THE USE OF ATOMIZATION FOR WASHING
AND SHOWERING TO CONSERVE WATER

Alexander B. Morse

A thesis submitted to the Faculty of Graduate Studies and Research of McGill University, Montréal in partial fulfillment of the requirements for the degree of Master of Architecture.

August, 1976.

ABSTRACT

In order to reduce the amount of water needed for individual bathing, and, in turn, to reduce household consumption of water in areas of water scarcity and in areas having polluted water, the use of atomized water is proposed.

Combinations of pressure systems and nozzles for showering are examined; and bathing feasibility by this method is tested. Results show a water saving of over 90%.

AVANT PROPOS

Afin de réduire la quantité d'eau nécessaire pour prendre une douche et, donc, réduire la consommation domestique d'eau dans les régions arides ou les régions où l'eau est polluée, on propose ici l'emploi d'appareils d'atomization.

Différentes combinaisons de systèmes de pression et de becs sont mises à l'épreuve afin de déterminer le moyen le plus efficace, tout en utilisant le moin d'eau possible, pour prendre une douche. Les résultats démontrent une économie d'eau de plus de 90%.

Acknowledgements

I want to express my thanks and appreciation to the other members of the Minimum Cost Housing Group for their assistance and ideas, and humor; particularly Vikram Bhatt and Bernard Lefebvre.

And to Professor Alvaro Ortega and Professor Witold Rybczynski for their ideas, guidance and patience and in making this thesis possible.

And to Maureen Anderson for her moral support and great assistance in helping to edit this thesis.

And to R. Buckminster Fuller for his personal encouragement for this thesis.

And to Mr. Leonard A. Bird of John Brooks Canada, Ltd. for technical advice.

And to members of the McGill University Department of Engineering Faculty for technical advice.

And to Mayor Trepanier of Granby for his comments and interest.

And to members of the McGill University Medical Faculty for information.

And to Mr. Maurice Boulerice and Mr. Robert Boudeau of the City of Montréal Department of Health for skin bacteria tests.

And to Elinor Brady for encouragement.

And to Helaine Blumenfeld for encouragement.

And to Shirley Hallem for typing the thesis so handsomely.

CONTENTS

INTRODUCTION AND OUTLINE

The thesis is that atomized devices can be a great aid in conserving water; and specifically in showering. The first part of this paper deals with the problem of water shortage; then comes a survey of hygiene in relation to showering. Next, Part III defines atomization and its dominant characteristics and principles, and focuses on nozzles and their performance.

In Parts IV and V tests on nozzles and then their performance with pressure equipment for showering are reported.

Part VI presents final conclusions and the thesis ends with Appendix I, showing related design possibilities, and Appendix II, a report on skin bacteria tests.

Part I

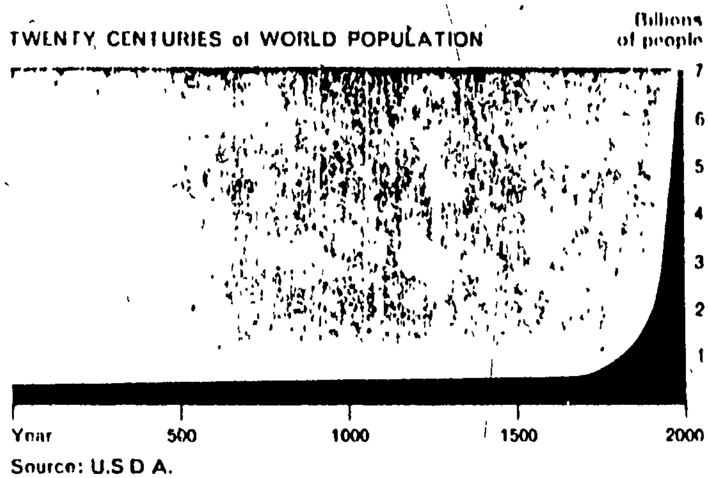
THE PROBLEM

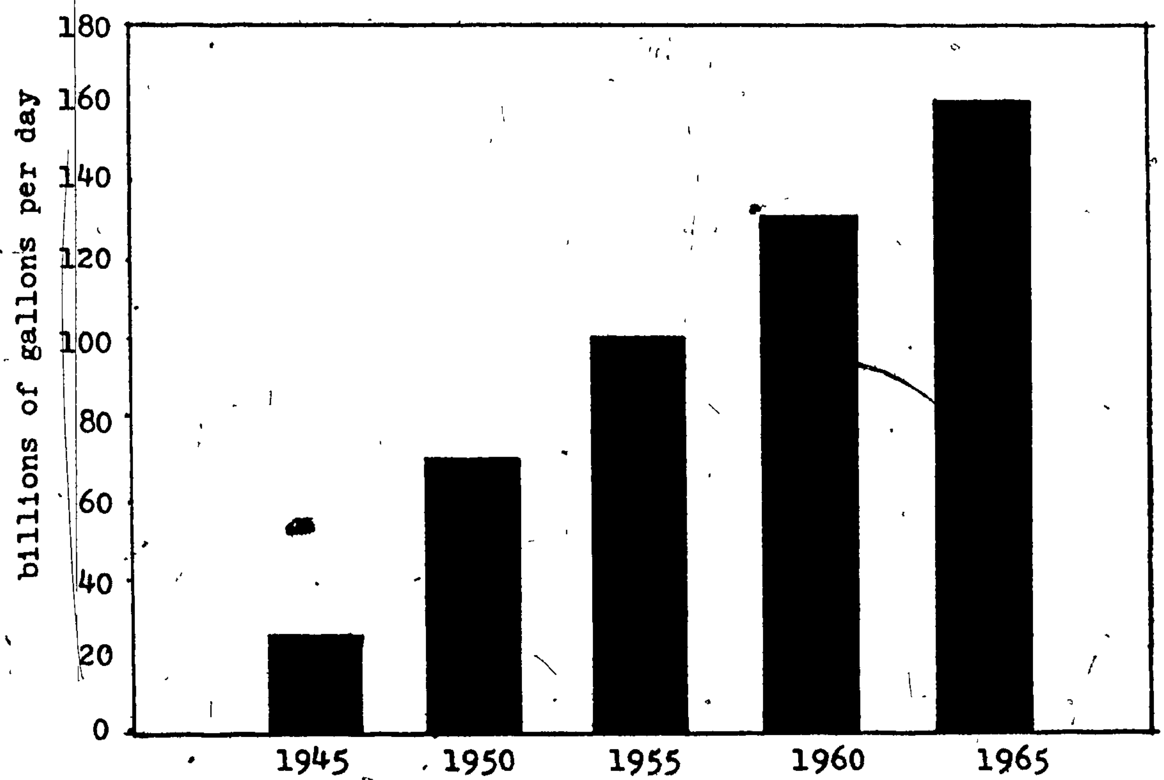
1. Water Economy

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 the water is often 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. A less usual case occured in the Québec town of Granby in 1975. A report on this begins on page 27 of this thesis.

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,[26] 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 problem of technological, biological, and organizational



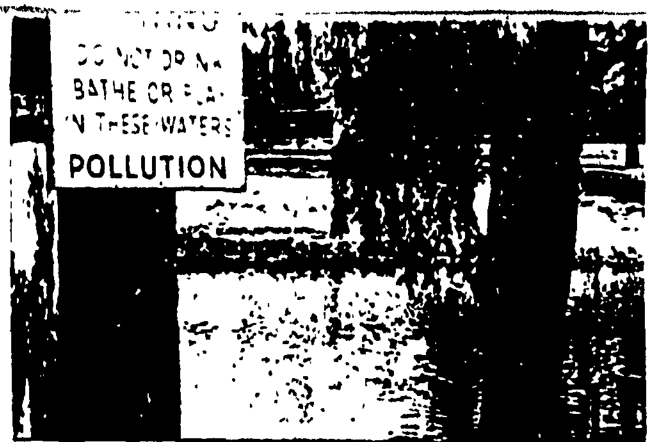


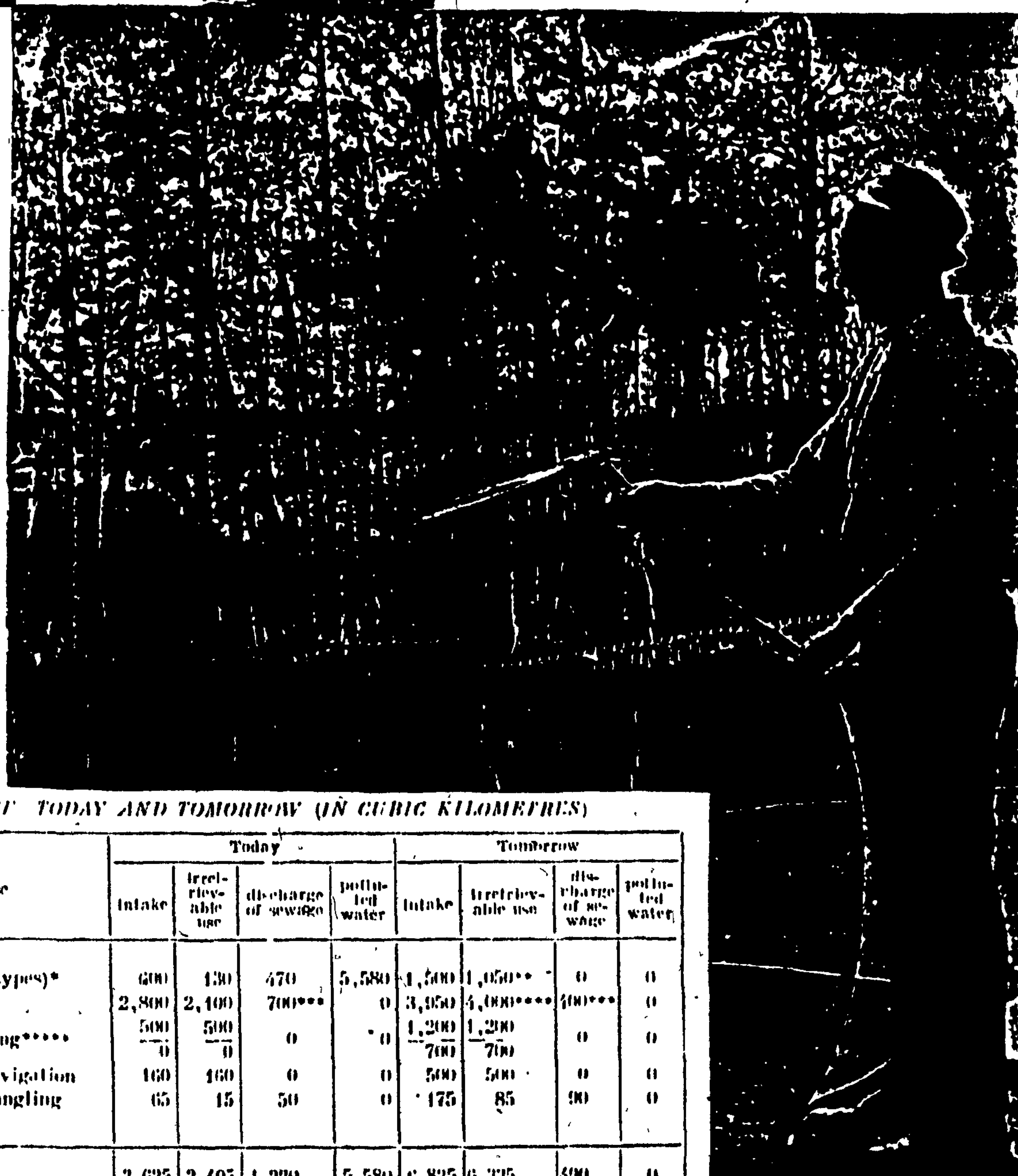
Industrial Use of Water in U.S.A.

from Journal, American Waterworks Association, Nov. 1969 measures. This thesis deals with a technological measure. Thus the water problem is one of water economy.

The Table on page 6, from a 1971 World Bank Report, Water Supply and Sewerage[50] 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 beds of lakes and rivers. In groundwater, they 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.





WATER USE TODAY AND TOMORROW (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	1,050**	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.

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 feasible physically in urban areas beyond a certain size. Moreover, in the case of water from vendors, the price is so high (see table on page 11) 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

Country and city	GNP of country per capita US$	Water statistics date/year	Population: Million	Population: Five year annual rate of increase (%)	Portion of total population served by: Private connections (%)	Portion of total population served by: Public taps (%)	Water production per capita per day (l)	Consumption/capita/day for population served: Total	Domestic	Industrial	Official	Other	Unaccounted water %	Average revenue per m3 consumed US$	Service connections as percentage of water connection
BRAZIL Sao Paulo city	250	1969	5.9	5.0	59		310	200	NA	NA	NA	NA	36	0.05	57
BURUNDI Bujumbura	50	1969	0.07	8.0	10	70	95	65	NA	NA	NA	NA	30	0.09	NA
CAMEROON Douala	130	1968	0.21	5.0	15	85	72	56	22	19	15		22	0.15	NA
Yaounde		1968	0.11	8.0	20	80	83	66	42	4	20		20	0.19	NA
CHINA Taipei	270	1968	1.69	7.0	71		281	183	NA	NA	NA	NA	35	0.04	
COLOMBIA Bogota	310	1969	2.52	6.7	97		215	160	146		12	2	25	0.02	NA
Cali		1969	0.92	7.9	NA		295	230	170	30	30		22	0.04	99
Palmira		1969	0.14	6.0	89		295	205	NA	NA	NA	NA	30	0.02	95
ETHIOPIA Addis Ababa	70	1969	0.75	6.4	67	20	40	29	27	2			27	0.1[illegible]	
GERMANY, Federal Republic of	1,970														
West Berlin		1963	2.18	NA	100		184	178	109	52	17		4	NA	NA
Hamburg		1963	1.92	NA	100		180	167	131	20	11		7	NA	NA
GHANA Accra	170	1970	0.68	7.0	50	50	86	59	34	14	10	1	31	0.32	1
Tema		1970	0.10	12.0	90	10	36	34	16	18			7	0.12	NA
JAMAICA Kingston	460	1969	0.60	4.1	93	7	235	180	119	36	25		24	0.08	16
MALAYSIA Kuala Lumpur	330	1970	0.70	3.9	75	10	271	220	176	44			19	0.07	71
NICARAGUA Managua	370	1969	0.33	6.0	73	8	250	205	160	25	20		[illegible]	0.[illegible]	NA
PAKISTAN Lahore	100	1969	1.80	4.0	38	26	144	90	NA	NA	NA	NA	37	0.01	11
Dacca		1969	0.80	3.2	32	63	176	81	57	8	16		54	0.02	21
Chittagong		1969	0.35	NA	12	57	62	33	30	3			16	0.08	
PHILIPPINES Manila	180	1969/70	4.5	NA	85		300	135	NA	NA	NA	NA	55	0.03	NA
SINGAPORE	700	1969	2.02	2.0	94	5	230	211	101	46	64		8	0.03	NA
TUNISIA Sousse area	220	1969	2.3	5.3	45	55	103	82	67	13		2	23	0.12	NA
UNITED STATES	4,980														
Baltimore Maryland		1969	1.49	NA	100		619	526	165	361			15	NA	NA
Phoenix Arizona		1969	0.58	NA	100		813	729	NA	NA			10	0.10	NA
Portland Oregon		1968/69	0.58	NA	100		655	533	NA	NA	NA	NA	19	0.06	NA
VENEZUELA Caracas	950	1969	2.0	5.0	100		230	190	130	45	5		12	0.13	NA

Source: ... World Bank Atlas

1 m3 = One cubic meter = 1000 liters = 264.2 U.S. gallons = 220 Imperial gallons

NA = Not Available

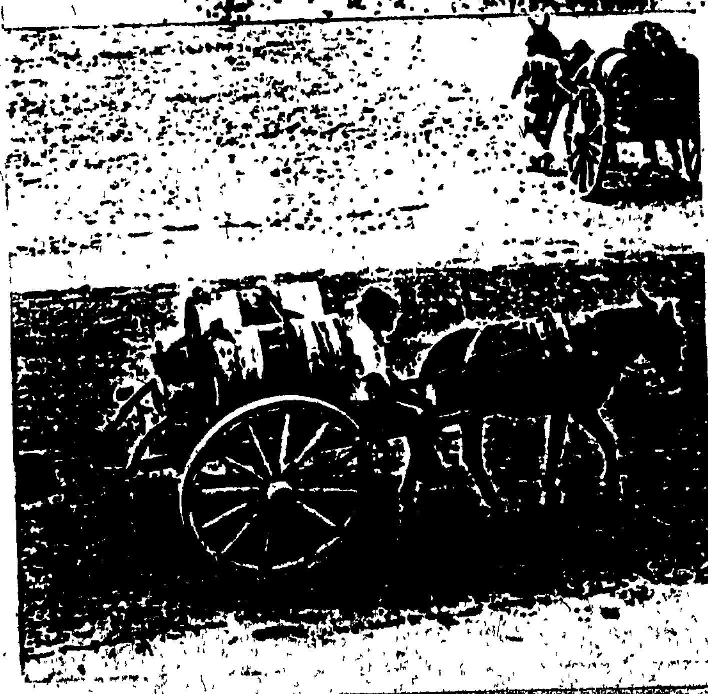
developing countries in recent decades, the typical experience is that service which may have been adequate at one time deteriorates as consumers are connected to the system at a faster rate than its capacity is increased. Once a system is operating above capacity, the quality of service deteriorates 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."

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 or 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.

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



DISTRIBUTION OF WATER

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 (see page26), 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 most critical. The least volume and weight the water supply uses, the better. Accordingly, Martin Marietta designers contracted by the National Aeronautics and Space Administration[35] 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.

COST OF WATER TO CONSUMER

	Price charged by water vendors		Metered domestic rate to customers served by the city water system	
	per 1000 U.S.gal.	per m^3	per 1000 U.S.gal.	per m^3
Dacca	$4.20- 8.40	$1.11-2.22	35¢	9¢
Kampala	$5.84-14.16	$1.55-3.86	70¢	18¢
Istanbul	$3.52	$0.93	35¢	9¢
Singapore	--	--	21¢	6¢
typical U.S.	--	--	25¢-50¢*	7¢-13¢
typical German	--	--	40¢-75¢	11¢-19¢

Water Supply and Sewerage Sector Working Paper - World Bank 1971 50

* In a Washington, D.C. suburb, in 1976, the cost of metered water is $1.30/1000 gal.

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.[45]

Allocation of Water in a Large City

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%

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 cooking, and drinking on the one hand, and water 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 21) 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.

Daily Water Consumption per Person

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.)

– EPROM Report[37] Minimum Cost Housing Group, McGill University.

Domestic water use on world surveys varies, but the average recommended by Wagner and Lanois in WHO Report #42[46] 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.

Source	Author	Comments	Gal./day	Liters/day
WHO Report #23	Dieterich & Henderson /1963	N.American household	40.0	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	Belanger/1970	plumbing system under pressure (see p.14 in thesis)	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

"Very low values tend to reflect a grossly inadequate supply rather than actual demand for beneficial use; the higher values tend to reflect gross water waste".

WHO Report #23

Here's a good example of how availability increases consumption (and waste): When water has to be carried from a well, average usage is 36 liters per day (8 gallons). When a pump is put at the kitchen sink, consumption increases to 45 liters (10 gallons) per person per day. Put in a faucet and that figure goes up to 54 liters (12 gallons). Introduce hot water in the kitchen and you'll use 81 liters (18 gallons) a day. But---put in a complete plumbing system under pressure, and usage increases to 135 liters (30 gallons) a day. This includes anywhere from 36-90 liters (8-20 gallons) each time the bathtub is used, 13.5-22.5 liters (3-5 gallons) each time a toilet is flushed and 4.5-9.0 liters (1-2 gallons) each time a bathroom washbasin is used.

Countryside by Jérome Bélanger
Whole Earth Catalog

3

Expected water withdrawal is estimated at 18 liters (4 gallons) per person per day for a hand operated pump in a small locality with a population of less than 2000. For villages of 2000-10,000 a piped water supply should provide 68 liters (15.1 gallons) per person per day. Standpipes can serve 150 people each.

WHO Chronicle #21, 1967

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Breakdown of water quantities used for cleaning (per person per day)

Source	Shower	Bath	Handwashing
Ultraflo Corp., Sandusky, Ohio Data on ordinary facilities	54 l. (12 gal.) 5 minutes	--	6 liters (1.3 gal.)
NASA Skylab Shower:	2.5 l. (.66 gal.) 9 minutes	--	--
Minimum Cost Housing Group, McGill University EPROM	--	70 liters (15.5 gal)	7.5 liters (1.6 gal.)
Minimum Cost Housing Group, McGill University Data on ordinary facilities	10.0 l.(21.9 gal)	--	5.0 liters (1.1 gal.)
Minimum Cost Housing Group McGill University Ecol Operation Data on spray facility	15.0 l.(3.3 gal.)	--	.05 liter (0.1 gal.)
NOVA Data on ordinary shower	94 l. (25 gal.) (10 minutes)	--	--
MINUSE Data on ordinary shower	94 l. (25 gal.) (5 minutes)	--	--
PERSONAL use in ordinary facilities	48.15 l.(10.7gal.) (5 minutes)	112.5 l. (25 gal.)	2.8 liters (.6 gal.)

Quantities of water for daily personal use by the author:

Brushing teeth	2.8 liters	(1/2 gal.)	X 2	= 5.6
Shaving	2.8 "	"	X 1	= 2.8
Facewashing	2.8 "	"	X 2	= 5.6
Handwashing	2.8 "	"	X 3	= 8.4
				22.4 liters (3.9 gal.)
Tub Bath 1/wk	112.5 "	(25 gal.)	X 1/7	= 16.1
Hair Washing 1/wk	13.5 "	(3 gal.)	X 1/7	= 2.0

40.5 liters/day
X7 days

TOTAL 283.5 liters/week (63 gal,wk)

The lavatory bowl holds 9 liters (2 gallons)

Most washing operations filled bowl about 1/4 full.

Running water amounted to about 1/4 full bowl.

These personal amounts may be less than average.

5. Devices for Water Conservation

Since the problem of water shortage focuses on domestic use, that being the greatest area of utilization, it is mainly here that steps have been made towards better water management. The greatest use in the home is for flushing toilets, a use not vital to Man's survival. Alternative methods of flushing with less water have been proposed but only modify the situation slightly. Aerobic systems such as the Clivus Multrum mouldering toilet offer a definite advantage, since they use no water at all. However, difficulties arise for these systems in new urban installations, particularly in high-rise situations. The waste collection raises problems.

Devices for conserving water at the point of use have been offered which greatly reduce waste due to inefficient devices, as well as inefficient use. Also, reduction in the quantity of water to do the same task is proposed. Some of these devices are, for example:

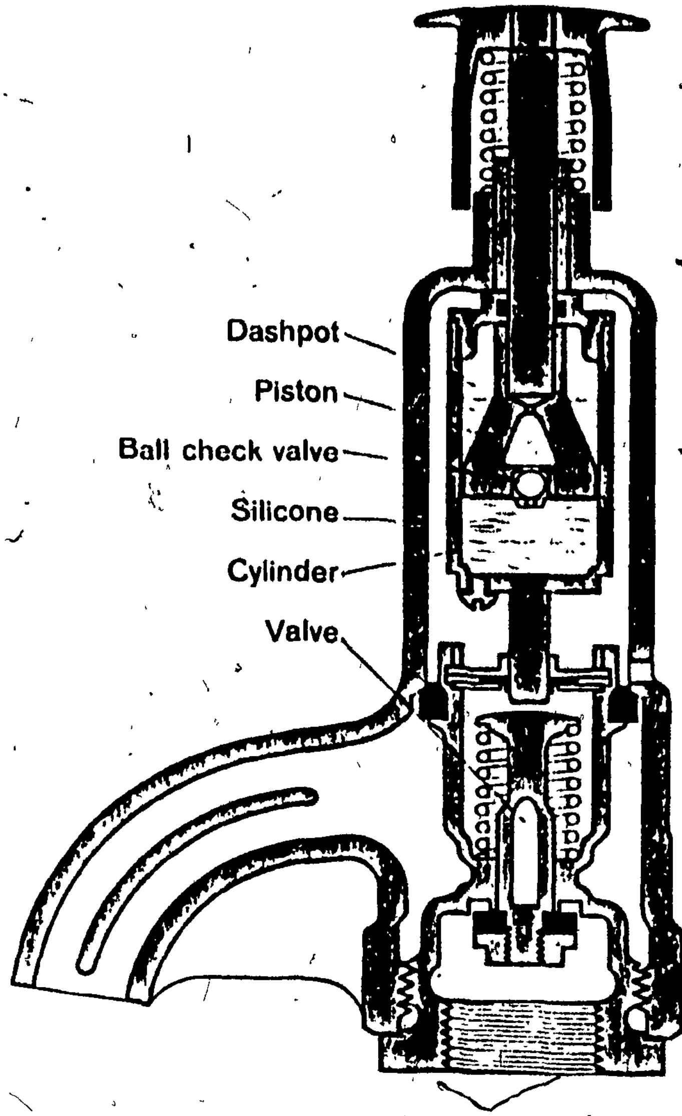
- Fordila Middleway faucet
- Ultraflo plumbing system
- Minuse Shower
- Nova showerhead
- Dole pressure reducing valve
- Watts pressure reducing valve

Two other water savers[4] which are in regular use are the front-loading dishwasher (in preference to the top-loading type) and the pedal operated faucet.

