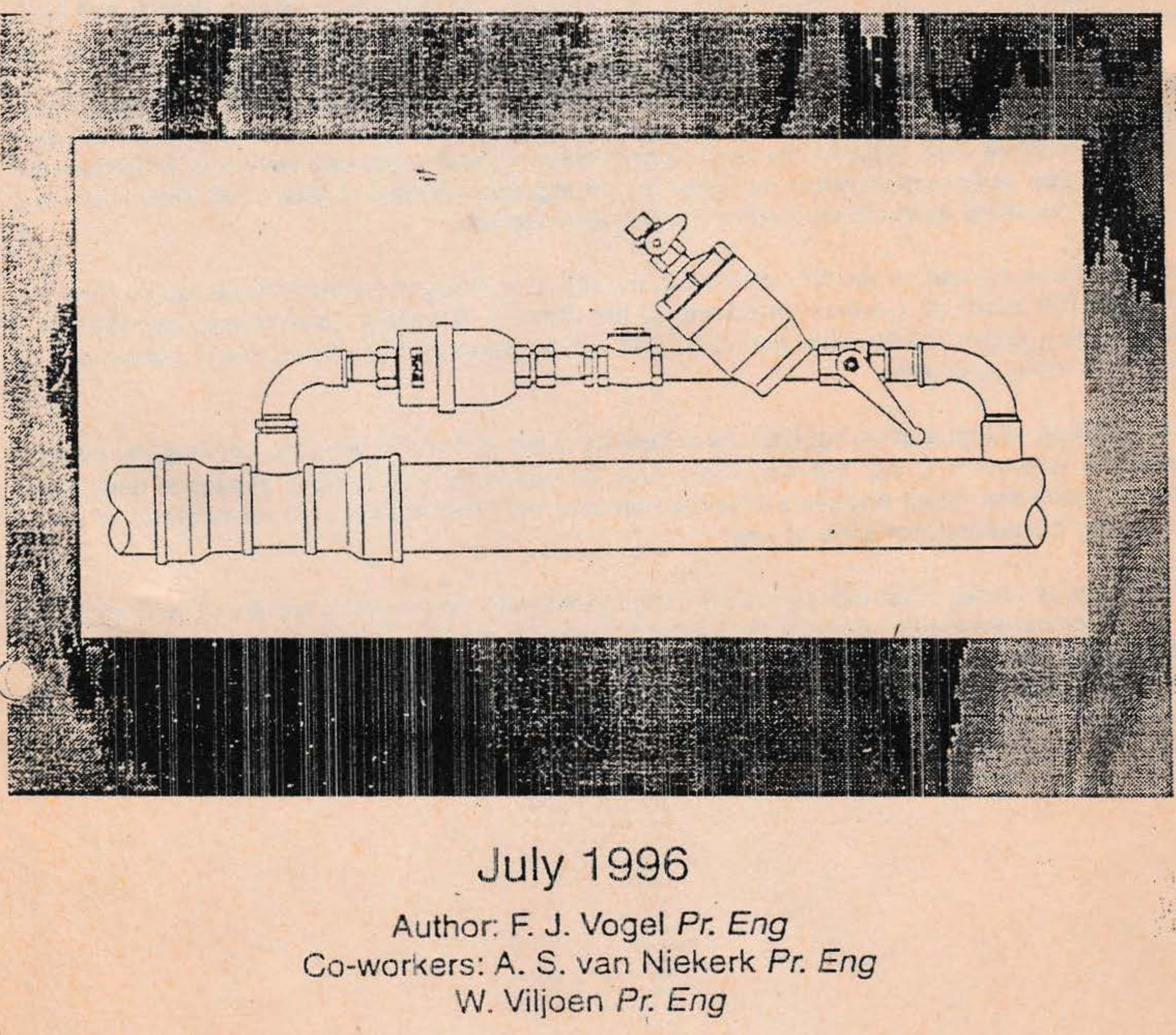
E Water: waterwerk

IRRIGATION WATER-METER

least prone to blokages

An inexpensive, robust water meter

Do-it-yourself manual



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Irrigation Water-meter.

Synopsis:

An inexpensive, easily erectile and robust irrigation water-meter was designed to measure raw irrigation water containing high concentrations of organic and abrasive matter such as leaves, twigs, algae, sand, silt and mud. The 80 mm water-meter described here, is capable of measuring flow from as low as 5 m^3 /h to as high as 130 m^3 /h.

The meter has only a slight restriction in the flow path which forms a venturi, making it virtually clog proof. The absence of any moving parts in the main flow stream (which can be worn out by abrasive matter like sand, mud or silt) results in a very durable meter.

The meter has a bypass circuit in which a small, inexpensive household flow meter is installed to measure the water flow in the main passage. To protect this small flow-meter against abrasive and organic matter, a small filter, (using a screen element), is installed before it. The only maintenance required is the regular flushing of this small filter and the thorough cleaning of the filter element at regular intervals.

