CIB-W62 SYMPOSIUM

Rainwater Utilization System in Building

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Rainwater Utilization System in Building

12th CIB-W62 SYMPOSIUM - TOKYO -

WATER SUPPLY AND DRAINAGE FOR BUILDINGS

APRIL 9, 10, 1985 : KENCHIKU KAIKAN

Summary

From the perspective of the efficient utilization of water resources, the application of Rainwater Utilization Systems in buildings in our country has begun to attract attention in recent years.

What is called the Rainwater Utilization System here is the collection and storage of rainwater that falls on buildings and building sites, and the simple treatment of that water for use in washing, air conditioning cooling , industrial cooling, etc.

We have, in the operation of rainwater utilization systems, performed a variety of tests. Below, we have outlined the contents of the general results.

1) Introduction
2) Outline of Rainwater Utilization System
3) Current Situation of Rainwater Utilization in Japan
4) Examination of Rainwater Quantity
5) Examination of Rainwater Quality
6) Examples of Actual Uses of Rainwater
7) Conclusion

Résumé

Dans la perspective d'une utilisation efficace des ressources en eau, la réalisation des Systèms Utilisant l'Eau de Pluie dans les immeubles de notre pays a commencé a attirer l'attention ces dernières années.

Ce qui est appelé Système Utilisant l'Eau de Pluie est la récolte et le stockage de l'eau de pluie qui tombe sur les bâtiments et les terrains attenants, ainsi que le traitement simple de cette eau en vue d'une utilisation pour le lavage, les refroidissements de la climatisation, les refroidissements industriels, etc.

Nous avons, dans le fonctionnement des systèmes utilisant l'eau de pluie, effectué différents tests. Ci-dessous, nous décrivons le contenu des résultats généraux.

1) Introduction
2) Systèms utilisant l'eau de pluie
3) Utilisation courante de l'eau de pluie au Japon
4) Examen de la quantité d'eau de pluie
5) Examen de la qualité de l'eau de pluie
6) Exemples d'utilisations réelle de l'eau de pluie
7) Conclusion

Zusammenfassung

Aus der Sicht der effektiven Nutzung von Wasserquellen hat die in unserem Land bereits seit längerem eingeführte Anlage für Nutzung von Regenwasser seit einigen Jahren Anerkennung gefunden.

Unter Anlage für Nutzung von Regenwasser verstehen wir das Sammeln desjenigen Regenwassers, das auf die Dächer und den umgebenden Boden von Gebäuden fällt sowie die einfache Behandlung des Wassers für Nutzung als Waschwasser, Kühlwasser für Klimatisierung , Kühlwasser für industrielle Anwendungen usw.

Wir haben bei Betrieb von Anlagen für Nutzung von Regenwasser eine Reihe von Tests durchgeführt. Nachfolgend werden Inhalt und allgemeine Ergebnisse dieser Tests umrissen.

1) Einleitung
2) Grundriß der Anlage zur Nutzung von Regenwasser
3) Momentane Nutzung von Regenwasser in Japan
4) Untersuchung der Regenwassermenge
5) Untersuchung der Qualität des Regenwassers
6) Beispiele für tatsächlichen Gebrauch von Regenwasser
7) Schlußbemerkung

概　要

水資源の有効利用の観点から、近年我が国において注目され始めたのが建築物における雨水利用システムである。

ここで言う雨水利用システムとは、建物内あるいは敷地内に降った雨水を、集水貯留し簡単な処理を施して、水洗便器用水や空調用・生産用冷却水などの雑用水として利用しようとするものである。

我々は、雨水利用システムの実施にあたり、各種の検討を行ってきた。

ここでは、その一端を以下の内容にそって紹介する。

1) はじめに
2) 雨水利用システムの概要
3) 日本における雨水利用の現状
4) 雨水の水量面の検討
5) 雨水の水質面の検討
6) 雨水利用の実施例
7) おわりに

1. Introduction

Although rain water is degrading to some extent by atmospheric pollution, it is still a precious water resource purified through the natural water circulation cycle. Today when insufficient water supply is a source of anxiety in urban area in association with concentrating population, it is wasteful to leave such valuable water resource without use.

From viewpoints of effective water resource utilization, the rain water utilization system in buildings has come to public attention recently in our country. The purposes of "rain water utilization system" as used herein is to use the rain water falling on the building or premise of which immediate discharge was a major concern in the past as the closet water and air-conditioning and production cooling water, etc. by collection, storage and simple treatment.

This system has a number of advantages such as easy facility maintenance and control, low initial cost and running cost, high treated water quality and applicability to various purposes as compared to drainage recycling system in the building, although it has drawbacks such that it is hard to secure enough water volume. As such positive utilization of rain water falling on the urban area reduces not only tap water consumption but also rain water load imposed on sewer system (in the case of combined system of sewage).

However, the rain water utilization system in the building has been in practical operation for only a short period and various data are yet to be accumulated.

In introducing the rain water system, we have performed a variety of tests. Some of our study results are given below :

2. Outline of Rain Water Utilization System

The rain water utilization system is described referring to Figs. 2-1 and 2-2.

This system consists roughly of four processes of collection, storage, treatment and utilization, an outline of which is as follows:

① Collection: Limiting rain water collection area to building rooftops gives better rain water quality and facilitates treatment thereafter. When it is desired to store a large volume of rain water, the rain water falling on premise other than the building will be added.

② Storage: The rain water falling on the collection area runs through rain water riser and catchment pipe to the rain water storage tank. When full, the rain water is discharged to sewer system by flow channel switching.

③ Treatment: Depending on collected rain water quality and usage, simple treatments such as natural sedimentation, rapid filtering and chlorination before or after the rain water storage tank are made.

④ Utilization: The rain water is supplied as closet water, production and air-conditioning cooling water. In an emergency, it can be used as potable water by passing through a simple purifier. Examples of rain water usage are listed in Table 2-1 for information.

Areas that are considered suitable for rain water utilization are as follows:

① Areas with higher precipitation throughout year

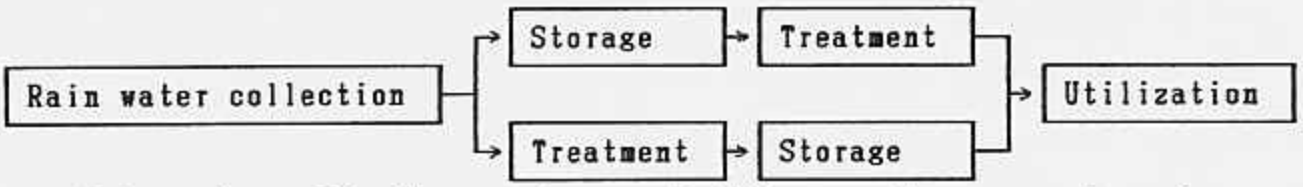
② Areas with scarce tap water supply

③ Areas with high tap water charge

④ Areas subject to rain water discharge restriction

Table 2-1 Usage of Rain Water

Living and business water :	Closet water
	Air - conditioning cooling water
	Cleaning, car washing and sprinkling water
	Bath water
	Potable water (in an emergency)
Industrial water :	Production cooling water
	Air - conditioning cooling water
Environmental water :	Road cleaning, snow melting water
Landscaping water :	Pond, brook
Fire fighting, others	



[Rain water collecting surfaces : Building rooftops, paved roads, greenbelts surrounding buildings, pools, athletic fields, etc.
Water treatment system : any selected from screen, sedimentation, coagulation sedimentation, filtering, chlorination, etc.]