But of more relevance here is the remarkable water-saving shower in the NASA Skylab which used 2.5 liters (1/2 gallon) of water for a 9 minute showerbath. The precedent for this was first conceived of by Buckminster Fuller[15] and tested by his students at the Institute of Design in Chicago in 1948. His Fog Gun could spray at the rate of .56 liters/minute (1/8 gallon/minute). (see page 67)

Devices for atomization of water would make it possible to extend greatly the water supply in developing countries. Clean water shipped in containers can overcome the shortage due to polluted water, and water atomization devices could extend the supply while at the same time lowering its relative cost.

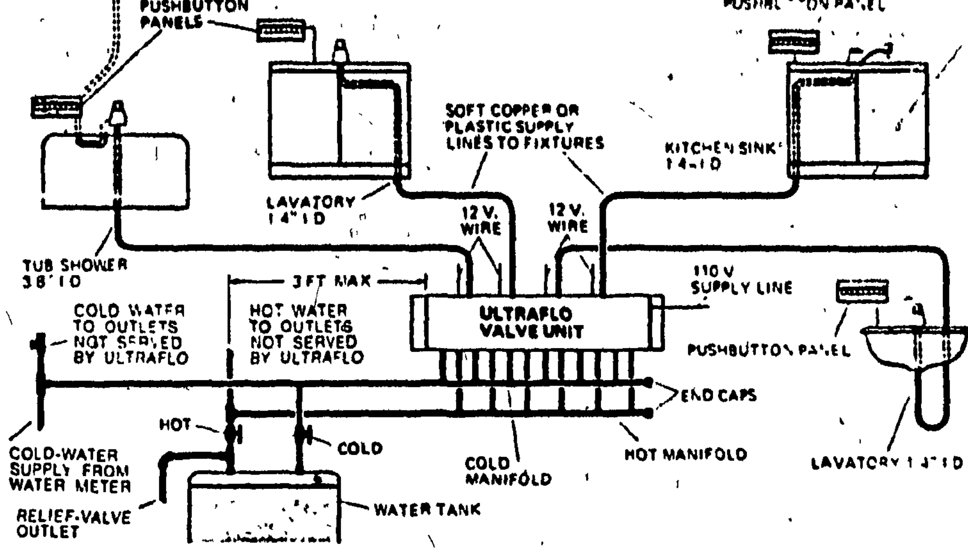
This is an answer to the problem of water shortage.

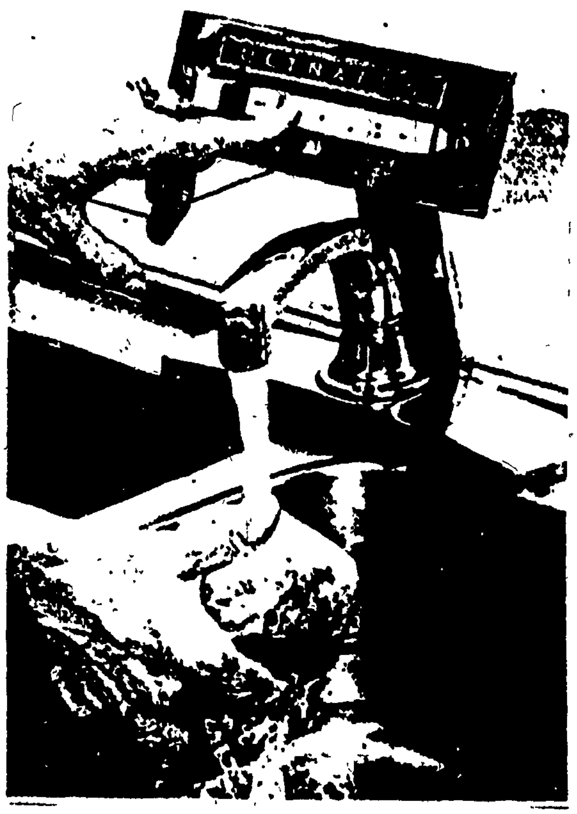


The Fordilla Middleway faucet is primarily concerned with preventing wasteful running of unused water. It operates with a spring-loaded button, which automatically shuts off if held down longer than 5 to 10 seconds. It discharges approximately 1 liter per time.

—Ford Meter Box Co., Inc.
Wabash, Ind.

Typical Ultraflo Installation





There are eight buttons for the kitchen sink. When OFF button is pushed, the only water left in the line is in the 3 ft. section between water tank and valve unit.

The Ultraflo system uses an electric push-button control and small supply pipes. Waste is prevented by eliminating the running of water to get desired temperature. Solenoid valve near water heater responds to push button and delivers water at preset temperature.

Ultraflo Corp.,
Sandusky, Ohio.

Believe it!

The Minuse Shower does it!

Minuse means Minimum Use . . . and a cleansing, luxurious shower at a water flow rate of only ½ gallon per minute . . . is Minuse.

COMPARE

Conventional shower	5 minutes =	25.0 gallons of water
Minuse shower	5 minutes =	2.5 gallons of water
Savings per 5 minute shower		22.5 gallons of water

The Minuse Shower (patent pending) represents new "state of the art" technology which can best be described as conservation technology dedicated to solving environmentally based problems at a true economic savings. The application of this technology has produced the world's most efficient shower which delivers a dramatic 90% SAVINGS in water and energy over the ordinary plumbing fixture.

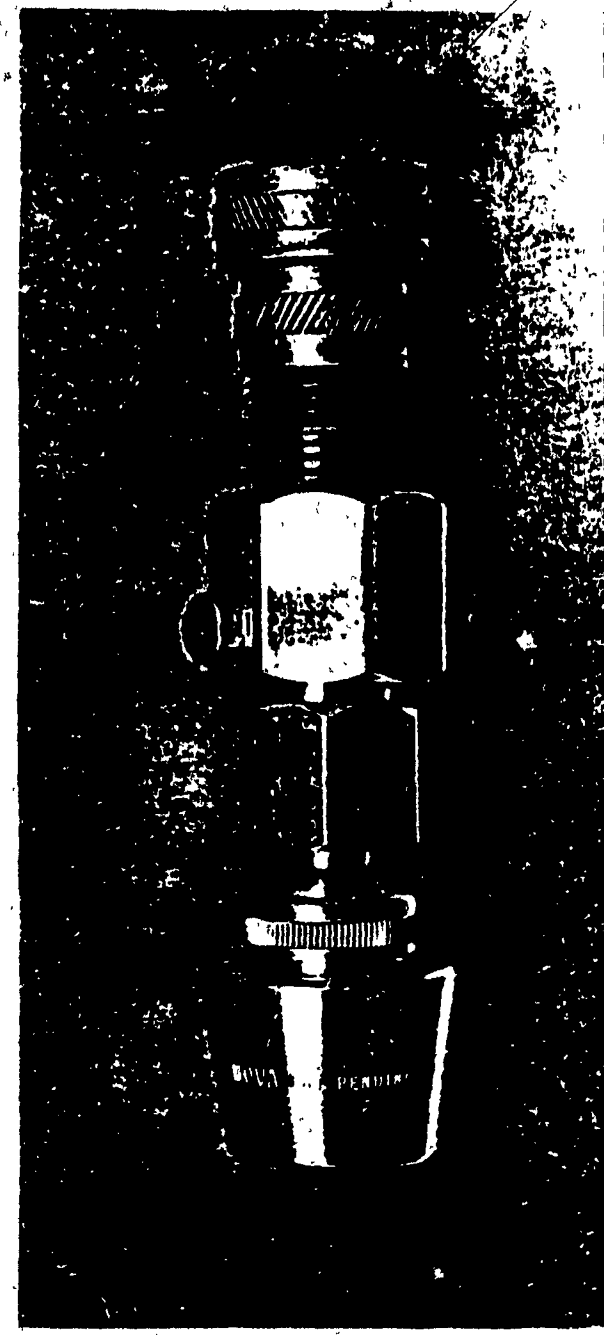
Bathing is the second largest consumer of water in the household and the largest (exclusive of heating and cooling) consumer of household energy. Reduce the water used in bathing and you save three valuable resources . . . WATER, ENERGY, and MONEY. Reduce the water used in bathing and you effectively expand the "capacity" of sewer and septic systems by reducing sewage effluent.

The Minuse Shower can be readily installed in any new construction and retrofitted in almost any existing shower.

MINUSE SYSTEMS, INC.

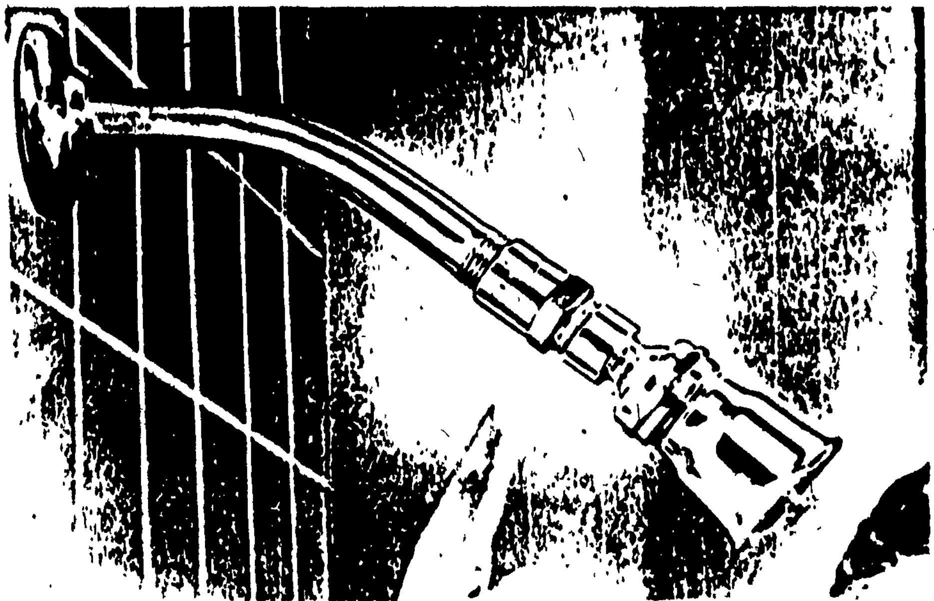
The water issues from three orifices in the nozzle head. An air blower imparts additional velocity, similating a conventional shower flow. Its rate of water consumption is 1.8 liters/minute (.5 gal./min.)

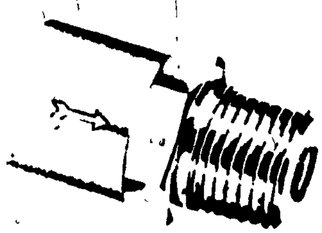
Minuse Systems, Inc.,
Jackson, Cal.

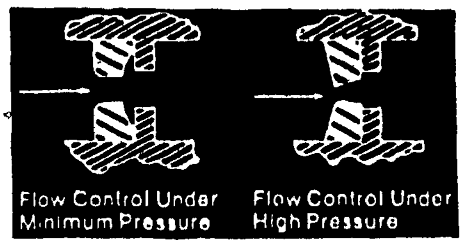


The Nova showerhead reduces water consumption at the point of use. Its construction allows nozzle adjustment from "fine needle" to "soft rinse" and has a button cut-off for the soaping-up period. Its capacity at 1.3 atmos. (15 psi) is 6 liters/minute (1.35 gal./min.)

Jay Norris Corp.,
Ecological Water Products, Inc.,
Freeport, N.Y.





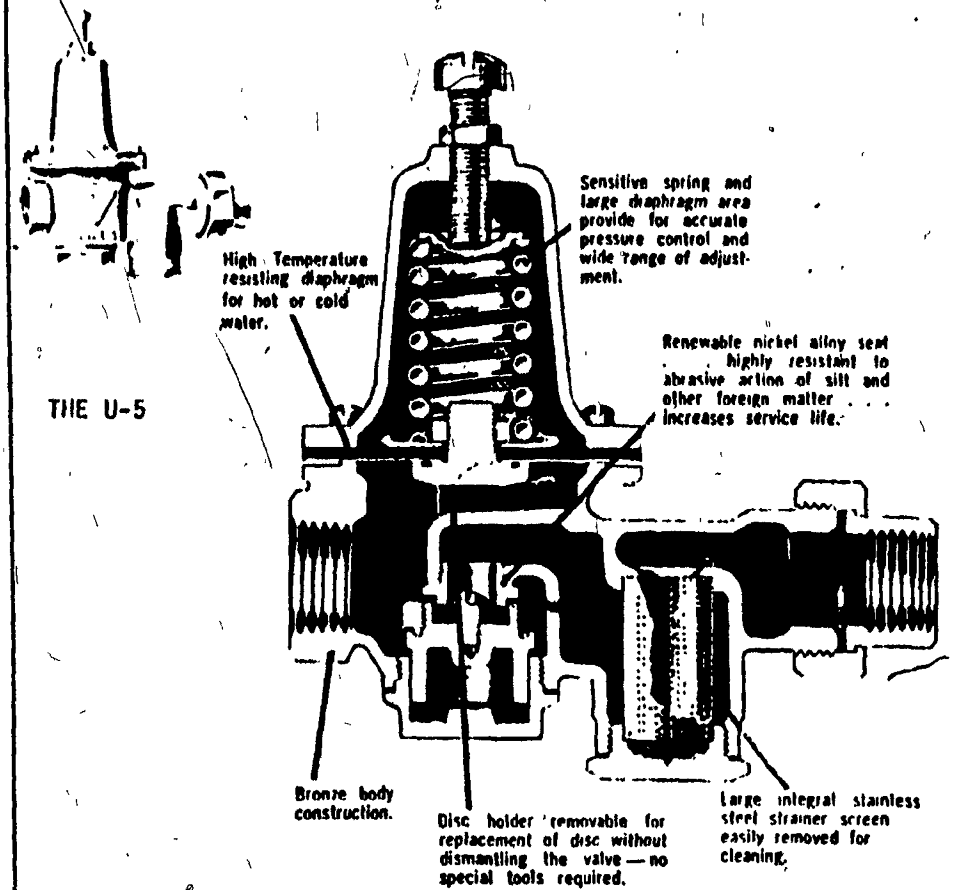


DOLE® FLOW REDUCING VALVES

Water volume reducing valves for retrofitting household fixtures

This water flow reducing valve can be fitted onto existing fixtures. It would reduce the pressure independently of other fixtures. "It is recommended for all fixtures people tend to let run independently of volume delivered for as long as they need washwater."

Eaton Corp.,
Carol Stream, Ill.



WATTS PRESSURE VALVES — WATTS REGULATOR COMPANY

Water pressure-reducing valves for water and fixture-saving purposes

The Watts pressure valve can be used to reduce pressure on independent fixtures or on the whole house system.

Watts Regulator Co.,
Lawrence, Mass.

It is interesting to note the water use standards adopted by the World Health Organization[1] 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 liters (22 gallons) per person per day.

Recommended standard for showers is 20-30 liters/person/day (4.4-6.6 gallons). 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 liters (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 liters/per week (6.6-7.7 gallons)."

6. The Case of Granby

Upon hearing about the sudden water shortage in the town of Granby in the Québec, Eastern Townships, it was decided to offer our research to the services fo the Mayor. Possibly devices for atomization of water could help. Emergency nozzles could be attached to faucets and the Town water pressure could be lowered.

Mayor Trépanier and the Town Engineer agreed to meet and discuss the proposal for immediate realization. Literature, notes from research and spray devices were shown and demonstrated at the City Hall. The following data was obtained:

Present Granby Population: 37,000

Projected Population: 75,000

Water is delivered by 1 meter (3') mains from a reservoir lake (after being filtered) it has not been chlorinated but Provincial law now requires it.

Water use is mainly divided equally between residential and industrial use (15 industries). The largest industry consuming water is a dairy coop.

Residential Consumption	8 million liters/yr	(1.8 million gal./yr)
Industrial Consumption	7 " " "	(1.6 " " ")
Hospital Consumption	6.5 " " "	(1.5 " " ")
Convent of 150 people	1 " " "	(2.2 " " ")

Apparently some supplies are metered. Average individual residential use is 450 liters/day (100 gal./day)*, more in summer.

Individual use combining residential and industrial is 1125-1350 liters/day (250-300 gal./day).

Water shortage caused by drought in relation to demand. This would not have happened 10 years ago.

As to solutions, the first was all industries agreed to voluntary water rationing (see page 31); some reduced as much as 80% their regular daily use. Some of the main valves were closed off. Proposals for other action were studied but found too costly: for example, importing water by train tanks; drilling wells, buying water and dispensing devices. Dispensing devices would have brought the cost of water to 11¢ a liter (50¢ a gallon).

Mayor Trépanier would have liked to have known about atomizer devices before spending $3.5 million on water plant three years ago. He says it would be useful for architects to specify such devices but the city cannot force people to install them.

Before installing them, the Town Engineer felt the results of metered water would prove to people tha necessity of some such devices to save water (and money).

Didn't get figure on total water consumed per year. Engineer said if people were careful to use the minimum amount of water necessary it would be 4.5 billion liters/yr (1 billion gal./yr).

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* compared to MCHG study showing 250 liters/person/day (55 gal.person/day)

Asked if atomizer devices installed as an emergency measure was feasible, the Engineer said it depended on how long the emergency lasted. It would have to be over 3 weeks in Granby. There would be problems: where to get the devices; how long it would take to install them (say 7,000 to 8,000). Also the problem of finding enough plumbers. He repeated it would be best to have architects specify atomizer devices in new construction for industry as well as new communities but that meters would dispose residents to buy them. Tax incentives could also be used.

So the concept of using atomizer devices as emergency relief would be workable depending on the degree of emergency, where duration is easily predicted as after earthquakes, the feasability is certain. For limited emergency in an established community, it would be a matter of cost, so a feasibility study was suggested by the Mayor, possibly supported by industry.

The Mayor was very impressed with the idea and the devices and was very enthusiastic. The Town Engineer pointed out that the devices would mean reducing water pressure. The pressure in Granby is by gravity and varies from 40 to 100 psi which is the same as downtown Montréal - around 2.7 atmos. (40 psi) for taps and 6.8 atmos. (100 psi) for fire sprinkler devices.

Granted, since the greatest expenditure of water is in toilets, toilet water reduction is a higher priority than devices to reduce water used for bathing. However, the exercise proved valuable in expanding information about possibilities for realization and in establishing the level of priority of this thesis' proposition, as far as one town is concerned.

L'HOTEL DE VILLE — GRANBY — 27 août, 1975.

RE: CAMPAGNE DE CONSERVATION D'EAU

A L'OCCASION DE LA REUNION TENUE A L'HOTEL DE VILLE MARDI SOIR, LE 26 AOUT, 1975, CERTAINS MANUFACTURIERS ONT ACCEPTE VOLONTAIREMENT DE REDUIRE LEUR CONSOMMATION D'EAU.

	NOM	CONSOMMATION QUOTIDIENNE	A ACCEPTE DE REDUIRE DE—	CONSOMMATION REDUITE PAR JOUR	SI REALISE, ECONOMIE DE—
1	COOPERATIVE AGRICOLE	960,000	50%	480,000	480,000
2	PEETERS TEXTILE	484,972	50%	242,000	242,000
3	MONTROSE WORSTED MILLS	384,320	35%	249,661	134,659
4	ESMOND MILLS	300,888	35%	195,578	105,310
5	HAFNER FABRICS	281,411	50%	140,705	140,705
6	THOR MILLS	229,150	45%	126,023	103,117
7	SIMONDS CUTTING TOOLS	224,536	55%	101,052	123,494
8	KLOCKNER-MOELLER	30,249	70%	7,705	22,748
9	FEDERAL PIONEER	24,983	50%	12,500	12,500
10	J.L. DeBALL	141,560	35%	92,104	49,546
11	BURLINGTON INDUSTRIES	201,755	35%	131,150	70,614
12	EPSM CO.	169,923	50%	85,000	85,000
13	BOW PLASTIC	149,261	60%	59,705	89,556
14	VIVA KNITTING	28,831	0%	28,831	-0-
15	TREBOR LEEDS	24,390	50%	12,200	12,200
16	POLIPLASTIC CO.	49,253	60%	19,710	29,551
17	CRESSWELL-POMEROY	34,242	70%	10,273	23,969
18	STEEL HEDDLE CO.	28,094	50%	14,000	14,000
19	MINER RUBBER	92,399	80%	18,480	73,919
20	PLASTUBE (TWIN-PAK)	26,982	80%	5,589	21,593
				TOTAL:	1,842,691

L'ECONOMIE ACCEPTEE VOLONTAIREMENT PAR CES 20 INDUSTRIELS SERAIT DE 1,842,691 DE GALLONS D'EAU PAR JOUR.

TOUTES LES AUTRES INDUSTRIES PRESENTES — 55 — AUSSI ONT ACCEPTE DE REDUIRE LEUR CONSOMMATION D'EAU D'ENVIRON 50% DE LEUR CONSOMMATION NORMALE SANS REDUCTION DE LEUR PERSONNEL.

HORACE BOIVIN
COMMISSAIRE INDUSTRIEL

VILLE DE GRANBY

Part II

HYGIENE

1. <u>Bathing and Health</u>

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: [12] "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[32] 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."

Although the skin diseases found after prolonged non-washing of the subjects tested did not interfere with their work, it can be expected that over a much longer period it would have a deleterious effect on their ability to work.

2. What is Clean Water?

The WHO Guide to Sanitation in Natural Disasters[1] 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 are:

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 bacteriological 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

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3. Microorganism in and on Human Beings

Frobisher and Fuerst in Microbiology in Health and Disease[14] describe microorganisms' relation to the human body: " Numerous micro-organisms 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 hearbors millions of microorganisms 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."

organisms regardless of their shape alone, the term **Bacillus** being reserved for those which resemble a rod in shape.

Between thirty and forty years ago, when scientists were first turning their attention to this field of research, a somewhat heated controversy arose between botanists and zoologists as to whether bacteria belonged to the vegetable or to the animal kingdom, a dispute which is now considered to be settled in favour of the claims of the former. But before this settlement was arrived at, a sort of truce was patched up between the contending parties at the instance of certain French scientists, Sédillot, in 1878, suggesting that the term Microbe (from the Greek *mikros*, small, and *bios*, life), might be used without definitely giving the decision in favour of either party. At the present day this word microbe is still a useful term for describing microscopic organisms both vegetable and animal, or where doubt yet exists as to which great group should contain them.

A similar use is made of the somewhat popular term **Germ** (from the French *germe*, and Latin *germen*, a bud), which signifies merely some rudimentary form of living matter, whether plant or animal. Indeed, the dispute is a somewhat profitless one, as the terms "plant" and "animal" were, of course, invented long before these simpler, and practically intermediate, forms of life were discovered. It is an easy matter to distinguish, say, a cat from a cabbage, or a butterfly from a flower; but, as we pass lower and lower down the scale, it becomes more and more difficult, and in truth, at the very bottom, no hard and fast line of demarcation *can* be drawn between the two categories. Bacteriologists are still in doubt as to whether some of the organisms with which they deal should be classed as animal or vegetable; and their difficulties in classification are now still further increased by the comparatively recent discovery of the existence of certain still smaller living organisms—the so-called ultra-microscopic **filter-passers**, for which the name "Chlamydozoa" has been suggested—which are so minute that they are scarcely visible or even quite invisible with the highest powers of the microscope at present available, but which can be proved by experimental methods to be the cause of certain diseases such as smallpox, yellow fever, infantile paralysis, foot-and-mouth disease, and other acute infective fevers, including in all probability measles and scarlet fever, as well as swine fever, pleuro-pneumonia in cattle, fowl-plague, and other diseases of the lower animals. The exact nature of these filter-passers is not yet established, and it is as yet too soon to speculate as to whether they are bacterial or protozoal, or belong to an entirely new and distinct class by themselves. Some of them have now been successfully cultivated outside the body, notably the microbe of pleuro-pneumonia by Nocard and Roux, and of infantile paralysis by Flexner and Noguchi of New York.

At the lowest part of the ladder of life, then, there are numerous very simple forms, the animal gradually merging with the vegetable, and to this group of simplest forms the German naturalist, Haeckel, has proposed that the term **Protista** or **Protists** should be given. Under this term he includes primitive plants (**Protophyta**) and primitive animals (**Protozoa**), both of which will have to be briefly studied under our sub-title of "**Man's Microbe Friends and Foes.**"

We may now therefore, conveniently review in tabular form the scientific classification of vegetable and animal life, in order to realise the position of these microbe plants and animals, for the fuller consideration of which reference may be made to special works on Botany and Zoology.

It may be said that these classifications are of interest only to specialists and scientists, but they are included here merely to indicate the orderly arrangement that is necessary in the minuter study of such subjects, and to demonstrate the position of the group of organisms, whether we call them microbes, germs, bacteria, or designate them by other names.

It is to the lowest group in each series, the **Thallophytes** and the **Protozoa**, that our attention will be more particularly directed, and therefore the subdivisions of these special groups are given somewhat more fully.