The maintenance can easily be carried out by either opening an integral flush tap on the filter, or in the event of a thorough cleaning, the closing of a valve to dismantle the filter in order to gain access to the filter element. This can be done without disrupting the water supply in the main passage.

Construction of this meter requires the minimum tools and skills; welding, drilling and some plumbing experience. All the materials and components are readily available over the counter; only the small household flow meter and the filter is specified for reasons of performance, durability and ease of use.

This meter is highly cost effective when compared with commercial meters. It is designed to be far more durable in dirty water which represents a very hostile environment in which it has to operate (abrasive matter which causes rapid wear and organic matter which causes clogging). It is virtually clog proof and requires minimal maintenance which is facilitated by the built-in qualities which make maintenance possible without disrupting the water supply.

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1 Introduction

The measuring of raw irrigation water (i.e. unfiltered and thus containing anything from mud and silt to twigs and leaves), is a common problem. There is virtually no irrigation scheme worldwide where problems do not occur with the fair distribution of water according to the allocated quotas. However, this problem can be solved easily if the supply to each user in the scheme can be measured accurately.

The problem is generally worsened by the fact that mechanical flow meters become inoperative due to objects blocking the mechanical movement of impellers and other devices, or it becomes worn through the abrasive action of the mud and silt, affecting or severely impairing its accuracy over a period of time. The subsequent maintenance requirements are frequent cleaning as well as periodic rebuilding and calibration at high cost.

Contrary to this, electronic flow meters (with no mechanical, moving parts) require electricity supply of some kind. Due to the remote location of irrigation schemes and the wide spacing of such flow meters, this is usually not available. Furthermore, the use of solar power for electronic flow meters is extremely costly and the solar panels are vulnerable to vandalism, theft and hail damage.

This flow meter works through the application of basic hydraulic principles with one or two additional components to facilitate maintenance.

2 Method of construction

This meter can easily be constructed in any workshop with welding and drilling facilities. All the material and components are standard items used for water distribution and are therefore easily obtainable. The water-meter is inexpensive, robust and it compares favourably with meters that are commercially available.

2.1 Working principle

This raw irrigation water-meter operates on the principle that, when water flows through a restriction in the pipe, a pressure reduction occurs at that point (the venturi effect). If a bypass is connected between the point of restriction and the supply, some of the water will flow through the bypass. The amount of flow in the bypass is proportional to the amount of flow in the main pipe. By measuring the flow in the bypass, the flow in the main supply can be deduced.

The advantage of measuring the flow in the bypass, is that the flow in the main stream is left unrestricted, therefore allowing an easy passage for foreign objects. Another advantage is the size of the flow meter (or any other component used) in the bypass: it needs to be small in comparison to full bore flow meters installed in the main stream, since the flow in the bypass is only a fraction of the flow in the main stream.

2.2 The practical application of the principle

In the application of this principle, a small, inexpensive household flow meter is installed in the bypass passage. This creates an easier passage for foreign matter in the main stream by allowing it to follow the path of least resistance, and thus protecting the smaller flow meter against most of the foreign matter. A small amount of impurities will, however, flow into the bypass in which the small filter is placed to catch this matter before it can damage the flow meter.

It is important that the filter is flushed and cleaned from time to time to prevent it from becoming blocked which will make the meter inoperative. To ease the regular cleaning and flushing of the filter, a filter with a flush tap has been chosen.

For a thorough cleaning of the filter, it is necessary to dismantle the filter and remove the filter element. A ball type valve is installed in front of the filter and a non-return valve behind the filter which will prevent water from flowing from the dismantled filter. While this maintenance is carried out, water in the main passage is uninterrupted.

2.3 Materials and components required

The following materials and components are required to construct the water-meter:

Quantity	Materials and components
1	80 mm galvanized steel pipe
2	cast iron 80 - 65 mm reducing sockets (female-female)
1	65 mm barrel nipple
1	25 mm AMIAD* plastic filter with a 500 micron nylon screen element
1	25 mm flap type brass non-return valve#
1	20 mm ARAD+ household water-meter

The pipe fittings on this water-meter, are as follows:

Quantity	Fittings
2	25 mm sockets (welded to the 80 mm and 65 mm pipes)
1	25 mm long bend (female-male)
1	20 mm long bend (female-male)
1	25 mm barrel nipple
2	25 - 20 mm galvanized reducing bushes

* Please refer to paragraph 4.1.2 for details
+ Please refer to paragraph 4.1.1 for details
# Please refer to the end paragraph of 3.1 for installation details.

2.4 Construction of the water-meter

Following the pictures and step by step instructions below carefully, one will be able to construct the water-meter with ease.

