British Gas

WH/T/92/117 August 1992

CONFIDENTIAL

Restricted to
British Gas

SUMMARY REPORT ON THE HYDROPATH WATER CONDITIONING DEVICE

R.L. STEVENS

Materials Engineering Division
Research and Technology

British Gas plc
Research & Technology
Watson House Research Station
Peterborough Road
London SW6 3HN
Telephone 071 736 1212

British

Gas plc
Research and Technology Division
Watson House Research Station
Peterborough Road
London SW6 JHN

Security Classification

CONFIDENTIAL

RESTRICTED TO BRITISH GAS

Report No. WH/T/92/117

SUMMARY REPORT ON THE HYDROPATH WATER CONDITIONER DEVICE
(Project No: W05223A05)

Author: R L Stevens

Date: August 1992

SUMMARY

There has been an increase in the distinct problem related to scale blockage of heat exchangers on some has fired instantaneous water heaters and combination boilers. This is primarily due to more combination boilers being installed.

Customer Services Division (HQ) therefore requested WHRS to evaluate a selection of water conditioning and automatic chemical dosing devices, in order to establish their effectiveness in protecting appliances from scaling and identify the potential benefits to British Gas resulting from reduced service and maintenance.

This report is a summary of the evaluation and performance of the Hydropath HP 18 water conditioning device. In tests on the WHRS test rig this unit has performed significantly better than the majority of other non chemical devices tested. It has been demonstrated that the device has the potential to extend the time for a hot water heat exchanger to block to 263 weeks. This is compared with 99 weeks for the best of the other water conditioning devices and 40 weeks if no conditioning is used.

If adopted in only the most severe cases of scaling problems ie (normally 1%) of boilers, the potential savings in servicing to BG should be not less than £72.5m in the first 5 years.

Research and Technology Division
Watson House Research Station
Peterborough Road
London SW6 3HN

CONFIDENTIAL

RSTRICTED TO BRITISHGAS

Report No.WH/T/92/117

SUMMAY REPORT ON THE HYDROPATH WATER CONDITIONING DEVICE

(Project No: W05223A05)

CONTENTS

			PAGE
1.	INTRODUCTION		1
2.	BACKGROUND TO HARD WATER SCALING OF HEAT EXCHANGERS		2
3.	METHOD OF EVALUATION OF WATER CONDITIONING DEVICES		3
4.	HYDROPATH (HP 18) CONSTRUCTION AND INSTALLATION		5
	4.1	Performance	5
	4.1.1	Summary of Test Results	6
	4.142	Hydropath Units Tested	7
	4.1.2.1	Reproduction Unit	7
	4.1.2.1	Production Unit	8
	4.1.3	Reliability of the Device	9
5.	TECHNOLOGY		10
	5.1	Mode of Operation	11
	5.1.1	Morphology and Crystals	12
	5.1.2	Effect of Temperature	12
	5.1.3	Comparison with other Water Conditioning Devices	13
6.	BENEFITS TO BRITISH GAS		13
7.	CONCLUSIONS		14
8.	RECOMMENDATIONS		15
9.	REFERENCES		

Rosarch and Technology Division
Watson House Research Station
Paterborough Road
London 5W6 3HN

CONFIDENTIAL

RESTRICTED TO BRITISH GAS
Report No. WH/T/92/117

SUMMARY REPORT ON THE HYDROPATH WATER CONDITIONING DEVICE

(Project No: W05223A05)

1. INTRODUCTION

Hard water scaling progressively reduces the efficiency of water heating appliances and ultimately results in over heating and corrosion failure of heat exchangers.

At the request of Customer Services (HQ, Holborn), WHRS has evaluated a selection of water conditioning and automatic chemical dosing devices, in order to establish how effectively they protect appliances from scaling. An evaluation of economic benefits resulting from reduced service and maintenance was also requested. Water conditioning devices do not change the composition or quality of water. It is claimed that they interfere with the nucleation and morphology of calcium carbonate scale, which in turn prevents hard water scaling of heat exchangers.

