water conservation and the mist experience

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ACKNOWLEDGEMENTS

The work on mist washing was initiated by Alvaro Ortega, the founder of the Minimum Cost Housing Group, in 1971 and much of the credit for the work that follows belongs to him. The work described in Chapters 4,5 and 6 was carried out by Alexander Morse in 1975 and appeared in slightly different form as his Master of Architecture Thesis "The Use of Atomization for Washing and Showering to Conserve Water", McGill 1976. Many members of the Minimum Cost Housing Group contributed to this project since it began, particularly Samir Ayad, Wajid Ali and Bernard Lefebvre. Arthur Acheson took part in the design of the Mini-Mister with Vikram Bhatt.

We also acknowledge the early work of Buckminster Fuller and his "fog gun" which inspired us all. On a visit to Montreal in 1971 Dr.Fuller had the opportunity to try the Diaspray hand washer, and his words of encouragement are appreciated.

This publication is a companion volume to Stop the Five Gallon Flush *and we hope that it finds as wide appeal, and usefulness, as that book did.*

Witold Rybczynski
Director, Minimum Cost Housing Group

water conservation and the mist experience

by

alex morse, vikram bhatt & witold rybczynski

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Foreword

Since its inception the Minimum Cost Housing Group has, amongst other interests been concerned with water conservation and sewerage and in the summer of 1973 published its first book on alternative sanitation systems entitled "Stop the Five Gallon Flush". This present book, published five years later, reports the results of studies carried out by members of the group on methods of controlling water usage in everyday activities by means of various mechanical aids. In addition, methods of controlling the water supply to ensure that the amount and flow of water is directly related to the specific need have been research and carefully catalogued.

For many regions of the world which suffer extreme shortages of fresh water, at least seasonally, such methods of control can be useful in reducing wastage. In other regions, the discharge of polluted effluents into the fresh water supply has threatened its quality and has necessitated expensive alternatives of providing usable water. In such cases, a reduction in the quantity of water used would also be welcome.

Perhaps a new generation, inspired by a conservation ethic, will welcome methods of reducing wastage of what has increasingly become practically a non-renewable and dwindling resource and demand that such controls become mandatory. Members of the Minimum Cost Housing Group have provided directions for those so inclined and, one hopes, the motivation for others to follow.

Derek Drummond, Director
School of Architecture
McGill University

1. World Water

1. Water Economy

Water shortage is generally the result of two major man-made causes: population growth and industrialization. There are more people wanting to use the available water supply while often the water is polluted.

In many areas which depend on regular rainfall for their water supply, another cause for water shortage is drought. This is a regular occurence in arid regions of the world.

We should have a clear picture of the context of the water problem. The idea of a water shortage is deceptive. According to a leading Soviet scientist, M.I. Lvovich, the water resources on earth fully suffice to meet all of man's steadily growing needs for an indefinite time. But man, he says, must strictly adhere to a correct policy of using water and reshaping the hydrologic cycle, which links up all parts of the hydrosphere - (the seas, lakes and streams, groundwater, soil moisture, atmospheric vapor) into a single whole; and water balance, the quantitive expression of the hydrocycle and its components. Man must practice extended reproduction of suitable water resources. The water problem, Lvovich believes, cannot be solved by one-sided measures but by an integrated program of technological, biological, and organizational measures. This report deals with a technological measure. Thus the water problem is one of water economy.

A 1971 World Bank Report, Water Supply and Sewerage[1] in 17 countries, reveals the following facts which bring the problem into focus: urban populations have been increasing by an average 5.9% per year, reflecting substantial immigration from rural areas. This creates an abnormal load on the water supply. In one third of the 26 cities studied, the majority of consumers are served by public taps rather than by home connections. Most taps are not metered, and this results in careless drawing of the water, which makes for much wastage. In half of the cities, more than 25% of the water produced is unaccounted for. Here is more waste.

City sewage and waste from mines and factories may be regarded as the chief cause of water pollution. A lesser cause, but a growing and important one, is the pollution created by chemicals used to kill insects and to fertilize crops. The water polluted by these chemicals finds its way into lakes and rivers - bodies of water upon which people rely for drinking, cooking and washing. Increasingly, radioactive wastes, from factories using uranium, have become a considerable cause of water pollution. Pollutants are absorbed into the earth where they disappear from sight, but move slowly and pervasively poison new streams and water. The result is outbreak of disease.

2. Water Supply and Sewerage

The World Bank Report goes on to state: "Individuals need a minimum amount of water for drinking and preparation of food. Because this minimum requirement is an absolute necessity, people not being served by a piped water system resort to alternatives ranging from carrying water long distances or purchasing water from vendors, to use of heavily polluted ponds or roadside ditches. These alternatives are not the price is so high (see table on page 4) that only very small quantities are bought.

Domestic consumption is only one of the uses of water in urban areas although it is the major one, typically accounting for 50-75% of total consumption. Industrial, commercial and government (schools, hospitals, etc.) consumption is frequently also important. Water is vital for many industrial processes. Where there is sometimes the alternative available to large industry of developing a private supply, it is seldom cheaper than a well-run municipal system. Economies of scale are important in water and usually favor a central system when all costs are considered. The different time patterns of household and industrial demand also make a central system the least expensive way to satisfy differing peak demands.

Because of the explosive acceleration of urbanization in many developing countries in recent decades, the typical experience is that service which may have been adequate at one time deteriorates as consumers are connected to the system at a faster rate than its capacity is increased. Once a system is operating above capacity, the quality of service deteriorates for all consumers connected to it. A good example of this "network" effect is one large South Asian city which has lagged far behind the rapid growth of the urban complex and not been properly maintained. As a result, an estimated 40% of the water put into the system is lost in distribution. Service is now available for only a few hours a day because the limited water is allocated by rotation to different areas of the city. Consequently almost every structure has a roof tank and many have pumps to try to suck more water out of the system. The cost of these facilities is enormous, and may exceed the incremental cost of a proper system. A few years ago, when the seasonal rains were inadequate, the very life of the city appeared threatened. Faced with exhaustion of the reservoirs, contingency plans were made to move a part of the population out of the city, and most industry was shut down for weeks. These were the consequences of the failure of the water system to keep pace with the growth of the city.

Even in less dramatic circumstances, the cost of inadequate water facilities in terms of debilitating diseases, associated medical treatment and reduced productivity is undoubtedly high, but the magnitude of these costs is not easily measured. The studies which demonstrate in developed countries the public health benefits of safe water (reduction in enteric disease) do not separate the benefits of adequate piped water from those of adequate medical services, shelter, food, etc. Public health benefits are thus rarely included in quantitative estimates of the benefits of improved water services. As a result, water projects are often penalized inappropriately when compared with the projects in other sectors for which economic returns on investment reflect more comprehensive measurement of benefits; this may account in some degree for the widespread inadequacies of water services in most parts of the developing world."

WATER USE TODAY AND TOMORROW[2] (IN CUBIC KILOMETRES)

Types of use	TODAY				TOMORROW			
	intake	irretrievable use	discharge of sewage	polluted water	intake	irretrievable use	discharge of sewage	polluted water
Water supply (all types)*	600	130	470	5,580	1,500	1,500**	0	0
Irrigation	2,800	2,100	700***	0	3,950	4,000****	400***	0
Non-irrigated farming*****	500 / 0	500 / 0	0	0	1,200 / 700	1,200 / 700	0	0
Hydropower and navigation	160	160	0	0	500	500	0	0
Fish-breeding and angling	65	15	50	0	175	85	90	0
TOTAL	3,625	2,405	1,220	5,580	6,825	6,335	490	0

* Second forecast variant.
** Not counting 450 cubic kilometres of sewage used in irrigation.
*** Water returned after irrigation.
**** Including 450 cubic kilometres of sewage used in irrigation.
***** The numerator is the additional streamflow used in non-irrigated farming compared with past flow; the denominator is the same in comparison with present flow.

3. Water Demand and Costs

In areas of greatest scarcity, water is sold from carts. For example, in Dubai in 1975, a water-seller was charging $60.00 for 3,375 liters (750 gallons) i.e. 1+¢ per liter of 8¢ per gallon. That was enough water to serve a household of 16 persons for one month. Only a fraction of this is used for washing; most of it is used for cooking and drinking.

COST OF WATER TO CONSUMER[1]

Prices charged by water vendors per m^3	*Typical urban metered rate per m^3*	
$1.11-2.22	*$0.09*	*Dacca*
$1.55-3.86	*$0.18*	*Kampala*
$0.93	*$0.09*	*Istanbul*
-----	*$0.06*	*Singapore*
-----	*$0.07-0.13*	*US city*
-----	*$0.11-0.19*	*German city*

Water supply is also critical on ships where a sufficient quantity must be carried for long voyages. The latest super-cargo ships never put in to ports but are supplied at sea. Caravans and trailers, too, often need to carry their water supply along into areas of arid desert or where water is polluted. For example, in temporary housing for work gangs at locations for resource development.

Recreation vehicles such as campers also need to store water. Aircraft, too, must carry their own water, although its time away from a supply source may be short so the need is less critical except in case of emergency.

Of great need also is emergency water supply in disaster zones not only because of shortage due to broken mains but also because the impossibility of usual treatment results in a polluted water supply.

Spacecraft are the extreme example of the need for water economy. Here, compactness is more critical. The least volume and weight the water supply uses, the better. Accordingly, Martin Marietta, designers contracted by the National Aeronautics and Space Administration came up with a water recyclable atomized shower which, except for its zero gravity requirement, would be applicable in any of the cases cited above.

The atomizing system used on the NASA Skylab is not on the market; however, similar components are available and these could be combined for bathing and washing devices. Further on in this study some such products will be reviewed along with tests and evaluation of their effectiveness.

Were such atomized water devices to be used in places of scarcity and pollution, then water demand and with it relative water costs would be greatly reduced.

4. Water Use Data

Of most interest to official surveys is the total water use and its breakdown into domestic as well as other uses as shown in the following table from H.F. Vallentine's book Water In The Service of Man.[3]

Whereas general water use has been measured by various agencies, seldom is the use broken down by type, i.e., the differentiation between water used for cocking and drinking, on the one hand, and wated used for washing and cleaning, or for toilets, on the other. Little documentation is available, which explains why findings given here are so disparate. This is understandable, since this degree of statistical refinement has apparently not yet been required by official agencies. (An exception is the private study by the Ultraflo Corporation in comparing their water-saving system (see page 52) to conventional water use.) Most data is supplied from reports by such bodies as the World Health Organization of the United Nations, the World Bank, and the Department of Health, Education and Welfare of the United States.

About half the water consumed in urban homes is used for flushing toilets. The remainder is used for domestic purposes, i.e. drinking, cooking, cleaning, washing and bathing. Washing (face and hands) and bathing (whole body) account for 30% of total domestic water used.

Domestic water use on world surveys varies, but the average recommended by Wagner and Lanoix in WHO Report #42[4] and the one most used for planning criteria is 250 liters per person per day (55.5 gal.). Of course needs vary for cultural and regional reasons.

It is interesting to note the water-use standards adopted by the World Health Organization in the following statement for emergency programs for disaster areas; also, their preference for showering over bathing: "As soon as the early days of emergency have passed and the water supply has been increased restrictions should be lifted, since there is a correlation between water consumption and cleanliness on the one hand, and between cleanliness and the incidence of diseases on the other. With no restrictions the use of water may approach 100 litres (22 gallons) per person per day.

Recommended standard for showers is 20-30 litres/person/day (4.4-6.6 gal.). Recommended fixture distribution is 1 handbasin/10 persons; 1 showerhead/50 persons in temperate climates, and 1/30 persons in hot climates.

Showers are preferable to baths both for sanitary reasons and to save water. ...everybody in camp bathes at least once a week. In hot climates cold water should be sufficient. If hot water is provided, 20 litres (4.4 gallons) should be supplied for each bath; over-all consumption of water for bathing should be calculated on the basis of 30-35 litres/per week (6.6-7.7 gallons)."

Daily Water Consumption per Person[5]

Bathing	70 liters	(15.5 gal.)
Toilet flushing	110 "	(24.4 gal.)
Handwashing	7+ "	(1.5 gal.)
Laundry	28+ "	(5.2 gal.)
Cooking	15 "	(3.3 gal.)
Dishwashing	12 "	(2.6 gal.)
Garden	8 "	(1.7 gal.)
TOTAL	250 liters	(55.5 gal.)

Bathing and handwashing 77 liters (17.0 gal.)

Bathing and handwashing for family of four: 308 liters (68.2 gal.)

Allocation of Water in a Large City[3]

Use			% of total
Domestic:-	Sanitation	16%	
	Cooking, laundry, misc.	10%	44
	Household gardens	18%	
Industrial			22
Commercial			18
Public (parks, street cleaning, etc.)			7
Hospitals and institutions			5
Primary production (market garden, poultry)			4
			100%

A water-vendor in the United Arab Emirates replenishes his stock in trade.

World Survey of Domestic Water Use

Source	Author	Comments	Gal./day	Litres/day
WHO Report #23	Dieterich & Henderson/1963	N.American household	40	180
WHO Report #42	Wagner & Lanoix 1961	houses w/i handpump	8.4	38
		" w/i faucet	10	57
		" w/h.& c.water: kitchen, laundry, bath & W.C.	42	190
		Recommended	55.5	250
The World's Water	Lvovich/1973	Cities of the world	33	150
		Rural areas	11	50
		Norm	44	200
		(urban average incl. all water)	(88)	(400)
Water Supply & Sewerage World Bank	--/1971	in 17 cities (S.Am.) incl.public taps	20	93
U.S. Joint Commission on Rural Sanitation	H.E.W./1954	rural w/taps	42	190
Enquêtes sur les Consommations d'eau Potable en France	Neveux/1954	urban	54	245
Countryside Whole Earth Catalog	Bélanger/1970	plumbing system under pressure	30	135
Ecology Bulletin Ultraflo Corp. U.S.A.	--/1973	typical N.American family w/3 children	75	337
Water Use in the U.S. in 1965 Journal American Waterworks Association	Nov./1969	Western USA	147	662
		Eastern USA	90	405

BREAKDOWN OF WATER QUANTITIES USED FOR CLEANING (per person per day)

Source	Shower	Bath	Handwashing
Ultraflo Corp., Sandusky, Ohio Data on ordinary facilities	54 litres (12 gal.) 5 minutes	--	6 litres (1.3 gal.)
NASA Skylab Shower:	2.5 litres (.66 gal.) 9 minutes	--	--
Minimum Cost Housing Group McGill University EPROM	--	70 litres (15.5 gal.)	7.5 litres (1.6 gal.)
Minimum Cost Housing Group McGill University Data on ordinary facilities	10 litres (21.9 gal.)	--	5 litres (1.1 gal.)
Minimum Cost Housing Group McGill University Ecol Operation Data on Spray facility	15 litres (3.3 gal.)	--	.05 litre (0.1 gal.)
NOVA Data on ordinary shower	94 litres (25 gal.) (10 minutes)	--	--
MINUSE Data on ordinary shower	94 litres (25 gal.) (5 minutes)	--	--
PERSONAL use in ordinary facilities	48.15 litres (10.7 gal.) (5 minutes)	112.5 litres (25 gallons)	2.8 litres (0.6 gal.)

2. Atomization

1. Definition of Atomization

Atomization is defined as the mechanical subdivision of a bulk liquid. Spraying implies production of coarse drops (100 to 1000 Microns). Sprinkling suggests very coarse drops larger than 1000 Microns. The term misting is applied to the production of fine drops (10 to 100 Microns). Nebulizing is applied to very fine drops (under 10 Microns), and is usually used in inhalation aerosol therapy.

Except where otherwise specified, the term "spray" is used further on in a general sense.

2. Drop-production Techniques

a) Geometry of devices: Nozzles

"Drop-production techniques are distinguished by either the geometry of the atomizing device (i.e. nozzles), or by the source of the external motivating force employed" says the McGraw-Hill Encyclopedia of Science and Technology. The first three categories of atomizing techniques which they list are pertinent to this study. They are: Hydraulic (pressure), Pneumatic, and Rotary. The Encyclopedia goes on "Under normal operating conditions (30-200 psi) (2-13.6 atmospheres) hydraulic nozzles produce relatively coarse drops 100-300 Microns diameter, the finest ones being produced by small swirl nozzles wherein pressure is converted into high relative jet velocity. Hydraulic nozzles are exemplified by garden hose nozzles, insecticide spray nozzles, and nozzles in humidification and scrubbing towers.

Pneumatic atomizers normally use compressed air (30-100 psi) (2-6.8 atmospheres) and produce drops in the 5-100 Microns diameter range. They are used in spray painting and fine misting applications, scrubbers or reactors (Venturi atomizers), and aircraft application of insecticides." Pneumatic nozzles are two-fluid internal mix, external mix, and combination mix types. These could be, for example a mixture of liquid and air, using the siphon principle.

Rotary atomizers (spinning discs) are basicly hydraulic atomizers, in which the pump and nozzle are combined and normally produce drops in the 30-300 Microns diameter range. They are widely used in spray drying because of their ability to handle viscous liquids or slurries.

The Bete Fog Nozzle Inc. of Greenfield, Massachusetts states in their catalog: "When selecting a nozzle, consideration should be given to desired capacity, pattern, fineness of spray or fog, available pressure and orifice size where clogging may be a problem. Smaller nozzles, wider angle patterns and higher pressures result in a finer drop size". They go on to explain spray pattern selection: "There are fan or flat spray patterns for washing, applying chemicals, or flooding an area. The narrow patterns are used where a hard scrubbing action is desired. Hollow cone nozzles are usually used in multiples where their patterns overlap for wide coverage and high capacity. Full cone nozzles are most widely used and are recommended for fire protection, scrubbers, cooling and other applications because of their uniform coverage. The exclusive patented Bete spiral nozzles, for full or hollow cone sprays, feature high efficiency and are non-clogging." (these have a corkscrew-like spiral at the front of the nozzle). Flow rate is described by the term "nozzle capacity".

The Spraying Systems Company of Weaton, Illinois, also nozzle manufacturers, goes into more detail. Their useful Spray Performance Characteristics table from their current catalog is reproduced on page 9 of this study.

Solid cone spray patterns can be produced with nozzles which are swirl jet, impinging jet, or rotary (spinning disc). Hollow cone spray patterns can be made with tangential swirl and impinging jet types. The two-hole simplicity of the tangential swirl type is relatively clogproof. Flat sprays can be made with a jet on a deflector plane or planes, or with a slot orifice.

Fog patterns can be made with a jet deflected by a turned back pin interrupting the stream or by the combination of a small orifice and high pressure.

b) External motivating force: Pressure

The source of the external motivating force employed for atomization may be manual or mechanical. The force creates the pressure to move the liquid. There are four cases:

1) Manual force makes instant pressure
   e.g. household sprayers using siphon or pump principle
2) Manual force makes stored pressure
   e.g. garden sprayers
3) Mechanical force makes instant pressure
   e.g. water-pic toothbrushes
4) Mechanical force makes stored pressure
   e.g. paint sprayer using siphon or pump principle

6

SPRAY CHARACTERISTICS

SPRAY PATTERNS

CAPACITY (Flow Rate)

All capacity tabulations in this catalog are based on water. Since the specific gravity of a liquid affects its flow rate, tabulated catalog capacities must be multiplied by the conversion factor that applies to the specific gravity of the liquid sprayed . . . as follows:

Specific Gravity	.84	.96	1.00	1.08	1.20	1.32	1.44
Multiply by Factor	1.09	1.02	1.00	.95	.91	.87	.83

Nozzle capacity varies with spraying pressure. In general, the relationship between GPM and pressure is as follows:

$$\frac{GPM_1}{GPM_2} = \frac{\sqrt{p.s.i._1}}{\sqrt{p.s.i._2}}$$

See capacity tabulations on following pages.

SPRAY ANGLE

Tabulated spray angles indicate approximate spray coverages based on water. In actual spraying, the effective spray angle varies with spray distance. If the spray coverage requirement is critical write for specific spray coverage data. See next page for "Spray Angle Data." Liquids more viscous than water form relatively smaller spray angles (or even a solid stream), depending upon viscosity, nozzle capacity and spraying pressure. Liquids with surface tensions lower than water will produce relatively wider spray angles than those listed for water.