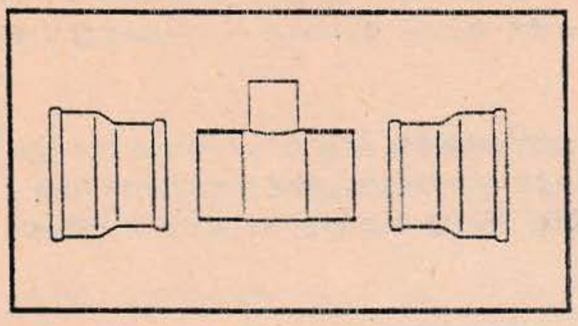

Fig. 1: Construction of the venturi

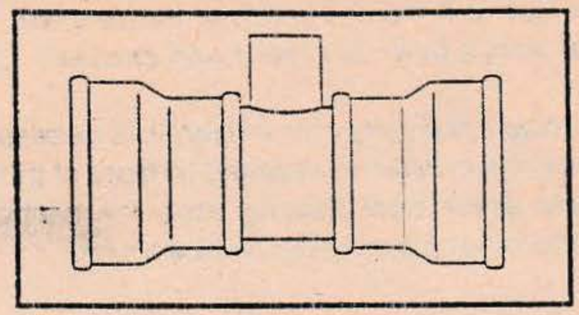

Fig. 2: Completed venturi

Fig. 1 and Fig. 2:

1. Weld a 25 mm socket onto the 65 mm barrel nipple.
2. Fit two 80 - 65 mm reducing sockets to both ends of the 65 mm barrel nipple, using Teflon (P.T.F.E.) tape to seal the joints.
3. Drill the barrel nipple through the 25 mm socket with a 30 mm drill.
4. File away the resulting burr from drilling the barrel nipple.

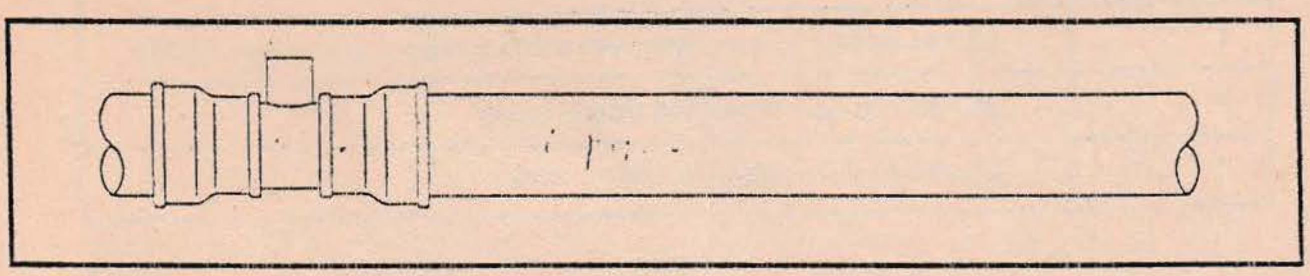

Fig. 3: Venturi with 80 mm steel pipe connected

Fig. 3:

Fit the 1 m length of steel pipe to one end of the reducing socket. ***(Remember to seal all joints thoroughly with Teflon tape as it will be practically impossible to disassemble the unit in order to redo it if any of the joints should leak.)***

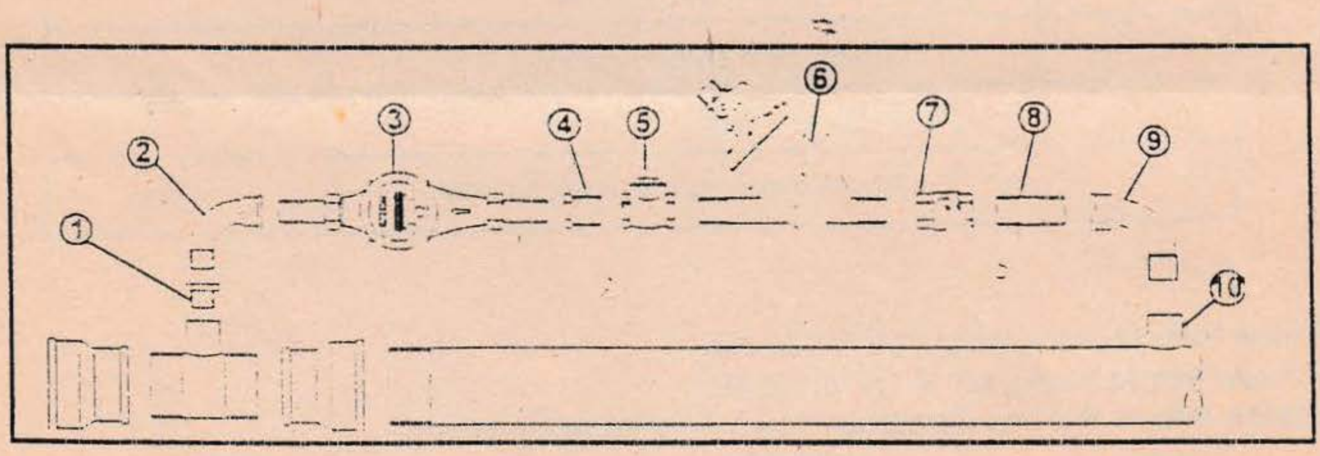

Fig. 4: Exploded diagram of the meter: assembling the bypass circuit and weld the 25 mm to the 80 mm pipe

Fig. 4:

The bypass components are assembled in the following order (from left to right):

1. Start from the 25 mm socket welded onto the barrel nipple. **(Please note that the arrows indicating the direction of flow on the components should all point towards the venturi or restriction).** Install the components in the following order:

1 25 - 20 mm reducing socket on the 25 mm socket (welded to the nipple),
2 20 mm bend,
3 20 mm household flow meter
4 20 - 25 mm reducing socket
5 25 mm non-return valve
6 25 mm AMIAD filter
7 25 mm valve (ball type)
8 25 mm barrel nipple,
9 25 mm long bend
10 25 mm socket.