This report summarises the evaluation and performance of one of the devices, the Hydropath HP18. This electromagnetic device, has some unique operating features which involves continuous operation at high temperature and unlike all other devices tested to date, works at all flow rates of water. Other devices are subject to flow rate and variation in magnetic gap. The HP18 showed significantly superior performance to the other devices tested. Tabulated comparisons of performance with other devices are given and the benefits from the use of the HP18 device are indicated.

CONFIENTIAL
WH/T/92/117

2. BACKGROUND TO HARD WATER SCALING OF OF EXCHANGERS

It is estimated that scaling of heat exchangers costs industry in the UK over £2 billion a year. Water hardness is derived from calcium carbonate, calcium Sulphate, calcium Phosphate, magnesium hydroxide and silicates dissolved in the water as hardness salts. Calcite, the Commonest form of calcium carbonate in hard water scale, deposits out of solution, when water is heated, to form a hard scale on pipes and heat exchanger surfaces. This deposit Progressively reduces the efficiency of water heating appliances and ultimately results in overheating and possibly corrosion failure of heat exchanger tubes. Depending upon the amount of calcium carbonate present in water, the problem of scale formation can be exacerbated. Hardness salts have an inverse solubility in water, ie, as the water temperatures increases, these salts becoming insoluble and precipitate out of solution. The amount deposited out, increases with the rise in temperature of the water. For example, a water with a l45ppm of Calcite flowing at 5000 litres per day can produce 4.8 Kg of scale each year at a water temperature of 60^{0}C, but at 80^{0}c it produces 29.9 Kg. This has implications for service and maintenance of water heating appliances, ie, instantaneous water heaters. These can be subject to rapid scale formation, Particularly in high water hardness areas in the UK (> 300ppm hardness).

There are several methods used to help the prevention of scaling in heat exchangers. Water softening and chemical treatment are both expensive and labour intensive. Water conditioning using magnetic and electronic devices has been around for some 50 - 60 years without success, because of the dearth of scientific evidence to establish their effectiveness to prevent scale. Within the last five years, there has been a resurgence in the claims for new designs. Such claims include better performance than their predecessors; their numbers and variety have proliferated in the domestic scene. As part of a general environmental drive, research in many countries has increased in recent years and there have been well-designed experiments, which have provided positive results, with basic benefits and explanations of mechanisms for preventing scale.

More recently there has been an increase in district problems experienced on some gas fired instantaneous water heaters and combination boilers.

Customer Services Division (HQ) therefore requested WHRS to evaluate a selection of water conditioning and automatic chemical dosing devices in order to establish their effectiveness in protecting appliances from scaling and identify the potential benefits to British Gas from reduced service and maintenance.

3. METHOD OF EVALUATION OF WATER CONDITIONING DEVICES

A number of magnetic and electromagnetic water conditioning devices have been tested on the WHRS test rig in a hard water area (>300ppm hardness). A series of identical instantaneous water heaters were operated in parallel circuits. Of these, all but the two control appliances had different water conditioning devices installed upstream in accordance with the water conditioner manufacturers instructions. All the water heater appliances were fully instrumented and were run on the same cyclic pattern until they blocked with scale and automatically shut down. The recorded time to failure through blockage was extrapolated to account for the typical usage pattern of the water heaters. Results are compared in Table 1. A more detailed analysis of the results is in progress and will be reported in due course in a full R & T technical report.

The test regime was designed to be representative of real but severe domestic use of water heaters and the appliance was chosen to provide controlled water flow rates, heat flux and heat exchanger geometry, to test the Propensity for this new generation of improved (design and field strength) water conditioning devices, Small diameter finned tube heat exchangers with high heat flux provided a stringent test for these devices.

Although all the devices had some Physiochemical effect on calcium carbonate in the water, none of the physical permanent magnetic devices were significantly effective in Preventing the water from scaling. Most devices appeared to Partially restrict the formation of hard calcite at the expense of aragonite, which is a less dense form of scaling but which still adheres to tube walls at temperatures in excess of 55^{0}C.

The electrolytic, electromagnetic and electrosonic devices were only able to increase the time to failure by approximately 50%. The chemical automatic dosing devices (Fernox Limited "Quantomat" and the Cistermiser Limited "Combimate") prevented blockage throughout the duration of the test. These are polyphosphate dosing devices which have proved themselves on district.

