

# The Chain and Washer Pump

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## Background

The chain and washer pump, sometimes called the pater-noster pump because of its resemblance to a string of rosary beads, is a pumping device that has been known and used for many centuries both in China and Europe. It works by the action of the chain and washers which are pulled in a continuous loop up inside a closely fitting pipe over a geared chain wheel, and down again to the bottom of the pipe. Water is carried up between each washer from the mouth of the submerged pipe, and discharged at the top of the pipe into a trough:-

The maximum practical lift for this sort of pump is about 15 to 20 metres and several chain and washer assemblies can be fitted on the same axle. The chain and washer pump is large and bulky, and can be described as a high mass/low power ratio pump. This means that each component of the device is not under great load or highly stressed, allowing relatively soft materials such as wooden or rope chains, oiled wood bearings etc., to be used.

The pump was widely used in Europe from the 16th Century onwards to drain mine workings, and was used in preference to the piston suction pump because of its low cost, ease of construction, and reliability. The pipe was usually built from iron bound timber planking, and the washers were made from balls of leather covered horse-hair. The balls were fairly flexible and made a good fit inside the pipe even if the diameter of the pipe varied. The leather bound ball washers were often replaced with bundles of rags which were cheaper and although less efficient, served the same purpose in lifting the water up the pipe.

Now the leather or cloth balls are replaced with discs made from wood or iron plates, and the discs are often fitted with a rubber seal to reduce water leakage down past the discs.

Chain pumps have many advantages over other types of pumping devices. They are robust and can be made from local materials to low construction tolerances by local craftsmen; they are slow moving and the corrosion, wear, or failure of one part will not usually prevent the pump from working. The pumps can manage water containing silt and other solids, and they can be easily maintained and serviced. They are slow moving devices, and can therefore be powered by men, animals, wind power, or slow turning internal combustion engines, with the minimum of gearing or high performance bearings. Their reliability is such that they were used up until the second half of the 19th Century as bilge pumps for the ships of the British Royal Navy.

## Principles of Operation

The robust chain and washer pump with its high mass, low power ratio, contrasts with the more modern and widely used smaller centrifugal pumps, which have a low mass/high power ratio. With the chain pump, therefore,

the sturdy slow moving components do not need great skill and tolerance in manufacture, or skilled maintenance. The centrifugal pump, on the other hand, is relatively small, and has to concentrate the pumping effort through the faster moving, smaller components that need to be made from stronger materials, with very accurate workmanship. To make them work at all, expensive gearing has to be used. This gearing, if it is not to waste most of the pumping energy during transmission, must be accurately made and maintained.

Perhaps the greatest advantages of the chain and washer pump for rural areas are the slow speed of rotation and the steady unvarying rate of working that are completely compatible with the speeds at which men, animals, wind machines and slow speed diesel engines can work. The continuous loop of linked chain and washers is pulled up the rising main pipe, carrying water with it between the washers. Unless the washers are a reasonably tight and accurate fit, water will leak back down the pipe, and the pump will not work at all efficiently. However, the 'cascade' of washers will probably limit the leakage to acceptable amounts. An alternative design has an accurately made and close fitting section of pipe at the submerged lower end of the pipe. The rubber sealed washers make a tight fit in this section of pipe (which may be steel or plastic), and fit only loosely in the wider section of pipe above. The washers do the work of lifting in the close fitting section, reducing leakage to a minimum; in the looser and cheaper section of pipe above, they do no lifting work, but they also do not wear themselves out against the sides of the pipe in friction.

This is a most useful innovation. It might be possible to manufacture the washers and the lower pipe section in a work shop, then distribute them to local areas to be built into the locally made body of the pump. Other innovations include a bell mouth entry at the bottom of the pipe to guide the washers into the pipe, and a non-return ratchet on the chain wheel to prevent the chain from running backwards under the weight of water in the pipe.