2. The whole assembly should be positioned in such a way that the 25 mm socket touches the 80 mm steel pipe (it might be necessary to shorten the 25 mm socket to reach this objective). Weld the socket to the steel pipe.

Very important

Give special attention to the position of the non-return valve to ensure that it operates correctly in this application: the valve should be installed in such a way that it is in a position where the flap will normally open fully on its own accord under gravity. See paragraph 3.1 for the recommendations about the position in which the meter should be installed to operate correctly.

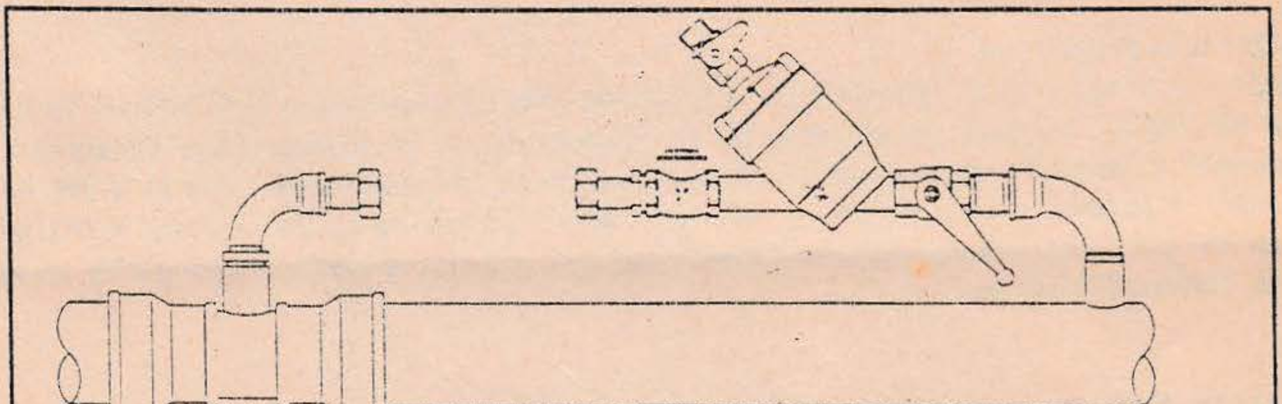

Fig. 5: The household flow meter is removed from the bypass circuit

Fig. 5:

Remove the household flow meter from the bypass circuit. (Its connections are designed to facilitate such removal with ease) by undoing the nuts and sliding the household flow meter out. Take care to retain the sealing rings.

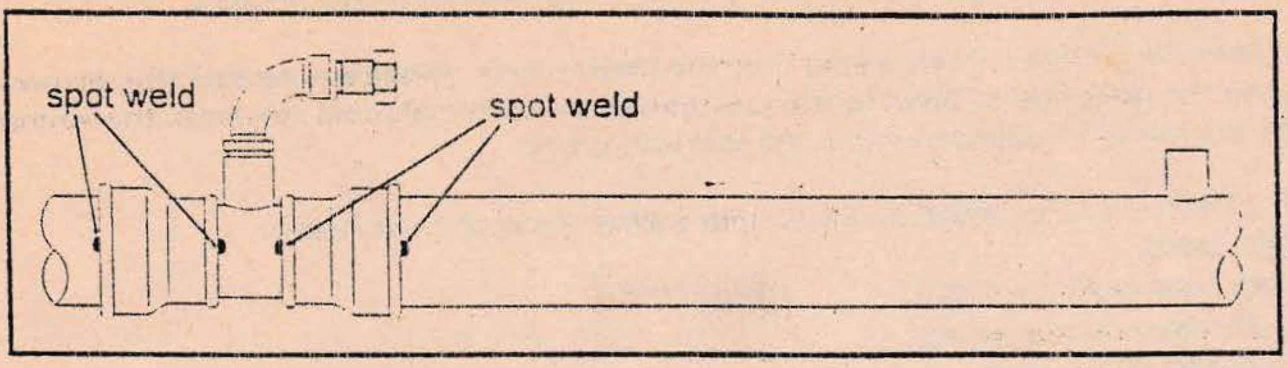

Fig. 6: All the bypass circuit components removed as a unit to drill the pipe through the 25 mm socket.