It is considered that the ideal device for reducing or eliminating hard water scaling problems should be continuously effective, cheap and simple in operation, need no constant attention from the user and have long periods of operation without the necessity for servicing.

The Hydropath electromagnetic water conditioning device came close to this ideal on our test rig and it surpasses the Performance of all the other non-dosing devices by a large margin. Its performance in comparison with the other devices is apparent (Table 1) and would warrant full scale field testing on district, which has now been initiated by Customer Services, HQ, Holborn. To date, no failures on district have been reported and the units are working satisfactorily on new and Previously scaled gas fired appliances.

4. HYDROPATH (HP18) CONSTRUCTION AND INSTALLATION

The Hydropath is a precision engineered e1ectromagnetic water conditioning device (Figure 1). The electromagnetic field produced is AC. It is a high frequency propagating field generated at low power 4 - 6 watts.

Construction details reveal that the device consists of a power supply unit, which also includes microchip electronics and a transducer. The power supply unit contains the energy source and control electronics. The unit is simply plugged into a 13 amp socket. The transducer is easily attached to the water pipe, usually on the rising main in a house, or to the water inlet pipe to protect an appliance or heating system. The transducer unit contains the sensor to detect water flow and the electromagnetic transmitter.

The manufacturer claims that the Hydropath HP18 is unique in its ability to condition the water in direct proportion to the rate of flow. Furthermore the level of treatment automatically adjusts to rid the system of previously deposited scale This effect propagates throughout the entire water pipe system of the house or the installation.

4.1 Performance

From Table 1 it is clear that the Hydropath has provided a level of performance under the severe test regime, almost three times better than the best of the other water conditioning devices. This is the first non-chemical water conditioning device, of the type required by British Gas, to show potential for reducing the scale formation, and to offer economic benefits from reduced service and maintenance on gas fired water heaters and boilers.

4.1.1 Summary of Test Results

Table 1 illustrates the high performance of the Hydropath HP18, compared to the other devices tested, and shows it increases the time to blockage for up to 5 years. Table 2 provides additional data on performance compared with the control or reference water heater, with no protection device fitted to the appliance. The automatic chemical dosing devices, Quantomat and Combimate are included for completeness of the types of device tested. The Quantomat and Coinbimate prevented blockage throughout the duration of the test. These are polyphosphate dosing devices which have proved themselves on district.

It is noted that blockage occurred in section number 5 of the heat exchanger for the Hydropath unit and the majority of the other devices (Figure 2) while the control showed blockage in several channels, indicating the normal method of scale deposition in the heat exchanger. It is also apparent that the accepted deposition of scale does occur on the high heat flux surface of the elliptically shaped heat exchanger tubes, whether aragonite or calcite is deposited (see ratios in Table 2). Some of the devices show a high proportion of aragonite but this did not stop the heat exchanger from scaling and blocking up. It is commonly advertised by manufacturers of these devices that soft scale is produced which does not adhere as strongly to heat exchanger surfaces and is normally flushed out of the system with flow of the water but this did not occur in these tests.

Blockage may occur because of the small bore and elliptical shape of the tubes. From our results whichever form of calcium carbonate deposits out, the scale adheres to the heated surface.

The literature usually suggests that aragonite (softer form) is predominately formed. However what dictates which form of calcium carbonate (calcite or aragonite) is deposited and the reason why, is not fully understood although there are a number of current theories (1,2). Furthermore, the turbulence caused by the force field, convection currents produced on heating the water and hetero—nuclei in the water, will play a role in nucleation and final morphology of the calcium carbonate crystals formed.

Usually at temperatures below 55°C, aragonite predominates and at higher temperatures, calcite.

Since it is suggested that these conditioning devices cause crystals of calcium carbonates to drop out of solution into the flowing water, the water is said not to be saturated with respect to calcium carbonate. Therefore, when it flows over existing scale, the mechanism proposed by the manufacturers is the redissolution of old scale at temperatures lower than at the high heat flux sites. Sections of the heat exchanger nearer the cold water- inlet are at a lower temperature in the early part of the heating cycle.