Fig.2-1 Basic rain water utilization system

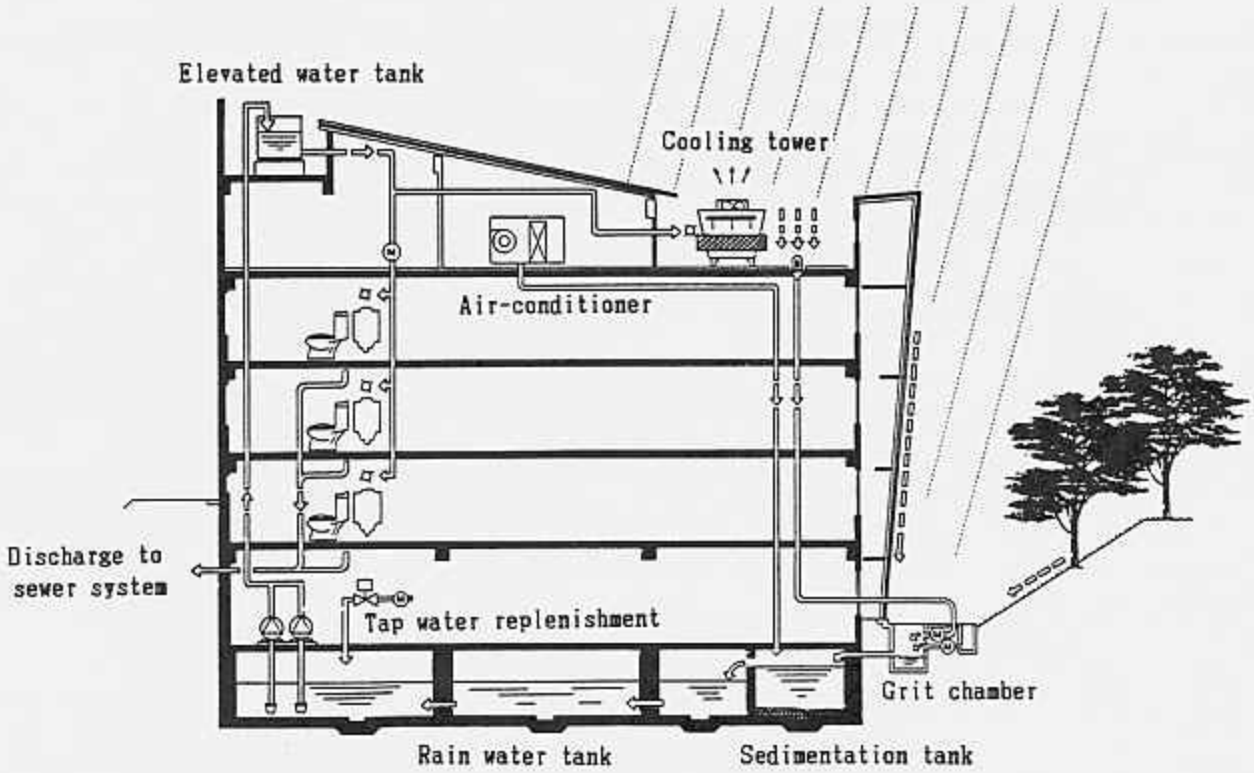


Fig.2-2 An example of rain water utilization system
(at main building of Ohbayashi-Gumi Technical Research Institute)

3. Current Situation of Rain Water Utilization in Japan

In our country, rain water utilization systems are increasing year by year as shown in Fig.3-1, particularly in large urban areas.

An outline of these systems is as follows:

① Rain water collection surface : Such as building rooftop surface
② Rain water collection area : 200 - 10,000 m²
③ Rain water storage capacity : 30 - 3,000 m³
④ Rain water treatment method : Such as natural sedimentation, rapid filtering
⑤ Rain water usage : Such as closet water, air-conditioning cooling water, sprinkling water, fire fighting water

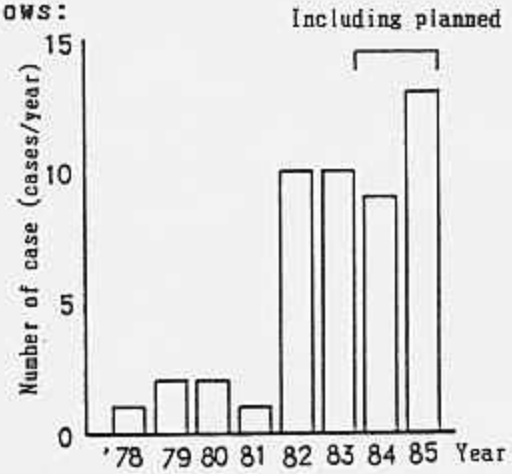


Fig.3-1 Cases of rain water utilization in Tokyo (according to our originai survey)

Table 3-1 lists a part of rain water utilization facilities built by us.

Table 3-1 A part of rain water utilization facilities built by us

Places of survey	Main building of Ohbayashi-Gumi Technical Research Institute	Taiyo Life Insurance East Ikebukuro building (Nippon Shinpan Ikebukuro building)	NTV north main building
Location Total building area Structure Date of rain water use started Collecting area Storage tank capacity	Kiyose City, Tokyo 3,800 (m²) 3 stories above ground and 1 story below ground June, 1982 1,200 (m²) 28 (m³)	Toshima-ku, Tokyo 13,800 (m²) 8 stories above ground and 2 stories below ground October, 1982 1,500 (m²) 92 (m³)	Chiyoda-ku, Tokyo 24,300 (m²) 8 stories above ground and 3 stories below ground June, 1983 2,500 (m²) 133 (m³)
Treatment method and design flow rate	Sand sedimentation and sedimentation	Rapid filtering 3.0 m³/hr	To parallel other facility.* 6.0 m³/day
Treated water quality pH Electric conductivity SS COD	 7 ~ 9 80 ~ 160 μS/cm 0.3 ~ 3.0 mg/l 1.5 ~ 3.5 mg/l Including equipment drain (20%)	 7 ~ 8 300 ~ 450 μS/cm 0.3 ~ 1.5 mg/l 2.5 ~ 5.0 mg/l Including cooling tower blow water (50%)	 7 ~ 8 100 ~ 150 μS/cm 0.3 ~ 3.0 mg/l 2.0 ~ 3.5 mg/l
Application of rain water	Closet water Air-conditioning cooling Fire fighting water Cleaning water	Closet water Air-conditioning cooling (in an emergency)	Closet water Air-conditioning cooling Pond replenishment water

* waste water reutilization facility

4. Examination of Rainwater Quantity

Possibility of more than a certain volume of precipitation is prerequisite to rain water utilization as described in Chapter 2. Precipitation distribution in our country is shown in Fig.4-1 for information. Japan enjoying relatively high benevolent influence of precipitation records an annual average precipitation of approximately 1,750mm. In view of 750 - 800mm precipitation estimate of the world and 1,000mm or less annual precipitation in most of the Temperature Zones, it can be said that this value is relatively high.

One of important points for planning the rain water utilization system is to examine how much rain water out of precipitation can put to practical use.

In the rain water utilization system, the entire precipitation cannot be used always. General flow of rain water utilization is shown in Fig.4-2.

The rain water falling on earth flows out, evaporates and permiates and volume flown out from surfaces can be used. The percentage of rain water flow out is given by flow-out factor, approximate values of which are shown in Table 4-1 and Fig. 4-3.

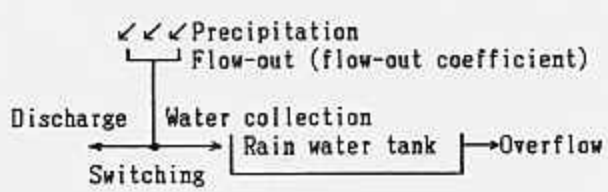


Fig.4-2 Rain water utilization flow

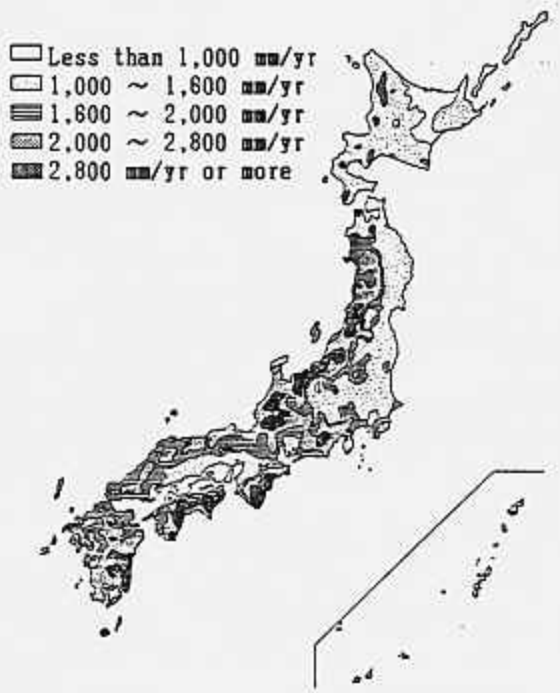


Fig.4-1 Domestic precipitation (per National Land Agency and Geographical Survey Institute)

A large rain water tank capacity may allow collected volume to be equal to flow out volume. But actually, in some cases insufficient rain water tank capacity might not allow rain water to be completely collected in case of heavy rain and a long period of rainfall.

To answer to these questions and predict how much rain water is usable in running rain water utilization systems in various buildings, a simulation program has been developed. This program allows calcula-tion of usable rain water volume, rain water - tap water replacement ratio and optimum rain water tank capacity using precipitation data and based

Table 4-1 Standard flow-out coefficient (per Japan sewer system design guideline)

Flow - out coefficient	
Roof 0.85～0.35	Road 0.80～0.90
Water level 1.00	
Intermediate land	0.10～0.30
Park rich in lawn and trees	0.05～0.25
Moderately sloped mountain	0.20～0.40