SPRAY ATOMIZATION

- 800 Microns
- 1,200 Microns
- 5,500 Microns

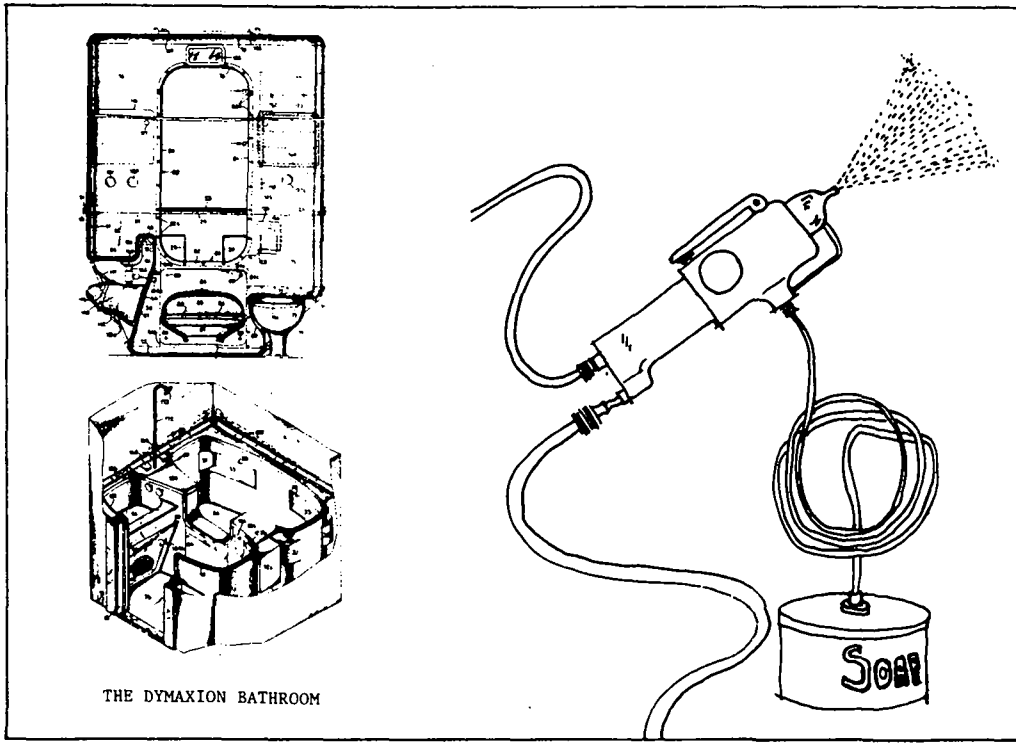
Fine atomization is most easily obtained with air atomizing nozzles because compressed air is used to break up the liquid into fine particles. Above this level, hydraulic spray nozzles produce a larger particle size spray range depending upon such factors as nozzle type, capacity, spray angle and pressure.
Wide angle hollow cone, low capacity hydraulic spray nozzles operating at higher pressures produce smaller spray particles. Spray particle sizes become coarser as nozzle capacities increase, spray angles become narrower as pressures decrease. The largest particles are obtained with the largest capacity full cone nozzles spraying at the lowest pressure. For specific spray nozzle particle size data . . . write for information.

IMPACT

The total theoretical impact of a spray depends primarily upon the GPM and spray pressure. The highest impact per square inch is produced by solid stream and flat spray patterns . . . using large capacity nozzles operating at higher pressures. Lowest impact efficiency is provided by wide spray full cone and wide spray hollow cone spray nozzles.

VELOCITY

The theoretical velocity of a spray leaving the orifice of a nozzle, depends upon the spraying pressure. Solid stream and flat spray nozzles have the highest velocity efficiencies . . . while wide angle full cone nozzles and wide angle hollow cone nozzles have the lowest velocity efficiencies.

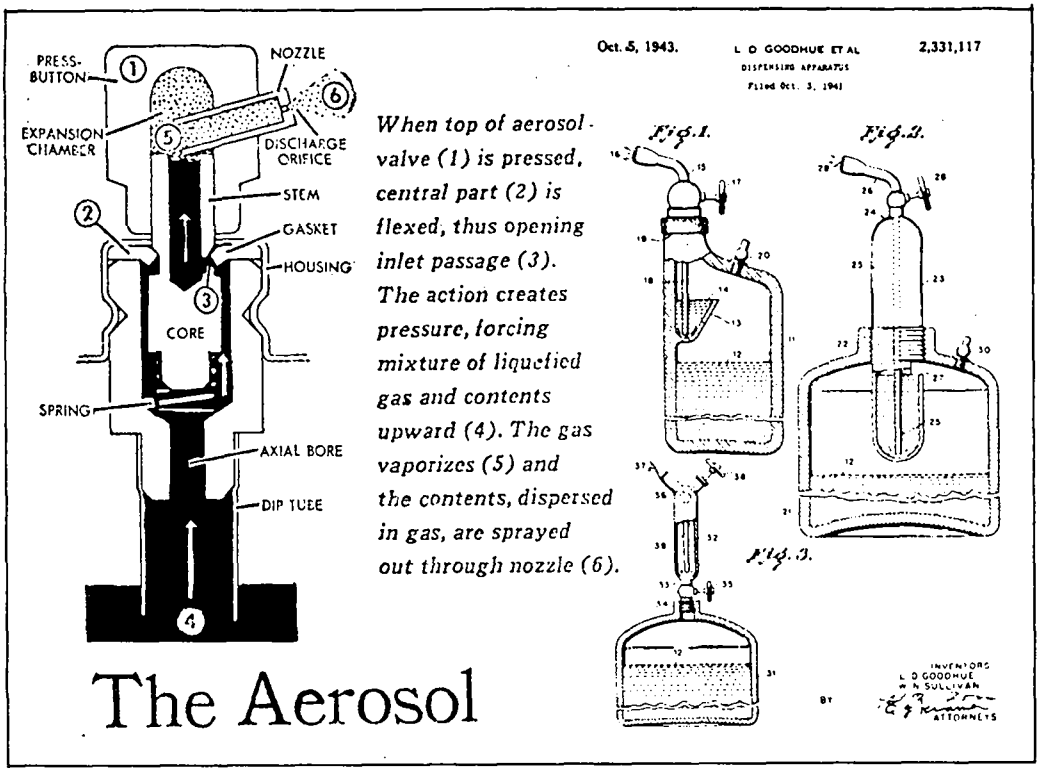


THE DYMAXION BATHROOM

BUCKMINSTER FULLER AND THE FOG GUN

Fuller considered the Dymaxion bathroom as an interim, mass-producible, sanitary facility; his fog gun, pictured here, afforded a new method of bathing. It combined compressed air and atomized water with triggered-in solvents. The kinetic force of the high-pressure air stream was utilized without the skin-damaging effect unavoidable in high-pressure needle-pointing of water streams. Generalizing from his Navy experience, in which engine room greases on the skin were almost unnoticeably removed by wind and fog on deck, Fuller reasoned-and later demonstrated-that the feeding of atomized water and air at high pressure on the skin surface would accelerate the surface oxidation, and release the surface cells themselves, along with the attached dirt.

Research students at the Institute of Design, Chicago, in 1948 testing the Fog Gun. (Subsequent experiments were conducted at Yale and other universities.) A one-hour massaging pressure bath used only a pint of water. If fog gun bathing were done in front of a heat lamp, all the sanitary and muscle-relaxing effects of other types of bathing could be effected without the use of any bathroom. Since there were no run-off waters, tons of plumbing and enclosing walls could be eliminated, and bathing would become as much an "in-the-bedroom" process as dressing. Fuller holds that the other functions of the bathroom may be effected by odorless, dry-packaging machinery, employing modern plastics, electronic sealing, dry-conveying systems.



3. Aerosols

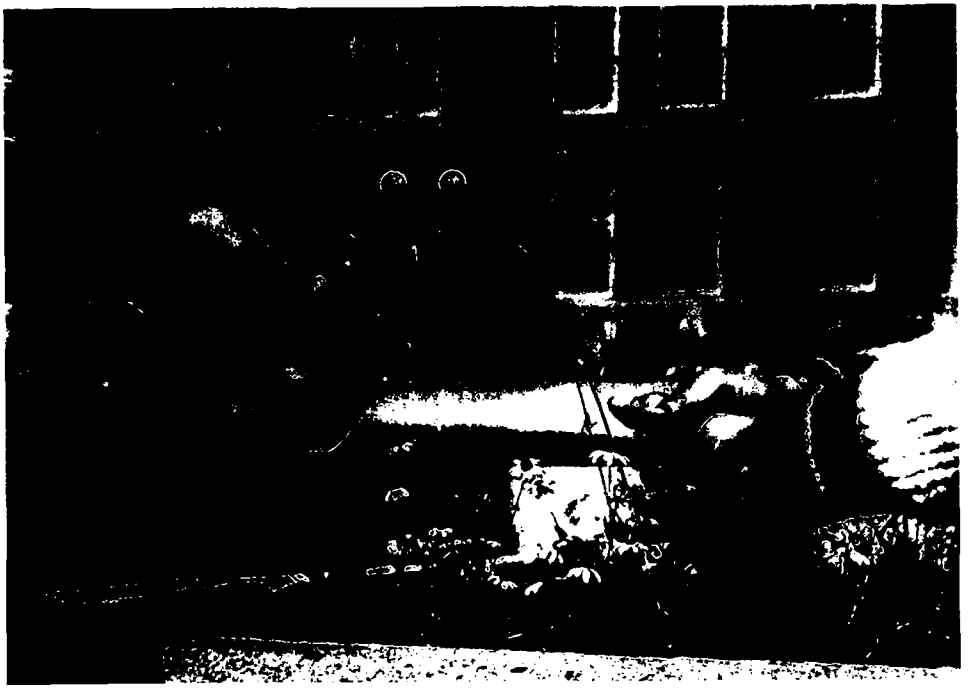
Aerosol sprayers come under the category of pneumatic atomizing techniques and are included here only because they are a special case. They are cans containing a fluid and a propellant, which is a type of gas which compresses to a liquid. The top of the can has a nozzle which releases the fluid mixed with the propellent, but the propellant, a fluorocarbon, bursts into a gas when released from the can. The nozzle is usually a two-fluid internal-mix pneumatic type. The contents have been mechanically stored in the container.

The major objection to aerosols is the propellant's effect on the environment. It has been found that fluorocarbons when released float up to the stratosphere and, when mixed with the ozone layer, convert ozone to oxygen, thereby thinning the protective ozone shield and allowing the penetration of the earth's atmosphere by lethal ultra-violet rays which are believed not only to cause skin cancer but, perhaps more importantly, the destruction of food chains, of normal plant growth; and can, moreover, cause seasonal changes which effect our food source.

4. Atomization: Summary

Atomization of a liquid by spray nozzles is a highly developed technology. Spray control is achieved by varying nozzle details and pressure. Finer sprays can be achieved with higher pressures and smaller orifices. But, as a result, the velocity decreases. The range of atomization is from relatively fast-moving large droplets to relatively slow-moving small droplets. The optimum being sought for a shower-bath spray is in between i.e. fast-moving small droplets. Fast-moving for dependable coverage and small droplets for the conservation of water.

3. Early Work



Handwashing with the Japanese "Diaspray" atomizer - 111 times with a liter of water !

In 1971, the Minimum Cost Housing Group, in its first year of research choose to investigate the world-wide problem of domestic water shortage. Buckminster Fuller's early work with the Fog Gun (see p. 10) suggested a direction for proceeding. The first work was concerned with manual sprayers. A number of different types of manual spray equipment and hand-held atomizers were collected and tested for pressure fineness of spray, and rate of water utilization. Also. a number of different fog nozzles and adjustable garden spray nozzles were tested. We were interested in finding atomizers that gave the finest spray coupled with the minimum water used, and minimum physical energy.

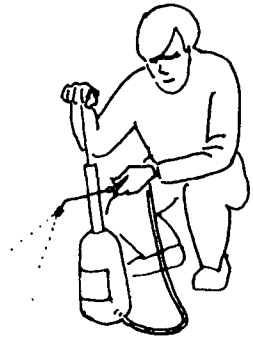
Later, in the ECOL house (1972) , an experimental integrated alternative energy house, the bathroom was equipped with an atomized handwasher using a footpedal, much like those found in hospital operating rooms.

Recent work has concentrated on the design of a shower device using components readily available in the industrial market. Further investigation was involved with the nature of atomization as well as with the question of washing related to health.

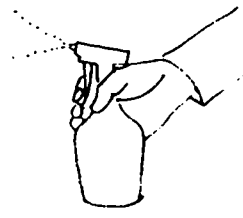
This work presents the combined research studies of the Minimum Cost Housing Group with respect to water conservation and washing. Investigation of sanitation and waterless toilets is included in the book entitled Stop the Five Gallon Flush[8].

* DIASPRAY
  Japan $0.69
  Volume: 0.2 litre (0.5 gal.)
  Height: 13 cm (5")
  Capacity (flow rate): with regular spraying
  2.2 litre/hr. (0.5 gal/hr.)

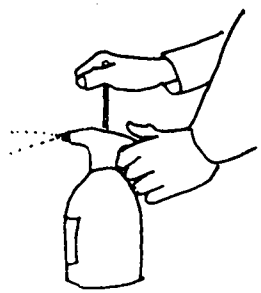
*SUPERSPRAY 30
  U.K. $10.00
  Volume: 5.5 litre (1.4 gal.)
  Height: 70 cm (27")
  Capacity(flow rate): at .34 atmos (5psi)
  (20 strokes of pump):
  Standard nozzle: lo.4 litre/hr. (2.9 gal./hr.)
  F-20 nozzle: 5.7 litre/hr. (1.5 gal/hr.)



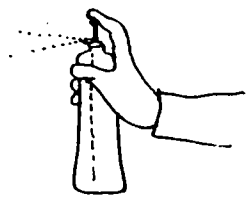
* SUPERSPRAY 20
  U.K. $2.00
  Volume: 0.6 litre (.15 gal.)
  Height: 23 cm (9")
  Capacity (flow rate): with regular spraying
  5.5 litre/hr. (1.4 gal./hr.)



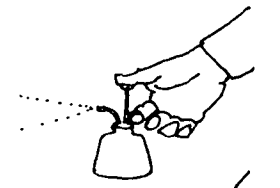
*SUPERSPRAY 10
  U.K. $7.00
  Volume: 1.0 litre (0.26 gal.)
  Height: 30 cm (12")
  Capacity (flow rate): at .34 atmos (5 psi)
  (17 strokes of pump) 5.7 litre/hr. (1.5 gal./hr.)



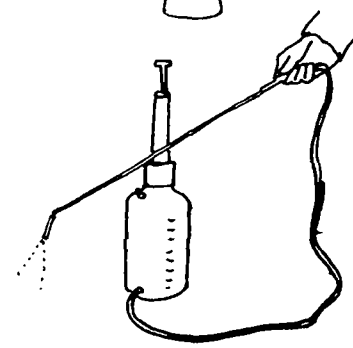
* WINDEX
  Canada $0.20
  Volume: 0.6 litre (.15 gal.)
  Height: 28 cm (11")
  Capacity (flow rate): with regular spraying
  2.2 litre/hr. (.58 gal./hr.)



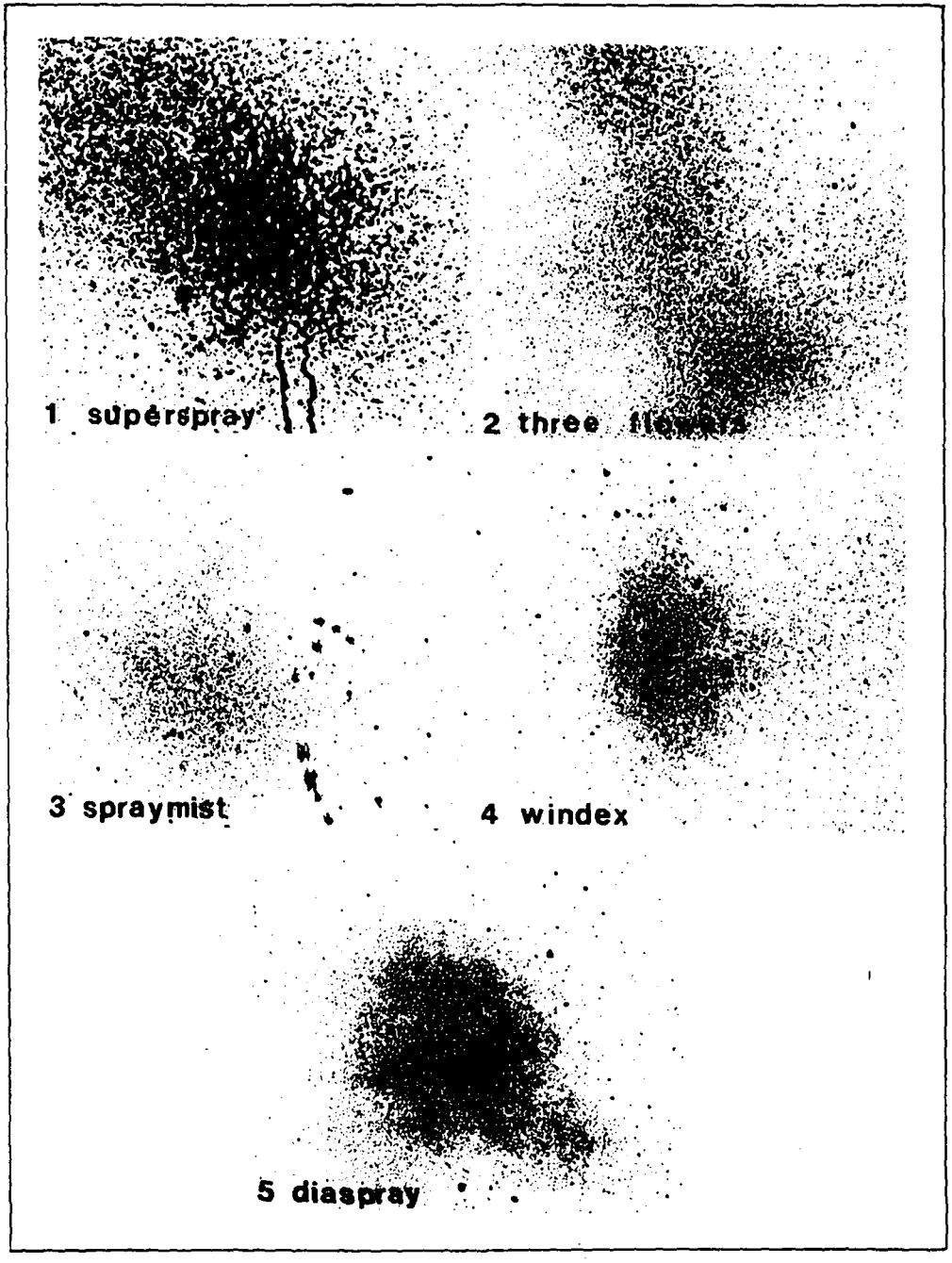
* THREE FLOWERS
Hong Kong $1.80
Volume: 0.3 litre (.07 gal.)
Height: 15 cm (6")
Capacity (flow rate): with regular spraying
8.2 litre/hr. (2.2 gal./hr.)