The effect of temperature on precipitation of calcium carbonate cannot be overidden.

Therefore the device should be capable of functioning at high temperature, in the same way as it does at temperatures below 55°C. The Hydropath HP18 appears to do this as evidenced by its betterment value under the same conditions of test as the other devices and therefore has shown potential to cover the range of temperatures for water heating appliances, unlike the other devices tested.

4.1.2 Hydropath Units Tested

4.1.2.1 Preproduction Unit

Two HP18 devices were tested. One a preproduction laboratory manufactured unit and the other unit taken from the initial production line.

It should be noted that the preprociuction unit completed 11,425 plus 8,625 cycles (20,050 cycles) before failure of the red LED light on the device, indicating it was not working. This was due to a sticking potentiometer, caused by the high heat and humidity in the environment of the test rig. The preproduction unit was replaced under guarantee by the manufacturers with a production unit.

4.1.2.2 Production Unit

Exactly the same design but the microchip technology had been improved and some components had been modified including the transformer. The unit was also subjected to manufacturing quality control.

This unit was scheduled to protect a modified heat exchanger. The modification consisted of 2mm diameter temperature probes being inserted into the water channel at the 2, 3, 4 and 5 water sections of the finned heat exchanger body, midway along the length, in the central path of water flow. The heat exchanger unit blocked with scale after 5,256 cycles. The Hydropath unit LED light was on, indicating the unit was operational but the chromed contact screws on the transducer unit were not all in contact with the 15mm diameter cold water copper pipe inlet to the appliance. This could have been caused by relaxation of the nylon ties used on fixing the transducer to the pipe or local vibration on the test rig on which it was mounted. It is possible that this was the source of the unexpected premature blockage on this heat exchanger unit.

The circuit resistance is normally very low, but is significantly increased, with a large drop in current at the copper pipe/water interface, if proper contact is not made with the copper pipe. This could reduce or influence the rate at which scale is prevented from depositing. It may suggest a question of reliability of the device.

4.1.3 Reliability of the device

The electronic circuit of the water conditioner is made up of a moderate number of discrete components such as resistors, capacitors, diodes, transistors, transformers and three integrated circuits. All components are of well established technologies and there should be no difficulties in carrying out the standard theoretical failure rate analysis using for example MIL-HDBK-217 data. This could be done ‘in–house’.

Alternatively, or in parallel with the theoretical reliability analysis, the usual accelerated statistical life tests on a number of these water conditioners can be carried out using the high temperature stress method. As the effective performance of the water conditioner is determined by the high frequency current induced in a length of a copper pipe, it will be necessary to devise a method of measuring and recording the relevant parameters of the current to determine any gradual time dependent degradation in performance or a catastrophic failure of the water conditioner.

A weak feature of the conditioner is the method of electrically connecting the transducer unit to a copper pipe with standard nylon ties. Four chromium plated screw heads are used as contacts, but as the circuit resistance is very low, any increase in the contact resistance, due to, for example, corrosion or the thermal expansion of the nylon plastic ties, will significantly increase the circuit resistance.

If such an increase in circuit resistance occurs, the amplitude of the high frequency current will decrease, with the corresponding reduction in the effectiveness of the water conditioner. It is suggested that a more reliable method of electrical contact should be used, for example spring loaded probes.

Another weak feature is the lack of indication or signalling in the event of a failure: it may take weeks before the user notices that the water conditioner' is not working, possibly only being suspected when a heat exchanger becomes blocked.

Finally the unit should be tested to a relevant radio emission standard to verify that it conforms with the EC Directive on EMC.

5. TECHNOLOGY

The Hydropath unit is unique in the way in which the electromagnetic field is applied to the water and the way the device varies the strength of the field according to flow rate, monitored by the sensor in the transducer unit. These two factors are critical to the propensity for this device to work efficiently to prevent scale deposition at low and high temperature under varied heat flux conditions. These. factors set it apart from other electromagnetic devices.