CHIEF DIVISIONS OF THE ANIMAL KINGDOM

A. **Vertebrata**, or back-boned animals: mammals, birds, reptiles, amphibia, fishes, &c.

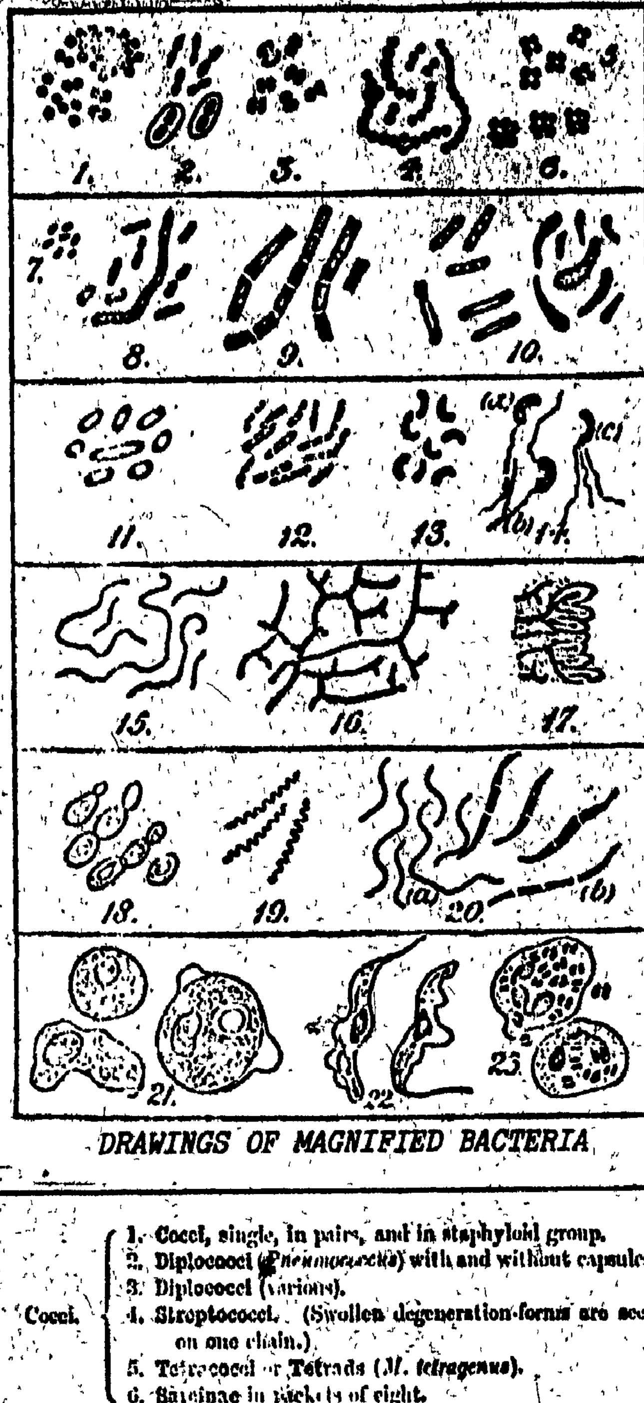
B. **Invertebrata** (with no back-bone):

I. [illegible]

II. [illegible]

III. [illegible]

IV. [illegible]



DRAWINGS OF MAGNIFIED BACTERIA

Cocci.	1. Cocci, single, in pairs, and in staphyloid group.
	2. Diplococci (*Pneumococcus*) with and without capsules.
	3. Diplococci (various).
	4. Streptococci. (Swollen degeneration forms are seen on one chain.)
	5. Tetracocci or Tetrads (*M. tetragenus*).
	6. Sarcinae in packets of eight.
Bacilli.	7. Bacilli, small (*B. influenzae*).
	8. Bacilli. (A thread-like element, often seen in cultures of the Coli-Typhoid group, is present.)
	9. Streptobacillus (*B. anthracis*).
	10. Bacillus showing **Granules and Degeneration Forms** (*B. diphtheriae*).
	11. Bacillus showing **Bipolar Staining** (*B. pestis*).
	12. Bacillus showing **Beaded Staining** (*B. tuberculosis*).
Vibrios.	13. Vibrios or Comma Bacilli (*V. cholerae*).
	14. Vibrios showing various types of **Flagellation**.
[illegible]	15. Leptothrix, i.e., unbranched threadlike forms.
	16. Streptothrix, i.e., branching threadlike forms.
	17. Streptothrix showing "**Clubbing**" of **Sheath**.
Yeasts.	18. Saccharomyces or **Yeast**.
Protozoa.	19. Spirochaetes, **Treponema pallidum** of **Syphilis**.
	20. (a) Spirochaetes and (b) *B. fusiformis* (from case of **Vincent's Angina**).
	21. **Entamoeba histolytica of Tropical Dysentery.**
	22. Trypanosomes (*T. gambiense*), the cause of **Sleeping Sickness**.
	23. Leucocytes containing **Gonococci**.

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. (see table page 40).

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 micro-organisms aided by the warmth and moisture present, and bits of food and desquamated epithelium around the teeth provide nourishment. The normal conjunctivae 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."

"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 organisms 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 limpids with either produces a significant decrease in the bacteriocidal action of the skin." - Medical Technology
Anti-Microbial Agents - Hedgecock 1967

Microorganisms That May be Found More or Less Regularly in or on Apparently Normal Persons

Scalp: *Staphylococcus epidermidis (S. albus)*† *Corynebacterium acnes*†	**Perianal folds and area:** *Mycobacterium smegmatis* *Escherichia coli** and coliforms Enterococci† *Clostridium* sp.† *Lactobacillus* sp. *Corynebacterium* sp. *Staphylococcus epidermidis*† Spores of fungi and yeasts
Conjunctivae: *Corynebacterium xerosis* *Staphylococcus epidermidis* *Haemophilus* sp.*	
Ears: *Mycobacterium phlei* *Corynebacterium* sp. *Staphylococcus epidermidis*†	
Nose, mouth, and pharynx: *Streptococcus pyogenes** *Streptococcus salivarius* *Streptococcus mitis* *Streptococcus faecalis*† *Diplococcus pneumoniae** *Corynebacterium pseudodiphtheriticum* *Corynebacterium xerosis* *Corynebacterium diphtheriae** *Haemophilus influenzae** *Borrelia vincentii*†? *Borrelia buccalis* *Fusobacterium fusiforme*†? *Trichomonas* sp. (*tenax*?)	*Staphylococcus aureus** *Staphylococcus epidermidis* *Neisseria catarrhalis* *Neisseria meningitidis** *Mycobacterium phlei* *Lactobacillus casei* *Lactobacillus fermenti* *Candida albicans** Spores of *Bacillus*, yeasts, and molds Any microorganisms of food or air Filamentous actinomycete-like organisms around teeth (*Leptotrichia buccalis*?) Influenza and adenoviruses*
Axillae: *Mycobacterium smegmatis* *Mycobacterium phlei* *Staphylococcus epidermidis*† *Corynebacterium* sp.	**Genitalia:** *Mycobacterium smegmatis* *Treponema refringens* (esp. male) *Corynebacterium* sp. *Lactobacillus acidophilus* (vagina) *Trichomonas vaginalis**
Glabrous skin: *Staphylococcus epidermidis*† *Staphylococcus aureus** *Corynebacterium acnes*,† etc. Any organisms of surrounding air, clothing, etc. Spores of *Bacillus*, molds, etc.	**Hands:** Variable, depending on materials being handled; commonly microorganisms of skin, respiratory tract, feces, and perianal region
Colon: *Escherichia coli** and coliform group *Shigella* sp.* *Salmonella* sp.* *Bacteroides fragilis** *Bacteroides serpens** *Clostridium perfringens*† *Clostridium tetani*† *Streptococcus faecalis* and enterococci† *Alcaligenes faecalis* *Lactobacillus bifidus* (esp. infants) *Lactobacillus acidophilus*	*Pseudomonas aeruginosa*† *Proteus vulgaris*† *Candida albicans** *Giardia lamblia* *Trichomonas hominis* *Entamoeba coli* *Entamoeba histolytica** Enteroviruses* Polioviruses* Virus of epidemic hepatitis*

*Primary invaders. †Secondary invaders, opportunists or lesser pathogens. *Note:* Fungi that cause dermatomycoses (skin infections) are not included in the table, although, in an unsuspectedly high percentage of our population, apparently normal persons have these organisms on their scalps, skin, ears and feet.

[redacted]

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[36] 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 biogical 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

Notes from <u>Elements of Water Bacteriology</u> by S.B. Prescott:

There are three types of bacteria: Prototropic
Metatropic
Paratropic

Prototropic bacteria are characterized by organic nutriant requirements.

Metatropic bacteria are characterized by mineral nutrient requirements.

Paratropic bacteria are true parasites; they exist only within the living tissues of other organisms.

Protozoa kill bacteria.

Bacteria are:
- few in air
- abundant in soil
- therefore plenty in rivers and streams
- very few in still water lakes
- very few in naturally filtered ground water.

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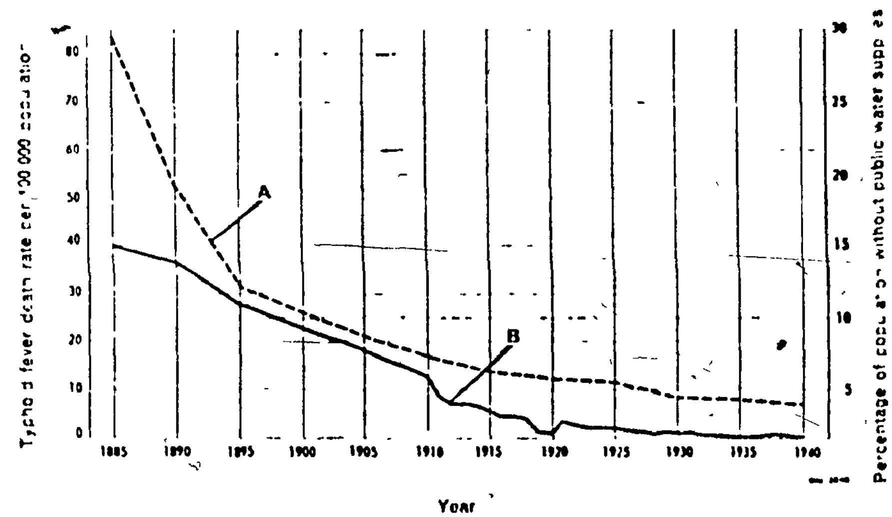
RELATION OF TYPHOID FEVER DEATH RATE TO PERCENTAGE OF POPULATION WITHOUT PUBLIC WATER SUPPLIES IN THE STATE OF MASSACHUSETTS, USA



A — Population without public supplies
B — Typhoid fever death rate

10

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. <u>Bacterial Removal</u> [36]

"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 bacterial 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*[18] 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-been 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, led 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.:

$$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2$$

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 insolable 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

That's right, Harry--Use lots of lather. Don't miss your wrists and the backs of your hands.

Get under the fingernails--Bacteria love to hide with the dirt under fingernails.

Always wash your hands after visiting the toilet. Get rid of bacteria!

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.

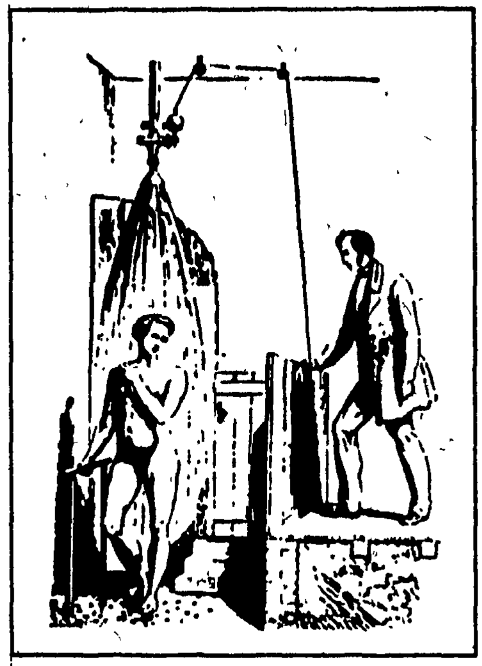
Soap, in addition to being a surface-active detergent, is bactericidal to some degree. It is especially effective against TREPONEMA PALLIDUM, the cause of syphilis. This organism is rich in lipids (fats)."

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 performs 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.



"In rural arid areas quantity of water is more important for disease reduction; in peri-urban zones water quality may be crucial. While the levels of volume and quality needed for various levels of health gains are uncertain, a tap and shower inside the home seem to be required for maximum benefit."

David J. Bradley in
Human Rights in Health
CIBA Foundation Symposium *49*

Part III

ATOMIZATION

1. Definition of Atomization[23]

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.

Drop size is measured by using the formula based on the force of gravity acting to pull liquid from the surface of a burette tip:

$$D_p = (6D_J S_J / P_J g_L)^{1/3}$$

where D_p = pendant drop

D_j = diameter of burette tip

S_j = liquid surface tension

P_j = liquid density

g_L = acceleration due to gravity

* Except where specified otherwise, the term "spray" is used in this thesis, 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.[23] 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

Summary of atomizing techniques

General technique (alternate names)	Type	Variations or examples	Description and characteristics
Hydraulic (pressure)	Simple (axial) jets	Stationary Rotating or moving *Fan spray*	Fluid pressure is converted into fluid velocity by passage of fluid through a plain orifice or nozzle to produce a rodlike stream. Atomization occurs as a result of a jet instability arising from relative velocity of liquid to the ambient gas. This technique requires high liquid pressures for fine atomization. In a rotating or moving jet, the relative velocity is increased by the physical motion of the atomizing nozzle (for example, a spray nozzle mounted on an airplane). Fan sprays are produced by use of a noncircular orifice or orifice feed chamber or both.
	Impinging jets	Impinging liquid jets Impingement of liquid jet on solid surface	Collision of two simple jets or impingement of a simple jet on a deflecting surface produces a sheet of liquid which subsequently breaks up into drops. This type of atomizer may produce a bimodal size distribution.
	Swirl nozzle (centrifugal)	Tangential entry *Vaned or grooved entry*	A circular orifice is preceded by a chamber in which the liquid is given a tangential velocity component either by a tangential liquid entry or by a series of inclined grooves or vanes. A hollow conical sheet is produced. The nonclog feature of the tangential type results from the ability to use larger apertures for a given capacity.
Pneumatic (two-phase or two-fluid)	Internal mix External mix Combination mix		The high relative velocity between gas and liquid is achieved by acceleration of the gas to high velocity rather than acceleration of the liquid. Gas and liquid are mixed prior to the gas expansion through the nozzle in the internal mix type and after the gas expansion in the external mix type. Power consumption is high but fine atomization is possible at relatively low pressure levels.
Rotary (spinning disk or cup)	Film (liquid flows parallel to disk surface)	Simple (flat, dished, cupped, or saucer; single or double) Vaned	Liquid is introduced at the center of a rotating disk and flows outward by action of the centrifugal force field. In the film type a liquid leaves the outer edge of the disk as a thin sheet. In the head type a liquid leaves as a ligament, or it may form a series of sheets through the peripheral holes or slits in the rim. This is basically a hydraulic technique, in which the pump and nozzle are combined as an integral unit. The film type is capable of producing uniform drops at low capacity and is relatively free from plugging problems. Fineness of atomization is limited because of rotational speed limits imposed by the strength of structural materials. In hydraulic techniques such limits can be avoided by using pumps with staged impellers.
	Head or basket (liquid flows normal to disk surface)	Perforated Slotted	
Vibrational	Mechanical Sonic	Vibrating tube Vibrating reed Compressed air siren Hartman whistle	A liquid is fed to, or caused to flow over, a surface which vibrates at a prescribed frequency and amplitude. The droplet size is primarily a function of the frequency. Uniform drops may be produced at low feed rates. This technique is relatively undeveloped.
	Ultrasonic	Solid-state oscillators	
Explosive			A bulk liquid is exposed to expanding gas products from a detonating system. This is probably a special case or extension of the pneumatic technique. Chemical decomposition of the liquid may occur because of the high temperature. Although atomization may be fine, coarse debris may also be present.
Electrostatic	Low intensity	Atomization the result of Rayleigh instability, in which presence of charge in surface counteracts surface tension	The liquid jet or film is exposed to an electric field. The force on the liquid may be due to either free charges in the surface or to liquid polarization. This technique is relatively undeveloped. Much of present day research is aimed at rocket propulsion by charged droplets generated in high vacuum. Conventional electrostatic spray painting usually employs an electrostatic field for deposition of drops on surface, rather than in generation of the drops themselves.
	High intensity	Atomization claimed to be the result of stress sufficient to overcome tensile strength (or chemical bonds) of liquid	
Gravitational	Pendant or hanging drop	Quasi-static emission of a drop from a wetted surface, as from the end of a buret (discontinuous surface) or from the underside of a horizontal surface (continuous surface)	These are classic examples of common atomization processes in nature. They are, however, normally limited to either low-rate or coarse atomization.
	Dripping drop	Periodic emission of drops from the bottom side of a surface to which a liquid is fed continuously, as in dripping of water from leaves	
	Falling or splashing drop (or object)	Satellite drops generated because of impact of object on a liquid surface	
Film bursting	Bursting bubble		Generation of droplets results from the sudden failure of a stressed film of liquid. This is a low-capacity atomizing technique.
	Flashing fluid (superheated)		

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:[5] "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 many 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).

The Spraying Systems Company of Weaton, Illinois, also nozzle manufacturers, goes into more detail. Their useful Spray Performance Characteristics table[41] from their current catalog is reproduced on page 54 of this study. A typical example of the variety of nozzles offered is shown on the next page.

Spray Performance Characteristics

SPRAY CHARACTERISTICS	DESCRIPTION

SPRAY PATTERNS

Hollow Cone · Full Cone · Flat Spray · Solid Stream · Air Atomizing

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	.96	.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.

Note: The catalog tabulations show orifice dimensions as "Nom" (nominal). Exact decimal dimensions are available on request.

TABLES OF EQUIVALENTS

Linear Unit	LINEAR UNITS—EQUIVALENTS: Micron	Mil	Millimeter	Centimeter	Inch	Foot	Meter
Micron	•	0.039	0.001	1.0×10^{-4}	3.94×10^{-5}		
Mil	25.4	•	2.54×10^{-2}	2.54×10^{-3}	0.001	8.33×10^{-5}	
Millimeter	1000	39.4	•	0.10	0.0394	3.28×10^{-3}	0.001
Centimeter	10000	394	10	•	0.394	0.033	0.01
Inch	2.54×10^{4}	1000	25.4	2.54	•	0.083	0.0254
Foot	3.05×10^{5}	1.2×10^{4}	305	30.5	12	•	0.305
Meter	1.0×10^{6}	3.94×10^{4}	1000	100	39.4	3.28	•

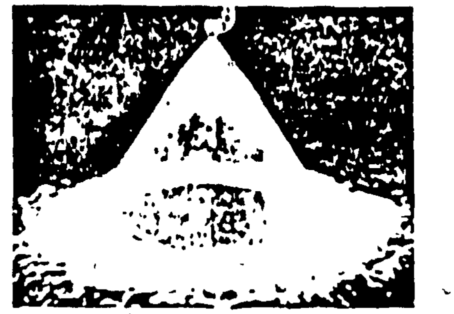
Volumetric Unit	VOLUMETRIC UNITS—EQUIVALENTS: Cubic Centimeter	Fluid Ounce	Pound of Water	Liter	US Gallon	Cubic Foot	Cubic Meter
Cubic Centimeter	•	0.034	2.2×10^{-3}	0.001	2.64×10^{-4}	3.53×10^{-5}	1.0×10^{-6}
Fluid Ounce	29.6	•	0.065	0.030	7.81×10^{-3}	1.04×10^{-3}	2.96×10^{-5}
Pound of Water	454	15.4	•	0.454	0.12	0.016	4.54×10^{-4}
Liter	1000	33.8	2.2	•	0.264	0.035	0.001
US Gallon	3785	128	8.34	3.785	•	0.134	3.78×10^{-3}
Cubic Foot	28320	958	62.4	28.3	7.48	•	0.028
Cubic Meter	1.0×10^{6}	3.38×10^{4}	2202	1000	264	35.3	•

1 Imperial Gallon = 1.2 U.S. Gallon

1 Cubic Centimeter = 1.000028 Milliliter

Liquid Pressure	LIQUID PRESSURES—EQUIVALENTS: Lb/In^2 (p.s.i.)	Ft Water	Kg/Cm^2	Atmosphere	Bar	Inch Mercury	Meter Water
Lb/In^2 (p.s.i.)	•	2.31	0.070	0.068	0.069	2.04	0.704
Ft Water	0.433	•	0.030	0.029	0.030	0.882	0.305
Kg/Cm^2	14.2	32.8	•	0.968	0.981	29.0	10.0
Atmosphere	14.7	33.9	1.03	•	1.01	29.9	10.3
Bar	14.5	33.5	1.02	0.987	•	29.5	10.2
Inch Mercury	0.491	1.13	0.035	0.033	0.034	•	0.346
Meter Water	1.42	3.28	0.100	0.097	0.098	2.89	•

WhirlJet NOZZLES with removable caps



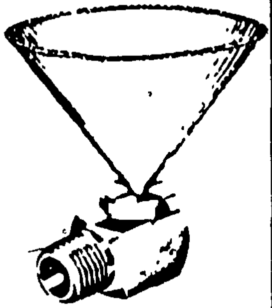
Spray Characteristics—Hollow cone spray pattern with uniform distribution.

Construction—Two piece design with removable cap. Large diameter body inlet and cap orifice for non-clogging free flow. Choice of types A and B with standard whirlchamber design or types AX and BX with the exclusive longer lasting, patented slope-bottom design.

Materials—Made in choice of brass, steel, and types 303 and 316 stainless steel . . . other materials to order.

Type A standard and Type AX slope bottom designs female connection

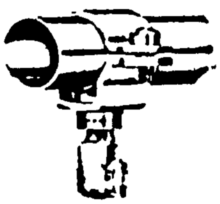
HOLLOW CONE SPRAY PATTERN



Type B standard and Type BX slope bottom designs male connection

EXCLUSIVE PATENTED SLOPE-BOTTOM DESIGN for Type AX and BX

Diffuses the vortex forces, prevents the "drilling" effect normally found in standard design whirlchambers. Materially increases nozzle life.



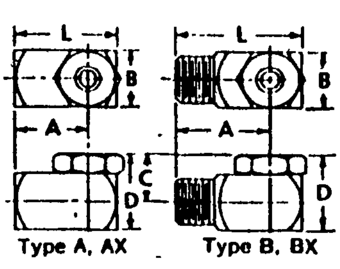
WhirlJet Nozzle held by easy to install Split Eyelet Connector. See pages 54 through 61 for spray nozzle accessories.

Nozzle No. Type A, AX Female Conn	Nozzle No. Type B, BX Male Conn	Size	Pipe Conn NPT	Body Inlet Diam Nom	Orifice Diam Nom.	CAPACITY GPM (gallons per minute) at p.s.i. (pounds per square inch) 3 p.s.i.	5 p.s.i.	10 p.s.i.	15 p.s.i.	20 p.s.i.	30 p.s.i.	40 p.s.i.	60 p.s.i.	80 p.s.i.	100 p.s.i.	SPRAY ANGLE* 7 p.s.i.	20 p.s.i.	80 p.s.i.
		0.5	1/8"	1/32"	3/64"			05	06	07	09	.10	.12	14	16	34°	58°	69°
		1	1/8"	1/16"	1/16"			.10	.12	14	17	20	24	28	31	36°	64°	76°
1/8A-	1/8B-	2	1/8"	5/64"	5/64"		.14	20	25	.28	35	40	48	56	63	52°	61°	69°
		3	1/8"	3/32"	3/32"		.21	30	37	42	52	60	73	85	95	52°	64°	77°
1/8AX-	1/8BX-	5	1/8"	1/8"	1/8"	27	35	.50	61	70	86	10	12	14	16	56°	67°	76°
		8	1/8"	5/32"	5/32"	44	57	80	98	11	14	16	20	23	25	56°	65°	70°
		10	1/8"	11/64"	11/64"	.55	.71	1.0	12	14	17	20	25	28	32	55°	65°	72°
		1	1/4"	1/16"	1/16"			.10	.12	14	17	20	24	28	.31		53°	67°
		2	1/4"	5/64"	5/64"			.20	.25	28	35	40	48	56	63	48°	62°	71°
1/4A-	1/4B-	3	1/4"	3/32"	3/32"		.21	30	37	42	52	60	73	85	95	51°	65°	78°
		5	1/4"	9/64"	9/64"	27	.35	.50	61	70	86	10	12	14	16	63°	73°	79°
1/4AX-	1/4BX-	8	1/4"	5/32"	5/32"	44	.56	80	.98	11	14	16	20	23	25	61°	69°	73°
		10	1/4"	3/16"	11/64"	.55	71	10	12	14	17	20	25	28	32	63°	70°	74°
		15	1/4"	19/64"	13/64"	.82	11	15	18	21	26	30	37	42	47	63°	71°	72°
		5	3/8"	9/64"	1/8"	27	35	50	61	70	86	10	12	14	16	64°	73°	79°
		8	3/8"	11/64"	5/32"	44	56	80	98	11	14	16	20	23	25	62°	70°	74°
3/8A-	3/8B-	10	3/8"	13/64"	11/64"	55	.72	10	12	14	17	20	24	28	31	64°	72°	75°
		15	3/8"	15/64"	7/32"	82	11	15	18	21	26	30	37	42	47	64°	72°	74°
3/8AX-	3/8BX-	20	3/8"	9/32"	1/4"	11	14	20	24	28	35	40	49	56	63	63°	70°	74°
		25	3/8"	19/64"	19/64"	14	18	25	3.1	35	43	50	6.1	71	79	63°	70°	74°
		30	3/8"	21/64"	5/16"	16	21	30	37	42	52	60	73	8.5	95	63°	70°	74°
		15-30.1	3/8"	19/64"	5/16"	13	16	23	28	32	40	46	56	65	73	40°	50°	54°
3/8A-	3/8B-	25-30.1	3/8"	19/64"	5/16"	15	20	28	34	40	48	56	69	80	89	40°	47°	51°
		50-50.1	3/8"	11/32"	3/8"	27	35	50	61	71	87	100	123	142	158	40°	47°	50°
		50-50.3	3/8"	11/32"	3/8"	27	35	50	6.1	71	8.7	100	123	142	158	72°	76°	78°
		25	1/2"	3/8"	1/4"	14	18	25	31	35	4.3	50	6.1	71	79	63°	66°	71°
1/2A-	1/2B-	30	1/2"	3/8"	19/64"	16	21	30	37	42	52	60	73	85	95	67°	71°	75°
		40	1/2"	3/8"	23/64"	22	28	40	49	57	69	80	98	113	126	72°	76°	78°
1/2AX-	1/2BX-	50	1/2"	3/8"	7/16"	27	35	50	61	71	85	100	123	142	158	74°	79°	82°
		60	1/2"	3/8"	33/64"	33	43	60	73	85	104	120	147	170	190	77°	82°	86°
		40	3/4"	1/2"	5/16"	22	28	40	49	57	69	80	98	113	126	70°	73°	74°
		50	3/4"	1/2"	3/8"	27	35	50	6.1	71	8.5	100	123	142	158	72°	75°	77°
		60	3/4"	1/2"	7/16"	33	43	60	73	85	104	120	147	170	190	74°	76°	79°
3/4A-	3/4B-	70	3/4"	1/2"	1/2"	38	50	70	85	99	121	140	171	198	22	76°	79°	83°
		80	3/4"	1/2"	9/16"	44	57	8.0	98	113	138	160	196	23	25	78°	82°	84°
3/4AX-	3/4BX-	90	3/4"	1/2"	37/64"	49	64	90	110	127	156	180	22	25	29	81°	84°	84°
		100	3/4"	1/2"	5/8"	55	7.1	100	122	141	173	20	25	28	32	83°	86°	86°
		110	3/4"	1/2"	43/64"	60	78	110	135	155	190	22	27	31	35	85°	88°	88°
		120	3/4"	1/2"	23/32"	66	8.5	120	147	170	21	24	29	34	38	87°	90°	90°

*See page 3 for spray angle data.