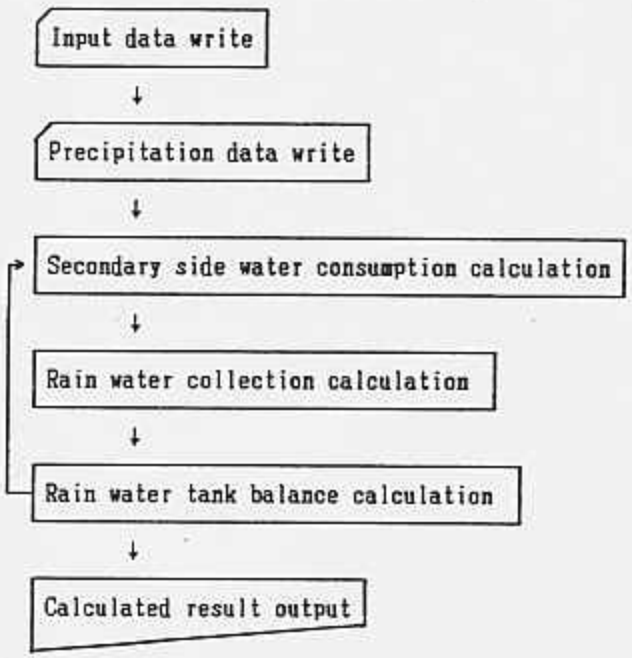


Fig.4-4 Program flow

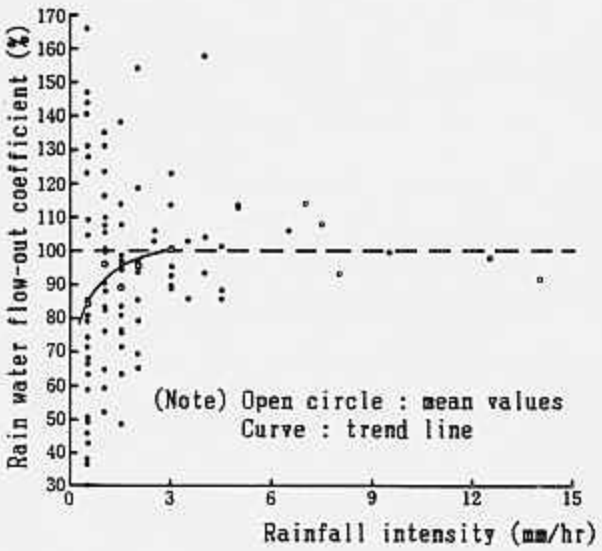


Fig.4-3 Relationship between rain water flow-out coefficient and rain intensity

on various conditions of respective buildings (planned area, building application, total building area, rain water collecting surface and their areas, rain water usage and its volume, etc.).

The precipitation data used for calculation include hourly precipitation data throughout Japan and worldwide daily precipitation data. Fig. 4-4 shows the program flow.

An example of simulation by this program is described below. Calculation conditions and the results of this simulation are shown in Table 4-2 and Figs. 4-5 and 4-6, respectively.

Replacement ratio used in the figures is defined as the rate at which tap water consumption is replaced by the rain water.

Table 4-2 Planned conditions

	Building A	Building B
Planned area	Tokyo	Tokyo
Building usage	Office	Factory
Total building area	10,000 m²	3,000 m²
Collecting area	1,000 m²	2,000 m²
Rain water tank capacity	50 m³	50 m³
Application	Closet water 25 m³/day	Closet water 5 m³/day

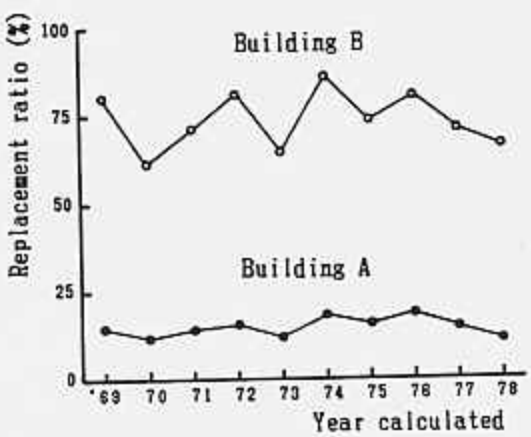


Fig.4-5 Rain water - tap water replacement ratio (by year)

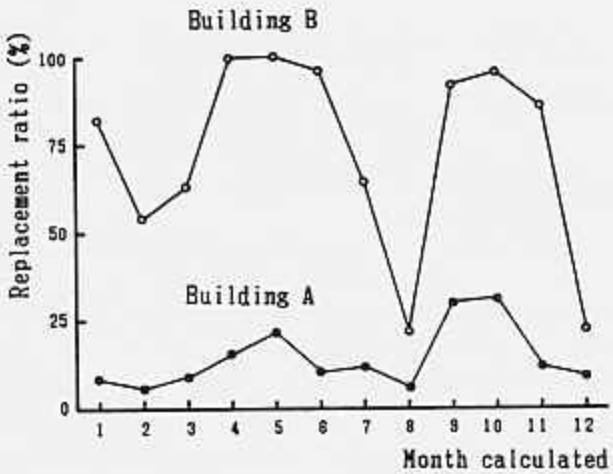


Fig.4-6 Rain water - tap water replacement ratio (by month), 1971

5. Examination of Rainwater Quality

It is essential for rain water utilization to evaluate water quality. Above all, water quality immediately after collection of rain water has large effects on treatment easiness thereafter and quality charge in association with storage.

Thereafter, quality investigation on rain water flowing from various surfaces (such as building rooftop, asphalt paved road, lawn) has been conducted in various aspects.

Factors having direct or indirect effects on rain water quality considered are listed in Table 5-1.

This paper describes the results of water quality investigation conducted on rooftops of main building of Ohbayashi - gumi in Tokyo from January, 1980 to October, 1982.

An outline of the building under investigation is listed in Table 5-2 and the results of water quality measurement are shown in Table 5-3 and Figs. 5-1 through 5-3.

The rainfall (just before it falls on the earth) has less pollutants and is water purified through natural water circulation cycle, although it is contaminated by air pollution.

The pH of rain water (collected after flow-out from building rooftop) ranged from 6 to 9 due to $Ca(OH)_2$ dissolved therein from cement material of rooftop concrete. In addition, in terms of electric conductivity, various ion components, COD, SS and bacteria contents the values were high at the start of precipitation followed by gradual decrease and approach to the rainfall quality.

As shown in Fig.5-4, electric conductivity at the start of precipitation and previous fine weather period (period from the end of previous rainfall to the start of rainfall in this time) indicated high correlation.

Although the quality of rain water collected from building roof-top was relatively good as cited earlier, major problems for use as miscellaneous water are as listed below:

① $_{P}H$: Although rainfall is originally acid, collected rain water varies with nature of collecting surfaces, that is, acid on steel sheet roof or alkali on mortar or light weight concrete finished roof.

② SS : Sand mixture

③ Bacterium : Rain water is contaminated by bacterium during rain drop formation and during rainfall and flow-out.

Table 5-1 Factors determining rain water quality

- Precipitation factors (rainfall quality, precipitation, rain intensity)
- Dry fallout —— gravitational fall of aerosol on earth
- Surface factors (Composition of surfaces of precipitation and rain water flow-out, weathering, etc.)
- Environmental factors (building location, building height, etc.)
- Natural factors (wind velocity, temperature, humidity, sun exposure, etc.)

Table 5-2 Outline of surveyed building

- Location : Kanda, Chiyoda-ku, Tokyo
- Building usage : Office
- Structure : SRC structure (9 stories above ground)
- Total floor area : 11,187.01m²
- Completion date : Sept., 1961
- Rooftop : water-proof layered with overlaying light weight concrete and clinker tiled

Table 5-3 Rain water quality as collected

(Note) * Japan

	pH	Evaporation residue mg/l	Cl^- mg/l	SO_4^{2-} mg/l	COD_{Mn} mg/l
Rainfall	4～7	10～40	0～7	4～15	1～10
Rain water (from start to 2.0 mm) Rain water (2.0 mm and over)	6～9 7～8	250～300 10～80	3～60 ——	4～140 ——	3～40 1～8
Industrial water supply standards* Water works standards*	6.5～8.0 5.8～8.6	250 or less 500 or less	80 or less 200 or less	—— ——	—— ——

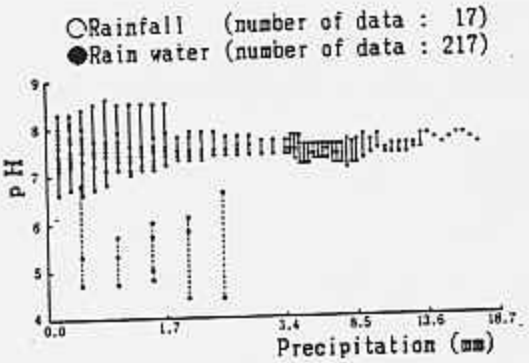


Fig.5-1 pH of rainfall and rainwater

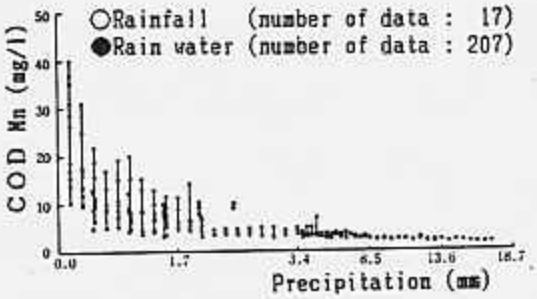


Fig.5-2 COD of rainfall and rainwater

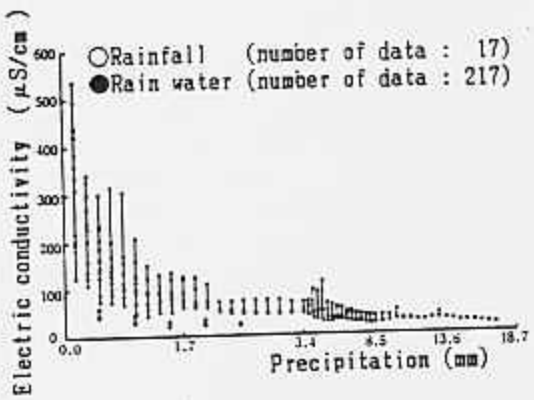


Fig.5-3 Electric conductivity of rainfall and rainwater

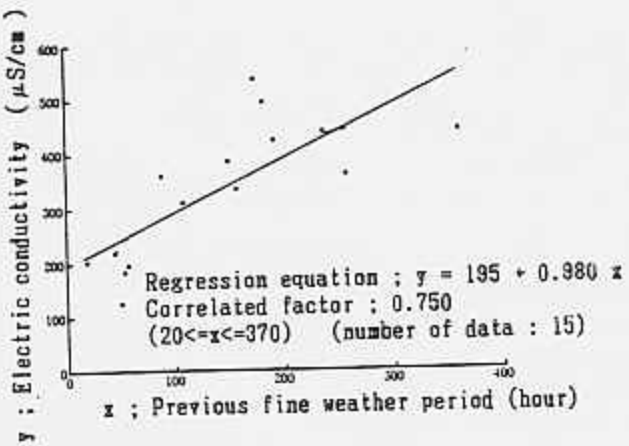


Fig.5-4 Relationship between rainwater electric conductivity in initial stage and previous fine weather period