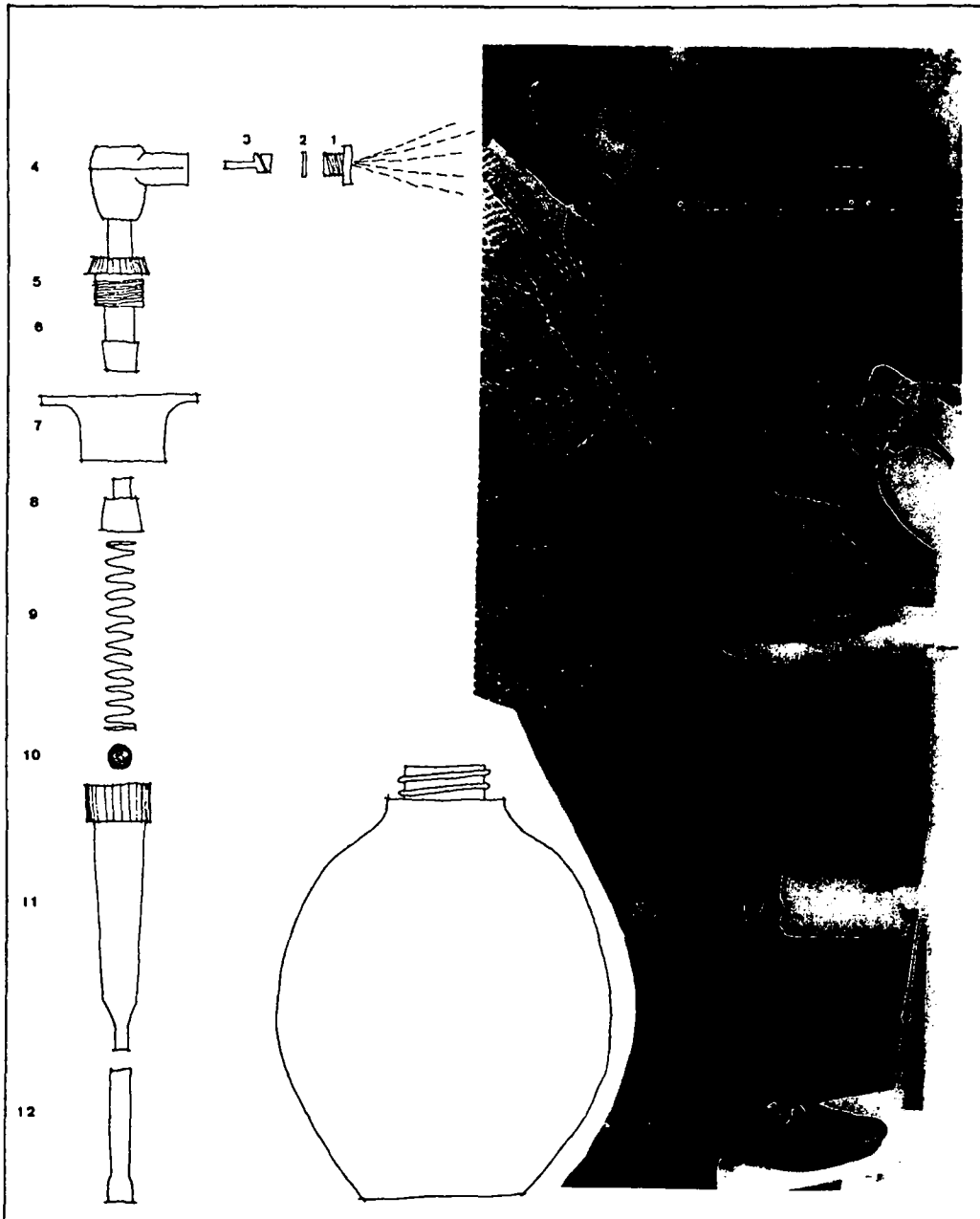


* KILLASPRAY
U.K. $18.00
Volume:8.0 litre (2.1 gal.)
Height: 75cm (30")
Capacity (flow rate): at .34 atmos (5 psi)
10.4 litre/hr. (1.5 gal./hr.)

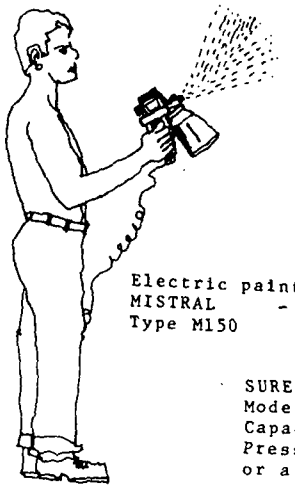


	*DIASPRAY	*SPRAYMIST	*THREE FLOWERS	*WINDEX
100 strokes	60 ml.	130 ml.	250 ml.	50 ml.
Per Stroke	0.6 ml	1.3 ml.	2.5 ml.	0.5 ml.
Water required for washing hands	10-20 strokes 6-12 ml.	7-14 strokes 9-18 ml.	4-8 strokes 10-20 ml.	12-24 strokes 6-12 ml.
Average	9.0 ml.	13.5 ml.	15 ml.	9.0 ml.
Number of hand-washings with one litre of water	111	74	66	111
Number of strokes per minute	62	72	55	75
Amount of water spray per minute	37 ml.	93 ml.	137 ml.	37 ml.
Amount of water spray per hour	2.2 l.	5.5 l.	8.2 l.	2.2 l.

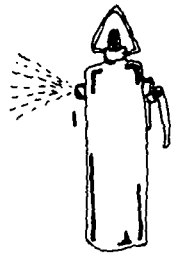

1 superspray
2 three flowers
3 spraymist
4 windex
5 diaspray



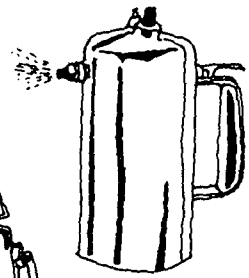
DIASPRAY



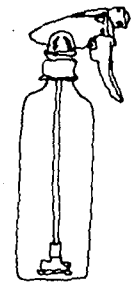
Electric paint sprayer.
MISTRAL - $100.00
Type M150



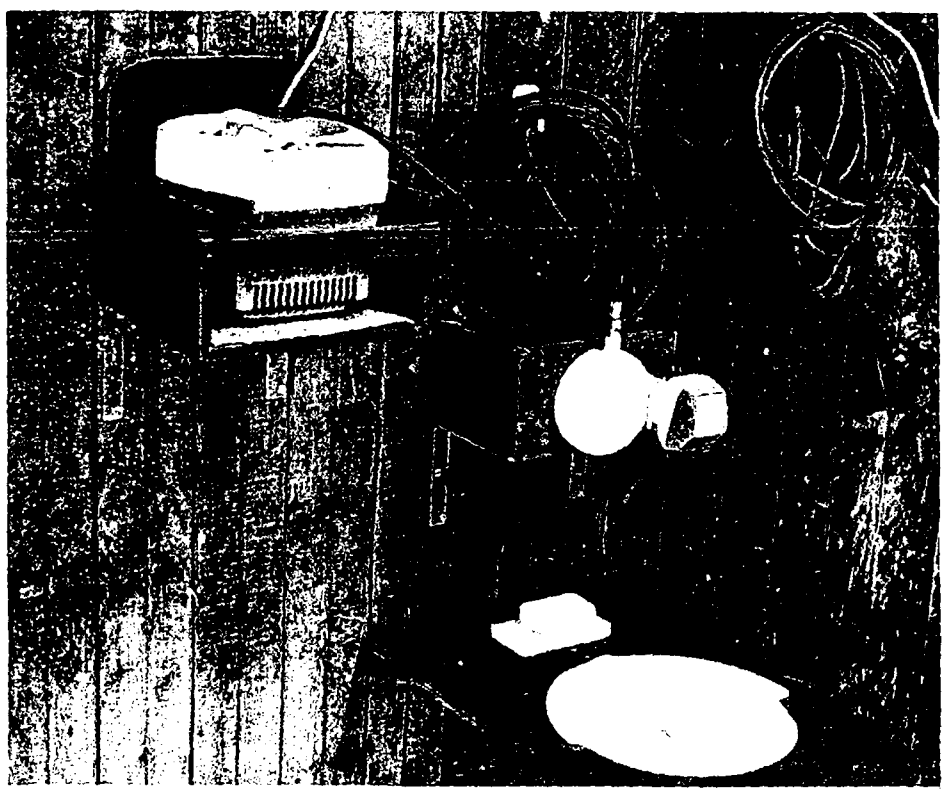
SURESHOT
Model "C" - $9.55
Capacity: 6 oz.
Pressurized with a garage tire pump
or a hand-pump. Re-usable.



SURESHOT
Model "A" - $22.30
Capacity: 40 oz.



Common atomizer.



Black & Decker Paint Sprayer adapted to hand-washing use in the MCHG workshop

There have already been a number of small field trials on the feasability and the acceptability of mist washing. These have been thanks to the iniative of Alvaro Ortega, a Colombian architect who has worked for a number of years for the United Nations, and who was also the founder of the Minimum Cost Housing Group, in 1971.

The first application took place in Peru in 1970 as part of the PREVI (Proyecto Experimental de Vivienda) project, a UN sponsored program in experimental housing. A number of pesticide sprayers (Killaspray type, see p.14) were distributed to people in Lima who did not have water supply. Further field applications took place in Manila, the Philippines, in 1976 (see photo below) using the Diaspray hand-held washer. The most recent application has been in the United Arab Emirates, where a considerable number of piston-type pesticide sprayers has been distributed to immigrant workers. The result of this recent experience is favourable and indicates that public acceptance of this novel form of washing is less problematic than skeptics would have us believe.

There is a great potential for improving health in areas where water supply is scarce, or expensive. Experience with popular use of mist washing is limited but so far indicates that if the devices are inexpensive and convenient to operate they will be used (especially for washing children), and that the advantage of using a very small quantity of water is readily appreciated.

4. Nozzles

1. Nozzles

The nozzles reviewed are simple ones. Complex types such as the two-liquid and solid vehicle ones used in the paint and food industries have been omitted since the requirement is for a simple technology for developing countries and at low cost. However, those tested range from a garden hose nozzle to household sprayer nozzles.

The problem was to find *a)* a nozzle of adequate capacity to insure a given duration of flow with a minimum supply of water and *b)* whose spray velocity was sufficient to reach the skin surface from a comfortable distance (about 8") and *c)* of sufficient impact to remove soapy water in the rinsing process. To get the skin wet does not require much impact, but convenient distance of nozzle from skin is desirable. To remove the suds requires a more forceful spray.

The nozzle tests were based on matching the performance of the nozzle used in the NASA Skylab shower. Using a duplicate nozzle we were never able to achieve that standard, possibly because the NASA nozzle performance was based on zero-gravity; however our main goal was to sustain pressure to give a 5 to 10 minute shower using as little water as possible.

For air pressure, an electric compressor was used, and some tests were repeated with a bicycle pump. The compressor had a constant pressure of 2.0 atmos (about 20 psi). Eighteen strokes on the bicycle pump produced a pressure of 3.3 atmos (about 48 spi) but after 12 minutes it was 1.7 atmos (about 25 psi).

2. Test Equipment

The test equipment comprised:

1 Black and Decker Paint Sprayer compressor -
This was rated at 9.2 amps, 115 volts, and the pressure was capable of reaching 4.0 atmos (60 psi), although we were using about 1.3 atmos (20 psi).

1 Volkswagon teflon window washer tank -
Having a volume of 2.5 liters (.55 gallon), this was filled with 1 or 2 liters of water.

1 1/4" vinyl hose to fit over the nodes on the VW tank. 1/8" hose was used for tests on the NIAGARA and ESTRA nozzles.

1 Chapin garden hose hand control valve with off-on device.
This was adapted to receive all except the NIAGARA and ESTRA nozzles which had built-in hand controls.

1 Stopwatch for timing the flow.

Nozzles:

1. Black & Decker Paint Sprayer
2. Spraying Systems Whirljet 1/8A-.5
3. Bete P20
4. Bete W5080F
5. Bete F200
6. Niagara 71
7. Steinen TM21
8. Steinen TM051
9. Estra 6400
10. D.B. Smith 147

3. Specifications

Specifications assumed for selecting a water nozzle:

1. Capacity (flow rate: 0.25 liters/minute (.06 gal./min.)
2. Spray pattern: hollow cone
3. Material: brass
4. Connection: 1/2" o.d. male
5. Orifice: 1/64" to 1/16"
6. Right angle head
7. Spray angle: 80^{o} - 90^{o}
8. Atomization (droplet) size: "Spray" - 100-1000 microns (see p.8 for definitions)

Determinants for above specifications:

1. Capacity (flow rate) - based on NASA standard: 2.5 liters/10 min. (.66 gal./9.7 min.)
2. Spray pattern - hollow cone preferred over solid
3. Material - brass selected for its durability and non-corrosiveness
4. Connection - for convenience. In some cases nozzles were available only in this size
5. Orifice - small orifice helps produce fine droplets
6. Right angle head - convenient for directing spray
7. Spray angle - narrow angle better to conserve water and prevent overshoot at 8".
8. Atomization (droplet size) - this should be between "sprinkle" which is over 1000 microns, and "mist" 10-100 microns, to wet easily and quickly.

4. Preliminary Tests of the Atomized Water Device

First test of the atomized water device: December 5, 1975.

Set-up:	Black & Decker compressor Plastic jug of 4.5 liters (1 gal.) 1/4" vinyl hose Brass fittings at hose ends Bete W5080F Nozzle Chapin garden hose control valve.
Procedure:	Jug filled with 2 liters (0.5 gal.) water Jug sealed Compressor turned on Sprayer functioning okay, but flow appears very fast. About 1 liter/minute (0.25 gal./min.) After about one minute, jug had swelled to a rounded form, then burst.
Conclusion:	Test demonstrated that the device will work. Jug too weak to withstand 1.3 atmos (20 psi) air pressure from compressor. Nozzle performed well. Hose control performed well. Hose performed well.

A second test, December 12, 1975 substituted for the water tank a windshield water tank made for the Volkswagon Bus. The tank walls were 6.3 mm. (1/4") thick, and could contain 2.5 liters (0.6 gal.) of water. It proved to be sufficiently strong to withstand the pressure of 1.3 atmos (20 psi) and was able to hold some pressure for at least 2 months.

5. Record of Tests

Record of tests of nozzles for capacity (flow rate). Tests were made between December 1975 and July 1976. Method: Tank was filled with 1 liter of water, compressor was turned on and spray was timed until all water was out of the tank.

6. Nozzle Test Results

The results of the tests showed that nozzles with smaller orifices (as on the Niagara and Estra) helped sustain the flow of water for a longer period than nozzles with larger orifices; however, the quality of spray was finer with the small orifice and the impact, less. Nozzles with larger orifices yielded capacities too high for a workable shower.

The goal criteria of 1 liter in 5 to 8 minutes (0.25 gal./5min.) was achieved, but at the cost of very low impact.

The Bete P20 nozzle performed at .33 liters/minute (.07 gal./min.) but its projecting pin would disqualify it on the basis of safety to the bather as well as its liability to damage. However. a protective collar-cap attached to the nozzle would be a simple corrective. Although having very good capacity, the Estra's spray impact was less satisfactory in removing sudsy water.

The best performance in both impact and duration was found in the Steinen TM501 and the Bete F200 nozzles.

7. Reassessment of Goals

Since nozzles with the required range are rarely manufactured, perhaps the use of standard components is impractical, and since the goal of a nozzle capacity of .25 liters/minute (.05 gal./min.) i.e., a shower using 1 liter (.22 gal.) of water and lasting about 8 minutes, is too extreme, the goal should be revised. A more practical standard would be to employ 3 or 4 liters (.6 or .8 gal.) of water for showers lasting about 8 minutes. This would require a nozzle with the capacity of .5 liters/minute (.00 gal./min.) which is readily available from manufacturers. The water-saving would still be enormous: a saving of over 90% of current average water quantity used for showering (50 liters or 11 gallons).

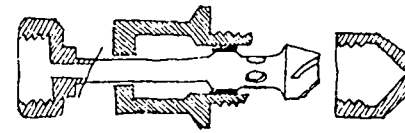
The other alternative, and one which would keep the original capacity goal, and perhaps lower still more the cost, would be to develop Niagara and Estra type plastic nozzles. This, of course, requires mechanical engineering design which would be the next step in the development of atomized shower devices. This study has only explored the possibilities and merely sought to establish standards for atomized showering.

Nozzles in order of testing	Test 1	Test 2	Test 3	Capacity liters/min	Water used in hypothetical 5 min. shower
D.B.Smith	56 sec.	1min.5sec.	50sec.	1.o	5.0 liters
Spraying Systems Whirljet 1/8A.5	2min.19sec.	2min.18sec.	2min.18sec.	.43	2.17 "
Bete W5080F*	1min.1sec.	1min.	1min.	1.4	7.0 "
Bete P20	2min.18sec.	3min.	3min.	.36	1.8 "
Niagara 71	10min.45sec.	10min.30sec.	13min.	.08	.435 "
Estra 6400	6min.	4min.15sec.	7min.45sec.	.17	.86 "
Black & Decker Paint nozzle	59sec.	1min.	1min.	1.0	5.0 "
Steinen TM21	2min14sec.	2min18sec.	2min18sec.	.43	2.17 "
Steinen TM501	3min.30sec.	3min.25sec.	3min.30sec.	.3	1.5 "
Bete F200	2min.35sec.	2min.15sec.	3min.	.38	1.92 "
* NASA claim for this nozzle				.25	1.25 "

✸ D.B. Smith #147

Manufactured by:
D.B. Smith Co.,
Utica, N.Y.

Type: hydraulic swirl nozzle with grooved entry.
Orifice Size: approximately 4.76 mm. (3/16")
Spray Pattern: hollow cone
Capacity (flow rate): as tested: 1 liter/min.
mfgr's claim: not available
Spray Angle: 75°
Atomization size: sprinkle (10000 microns)
Impact: very good



This nozzle is adjustable from full spray to closed. It is primarily used for garden houses. Not satisfactory for capacity.

✸ Steinen TM051

Manufactured by:
Wm. Steinen Mfg.Co.
Parsippany, N.J.

Type: hydraulic
Orifice Size: .59 mm. (0.28")
Spray Pattern: hollow cone
Capacity (flow rate): as tested: .3 liter/min.
mfgr's claim: .28 liter/min.
Spray Angle: 70°
Atomization Size: spray (100-1000 microns)
Impact: good

This nozzle performed well in both flow rate and spray force. Satisfactory.

✸ Bete P20

Manufactured by:
Bete Fog Nozzle Inc.
Greenfield, Mass.

Type: hydraulic
Orifice Size: .59 mm (.02")
Spray Pattern: fog
Capacity (flow rate): as tested: .33 liter/min.
mfgr's claim: 0.27 liter/min.
Spray Angle: 90°
Atomization Size: Mist (10-100 microns)
Impact: good

The projecting pin on this nozzle which is easily subject to damage disqualified it for shower use.

✱ Whirljet 1/8A.5

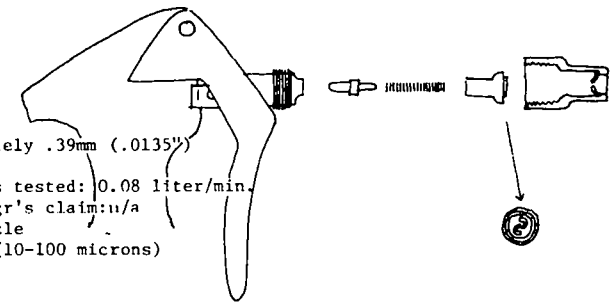
Manufactured by:
Spraying Systems Co.,
Weaton, Ill.

Type: hydraulic swirl nozzle with tangential entry.
Orifice Size: 1.2 mm. (3/64")
Spray Pattern: hollow cone
Capacity (flow rate): as tested: .4 liter/min.
mfgr's claim: .27 liter/min.
Spray Angle: 58°
Atomization Size: Spray (100-1000 microns)
Impact: good

This nozzle is the simplest in construction. The body has one eccentric hole. The cap has a central hole. Not satisfactory for capacity.

✱ Niagara #71

Manufactured by:
FMC,
Colmar, Pa.

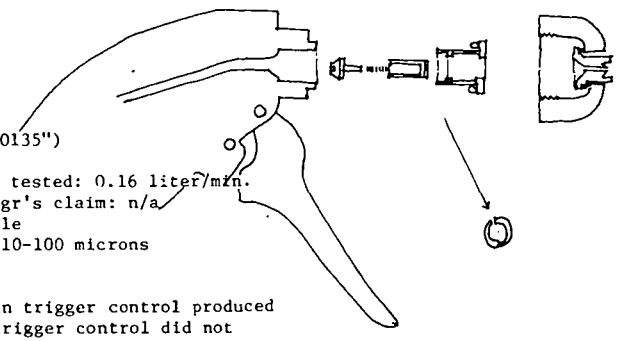


Type: rotary disc
Orifice Size: approximately .39mm (.0135")
Spray Pattern: fog
Capacity (flow rate): as tested: 0.08 liter/min.
mfgr's claim: n/a
Spray Angle: 30° at nozzle
Atomization Size: mist (10-100 microns)
Impact weak

Like the Estra this nozzle has a built-in trigger control, which did not function. Impact not satisfactory.

✱ Estra 6400

Manufactured by:
The Afa Corporation,
Miami, Fla.



