DTU

Ram Pump Programme

RAM PUMP SYSTEM CALCULATORS

TECHNICAL
10
RELEASE

DTU Technical Release TR10 *1996*

Cardboard Calculators for Designing Ram Pump Systems

1 INTRODUCTION

In the Development Technology Unit we have for many years been designing water systems that use hydraulic ram pumps. We have also trained water specialists from over 10 countries how to make the pumps and design systems to put them in. To design a good system, you have to do some calculations. We have found that most people do not enjoy using formulas or doing maths, so we have developed special cardboard 'calculators' that can be used instead of formulas. They give the same answers as the formulas in books but are much easier and quicker to use.

When we design a water system using ram pumps, we like to be able to know *before* we build it how much water it will deliver. This is called the "delivery flow". The first DTU calculator is the *Ram Pump System Design Calculator* and is meant mainly for working out such delivery flows.

The second cardboard calculator is called the *Friction Headloss Calculator*. We use it to help select the right sizes for the different pipes in a ram pump system. It can also be used for choosing the pipe sizes in a gravity-feed water system.

In this Technical Release we describe how to make the two calculators and how to use them.

The last three pages of this Technical Release are single-sided master pages to be photo-copied each time you make a calculator. We suggest that the first photo-copy you make should be attached to this Release in case the copy masters get separated and lost.

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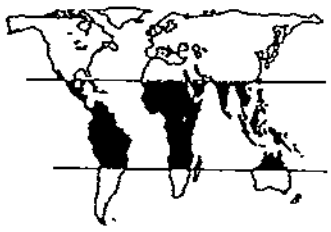

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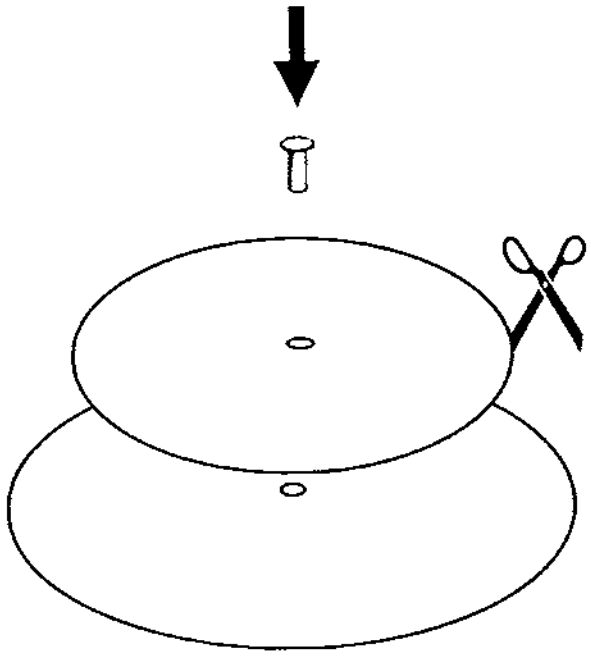
2 MAKING THE CALCULATORS

Start by photo-copying the calculator parts printed on the 3 pages at the end of this Release. The thicker the paper or card you can use for these copies, the better; card as thick as 180 gpm can be fed through some slow photo-copiers. The *Delivery Flow Calculator* has 2 parts, both on the same page. The *Friction Headloss Calculator* has 3 parts, spread over the two following pages.

Carefully cut out the parts of the *Delivery Flow Calculator.* You will be assembling them by pushing a rivet through the centre holes and turning the ends over, so the cut-out circles for these centre holes should be the same size as the rivet you will be using. It is important to make these holes round and put them in exactly the right place on the disc.



The rivet can be of plastic or soft metal. We have successfully made rivets from short strips cut from thick plastic piping, rolled on sandpaper to make them round and then turned over at the ends with a hot iron. You could also use a short plastic or steel bolt with washers and two nuts: the nuts have to be tightened against each other so that they hold the discs not quite tight.The holes can be reinforced with self adhesive "ring reinforcements" sold in some stationery shops to strengthen the holes on paper sheets held in ring-binders.

If the calculator is always to be used in one office, the 2 discs can be held by a drawing pin (through their exact centres) onto a notice board. The pin must be loose enough to allow the discs to rotate freely.

