, the ausculatory method is more commonly used.

As the above method is much dependent on the person measuring BP, attempts have been made to automate the indirect procedure. As a result a number of automatic and semiautomatic systems have been developed. Most devices of this type utilize a pressure transducer connected to the sphygmomanometer cuff, a microphone placed beneath the cuff, (over the artery), and a standard physiological recording system on which cuff pressure and the Korotkoff sounds are recorded. The basic procedure essentially parallels the manual method. The pressure cuff is automatically inflated to about 220 mm Hg and allowed to deflate slowly. The microphone picks up the Korotkoff sounds from the artery near the surface, just below the compression cuff. The pressure reading at the time of the first sound represents the systolic pressure, the diastolic pressure is the point on the falling pressure curve where the signal representing the last sound is seen. A popular automatic BP meter is the programmed electro sphygmomanometer

PE- 300 illustrated in figure-2 below in block diagram and in pictorial form.

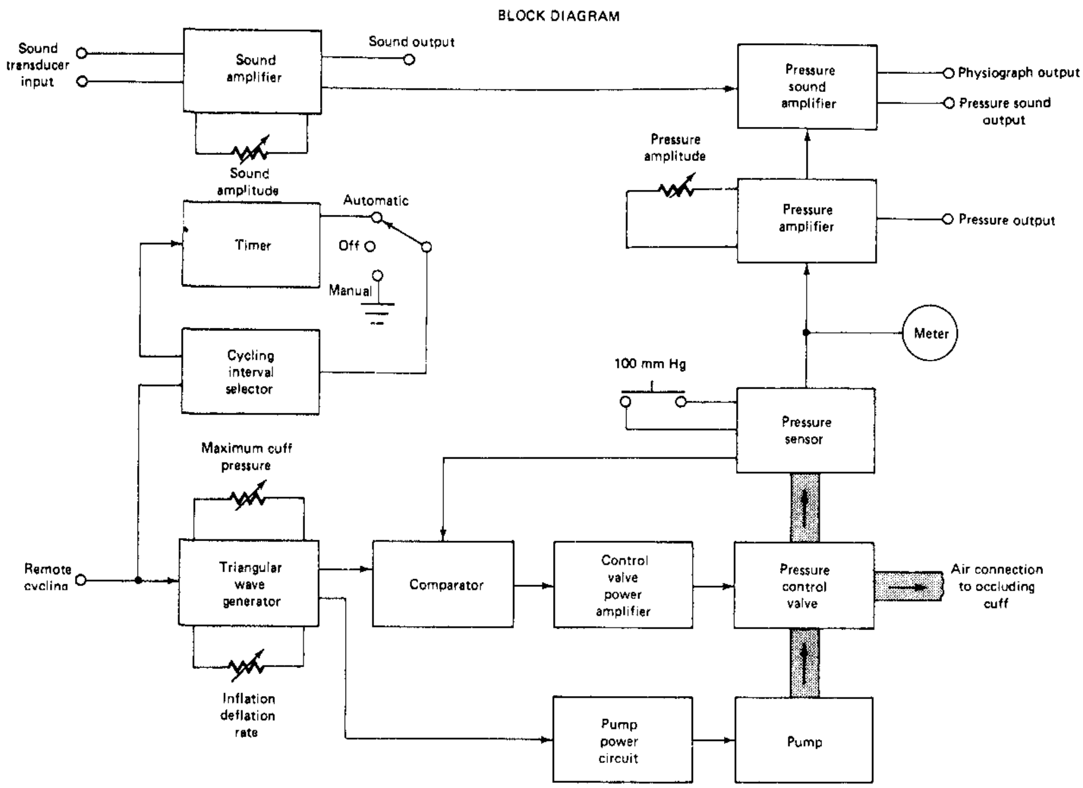


Figure-2(a)

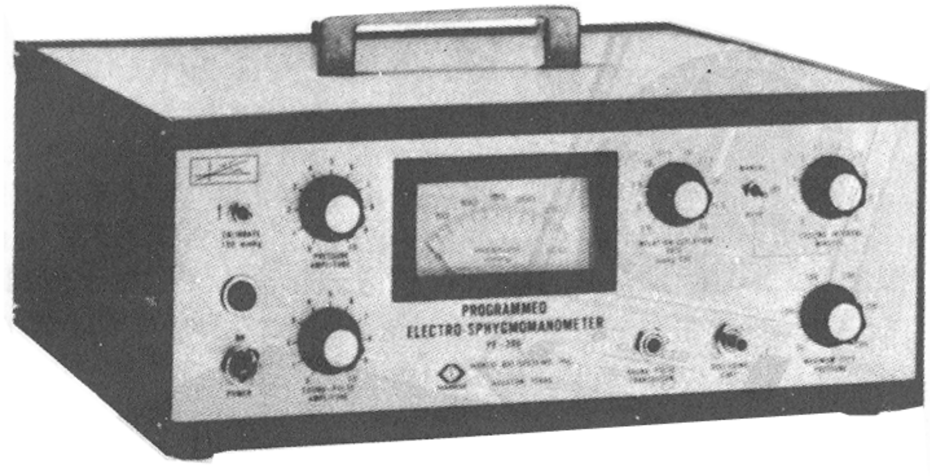
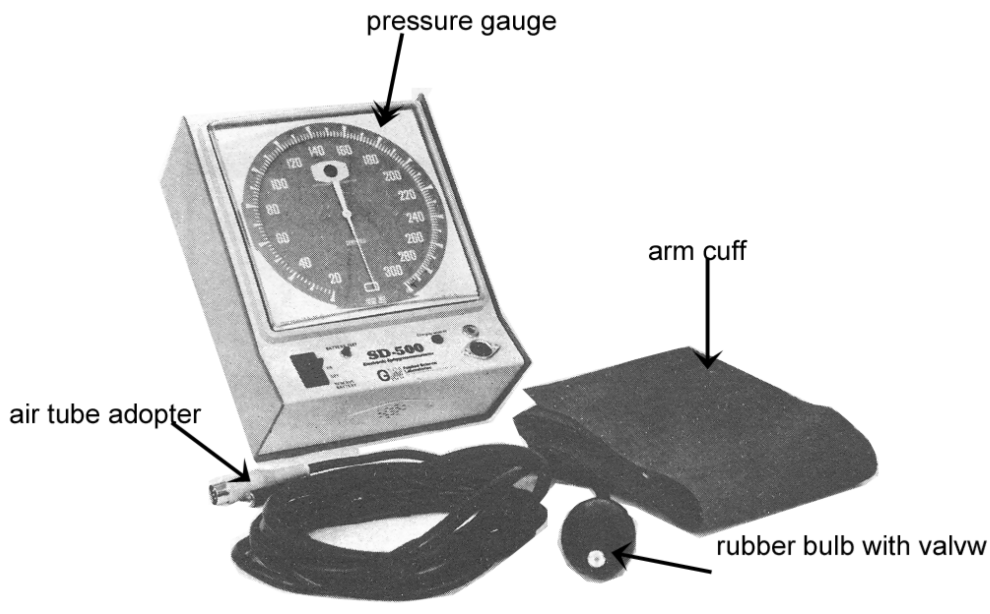