5.1 Mode of Operation

It is considered that the mode of operation is based on an alternating electromagnetic field being applied across the water carrying copper pipe, perpendicular to the direction of water flow. Field strength exhibits sinusoidal decay and the pulse rate is modulated by a water flow sensor (a microphone). The manufacturers claim the effect of the magnetic field propagates through the entire system. This is in keeping with the current flow in a coaxial field, ie, the copper pipe and the water which are both good conductors. The effectiveness of the device is determined by the high frequency current induced in the copper pipe.

A skin effect is generated in any AC coaxial high frequency conductor, ie, current flow is more intense at the center than at the surface of the conductor. The loss at high frequencies in coaxial conductors is due to. the skin effect, which forces current in the central core to flow near to its surface which increases the resistance of the conductor. In the case of the copper pipe with water as the coaxial system, all the electrons (current) travel at the pipe/water interface. Therefore, there will, be current carried by the pipe and current in the water. All the electrons (current) in the water would be flowing at the skin interface while electrons (current) on the pipe will flow in the copper pipe. A protective shield is established to force nucleation of calcium carbonate both in the centre and at the interface.

In the electromagnetic field the lines of force are most intense in the centre of the conductor. In any system there is a growth and decay of the field and the velocity of this process is increased as the frequency goes up A back emf is set up, which increase the resistance of the centre conductor (water) which pushes the current to the surface of the conductor (the pipe/water interface). The power supplied for the process of interaction with charged species in the water is controlled via the flow sensor in the transducer unit.

Crystal growth is preceded by nucleation, although the actual mechanism is still uncertain. Any species of material (salts, etc) in the water will tend to concentrate close to the pipe water interface, particularly charged species and these interact with and will be influenced by the magnetic field. They will be held and repelled by the field at the interface and away from the pipe wall. Free electrons generated at the interface will interact to assist in nucleation of charged species, while hetero—nuclei (organic matter, rust particles, corrosion products) will also play a part in seeding embryonic nuclei.

5.1.1 Morphology and Crystals

Clusters of charged species of these nuclei are repelled from the interface force field to form crystals (microns in size) and move downstream.

Because there is an AC field these charged species are held and released alternatively, in an intense field from the centre to the interface. The co-operation of hetero-nuclei and thermal vibration from heating the water may also dictate the final embryonic nuclei and morphology of the crystals, which form a fine suspension and finally coagulate to form larger crystals in a turbulent environment of flow of water and convection from heating the water.

The Hydropath operates continuously and is not dependent upon flow although it does sense it, and by its AC pulsed field it holds and. releases nuclei continuously throughout the system. Because it is a coaxial system the current flow is along the entire length of the pipework system, but diminishing somewhat down stream, at bends particularly. It therefore covers the whole circuit. Current flow, on the copper pipe in the low power, AC, high frequency device is unlikely to cause corrosion.

5,1,2 Effect of Temperature

The Hydropath HP18 can operate at high temperature (95 100°C). This is because of the continued conductivity at the pipe water interface in a coaxial circuit. Both copper pipe and water have a positive coefficient of resistance and there is no diminution in the activity of the device on scale reduction at higher temperatures.

5.1.3 Comparison with other Water Conditioning Devices

None of the other electromagnetic devices on the market have the unique facilities of the Hydropath, since the other units only effect the water hardness salts in the vicinity of the device within the force field delivered. Similarly other permanent magnet devices influence scale reduction in the vicinity of the force field and only under set flow conditions and annular gap restrictions according to design. The Hydropath HP18 works continuously throughout the system and is flow independent, while the other devices are flow dependent.

It is important to note the mode of operation of ordinary magnetic devices and that hardness salts have an inverse solubility in water, ie, as temperature is increased calcite and aragonite (crystalline forms of calcium carbonate) are deposited out as hard scale on heat exchanger surfaces. At lower temperatures <55°C some of the magnetic devices appear to show that something is happening to influence nucleation of calcium carbonate in either crystal form, to prevent the rapid rate of scaling. At temperatures of 70, 80 and 90°C there is a decrease in the ability for these devices to cope. The Hydropath by design would appear to cater for this critical temperature range for gas fired instantaneous water heaters, where small diameter tube and high heat flux are important to the design of these appliances and future designs of heat exchangers for combination boilers and high efficiency condensing boilers appliances.