6. Examples of Actual Uses of Rainwater

This Chapter introduces rain water use facility measurement data at the main building of Ohbayashi-Gumi Technical Reseach Institute. In this building, the rain water flowing from rooftop and paved road surfaces is collected and after sand sedimentation and sedimentation treatment, is used as closet water, air-conditioning cooling water, fire fighting water and cleaning water.

From the results of water volume investigation, rain water - tap water replacement ratio (including equipment drain reused) is shown in Fig.6-2. Annual replacement ratio for closet and for the entire building are 85.5% and 34.8%, respectively, indicating that the rain water has replaced much of closet water requirement.

Table 6-1 lists water quality measurement results of rain water used. The results showed a somewhat higher pH value at the start of rain water use due to $Ca(OH)_2$ dissolved therein from light weight concrete of rooftop surfacing and thereafter a nearly constant level raining from pH 8 to pH 9. The electric conductivity was approximately 100 - 200 μS/cm and concentration of dissolved components such as SO_4^{2-} ion, Cl^- ion, etc. was generally lower than that of land water (river, lake and swamp). SS is 1 - 2 mg/l and COD approximately 1 - 4 mg/l, both lower than those at the start of water collection, indicating ramarkable sand sedimentation and sedimentation effects.

The rain water is stored in storage tanks for a few days to a few weeks before its use. During this period, water quality will somewhat change. Fig.6-3 shows growth of bacterium in rain water in storage tank as an example of change caused with time in storage.

The results of questionaire revealed that most of the people are not uncomfortable with closet cleaning by rain water as listed in Table 6-2.

Table 6-1 Rain water quality during use

Survey date	pH	Electric conductivity μS/cm	Cl^- mg/l	Total hardness mg/l	COD_{Mn} mg/l	SS mg/l	coli bacillus CFU/ml	Proportion of tap water %
1982. 8. 9	8.9	101	1.8	20	1.6	0.6	0	0
11.25	8.8	159	6.5	45	2.0	1.1	0	0
1983. 2. 3	7.3	276	22.5	79	1.2	0.2	0	87
5.10	8.7	126	3.8	37	1.6	0.5	0	0
8.31	7.7	143	5.0	48	1.4	0.4	0	33
11.30	8.2	145	5.5	47	0.9	0.3	0	30
1984. 2.28	7.9	184	11.6	53	1.8	1.4	0	9
5.31	8.5	136	4.9	46	2.4	0.5	0	2

Table 6-2 Contents and results of questionire

Q. Let me ask you about toilet

① Do you feel uncomfortable about use of rain water for closet washing ?

1. Sometimes ---- 1 %
2. Ocasionally -- 2 %
3. No ---------- 97 %

② Current washing water consumption per time (approx. 8 ℓ) is :

1. Too much ----- 2 %
2. Adequate ----- 79 %
3. Little ------- 10 %

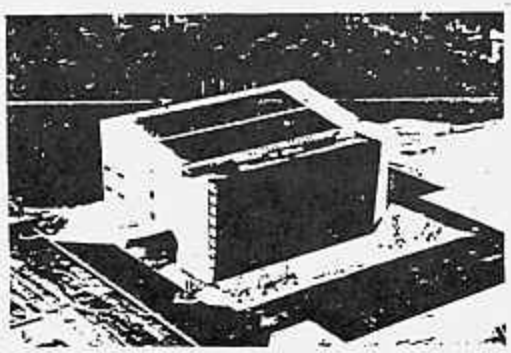


Fig.6-1 Main building of Ohbayashi-Gumi Technical Research Institute

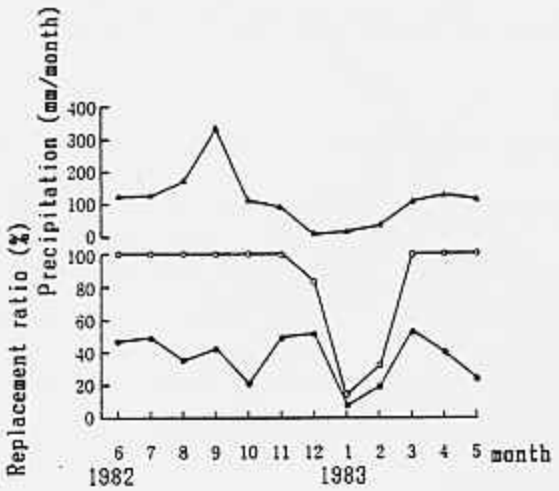


Fig.6-2 Rain water - tap water replacement ratio

△ : Precipitation
○ : Replacement ratio 1 (to closet water consumption)
● : Replacement ratio 2 (to total building water consumption)

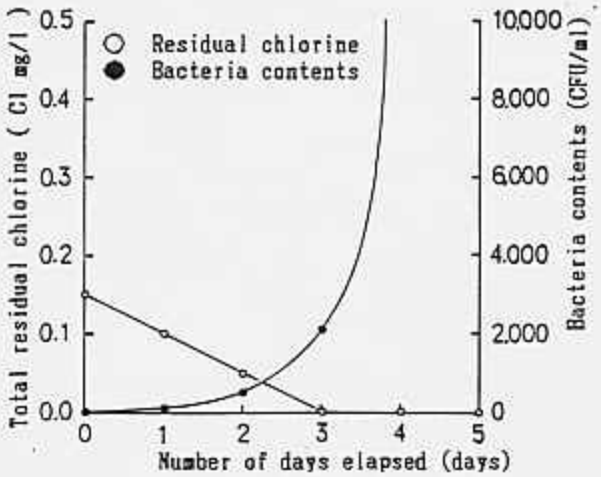


Fig.6-3 Bacteria growth in rain water

Mixing ratio : 53% rain water
47% tap water
Water temperature : 18～22℃
Water depth : 65～55cm

7. Conclusion

The rain water utilization studied by us has been described.

Water is one of limited resources like fossil fuels. As a method to use this valuable water rasource, researches on this system will be continued.

We are conducting the following studies.

① Prediction of usable rain water volume by simulation program
② Investigation of rain water flow coefficient
③ Quality investigation of rain water flowing from various surfaces
④ Examination of the effect of excluding rather highly contaminated rain water at the begining of precipitation
⑤ Examination of various water treatment methods to improve rain water quality
⑥ Investigation of rain water quality variation with time in case of prolonged storage
⑦ Investigation of rain water disinfection
⑧ Examination on use of rain water for drinking purpose in an emergency

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CIB-W62 SYMPOSIUM

Application Example of Waste Water Recycling Facility

Yukimasa Ogawa

April 9,~10, 1985

TOKYO, JAPAN



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APPLICATION EXAMPLE OF WASTE WATER RECYCLING FACILITY

12th CIB-W62 SYMPOSIUM -TOKYO-
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9 - 10, 1985 : KENCHIKU KAIKAN

Summary

The waste water recycling facility of the north wing of the head office building of Nippon Television Network Corporation was constructed to effectively use the water in the Broadcast Cultural Center of the corporation located in the center of the metropolitan Tokyo. The operation of this facility was started simultaneously upon completion of the construction of the north wing building in October 1982, and the recycling of water began in June 1983 when the quality of treated water after trial operation and adjustment was stabilized, which is continuing up to this date.

This facility consists of three sections . The first is the recycled water plant for treating waste water and recycling it as toilet flush water or cooling tower makeup water ; the second is the potable water model plant for further treating part of the recycled water by the advanced purification process, mainly by the land treatment, to obtain drinking water in case of emergency; and the third is the rainwater utilizing plant for pooling and using the rainwater collected on the rooftop of the building.

Already a year and a half have been passed since the recycling of water of this system began, and the initial objectives of the plan have been almost entirely achieved. This paper shows the outline of this facility and reports the operating records.

Résumé

L'installation de recyclage des eaux usées du Pavillon Nord de la Nippon Television a été construite pour permettre une utilisation rationnelle de l'eau au niveau du Centre Culturel de la Nippon Television Network Corporation situé au coeur de la ville de Tokyo. Mise en service en octobre 1982 à l'achevèment des travaux du Pavillon Nord, elle recycle effectivement l'eau depuis le mois de juin 1983. c'est à dire depuis que la qualité de l'eau s'est stabilisée en fin de période d'essais de marche et de réglages.