Figure-2(b)

Figure-3 below shows another commonly used electronic sphygmomanometer. This is an example of a device incorporating a large guage for easy reading. Here the cuff is inflated manually and Korotkoff sounds are automatically detected by microphones and a light flash at systolic pressure, which stops at the diastolic value.



Nowadays, along with the systolic and another parameter known as mean arterial pressure (MAP) has become very popular .Most electrical monitors now provide a single value of MAP indication along with the routine systolic and diastolic values. Figure-4 below shows an instrument that is most widely used for automatic detection MAP.

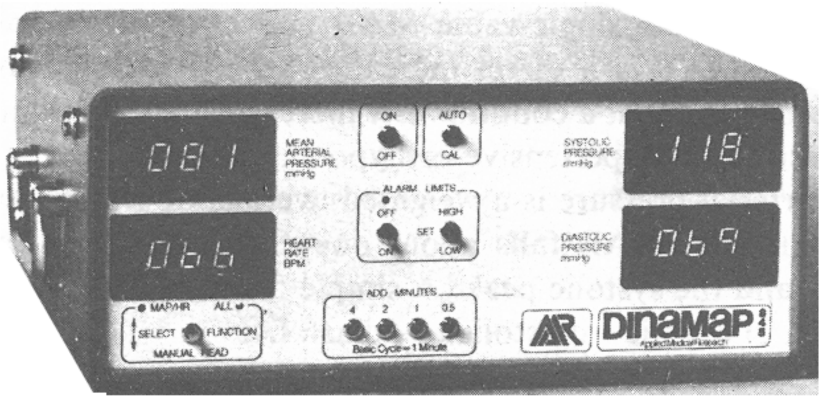


Figure-4

MAP is a weighted average of systolic and diastolic pressure. Generally MAP falls about one third of the way between diastolic low and systolic peak. A simple formula for calculating MAP is

MAP = 1/3 (systolic – diastolic) + diastolic

It is now generally recognized that MAP is a direct indication of the pressure available for tissue perfusion and that a continuously increasing or decreasing MAP can ultimately result in a hypertensive crisis.

2.1.0 DIRECT MEASUREMENTS

Direct measurement or BP is usually obtained by one of three methods :

2.1.1 Percutaneous insertion.

2.1.2 Catheterization (vessel cut down)

2.1.3 Implantation of a transducer in a vessel or in the heart.

Figure-5 below gives general idea of the direct method. Essentially, a long tube catheter is introduced into the heart of a major vessel by way of superficial vein. Then BP is measured either by introducing a saline solution and noting the pressure variation or by introduction the transducer into the catheter and measuring BP directly.