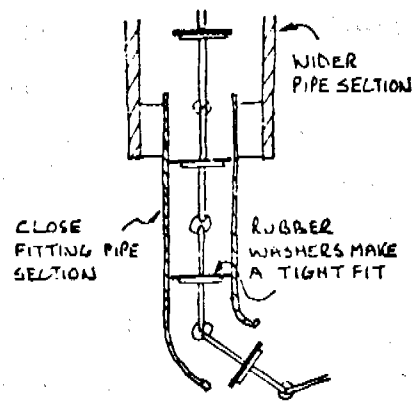
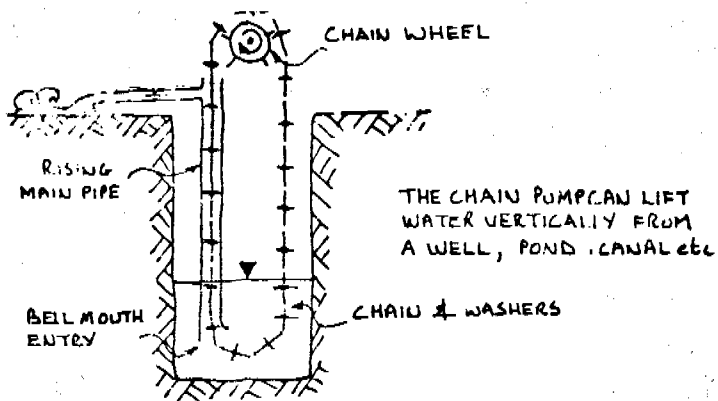
## COMPONENTS OF THE PIPE

### The Rising Main Pipe

This pipe holds the water between the chain washers as it is being lifted up to the surface. It must be smooth inside to prevent leakage past the washers, and to reduce wear on the washers as they rub against it. It must be robust, water-tight, cheap and easily made or replaced.

The pipe is hung down into the water from the surface. It has only to support its own weight and to stay steady as the chain passes through. It does *not* have to carry the weight of water inside the pipe.

Many different materials can be used to make the pipe, — timber, bamboo, iron, waterpipe, plastic, asbestos, etc., and the shape can either be square or circular. However, the difficulties of making sure that square washers enter the square pipe at the correct angle make the square section a poor choice; it is normally used where the only material that can readily be used is timber planking. The internal diameter of the pipes does not generally exceed 10cm.



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We have already mentioned the innovation of using a close fitting short section of smooth, accurately made pipe at the lower submerged end of the rising main, which prevents leakage past the washers. This may be made of plastic, smooth iron, or a carved hardwood resistant to decay. It may be fitted at the end of a cheaper, loose fitting pipe, which may then be of any shape and made from any material so long as it is water tight. At least two washers must be passing through the lower section at any one time.

Some rising main pipes that are commercially manufactured have iron pipes flanged at the top and bottom so that the pipe may be lengthened deeper into the water. Iron piping is, of course, very much heavier than the equivalent plastic or timber pipe, and will need supporting on solid ground under the water.

Bell mouth entry sections are usually fitted to the bottom end of the rising main pipe to guide the chain and washers into the pipe. These are made of timber, or more often, galvanised iron sheeting.

### The Chain and Washers

The original leather and horsehair or rag balls that were used as washers in the early chain pumps moulded themselves to the varying shape of the rising main pipe, reducing leakage to a minimum, but had high friction losses as they were pulled up the pipe. They would wear away quickly and probably rot in the water after a few months.

The washers that are mostly used today are wood or steel discs cut accurately to fit exactly into the rising main pipe. They must have a short section of solid chain passing through them to hold them in the correct position both as they enter the pipe and pass up the pipe. The washers must be supported both below and above on the chain link to carry the weight of water and take the full load on the chain as it is turned on the cogged teeth of the chain wheel.

The careful and accurate construction of the washers will reduce water losses and wear, but will increase costs and a balance must be made between the increased costs of this component with the increased efficiency. As the chain and washers and rising main pipes are the most important part of the pump, it is perhaps worth the extra expense to fit the washers with rubber seals.

The chain is made from pegs, shaped wooden rods, rope or 5mm diameter steel chain links.

The links must support both the weight of the loop that hangs from the chain wheel, and the weight of water in the rising main pipe. In a typical pipe of 10cm internal diameter, the weight of water supported over a 20 metre lift would be about 150 kgm; with a smaller pipe of 7cm internal diameter, and a 10 metre lift, the weight of water supported would be 50 kgm. Deep wells and large pipes, therefore, need strong metal chains; wooden or rope chains should only be used for the shorter lifts.

Nylon and rubber balls are a useful possibility for the chain and washers, but the chain would need to be made carefully to fit exactly on the cogged teeth of the chain wheel. There would also be difficulties if the nylon rope stretched under load, as the discs or balls would not then coincide with the chain wheel.