Type: rotary disc
Orifice Size: .39mm. (0.0135")
Spray Pattern: fog
Capacity (flow rate): as tested: 0.16 liter/min.
mfgr's claim: n/a
Spray Angle: 30° at nozzle
Atomization Size: mist (10-100 microns
Impact: weak

This nozzle with built-in trigger control produced the slowest spray. The trigger control did not function under mechanical pressure of 1.3 atoms. (20 psi.) Impact not satisfactory.

✱Steinen TM21 - 1/8"

Manufactured by:
Wm. Steinen Mfg. Co.
Parsippany, N.J.

Type: hydraulic
Orifice Size: 3.17 mm. (1/8")
Spray Pattern: hollow cone
Capacity (flow rate): as tested: 0.4 liter/min.
mfgr's claim: .54 liter/min.
Spray Angle: 90°
Atomization Size: spray (100-1000 microns)
Impact: good

This nozzle did not prove satisfactory in flow rate.

✱Bete W5080F

Manufactured by:
Bete Fog Nozzle Inc.
Greenfield, Mass.

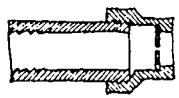
Type: hydraulic
Orifice Size: 2.38 mm. (3/32")
Spray Pattern: solid cone
Capacity (flow rate): as tested: 1.4 liter/min.
mfgr's claim: 1.35 liter/min.
Spray Angle: 80°
Atomization Size: Spray (100-1000 microns)
Impact: good

This is the same type of nozzle used on the NASA Skylab. We were not able to achieve the capacity claimed by NASA, possibly because they used it under zero-gaevity conditions. No satisfactory for capacity.

✱Bete F200

Manufactured by:
Bete Fog Nozzle, Inc.,
Greenfield, Mass.

Type: hydraulic
Orifice Size: .59 mm.(.02")
Spray Pattern: fan
Capacity (flow rate): as tested: .33 liter/min.
mfgr's claim: .135 liter/min.
Spray Angle: 60°
Atomization Size: spray (100-1000 microns)
Impact: very good



This nozzle performed best in capacity and impact. The advantage of the fan spray pattern is its ability to move soap suds on the skin surface. Satisfactory.

5. Hygiene

1. Bathing and Health

Bathing has usually been regarded as related to health but it is also a pleasure, a social activity, a ritual. Baths were used for cooling and warming. The Turkish steam bath, the Scandinavian sauna, the American Indian sweat, were intended to open the pores of the skin and to promote sweating, thereby removing poisons and dirt and leaving one feeling exhilarated.

The bath as it is now practiced, except in Japan, uses soap, leaves the dirt in the bathwater, from which the bather emerges with some of the dirt clinging to his skin (the Japanese bather rinses outside the tub). Showers are a relatively recent invention, and an improvement, hygienically, on the contemporary bath. In a shower, the dirt is washed away down the drain while the bather is continuously wet with clean water. Also, the shower is more stimulating to the skin, because of the impact of a needle-like spray. This mild massage leaves the bather feeling invigorated. Another advantage of the shower over the tub is the ease with which hairwashing is accomplished.

In both the bath and the shower, the purpose is to use clean water (with soap) to produce clean skin. But what are clean water and clean skin? The measure is relative, so the concept is deceptive. To understand this relativity, we must look to the science of Microbiology. Clean water is often measured by the amount of E.Coli bacteria present. Skin cleanliness has not been so easily measured.

Reports of water shortages seldom refer to the effects on bathing habits. Most deal with cooking and drinking needs. In many developing countries, bathing is carried out in nearby rivers and ponds, often where floods alternate with droughts. In some cases villages are not near bodies of water and bathing is perfunctory, most of the bought water being used for cooking and drinking.

Most diseases associated with the drinking of polluted water can also be got from bathing with that water since it has the opportunity of entering all of the nine orifices of the human body as well as through sores and cuts. Pores of the skin also are likely to absorb pathenogenic microbes. A case in point is seen in Hassan Fathy's book Architecture for the Poor:[9] "All the water of Egypt is infested with cercaria, or bilharzia worms, and every peasant works and bathes in this infested water. In the hot summer everyone bathes in the canals and ponds. Children especially paddle and splash about in every patch of water they can find, in ditches, puddles and stagnant ponds. Since it is practically certain that anyone who stands for ten minutes in an Egyptian canal will contract bilharzia, it is not surprising that the incidence of disease is so high."

Even if disease does not enter the body in this way there is still the possibility of disease resulting from lack of washing. A USSR space flight hygiene report on prolonged restriction of washing makes this clear: "An active source of contamination of the skin is the skin itself. Products excreted by the sweat and sebacceous glands and also particles of desquamated epithelium and hair constitute an important source of contamination of the skin. The samples of microflora on the test subjects' skin surface and underwear consisted mainly of saprophytic species: Staphylococcus epidermidis, staphylococcus albus, diptheroids, and Sarcina. The test subjects developed (after 60 days) skin diseases which are fairly widespread under normal conditions of life. The commonest disease encountered was follicilitis mainly in the region of the buttocks and thighs. Other diseases found were: furunculosis; streplococcal interigo; acne vulgaris; dermatitis and fungus diseases of the feet."

2. What is Clean Water?

The WHO Guide to Sanitation in Natural Disasters[10] describes water treatment in emergency situations: "The purpose of disinfection is to kill pathogenic organisms and thereby prevent water-borne diseases. The disinfection of water can be accomplished by boiling or by chemical treatment. Chlorine and chlorine-liberating compounds are the most common disinfectants.

Until the laboratory facilities of urban water supply systems can be restored to normal operations, complete tests of water samples should be made at laboratories in the vicinity of the disaster area. The most important tests to be carried out under emergency and field conditions:

1. determination of residual chlorine (free and combined)
2. bacteriological examination for coliform bacteria.
3. determination of hydrogen-ion concentration.
4. determination of type of alkalinity."

Clean water is a relative term involving chemical and bacterialogical quality and quantity. The standard, for disease prevention, is the count of E. Coli present - a bacteria found in the typical human faeces. The following table shows the relative amounts permissable and desirable.

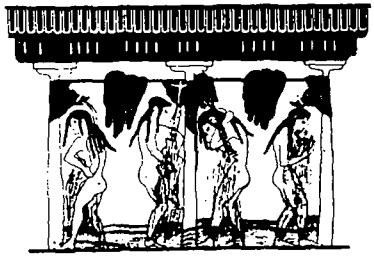
Surface Water Criteria for Public Water Supplies

	Microbiological factors and fecal coliforms (E. Coli)	Count of coliform organisms (total)
	E. Coli	Total Coliforms Present
permissable count	2,000/100	10,000/100
desired count	20/100	100/100

NOTE: *read as* 2,000 colonies of E.Coli / per 100 cubic centimeters of water

and 10,000 colonies of combined pathogenic and non-pathogenic organism / per 100 cubic centimeters of water

From Report on Commission on Water Quality Criteria, 1972 USA[11]



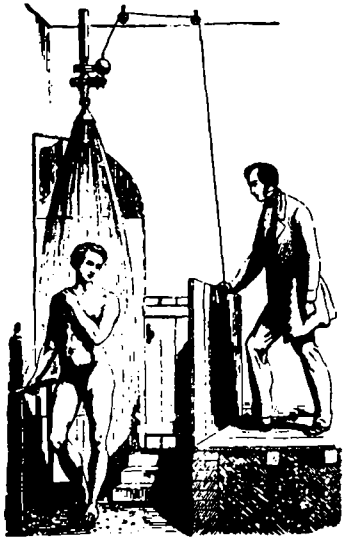
3. Microorganism in and on Human Beings

Frobisher and Fuerst in Microbiology in Health and Disease[12] describe microorganisms' relation to the human body: "Numerous microorganisms find their optimum (and for several pathogenic species their only) habitat in or on the bodies of man or of animals. The healthy human body harbours millions of micro-organisms on the skin, in the mouth, eyes, ears, genitourinary tract, and in the intestine, in short on every surface that comes in contact with the outside world with respired air or with food. The human body is a complete ecosystem.

Most of these microorganisms rarely or never cause disease under normal conditions but some may, under certain circumstances (e.g. in wounds or after surgery) gain entrance to the deeper parts of the body, where bacteria are not usually present and produce what we call an infection. Each region of the body in contact with the exterior normally has its characteristic microorganisms.

The skin carries large numbers of bacteria, picked up from the various things with which it comes in contact. In addition, STAPHYLOCOCCUS AUREUS, the common cause of boils, carbuncles, breast abscess, and other conditions is found at times in the hair follicles and sweat glands. The skin cannot be made absolutely sterile even with the most thorough scrubbing and the application of antiseptics because although the bacteria in the outer layers of the skin can be removed, it is impossible to get rid of those in the deeper layers and in the sweat and sebaccous glands, hair follicles and so on.

The mouth and throat constantly contain numerous kinds of microorganisms aided by the warmth and moist-ure present, and bits of food and desquamated epithelium around the teeth provide nourishment. The normal conjunctivae usually usually contain bacteria of a harmless kind. This is also true around the genitalis. For example, the vagina normally contains certain distinctive nonpathogenic bacteria. Prominant among the intestinal bacteria is the relatively harmless ESCHIRICHIA COLI which is viewed as an index of fecal pollution when found in drinking water. A group called enterococci are always found present in faeces and fresh sewage, and is sometimes used instead of E. COLI as an indicator organism of fecal pollution."



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Bacterial flora of the normal skin has been classified as "transient" and "resident". "Transient" flora is subject to removal by mechanical and chemical techniques. "Resident" flora is limited to only a few species: acnes, micrococcus epidermis, staphylococcus albus aureus. Transient pathogenic bacteria may become residents. Time helps.

Viable skin has the capacity to destroy many orgnaisms implanted on its surface. The bacterial action of the skin has been attributed to pH and also to the presence of fatty acids and soap fractions.

The normal skin surface has a pH of from 5 to 6. The acid reaction has been attributed to excess sweat, which has a similar pH and to lactic acid which accumulates as the sweat evaporates.

The amino acids released or discarded in the formation of keratin may also contribute to the low pH of the skin surface. Fatty acids and soaps may contribute to the sterilizing action of the skin. Fat soluble extracts of the skin are bacteriological and removal of the surface lipids with either produces a significant decrease in the bacteriocidal action of the skin." - Medical Technology Anti-Microbial Agents - Hedgecock 1967.[13]

4. Washing with Atomized Water

NASA research has been very helpful in supplying relevant information on the subject of hygiene. Their primary concern was the quality of cleanliness achieved with atomized water. Portions of the NASA report Space Shower Habitability Technology[14] follow:

"There are three items that are basic for cleansing the body of foreign matter, dead skin and body secretions:

1. a mechanical action which helps to dislodge and break down the foreign matter and dead skin.
2. a chemical agent which breaks down and emulsifies the oils.
3. a solvent to pick up and carry off the accumulated materials.

This is accomplished by using the hands or a washcloth for a massaging and lathering action, soap for an emulsifier, and water as the solvent.

The cleansing agent used must cleanse the body and also control the bacteria on the skin. Presently there are emulsifiers available that have varying chemical compositions. These different agents act as biodegradable soaps that do not halt bacterial growth and can be broken down by bacteria, biostatic soaps which control the growth of bacteria, and as biosidal soaps which actually deactivate the bacteria. (A shower is generally described as refreshing and revitalizing. To enhance this feeling, the cleaning agent should not only help control bacterial growth but also give a feeling of cleanliness after each shower.) Ordinary bar soaps were not considered because of their high sudsing and their toxic effects on the eyes. Ideal cleansing agents should not be toxic on the body, should not dry out the skin, should not sting or irritate the eyes, and should not cause internal toxicity." The NASA Skylab designers were particularly concerned with the ability of the atomized shower to remove bacteria.

5. Bacterial Removal

Samples of bacteria were taken to determine what types were added to the shower waste water, what types were found on various parts of the body, and to examine the suitability of showering to remove bacteria from the body. Samples of bacteria were taken of influent shower water and from the left axilla, the groin, and between the toes, both before and after showering. A definite ten-fold reduction of bacteria in the groin and toe region of the test subject occured when the subject washed, using pHisoHex as a cleansing agent. A definite seven to ten-fold reduction of bacteria occured in the groin and toe when the subject used Miranol as the cleansing agent.

Not all the bacteria were removed from the subject in the actual showering process, as demonstrated by the effluent water samples. A good portion of the bacteria was removed in the toweling (drying) off process where the scaly skin was removed taking some of the bacteria with it. Typical bacteria found in these tests were E. Coli, staphylocuccus, bacillus, and streptococcus.

A definite correlation exists between the way a person showers and the quantity of bacteria removed. The difference in the amount of total bacteria removed in the showering process is demonstrated between the different methods of bathing by the same subject in replicate showers. The more scrubbing and friction created by the soap or water in washing to break down surface tension, the greater the total number of bacteria recovered (or removed) from the subject. Soap and warm water are definitely required for a person to feel completely clean and comfortable after showering. Greater bacteria removal justifies making soap a requirement in showering."

In a discussion on the question of a standard with Dr.J.L. Meakins of the Department of Microbiology & Immunology of McGill's Medical School, he said there is no specific measurable standard for hand-washing cleanliness prior to surgery. But, he went on to say, classic instructions are for a ten minute scrub particularly of forearm and fingernails. He stresses vigor of scrub over duration. Although rubber gloves are used, they have been known to develop holes, so that any contamination could thereby easily be transmitted.

6. Soap and Other Detergents

What is soap? How does it work? Kenneth Hutton in his book Chemistry[15] gives an analysis of soap as follows: "Soap, which has been known for over 2000 years, is prepared from naturally-occuring fats, such as cotton-seed or linseed oil, soya-bean oil, ground-nut oil, palm oil, and coco-nut oil, by boiling with alkali:

Glyceryl stearate (fat)	+	Sodium hydroxide (caustic soda)	=	Glyceryl hydroxide (Glycerol)	+	Sodium stearate (soap)

$$C_3H_5\ (O.C)\ C_{17}H_{35})_3 + 3NaOH = C_3H_5\ (OH)_3 + 3C_{17}H_{35}\ COON_2$$

Fundamental research work, largely by N.K. Adams on the nature of surface forces, soap films, and so on, let to the conclusion that the soap was attached to the water surface by the ionized group $-C_{O-}^{O}Na^{+}$ and that the long-chain part of the molecule ($C_{17}H_{35}$) i.e.:

$$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2$$

was sticking up in the air away from the surface, because it is water repellent. Most dirt is held on the clothes or hands by greasy substances, i.e. fats; the fats are attracted to the long chain part of the molecule and therefore come off the clothes or hands into the water; there is then nothing for the dirt to cling on to and it also comes away. In districts where the water is hard, a good deal of soap is used in removing calcium from the water. This is because calcium stearate (which is insoluble and so is useless for removing dirt) is formed from the sodium stearate (the soap) until all the calcium compounds have been converted into sodium compounds.

Once the action of soap had been explained it became possible to develop soap substitutes containing a water attracting group at the end of a moderately long water repellent molecule, and the World War II scarcity of fats gave a special impetus to their development. Over a thousand substances have been prepared and patented, while several hundred of them are available in commercial quantities in America and also in Britain: D.10, Teepol, Quix, Fab, Wisk, Tide, and many others are household words. The world consumption of soap and soap products in 1952 was 5,000,000 tons, and of soapless detergents over 1,000,000 tons.

Household soap is a good detergent or cleansing agent, largely because it is a powerful surface-tension reducer. It is a highly effective emulsifier of fats and oils. It thus aids in the mechanical removal of bacteria, especially from oily surfaces like the skin. Many of the currently widely advertised detergents are not soap but surface tension reducers, Tide, Cheer, and Electra Sol (used only in automatic dishwashers) are representative. They have cleaning and emulsifying properties like those of soap, but they are not disinfectants. An important ingredient in most of them was the potent surface-tension reducer alkyl benzene sulfonate ("ABS"). This refused to be decomposed by the microorganisms in sewage disposal plants. The result was pollution of rivers and lakes with detergents as evidenced by excessive foaming, a major problem in sanitary engineering.

Soap, in addition to being a surface-active detergent, is bactericidal to some degree. It is especially effective against TREPONEMA PALLIDUM, the cause of syphillis. This organism is rich in lipids (fats)."

7. Conclusion

NASA's concern for extreme cleanliness may have to do with wanting not to leave pathogenic bacteria on the Moon or in Space. Also, the degree of cleanliness required for surgery is understandable. Perhaps for purposes of bathing we do not need to be so particular about measuring bacteria. As we have seen viable skin destroys organisms implanted on the skin, yet excreted products themselves are a source of contamination. So, for this reason we must control these bacteria. Moreover, where there are cuts or sores the individual is vulnerable to infection by entry of pathenogenic bacteria into the body.

So we are concerned with three things: bacteria control, removing dirt from the body, and the refreshed feeling a shower gives. Needless to say, some kinds of dirt will have to be removed with more water, i.e., grease and stain, for example. But on a regular basis, the atomized water shower performes well by washing away bacteria and normal dirt and sweat.

According to Dr.Vos, of the McGill Medical Department of Immunology and Bacteriology, the abundance of suds in washing is no advantage in removing bacteria. This is important in considering the atomized water shower where low suds soap is preferable over a sudsy soap since the latter uses too much water.

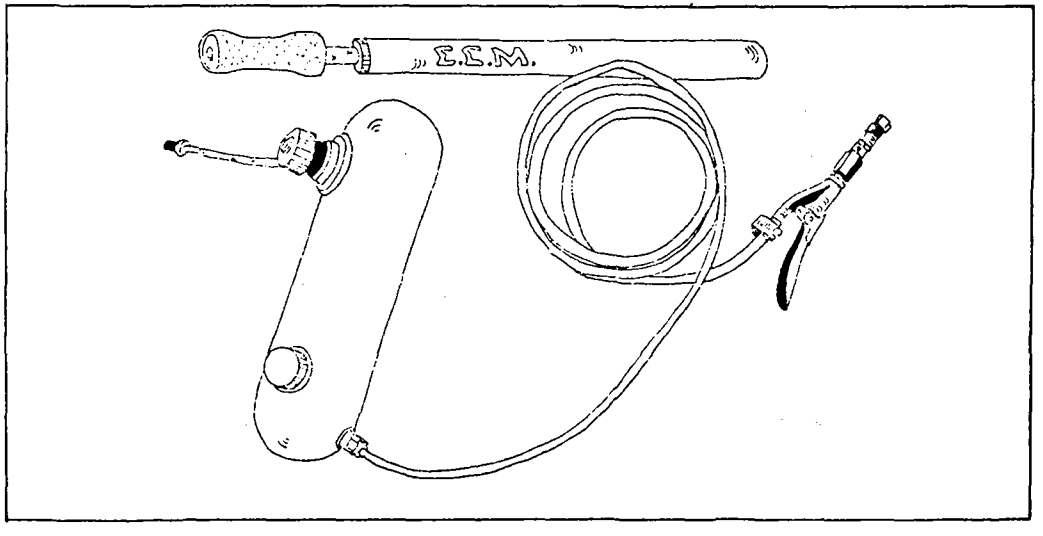
6. Mist Showering

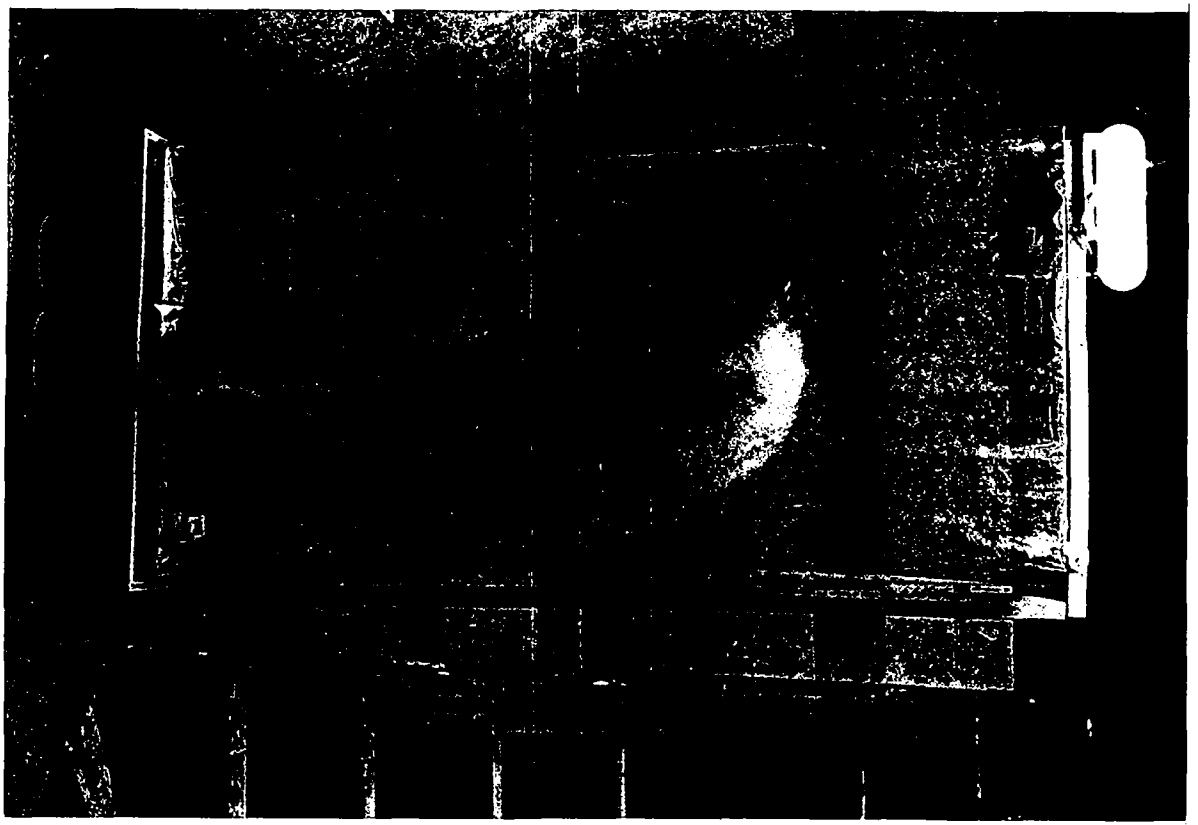
1. Testing the Mist Shower

The first series of tests with atomization concerned hand-washing, both with manually operated atomizers and later with electric sprayers such as the Black and Decker paint sprayer. These experiments proved convincing enough that we felt we could proceed to the next step : a test of full body showering.