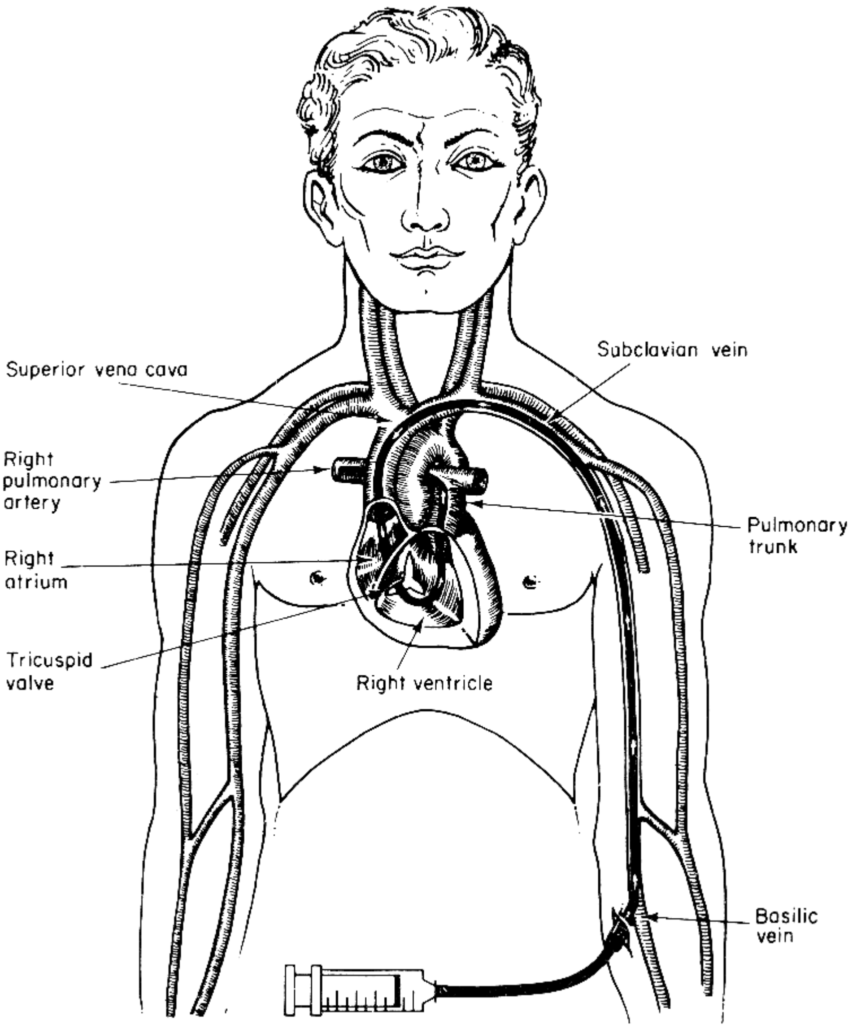


Figure-5

Cadiac catheterization. The tube is shown entering the basilic vein in this case.

2.1.4 ADVANTAGE AND DISADVANTAGE

The direct method do provide a continuous read out or recording of the BP waveform. But it requires a blood vessel to be punctured in order to introduce the sensor. Hence this method is risky and more painful to the patient. This limits their use to those cases in which the condition of the patient warrants invasion of the vascular system. But this method has become a major diagnostic technique for analyzing the heart and other components of the cardiovascular system. Apart from obtaining BP in the heart chambers and great vessels, this technique is also used to obtain blood samples from the heart for oxygen content analysis and to detect the location of abnormal blood flow pathways. This is also useful where the BP data is to be received remotely like gathering information on exercise, the effect of drugs and extreme environments and acceleration and impact studies.

The indirect method on the contrary does not require entrance into the body and is therefore safe and painless. Though it does not give a continuous recording of BP, it is found that for a routine clinical diagnosis and care, the indirect method give sufficiently reliable recording of BP.

After glancing through all the available BP measuring instruments. We will go into the full details of mercurial sphygmomanometer, as even today, this is the most widely used BP measuring instrument.

3.0.0 OPERATING INSTRUCTIONS

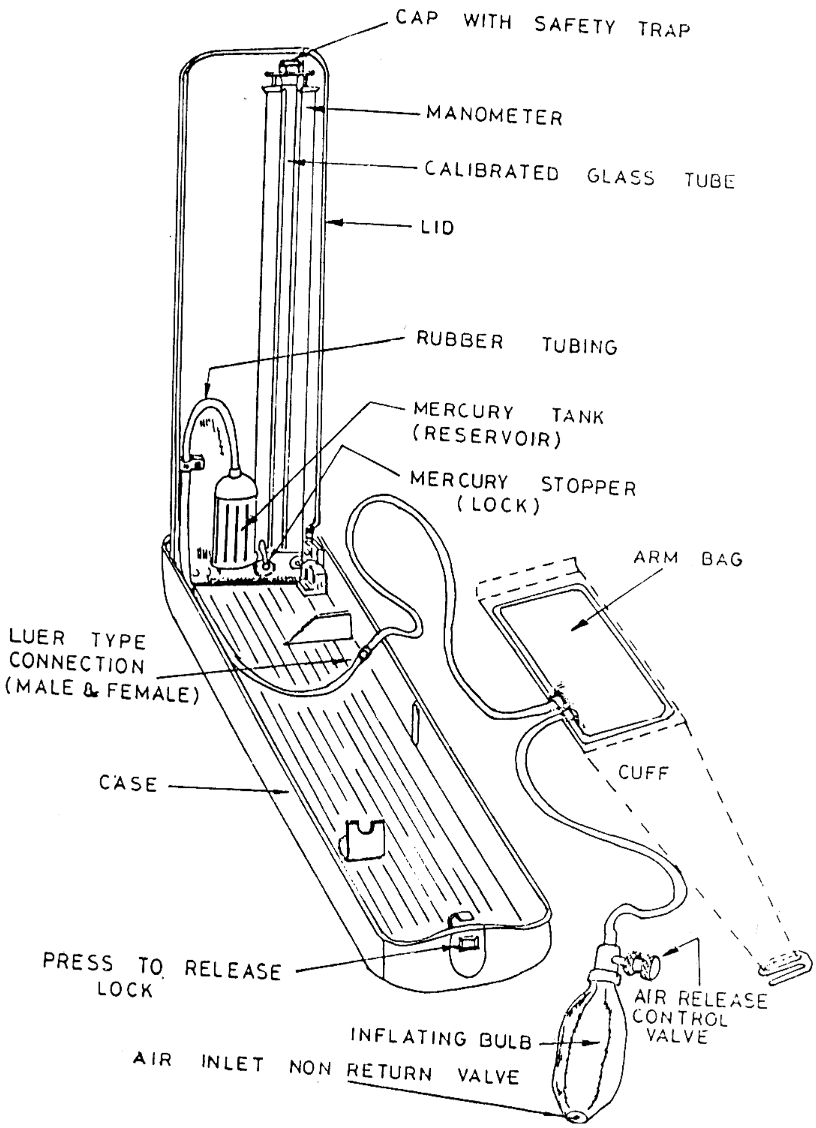


Figure-6

Figure-6 below shows the measurement of BP of a patient using the instrument.