INTERMEDIATE CAPACITIES—Caps are interchangeable for in between capacities within each pipe size group . . . write for Data Sheet 3055, 3986 and 3987 . . . and Bulletin 102.

WHEN ORDERING—specify complete Nozzle No. and material. Example: 1/8A5 WhirlJet Nozzle, steel.



Type A, AX Female Conn.	Net Weight Max.	A Max.	B Max.	C Max.	D Max.	L Max.	Type B, BX Male Conn.	Net Weight Max.	A Max.	B Max.	C Max.	D Max.	L Max.
1/8A,AX	1½ oz.	11/16"	5/8"	7/16"	3/4"	1"	1/8B,BX	1½ oz	7/8"	5/8"	7/16"	3/4"	1 1/16"
1/4A,AX	2⅜ oz.	7/8"	3/4"	17/32"	29/32"	1¼"	1/4B,BX	2½ oz	1"	3/4"	17/32"	29/32"	1⅜"
3/8A,AX	4¼ oz.	1 1/32"	7/8"	5/8"	1 1/16"	1 15/32"	3/8B,BX	4 oz	1⅛"	7/8"	5/8"	1 1/16"	1 9/16"
1/2A,AX	8¾ oz.	1⅜"	1⅛"	25/32"	1 11/32"	1 13/16"	1/2B,BX	7 oz	1⅜"	1⅛"	25/32"	1 11/32"	1 13/16"
3/4A,AX	11 oz.	1 9/16"	1¼"	7/8"	1½"	2 3/16"	3/4B,BX	10¼ oz	1⅝"	1¼"	7/8"	1½"	2¼"
3/8A 30.1	4 oz.	31/32"	3/4"	3/4"	1⅛"	1 11/32"	3/8B 30.1	3¾ oz	1⅛"	3/4"	3/4"	1⅛"	1½"
3/8A 50.1	3¾ oz	31/32"	3/4"	27/32"	1 7/32"	1 11/32"	3/8B 50.1	3½ oz	1⅛"	3/4"	27/32"	1 7/32"	1½"
3/8A-50.3	3¾ oz.	31/32"	3/4"	11/16"	1 1/16"	1 11/32"	3/8B 50.3	3½ oz	1⅛"	3/4"	11/16"	1 1/16"	1½"

Patent Nos. 2,815,248, 3,326,473 and Foreign Patents.

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

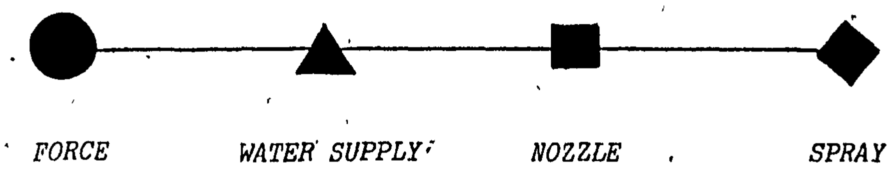
The source of the external motivating force employed for atomization may be manual or mechanical. The force creates the pressure to move the liquid. There are four cases:

1) Manual force makes instant pressure
   e.g. household sprayers using siphon or pump principle

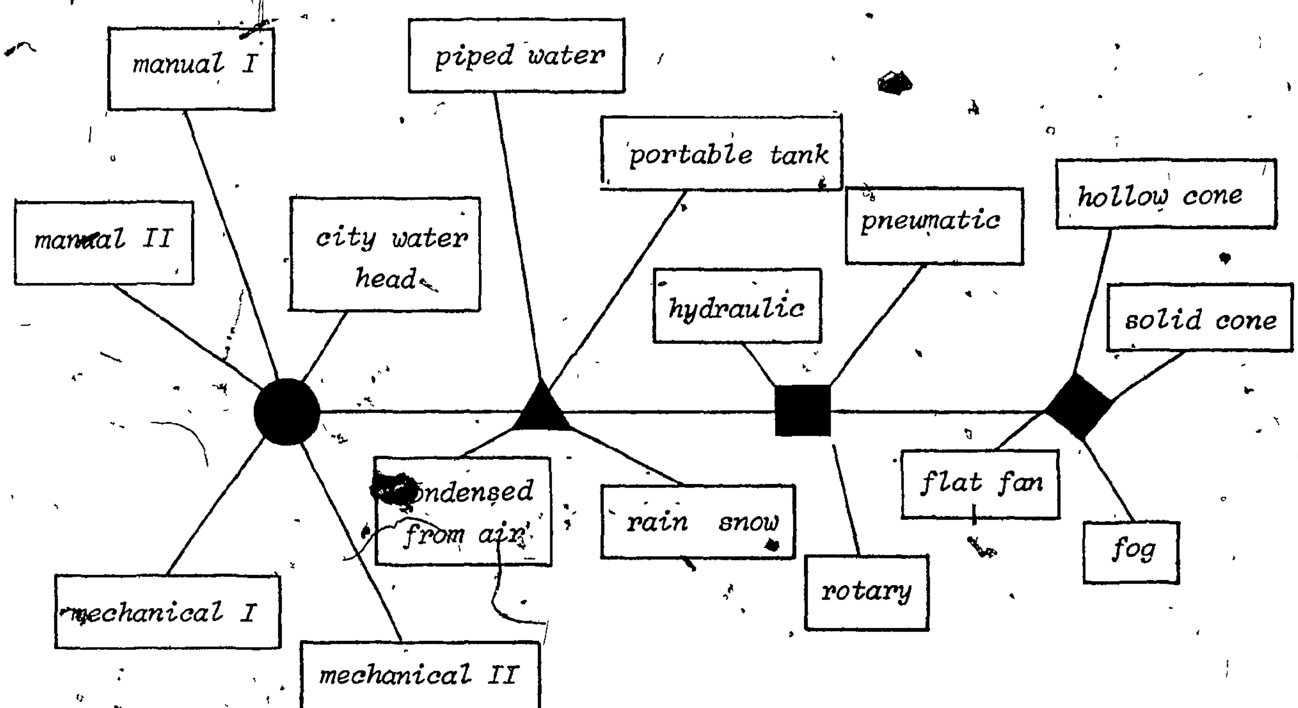
2) Manual force makes stored pressure
   e.g. garden sprayers

3) Mechanical force makes instant pressure
   e.g. water-pic toothbrushes

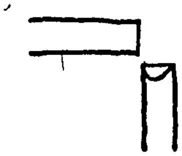
4) Mechanical force makes stored pressure
   e.g. paint sprayer using siphon or pump principle.



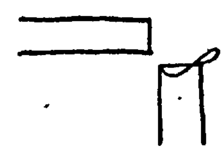
ELEMENTS OF ATOMIZATION



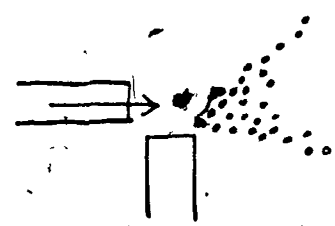
FORMS OF ELEMENTS



1. water pulled by vacuum (low pressure)



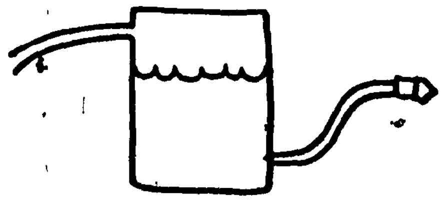
2. low pressure pulls water out



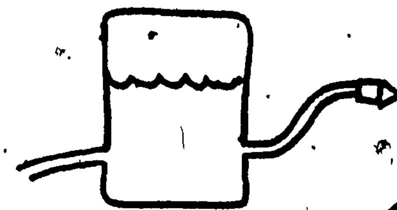
3. water pulled into air is broken into particles by onrushing air equal dispersion causes cone shape

ATOMIZER SIPHON PRINCIPLE

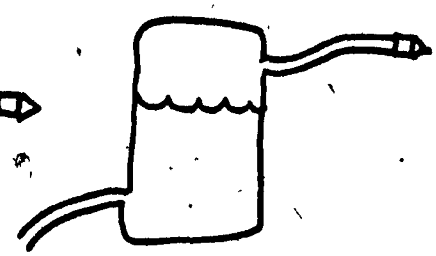
WILL THESE WORK ?



empties w/o pressure

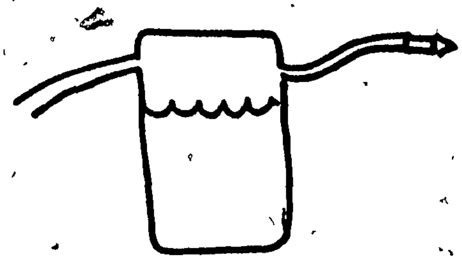


water can get into air line

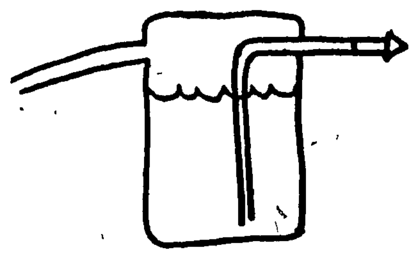


water can get into air line

water cant get to nozzle

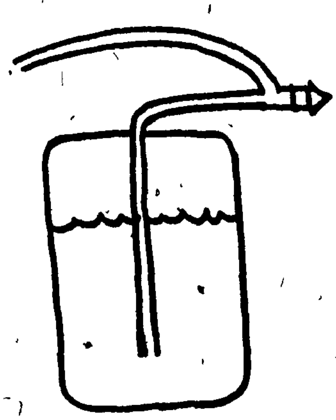


water cant get to nozzle

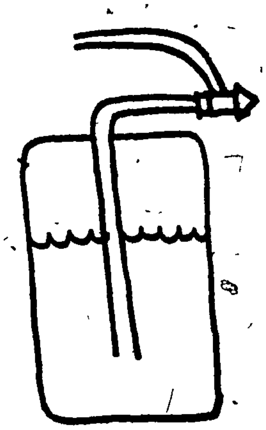


o.k.

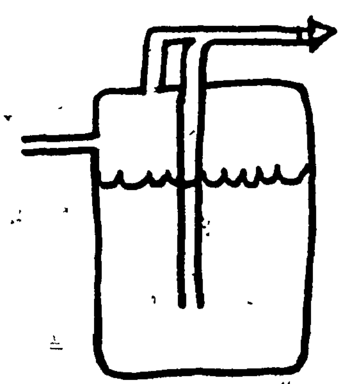
air pressure against contained water forces it through tube and nozzle



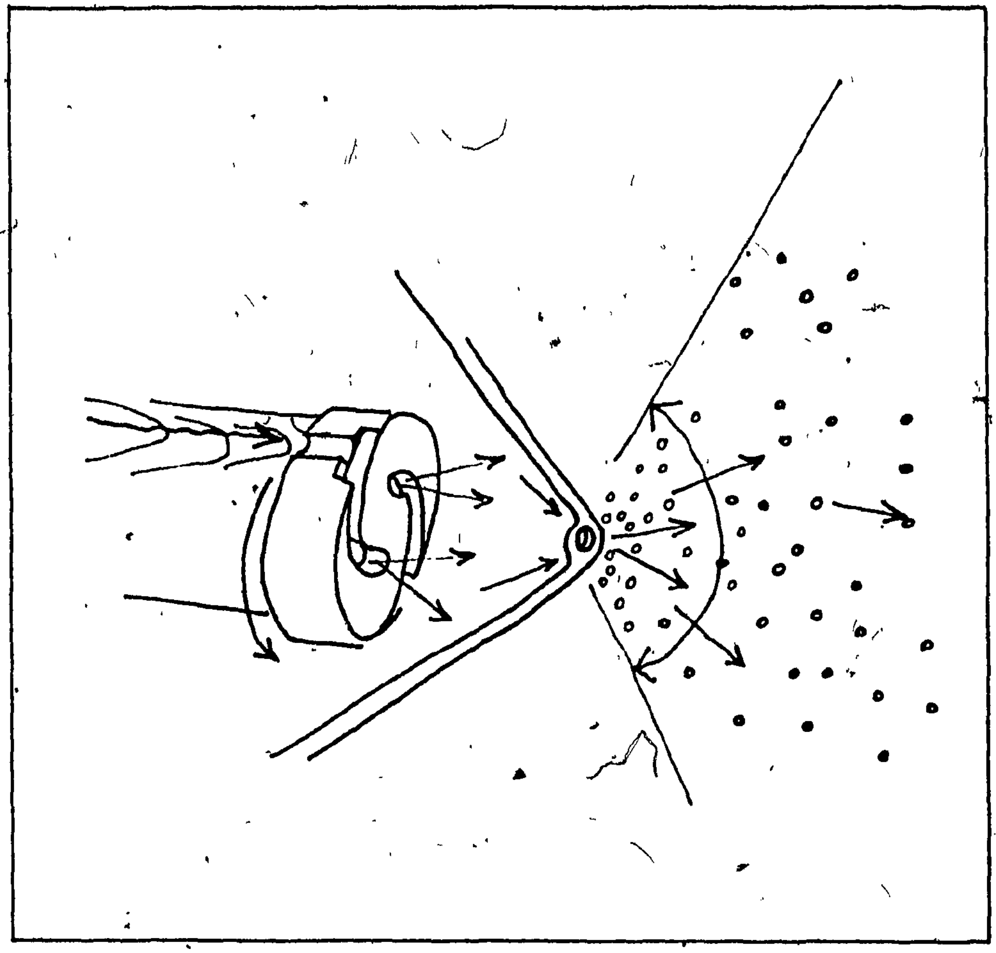
siphon variation 1



siphon variation 2



siphon vacuum and air pressure on water combined



SPINNING DISC ATOMIZATION

3. Aerosols[40]

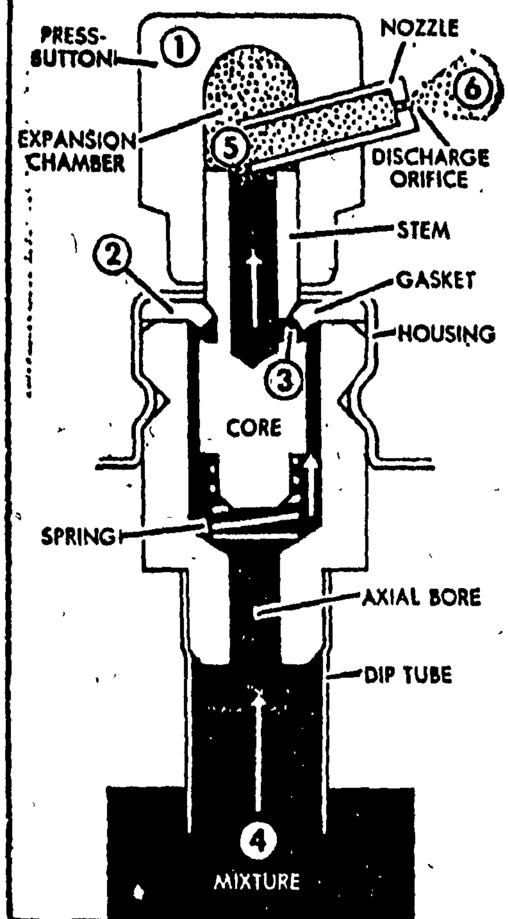
Aerosol sprayers come under the category of pneumatic atomizing techniques and are included here only because they are a special case. They are cans containing a fluid and a propellant, which is a type of gas which compresses to a liquid. The top of the can has a nozzle which releases the fluid mixed with the propellant, 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.[11] 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 affect our food source.

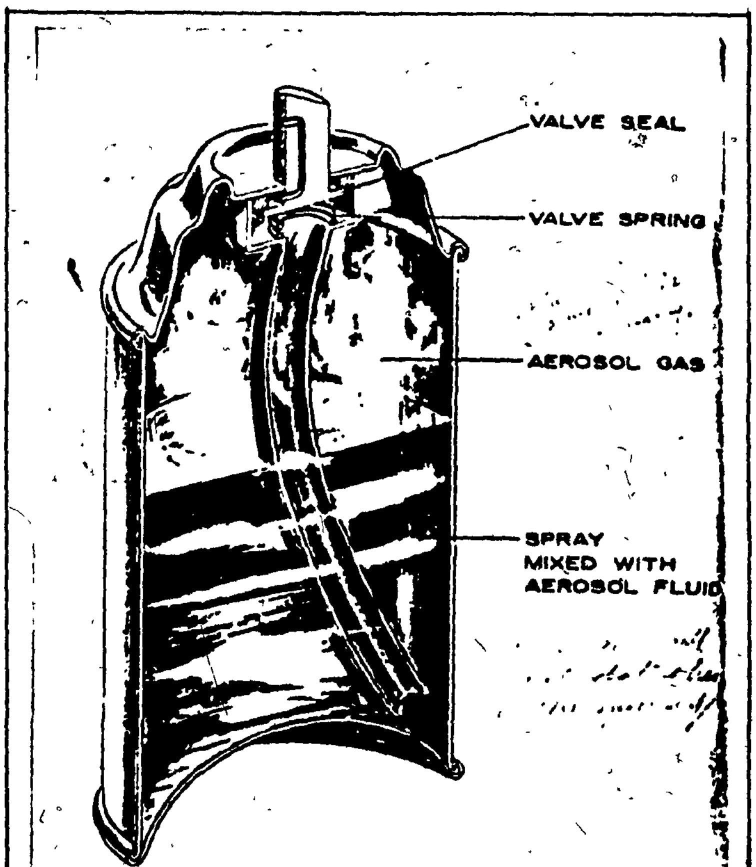
4. Atomization: summary

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

The Aerosol

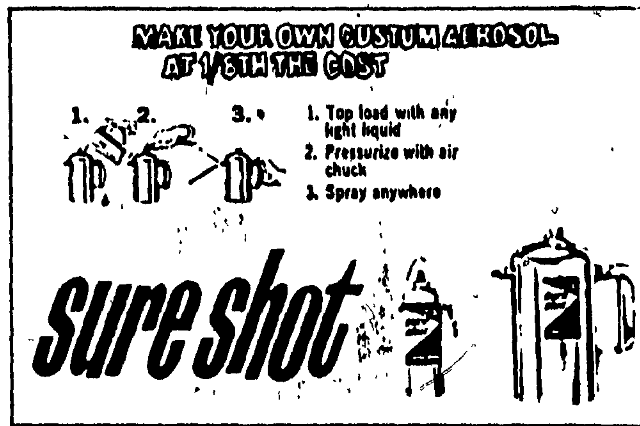


When top of aerosol valve (1) is pressed, central part (2) is flexed, thus opening inlet passage (3). The action creates pressure, forcing mixture of liquefied gas and contents upward (4). The gas vaporizes (5) and the contents, dispersed in gas, are sprayed out through nozzle (6).



AEROSOL SUBSTITUTE

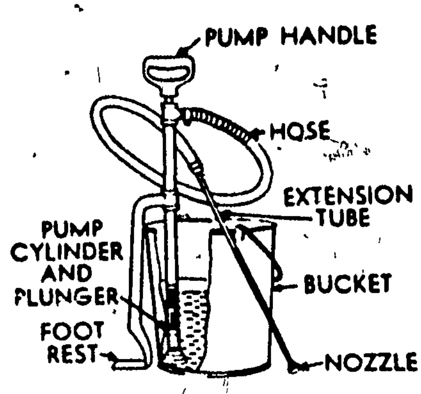
■ Refillable, reuseable. Extra versatile. ■ Pressurized by free air. Big savings over aerosols. ■ All metal construction. Built to last, nothing to break. ■ Completely portable. No trailing hose or wire. ■ Interchangeable spray nozzles. Choose jet stream or mist spray. ■ Controlled spray action for uniform application.



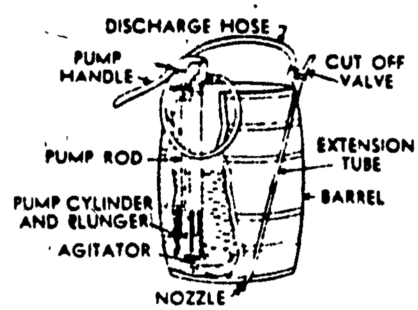
VACUUM CLEANER POWER

PORTABLE COMPRESSOR OPERATES WITH A GAS ENGINE OR AN ELECTRIC MOTOR

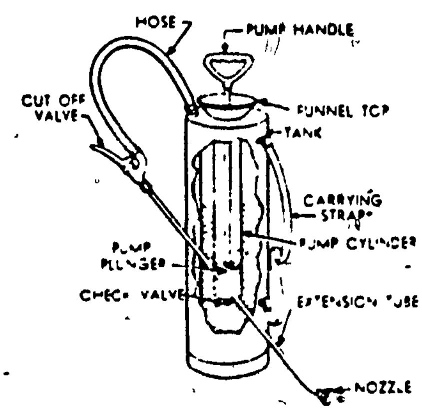
GARDEN SPRAYERS - MANUALLY STORED PRESSURE



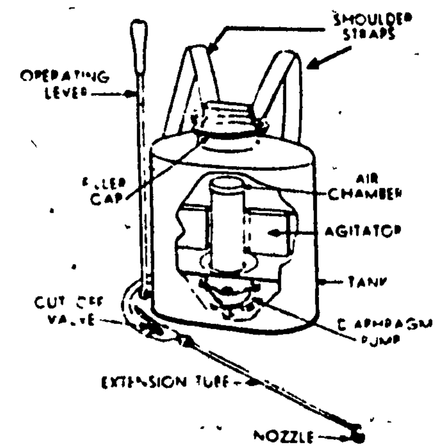
Bucket pump sprayer.



Barrel pump sprayer.