L'installation se compose de 3 ensembles. Le premier est une unité de traitement qui traite les eaux usées, l'eau qu'elle recycle étant utilisée pour les chasses d'eau de toilettes pour le refroidissement de la tour de climatisation. Le deuxième est une installation expérimentale qui, par un procédé de purification très élaboré à base de filtration sur terre, purifie de façon plus poussée une partie de l'eau recyclé pour la rendre potable et fournir ainsi une alimentation de secours en eau potable. Le troisième ensemble est un système de recyclage de l'eau de pluie qui récupère l'eau de pluie sur le toit et la met en réserve pour réutilisation.

L'installation est opérationnelle et recycle effectivement les eaux depuis un an environ et les objectifs visés par le projet sont pratiquement atteints. On trouvera dans le présent rapport un présentation générale de l'installation ainsi que les résultats d'exploitation.

Zusammenfassung

Die abwasser-Aufbereitungsanlage im Nordflügel des Hauptsitzes der Nippon Television Network Corporation wurde Konstruiert, um den Wasserverbrauch in dem in der Stadtmitte Tokios gelegenen Kulturzentrum der Firma zu optimieren. Dises Anlage wurde gleichzeitig mit der Fertigstellung des Nordflügels dieses Gebäudes im Oktober 1982 in Betrieb genomen; mit der bis heute fortgesetzten Wiederaufbereitung des Abwassers wurde im Juni 1983 begonnen, nachdem im Probebetrieb die Qualität des aufbereiteten Wassers stabilisiert werden konnte.

Diese Anlage besteht aus drei Abschnitten. Der erste Abschnitt stellt die Abwasser-Aufbereitungsanlage dar, in dem das Abwasser fur die Verwendung in Toiletten und Kühltürmen aufbereitet wird. Im zweiten Abschnitt wird mit Hilfe fortschrittlicher Klärprozesse und Erdfilter Trinkwasser für den Notfall erzeugt. Der dritte Abschnitt umfaßt eine Regenwasser-Nutzungssystem, das das am Gebäudedach gesammelte Regenwasser weiterverwendet.

Eineinhalb Jahre nach Inbetriebnahme dieser Abwasser-Aufbereitungsanlage kann gesagt werden, daß die anfänglichen Erwartungen in dieses System fast vollständig erfüllt werden konnten. Diese Schrift beschreibt die Konstruktion dieser Anlage und berichtet über die Betriebsergebnisse.

1. Introduction

Japan is one of the highest precipitation nations in the world, but per capita the rainfall is about 1/5 of the world's average. Accordingly, water resources are insufficient in the metropolitan area or industrial district where a colossal amount of water is consumed every day. At the same time , it is becoming difficult to obtain clean water because the rivers and lakes are yearly contaminated by the domestic waste water or industrial waste water. In this situation, in Japan, the finiteness of water must be recognized, and it is necessary to use the limited resources effectively. Furthermore , in the urban districts where buildings are standing higher and higher, the number of waste water recycling installations sharply increased from the mid-1970s because of the shortage of the capacity of the sewage facilities for receiving waste water and the increase of cost of city water and sewage treatment service. In 1984, the number of waste water recycling facilities exceeds 100, and the total number including the installation under construction or being planned is said to be about 200. Most of these installations are located in Tokyo and Fukuoka. In these two cities, it is instructed, by the municipal regulations and other rules, to recycle the waste water in large buildings consuming great quantities of water.

This report relates to an example of a building situated in the center of the metropolitan Tokyo , in which there is a model plant for obtaining drinking water for emergency use from the waste water, as well as the waste water is treated and recycled in miscellaneous use, and also it is attempted to use rain water. The record of operation is reported in this paper.

2. Outline of the facility

The Nippon Television Broadcasting Cultural Center is the core facility of Nippon Television Network Corporation accommodating the studios, broadcasting equipment and management and clerical departments. This Center is located in

Chiyoda Ward of Tokyo, and it consists of three main buildings (West, South, and North Wings).

In the North Wing, the latest building completed in October 1982, the "waste water recycling facility" for treating and recycling waste water was installed. The appearance of this Center is shown in Photo 1, and the outline of the three buildings is given in Table 1.



Photo 1. Appearance of this Center

Table 1. Outline of the three buildings

	North Bldg.	South Bldg.	West Bldg.
Number of floors	7F , B3F	10F , B3F	8F , B2F
Gross floor area	24,297 ㎡	17,128 ㎡	10,868 ㎡
Application	Studio Office	Office Restaurant	Office Dining room for staff Restaurant

The waste water recycling facility consists of three plants. The first plant is the water recycle plant for treating waste water and supplying it as toilet flush water , cooling tower make-up water, etc. The second plant is the drinking water model plant for further purifying part of the recycled water by an advanced process mainly employing the land treatment in order to obtain drinking water for emergency use. And the third plant is the rainwater utilizing system for collecting rain water on the rooftop and using it effectively. This facility is intended to use the precious water resources effectively and to keep a minimum requirement of water in case of emergency such as earthquake considering the public aspect of the building as the press organ. At the same time, from the viewpoint of returning the water to the nature in a clean state, as well as widely spreading the effective use of water, this facility serves an experimental role of collecting necessary data for advanced treatment of waste water.

This facility treats the waste water occurring in the three main buildings, and recycles it to be consumed in the three buildings again. The land treatment equipment having the central function of the drinking water model plant makes use of the lawn portion of the existing garden within the Center. Rain water is collected on the rooftop of the North Wing only. The water feed and discharge flow of the three main buildings comprising the waste water recycling facility is shown in Fig.1.

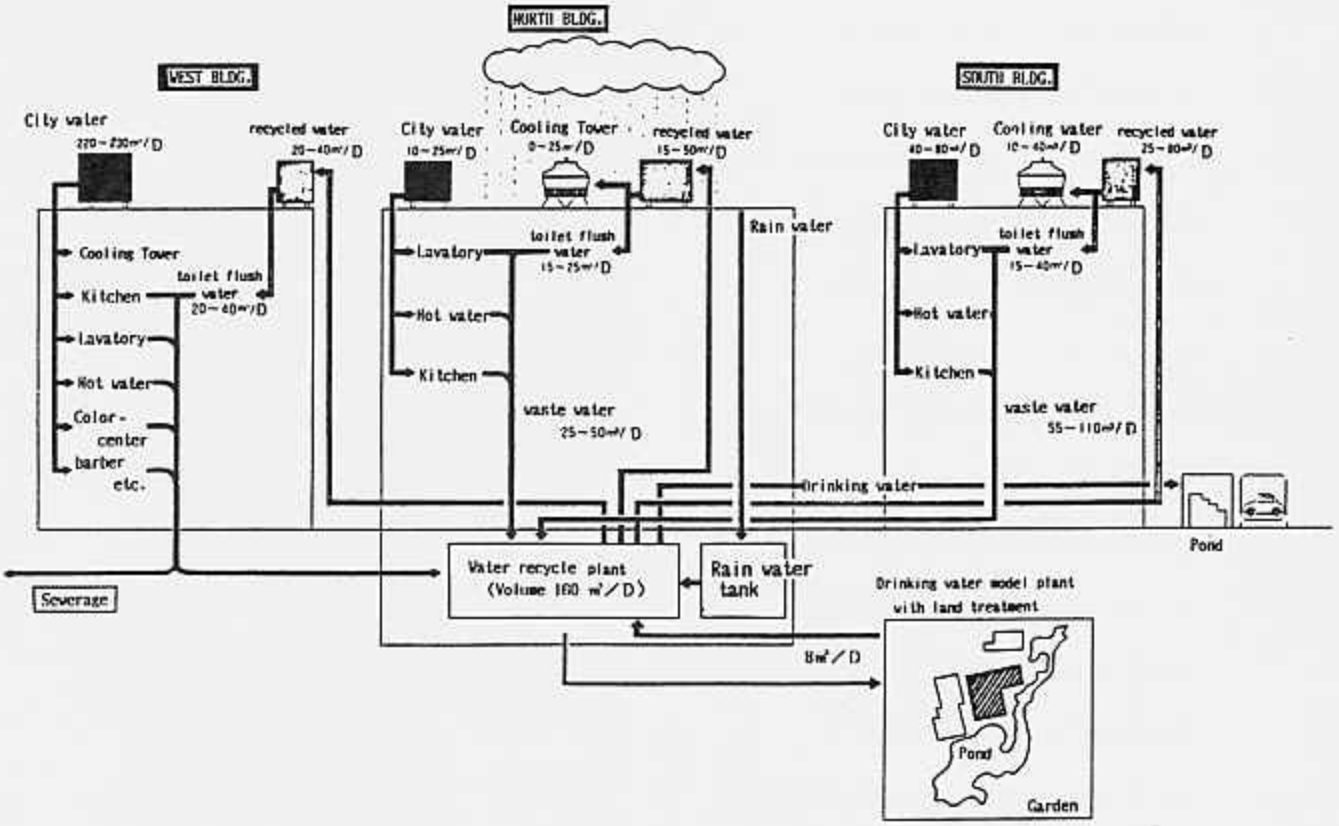


Fig.1 Water feed and discharge flow of the buildings

3. Treatment process and design specifications

3.1 Water recycle plant

In this plant, by effectively using the purifying power of the nature, the waste water is treated only biologically in the light of saving resources and energy. The design specifications of this facility are as follows.