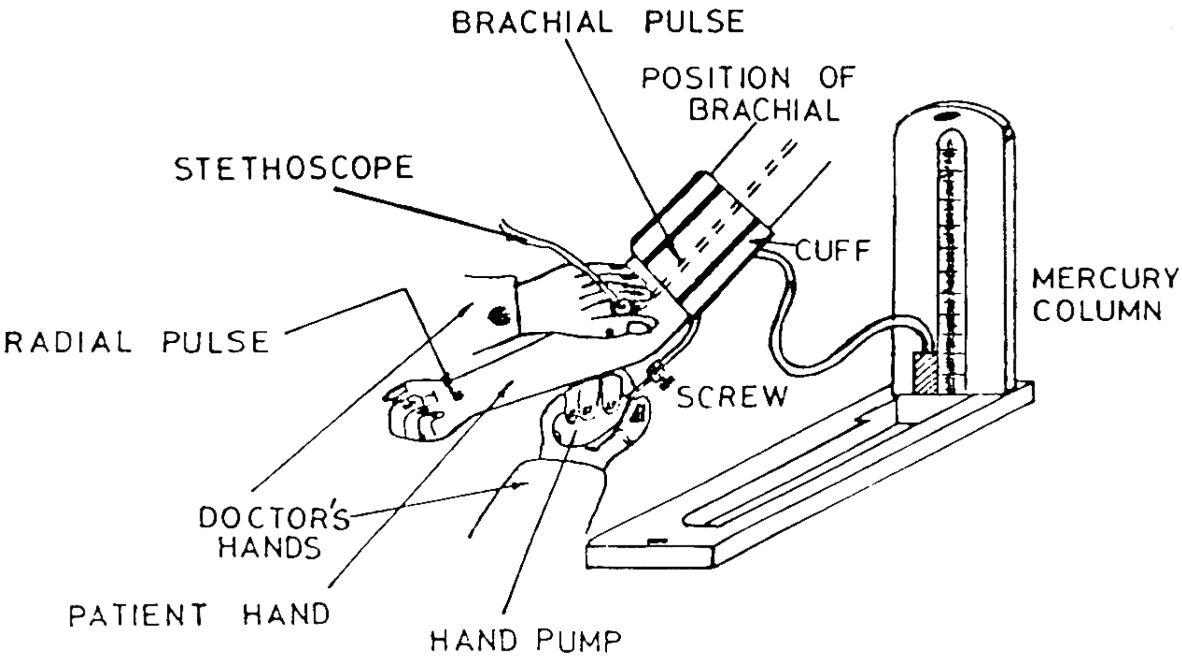


Figure-7

The instrument should be used strictly as per following instructions :

3.1.0 Wrap the cuff of a sphygmomanometer around the upper arm.The cuff

must be smooth with the rubber against the inside of the upper arm and the rubber tube with its valve to the front;

3.2.0 Connect the tubing from the mercury manometer to the cuff ;

3.3.0 Tighten the screw of the rubber bulb (hand pump);

3.4.0 Locate the pulse of the brachial artery, medical to the middle of the elbow, below the cuff;

3.5.0 Feel the radial pulse. Inflate the cuff until the radial pulse is no longer felt and then increase the pressure a little more;

3.6.0 Place the end of a stethoscope over the place where the brachial artery pulse was felt;

3.7.0 Slowly loosen the screw of the pump to allow the air to escape from the cuff, listening for tapping sound (pulse beat) through stethoscope.Note the height of the mercury column at the point when the pulse beat is heard.This is the systolic blood pressure, the pressure in arteries when heart is contrcacted;

3.7.0 Let out air, as the sound first becomes louder and then suddenly quieter (muffled). Note the height of the mercury column at the front when the sound becomes quieter again;

3.8.0 Continue to let the pressure fall listening for the sound to disappear.The point at which the sound diaappears should be taken as the diastolic blood pressure;

3.9.0 Continue to allow the air to escape making sure that the sound does not return.Occasionally there is a silent gap and unless listening is continued, a false high diastolic pressure may be observed;

3.10.0 Blood pressure (BP) is indicated as height in millimeters of mercury (mm Hg) as follows :

3.10.1 Systolic BP/ diastolic BP or Systolic BP/level of muffling/level of disappearance.

The blood pressure of most adults at rest varies from 95/55 to 140/90. It is generally observed that BP increases with age.

4.0.0 MAINTENANCE

4.1.0 Removal of Glass Tube

4.1.1 Open up the instrument and set it in its positon, i.e. the lid with the manometer etc. is upright and vertical to the table;

4.1.2 Tilt it sideways towards the reservoir side as shown in figure 8 so that the mercury in the glass tube back completely into the reservoir;

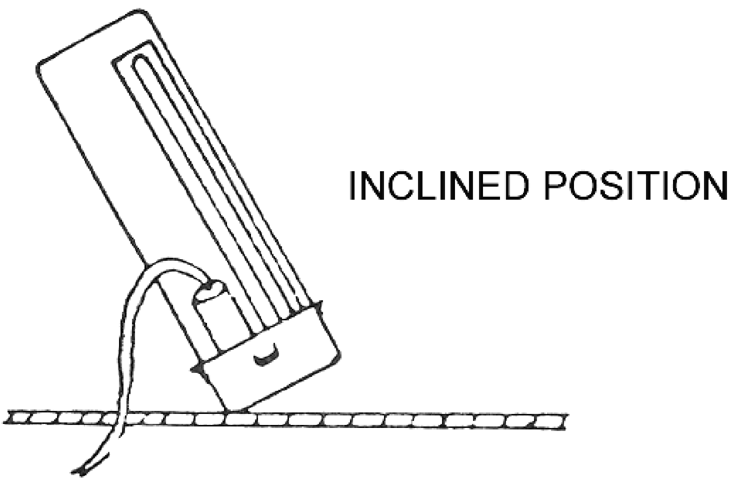


Figure-8

4.1.3 Close lock, i.e. stop valve; so that mercury does not flow back to the glass tube;

4.1.4 In case there is no lock, hold the lid in its inclined position firmly from the back side ;

4.1.5 Carefully lift the tube holder at the top with one hand and pull out the tube with the other hand as shown in figure 9; and