6. BENEFITS TO BRITISH GAS

There are approximately 12.5 million water heating appliances in British Gas installations throughout the UK. This is made up of 9 million boilers, 1 million combination boilers and 2.6 million instantaneous water heaters. In certain hard water areas problems often arise from prematur blockage by scale within 6 months of installation, particularly with instantaneous water heaters, cast iron boilers and combination boilers.

For contractors to descale boilers, the cost would be approximately £300/boiler, depending upon severity of scaling. This involves isolation of the boiler on site, descaling (24 -48 hours pumping), and neutralising and finally flushing, prior to the reinstallation. It is a 24 -72 hour job and is labour intensive.

The going rate for instantaneous water heaters is a call—out charge plus cost of heat exchanger which is on average £40 per appliance. This is simple and easier than for boilers.

On average the call-out and descaling charge for both boilers and instantaneous water heaters would be approximately £170 per appliance. If only 1% of the total population of appliancas were at risk from scaling and assuming 3 star customers, ie, 125,000 appliances, the cost to our industry would be £21.25 million per annum. Therefore, for a modest investment in the purchase of a Hydropath device to be installed in high and medium risk areas the benefits and savings to British Gas would be, over 5 years, £85 million, minus the investment in Hydropath units on district of £12.5 million, which gives a total saving of £72.5 million.

7. CONCLUSIONS

Under the severe test regime of small bore pipe and high heat flux it has been shown that Hydropath HP18 performs significantly better than the other non-chemical devices tested with substantial benefits to service and maintenance of water heating appliances. Lifetime results from this work would suggest at least tow and a half to five years between any servicing or blockage depending upon the reliability of HP18 components.

The technology is in large measure substantiated according to the claims of the manufacturers and it is the only device to approach an ideal device for reducing/preventing scale formation on a continuous operational basis at high temperature. This is an essential and unique feature required by gas fired water heating appliances.

Installation is simple involving only mounting the transducer unit on the rising main and plugging the power unit source into a 13 amp socket. Then are no moving parts, the unit is externally mounted but there are currently questions on reliability, which need to be addressed especially the method of mounting the transducer to the pipe.

The adoption of the device, with full regional trials, should provide data on the wider economic benefits to service and maintenance of a large population of existing and future appliances.

8. RECOMMENDATIONS

Due consideration should be given to the wide use of the Hydropath device in the Regions, to reduce service and maintenance costs resulting from hard water scaling problems.

9. REFERENCES

1) J.D. Donaldson, Scale Prevention and Descaling Tube International 1988, pp 39–49.

2) S.N. Grimes, Magnetic Field Effect on Crystals Tube International 1988, pp 111–114.