Planned treating capacity : 160 m³/day

Consumption of recycled (treated) water : 80 to 160 m³/day

Quality of raw water and treated water (planned) :

	BOD[mg/l]	COD_{Mn}[mg/l]	SS[mg/l]	pH [-]
Raw water	300	120	250	—
Treated water	3	10	10	6.0 ~ 8.0

In this plant , the biological film processing is selected for both secondary and tertiary treatment, which consumes less energy among other processes, and is resistant to load fluctuations and stable in performance, and is easy to maintain and control. That is, in the secondary treatment, the bio rotating disk process is adopted because it is particularly excellent in the ease of maintenance and control of operation , while the bio contact process is employed in the first stage of the tertiary treament which is high in treating efficiency of low concentration waste water and is stable in performance and the bio filtering process is employed in the second stage for the purpose of finishing the biological treatment and seeking the limit of biological treatment. The treating process of this plant is shown in Fig. 2, and the specification of principal equipment is given in Table 2.

Table 2. Specification of water recycle plant

Name	Item	Specification
Flow equalization tank	Effective volume	112m³
	Detention time	16.8h
Bio-rotating disk	Shafts. tanks	2 shafts · 4 Tanks
	Water volume	44.0m³
	Detention time	6.6h
	Diameter of disk	2.4m
	BOD load	8.0 g/m²·Day
Secondary settling tank	Effective volume	26.0m³
	Detention time	3.9h
Bio contact tank (5 tanks)	Effective volume	67.3m³ (5 tanks total)
	Detention time	10.1h (〃)
	BOD load	0.05 kg/m³·Day
	Contact media	Honey comb tube (2 tanks)
		Spherical media made of styrene (3 tanks)
Final settling tank	Effective volume	21.1m³
	Detention time	3.2h
Bio filtering tank (3 tanks)	Effective volume	30.1m³
	Detention time	4.5h
	Contact media	Light weight aggregate (Mesalight®)
Disinfection	Chemicals	Solid Chlorine
	Residue chlorine	Over 0.3 mg/ℓ
Monitor	Automatic monitor	Ultra-violet adsorption meter

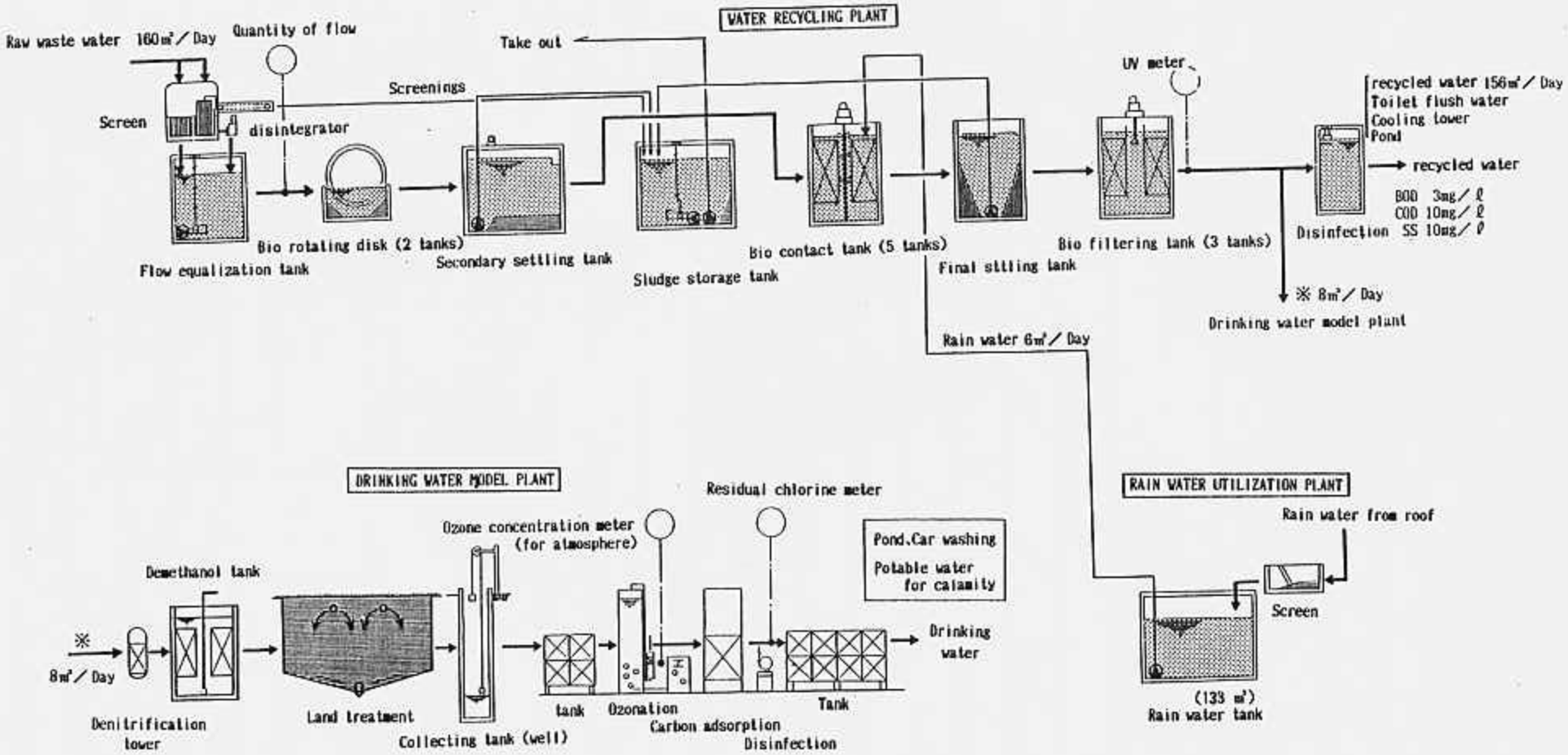


Fig. 2 Treating process flow of waste water recycling facility

3.2 Drinking water model plant

This plant is intended to obtain a short-term drinking water for emergency use by further purifying part of the recycled water (after tertiary treatment). The design specifications of this plant are as follows.

Treating capacity : 8 m³/day in emergency ; 5 to 6 m³/day usually

Influent : tertiary treated water before disinfection of the water recycle plant

Treated water quality : to satisfy the city water quality standard of the City Water Law.

In this plant, in order to make the best use of the purifying power of the nature and save the resources and energy, the land treating equipment is installed as the central unit. And it is assisted by the biological denitrification equipment, ozonation , activated carbon adsorption , and chlorine disinfection. The processing flow of this plant is as shown in Fig. 2. The nitrification equipment was not installed at the time of construction of this facility, but after the limlit of denitrification effect by the land treatment had been understood, this equipment was additionally built in December 1983. The principal components of this plant are shown in Table 3.

. The treated water of this plant (potable water) is usually used in refilling the pond and washing cars. In the event of earthquake or other dis-

Table 3.Specification of drinking water model plant

Name	Item	Specification
Denitrification tower	Effluent	T-N under 10 mg / ℓ
	Dimension	0.9 mD × 3.0 mH
	Filling media	Light weight aggregate (Mesalight®)
Demetanol tank (Bio contact tank)	Effective volume	3.6m³
	Contact media	Spherical media made of styrene
Land treatment	Area	85.3 m²
	Water spray load	Emergency 94 ℓ / m² · Day
		Normal 59 ℓ / m² · Day
	Water supply	To be pumped intermittently
	Thickness of soil	2.0m
	Type of infiltration	To infiltrate water from buried pipe
Ozonation	Dimension	0.4 mD × 4.8 mH
	Type	Counter flow contact type
	Ozone injection	5 mg / ℓ
Carbon adsorption	Dimension	0.6 mD × 2.3 mH
	Type	Down flow type
Disinfection	Chemicals	Liquid chlorine
	Residue chlorine	Over 0.2 mg / ℓ

aster,it is used as drinking water temporarily from the emergency taps.

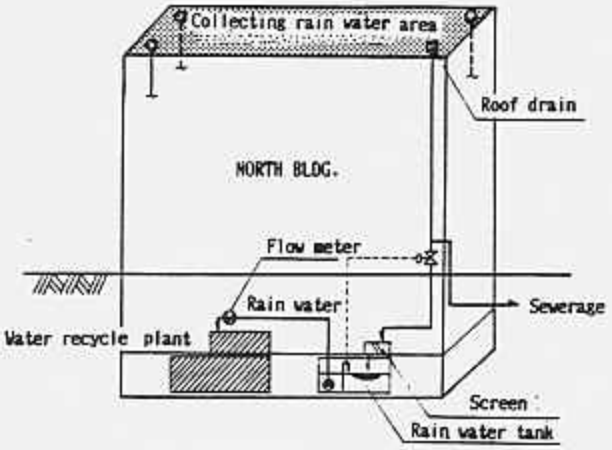


Fig.3 Rainwater utilization system

3.3 Use of rainwater

Rainwater is clean water distilled in the water circulation cycle of the nature. Accordingly, rainwater falling on the rooftop of the North Wing , an area of about 2,500 ㎡,is collected and stored in the cistern provided among the underground beams of the building to be used as the water source for water recycle plant. The rain water is sent into the water recycle plant at a constant flow (about 6 ㎥/day) and serves as a precious water resource in case of emergency ,and ,only very slightly , contributes to improvement of the quality of treated water. In the event of a heavy waterfall, when the cistern is filled, the rainwater can be directly discharged into the sewer through the changeover valve provided in the rainwater riser pipes. The system of rain water use is shown in Fig. 3, and the treatment and destination of rain water are given in Fig. 2.