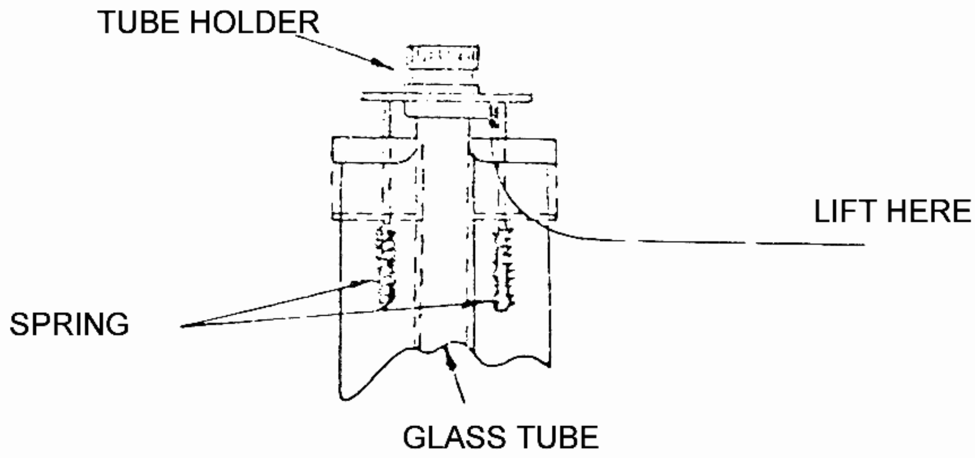


figure-9

4.1.6 Keep the instrument in the inclined position, resting on any support.

4.2.0 CLEANING OF GLASS TUBE

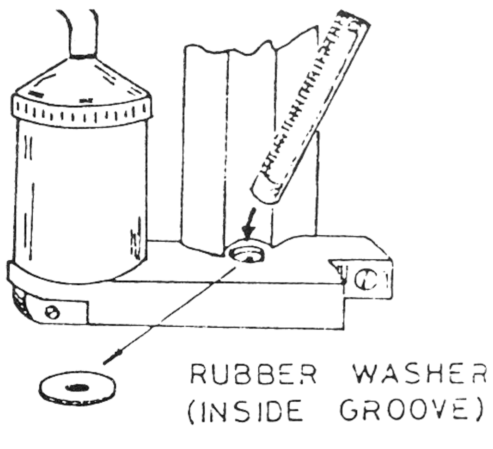
4.2.1 Wipe the inside of the glass t ube with the special brush available for this purpose , by gently interesting it from one end and pulling it out from the other; and

4.2.2 Repeat the above action till it is free from dirt and dust.

4.3.0 REPLACEMENT OF GLASS TUBE

4.3.1 Bring the instrument from its inclined rest positon and hold its lid firmly from the back side;

4.3.2 Put a new washer inside its groove as shown in figure 10;



Fifure-10

4.3.3 Insert the bottom end with "0" marking of the tube into the groove on the reservoir assembly with the rubber washer in position;

4.3.4 Lift the top until the top end of the tube can be positioned properly. Now gently release it to hold the top end of the glass tube firmly; and

4.3.5 Bring back the instrument to its erect position, open the lock; if any. Allow the mercury to flow back to the glass tube freely.

4.4.0 ADDITION OF MERCURY

The top surface of the mercury column the glass tube takes a curved shape as shown in figure 11 due to its surface tension.

For some reasons, there may be partial or total loss of mercury.Then, the required quantity of mercury is to be added correctly.

For this process, proceed as follows :

4.4.1 First of all observe that,in erect position, when the amount of mercury is correct, the top of the curved surface of the mercury should be in level with the 'O' level mark as shown in figure 11;

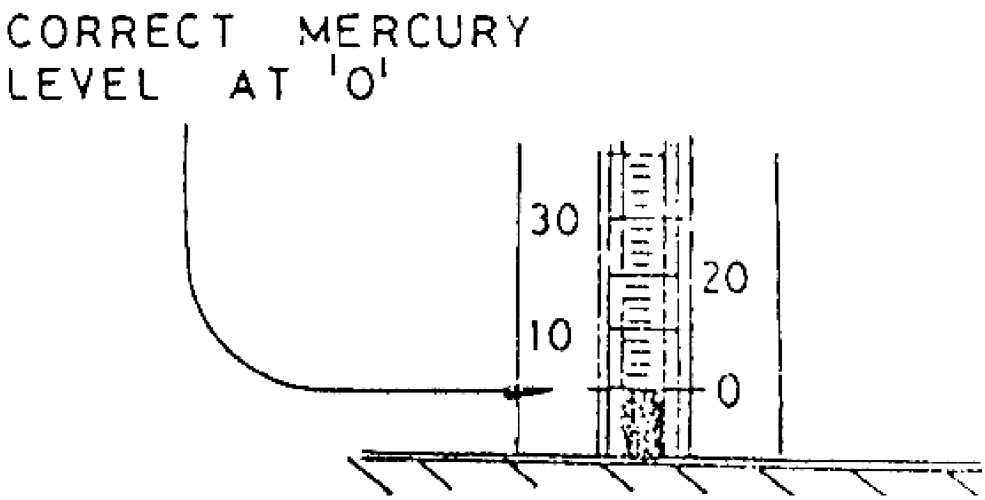


Figure-11

Surface of mercury inside glass tube

4.4.2 If the level of mercury is below the 'O' marking then fresh mercury is to be added to bring it to the "O" marking;

4.4.3 For addition of mercury, unscrew the cap of the top tube holder and fit the stem of the funnel on top of the holder as shown in figure 12; and

4.4.4 Add mercury through the funnel, in small quantities at a time until the level is correct i.e. up to **"O"** marking.