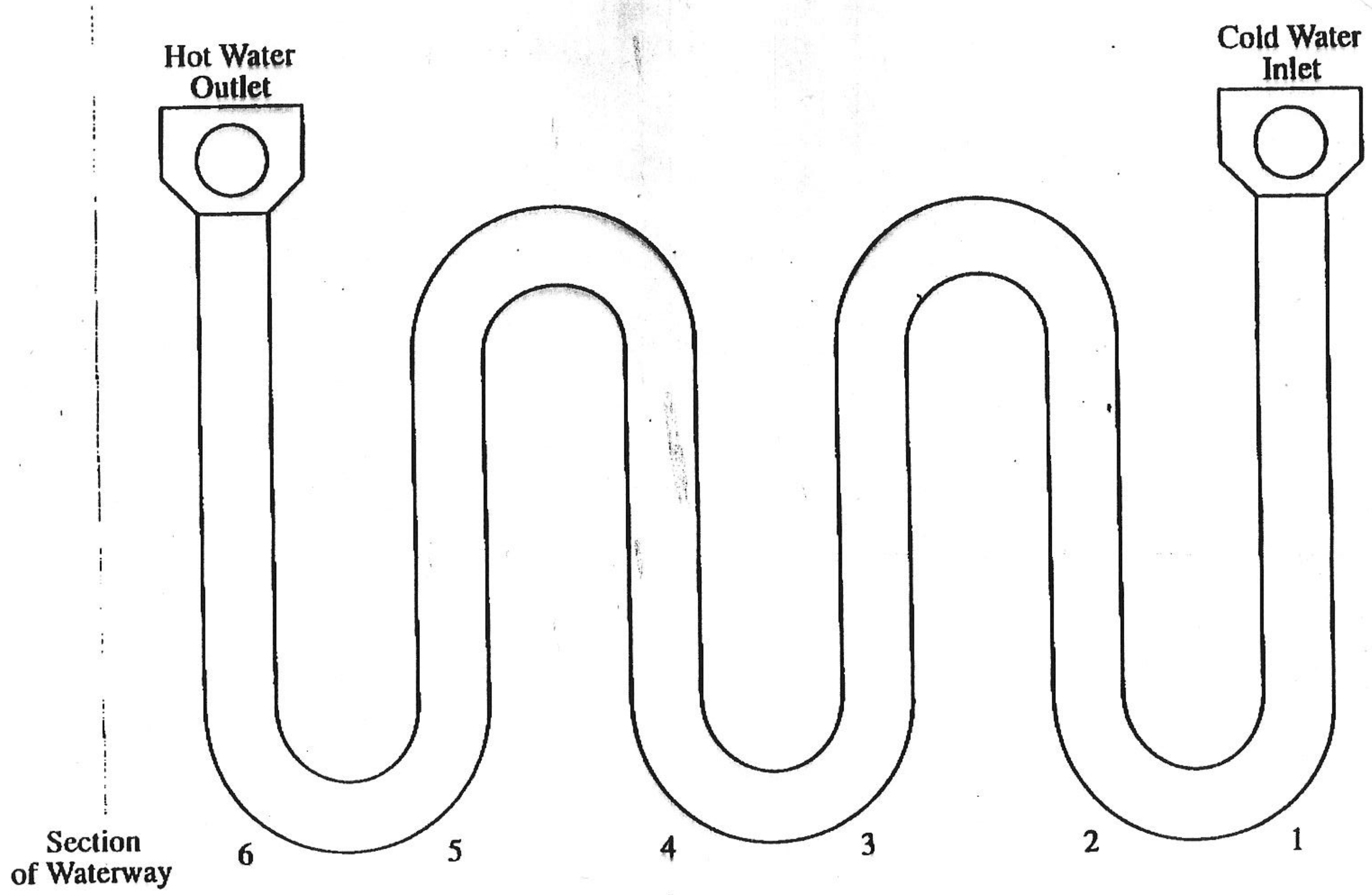

Figure 2
Sketch of Finned Copper Tube Heat Exchanger from Instantaneous Water Heater

TABLE 1

SUMMARY OF PERFORMANCE DEVICES TESTED

DEVICE	CYCLES TO BLOCKAGES	BETTERMENT NUMBER b/a	LIFE TO BLOCKAGE (WEEKS)	COST £
CONTROLS	1697 (a)	1.00	40.40	No device
HDL	1580 (b)	0.93	37.60	82.65 exc vat
AQUADIAL	1589 (b)	0.94	37.80	31.00 exc vat
WIZARD	1712 (b)	1.01	40.80	49.99 exc vat
POLAR	1999 (b)	1.18	47.60	151.23 exc vat
MAGNAFLO DESCALAMATIC	4176 (b)	2.46	99.40	232.14 inc vat
SCALEMASTER	1856 (b)	1.09	44.20	65.50 exc vat
SCALEWATCHER	3411 (b)	2.01	81.20	180.00 exc vat
HYDROMAG	3397 (b)	2.00	80.90	400.00 exc vat
HYDROPATH HP18 (PREPRODUCTION UNIT)	11425 (b)	6.50	263	100.00 inc vat
REPEAT TEST HYFROPATH HP18 (SAME UNIT AS ABOVE CONTINUING ON TEST)	8625 (b)	5.08	205	100.00 inc vat
HYDROPATH (PRODUCTION UNIT REPEAT TEST HYDROPATH)	5256 (b)	3.10	125	100.00 inc vat