4. Records of operation

4.1 Water recycle plant

(1) Volume and quality of raw water

Table 4 shows the volume of raw water and the consumption of recycled water in the water recycle plant in summer (the average in August, 1984). In this table, the rate of toilet water in the total waste water is higher than planned. Accordingly, the pH value of secondary effluent was lowered more than expected due to nitrification in the secondary treatment, which gave rise to the

necessity of feeding caustic soda in the secondary treated water. Figure 4 shows the monthly average of the treated water volume and the recycled water consumption. The increase of water consumption and treated water volume in August 1984 is due to the start of the use of recycled water in the cooling tower makeup water for air conditioning of the North Wing.

Table 4. Volume of water resource

[m³/ Day]

		Raw water	Recycled water	City water
South Bldg.	Kitchen	21	—	23
	Lavatory	2	—	
	Toilet flush water	39	39	—
North Bldg.	Kitchen	3	—	45
	Lavatory	42	—	
	Toilet flush water	21	21	—
	Cooling tower	—	32	—
	Drinking water	—	6	—
West Bldg.	Kitchen	23	—	192
	Lavatory	2	—	
	Toilet flush water	24	37	—
Else	Pond	—	25	—
Total		177	160	260

The quality of raw water is analyzed in Table 5. As compared with the planned values, each item of raw water quality was lower in concentration, and BOD and SS, in particular, were about half of the planned values. However, since the sampling point of raw water was near the outlet of the flow equalization tank, the actual values seem to be slightly higher than recorded in Table 5.

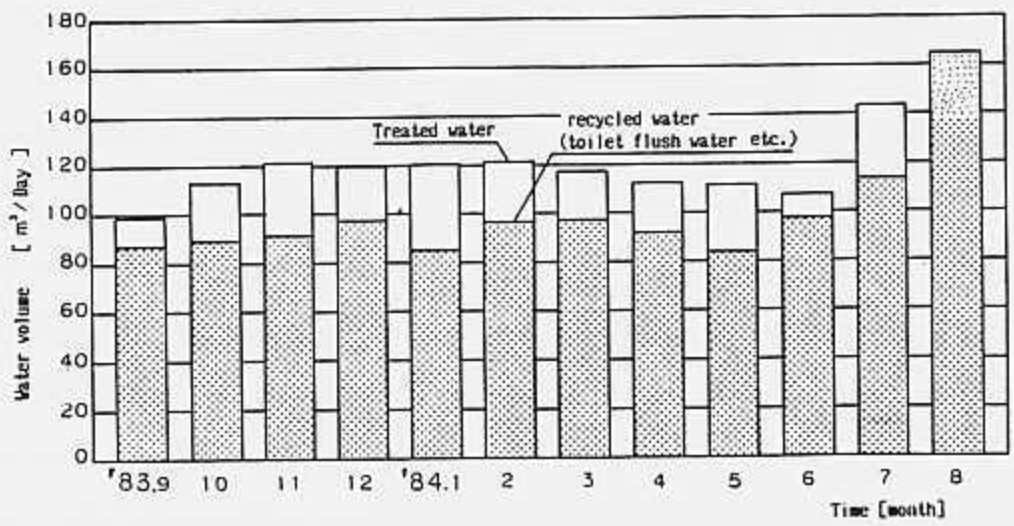


Fig.4 Volume of treated water and recycled water consumption

Table 5. Quality of raw water

		'83.9.7	10.5	11.2	12.1	'84.1.5	2.1	3.7	4.4	5.1	6.1	7.2	8.2	av.
pH	-	6.7	7.1	7.0	7.1	7.2	7.3	7.4	7.6	7.1	7.3	6.9	7.3	7.2
SS	mg/l	75.0	33.0	175	102	44	83.3	153	127	100	95	117	137	103
COD Mn.	"	88.8	57.7	124	107	88	88.5	120	121	140	95.2	109	109	104
BOD	"	60.8	89.4	156	105	104	83.8	167	182	211	108	162	156	133
Grease	"	10.0	2.0	16.0	8.5	12.0	14.0	16.0	24.0	20.0	6.5	7.0	18.0	13
MBAS	"	1.1	1.0	0.5	5.1	5.1	2.4	4.7	1.6	1.47	0.74	1.09	0.46	2.1
Water temp.	°C	29.5	26.5	22.0	22.0	19.0	20.0	20.0	21.0	22.0	25.0	25.5	28.5	23

(2) Quality of recycled water and records of use

The analytical results of the quality of the recycled water in the past year are summarized in Table 6. The quality of the recycled water nearly satisfied the design values, except for the COD concentration in winter. Whether the recycled water was treated to the limit of biological treatment or not was judged by the quality items based on organic matter, that is, BOD, COD and color. According to Table 6, BOD is very close to zero, and, in this respect, the treated water may be said to be nearly at the limit of treatment. However, there is a room for improvement with respect to COD and color.

Recycled water is used as toilet flush water, Japanese style garden pond refill water, and cooling tower makeup water for the North Wing. The quality of recycled water is sufficient within the provisional standard of toilet flush water as specified in the Health and Welfare Ministry Ordinance (April 1981) and the Construction Ministry Notification (April 1981), and no problem has been experienced so far with respect to the use of toilet flush water and the pond refill water. The use of recycled water as makeup water for the cooling tower was started in August 1984 only in the North Wing. Since the term of the use is short, this is not the time to evaluate for a long-term use. Meanwhile, dispersing agent and algicide are mixed in the cooling water of the North Wing, and the cooling water is automatically drained and filled on the basis of its

Table 6. Qquality of recycled water

	Time		Sep.7,'83	Dec. 1	Jan.5,'84	Feb. 1	Mar. 7	Apr. 4	May. 1	Jun. 1	Jul. 12	AUG. 1	Sep. 1	Oct. 3	Nov. 1
	Water Temperature	℃	29.0	19.0	17.0	19.0	18.5	——	——	24.0	——	30.0	——	——	——
1	pH	——	6.3	6.7	7.0	7.0	6.1	6.5	7.0	6.7	7.0	6.6	6.7	7.75	6.9
2	Conductivity (25℃)	μs / cm	628	678	660	655	650	885	690	705	516	610	655	715	798
3	COD (Mn)	mg / ℓ	9.5	9.3	9.7	10.3	12.0	9.7	9.3	8.4	7.2	8.5	7.9	7.7	9.7
4	BOD	〃	0.4	0.3	1.7	2.4	1.6	0.9	0.9	under 0.3	0.4	0.7	0.5	0.8	0.7
5	T-N	〃	31.9	31.9	25.7	29.4	29.3	29.9	26.4	29.4	15.2	25.0	23.0	33.2	30.4
6	NH_4-N	〃	0.38	0.18	0.21	0.42	0.64	0.23	0.42	0.41	0.37	0.62	0.51	0.40	0.53
7	NO_2-N	〃	0.04	ND	0.02	ND	0.03	ND	ND	ND	ND	ND	ND	ND	ND
8	NO_3-N	〃	29.5	22.4	22.0	27.8	27.0	27.9	24.8	20.3	14.0	23.3	20.6	24.7	26.1
9	A-N	〃	0.45	0.41	0.54	0.5	0.64	0.58	0.63	0.42	0.28	0.5	0.56	0.39	0.64
10	Coliform	C./mℓ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11	Bacteria content	〃	ND	150	ND	ND	130	ND	ND	ND	ND	ND	ND	ND	115
12	Dry residue	mg / ℓ	428	508	478	496	516	592	496	472	298	450	478	634	492
13	Chloride ion	〃	97.8	106	108	114	130	160	106	134	84.5	90.8	113	104	107
14	Sulfate ion	〃	39.1	58.9	26.2	42.9	39.5	44.6	27.3	36.2	31.9	29.7	40.8	56.6	57.3
15	Total hardness	〃	85.0	98.3	107	100	118	125	80.0	67.5	72.0	75.0	85.0	111	103
16	M-Alkalinity	〃	25.0	18.2	34.5	25.5	9.0	7.0	38	12.0	14.8	11.5	14.0	20.0	27.0
17	Sulfur ion	〃	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
18	Silica	〃	17.9	15.3	13.5	19.7	16.8	15.6	17.2	14.9	14.7	16.1	16.9	22.5	21.0
19	Fe	〃	ND	0.05	ND	ND	0.13	0.05	ND	ND	ND	ND	ND	0.25	0.17
20	Mn	〃	ND	ND	ND	ND	ND	0.03	ND	ND	ND	ND	ND	ND	0.009
21	Color	°	25	8	30	26	27	1	20	2	2	1	2	1	5
22	Turbidity	〃	under 1	0	0	under 1	0	0	0	0	0	0	0	0	0
23	Odor	——	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
24	MBAS	mg / ℓ	0.07	0.12	0.14	0.11	0.16	0.08	0.12	0.13	0.07	0.12	0.10	0.18	0.11
			After disinfection												

electric conductivity.