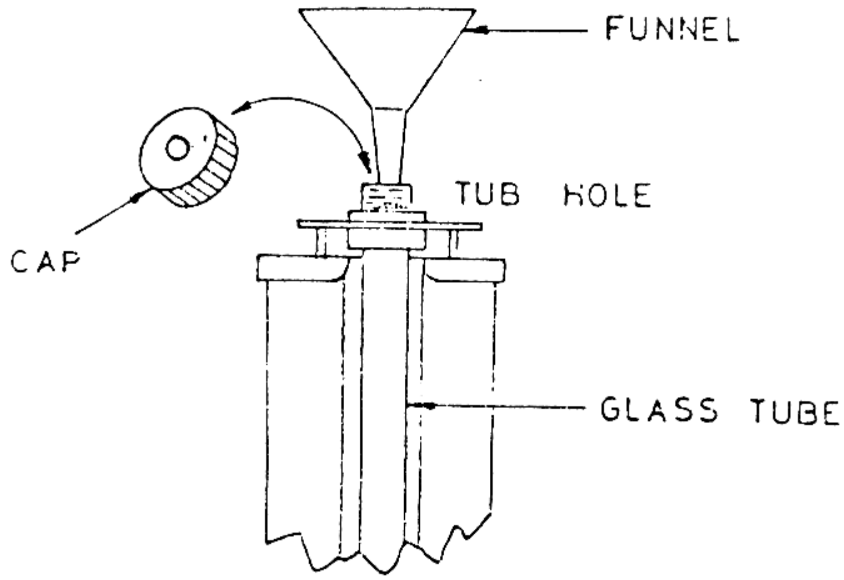


Figure-12

Filling of mercury in glass tube

4.5.0 TAKING OUT EXCESS MERCURY

In case more than required quantity of mercury has gone into the instrument, it can be taken out through top of the tube holder by tilting the instrument slowly and colleting the excess mercury in a container. Carry on the process until the excess quantity has been withdrawn

4.6.0 CLEANING OF SAFETY TRAP WASHER

Finally check and clean the safety trap washer in the cap and replace the cap firmly.

4.7.0 WORKING OF SAFETY TRAPS

There are two safety traps. One each at the top caps of tube holder and mercury reservoir. These allow only the air to pass through them but prevents passage of dirt and dust to go into tube and also the mercury to come out from the manometer.

In case safety traps become defective, they will allow dust and dirt to collect inside the tube and reservoir,and may also cause loss of mercury through them.

4.8.0 CLEANING OF INSTRUMENT

4.81 Remove the top cap of the glass tube holder;

4.8.2 Take out the mercury completely from the system through the open top of the tube holder by inclining the instrument. Collect the mercury in a container;

4.8.3 Take out the tube and clean it and keep it aside;

4.8.4 Disconnect the rubber tubings from the top of the reservoir, unscrew the cover, remove and clean it;

4.8.5 Clean the inside of the reservoir and the cover with a brush or lint free cloth;

4.8.6 Check and clean both the safety traps and if required change the defective ones;

4.8.7 Refit the reservoir cover and reconnect to its top;

4.8.8 Replace the cleaned glass tube into positon; and

4.8.9 Add clean mercury to the correct level.

4.9.0 REPLACMENT OF BROKEN GLASS TUBE

Procure an identical glass tube of same length and with same graduations. Also see that the portions below 'O' marking and above top marking are same as that of the original (broken) one. Then only the glass tube will fit properly and the instrument will give correct readings.

Take off the broken/ cracked glass tube and fit the replacement tube as described earlier.

4.10.0 REPLACMENT OF MERCURY RESERVIOR (TANK)

Sometimes the reservoir becomes defective and necessitates replacement.In such cases, proceed as follows:

4.10.1 Arrange an identical reservoir clean glass tube,after taking out mercury, as described earlier;

4.10.2 Disconnect the rubber from the top cover of the defective reservoir.

4.10.3 Remove the reservoir from the lid by reomoving the screws, fixing it to the lid;

4.10.4 Replace the defective reservoir with the new oneand have it fixed firmly with the screws;

4.10.5 Put a rubber washer in the groove meant for connecting the bottom of the glass tube;

4.10.6 Replace the glass tube, as per procedure described earlier; and

4.10.7 Add require quantity of mercury to the system.

5.0.0 TESTING OF REPAIRED INSTRUMENT

5.1.0 Incline the instrument in its erect position once towards left and once towards right and allow it to rest in its erect position. Observe if the mercury level is correct at 'O' marking. If not,bring it to the required level by adding or removing the required quantity of mercury as described earlier.