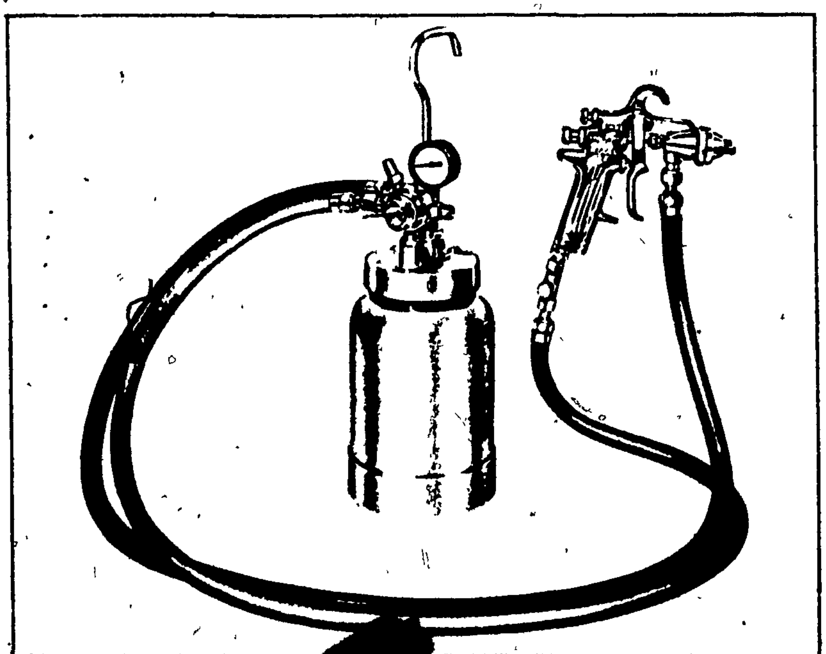


Compressed-air sprayer

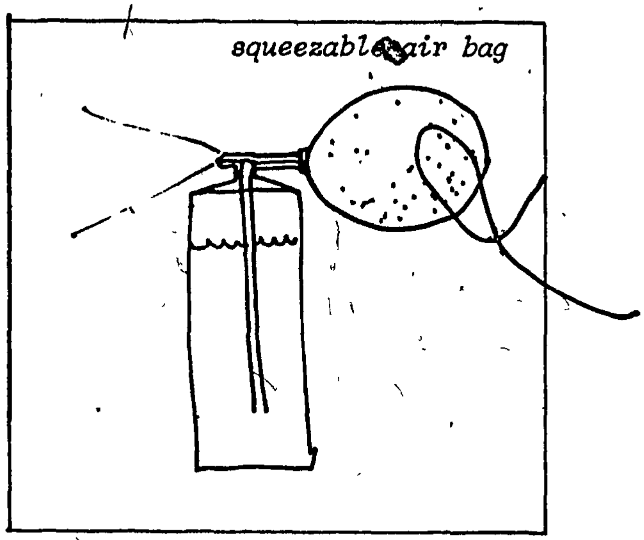


Knapsack sprayer

PAINT SPRAYER - MECHANICALLY STORED PRESSURE



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 showerbath spray is in between i.e. fast-moving small droplets. Fast-moving for dependable coverage and small droplets for the conservation of water.



BASIC SIPHON ATOMIZER

88–91 *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 to the skin surface would accelerate the surface oxidation, and release the surface cells themselves, along with the attached dirt.*

The round pictures show magnifications of the skin surface. Two of the pictures show the dirt interspersing the "coral reeflike" structure of the pores. (1927–1948)

92 *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 tions 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.*

Part IV

TESTING NOZZLES

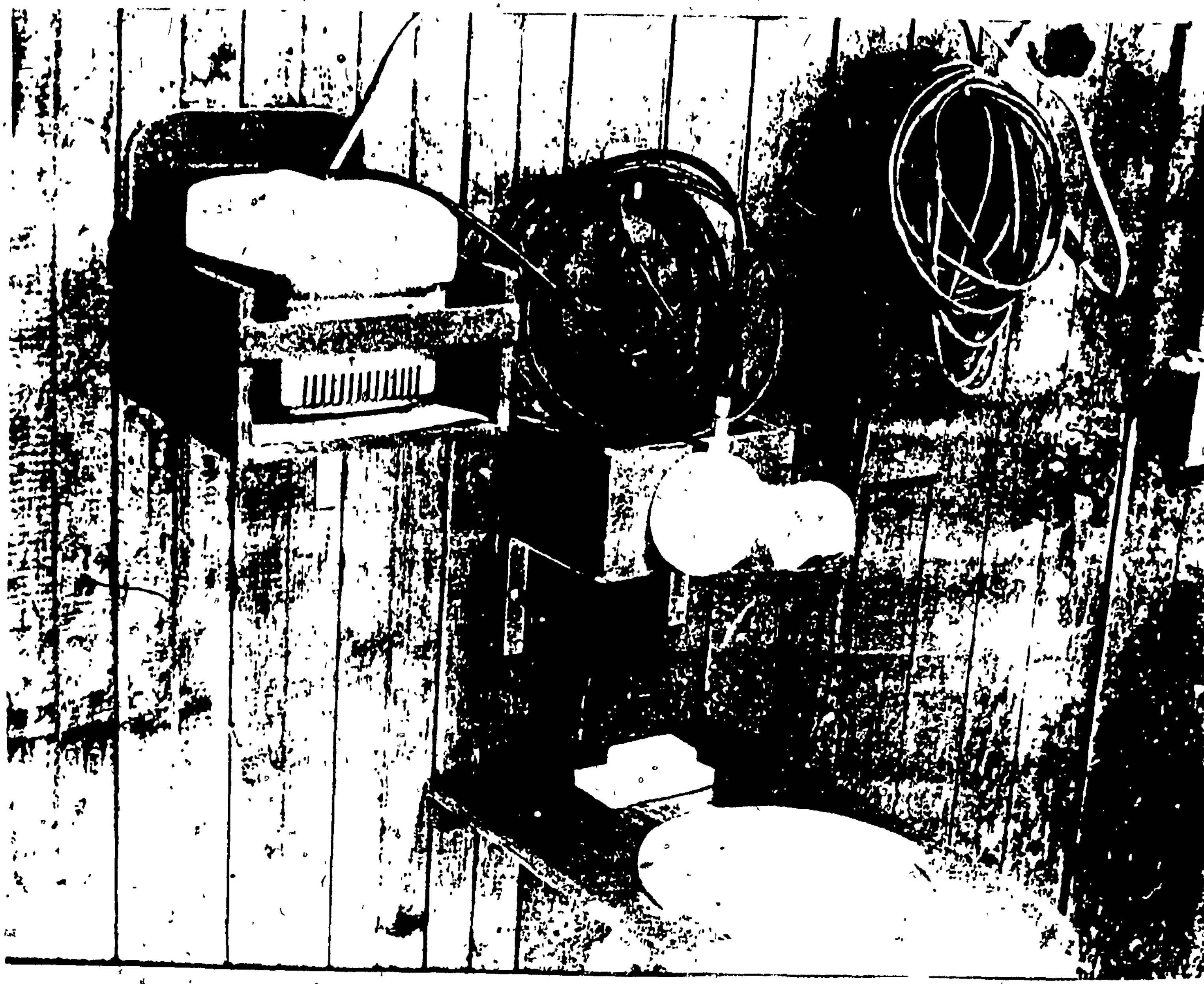
1. Nozzles

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[36] 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 psi) but



TEST SET-UP WITH BLACK & DECKER PAINT SPRAYER USED AS HANDWASHING FACILITY 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:		
	Black & Decker Paint Sprayer	Niagara 71
	Spraying Systems Whirljet 1/8A .5	Steinen TM21
	Bete P20	Steinen TM051
	Bete W5080F	Estra 6400
	Bete F200	D.B.Smith 147

BLACK & DECKER INTRODUCES AN INCREDIBLE PAINT-SPRAYING SYSTEM.

It's easy to use. It sprays latex as well as oil. It needs virtually no cleaning. It does a multitude of other jobs. And it costs under $55.

AMPS: 7.2 = 1 KW.
VOLTS: 115

In the past, you had a lot of reasons *not* to own a paint sprayer.

They were expensive. Heavy. And mostly, they sprayed only *oil* paint.

No more.

Black & Decker's come up with an incredible new home paint-spraying system.

It's powerful enough for the bigger jobs.

Compact enough for those small, hard-to-paint jobs, like shutters or wicker furniture.

It'll spray *latex* as well as oil-based paint.

And it costs under $55.

It's powered by an efficient, *piston*-driven air compressor—not a diaphragm—for greater reliability.

It comes with inexpensive, throwaway nozzles for easy cleanup. You can start with a fresh nozzle for each job, with no clogging or spattering. It'll give you that "professionally sprayed" look that a paint sprayer should give you.

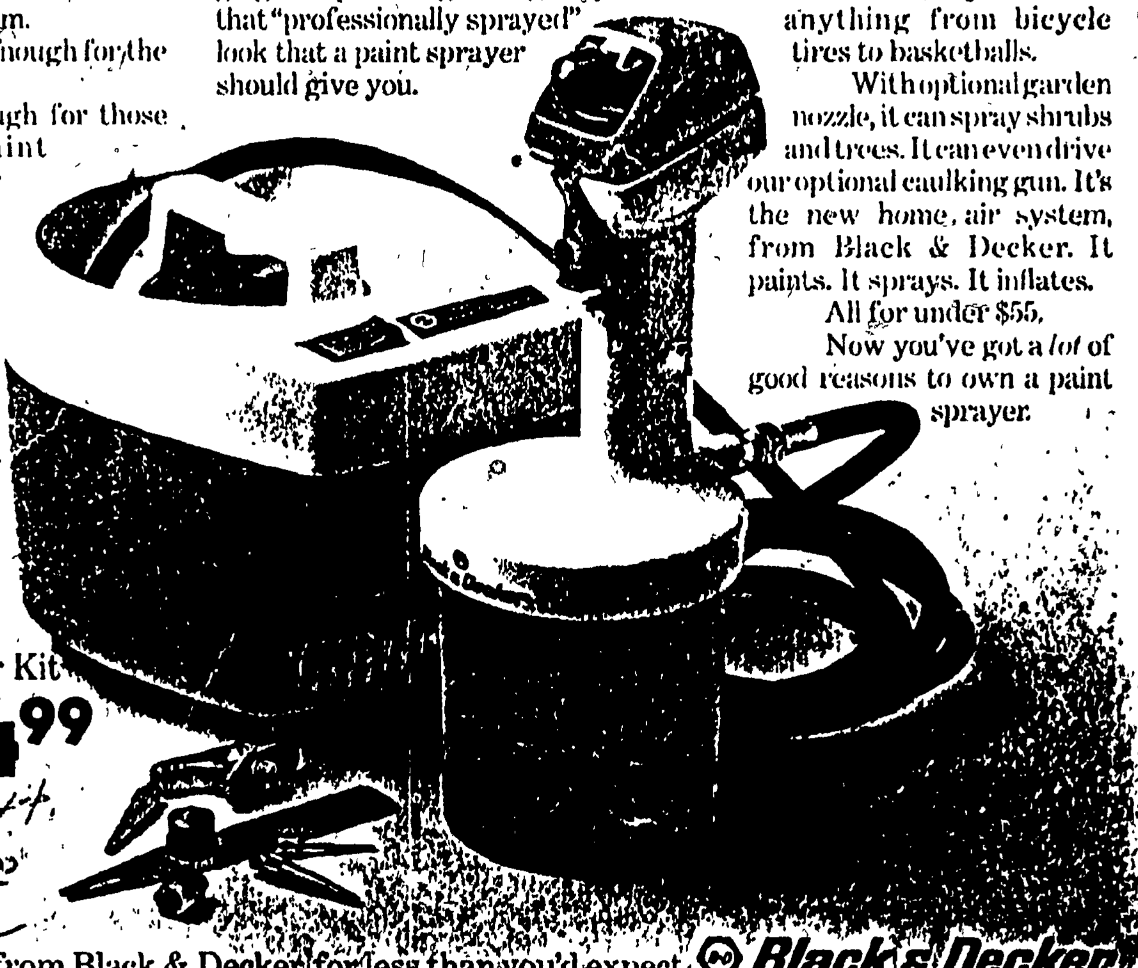
But one of the *best* things about it is that the compressor itself can be a wonderful new source of power around your house. For those annoying jobs you never seem to have the right equipment for:

It can inflate just about anything from bicycle tires to basketballs.

With optional garden nozzle, it can spray shrubs and trees. It can even drive our optional caulking gun. It's the new home air system, from Black & Decker. It paints. It sprays. It inflates.

All for under $55.

Now you've got a *lot* of good reasons to own a paint sprayer.



Universal Spray/Inflator Kit #7761

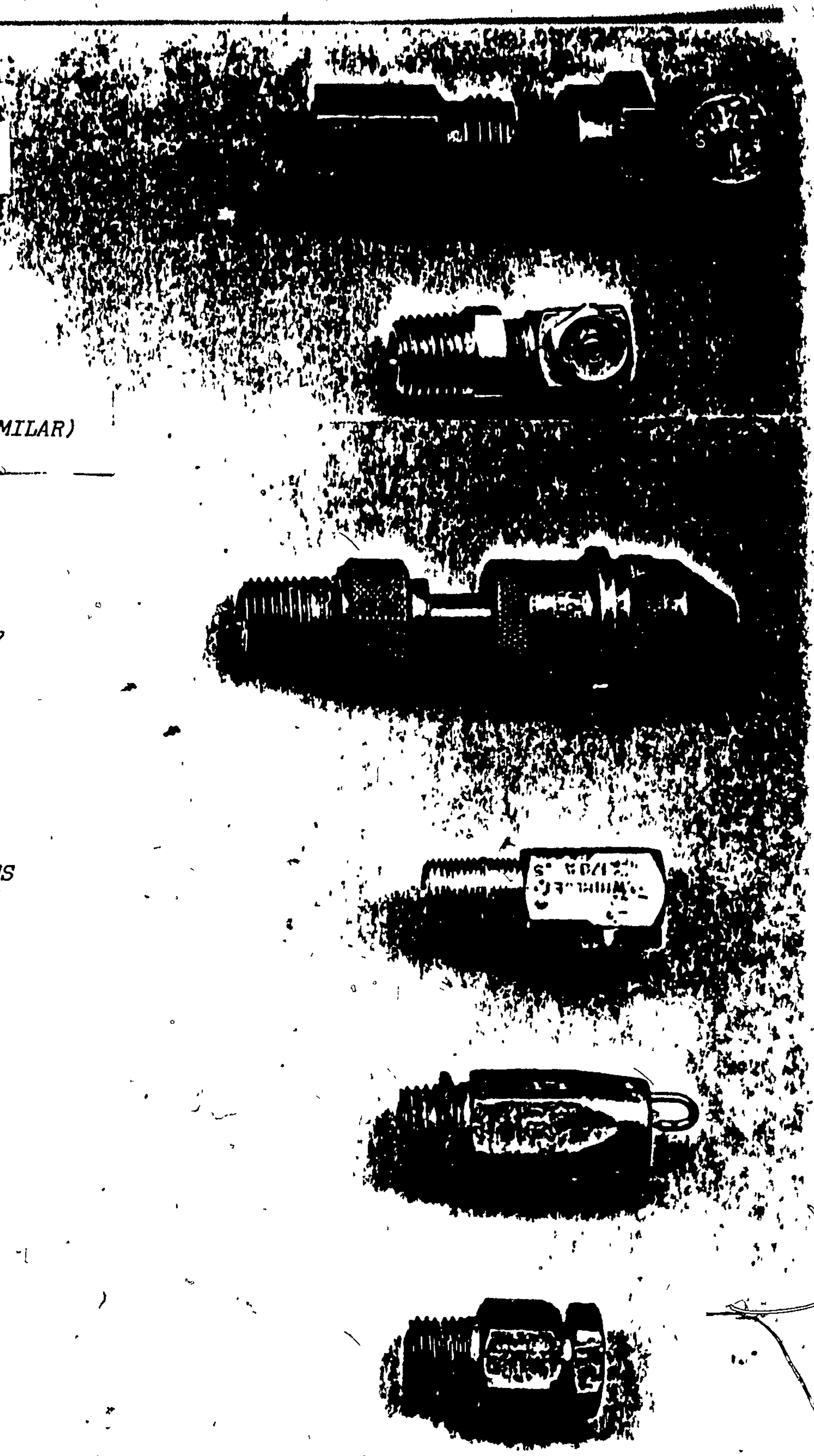
54.99

$71.50

#72.00
PASCAL

Expect the best from Black & Decker for less than you'd expect. Black & Decker

For your nearest Black & Decker Dealer, call 800-243-6000 FREE, day or night. In Connecticut, call 1-800-[illegible]



BETE F200

STEINEN TM051

(STEINEN TM21 SIMILAR)

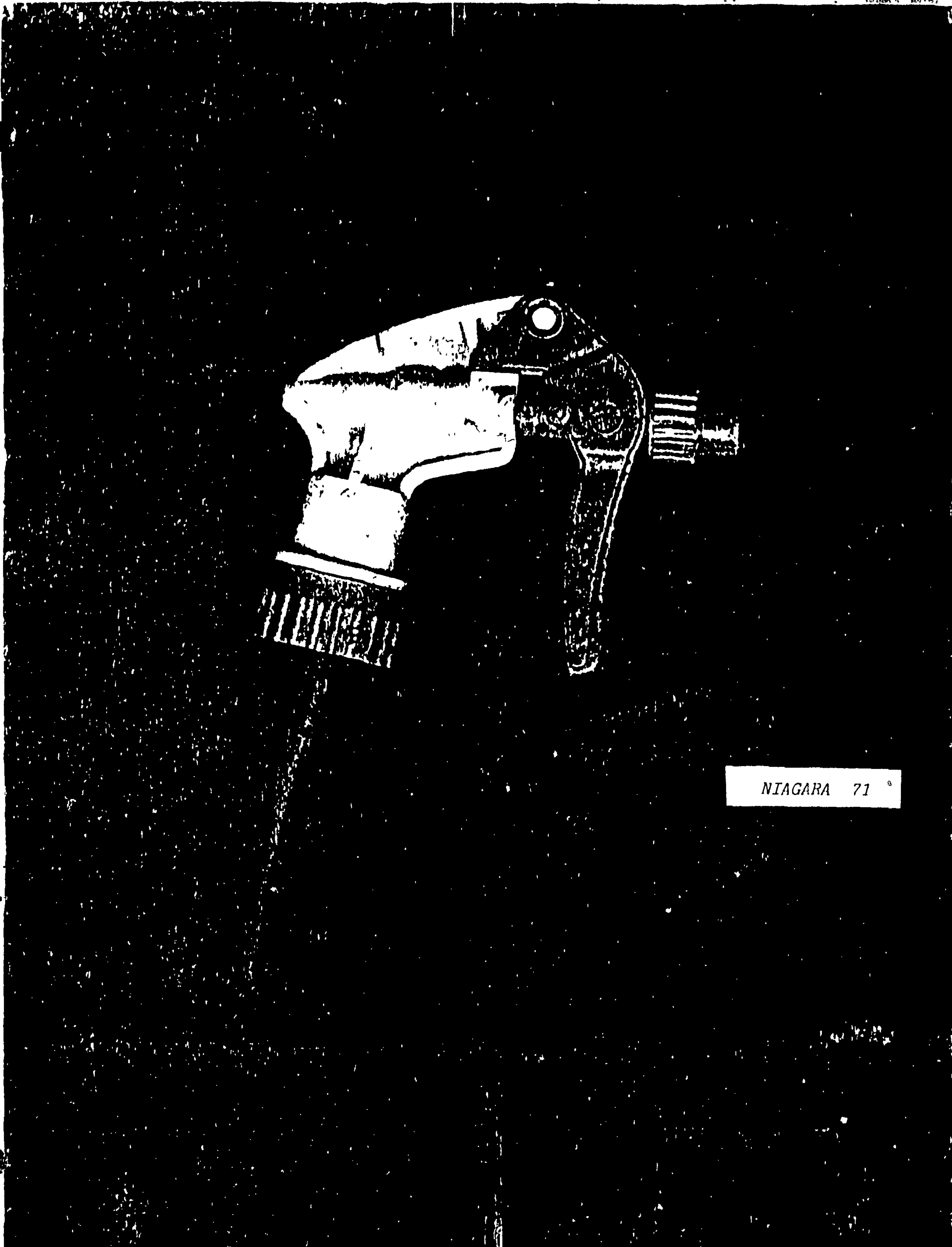
D.B.SMITH # 147

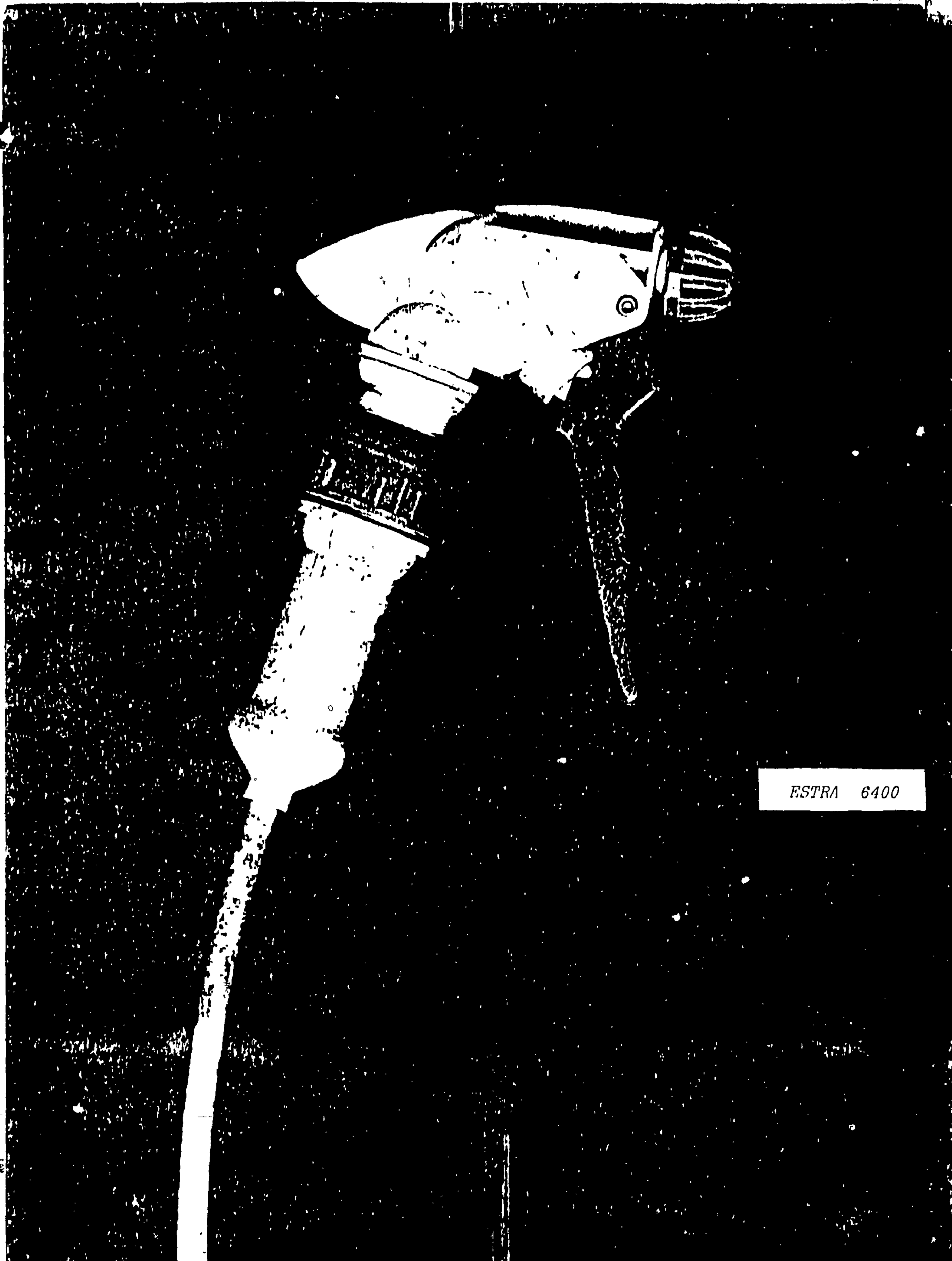
SPRAYING SYSTEMS
WHIRLJET 1/8A.5

BETE P20

BETE W5080F

ACTUAL SIZE OF NOZZLES TESTED


NIAGARA 71


ESTRA 6400

BLACK & DECKER INTRODUCES AN INCREDIBLE PAINT-SPRAYING SYSTEM.

It's easy to use. It sprays latex as well as oil. It needs virtually no cleaning. It does a multitude of other jobs. And it costs under $55.

In the past, you had a lot of reasons *not* to own a paint sprayer.

They were expensive. Heavy. And mostly, they sprayed only *oil* paint.

No more.

Black & Decker's come up with an incredible new home paint-spraying system.

It's powerful enough for the bigger jobs.

Compact enough for those small, hard-to-paint jobs, like shutters or wicker furniture.

It'll spray *latex* as well as oil-based paint.

And it costs under $55.

It's powered by an efficient *piston*-driven air compressor—not a diaphragm—for greater reliability.

It comes with inexpensive, throwaway nozzles for easy cleanup. You can start with a fresh nozzle for each job, with no clogging or spattering. It'll give you that "professionally sprayed" look that a paint sprayer should give you.

But one of the *best* things about it is that the compressor itself can be a wonderful new source of power around your house. For those annoying jobs you never seem to have the right equipment for:

It can inflate just about anything from bicycle tires to basketballs.

With optional garden nozzle, it can spray shrubs and trees. It can even drive [illegible]our optional caulking gun. It's the new home air system, from Black & Decker. It paints. It spray[illegible] inflates.

All for u[illegible]55.

Now you[illegible] a *lot* of good reasons to own a paint sprayer.

Universal Spray/Inflator Kit #7761

54.99

Expect the best from Black & Decker for less than you'd expect. Black & Decker

For your nearest Black & Decker Dealer, call 800-[illegible]6000 FREE, day or night. In Connecticut, call 1-800-[illegible]

3. Specifications

Specifications assumed for selecting a water nozzle:

1. Capacity (flow rate: .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 table on page 54 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 cone because its simplicity reduces clogging.*
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.

* it was found later in testing the Bete F200 that greater impact is provided with fan spray nozzles.