A test apparatus was constructed which was also the first step in developing a prototype mist shower that could be manually pressurized. The pressurized container is a Volkswagen window washing reservoir, which incorporates a water outlet tube as well as a pressuring valve that can be connected to the spare tire, or in our case, to a bicycle pump. The water outlet tube is connected to a variety of nozzles.

The procedure is as follows. The reservoir is filled with water (about 2.5 litres). A bicycle pump is attached to the valve and the tank is pressurized with about 20 strokes. The mist shower is now ready to be used.





Mist Showering

NOZZLE TYPE	PRESSURE atmos.	SHOWERING TIME mins.	WATER USED litres	OBSERVATIONS
Whirljet 1/8A.5	1.3	3.5	2.0	*Started by wetting body from face down; then stopped misting and soaped-up. The vinyl hose failed because of water temperature (40°C). Extra water was used to finish removing soap.*
Estra 6400	3.3	10.0	2.0	*Wetting completed after 1.5 mins. Difficulty encountered with removing soap due to falling pressure. Twenty additional strokes given to pump, and rinsing then completed successfully.*
Steinen TM 21	1.3	8.0	2.0	*After wetting and soaping the water was used up before rinsing was completed. Extra water had to be used to finish. Greywater measured and found to be only 0.75 l. out of 2.0 l.*
Steinen TM051	1.3	6.0	2.0	*Wetting, soaping and rinsing were successfully completed.*
Bete F200	2.4	10.0	1.9	*Wetting required as much as 3 mins. The pressure dropped before rinsing was completed.*

2. Conclusions

The performance of the nozzle is the single most important factor affecting showering. The more forceful (i.e.larger droplets) nozzles used water too rapidly, while the too fine droplet nozzles produced a spray too weak to remove soap in the required time. The Steinen TM051 nozzle achieved a good compromise, obtaining a 6 minute shower with 2 litres of water. In addition, the right-angled head proved comfortable for handling and wetting all parts of the body.

Another nozzle that satisfied the requirement is the Bete F200, whose greater impact was more effective than the Steinen TM051 in removing suds. The greater pressure would however require additional pumping.

The normal showerhead uses about 25-30 litres/minute. Special water-saving showerheads with flow restrictors and partial atomization can use as little as 6 litres/minute. The mist shower uses only 0.33 litres, quite a drastic reduction! Of course the mist experience cannot be directly compared to the conventional shower, or even to a "water-saving" shower.

3. Questions and Answers

The general problem was to conserve water by using a nozzle to break up the water into a spray, thereby using a lower volume of water per shower.

The specific problem was to select the proper nozzle. As a hypothetical basis, at the start, we used the performance of the NASA whole body shower. NASA claimed to shower a bather in 9 minutes with 2.2 liters (0.5 gallons) of water, at a pressure of 1.0 atmos (15 psi)[16]. This is a capacity (flow rate) of 0.27 litres/minute (0.06 gal./min.).

We obtained a duplicate nozzle to the one used in the NASA Skylab: the Bete W5080F, but were not able to get the performance claimed. This may be due to the fact that we were using it at gravity one instead of zero gravity as they did. We did, however get near the performance claimed in the manufacturer's catalog: 1.35 litres/minute (.30 gal./min.). This flow rate was too high.

In any case, we knew roughly where to begin the search. We tested several nozzles and finally found a capacity of .03 litres/minute (.11 gal./min.) to be the range of nozzle performance we needed. This flow rate is characteristic of the tangential whirl type nozzle, which has the added advantage of right angle head which when used with the Chapin valve control was comfortable for directing the spray.

The first one we found to satisfy this condition was the Steinen TM051 with a capacity of .135 litres/minute at 1.3 atmos (.03 gal./min at 15 psi). In the showering test it performed well: a 6-minute shower using 2 litres (.4 gal.) of water. The last nozzle tested, the Bete F200, performed even better because its fan pattern spray reduced the time and consequently the amount of water required to remove soapsuds in the rinsing process.

Both of these nozzles are inexpensive (about $3.00) and fairly simple to make.

✸ Did we accomplish what we set out to do?

Yes. The use of atomization for washing and showering for water conservation has been demonstrated. The water saving is 96% of the amount used in a normal shower.

The hygienic properties of showering with atomized water have been demonstrated. The search for equipment already on the market as components for the atomized shower device was also successful. The testing of a device to match the standard of performance (2 litres or 0.5 gallons for a 10-minute shower) established by NASA for the Skylab shower was not reached but served as guide.

The shower stall proved satisfactory, but could have been of lighter weight construction for portability and storage option. However, its drain and grey water collector did fuction well.

✸ How does it feel to use an atomized shower?

The atomized shower produces a different sensation from the normal shower. Although the device is similar to the telephone shower which can reach close to all parts of the body, the spray impact is much less, so the needle-like massage is missing and a softer flow of water is felt since the droplet size is finer. During rinsing, the soap comes off more slowly and sometimes must be wiped off with the help of a cloth or sponge since the weaker impact spray does not move the suds as fast as with the normal shower. But on completion, one has the same exhilaration and clean feeling as after the normal shower.

Perhaps it could best be compared to a gentle rain in contrast to a driving rain.

✸ What further advantages does the atomized shower have?

The concept of a plumbingless bathroom emerges. Although no piping for water supply nor sewer hook-up for waste discharge are present, the little waste water which does remain (grey water) is recycleable for garden irrigation or for cooling roofs or for fire-fighting reservoirs.

The water-saving shower and the elimination of water discharge to a sewer serves as environmental protection and energy conservation. Less fresh water for showering saves energy in treatment and plumbing. Less hot water is used; and less sewage is generated, which conserves energy used in heating and treatment. Considering the increasing demand for water, the increasing cost of energy, and increasing water quality requirements demanding better treatment, the implications for conservation by the wide use of such a shower system are very significant, especially when projected over the next few decades.

✸ What are other implications of the atomized shower?

In many parts of the world water supply is a problem and water may be a scarce and expensive commodity. This may be due to climate (arid), geography (Far North), location (sea water only available) or circumstance (spacecraft, mobile homes) and also in emergency situations and where water is polluted. In all these cases the low cost of a portable atomized shower or washing unit has distinct advantages. Existing water supplies could be greatly extended and, where water needs to be brought in, less of it would be required than before.

As a basic necessity of man, not only for survival and maintenance, but also for health resulting from adequate washing and showering, the atomized device would be a boon. This would lead to increasing the individual's energy and strength and raise both the standard and quality of life in other respects, since he would be freer from immobility caused by disease.

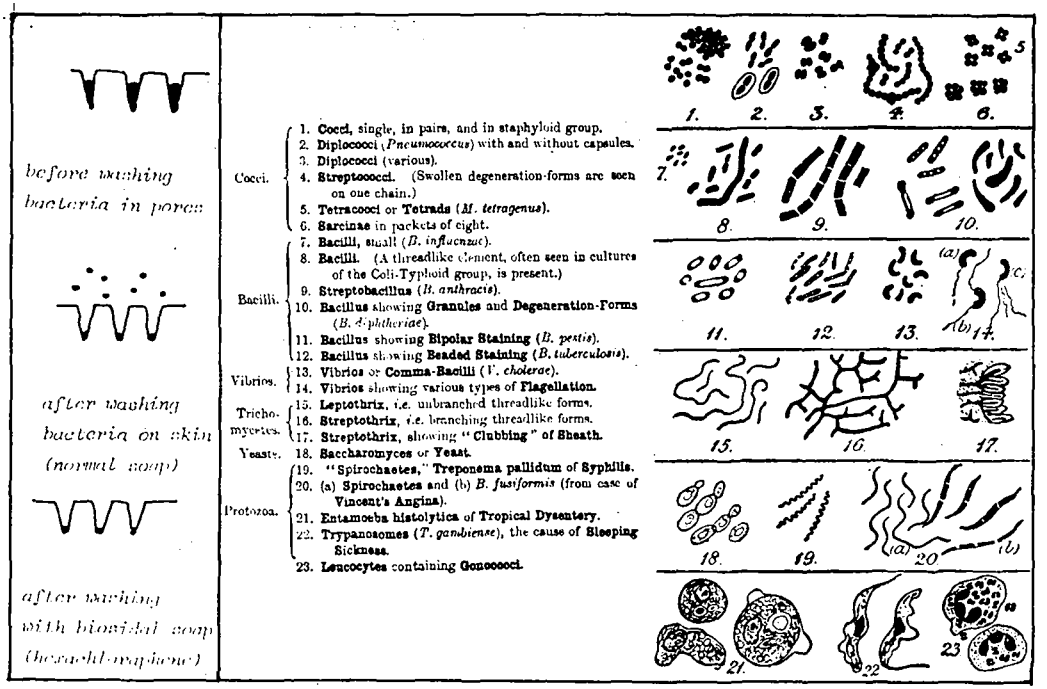
Economic growth potential increases rapidly as water becomes more plentiful, even in this way.

✸ What chance of public acceptance has the atomized shower?

In localities where bathing is minimal and disease a common condition, only by a long-range educational program can any new technology be accepted. In Domestic Water Use in the New Guinea Highlands[7] Richard Feachem reports on introducing new technology into a Highlands clan. He reports that cultural habits inhibit improvement of the water supply. Cited were fear of poison and of female contamination in the water source. These accounted for minimal water use, for example, total per capita usage being 0.68 litres daily of which 79% is drunk.

POSSIBLE APPLICATIONS OF THE MIST SHOWER

Location	Water Supply	Application
Urban I	Water main with pressure reducing valve.	*Domestic showers* *Institutional showers*
Urban II	Street vendor or public standpipe.	*Domestic showers* *Public bathrooms* *Manual or mechanical pressure.*
Rural I	Pumped water with pressure reducing valve.	*Domestic showers* *Institutional showers*
Rural II	Village pump	*Domestic showers* *Public bathrooms* *Manual pressure.*
Mobile	Tank	*Showers on planes, boats, buses and vans. Manual or mechanical pressure.*



4. How Cleansing is the Mist Experience ?

It was believed that a swab test of bacteria on the skin before and after washing could demonstrate that the atomized shower had as good a cleansing capacity as the normal shower. With the help of the Director of the City of Montréal Department of Health Laboratory, Mr. Maurice Bouleris, such tests were made of our skin using Bell-Parker reagent material. This is used to measure total bacteria present in one test, and presence of Staphylococcus in another test. The results were as they, not we, expected. The count of total bacteria increased from 260,000 colonies before washing to 450,000 colonies after washing. We were then told that this test had been done many times before so our results were not unique.

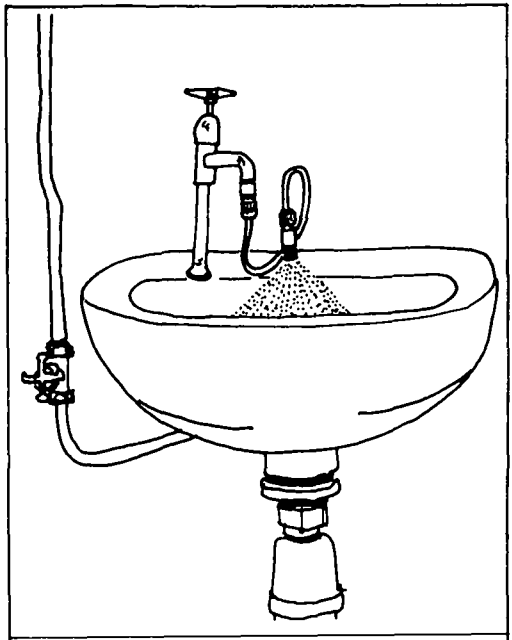
Strangely, no one knows why this happens. Scientists say it does not prove that there is more bacteria present on the skin after washing, but that there is more bacteria in the samples of the water after washing. The theory is that bacteria which lie deep in the pores of the skin are stirred up and come out when washing takes place. See sketch.

Soap is classified in three types, each having varying chemical compositions. These different agents act as biodegradable soaps which do not halt bacteria growth and can be broken down by bacteria, biostatic soaps which control the growth of bacteria, and biosidal soaps which actually deactivate the bacteria.

Only by using biosidal soap can the count of bacteria remaining after washing be less. Tests show, said Mr. Bouleris, that 98% less bacteria are present after one washing with soap containing Hexachloraphene.

So we made a second test with the atomized shower device again but this time a bar soap, Gamophan, containing 2% Hexchloraphene, (obtained on prescription from Dr. Boudreau of the McGill Medical Department) was used.

As expected, sample results taken after 48 hours in incubation showed a high absence of bacteria: about 95% less. Thus it has definitely been shown that washing by atomized water with biosidal soap reduces bacteria as much as normal washing with biosidal soap does. That is to say, the atomized shower device can be considered to give as hygienic a wash as a normal full water wash. Tests were made at the City of Montréal Department of Health Laboratory on August 11 and 18, 1976.



5. Other Research

The *Building Research Establishment* (BRE) in Great Britain conducted work in 1975-1976 in using atomised sprays for handwashing and showering.[17] This work is concerned with retrofitting atomizer nozzles to existing showers and faucets.

Handwashing was evaluated by installing an atomizer nozzle to a faucet in one of the washrooms at the research laboratories (see illustration at left). Staff at the labs made use of the spray faucet.

The conclusions were as follows:
1. People generally felt that their hands were "clean".
2. Soap was difficult to remove with the spray faucet.
3. The average water use was found to be about 0.14 litres per use, as compared to 0.80 litres for a conventional faucet.

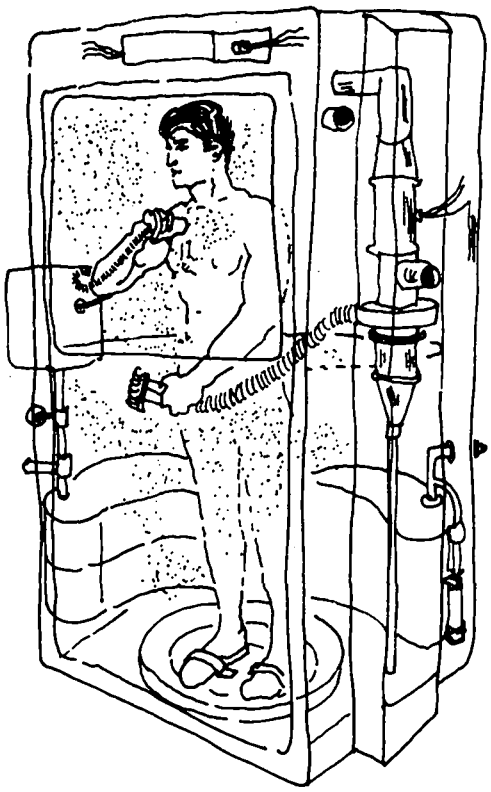
Further tests were carried out with regard to showering - a test stall was set up at the laboratory and fitted with an atomizer nozzle whose flow rate at 50 psi was 0.85 lpm (the flow rate of the handwashing nozzle was 0.33 lpm at 50 psi). The shower was tested by a number of people with both atomizer and conventional nozzles.

The conclusions were as follows:
1. Difficulty was encountered with hair washing and removing suds.
2. The time taken for the atomiser shower was slightly longer than that taken with the conventional shower, but the former used only about 40% of the hot water and energy of the latter.
3. The flow rate of the atomiser shower was generally considered to be minimum required.

Interestingly enough, although all the participants in the experiment rated the conventional shower higher than the atomiser shower, once they appreciated the savings that could be effected in energy (i.e. hot water) by using the atomiser shower, more than half were prepared to consider installing an atomiser showerhead in their homes.

Washing habits are undoubtedly culturally conditioned. Consider the Finnish sauna, the Cree sweathouse, the Japanese bath, the mediaeval harfabarf or the Roman thermae. So too is the spine-tingling shower, which may give way, eventually, to the MIST EXPERIENCE.

7. Mini-Mister



ZERO-GRAVITY SHOWER MODULE[16] (Vacuum Concept)

Developed by the Martin Marietta Corporation for NASA it uses ½ gallon for bathing the entire body. In spite of the fact that NASA-sponsored work is for space flight conditions it represents valuable (and unique) research on the subject of bathing and showering.

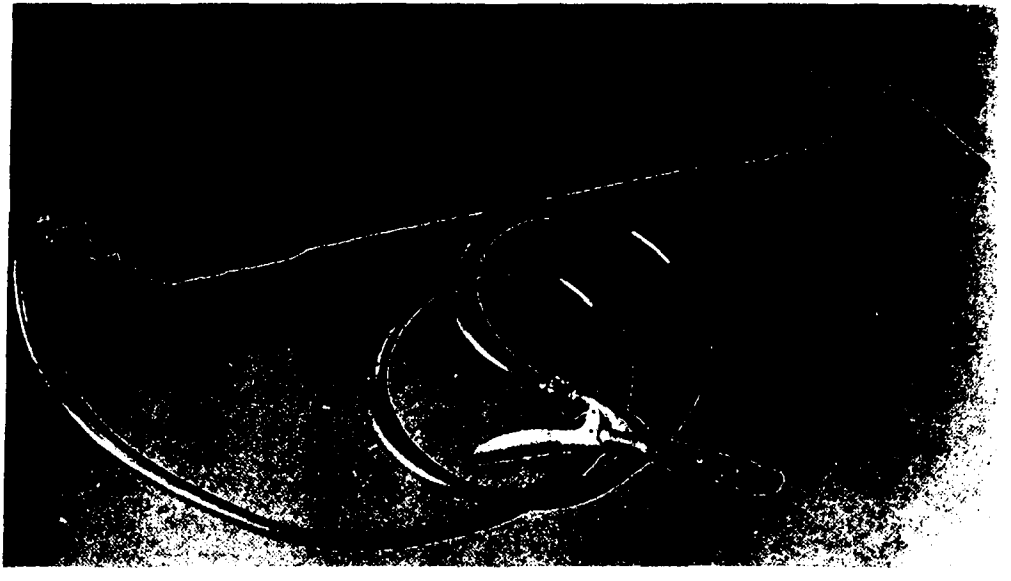
It is possible to build a small portable mist shower for well under ten dollars, and this section deals with the information required to build and operate your own MINI-MISTER.