If the calculators are to be carried around or taken out of doors, they will soon get torn or dirty. If at all possible you should cover each one on both sides with transparent plastic. Clear adhesive plastic sheet is sometimes sold in stationery shops for use to protect schoolbooks. If you place any hole-strengthener under the plastic, this will help prevent it falling off. It also helps if you can make a waterproof pocket to carry the calculators in.

The *Friction Headloss Calculator* is made in the same way as the *Delivery Flow Calculator.* except that there are now 3 parts free to rotate on the same rivet or pin.

3 USING THE 'RAM PUMP SYSTEM DESIGN CALCULATOR'

The *Ram Pump System Design Calculator* has two discs and a swinging arm. It carries four scales

Feed head H	Range 1.5 to 30 meters
Delivery head h	Range 10 to 120 meters
Feed flow Q	Range 10 to 800 litres/minute
Delivery flow q	Range 0.5 to 80 litres/minute

Check that you can find each of these scales.

The last scale is in three parts called "efficiency = 50%", "efficiency = 60%" and "efficiency = 70%". If you do not know what your system efficiency might be, use the "60%" part. If you think it might be rather low, use the "50%" part and if it might be very good use the "70%" part.

The calculator is for calculating the flow from a complete *system*, not just from a single pump. If your system has several pumps working side by side, you should use as Q the feed flow to the whole system, not the drive flow to just one of the pumps. The calculator will then tell you the delivery flow from the whole system and not just the output of one pump. If your system does have only one pump in it, there is no problem; the feed flow you use will all go through that one pump.

To learn how to use the calculator we suggest you practice with the following example.

Suppose you have a system in which
feed head = 4 meters,
delivery head = 40 meters,
feed flow = 50 litres per minute,
efficiency is unknown so we use 60%,
then the calculator should show a delivery flow of 3 litres per minute.

Here are the two steps.

Step 1 Hold the outside disk and turn the inside disk until 50 litres per minute on scale Q is exactly in line with 4 meters on scale H.

Step 2 Pinch the two discs together with your fingers so that one cannot slip past the other and then turn both disks together until the q scale is at the top. Find 40 meters on scale h and read the flow above it on the "efficiency = 50%" part of scale q. You should get close to 3 litres per minute.

The calculator is not super-accurate. It will give you an answer that is "close enough". If you followed the example above and got an answer that was not close to 3 litres/min it might be that

- you let the disks slip past each other,
- you used the wrong scales,
- the holes in the middle of your disks have become badly worn and the disks are very loose.

4 USING THE 'FRICTION HEADLOSS CALCULATOR'

When water flows through a pipe there is some friction between the water and the pipe walls. This causes something called "friction headloss" which is measured in meters. A pipe with a small diameter has a bigger headloss than a larger pipe for the same flow of water. A big headloss usually means that the system delivers less water than it should.

The *Friction Headloss Calculator* has two disks and a swinging arm. It carries four scales which you might look for:

Length of pipe	Range 2 to 3000 meters
Flow through pipe	Range 1 to 500 litres per minute
Bore of pipe ("Bore" is the same as "Inside diameter")	Range 16mm to 200mm
Headloss	Range 10cm to 100 meters

and the two small arrows on the swinging arm called "steel" and "plastic". At the top of the swinging arm is a big arrow labelled "flow through pipe".

You can use this headloss calculator to help you choose the best size for the delivery pipe, the feed pipe and the drive pipes in a ram pump system. You can also use it for pipes in gravity feed systems. We will now describe each of these four uses.

Use 1: Delivery pipes

When you come to choose the size of a delivery pipe, you will usually already know how long it is, how high it rises and how much water is to flow through it.

Suppose for example you know that at a particular site:

pipe length = 500 meters,

flow through the pipe = 10 litres per minute and the pipe is plastic,

the delivery height h = 60 meters.

Standard pipe sizes (*outside* diameters) are 20 mm, 25 mm, 32 mm and 40 mm. For medium pressure pipes, their bores (their *inside* diameters) will be about 2 mm smaller - typically 18 mm, 23 mm, 30 mm and 37 mm. Your problem is to decide which size is right.