Fig. 6:

1. Remove the rest of the bypass circuit components by undoing it, as a unit, from the freshly welded 25 mm socket
2. The 1 m length of the 80 mm pipe is drilled through the 25 mm socket with a 30 mm drill in the same way as the barrel nipple (remember to deburr this hole too).
3. The bypass circuit can now be reassembled again in the reverse order in which it was dismantled after the second socket was welded to the 1 meter of 80 mm galvanised steel pipe. The flow meter is now completed and can be tested to see if it works properly.
4. Once it is working satisfactorily, the two reducers and barrel nipple should be spot welded to prevent the components from turning during the installation which will result in damage to the bypass circuit components.

3 Calibration procedure

The flow meter should be calibrated as is the case with all commercial flow meters. In the case where the meters are used for instance by an irrigation board to register water consumption with the purpose of accounting, it would be necessary to have this procedure done by a certified testing facility. If used for private purposes only, the calibration factors as they appear in the technical section (for the ARAD household flow meters) can be used, but remember, this is only an **approximated calibration factor.**

To calibrate the flow meter, the procedure involves the use of another calibrated flow meter, or a flow meter of known accuracy, and some mathematics. The accurate flow meter is installed in series with this home made flow meter. The accurate flow meter should also preferably register **volume** and not flow rate. The volume of water which passes through the two flow meters at different flow rates (be sure to use a flow rate of more than 5 m^3/h for the test) over the same period of time, will differ: the known flow meter's reading will be different to that of the home made flow meter's reading as registered on the household flow meter. By dividing the larger of the two readings by the smaller reading, the result will be a figure called the **calibration factor** which will vary between 55 to 60.

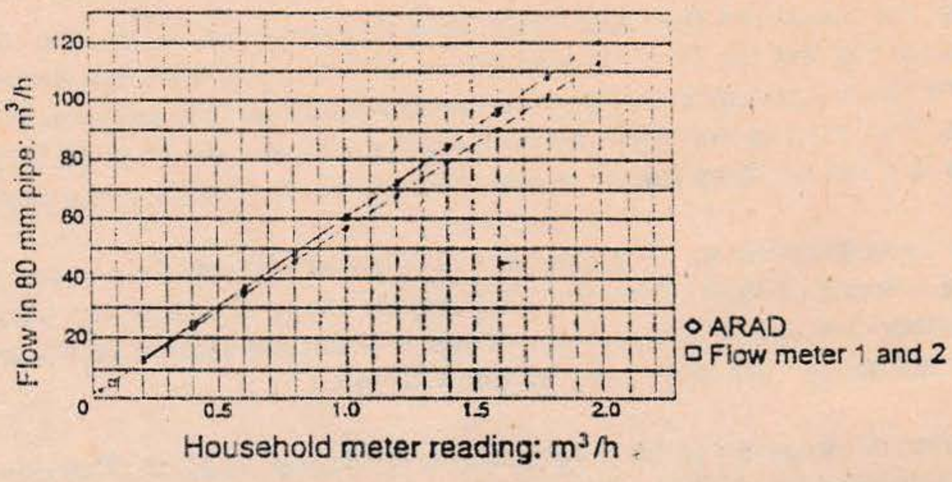

Fig. 7: Ratio between the flow meter reading and the flow through the meter

All readings on the homemade meter must be **multiplied** by this factor to determine the real volume registered by the flow meter. The calibration factor could also be determined from the slope of a graph similar to the one in fig. 7.

The calibration factor should be the same for all flow rates **for one flow meter** (the calibration facto of different flow meters will differ slightly from each other. This is why every flow meter, homemade or commercially bought, should be calibrated.

3.1 Considerations for installation

There are two considerations to be taken into account before any decision can be made about the position of the flow meter in any irrigation system. The first consideration to take into account is the maximum flow rate which the meter must be able to measure. This usually influences the size of the flow meter and the friction losses caused by that flow meter.

This particular flow meter is capable of measuring flow-rates from roughly 8 m³/h to flow rates as high as 120 to 130 m³/h. These are very high flow-rates for an 80 mm diameter pipe as this will cause high friction losses and it is therefore safe to say that the meter will measure almost any flow-rate that will occur in an 80 mm pipe.Any flow meter causes a certain amount of pressure loss due to the friction encountered by the water flowing through the meter. It is therefore necessary to make sure that there is enough pressure to overcome this pressure-loss **at the maximum flow rate** at which the meter is to be used (refer to Fig. 8 below).