It would be possible to utilize a Volkswagen windshield washer reservoir, which already has a built-in pressure valve, but as a car accessory this is quite expensive (about $20 for the reservoir alone). Instead we have developed a design that uses ABS (or PVC, though this costs more) plastic tubing and closures.

The main component is a piece of 75 mm(3") diameter tubing. This forms the reservoir whose capacity will depend on the length of the tube : 50 cm (20") contains about 2.3 litres (0.5 gallons) of water.

The ends of the pipe are closed with threaded clean-out caps, also of ABS plastic, which are cemented. A bicycle pump valve is attached to one of the caps, while a vinyl hose is attached to the other. At the end of this hose is the hand-operated control valve and handle, to which the atomizer nozzle is fixed. The vinyle hose can be made as long as desired, usually about 1.8 meters (6').

ABS plastic is an ideal material for the MINI-MISTER since it can be easily cut and drilled, is non-corrosive and readily cleaned, and can be glued and sealed with available plumbers' products. When not in use the hose and handle can be stored inside the reservoir.



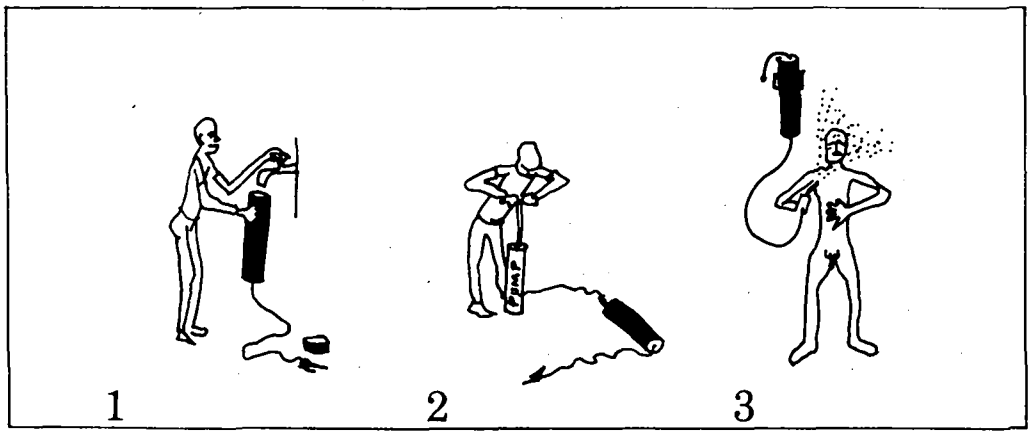
Assembly of the MINI-MISTER is as follows :

a. Cement the two caps (2 & 3) to the tube with ABS cement.
b. Drill a hole in the clean-out (4) to receive the insert (6). Place the insert in the hole and fasten the nut (7). Push the bicycle valve (8) snug onto the insert.
c. Screw the completed assembly into one end of the reservoir.
d. Drill a hole in the second clean-out (5)to receive the insert (9). Place the insert in the hole and fasten the nut (10). Push the end of the hose (13) over the insert and tighten the hose clamp (11) over the hose.
e. Insert the other end of the hose onto the control valve (14) and tighten a hose clamp (12) over the hose.
f. Screw the adapter assembly (15,16) into the control valve (14).
g. Screw the nozzle (17) into the adapter assembly.
h. Now screw the entire assembly into the other end of the reservoir.

Nozzles:*Steinen Spray Nozzle Model TM21 1/8"
available from: Masdom Corporation Ltd.
83 Sunrise Avenue
Toronto, Ontario M4A 1B1

Or, *Bete F 200
available from: Bete Fog Nozzle, Inc.
Box 311
Greenfield, Massachusetts 01301

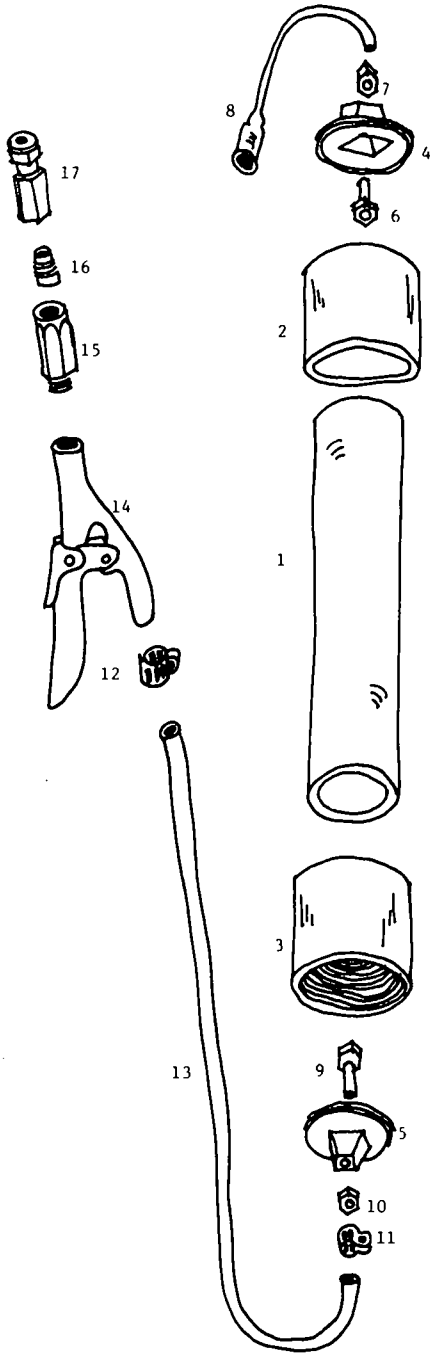
We recommend either one of these nozzles which have a flow rate of 0.3-0.4 liters per minute.



Step One : Unscrew the clean-out at the bicycle valve end of the pipe and fill the reservoir with water. Replace the clean-out snuggly.

Step Two : Pressurize the reservoir; either manually with a foot-pump (less work) or a hand-operated pump, or mechanically from a garage air pump, pressurized cannister or electric pump. The pressure should be 1-2 atmospheres (15-30psi).

Step Three : With reservoir in vertical position you are now ready to shower. A well constructed Mini-Mister should maintain its pressure for some time.



Mini-Mister

PARTS LIST

1. TUBE, ABS
   75 mm(3") diameter
   Length as required (approx. 50 cm,20")
2. THREADED CAP, ABS
3. THREADED CAP, ABS
4. CLEAN-OUT, ABS
5. CLEAN-OUT, ABS
6. INSERT, COPPER OR BRASS
7. NUT, COPPER OR BRASS
8. BICYCLE VALVE
9. INSERT, COPPER OR BRASS
10. NUT, COPPER OR BRASS
11. HOSE CLAMP
12. HOSE CLAMP
13. HOSE, VINYL
    6.3 mm (1/4") diameter
    Length as required (approx. 1.8m, 6')
14. CHAPIN CONTROL VALVE
15. ADAPTER ASSEMBLY, COPPER OR BRASS
16. ADAPTER ASSEMBLY, COPPER OR BRASS
17. ATOMIZER NOZZLE, BRASS

Almost all of these parts are available from plumbing suppliers. The ABS parts are for water drains and could be of PVC plastic as well, though ABS is cheaper. The hose and control valve could be common garden variety... depending on the ingenuity of the builder.

The MINI-MISTER can be used for hand-washing (see above) but a more economic and simpler alternative is the widely-available hand-held atomizer (sold in most hardware stores for about two dollars). It is awkward for body showering as it requires two hands, but is perfect for face and hands. We have been using these kind for a number of years for car trips, camping and for cooling off in desert climates.

8. Catalogue

The MIST EXPERIENCE effects a drastic cut in water consumption, however there are a number of more conventional devices that are currently available that will also conserve water. We have prepared a Catalogue of such devices, ranging from very inexpensive *Flow Restrictors* to sophisticated *Temperature Selection* systems. Also included are *Metering Faucets*, *Faucet Aerators* and water conserving *Showerheads*. This Catalogue is not a consumer guide as we have not had the opportunity to test all these devices, and though some are well known, others are quite recent innovations. The information given is taken from the manufacturers literature.

We feel that devices such as these deserve wider application. No longer is water conservation an issue that is restricted to only arid regions, though of course it is most serious there. Today, as water treatment and sewage treatment become increasingly expensive, the conservation of water has become increasingly important all over the world, whether in Arabian Gulf boom towns, squatter settlements in Southeast Asia, or in North America. This Catalogue indicates the variety of water conserving devices that already exists - it only remains to apply them.

From a conservation campaign in California, 1978. Santa Clara Valley Water District.

✱WATTS U-5

Pressure Reducing Valve

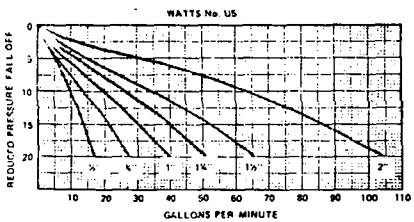
Manf. by:
Watts Regulator Co.
Lawrence, Mass. USA

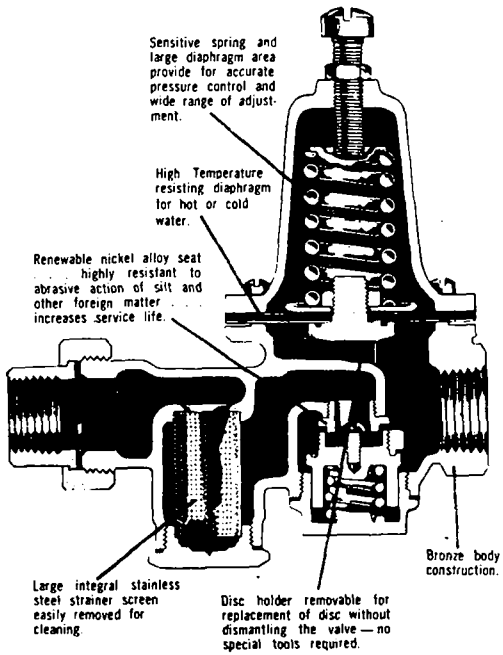
Watts Regulator of Canada, Ltd.
Weston, Ontario, Canada

Watts Regulator (UK) Ltd.
Stroud, Gloucestershire, UK

Price: $7.60 (wholesale)

This valve maintains a steady flow of water from the mains at a pre-selected pressure, thereby reducing wastage due to excess or varying mains pressure. It is also useful where there is a wide variation in line requirements, and where it is necessary to have a constant supply as well as equal capacity at all fixtures. Supply pressures of up to 50 kg/cm^2 can be reduced to within a range of 4.5 -13.5 kg/cm^2, and water savings of up to 30% are claimed.





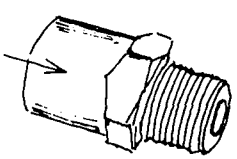
✱DOLE

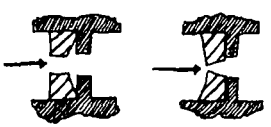
Flow Restrictor

Manf. by:
Eaton Corporation
191 E.North Ave.
Carol Stream, Illinois 60187, USA

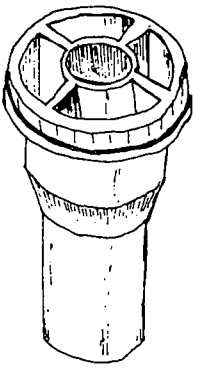
Price : Not available

This valve can be fitted into existing fixtures, and reduces pressure only within that fixture. It reduces water flow under higher pressures and would be particularly applicable to faucets in bathrooms and kitchens.





✱NOLAND FLOW CONTROL — Flow Restrictor



Manf. by:
Noland Co.
2700 Warwick Blvd.
Newport News, Virginia 23607, USA

Price: $1.00

This three-chambered cylinder type restrictor has no moving parts and regulates the flow at a pre-determined rate. It automatically compensates for varying pressures. The SFC-3 reducer cuts down the flow in a conventional 2 cm pipe from 25-30 lpm to 11.5 lpm.

✱STEDI-FLO/ VOLUME CONTROL VALVE — Flow Restrictor

Manf. by:
Chicago Faucet Company
2100 South Nuclear Drive
Des Plaines, Illinois 60018, USA

Price:

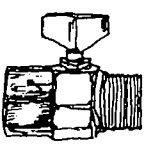
This valve limits water flow to 7.5 lpm for lavatory sinks, and to 11.4 lpm for showerheads. It is available in both male and female threads to fit into any standard fixture.

The volume control valve allows the user to stop the flow of water without varying the temperature of the water. This particularly useful while soaping up during a shower.

✱VOLUME CONTROL — Flow Restrictor

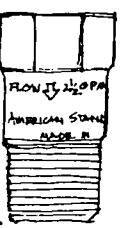
Manf. by:
Speakman Company
Wilmington, Delaware 19899, USA

Price: Not available



A volume control valve, normally connected between the showerhead and the main line, which allows the user to turn off the flow of water while soaping up, and then return to the normal flow of water without affecting the temperature.

✱AQUA-MIZER — Flow Restrictor



Manf. by:
American Standard Inc.
US Plumbing Products
PO Box, 2003, New Brunswick, NJ 08903 USA

American Standard
80 Ward Street
Toronto, Ontario M6H 4A7 Canada

Price : $5.00

This restrictor reduces water-flow to about 9.5 lpm from standard pressures of 25-30lpm. It can be introduced into standard fixtures by the user without professional help.

✱ND-76, ND-77 — Flow Restrictor

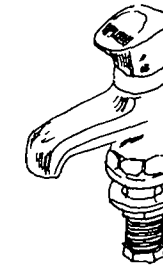
Manf. by:
NY-DEL Corporation
740 East Alosta Avenue
Glendora, Ca. 91740, USA

Price: $0.81 (ND-76)
$0.23 (ND-77)

The ND-76 reduces the water pressure while automatically compensating for varying line pressures. The water flow is reduced from an average of 25-30 lpm to about 9.5 lpm ; a saving of 15-20 liters of water per minute. This restrictor fits into most standard fittings.

The ND-77 is a concave type restrictor that fits into most ball-joint type shower heads. It is stainless steel and reduces water flow from 25-30 lpm to about 11.5 lpm.

✱EASY-PUSH — Metering Faucet



Manf. by:
Speakman Co.
Wilmington, Delaware 19899, USA

Price : Unavailable

This faucet is not only self-closing but also meters water accurately - the amount of water being predetermined by adjustment after installation.

✱KLO-SELF, NAIAD, TIP-TAP — Metering Faucet

Manf. by:
Chicago Faucet Company
2100 South Nuclear Drive
Des Plaines, Illinois 60018, USA

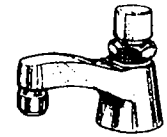
Price :

This faucet line incorporates slow-closing, drip-tight self-closing faucets that will conserve water in homes, schools and hospitals and office buildings. The TIP-TAP has an adjustable closing time.

KLO-SELF

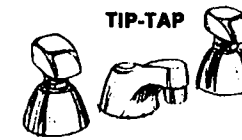
Release the handle and the faucet self-closes, drip-tight.

NAIAD



The push button economizer that self-closes.

TIP-TAP



Slow-closing faucet with adjustable closing time from 2 to 15 seconds.

✱FORDILLA

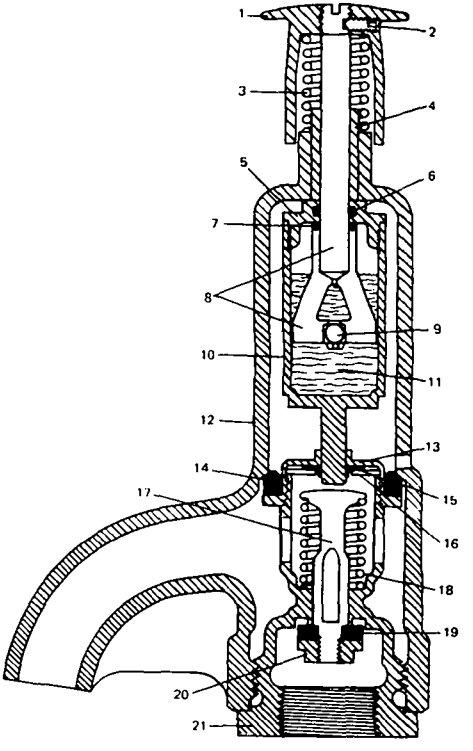
Metering Faucet

Manf. by:
Ford Meter Box Co. Inc.
PO Box 443
Wabash, Indiana 46992, USA

Price: $13.38

The Fordilla is a spring-loaded valve with a cast-iron body that is specially designed for use in public fountains. When the push button is pressed and held down approximately 2 liters of water are delivered. The flow then stops and the button must be pressed again to obtain more water. As the faucet cannot be left running inadvertantly, water wastage is considerably reduced.

The large majority of the urban population of the Third World is supplied not from house connections but from public standpipes. The adoption of metered faucets would not only reduce water consumption, but would also reduce flooding of the public standpipe areas.



1. PUSH BUTTON
2. SET SCREW
3. PUSH BUTTON SPRING
4. BRASS BUSHING
5. CYLINDER CAP
6. UPPER O-RING
7. LOWER O-RING
8. PISTON AND PISTON ROD ASSEMBLY
9. BALL CHECK VALVE
10. CYLINDER
11. SILICONE FLUID
12. MAIN BODY
13. PACKING CAP
14. RUBBER PACKING GASKET
15. PLASTIC PACKING
16. LOWER WASHER
17. VALVE STEM
18. VALVE SPRING
19. RUBBER DISC
20. VALVE DISC NUT
21. VALVE BASE

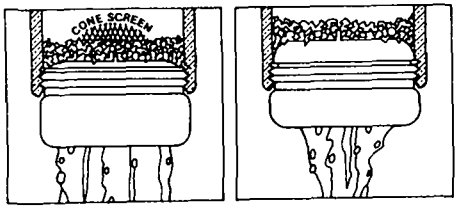
✱FLOW-RATOR

Faucet Aerator

Manf. by:
Moen, Division of Stanadyne
Elyria, Ohio 44035, USA

Price: $1.49

This aerator reduces water flow to about 11.3 lpm. A cone-screen reduces clogging. Model 3919 (male thread) and 3924 (female thread) fit all Moen faucets.



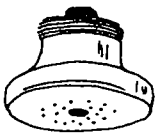
MOEN®

✱CONSERVAFLO, S-4450 Faucet Aerator

Manf. by:
Speakman Company
Wilmington, Delaware 19899, USA

Price: Unavailable

This is a spray outlet water saving device that is used in place of an aerator on lavatory faucets. It reduces the flow to approximately 1.9 lpm. A more conventional aerator (S-4450) reduces flow to 7.5 lpm and fits most regular (15/16" dia.) faucets.

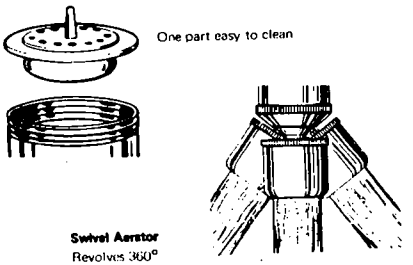


✱BUBBLE-STREAM Faucet Aerator

Manf. by:
Wrightway Manf. Co.
1050 Central Avenue
Park Forest South, Illinois 60466, USA

Price: $12.95 (complete kit)

This "kit" (WSK 300) consists of a showerhead (B-400-SC), a faucet aerator (MK-100-LV) and a swivel aerator (SMK-100-LV). At a standard water pressure the showerhead reduces the flow rate to about 9 lpm, and the aerators to about 8.5 lpm.



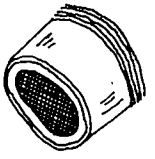
✱CONSERV-A-TOR Faucet Aerator

Manf. by:
Baron Industries Inc.
4204 N. Brown Avenue
Scottsdale, Arizona 85251, USA

Price: $2.39

This is a self-compensating constant flow restrictor and aerator which provides a water flow of approximately 7.5 lpm. It fits regular (15/16" dia.) faucets and a number of models are available for male (C-304) , female (C-314) or dual thread (C-324). Adapters are available for conversion to 13/16" dia. small faucets.

WATER SAVER™



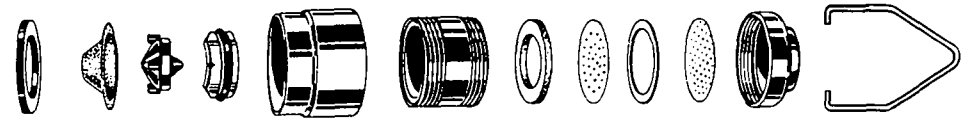
✸ ECONO-FLO

Faucet Aerator

Manf. by:
Chicago Faucet Company
2100 South Nuclear Drive
Des Plaines, Illinois 60018, USA

Price:

This aerator screws into a regular faucet and reduces water flow to about 2.8 lpm. Four models are available : E.24 and E.24-5 for Chicago faucets (male and female) and E.24M and E.24F for other makes (male and female).