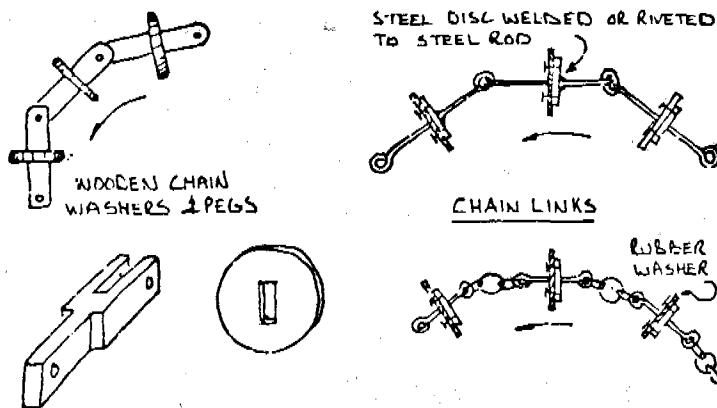
### The Structure

The framework that supports the chain and washers, rising main pipe, and chain wheel, must also be braced against the power source applied to it. This may be a hand crank, or a geared driving arm powered by oxen or horses. The solid timber framework of most of the examples demonstrates the size of structure needed.

Some chain pumps are built using the back axle and differential assembly of a motor vehicle as a transmission gear to take the power from an animal-drawn driving arm onto the pump axle. Special cast iron gears are used on the 'Liberation' type pump, pegged timber gears are widely used in Asia.

### The Bearings

The bearings that support the chain wheel axle will provide most of the frictional resistance of the pump, and much of the power loss will occur here. There is a dilemma in choosing the bearings for devices that are to be used in rural areas; they may be expensive, high performance, sealed bearings that will have to be completely replaced when they are worn out, or oiled wood block bearings which are not designed to keep the dust and sand out, but can be cheaply renewed when they are worn. Wood block bearings, if they are carefully made, prepared, and greased, are very suitable for the slow moving chain and washer pumps; wood bearings could not, of course, be used in high speed pumping devices.



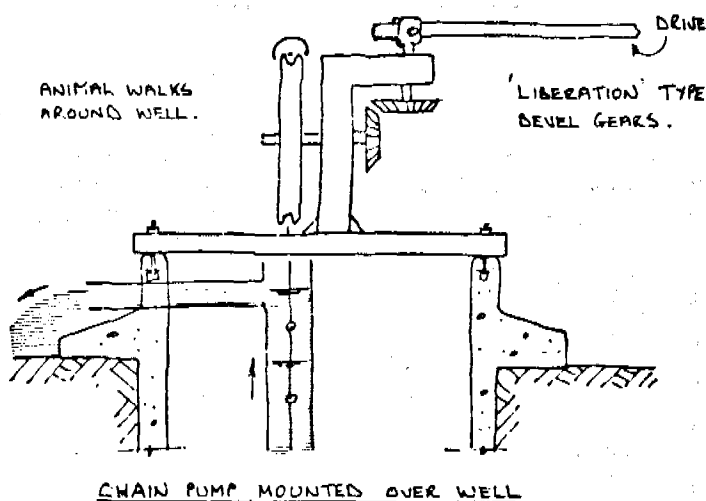
### The Chain Wheel

Various designs of the chain wheel can be made. They range from cut down wooden cartwheels, to especially prepared cast iron wheels. The wheels support the chain at a radius of between 20 to 30cm and must be robustly made to support the weight of the chain and pumped water in the rising main pipe. They are slow turning, and do not have to be dynamically balanced. The size is such that they can be made from cast iron in one small casting; a larger casting requires considerable skills and equipment.

The chain wheel is mounted in the centre of the axle shaft, which must be strong enough to support the complete pumping assembly. The axle may be made from wood, steel rod or pipe, but the ends must be made exactly circular to fit into the wood bearings. If a steel axle is used, the wood block bearing will wear away before the steel, and the axle will continue in good condition almost indefinitely.

Occasionally, as many as five chain wheels are fitted into a single axle, each chain wheel with its own chain and rising main pipe. The loops of chain and washers may then be added as they are needed to provide a crude but effective form of gearing.

*The author has written a book on this subject, Chinese Chain Pumps, to be published by Intermediate Technology Publications in May.*



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