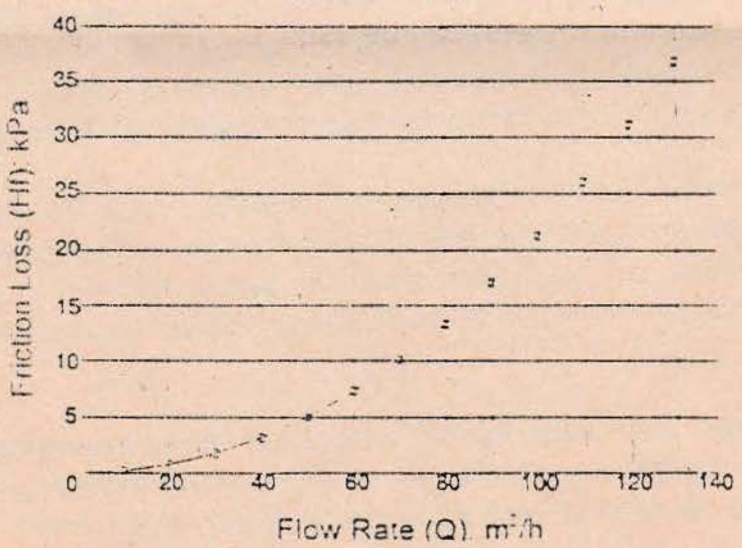

Fig. 8: Friction losses of the assembled meter

For example: the maximum flow rate which is to be measured, is 70 m^3/h. Starting at the horizontal scale, locate the line for 70 m^3/h and follow the line up to the point where it intersects with the graph. Follow the horizontal line at this intersection and read the value on the vertical scale, in this case 10 kPa. This means that the meter will cause a pressure loss of 10 kPa in your system when the flow rate is 70 m^3/h. One has to make provision for this loss in your system.

The second consideration to take into account is that, like all flow meters, this meter must be installed in a straight section of the line, 1,6 meters away from a pump, valve, bend, or any other obstruction which will cause turbulence in the line whilst the section of line downstream must be at least 0,4 meters away from any bend, junction or valve.

This flow meter is designed to be installed in a horizontal position. The orientation of the bypass circuit can be rotated round the main circuit into any position **as long as it is remembered that the non-return valve must be installed in such a way that the valve will be fully open under its own weight.**

3.2 Maintenance management

All the maintenance can be done through a simple procedure. It is suggested that the meter and its surrounding components should be protected against unauthorised tampering and vandalis y a locked enclosure.

Where the meters are used in an irrigation scheme, the scheme will usually employ a water bailiff. This person will have access to the meter enclosures keys and can therefore be employed to perform the simple maintenance chores. A practical work procedure would be to unlock the enclosure, open the tap on the filter to flush it, and then read and record the reading on the flow meter while the filter is being flushed. This will allow enough time for the filter to be well flushed before the tap is closed. The enclosure can now be locked again. It is suggested that this procedure should be followed on a weekly basis.

Once a month the bailiff should close the bypass valve, dismantle the filter and clean the screen element thoroughly instead of just flushing the filter. Once the filter is reassembled, the valve must be opened to check if the flow meter is registering flow (if there is any) and then the reading must be recorder before closing and locking the enclosure again.

One must not forget that the reading on the household flow meter is registering only a portion of the total flow through the meter. The reading on the household flow meter therefore has to be multiplied by a factor called the **calibration factor** to determine the actual volume of water consumed (please refer to paragraph 3 for the procedure to determine the calibration factor).

Remember that this flow meter registers the **volume of water** used. Do not forget to multiply the reading on the small household meter with the calibration factor **of that specific flow meter.** Also remember that a clogged filter will cause the small household flow meter to register less than it should. It is therefore imperative that the filter be flushed or cleaned regularly if the meter is to register correctly.

Before making any changes with regards to the choice of filter, household flow meter or venturi size, study the following sections carefully to understand the effect such changes could have on the performance, durability and calibration factor of the meter.

4 Technical design parameters and criteria

4.1 Bypass circuit element performance

The most critical performance of the meter is the minimum flow at which the meter will start registering. This parameter is determined by two opposing factors, namely the pressure difference over the venturi (formed by the reducers and the barrel nipple) and the friction losses due to the elements in the bypass circuit. The meter will start to register when the pressure difference accredited to the venturi surpasses the friction losses. The friction loss contribution of each element in the bypass circuit was also examined.

4.1.1 Choice of the household flow meter

There were three household flow meters available at the time of testing. The ARAD flow meter is imported from Israel whilst the other two are locally manufactured.