Suppose you think that the 30 mm bore pipe might be suitable. The calculator lets you find out if it is. The calculation goes as follows:

Step 1 Hold the outer disk and rotate the inner disk until 500 m on the Length scale is touching 30 mm on the Bore scale.

Step 2 Pinching the two disks together so that they do not slip, move the swinging arm until the big arrow at its top is touching 10 litres per minute on the Flow scale.

Step 3 Read the headloss scale underneath the "plastic" arrow. You should find about 1.6 m.

You now have to decide whether this headloss is OK. It should normally be between one fiftieth and one tenth of the delivery head h. If headloss is more than $h/10$ your system will be quite inefficient, so you should try a larger pipe. If it is less than $h/50$ you are using a delivery pipe that is too big: you could save money by trying a smaller pipe. In our example the headloss *is* between $h/50$ (1.2 m) and $h/10$ (6 m), so our pipe size of 30mm is OK.

Use 2: Feed pipes

Your ram pump system may have a feed pipe connecting a stream or spring to a drive tank from which drive pipes lead to each pump. The calculation for feed pipes is just like that for delivery pipes except that the flow is now the feed flow to the drive tank, and of course the length and diameter we use are those of the feed pipe. Feed pipes are usually plastic, so use the "plastic" arrow on the swinging arm. Common pipe sizes for feed pipes are 50 mm, 63mm, 75mm, 90 mm and 110mm outside diameter. The bores of these sizes for low-pressure pipe are about 47 mm, 59 mm, 72 mm, 86 mm and 105 mm. So first decide which bore you should try for the feedpipe, then use the calculator to work out its headloss.

When you have found the headloss, you should compare it with the *feed* head *H*). If it is over H/10, the feed pipe should be larger. If it less than *H*/50 the feed pipe could be smaller.

Use 3: Drive pipes

Each drive pipe carries the drive flow to a single pump: this is usually equal to the feed flow *Q* divided by the number of pumps running side by side. As the drive flow is not steady like the feed flow, but is constantly starting and stopping, the head loss in a drive pipe is higher than for other types of pipe. The *Friction Headloss Calculator* gives the right head loss for a steady flow. For a drive pipe with its unsteady flow we have to multiply the steady flow headloss by 2.

So choose a likely pipe size and for it calculate the steady flow headloss in the same way as for the delivery pipe, but using the length, bore, material and flow that belong to *one* drive pipe. Next multiply the calculator's answer by 2 to get the true headloss. Lastly check whether this true headloss lies between *H*/50 and *H*/10. If it lies outside this band, you should think of changing the drivepipe size. Notice that, as with the feed pipe headloss, we are comparing the drive pipe headloss with the *feed* head *H*.

Use 4: Pipes in gravity feed systems

In a gravity feed system, pipes are laid so that they slope downwards. The drop in height between where water enters a pipe and where it leaves it is what pulls the water through. For any one size of pipe, a bigger drop in height gives a bigger flow. We can use the *Friction Headloss Calculator* to work out what the flow will be. This is because in a gravity feed system, the friction headloss is exactly *equal* to the drop in height.

Let us take as an example a 1" galvanised iron pipe, whose length is 2 kilometres and which drops by 100 meters from one end to the other. We can now work out the flow through the pipe. The calculation goes as follows:

Step 1 Hold the outer disk still and turn the inner disk until 2 km on the length scale touches 26 mm on the bore scale. (A 1" GI pipe has a bore of about 26 mm)

Step 2 Keeping the two disks clamped together in your fingers, move the swinging arm until the "steel" arrow is touching 100 m on the Headloss scale.

Step 3 Read the flow opposite the big arrow on the Flow scale. You should get about litres/min.

If the flow is more than you wanted, try again with a smaller pipe. If the flow is too small, try a bigger pipe. Of course the flow through the pipe cannot be higher than the flow available at the entry to the pipe. So making the pipe bigger will only increase the flow if it is the pipe, and not the source, that is limiting it.

5 NOTE FOR ENGINEERS

The *Ram Pump System Design Calculator* is based on the simple formula:

delivery flow = efficiency x feed flow x feed head / delivery head ($q = Eff \times Q \times H/h$).

Most well-designed ram pump systems have an efficiency of between 0.5 and 0.7. Some pump manufacturers issue design tables based on the assumption that system efficiency is always 0.6. However you may meet systems that use undersize pipes or ram pumps operated at the very top of their drive-flow range or their delivery head range, where system efficiency is as low as 0.3.