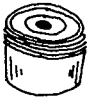


✸ CONSERVARATOR

Faucet Aerator

Manf. by:
Ny-Del Corporation
PO Box 155, 740 East Alosta Ave.
Glendora, Ca. 91740, USA

Price: $1.98



A self-compensating faucet aerator for regular (15/16" dia.) faucets that reduces flow from 20-30 lpm to about 7.5 lpm. It is estimated that with such an aerator in the kitchen and bathroom, daily water usage from these two sinks can be reduced from 150 liters to 50 liters.

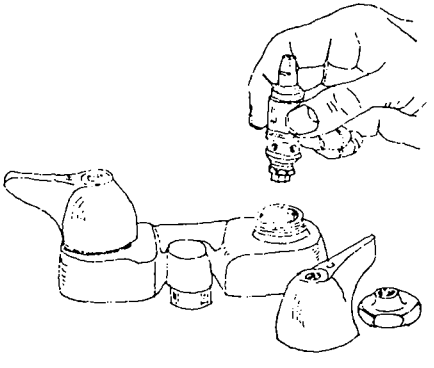
✸ CONTROL-A-FLO

Faucet with Restrictor

Manf. by:
Chicago Faucet Company
2100 South Nuclear Drive
Des Plaines, Illinois 60018, USA

Price:

This device is a "cartridge" that fits inside the faucet and allows the user to select the required water flow rate by a simple manual adjustment.



✱ AUTOFLO — Faucet with Restrictor

Manf. by:
Speakman Company
Wilmington, Delaware 19899, USA

Price: Not available

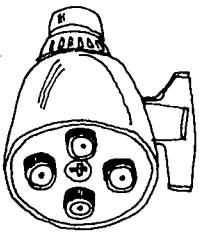
This is a built-in flow restrictor used on showerheads as well as faucets. It maintains a constant output flow rate in spite of varying line pressures. Various restrictors are available for 5.8 lpm, 7.6 lpm, 9.5 lpm and 11.3 lpm flow rates.

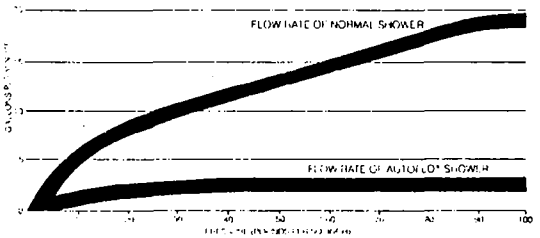
✱ ANYSTREAM — Showerhead

Manf. by:
Speakman Company
Wilmington, Delaware 19899, USA

Price: Not available

These brass showerheads incorporate the "Ultraflo" restrictor, and the conventional shower flow rate of about 45 lpm is reduced to 9,5 lpm (depending on the exact showerhead chosen). This will effect considerable savings in water and energy (i.e. hot water). A variety of showerheads are available, all with adjustable spray selectors (S-2252 AF, S-2251 AF, S-2253 AF, S-2220 AF, S-2270 AF).

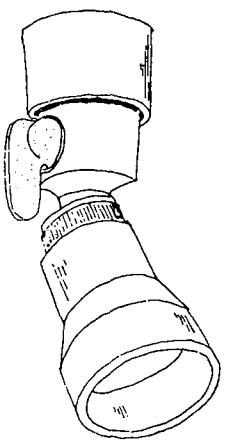




✱ 321 MARK III — Showerhead

Manf. by:
Ecology Sales Inc.
PO Box 509, Dunkirk, NY 14048, USA

Price: $14.95



This anodized aluminum showerhead is designed to deflect the jets of water against the interior of the "lens hood", breaking up the stream to a conical pattern which gives the effect of a much larger flow of water. The flow is rated at 7.5 lpm.

✱WATER SAVING SHOWERHEAD MODEL 550-11 Showerhead

Manf. by:
Ny-Del Corporation
PO Box 155, 740 East Alosta Avenue
Glendorra, Ca. 91740, USA

Price: $1.59

This ABS plastic showerhead reduces water flow to 9.5-11.3 lpm. The spray can be adjusted.

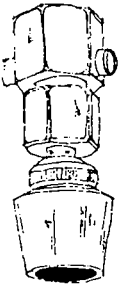
✱MOENFLO Showerhead

Manf. by:
Moen, Division of Stanadyne
Elyria, Ohio 44035, USA

Price: $5.95 - $23.45

This company manufactures a wide variety of showerheads of chrome plated brass, all of which are available with an optional 11.3 lpm flow control. The flow control kit for converting conventional Moen showerheads to this reduced flow is available for $1.50.

✱NOVA Showerhead



Manf. by:
Jay Norris Corporation
Ecological Water Products Inc.
Freeport, NY, USA

Price: $14.95

This solid brass chrome-plated showerhead reduces water flow to 6 lpm and the nozzle can be adjusted from "fine needle" to "soft rinse". There is a control that permits the user to cut off the water flow while soaping up, without affecting the temperature of the water.

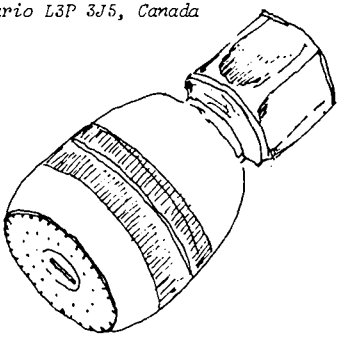
✱RADA 872 Showerhead

Manf. by:
Walker Crosweller & Co. Ltd.
Whaddon Works, Cheltenham GL52 5EP, UK

Walker Crosweller & Co.(Canada)Ltd.
PO Box 148, Markham, Ontario L3P 3J5, Canada

Price: $7.38

This showerhead has built-in flow control that maintains an even spray in spite of varying line pressure. It fits 2cm dia. pipes and is available in male and female threadings. In a controlled experiment in Toronto it is reported that the annual cost saving for an apartment building was $11.68 for water and $45.11 for water heating, per apartment unit.



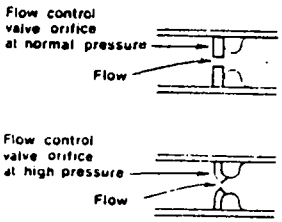
✸ WATERSAVER

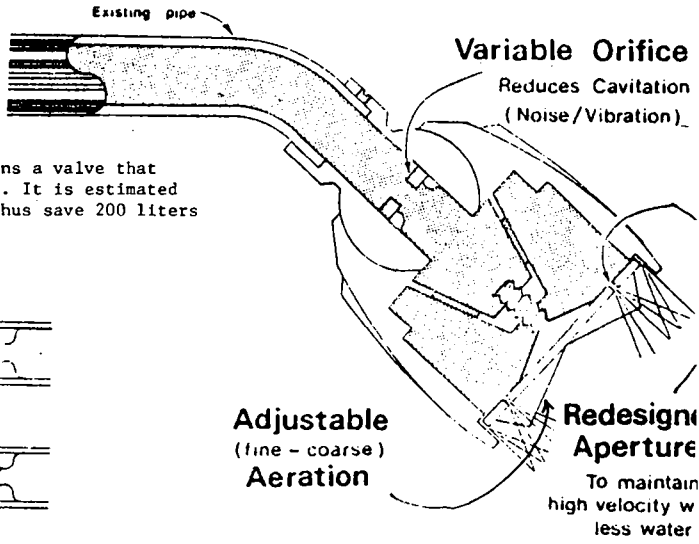
Showerhead

Manf. by:
Baron Manf. Co.
14439 North 73rd Street
Scottsdale, Arizona 85260, USA

Price : $5.95

This ABS plastic showerhead contains a valve that reduces the water flow to 11.3 lpm. It is estimated that the average household could thus save 200 liters per day.





✸ HYDROPOISE

Temperature Selection

Manf. by: Chicago Faucet Company
2100 South Nuclear Drive
Des Plaines, Illinois 60018, USA

Price:

A single control permits the user to select the desired temperature beforehand. A pressure balancing valve automatically holds the water temperature. This not only increases comfort but decreases water wasted while adjusting the water temperature.

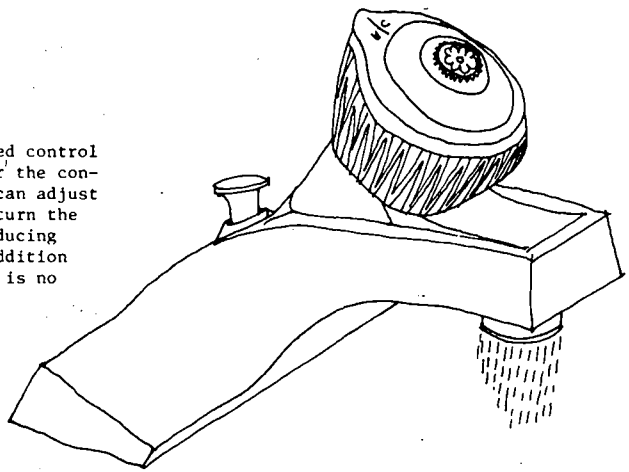
✸ MOENTROL

Temperature Selection

Manf. by:
Moen, Division of Stanadyne
Elyria, Ohio 44035, USA

Price : Wide variety

It has been estimated that single handled control can reduce water consumption by 50% over the conventional two handled faucet. The user can adjust temperature and flow more quickly, and turn the faucet on and off more rapidly, thus reducing water wasted. The Moen "cartridge" in addition virtually eliminates drips, since there is no washer and seat to wear out.



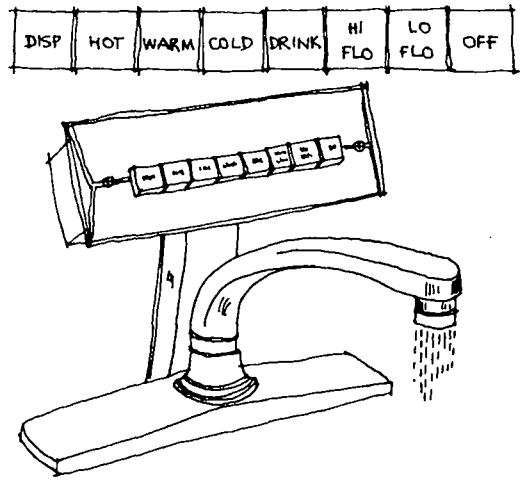
ULTRAFLO

Temperature Selection

Manf. by:
Ultraflo Corporation
PO Box 2294, Sandusky, Ohio 44870, USA

Price: Approximately $300.00
(Kitchen and bathroom, installation not included)

This is a centralized water distribution system that eliminates the use of manual mixing valves (i.e. faucets) to control the flow rate and water temperature. The conventional hot and cold pipe supply is replaced by a single line. The user selects a combination of pressure/temperature (e.g.WARM-LO FLO) and blending takes place at the water heater. The supply line is a small diameter (7 mm) flexible tubing. The amount of water saved by a single family could be as much as 500 liters per day. In addition, as hot water does not "stand" in the pipes, energy also is saved.



UNATAP 11

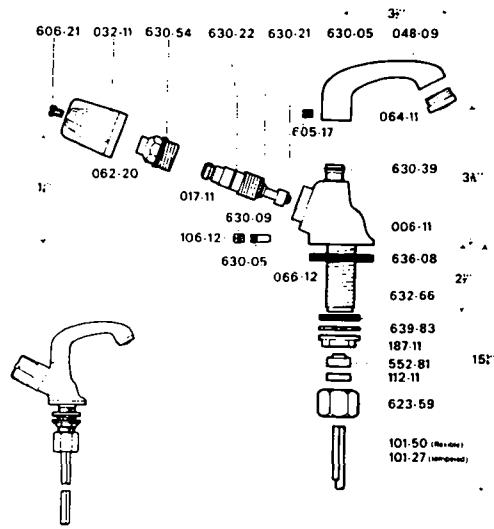
Temperature Selection

Manf. by:
Walker Crosweller & Co. Ltd
Whaddon Works, Cheltenham GL52 5EP, UK

Walker Crosweller & Co.(Canada) Ltd.
PO Box 148, Markham, Ontario L3P 3J5, Canada

Price: $58.94

This faucet generates a fine spray of water at a flow rate of 2.4 lpm. A flow adjustor is built-in and can be pre-set for any pressure. Finally, a single handled faucet allows the user to pre-determine the temperature of the water. The handle is push-pulled to turn the water on and off, and is rotated to vary the temperature. The combination of aerator-flow restrictor and temperature selection is said to effect water savings of up to 78%, which affects not only the cost of water but also the cost of hot water.



Supply Pressures

Unatap is suitable for installation with static water pressures between 3 PSI and 125 PSI. It can be installed with an inlet pressure ratio of up to 2—1 by adjusting the built-in flow regulators to suit installation conditions. The flow regulators can also be adjusted to provide exactly the required flow.

9. Bibliography

Serious students of water conservation, as well as researchers and engineers will be interested in this abstracted bibliography of thirty papers, books and reports dealing with saving water in the home. This chapter is adapted from a study that was carried out at the International Development Research Centre (Ottawa) with the collaboration of the World Bank, and is part of an extensive bibliography of over 500 references dealing with low cost sanitation. This entire study is available for a nominal price from:

International Development Research Centre
Publications Division
Box 8500
Ottawa, Ontario K1G 3H9, Canada.

The publication is entitled :

TECHNOLOGY OPTIONS FOR SANITATION - An Annotated Bibliography and Technical Review, by Witold Rybczynski, Chongrak Polprasert and Michael McGarry, published by the International Development Research Centre and the World Bank, Ottawa July 1978.

*ANON. Final Report on Washwater Waste Pretreatment System Study, U.S. National Aeronautics and Space Administration. U.S.A. Contract NAS 9-14518. 59 pp. March 1976

An evaluation of numerous chemical agents as antifoams for synthetic washwater. A low-foaming liquid soap for sponge bathing and hand washing is described.

*ANON. Evaluation and Performance Results of the Flushmate Tank, a report published by Water Control Products/N.A., Incorporated. U.S.A. 36 pp. November 1975.

Basic operating characteristics of the Flushmate Tank with three leading water closets have been investigated. Water supply and discharge characteristics of both Flushmate and gravity tank operated water closets have been measured and compared. Fixture performance tests and backflow prevention tests have also been conducted on both Flushmate and gravity tank fixtures.

The results of the testing programme have shown:

1. Flushmate operated water closets place a substantially lower water demand on the water supply system (52% less water usage).

2. Peak discharge flow rates were influenced primarily by bowl design, and Flushmate and gravity tank operated fixtures had similar discharge peak flow rates, however, the Flushmate discharge time was 49% shorter.

3. Flushmate operated units were good performance water closets.

*ANON. Shower with One Litre of Water, Research McGill, Canada. pp.5-7 May 1976.

This article describes work done in developing a shower which operates for 10 minutes using only 1 litre of water. A composting toilet which allows for the hygenic disposal of wastes without an elaborate plumbing system is also described.

*ANON. Saving Water in The Home, Building Research Establishment News, U.K. Volume 38. pp 4-5. Winter 1976.

Research on water-saving devices for British homes is described. A retrofitted device reduces flush-water consumption in toilets by 40%. Bathroom wastewater is recycled to be used for toilet flushing. Atomised water is proposed for washing. It is estimated that savings of up to 50% could be achieved by various combinations of these devices.

*ANON. How Ultraflo Systems Conserve Energy and Water, Ultraflo Ecology Bulletin. U.S.A. 10 pp. 1973.

Based on electronic monitored programs in actual households, data compiled on water use and user habits demonstrated with the Ultraflo pushbutton, one line system that there was a saving of 12 to 20% of total water consumed compared to households with conventional two line systems. The Ultraflo system eliminates waste or heated water normally left standing in lines between uses.

*ANON. Its Up To You - A Customer Handbook on Water-Saving and Wastewater Reduction, The Washington Suburban Sanitary Commission. U.S.A. 24 pp. May 1976.

Three reasons for water saving are given: (1) the fact that water resources are limited, (2) water costs are rising because of increased processing required to meet today's health standards for water, and costs of wastewater disposal; and (3) to reduce the load on collection and treatment systems potentially dangerous for pollution.

Many helpful hints for more effective use of conventional plumbing fixtures are offered. Mention is also made of water saving devices which attach to existing fixtures as well as alternative fixture equipment. Water use figures are stated to point up actual quantities of normal use and waste. Hints are given for water saving outside the house, and a table of plant watering guide is shown.

*BAILEY, J.R., BENOIT, R.J., DODSON, J.L., ROBB, J.M. and WALLMAN, H. A Study of Flow Reduction and Treatment of Wastewater From Households, Water Pollution Control Research Series 11050 FKE 12/69, Department of the Interior. Federal Water Quality Administration. U.S.A. 154 pp. December 1969.

This study identifies practical means of waste flow reduction for American households. Commercially available devices for water saving are described and literature on advanced water and waste treatment is reviewed. A consumer survey was conducted and showed that water used in household functions such as bathing and toilet flushing can be substantially reduced by the use of more efficient appliances and plumbing devices.

*BAILEY, J.R. and WALLMAN, H. Flow Reduction of Waste Water From Households, Water and Sewage Works. U.S.A. 118(3). pp.68-70. March 1971.

Water saving devices such as the dual flush toilet tank system and the vacuum toilet system are currently available. These systems are reported to provide, at no overall cost penalty to the homeowner, a water savings (and waste flow reduction) of 30 to 50 per cent. A limited survey indicates that the use of such water saving devices would be readily accepted by homeowners.

*BENDER, T. Living Lightly...Energy Conservation in Housing, A report published by Department of Architecture, University of Minnisota. U.S.A. pp.12-15. October 1973.

The conservation of water is related to energy conservation. Water requires energy for treatment, which in turn affects the physical environment. Water savings are possible by its reuse in toilets, water reduction devices, toilet redesign, use of compost toilets, and use of foot operated faucet valves on sinks and wash basins and locating them close to water heaters. Design of clothes washers and even clothing material can affect the amount of water used. Heated water is a great energy consumer. Use of solar water heaters, proper water heater location, and insulation can all save heat.

*BORJESSON, E. and BOBEDA, C. New Concept in Water Service for Developing Countries, Journal - American Water Works Association. U.S.A. 56(7). 11 pp. July 1964.

*This is a report about a system which effectively accomplishes an improvement in public health and social conditions in three areas in developing countries. The problem was to provide a permanent healthful water supply in adequate amounts to individual dwellings in all urban areas at a price that the customer could afford and that would also pay for the service. The solution was installation of a one-pipe water supply line serving a group of domiciles, each provided with a "Fordilla" spring-loaded

faucet. This device restricts the overuse and waste of water much as the hand pump does. Details of water distribution and costs and use data are presented, as well as public acceptance of the system.

*BOSTION, H.E., COHEN, S. and WALLMAN, H. Saving Water in the Home, Water Conditioning. U.S.A. 16(10). pp. 16-21. November 1974.

A report of two studies conducted by General Dynamics and by the Washington Suburban Sanitary Commission of equipment available for saving water in the home. This equipment includes reduced-flow toilets, flow-limiting shower heads, and faucet aerators. It is concluded that there is justification for installing such devices to save water.

*COHEN, S. and WALLMAN, H. Demonstration of Waste Flow reduction from Households, U.S. Environmental Protection Agency. U.S.A. Report No. EPA-670/2-74-071. 102 pp. September 1974.

A two-year demonstration programme was conducted to evaluate water savings, costs, performance and acceptability of various water-saving devices. Reduced flow toilets, and flow limiting shower heads were installed in eight single-family dwellings. In three of the homes bath and laundry water was filtered, disinfected, and reused for toilet flushing and/or lawn sprinkling. The experimental portion of the program ran from May 1971 to May 1973.