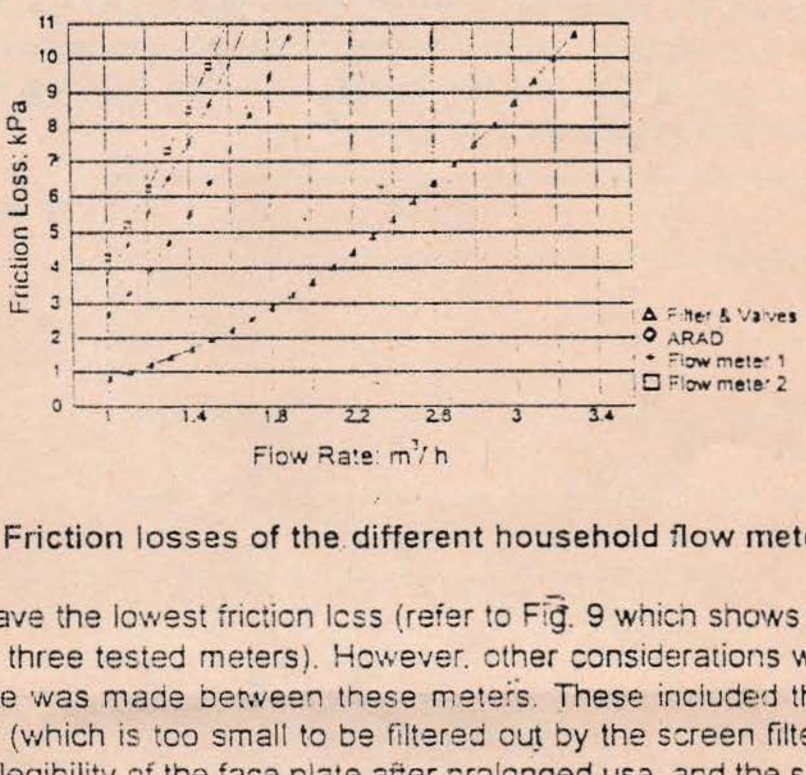

Fig. 9: Friction losses of the different household flow meters

The ARAD proved to have the lowest friction loss (refer to Fig. 9 which shows the relative amount of friction losses of the three tested meters). However, other considerations were also taken into account before a choice was made between these meters. These included the meter's ability to handle abrasive matter (which is too small to be filtered out by the screen filter in the bypass circuit), the durability and legibility of the face plate after prolonged use, and the size of the glass covering the face plate (the larger the glass the more susceptible it is to breakage and vandalism).

The first household flow meter has gears which run in the water for registering the volume and it is susceptible to wear but had a very small and robust glass covering for the registering mechanism. The second meter suffered from the same drawback as the first with regards to the gears being in direct contact with the water, as well as the added deficiency that the face plate would become illegible with time (as a result of deposits on the face plate originating from the turbid water precipitating when the water is not flowing).

The ARAD meter uses a mechanism which has no close- fitting parts in contact with the water. The registering mechanism is separated from the water by a sealed compartment with a magnet which transfers the movement to the counter mechanism.

The 80 mm flow meter started registering at 2 m^3/h when using the ARAD household flow meter. The first household flow meter, when used in the 80 mm flow meter, resulted in the 80 mm flow meter starting to register at 5 m^3/h and likewise, for the second household flow meter which resulted in the 80 mm flow meter starting to register at 3 m^3/h. The ARAD flow meter therefore also gives the lowest flow rate at which the 80 mm flow meter will start to register flow.

Although the face plate of the ARAD is large (undesirable), its durability and performance advantages make it the best choice for this application.

4.1.2 Choice of the filter

Other elements which contribute to the friction losses, are the filter and filter element. The AMIAD filter was chosen because it had an integral flush tap. It also has the lowest friction loss of filters in that size since it uses a screen element instead of a ring element. An added advantage of the screen filter is its tendency to a slow rise in pressure loss when it starts to clog in comparison to ring filters.

Tests were conducted with both a 20 mm and 25 mm AMIAD filter using an 80 - 65 mm venturi, and the calibration curve for the flow ratio between the bypass and the main circuit was measured. The reason for choosing the 25 mm filter over the 20 mm filter is the fact that the 25 mm filter has almost three times the filtering capacity of the 20 mm filter, resulting in longer periods between tl mandatory cleaning of the filter. The friction loss of the filter can be seen in Fig. 8, where it is compared to the friction loss of the three flow meters. It is clear from Fig. 8 that the filter has a much smaller friction loss than the chosen flow meter.