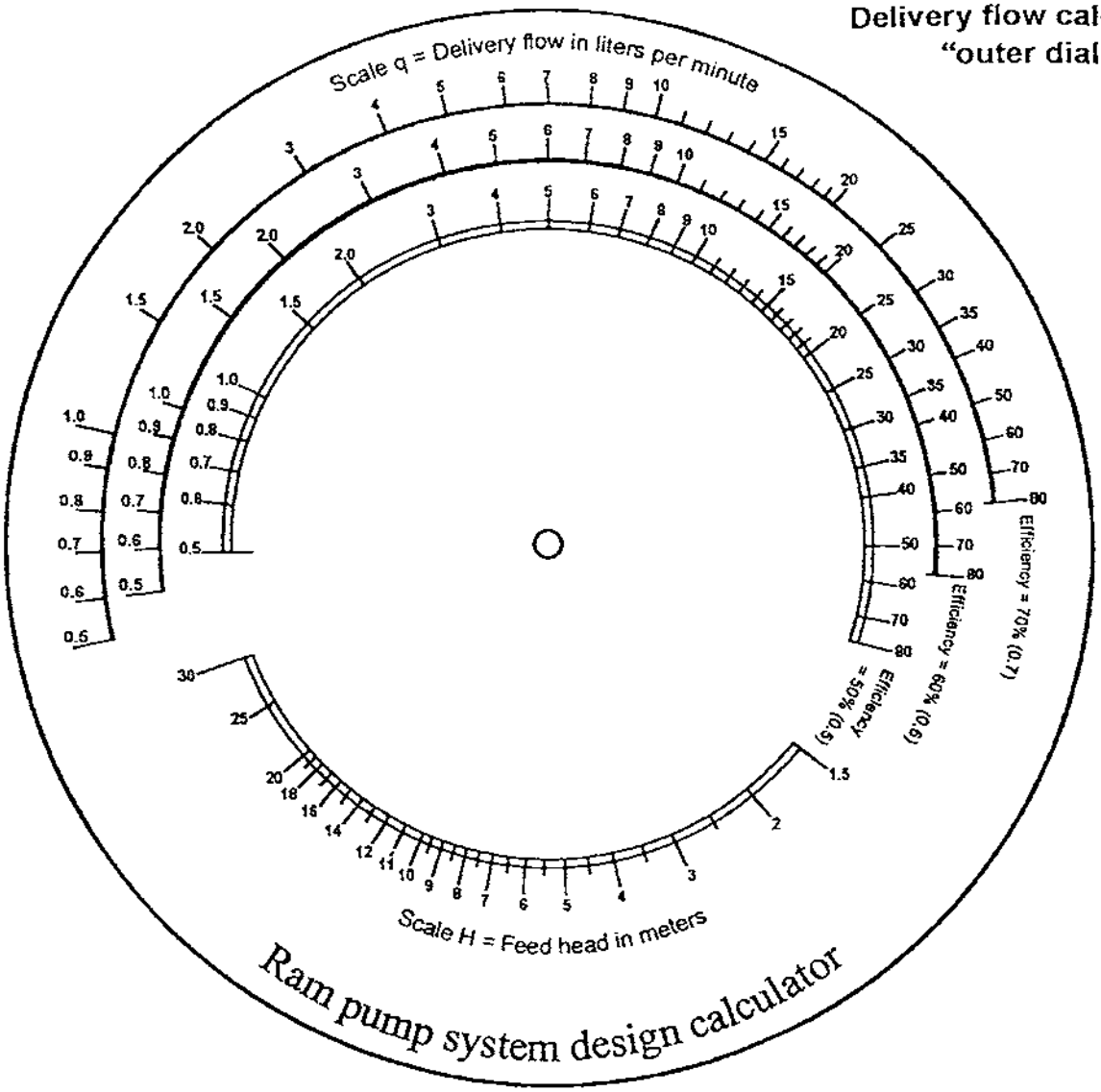
The *Friction Headloss Calculator* is based on an approximate formula because a more exact formula would be too complex to convert into a slide rule (which is what these cardboard calculators are). The flow in pipes in practical water systems is always highly turbulent. In the range of flows of interest to system designers it is safe to use the approximate turbulent flow formula:

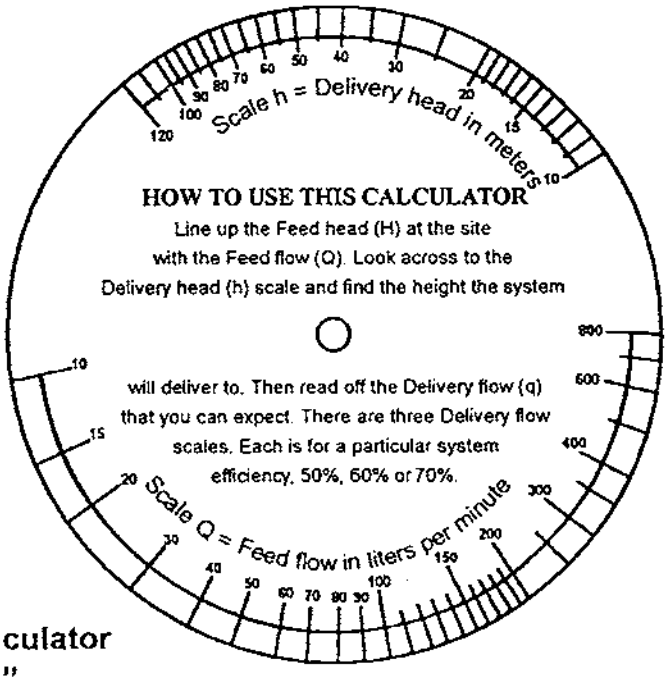
friction headloss = K x pipelength x flow $^{1.85}$ / internal diameter $^{4.9}$

If headloss and pipelength are measured in meters, diameter in mm and flow in litres per minute, then K = 650 for smooth plastic pipes and K = 800 for steel or GI pipes.

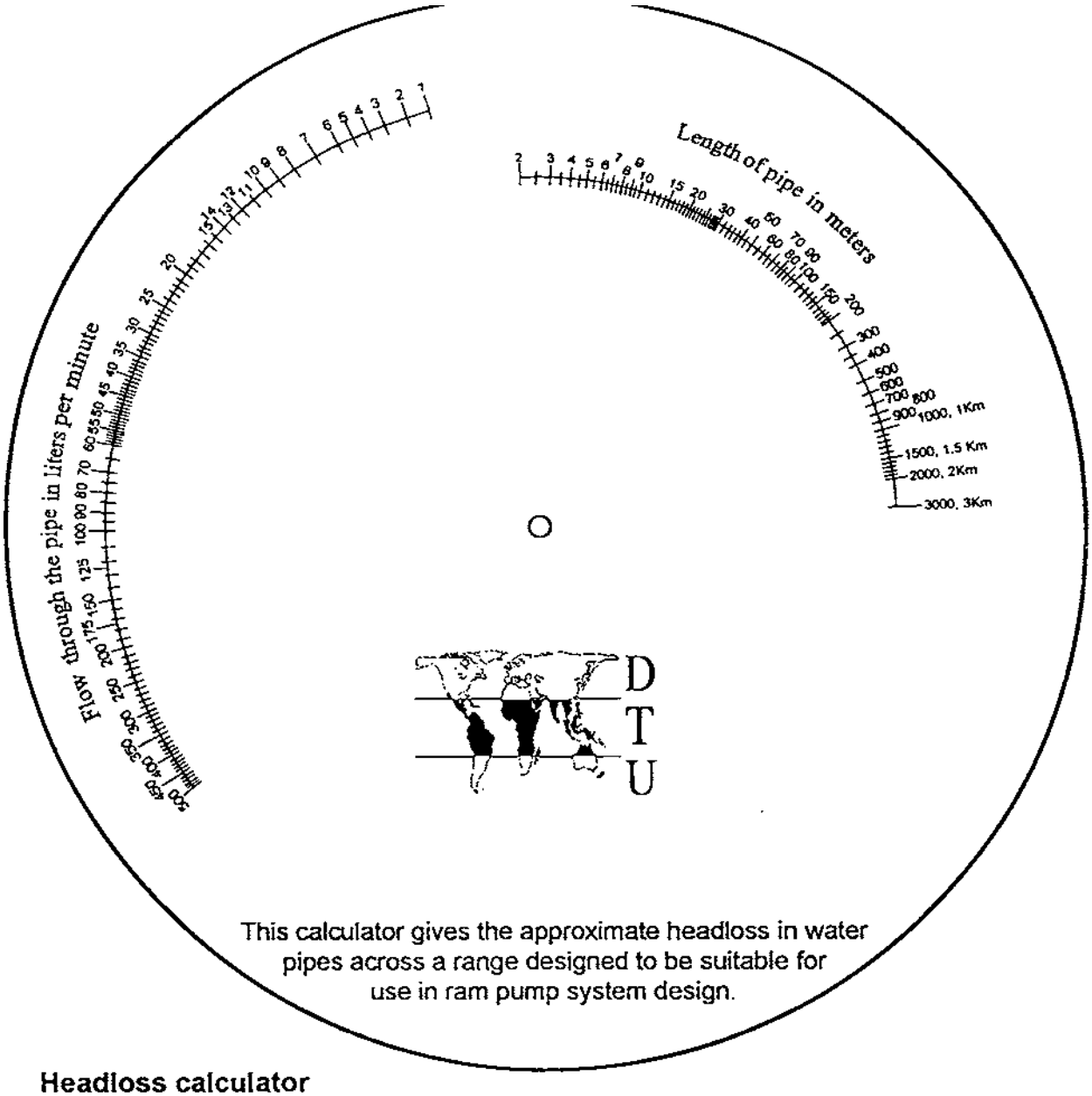
Headloss formulas are not very precise. The headloss may differ by +/-25% of the value predicted by the *Friction Headloss Calculator*. If you are using the calculator to predict flow in a pipe, you can expect to get within +/-10% of the actual value.