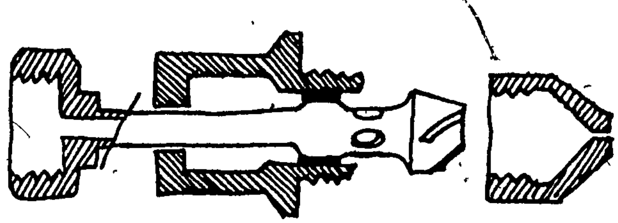
4. Catalog of Nozzles Tested

D.B. Smith #147

Manufactured by:

D.B. Smith Co.,
Utica, N.Y.

Section Drawing:-



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. (.22 gal./min.)
mfgr's claim: not available

Spray Angle: 75°

Atomization size: sprinkle (1000 microns)

Impact: very good

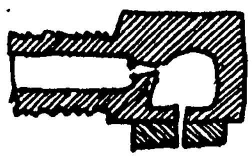
This nozzle is adjustable from full spray to closed. It is primarily used for garden hoses. Not satisfactory for capacity.

Whirljet 1/8A.5

Manufactured by:

Spraying Systems Co.
Weaton, Ill.

Section Drawing:-



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. (.08 gal./min.)
mfgr's claim: .27 liter/min. (.06 gal./min.)

Spray Angle: 58°

Atomization Size: Spray (100-1000 microns)

Impact: good

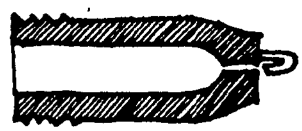
This nozzle is the simplest in construction. The body has one eccentric hole. The cap has a central hole. Not satisfactory for capacity.

Bete P20

Manufactured by:

Bete Fog Nozzle Inc.,
Greenfield, Mass.

Section Drawing:-



Type: hydraulic

Orifice Size: .59 mm. (.02")

Spray Pattern: fog

Capacity (flow rate): as tested: .33 liter/min. (.073 gal./min.)
mfgr's claim: 0.27 liter/min. (.06 gal./min.)

Spray Angle: 90°

Atomization Size: Mist (10-100 microns)

Impact: good

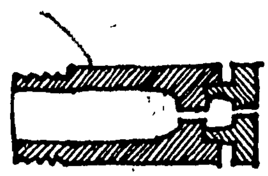
The projecting pin on this nozzle which is easily subject to damage disqualifies it for shower use.

Bete W5080F

Manufactured by:

Bete Fog Nozzle Inc.
Greenfield, Mass.

Section Drawing:-



Type: hydraulic

Orifice Size: 2.38 mm. (3/32")

Spray Pattern: solid cone

Capacity (flow rate): as tested:1.4liter/min. (.3 gal./min.)
mfgr's claim:1.35 liter/min. (.30gal.min.)

Spray Angle: 80^{o}

Atomization Size: spray (100-1000 microns)

Impact: good

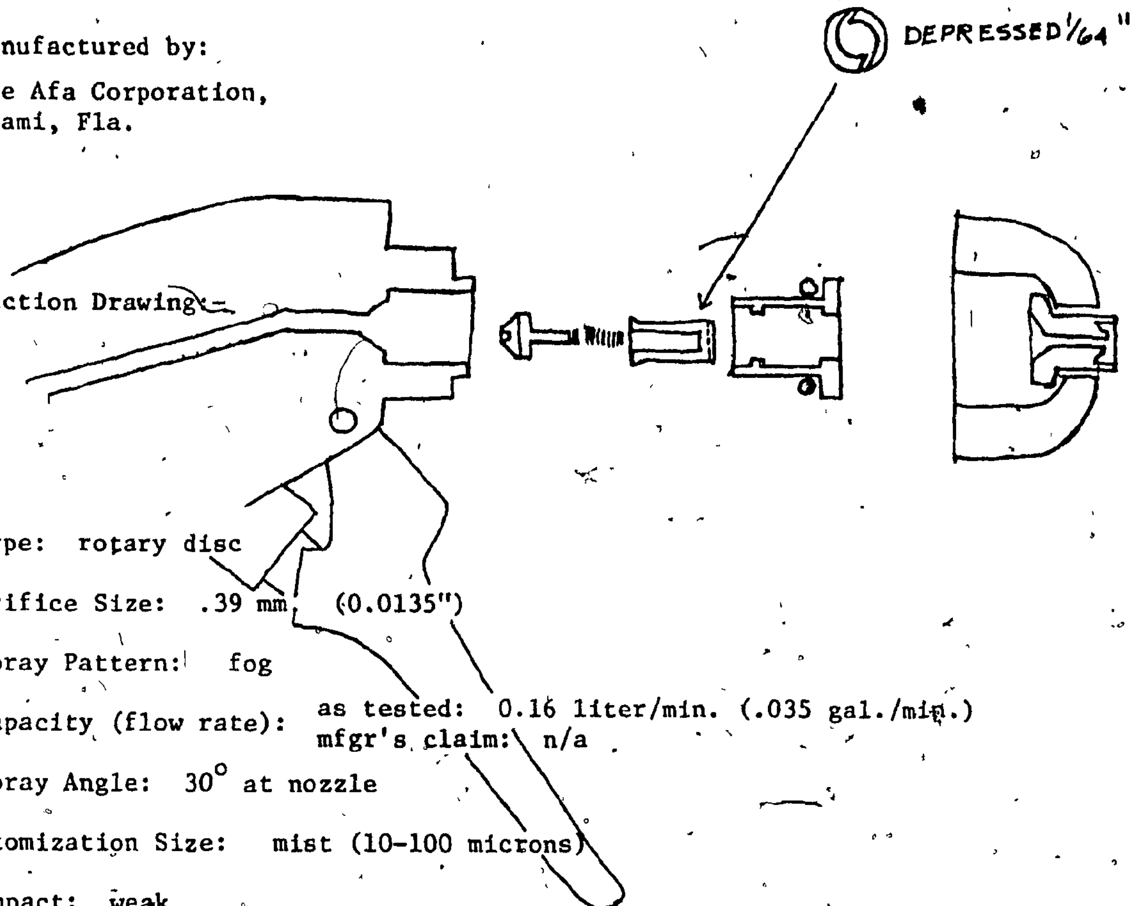
This is the same type of nozzle used on the NASA Skylab. We were not able to achieve the capacity claimed for this nozzle by NASA, possibly because they used it under zero-gravity conditions. Not satisfactory for capacity.

Estra 6400

Manufactured by:

The Afa Corporation,
Miami, Fla.

Section Drawing:–



Type: rotary disc

Orifice Size: .39 mm, (0.0135")

Spray Pattern: fog

Capacity (flow rate): as tested: 0.16 liter/min. (.035 gal./min.)
mfgr's claim: n/a

Spray Angle: 30° at nozzle

Atomization Size: mist (10-100 microns)

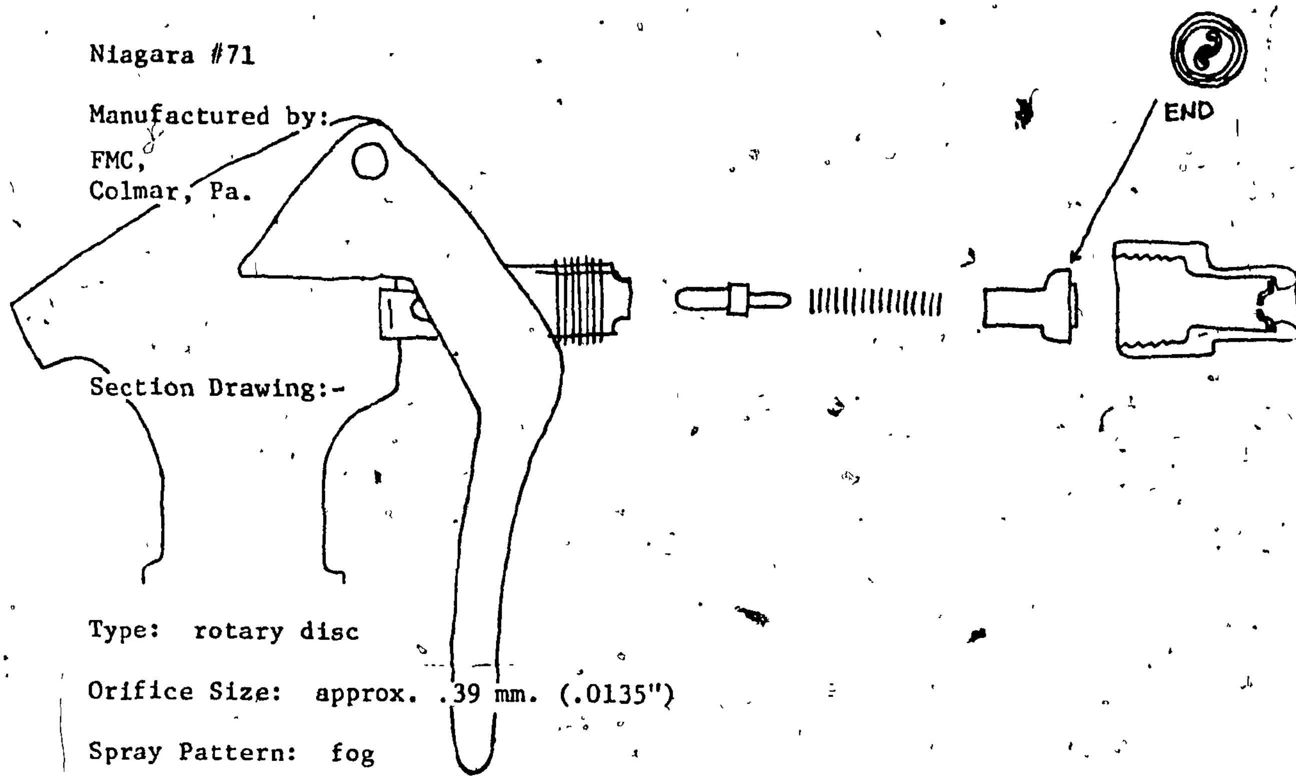
Impact: weak

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

Niagara #71

Manufactured by:
FMC,
Colmar, Pa.

Section Drawing:-



Type: rotary disc

Orifice Size: approx. .39 mm. (.0135")

Spray Pattern: fog

Capacity (flow rate): as tested: 0.08 liter/min. (.017 gal.min.)
mfgr's claim: n/a

Spray Angle: 30° at nozzle

Atomization Size: mist (10-100 microns)

Impact: weak

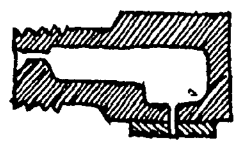
Like the Estra this nozzle has a built-in trigger control, which did not function. Impact not satisfactory.

Steinen TM21 - 1/8"

Manufactured by:

Wm. Steinen Mfg. Co.,
Parsippany, N.J.

Section Drawing:-



Type: hydraulic

Orifice Size: 3.17 mm. (1/8")

Spray Pattern: hollow cone

Capacity (flow rate): as tested: 0.4 liter/min. (.08 gal./min.)
mfgr's claim: .54 liter/min. (.12 gal.min.)

Spray Angle: 90°

Atomization Size: spray (100-1000 microns)

Impact: good

This nozzle did not prove satisfactory in flow rate.

Steinen TM051

Manufactured by:

Wm. Steinen Mfg. Co.,
Parisppany, N.J.

Section Drawing:-

Type: hydraulic

Orifice Size: .59 mm. (.028")

Spray Pattern: hollow cone

Capacity (flow rate): as tested: .3 liter/min. (.06 gal./min.)
mfgr's claim: .28 liter/min. (.069 gal./min.)

Spray angle: 70^{o}

Atomization Size: spray (100-1000 microns

Impact: good

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

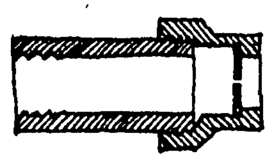
Satisfactory.

Bete F200

Manufactured by:

Bete Fog Nozzle, Inc.,
Greenfield, Mass.

Section Drawing:-



Type: Haudrolic

Orifice Size: .59 mm. (.020")

Spray Pattern: fan

Capacity (flow rate): as tested: .33 liter/min. (.07 gal./min.)
mfgr's claim: .135 liter/min. (.03 gal.min.)

Spray Angle: 60^{o}

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. 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. (see page 90)

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 (.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.

6. Record of Tests

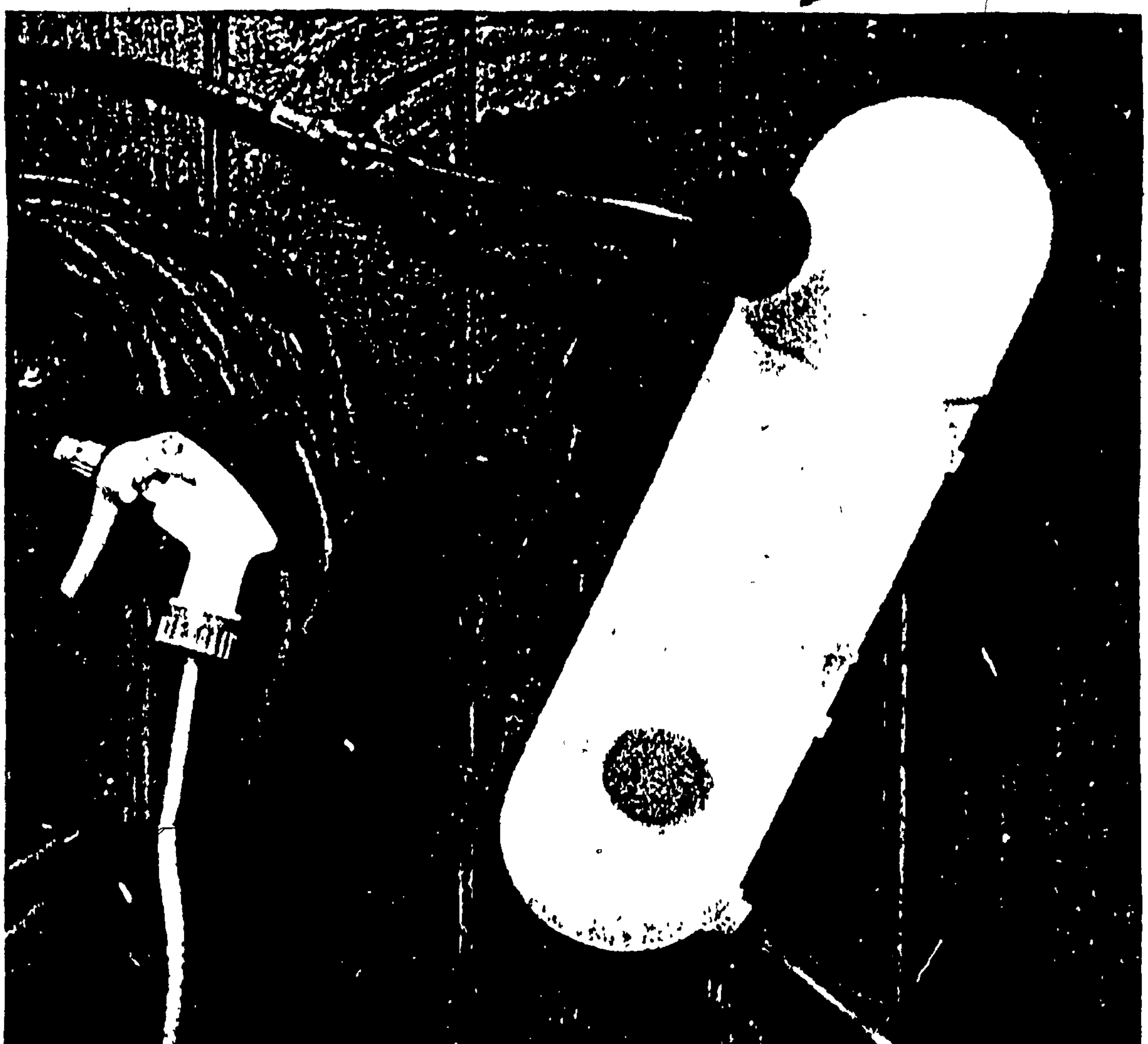
Record of tests of nozzles for capacity (flow rate).

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 tank.



Nozzles in order of testing	Test 1	Test 2	Test 3	Capacity (Flow Rate) liters/min	gals./min	Water consumed in hypothetical 5 minute shower liters	gallons
D.B. Smith 147	56 sec.	1 min5sec.	50 sec.	1.0	.22	5.0	1.1
Spraying Systems Whirljet 1/8A.5	2 min.19sec.	2min18sec	2min.18sec	.43	.08	2.17	.4
* Bete W5080F	1min.1sec.	1min.	1min.	1.4	.3	7.0	1.5
Bete P20	2 min.18sec.	3 min.	3 min.	.36	.07	1.8	.35
Niagara 71	10 min.45sec.	10min.30sec.	13 min.	.08	.01	.435	.05
Estra 6400	6 min.	4min.15sec.	7min.45sec.	.17	.03	.86	.15
Black & Decker Paint nozzle	59 sec.	1 min.	1 min.	1.0	.22	5.0	1.1
Steinen TM21	2 min.14sec.	2min.18sec.	2min.18sec.	.43	.08	2.17	.40
Steinen TM501	3 min.30sec.	3min.25sec.	3min.30sec.	.3	.06	1.5	.3
Bete F200	2 min.35sec.	2 min.15sec.	3 min.	.38	.07	1.92	.35
* NASA claim for this nozzle				.25	.05	1.25	.25

7. 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./5 min.) 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.

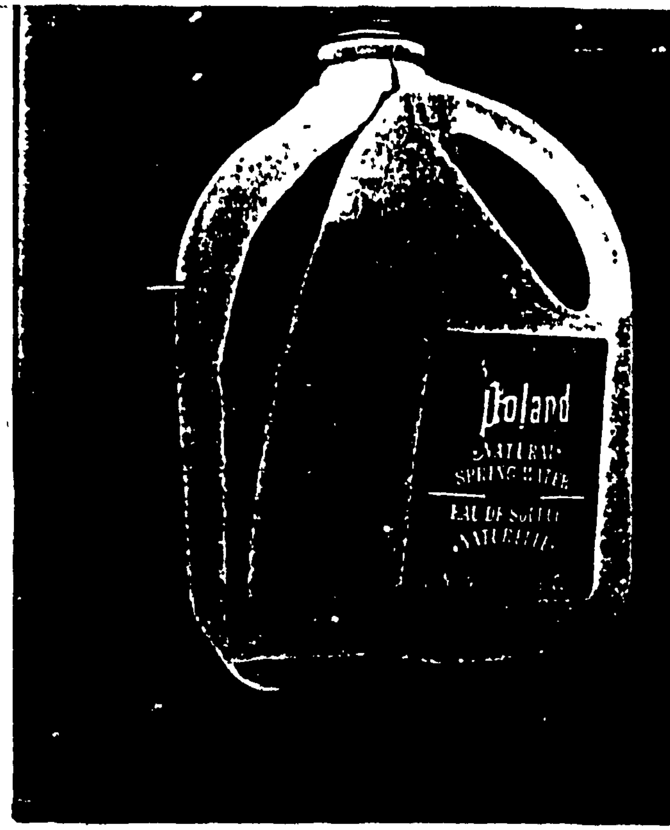
COMPARATIVE CAPACITIES:

Nozzles	Flow Rate per Minute	Impact	Duration
Bete P20	.33 liters/min. (.07 g./m.)	good	poor
Bete F200	.33 " " " "	very good	good
Steinen TM501	.28 " " (.06 g./m.)	good	good
Criteria: NASA claim Bete W5080F	.25 liters/min. (.05 g./m.)	n/a	good
Estra	.16 liters/min. (.03 g./m.)	poor	very good

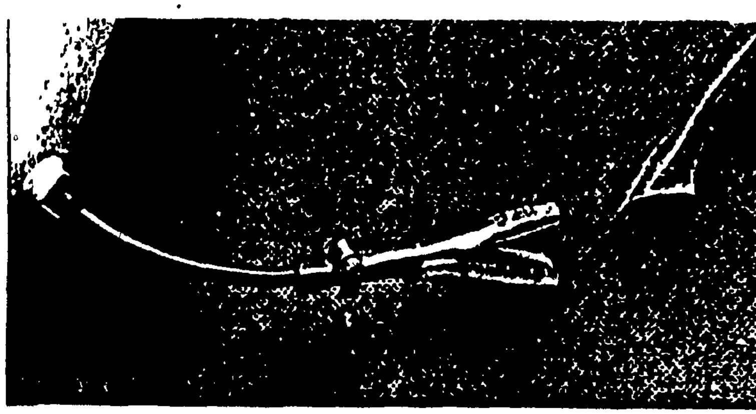
8. Reassesment of Goals

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 shower lasting about 8 minutes. This would require a nozzle with the capacity of .5 liters/minute (.11 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.



SPLIT IN PVC TANK USED IN FIRST ATOMIZED DEVICE TEST



BREAK IN VINYL HOSE IN SHOWERBATH TEST NO.1

Part V

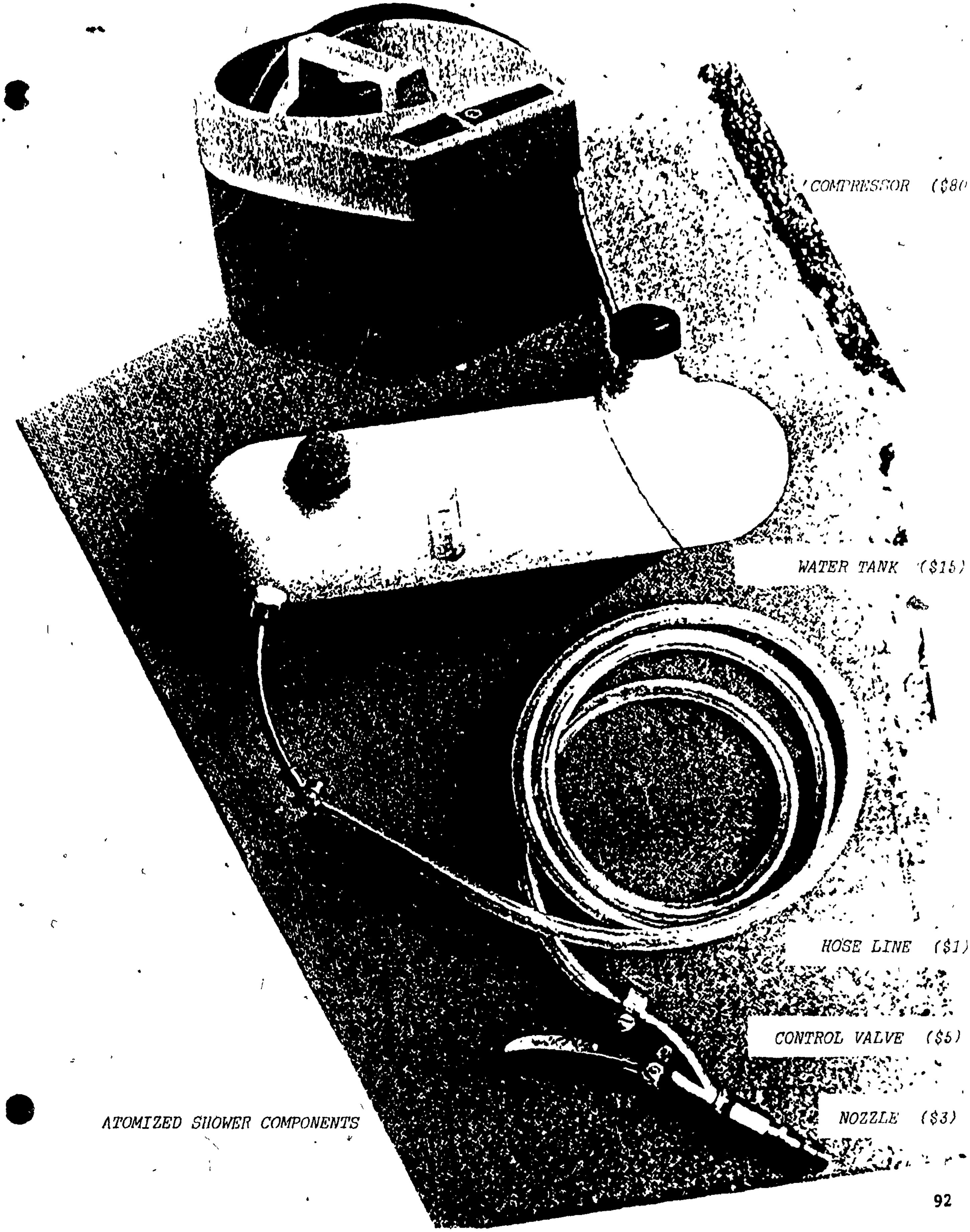
TESTING SHOWERING

1. Testing Showering

The purpose of this test series is twofold. First there is testing of atomizing devices for a satisfactory body cleaning; and secondly, there is the test to demonstrate the concept of a plumbingless showerstall unit.

The concept of the plumbingless bathroom derives from current studies of the Clivus Multrum toilet. This toilet utilizes aerobic decomposition of fecal matter in its operation to produce a compost. The system uses no water. Since neither the Clivus Multrum toilet nor the atomized showerstall unit needs a piped water supply nor a connection with a sewer drain, they would together constitute a plumbingless bathroom. The waste deposited in the Clivus is withdrawn as fertilizer, while the grey water collected in a container under the shower serves as garden irrigating water or as reserve water for firefighting.