Water requirements for toilet flushing were substantially reduced in an economically attractive and aesthetically acceptable manner. Shallow-trap and dual flush toilets resulted in average decreases in toilet water usage of 25% and 23%, respectively. Flow restricting shower heads proved to be relatively ineffective, however this result may have been due to use pattems unique to this study. Wash water recycle systems provided satisfactory operation throughout the test period. The average savings for toilet flushing reuse ranged between 23% and 26% of total water usage. The incorporation of lawn sprinkling as a supplemental reuse made further reduced waste flow from homes by 16% to 18%. For single-family dwellings, recycle systems could effect marginal cost savings in high water and sewer use rate areas. They are definitely warrented when septic systems with poor drainage (due to soil or topography) are encountered.

*FOWELL, A., BRANSDORFER, A., FLETCHER, P., OREND, R., PAVEL, H. and WILLIAMS, G. Residential Water Use and the Potential for Conservation, Water and Water-related Conservation in Buildings, USN CCIB/CIB International Symposium on Water Supply and Drainage, National Academy of Sciences. U.S.A. pp. 5-9. September 28-30, 1976.

Differences in U.S. and European domestic water consumption are attributed to personal habits, water consuming appliances, and mainly water closet design. Fixture and fitting minimum flow rates based on function have not been researched in the U.S., but two criteria for estimating potential for water saving in appliances and fixtures are given.

Energy savings can result from improved efficiency of water heaters, from reduced consumption of hot water, and by use of flow restrictors in showers and basin faucets. Research is needed to provide a comprehensive study of energy use in water supply and wastewater treatment systems; and from the point of view of: economic impact in contrast to technology of conservation, safe economic quantities of water required for acceptable performance of fixtures, safety and practicality of greywater use. Without thorough evaluation of water saving water closets and add-on devices, the result may be a hazard to health and double flushing of toilets.

In sum, research should establish energy impact of water conservation by energy-benefit analysis as well as impact of water saving measures.

*FULLER, B. and MARKS, R. The Dymaxion World of Buckminster Fuller, Anchor Books, Anchor Press/Doubleday U.S.A. pp.99-100. 1973

The author considers the Dymaxion bathroom as an interim sanitary facility. Fog gun combines water and air at high pressure to release skin cells and dirt. Illustrations show laboratory set-up and three magnified photographs of skin surface, and students researching fog gun use in bathing. With such fog guns tons of plumbing would be saved as well as bathroom enclosing walls.

*GAY, D.E. Spray Faucets Save Water and Energy, Building Systems Design. U.K. 71(4). pp. 35-36. June/July 1974.

A spray faucet system is reported to provide savings for both water and energy. Investigations conduct-

ed in London show that an average time taken for washing with spray faucets is less than 60 seconds, compared with 90 seconds for the traditional method. Future uses of this system are expected to increase.

* GOLDSTEIN, S.N. and MOBERG, W.J. Jr. Wastewater Treatment Systems for Rural Communities, Commission on Rural Water, National Demonstration Water Project. U.S.A. pp. 294-307. 1973.

Reducing water consumption in households by careful use by individuals, by reducing the amount of water that flows through plumbing fixtures, and by recycling water used in certain functions reduces wastewater, treatment facilities, allows more users to be served by water systems of lesser capacity.

Survey of available equipment includes illustration, identifies manufacturer, shows performance, characteristics, and includes comments.

* GUARNERI, C., REED, A. and RENMAN, R. Study of Water Recovery and Solid Waste Processing for Aerospace and Domestic Applications, NASA Contract NAS 9-12503, Manned Spacecraft Center. U.S.A. Volume I, 31 pp., Final Report Summary. Volume II, 192 pp., Final Report.

Land development in many parts of the country is discouraged by inadequate water resources or by incompatabilities between water supply and waste treatment plans. Many established areas cannot satisfactorily keep pace with rapidly expanding urban populations for the same reasons. In addition, the cost of additional water supply and waste management in such areas can be extremely high. Practical alternatives to conventional water and waste treatment systems are required in newly constructed or redeveloped communities where such difficulties exist. This report evaluates the manner in which current and advanced technology can be applied to develop practical solutions to existing and emerging water supply and waste disposal problems.

An overview of water resource factors as they affect new community planning, and requirements imposed on residential waste treatment systems are presented. The results of equipment surveys contain information describing: commercially available devices and appliances designed to conserve water; devices and techniques for monitoring water quality and controlling back contamination; and advanced water and waste processing equipment system concepts are developed and compared on the basis of current and projected costs. Economic evaluations are based on community populations of from 2,000 to 250,000. themost promising system concept is defined in sufficient depth to initiate detailed design.

* HERSHAFT, A. Wastewater Flow Reduction in the Home, Environmental Systems. U.S.A. 4(3). pp.217-239. Fall 1974.

Methods of residential wastewater flow reduction, devices and practices, are presented and discussed in detail. The author indicates a trend of future shortage of high quality water supply and suggests cooperation from institutions and government agencies in order to effectively carry out a programme to reduce household water usage.

* HERSHAFT, A., VON HASSELN, R. and ROOP, R. Water Management Alternatives on Long Island A report published by Booz, Allen and Hamilton, Incorporated and Environmental Technology Seminar, Incorporated. U.S.A. pp.39-44. October 1974.

Water reduction can be achieved through introduction of flow reduction and recycling devices that complement described conservation practices. Some more common owner installed flow reduction devices are listed in a table as to type, operation, effectiveness, cost and name of manufacturer. Recycling domestic water assumes that water quality need only be sufficient for the intended purpose. A promising approach to water reduction is water saving toilets, which are described as to their nature, operation, effectiveness, cost, and manufacturer of the more common designs. If flow reduction practices suggested by the Washington Suburban Sanitary Commission could shift water consumption to off-peak hours, they would be particularly effective in decreasing required water and wastewater treatment plant capacity.

* IRONS, F. Hand Sprayers and Dusters U.S. Department of Agriculture, Home and Garden Bulletin. No.63. U.S.A. 12 pp. 1970.

The pamphlet describes various hand-operated pesticide spraying and dusting devices for use in the home, in the garden, and on farms. Intermittant sprayers discharge the spray material only with each forward stroke of the pump. Continuous sprayers develop and maintain a constant pressure, and develop a continuous spray discharge of uniform pattern while the pump is being operated. Useful information such as operating pressure, tank sizes and spray patters is given as well as information on maintenance and pesticide handling.

*MANI, J.S.V., SRINIVAS, V., SUBBA RAO, V. and RAO, N. Atomization By Pressure Nozzles Indian Institute of Chemical Engineering Journal. India. Part I, pp. 111-118, Part II, pp.151-159, Part III, pp. 10-13. 1955-56.

An investigation on atomization of liquids by nozzles using a swirl-disk nozzle was conducted in India. The following characteristics: total flow-rate, volume-rate distribution, drop-size distribution and cone angles were determined. Correlation for the effect of pressure on total flow-rate, volume-rate, distribution, drop-size distribution, cone-angle and capacity were also attempted.

The effect of tangential and vertical velocity components on "atomization" in a swirl thread nozzle using water was examined as well as the effect of surface tension of liquids on "atomization", using aqueous isoamyl alcohol.

*MORSE, A.E. The Use of Atomization for Washing and Showering to Conserve Water Master of Architecture Thesis, School of Architecture, McGill University. Canada. 124 pp. August 1976.

A number of devices to reduce domestic water consumption are available on the American market. These include spring-loaded self-closing faucets, pressure-reducing shower-heads and flow-reducing valves.

These devices are based on pressurized water in the house. There is also a need for devices that allow bathing with extremely small quantities of water when the latter is not available within the home.

In order to reduce the amount of water needed for individual bathing, and, in turn, to reduce household consumption of water as well as production of wastewater, atomizer nozzles have been tested for washing and showering purposes.

Atomization is the mechanical subdivision of a bulk liquid (e.g. water) into a fine droplet spray. This is accomplished by passing water under pressure, through a nozzle. A test of a number of nozzles indicates best performance with industrial hydraulic nozzles having flow rates of 0.13 - 0.33 litres/minute at 1.3 atmospheres, which have enough impact to remove soap suds from the skin.

A prototype shower was built utilizing a 2.5 litre water tank in which pressure could be manually induced with a bicycle pump. A series of showering tests indicated a 5-8 minute shower utilized 2 litres of water. Some problems were encountered with rinsing excess soap-suds and hair-washing.

The atomized shower was pleasant to use and showed a water reduction of over 90% compared to a conventional shower.

In order to measure cleansing ability, a bacterial count was taken before and after atomized showering with biosidal soap. Sample results taken after 48 hours incubation showed a reduction in bacteria of 95%.

*MURAWCZYK, C., IHRIG, D., MAYEUX, J. and WEBER, R. Water Recovery and Solid Waste Processing for Aerospace and Domestic Applications NASA Contract NAS9-12504, Manner Spacecraft Center. U.S.A. 41 pp. January 1973.

The final report describes (a) compiling information needed to establish the current water supply and wastewater processing requirements for dwellings and (b) developing a preliminary design for a wastewater to potable water management system. Data generated as a result of item (a) above was used in the formulation of design criteria for the preliminary design of the wastewater to potable water recycling system. The system as defined herein was sized for a group of 500 dwelling units.

MILNE, M. Residential Water Conservation California Water Resources Center, University of California/ Davis Report No.35, March 1976.

A comprehensive report on reducing water demand in four sectors: economic, institutional, sociocultural and technological. Includes extensive bibliography and a directory of American manufacturers.

*ORTEGA, A. and RYBCZYNSKI, W. Stop the Five Gallon Flush! A Survey of Alternative Waste Disposal Systems School of Architecture, McGill University. Canada. 82 pp. April 1976.

The book is a survey of alternative domestic water conserving waste disposal systems. Part I reviews the known methods for the disposal of household waste, noting the advantages and disadvantages with special interest in self-contained systems and ones that use little or no water. Part II is a catalogue of data emphasizing low cost systems being manufactured in various countries, not purporting, however to be a consumer's guide. Classification of water disposal systems is by processes that occur to the human waste: manual removal, mechanical removal, destruction, infiltration, and decomposition. Part III describes the operation of composting toilets, and ends with a low cost design by the authors for use in temperate climates, which can be made for $100. or less. A useful summary chart gives concise data on all toilets listed herein.

*ROSENER, A., PARKER, D., BRZECZEK, M., OTT, G., HARRIS, S. and LENDA, J. Technology Development for a Zero-Gravity Whole Body Shower Contract No. NAS1-9819, National Aeronautics and Space Administration. U.S.A. 268 pp.

Initially, the programme consisted of theoretical and experimental investigations to establish design parameters. These design parameters were used to establish the test hardware for further experimental investigations in both one-gravity and zero-gravity environments. This report describes these efforts and the resulting conclusions concerning shower feasibility, shower design concepts. liquid-gas separation techniques, and their related zero-gravity design criteria.

During Task 1, an analysis of zero-gravity air-water behavious, stall configuration, and related habitability parameters was made before the test hardware was constructed. The Task 2 effort investigated and refined these concepts to establish the minimum impact on the contract baseline mission model.

Based on Task 1 and Task 2 test results, basic design criteria were established for two zero-gravity whole body shower concepts. The amount of water required to bathe the whole body, including the head, averages approximately 1/2 gallon, which is due to the use of hand-controlled nozzle, the nozzle design, operating procedures, and the tendency of the water to cling to the body.

*ROSENER, A., PARKER, D., HALL, J. and HARRIS. S. Space Shower Habitability Technology American Institute of Aeronautics and Astronautics Conference. U.S.A. Paper No. 71-873. 8 pp. August 9-11,1971.

A zero-gravity, whole body shower design has been developed that provides crewmen with bathing facilities similar to those used on Earth. In the absence of gravity, surface tension is the primary force which governs water behaviour. Shower stalls and associated hardware must be designed to effectively collect water for subsequent processing. The shower habitability parameters must be integrated with this technology to ensure crew compatability and comfort. Test results are presented concerning these habitability parameters and how they are effective in providing a shower to cleanse the hair and body and provide a psychological lift.

*SCHUMACHER, E. and LENDA, J. Design, Fabrication and Acceptance Testing of a Zero-Gravity Whole Body Shower American Institute of Aeronautics and Astronautics, Intersociety Conference on Environmental Systems. U.S.A. Paper No.A74-39144. 11 pp. July 29 - August 1, 1974.

This paper describes the three task effort to design, fabricate, and acceptance test of a zero-gravity whole body shower for the Space Station Prototype. Conceptual designs for various subsystems of the shower were established as part of Task 1. Task 2 involved the formulation of preliminary and final designs for the shower. The design has separate modules for the showering area, electrical and mechanical components. Task 3 included the fabrication and test of the shower assembly.

*SHARPE, W. Water Conservation and Wasteflow Reduction in the Home The Pennsylvania State University, College of Agriculture Extension Service and the Institute for Research on Land and Water Resources. U.S.A. Special Circular 184. 9 pp. 1977.

A step by step explanation of treatment of water supply and waste-water is given. What is shown are ways for the normal style of living. The less water we use the smaller the volume of waste water produced, and the less it costs for treatment. There is a description of water-using appliances and of water saving devices for taps, toilets, and showers; as well as a table showing water and cost savings by reusing wash water in toilets. Two-cycle, vacuum and incinerator toilets are also discussed.

*SOBOLEV, A. and LLOYD, C.J. Trials of Dual Flush Cisterns Journal of the Institution of Water Engineers. U.K. 18(1). pp.53-58. February, 1964.

This paper describes the construction of a dual-flush cistern, and the way it saves water. Details of trials carried out, to determine the saving likely to be achieved are given.

*VINCENT, L.J. and KEPPIE, G. Reduction of Water Waste by the Use of Constant-Flow Valves AID-UNC/IPSED Series Item No.2. U.S.A. 4 pp. September 1966.

Installation of inexpensive constant-flow valves rated at 9.1 1/min. in the supply lines to individual houses in Kitwe, Zambia reduces the water use by 25 to 30 per cent. No complaints regarding inadequate supply have been received. Cost of the constant flow valve is approximately U.S. $1.50 to $2.00.

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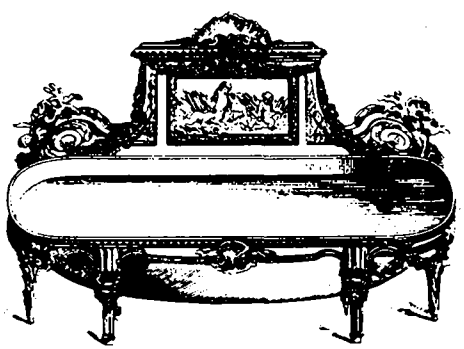
16. ROSENER, A.A. et al. Technology Development for a Zero-Gravity Whole Body Shower, NASA Contract #NAS 1-9819, Martin Marietta Corp., Denver, Colorado, 1971.

17. The BRE has not published results of its work with atomised sprays. The information given in this book is the result of a personal visit by one of the authors.



FLASH

Lilco Gives 800,000 Water-Saving Devices

Special to The New York Times

MINEOLA, L.I., March 11—The Long Island Lighting Company has started sending water-flow restricters to its 800,000 residential customers as an energy-saving measure that is also expected to save homeowners about $50 a year in water-heating costs.

The saving in oil, gas, electricity and water costs is based on estimates by the utility that a typical shower lasts five minutes, that each of the four members of the average family takes one shower a day and that the number of gallons of water used per shower would be reduced to 16 gallons from 40 gallons. Based on the utility's estimates, its customers would take a total of 1.68 billion showers a year.

The restricter, which is to fit into shower heads, is expected to save from $20 to more than $100 a year per household on heating costs alone because less water would be used.

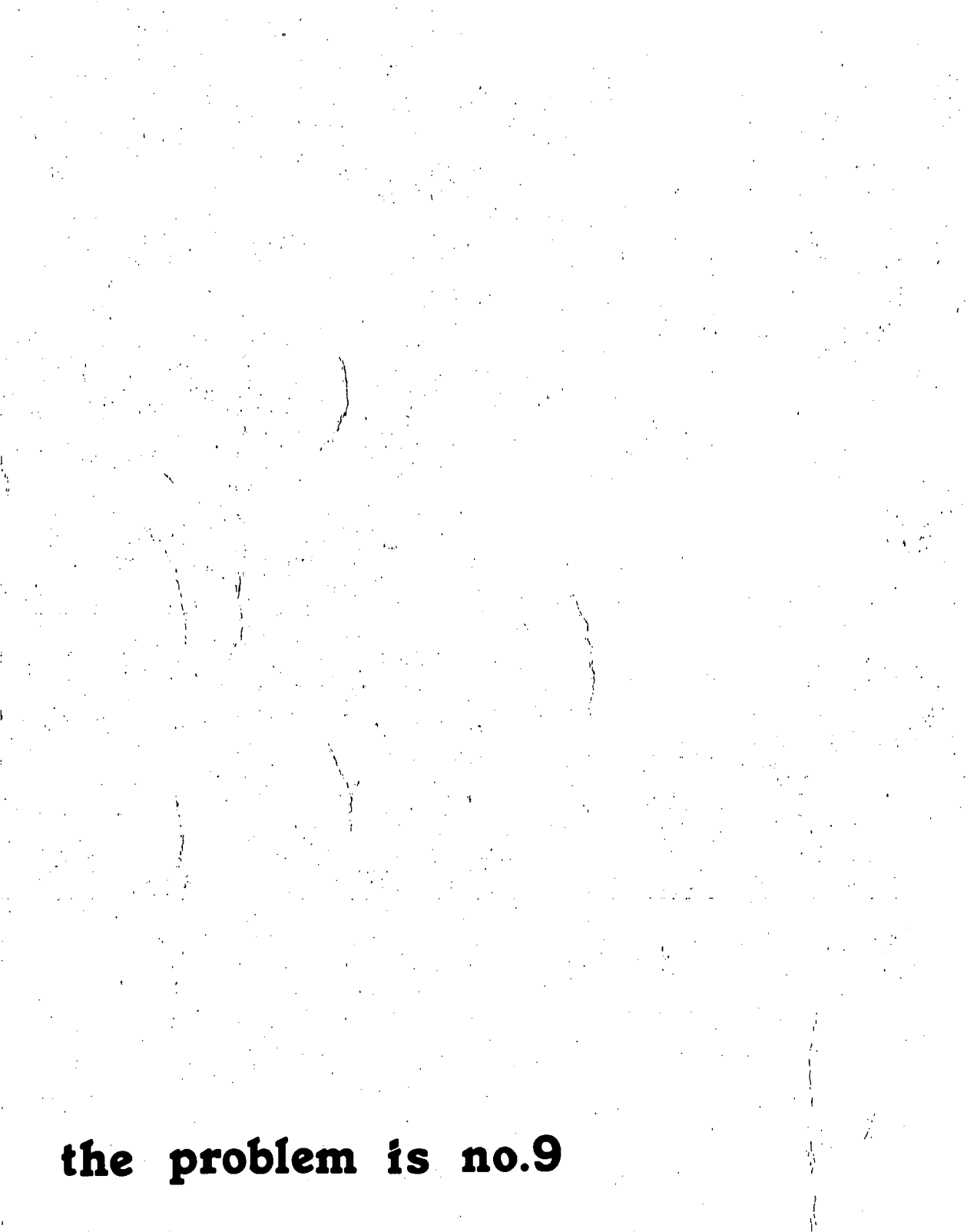
The utility is spending about $20,000 to send the restricters, which resemble dime-size metal washers, to its customers in Nassau and Suffolk Counties and on the Rockaway Peninsula of Queens. They are being sent as enclosures in bills to its residential electric and gas customers. Ira Freilicher, a vice president of Lilco, noted that about three-quarters of consumers use oil for heating hot water, 20 percent more use gas and about 5 percent use electricity.

The utility is unable to determine how much oil would be saved or precisely how much money the average family could save through the use of the water restricter because of such variables as the rate of water flow in the consumers' homes, the number and duration of showers taken and water temperature.

The utility's customers are being told that the installation of the restricter can be done simply with a pair of pliers or with an adjustable wrench. The shower head is removed and the restricter is inserted between the water pipe and coupling nut. This will limit the amount of water flowing through the shower head by as much as 60 percent.

Lilco says the device "should not interfere" with the operation of shower-massage attachments. Although the flow of water will be restricted, Mr. Freilicher said, the shower would be "comfortable." However, "if you really like a full-blasting, tough, sizzling shower, don't put it in," he added.

Lilco said the item became popular on the West Coast about a year ago during the drought when California distributed the devices as a water-conservation measure. Lilco says it is the first utility in the country to make such a mass mailing.



the problem is no.9