Delivery flow calculator
"outer dial"



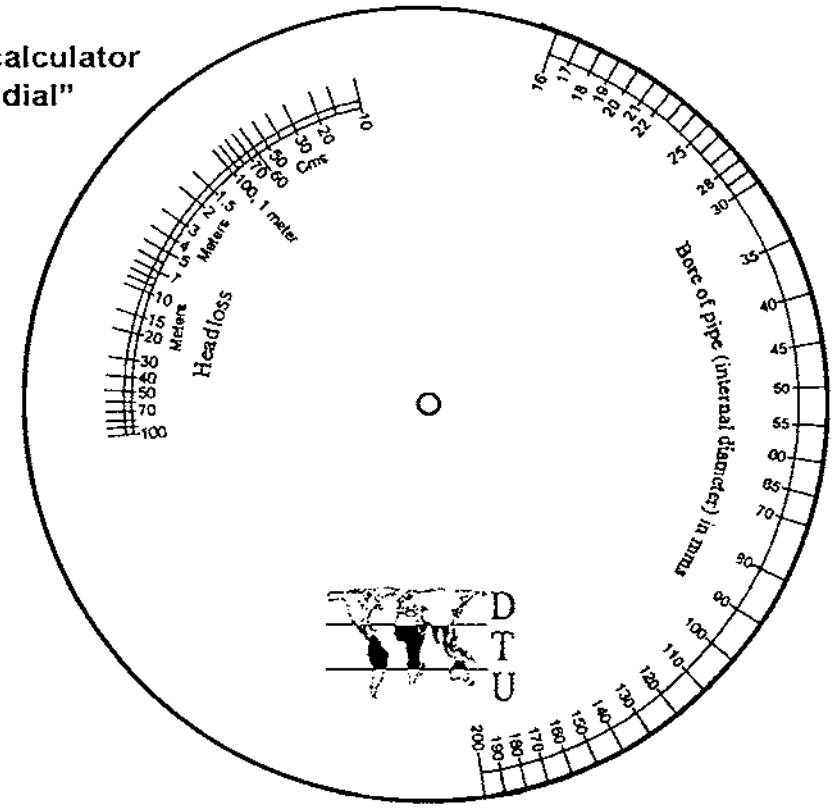


Delivery flow calculator
"inner dial"



Headloss calculator
"outer dial"

Headloss calculator "inner dial"



Headloss calculator "swinging arm"