The concept of the shower enclosure design was an open bag in which the bather stood on a duckboard above a drain. The unit could thus be easily compacted for storage. Instead of a parting curtain for entry, the cylindrical wall is lowered for the bather to enter and exit. This is similar to the shower used in the NASA Skylab (see page101). Manipulation of this we found to be awkward, so the parting curtain entry was used.



ATOMIZED SHOWER COMPONENTS

The equipment described in Part IV was tested for its performance during actual showering. The slower rated nozzles were used with the compressor for pressure in two cases and the bicycle pump for pressure in another case. The bathing test was divided into four parts: wetting, soaping with the sprayer turned off, rinsing, and towelling. The time involved was to equal that of a normal shower, i.e., from 5 to 8 minutes' duration.

One drawback with the atomized shower device is of course that one hand must be holding the sprayer most of the time, but this is no different from the popular telephone shower, and shares its advantages, i.e., its flexibility to reach all parts of the body; and to wash children and pets with more control than is possible with the conventional fixed shower spray. Another problem is with soap. Our findings corroborate those of NASA's tests on the whole body shower for the Skylab. We found that a sudsy soap prolongs the rinsing operation and in turn uses more water. Consequently, in Test No.3 we changed from using Ivory soap to using a glycerene soap. This enables complete removal of soap in the time and water limit.

Hairwashing was not included in the test because it involves a different washing operation. Normally it does not occur as frequently as body washing. Hairwashing would require additional water. This would be the subject of a further study.

2. Record of Tests

a) Showerbath Test No.1 - 3 P.M., January 26,1976.

Set-up: Black & Decker Compressor
Volkswagon 2.5 liter (0.5 gal.) water tank
Nozzle: S.S. Whirljet 1/8A.5
1/4" vinyl hose with Chapin garden hose control
Ivory soap

Precautions: Emergency water backup: bucket and sponge
Compressor set on higher level shelf to prevent backflow of water into compressor.
Nozzle control in "off" position.

Procedure: Tank filled to 2 liters (0.4 gal.) of water at 40°C (105°F) then strapped to showerstall post.
Compressor placed on higher level shelf.
Pressure 1.3 atmos. (15-20 psi).

Liters	Gallons	Time Table (minutes)	Operation
2.0	0.5	0.0	Start compressor.
		0.1	Start spraying from face down
1.0	0.25	0.9	Wetting completed - sprayer off. (compressor still on)
		1.0	Start soaping, using facecloth.
		2.5	End soaping, start rinse spray.
0.5	0.12	3.5	Supply line hose bursts(see page 90) Break happened on hose line 1" from tank between tank and nozzle. Cause: hot water concentrated at start of vinyl tube and softened it. Remaining soap removed with emergency water. Drain and container functioned satisfactorily.

Showering time: 3.5 minutes (interrupted)

NOTE: 1 lb./sq.in. = .068 atmos.
1 atmos. = 14.7 lb/sq.in. (psi)

THE AUTHOR TESTING THE ATOMIZED SHOWER

b) Showerbath Test No.2 - 4 P.M., February 9, 1976.

Set-up: Bicycle pump
Volkswagon 2.5 liter (0.5 gal.) water tank
Nozzle: Estra (with built-in control trigger)
1/8" vinyl hose, inoperable over 1.3 atmos. (20 psi)
Ivory soap.

Precautions: Emergency water backup: bucket and sponge.

Procedure: Tank filled to 1 liter (.25 gal.) cold water then strapped to shower stall post.
Air pumped by tire pump manually 18 strokes.
Pressure : 3.3 atmos. (48 psi) on pressure guage.

Pressure	Liters	Gallons	Time Table (minutes	Operation
2.4 atmos. (35 psi)	2.0	9.0	0.0	Tank set in place. Start wetting.
			1.5	Wetting completed. Spray off.
			3.0	Soaping completed. Spray on. Start rinsing.
.34 atmos. (5 psi)			6.5	Pressure too weak to remove soap.
2.4 atmos. (35 psi)	1.0			Pump air into tank (20 strokes).
			8.0	Resume rinsing.
1.4 atmos. (20 psi)	0.0		10.0	Rinsing completed. All water used.

Showering time: 10 minutes

c) Showerbath Test No. 3 - 11:30 A.M., May 18, 1976.

Set-up: Black & Decker Compressor
Volkswagon 2.5 liter (0.5 gal.) water tank
Nozzle: Steinen TM21
1/4" vinyl hose with Chapin garden hose control
Glycerene soap

Precautions: Emergency water backup: bucket and sponge.

Procedure: Compressor placed on higher level shelf to prevent back-flow of water into compressor.
Nozzle control in "off" position.
Tank filled with 2 liters of cold water (0.4 gal.) then set in cradle atop shower.
Pressure 1.3 atmos. (15-20 psi).

Liters	Gallons	Time Table (minutes)	Operation
2.0	0.4	0.0	Start compressor. Climb into shower.
		1.0	Start wetting from face down.
		2.0	Wetting completed. Sprayer off. Start soaping.
1.0	0.2	4.0	Soaping completed. Start spray for rinsing.
0.0	0.0	5.0	Rinsing incomplete. No water. Some soap remains.
		7.0	Compressor off.
		8.0	Emergency water required to remove all remaining soap.
			Showering time: 8 minutes (interrupted)
			Grey water recovery: 0.75 liter (3 cups @ 250 ml/cup)

d) Showerbath Test No.4 - 11:30 A.M., July 7, 1976.

Set-up: Black & Decker Compressor
Volkswagon 2.5 liter (0.5 gal.) water tank
Nozzle: Steinen TM051
1/4" ϕ vinyl hose with Chapin garden hose control valve.
Glycerene soap.

Precautions: Emergency water backup: bucket and sponge.

Procedure: Compressor placed on higher level shelf to prevent back-flow of water into compressor.
Pressure 1.3 atmos. (15-20 psi).

Liters	Gallons	Time Table (minutes)	Operation
2.0	0.4	0.0	Start compressor. Climb into shower.
		1.0	Start wetting from face down.
1.0	0.2	2.0	Wetting completed. Sprayer off.
		3.0	Soaping completed. Start spray for rinsing.
0.0	0.0	6.0	Rinsing completed. All soap off. Compressor off.
		7.0	Start towelling.
		8.0	Towelling completed.
			Total Time: 8 minutes
			Showering time: 6 minutes

e) Showerbath Test No.5 - 4 P.M., July 9, 1976.

Set-up: Bicycle pump

Volkswagon 2.5 liter (0.5 gal.) water tank

Nozzle: Bete F200

1/4" vinyl hose with Chapin garden hose control

Glycerine soap.

Precautions: Emergency water back-up: bucket and sponge.

Procedure: Tank filled to 2 liters (.4 gal.) cold water then strapped to shower stall post.

Air pumped by tire pump manually 21 strokes.

Pressure 35 psi on pressure guage.

Pressure	Liters	Gallons	Time Table (minutes)	Operation
3.3 atmos. (48 psi)	1.9	4.2	0.0	Tank set in place. Fine mist coming from nozzle. Start wetting.
	1.2	2.6	3.0	Wetting completed. It required all this time,
2.4 atmos. (35 psi)	0.8	0.17	5.0	Start soaping. Control lacking so spray continues. Completed soaping. Start rinsing from face down using hand and sponge to scrape off soap.
	0.2	0.04	8.0	Spray getting weak, losing force.
2.0 atmos. (30 psi)	0.1	0.02	9.0	Spray too weak to use. Skin still soapy.
1.7 atmos. (25 psi)	0.0	0.0	10.0	Emergency water required to remove all remaing soap.
				Showering time: 10 minutes (interrupted)

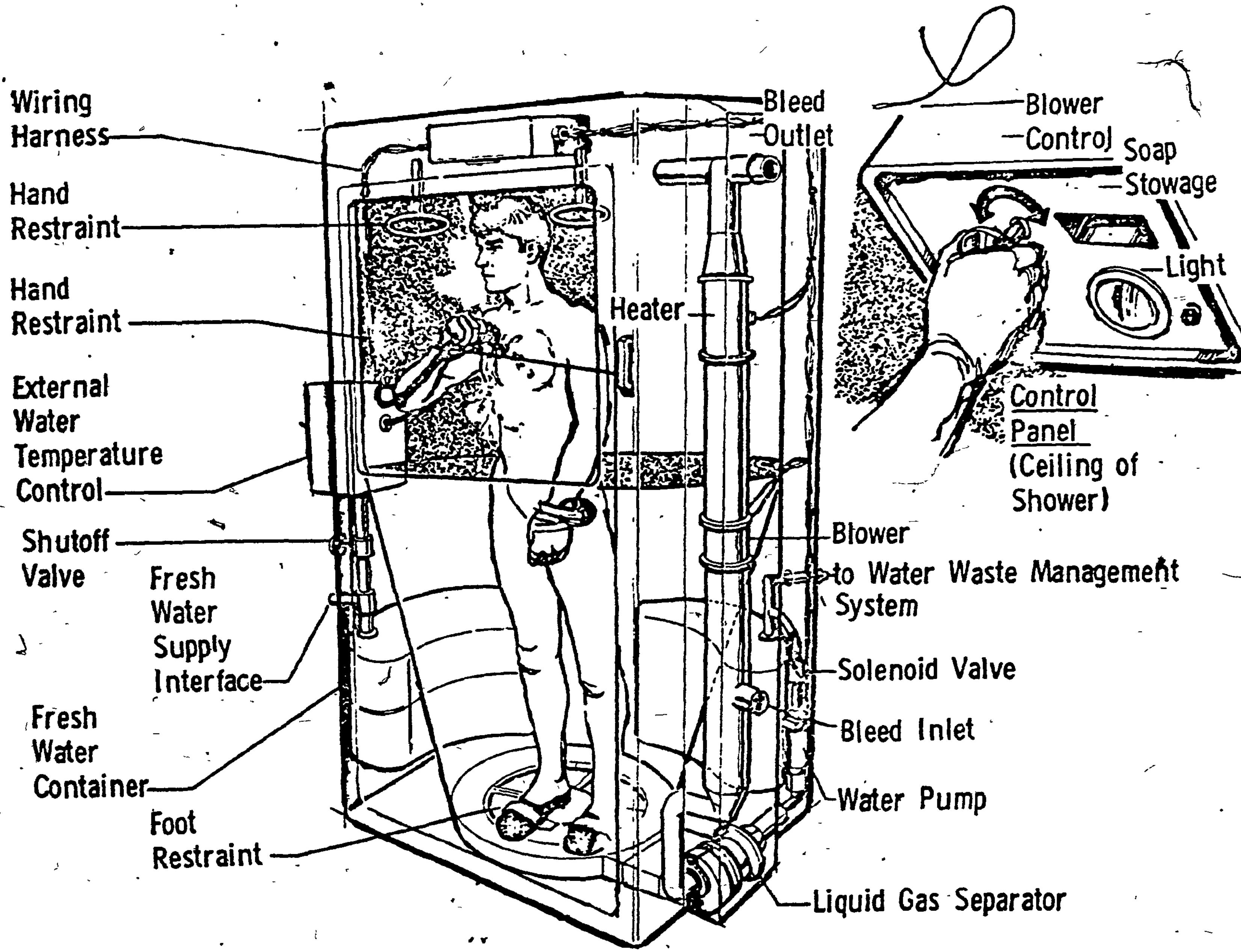


Figure 115.- Zero-Gravity Shower Module Air Drag Concept

DRAWING OF TEST SHOWER UNIT FOR NASA SKYLAB

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a pass whose beauty
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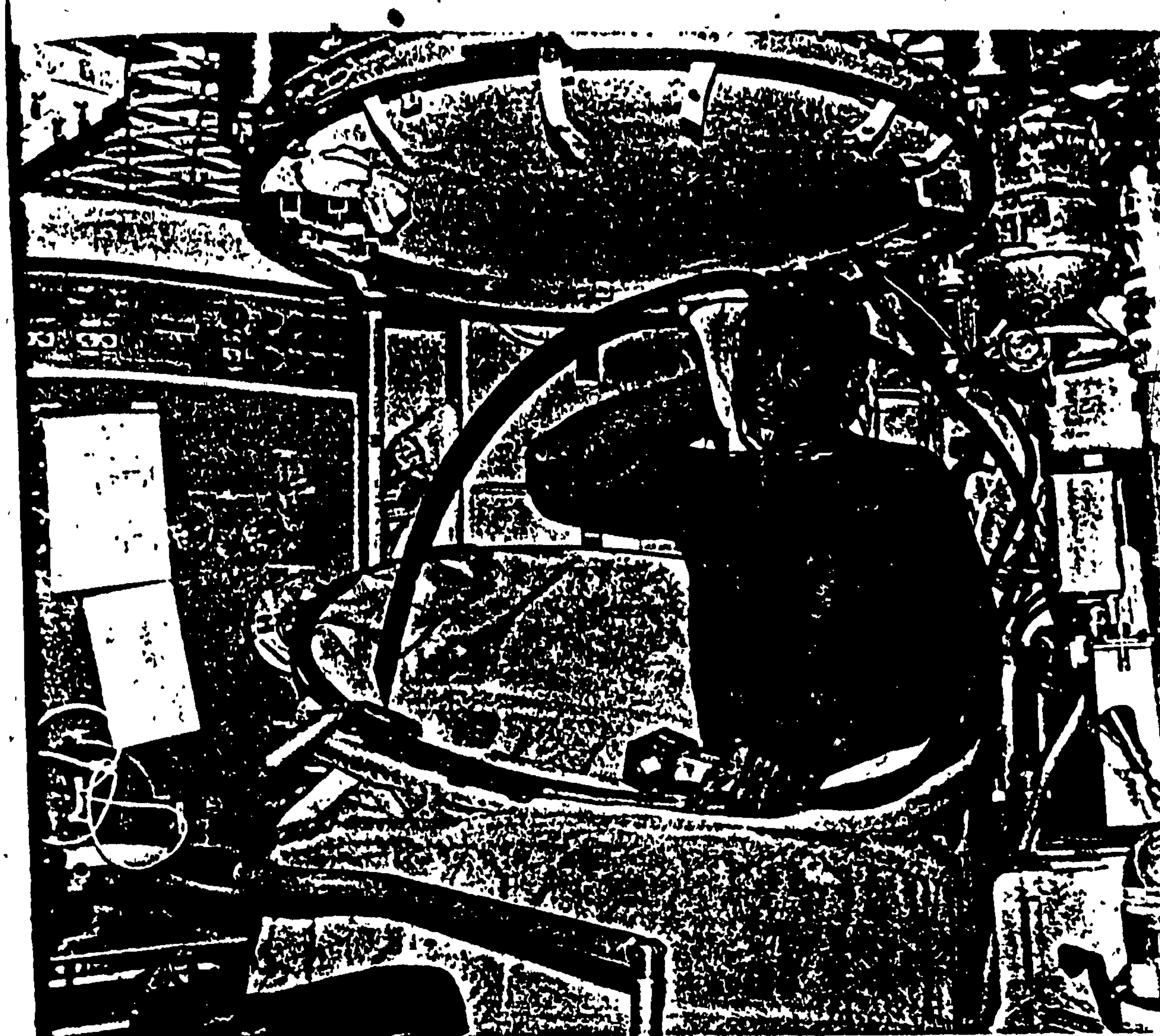


BOTH SKYLAB 2

All the comforts . . . sort of. In a weekly ritual that proved both boon and bane, Lousma soaps up in a shower stall. Fastening the cocoon to the ceiling, he will rinse with the spray spigot in his left hand, then dry off with a towel and a vacuum hose that sucks up drifting droplets.

The time-consuming process—45 minutes from start to finish—persuaded several astronauts to avoid showers in favor of rubbing down with damp towels.

NASA Design criteria:

" 1. *water quantity required for complete shower is 0.6 gallon.*

2. *a hand-held, movable spray nozzle is the most effective method of distributing water on the body during wetting and rinsing operations. The most suitable spray pattern is a 25° solid cone, at a pressure of approximately 20 psi.*

3. *showering operations including drying and shower clean-up should not exceed 15 minutes for maximum crewman comfort.* "

SKYLAB'S ATOMOZED SHOWER

3. Findings

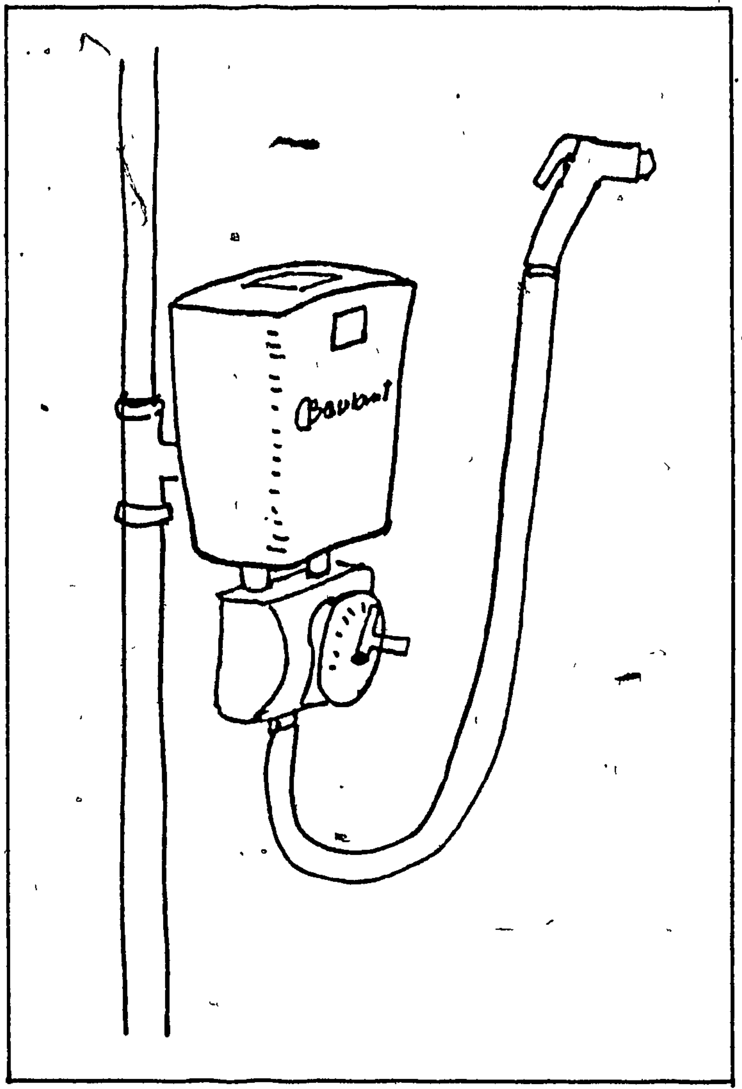
As stated in Part IV, the nozzle performance range affects the bathing. The more forceful and larger droplet nozzles used water too fast for a satisfactory shower, while the finer droplet nozzles produced a spray too weak to remove the soap in the required time and water supply. However, in Shower Test No.4, the Steinen TM051 nozzle achieved a good compromise obtaining a 6 minute shower with 2 liters of water. In addition its right angle head proved most comfortable for handling and for reaching all parts of the body.

Another nozzle which we found to satisfy the requirements was the Bete F200. Its greater impact proved more effective than the Steinen TM051 in removing soap suds. This was due to the concentration of droplets in a fan pattern. The drawback of the Bete F200, however, is that it does not have a right angled head. Of course this advantage or disadvantage depends on the type of control valve handle used.

The tests have positively demonstrated that a showerstall with an atomizing device could be a plumbingless unit, and together with the Clivus Multrum toilet could constitute a plumbingless bathroom. In fact, the shower unit could be used in any room of the house.

The normal shower uses about 50 liters (11 gal.) of water and takes about 5 to 9 minutes. This shower used 2 liters (0.5 gal.) of water for 5 to 8 minutes. This is a water-saving of 96%.

The tests have demonstrated the feasibility of the atomizing device to satisfactorily cleanse the body. Both the showerstall and the atomizing equipment tested were rather primitive, so further refinement would be necessary for optimum design performance.



ELECTRIC WATER HEATER FITS ON COLD WATER SUPPLY PIPE

PART VI

CONCLUSIONS

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). This is a capacity (flow rate) of 0.27 liters/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 liters/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 liters/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 a 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 liters/minute at 1.3 atmospheres (.03 gal./min. at 15 psi). In the showering test it performed well: a 6 minute shower using 2 liters (.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 liters 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 function well.

How does it feel to use an atomized shower?

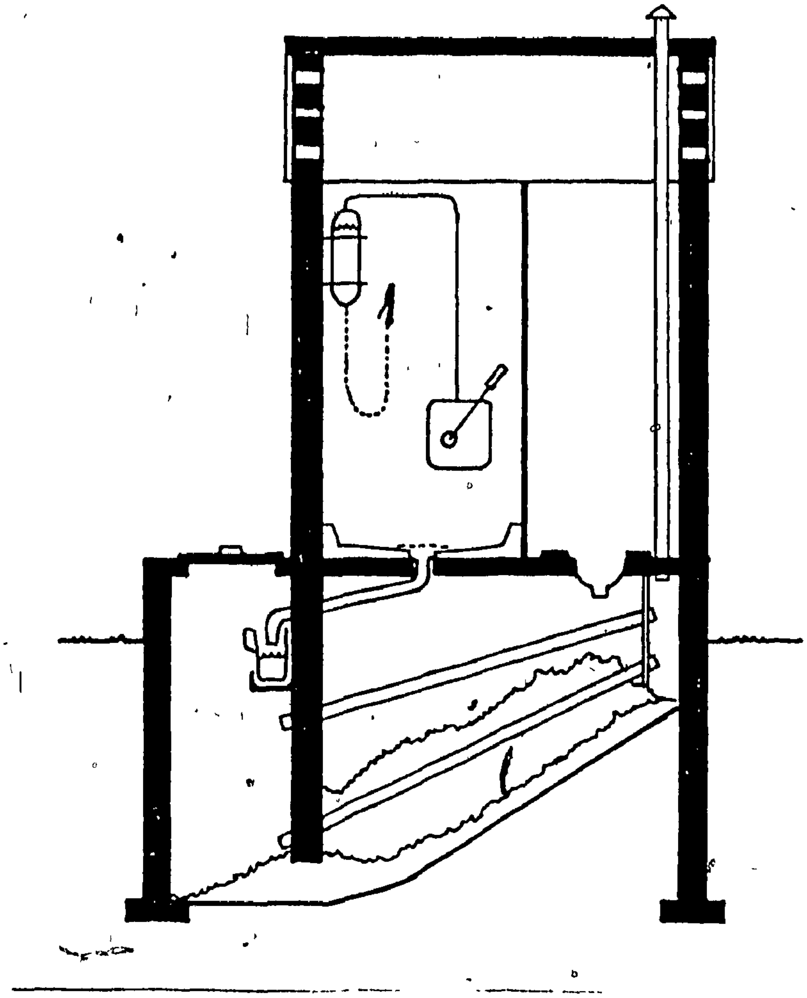
The atomized shower produces a different sensation from the normal shower. Although the device is similar to the telephone shower which can reach close to all parts of the body, the spray impact is much less, so the needle-like massage is missing and a softer flow of water is felt since the droplet size 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 the 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



THE PLUMBINGLESS BATHROOM: ATOMIZED SHOWER WITH CLIVUS TOILE 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?

We have seen in the case of Granby that certain barriers would exist. To convert in emergencies would be difficult but possible. To convince users to convert at other times would require demonstration, mainly of cost savings.

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,[13] 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 liters daily of which 79% is drunk.

However, not so resistant was a test group of workers in Dubai, in 1975. 500 workers were provided by the U.N. with inexpensive hand-pumped pressure sprayers from Taiwan which were used for showering. Documentation on this is not yet available, but it is reportedly a successful experiment.

The photograph on page110shows Philippine children intrigued with the idea of handwashing with a finger-pumped atomizer. Early familiarity with atomizers may reduce cultural resistance to new technology, which can help prevent future water shortage.

Despite potential cultural resistance and the time lag for new technology to be accepted, the concept makes sense. If the world is

to sensibly organize its water use, we must listen to the words of M.I. Lvovich:[26] "A water crisis can be averted by an integrated programme of technological, biological and organizational measures". The atomized shower is offered here as a technological measure.

Possible applications for atomized showers:

	Location	Water Supply & Pressure	Application
I	urban	water main w/ pressure reducing valve	bathrooms in houses, showers in industry, schools, hospitals.
II	rural	w/water taps w/pressure reducing valve	bathrooms in houses showers in schools.
III	rural	w/water delivered regularly compressed air	bathrooms in houses community showers
IV	rural wild	water carried on vehicles compressed air or manual pump	vehicles, showers camp showers

Summary of Conclusions:

1. The atomized shower is feasible.
2. Equipment for an atomized shower is available on the market.
3. Low suds soap must be used to minimize the quantity of water for rinsing.
4. The plumbingless bathroom is feasible when the atomized shower is used in combination with the Clivus toilet.
5. The atomized shower is hygienic.
6. Air pressure on the water should be 1.3 atmos. (15-20 psi).
7. Nozzles should be fan pattern, small orifice, under 1.58 mm. (1/16"), right angle and with capacity of about .135 liters/minute (.03 gal./min.).
8. Further research needs to be done on pressure sources, hairwashing, and multiple showers.
9. Shower water conservation of over 90% has been demonstrated.