5.2.0 Roll the arm bag and strap the cuff;

5.3.0 Connect the arm bag at the lower point and/or close the air release control valve;

5.4.0 Inflate the system by means of the rubber inflating bulb and observe the mercury column rising;

5.5.0 In case any leakage of mercury from the bottom end of the glass tube is observed, release the pressure by air release control valve.Examine the bottom end of the glass and the rubber washer in the groove by reomoving the glass tube as described earlier;

5.6.0 Replace defective parts. Refit glass tube and test again after adding the quantity of the mercury leaked out;

Inflate the system again until the mercury column rises to the maximum marking at the top. Wait for sometimes and see if the mercury column is failling fast or steady at one position. It should not fall at a rate of more than 10 mm per minute. If it falls faster, it indicates that there is some leakage of air in the inflating system. The leakage may be due to defects in rubber tubing, loose connection, arm bag, and air release control valve;

5.7.0 Identify the leaking portion/part.This may be done by blocking the rubber tubings at different portions starting from reservoir end and processing towards the inflating bulb. Repair, if possible or replace the defective portion; and

5.8.0 In case air bubbles rise through the mercury column before it reaches maximum,it shows that that the quantity of mercury is less in the system. Add required quantity of mercury and repeat the tests as described earlier.

6.0.0 Replacement of Rubber tubings, Arm Bag, rubber Inflating Valve

6.1.0 Keep the instrument at rest in its erect positon;

6.2.0 Disconnect the defective portion and replace with similar portion/length of tubing; and

6.3.0 Test the instrument after replacement as described earlier.

7.0.0 REPLACEMENT OF AIR INLET NON –RETURN VAVLE

It contains a small metallic ball inside a groove, as shown in figure 13.

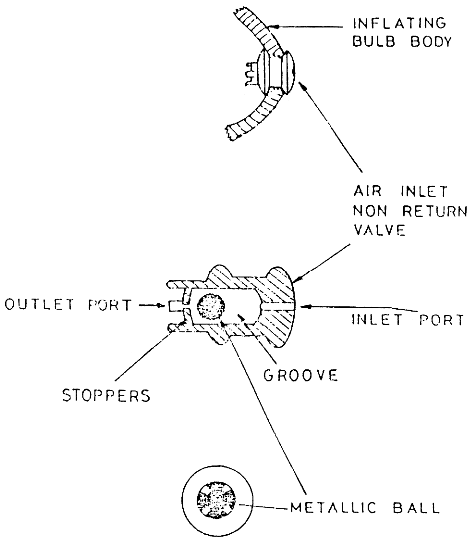


Figure-13

Sometimes either the ball is lost or gets stuck inside the groove due to dust, dirt or rust. This stops the valve action.

7.1.0 Replacement of ball

If lost, fit a small steel ball obtainable from any bicycle shop.Position the stoppers properly after inserting the ball.

7.2.0 Cleaning the valve

If stuck, first try to move it after putting a drop of light machine oil into the groove. In case valve is stuck very hard, open the stoppers carefully, remove the ball by pushing it through the inlet port.Clean the groove and the ball and reassemble it .Position the stoppers carefully.

8.0.0 Repair/Replacement of Air Release Control Valve

The assembly consists of an air release control valve and a non return valve, as shown in figure 14. The cross-sectional view of the valve is shown in figure 15. In some cases, this non return valve becomes defective.

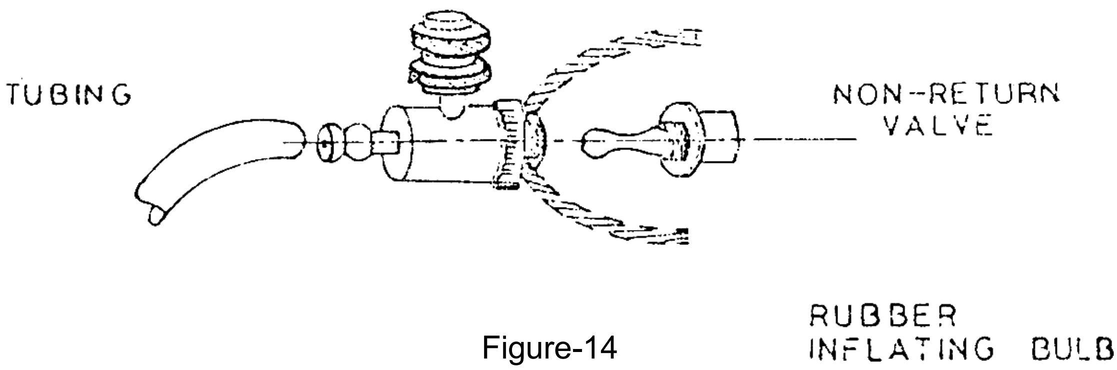


Figure-14

Air Release control valve and non-return valve

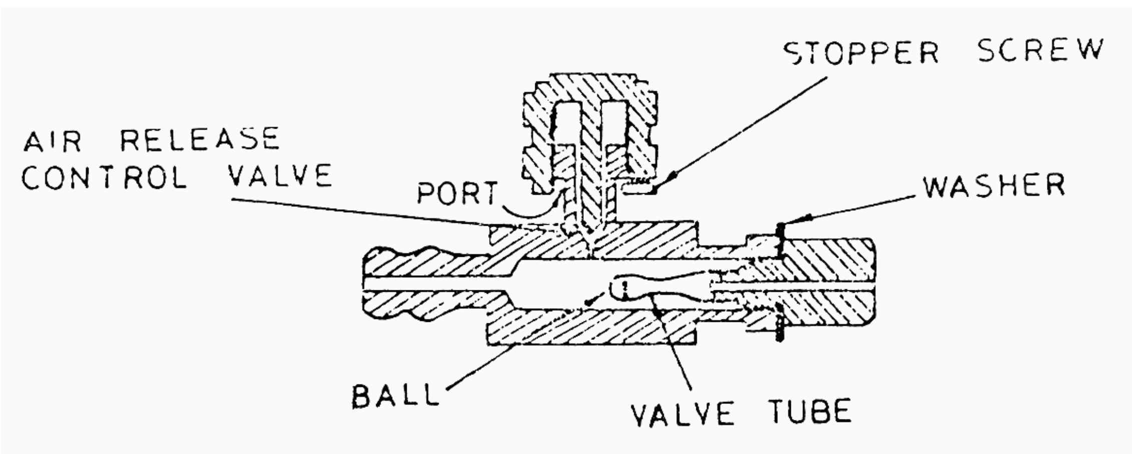


Figure-15

Cross sectional view of valve tube portion

8.1.0 Cleaning the valve

Open up the assembly and clean it with a brush. Examine the slit on the valve tube to see if it is in proper position or not.