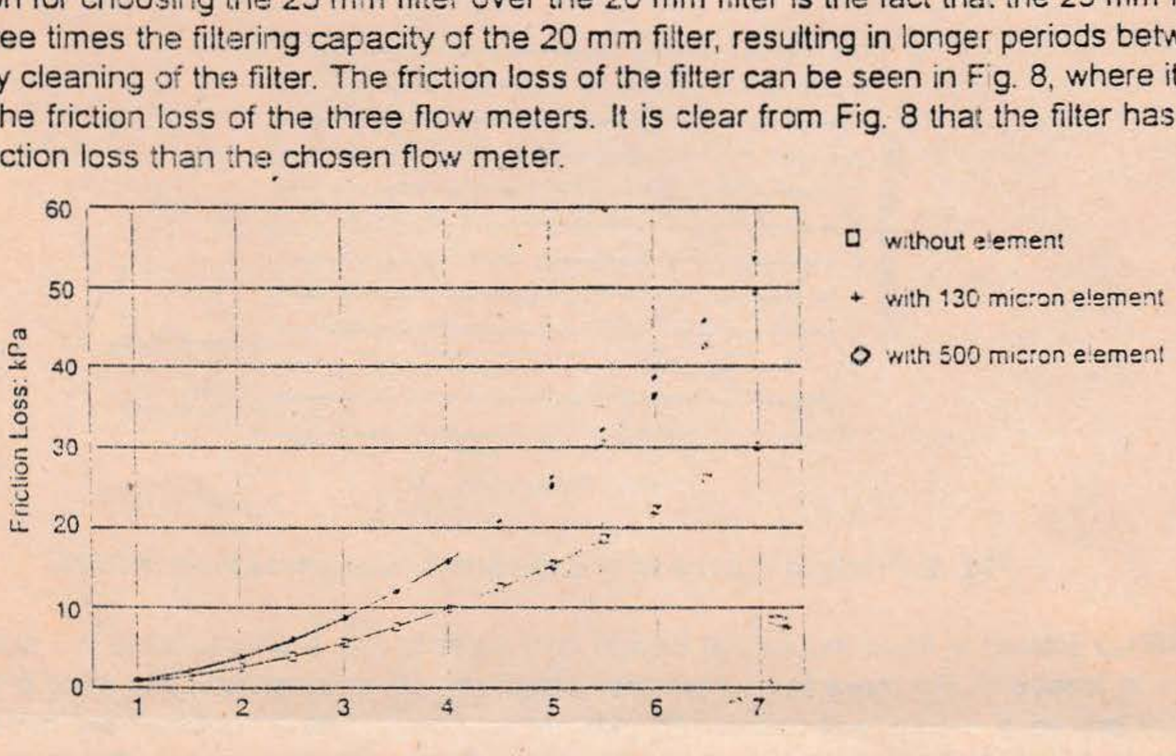

Fig. 10: Friction losses of the filter with different filter elements

Fig. 10 shows the effect of varying the filter element fineness, and clearly indicates that the fineness of the filter has a very small influence on the friction loss due to the fineness of the filter element. **(Adding the element naturally increases the friction loss considerably but it must be stressed that the flow meter should *never* be used without a filter element).** The finer the element the more protection it provides to the small household flow meter at the expense of becoming blocked much quicker, requiring shorter intervals between flushing or cleaning of the element. Since the maximum flow rate through the filter will not exceed 2 m^3/h, which corresponds to a flow rate of 120 m^3/h (a very high rate for an 80 mm diameter pipe), it can be seen in Fig. 9 that the filter with its element will contribute very little to the friction loss in the bypass circuit (in comparison with the household flow meter).

4.2 Choosing a venturi size

The choice of venturi size is mainly influenced by the flow rate at which the meter will start registering flow and the calibration factor. The friction loss, which is accredited to the venturi, determines the meter's overall friction loss. With the standard reducers, two venturi sizes can be created: 80 - 65 mm and 80 - 50 mm. With a venturi of 80 - 65mm, the flow ratio between the main circuit and the bypass came to 80:1, but with the 80 - 50 mm venturi it came to 40:1 (using a 20 mm filter). When the filter was replaced by a 25 mm filter, the ratio in the first instance increased to 60:1, the ratio for the 80 - 50 mm venturi was not tested as it was felt that the ratio of 40:1 was too low, resulting in the filter clogging too quickly, requiring too frequent maintenance of the filter.

5 Conclusions

The choice of the components in the bypass circuit is a determining factor in the performance and durability of the flow meter. The lower the friction losses of the components in the bypass circuit, the lower the flow rate at which the meter will start registering flow. The venturi size on the other hand will also determine the lowest flow rate at which the meter will start registering flow and the calibration factor: a smaller venturi will increase the flow meter's overall friction loss, increasing pumping costs which could lead to the possibility of requiring larger pumps to compensate for these friction losses. It also changes the calibration factor as well as the frequency of the filter maintenance.

The final 80 mm flow meter was designed with a 80 - 65 mm venturi (barrel nipples back to back), using a 25 mm AMIAD filter with a 150 micron filter and a 20 mm ARAD flow meter. The AMIAD filter was chosen for its screen filter element which has a slower rise in friction loss as it starts getting blocked and the integral flushing tap which simplifies the construction of the flow meter while at the same time contributing toward the ease of maintenance.

The maintenance required to flush or clean the filter is simplified by the ball type valve, non-return valve and the integral flush tap on the filter. Closing a single ball type valve is all that is needed to disassemble the filter for cleaning, resulting in no disruption of water supply while maintenance is carried out.

The ARAD household flow meter was chosen for this application for the lowest flow rate at which it started registering flow, and its durability due to the magnetic coupling to its registering mechanism. Although its large face plate makes it more vulnerable to damage or vandalism, the first two characteristics far outweigh the disadvantage of the large face plate.

The careful choice of components resulted in the largest venturi to be realized with standard reducers (80 - 65 mm) to give excellent flow rate registering and low overall friction losses for the 80 mm flow meter. This also results in less water diverted to the bypass circuit which in turn results in longer periods between filter maintenance.

6 References

The following references all refer to filters and will give deeper insight into the criteria for the choice of the filter used in this flow meter and the clogging characteristics of various filters in general:

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7 Trade Names

The following registered trade names of products were used during the experimental phase of this design:

AMIAD
ARAD
Kent
Castle Brass