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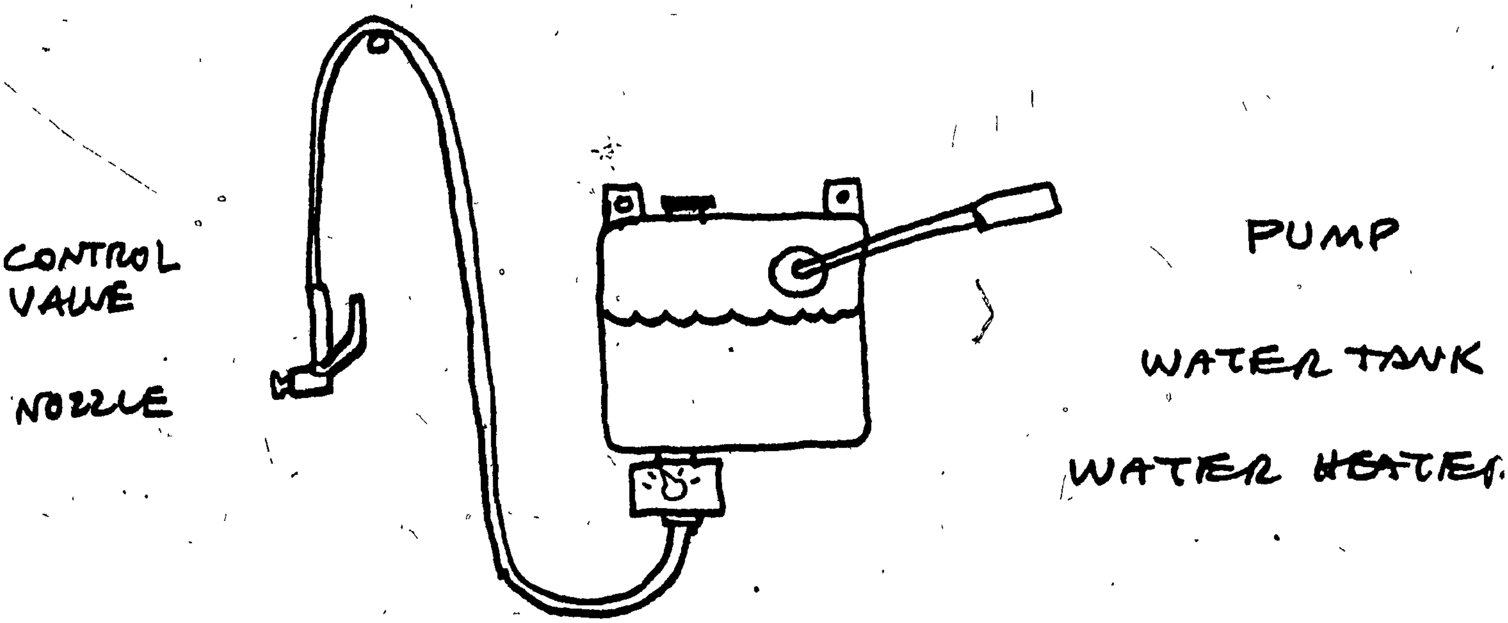
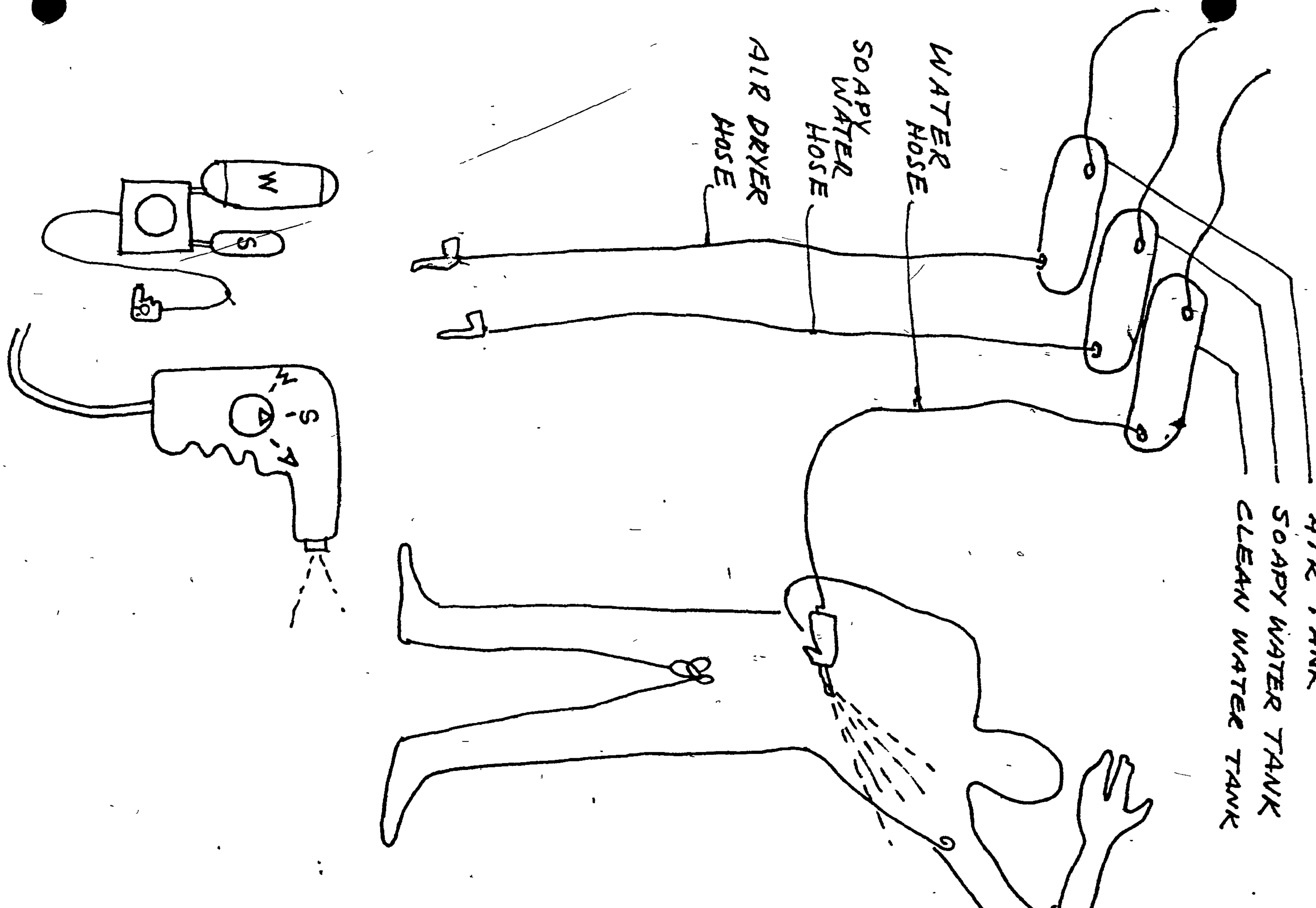
APPENDIX I : DESIGN POSSIBILITIES



ATOMIZED SHOWER UTILIZING BACKPACK SPRAYER AND INSTANT WATER HEATER

The lever operation makes pumping air for pressure easier than with other types of manual pumps. The backpack unit would be wall mounted along with the water tank. The electric instant water heating unit is economical where no other water is to be heated by electricity as in camps.

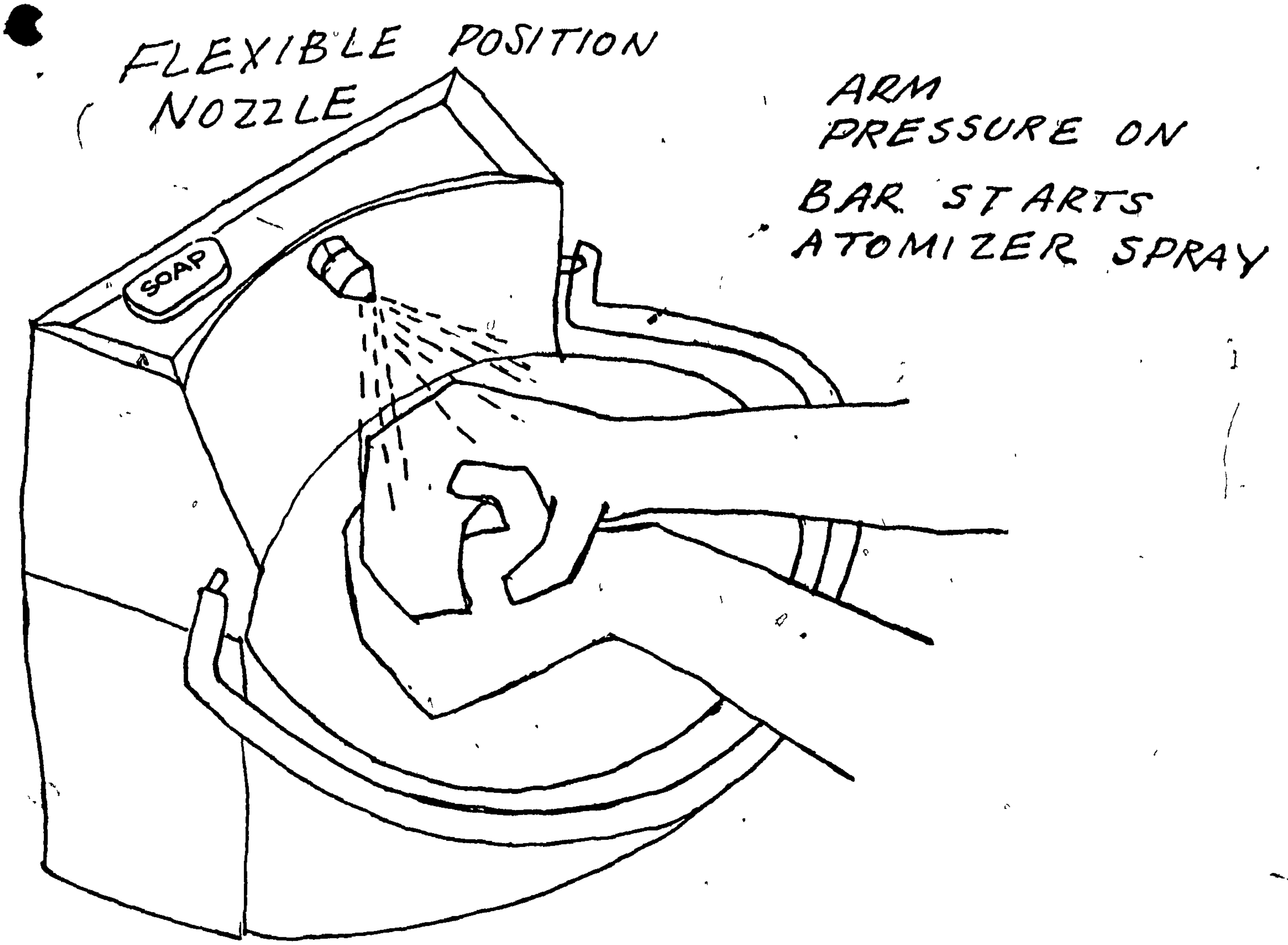


DIAL CONTROL SPRAY HANDLE

This valve control is for selecting plain water or soapy water.

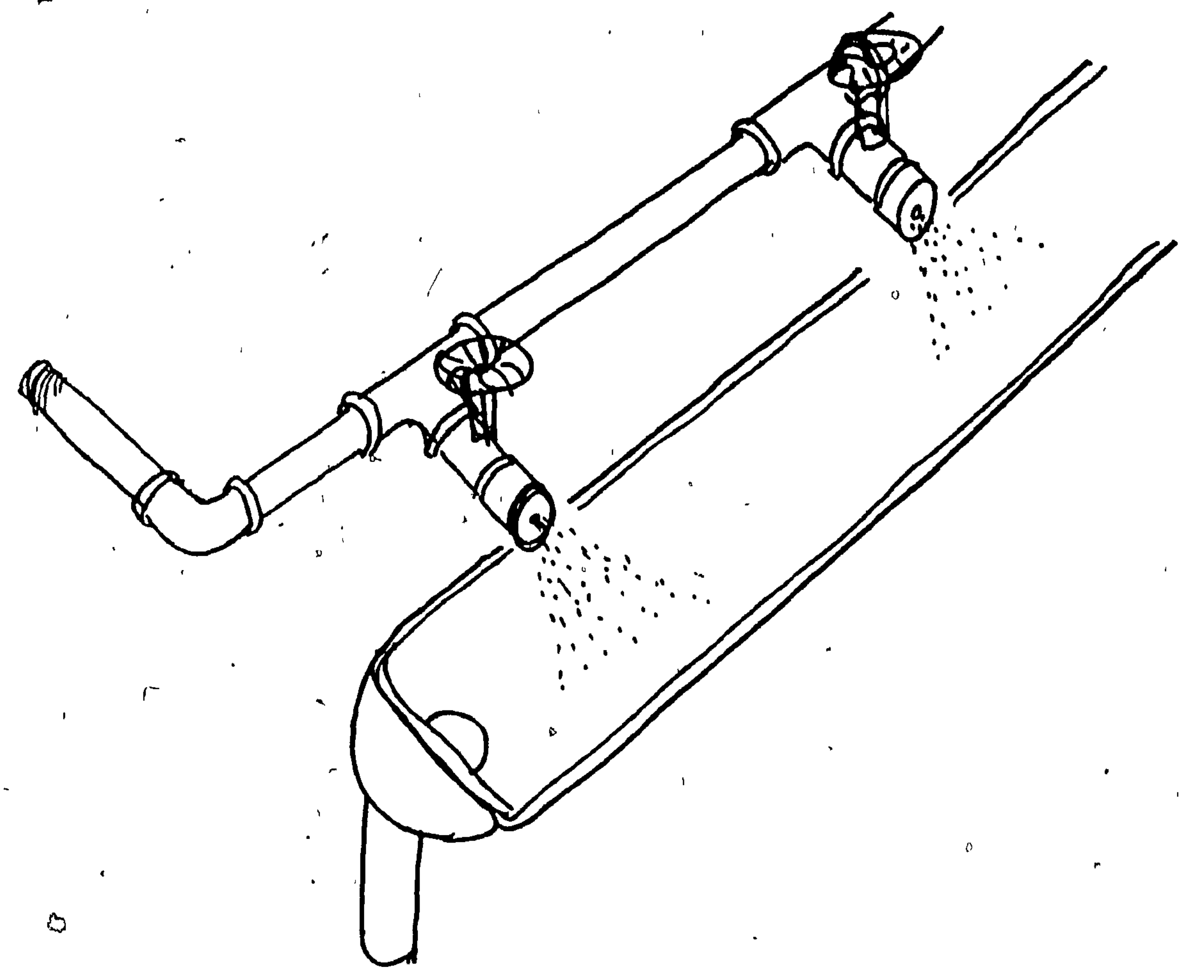
A third selection would be air for drying.

An alternative is seperate nozzles and hose each in turn for plain water, soapy water or air.



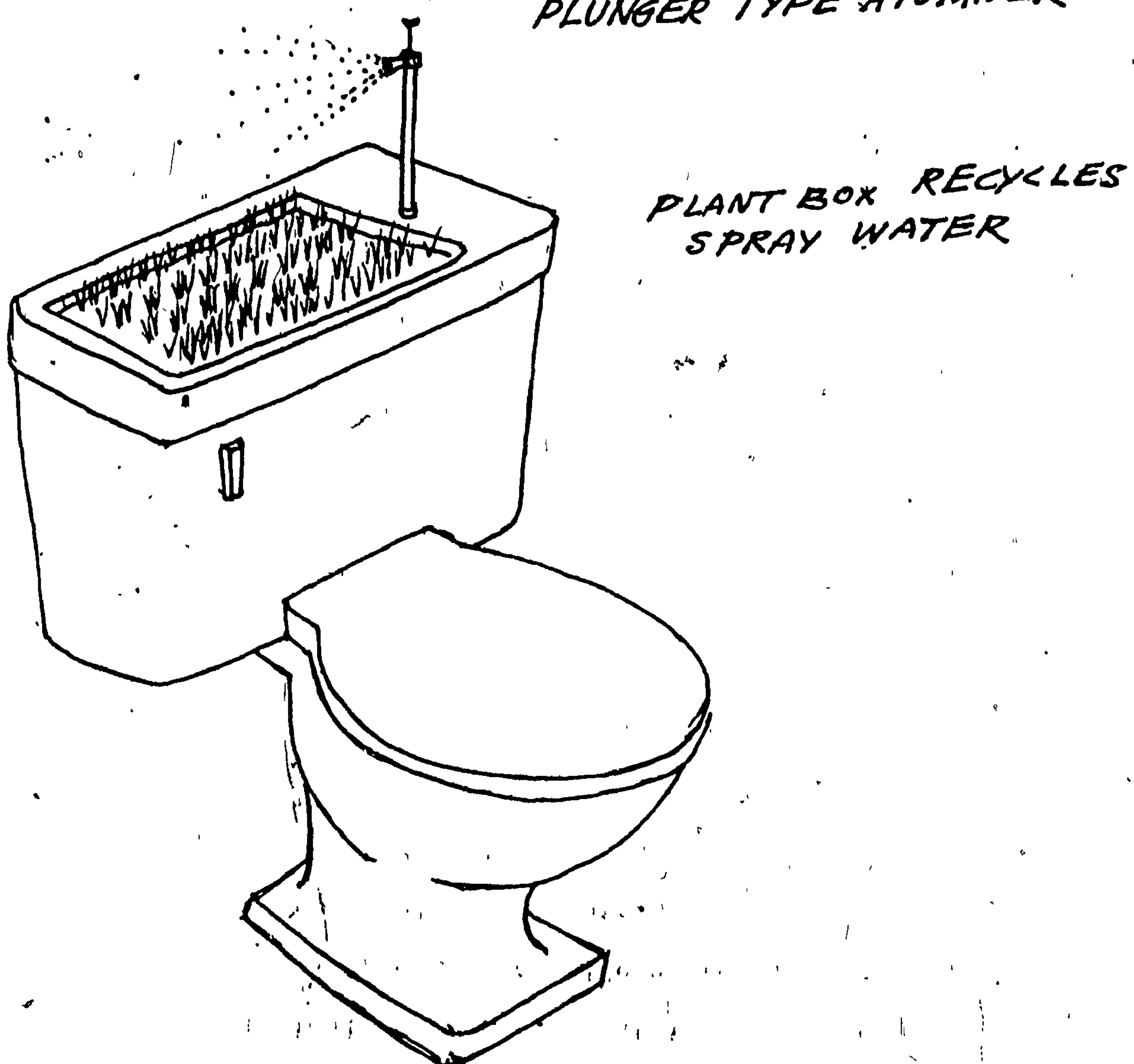
HANDWASH VALVE CONTROL is activated by the arms. It is preferred over foot and knee type pedals which cause uncomfortable balance.

Nozzle has flexible ball joint for aiming spray.



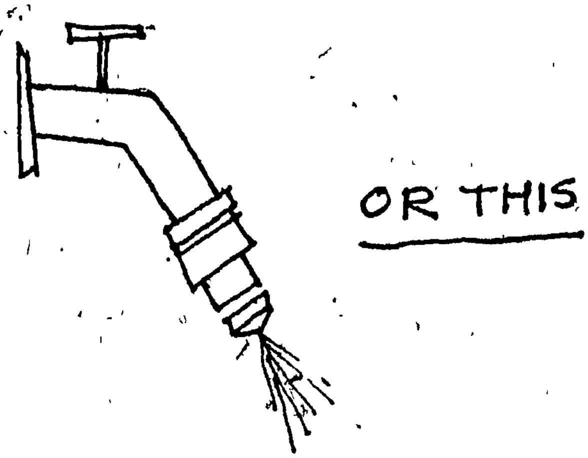
WASHROOM: INSTITUTIONAL & INDUSTRIAL INSTALLATION

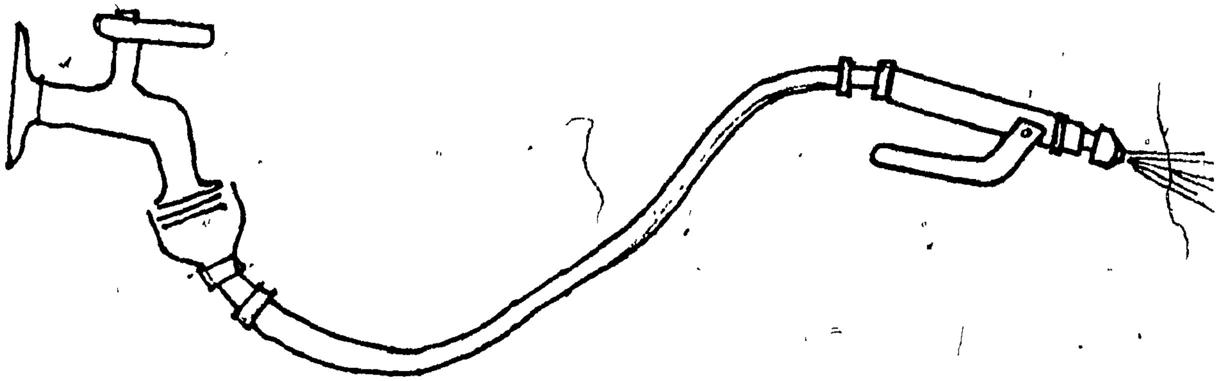
INDUSTRIAL APPLICATION of atomized handwashing sprayers. With pressure reducing devices gang water washing facilities can be converted to using atomizer nozzles. In new installations, spigot is replaced with twist "off-on" control at nozzle.



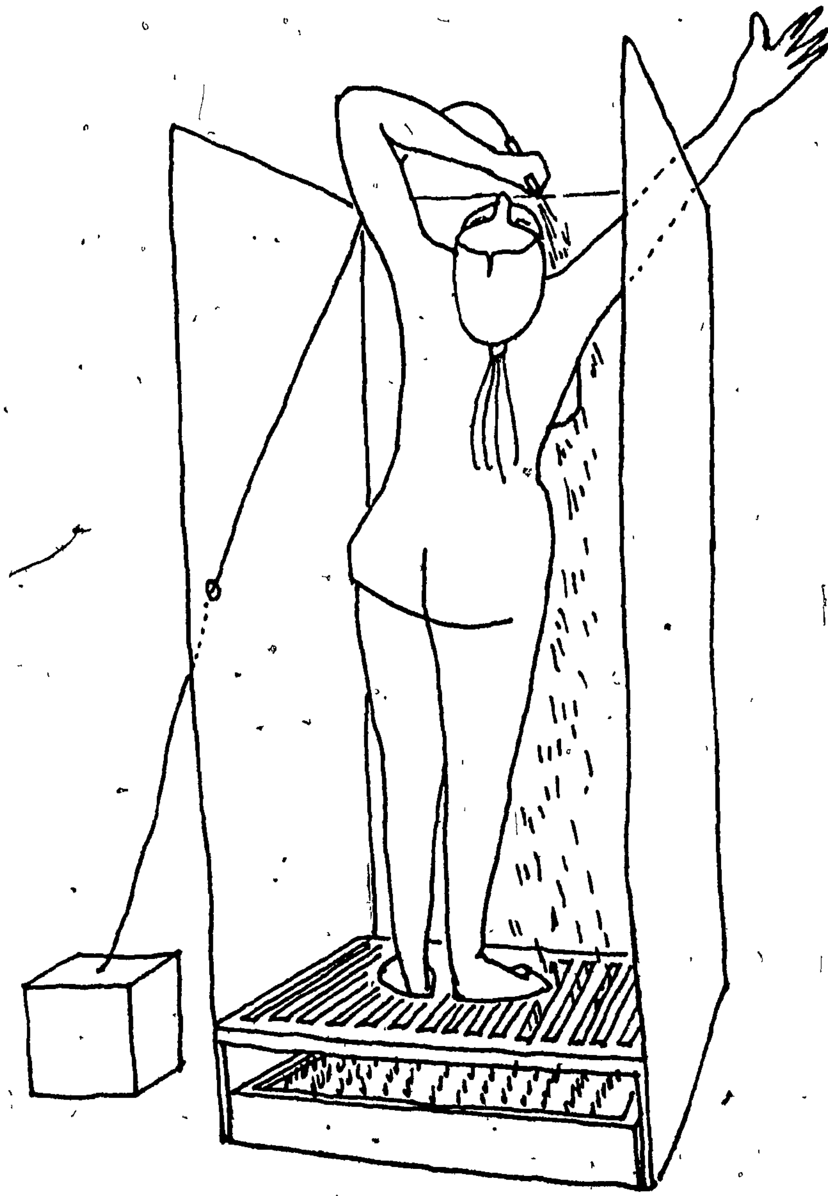
TOILET WATERBOX ATOMIZED HANDWASHING

For situations where anarobic toilets are used. Manual type atomizer's tube extends into water box. It is used for after or before toilet hygiene.





Atomized shower can be adapted to existing facility by use of pressure reducing valve.



Shower water may be captured in plant tray under shower floor.

APPENDIX II : SKIN BACTERIA TEST

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[35] 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% Hexachloraphene, (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.

before washing bacteria in pores — *after washing bacteria on skin (normal soap)* — *after washing with biosidal soap (hexachloraphene)*

BACTERIA IN SKIN THEORY