8.2.0 Assemble and testing

Assembly the unit and test it by connecting to the inflacting system to see if it is working properly or not.

8.3.0 Replacement of valve

If the non-return valve is found to be defective,replace the valve tube portion with an equal portion of valve tube. This is similar to what is used in bicycles.

Figure 16 shows the procedure to cut two small slits on opposite sides by single press of blade.

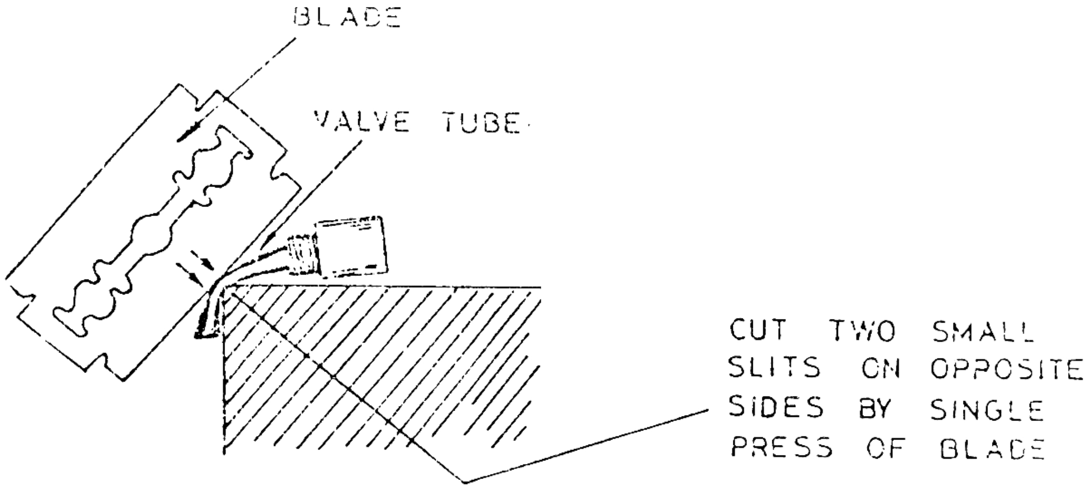


Figure-16

Making of slits with razer blade

Be careful when making the slits with the help of a sharp razor blade. Keep the mid portion of the valve tube across the edge of some wooden piece or the working table.Fit the valve tube in position with the small ball at one end.

8.4.0 Assembly and testing

Assemble the unit and reconnect it to the system and test it again.

9.0.0 Testing the Repaired blood pressure instrument with standard instrument

9.1.0 connection of both instruments

Connect both the instruments to one set of Arm bag and inflating bulb by means of a 'Y' 3 way connector.The 'Y' may be taken from stethoscope or may be made locally.The required arrangements shown in figure 17.

9.2.0 Inflating to maximum

Close the air release control valve and inflate the system slowly and gradually till the mercury column reaches almost the maximum limit in the glass tubes.

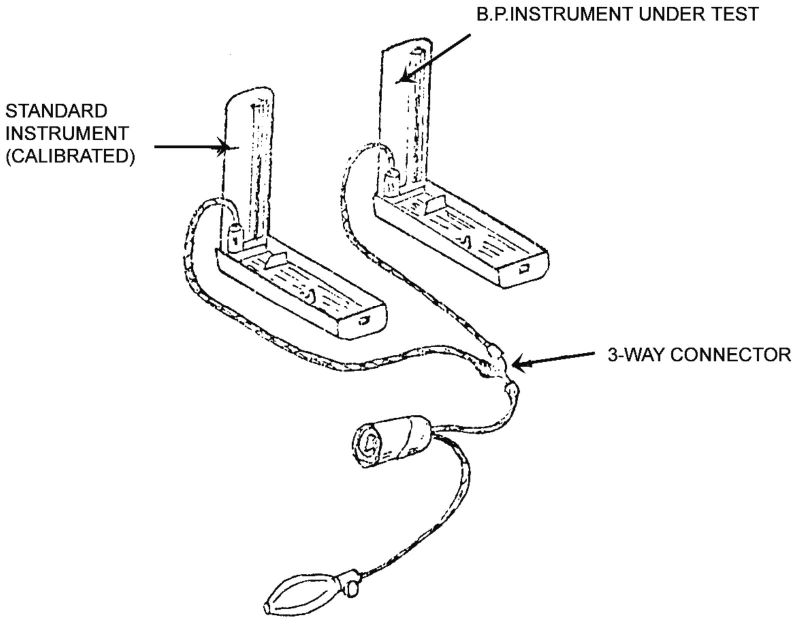


Figure-17

Test of repaired blood pressure instrument with standard instrument

10.0.0. Testing

Slowly release the air pressure by the AR control valve, in steps. and note the readings on the standard instrument and the corresponding readings on the instrument under test.

The difference of the standard (accurate) instrument reading and corresponding reading on the instrument under test taken at any position on the scale shall not exceed +-2 mm Hg, as prescribed by Bureau of Indian Standards as per their specification No. IS : 3390-1965.

11.0.0 Preventive Maintenance

At least once in a week, perform following check:

The mercury column should be checked for its smooth rise and fall; and

Check that the cuff is inflated to full extent.

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