In this facility, the UV meter (ultraviolet absorption photometer) is used to monitor the quality of tertiary treated water. While the tertiary treated water is stable at COD 8 tO 10 mg／ℓ, the correlation between the UV value and COD is insignificant, but when the water quality is worsened, the COD and turbidity rise, and the UV value also increaes, thereby telling the abnormality of the tertiary treated water. Therefore, the UV meter can be used as the monitor of the water quality when the quality is worsened. It is because it is less expensive than the automatic COD meter for measurement of COD, easy in maintenance and usable in continuous measurement to use the UV meter as the water quality monitor in this facility.

4.2 Drinking water model plant

(1) Treated water volume and potable water volume

The drinking water model plant started its operation in June 1983 and collection of the water volume and quality data began in September of the same year after the trial run and adjustment. Figure 5 shows the monthly average of the daily treated water volume (the feed to the soil), potable water of this plant. It is clear from this diagram that the plant is operated at about 5 m³／day, approximate to the design value in usual state, excluding a specific month. The drop of the treated water volume in December 1983 is due to the shutdown of operation for about two weeks because of the additional work for denitrification equipment. The potable water had been used in cleaning of this water treating facility until the

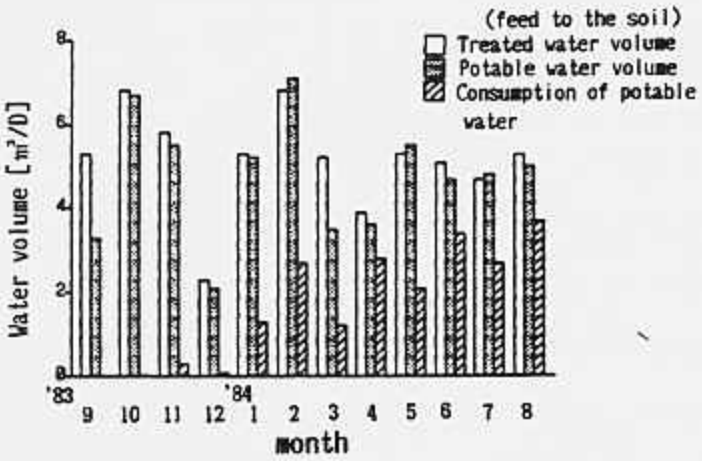


Fig.5 Monthly average of daily treated volume

denitrification equipment was installed and the consumption had been small. After the installation, the consumption increased as the water began to be used as refill water for the garden pond and others.

(2) Quality of potable water

The quality of potable water has been analyzed every month since January 1984 after the installation of the denitrification equipment. The analytical results of water quality at the service end taps of potable water are shown in Table 7, together with the city water quality standard values of the City Water Law. Ever since the first analysis in January 1984, the quality of the obtained potable water is always satisfying the Japanese city water quality standard. Comparing the analytical values with the standard values, it is noted that the dry residue concentration is close to the standard value, which arouses an attention. The majority of the dry residue is considered to be inorganic matter such as $C\ell^-$,M-alkalinity, hardness, and inorganic carbon. Since a process to remove these inorganic substances is not incorporated in this plant, it is impossible to control the dry residue concentration. However, as far as the properties of the waste water remain unchanged henceforth, it seems hardly possible that the concentration exceeds the standard of 500 mg／ℓ. Meanwhile, since cyan and other heavy metals are not discharged in this broadcasting station building, their concentrations in the waste are negligible, and will not exceed the standard value unless these substances are added intentionally.

In order to compare the quality of the potable water and that of the city water supplied to this building, the analytical results of the city water in the South and West Wings are shown in Table 7. The manufactured potable water was found to be higher in NO_3^-, NO_2^-, $C\ell^-$, total hardness and dry residue concentrations, and lower in $KMnO_4$ consumption. The high level of $NO_3^- \cdot NO_2^-$-N in the potable water seems to be because the nitrogen concentration in the waste water is higher than that in the city water source and is not completely

Table 7. Quality of drinking water from model plant

		Water quality standard of city water (Japan)	Drinking water from model plant								City water average (data no.)	
			Jan. 26, '84	Mar. 7	May. 1	Jul. 2	Aug. 1	Sep. 1	Oct. 3	Nov. 1	South Bldg.(8)	West Bldg.(14)
$NO_3^- \cdot NO_2^- - N$	mg/ℓ	under 10	5.9	2.8	4.7	3.0	2.0	2.07	1.85	1.8	1.5	1.5
Chloride ion	〃	under 200	93.1	114	98.9	106	101	75.4	101	109	21.6	23.5
$KMnO_4$ consumption	〃	under 10	under 1.0	0.7	0.3	0.5	0.6	0.7	0.9	0.5	1.9	1.8
Bacteria content	c./mℓ	under 100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Colifrom	〃	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cyanide ion	mg/ℓ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury	〃	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Organic phosphate	〃	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cu	〃	under 1.0	under 0.006	under 0.005	ND	ND	ND	ND	0.007	0.004	ND	ND
Fe	〃	under 0.3	0.18	0.010	ND	0.04	0.18	ND	0.04	0.088	0.03	0.010
Mg	〃	under 0.3	under 0.005	0.003	ND	ND	0.005	ND	ND	ND	ND	0.003
Zn	〃	under 1.0	0.027	0.040	0.070	0.16	0.02	0.03	0.01	0.021	0.010	0.075
Cr^{6}	〃	under 0.05	under 0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	〃	under 0.01	under 0.004	ND	ND	ND	ND	ND	ND	ND	ND	ND
As	〃	under 0.05	under 0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND
F	〃	under 0.8	under 0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total hardness	〃	under 300	144	145	135	161	162	141	176	161	68.7	72.9
Dry residue	〃	under 500	408	436	410	466	458	438	438	448	123	148
Fennol	〃	under 0.005	under 0.005	ND	ND	ND	ND	ND	ND	ND	ND	ND
MBAS	〃	under 0.5	under 0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pb	〃	under 0.1	under 0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND
pH	—	5.8 ~ 8.6	7.3	7.4	7.4	7.6	7.6	8.0	8.0	7.8	7.0	7.0
Odor	—	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Taste	—	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Color	度	under 5	1	1	1	3	1	1	0	0	2	1
Turbidity	〃	under 2	under 1	0	0	under 1	1	0	0	0	under 1	0

removed in the denitrification equipment, and also due to the effect of the lawn fertilizer applied on the surface of the soil used in the treatment. The favorable $KMnO_4$ consumption as compared with that of city water is because the activated carbon adsorption is incorporated in this plant as the finishing process. All other items of water quality were similar between the manufacctured potable water and city water.

(3) Trace organic matter

As for tri-halo-methane which is contained in the city water and is recently discussed in relation to its carcinogenicity , the content in the potable water was analyzed, of which result is shown in Table 8. As compared with the measurement in Naito-cho of shinjuku-ku , the vicinity of this building, of the Tokyo metropolitan city water, the value of the water sampled on April 18 , 1984 was slightly higher , but the measurement on July 19 was 1/10, and when compared with the city water provisional satandard value of 0.1 mg ／ℓ , the both analytical values are respectively about 1/2 and 1/30. This seems to be the result of removal of precursors by ozonation and activated carbon adsorption conducted in this plant, which are also attempted in the municipal water purification stations as the measures for decreasing tri-halo-methane.

Table 8. Concentration of trace organic matters 1)

	Before disinfection '84.7.19 [mg/ℓ]	After disinfection '84.7.19 [mg/ℓ]	After disinfection '84.4.18 [mg/ℓ]	City water (Tokyo) [mg/ℓ]
Chloroform	under 0.0001	under 0.0001	0.0021	0.018
Bromo-di-chloro-methane	under 0.0001	0.0024	0.045	0.012
Di-bromo-chloro-methane	under 0.0001	0.0010	0.0016	0.004
Bromoform	under 0.0001	under 0.0001	under 0.0001	0.000
Tri-haro-methane-total	under 0.0005	0.0034	0.049	0.034
1.1.1 Tri-chloro-ethylene	under 0.0001	under 0.0001	——	——
Tri-chloro-ethylene	under 0.0001	under 0.0001	——	——
Tetra-chloro-ethylene	under 0.0001	under 0.0001	——	——

At the same time, contents of 1.1.1-tri-chloro-ethane, tri-chloro-ethylene and tetra-chloro-ethylene in the potable water were analyzaed as shown in Table 8. Their city water provisional standard values are respectively less than

0.3 mg/ℓ、less than 0.03 mg/ℓ and less than 0.01 mg/ℓ, and the analytical values are all found to be within these limits.

4.3 Use of rainwater

The rainwater utilization facility began to collect rainwater in June 1983 when the concrete of the cistern was sufficiently washed out, and water feed to the inlet side of the tertiary treatment water tank was started. The rainwater feed rate was, as shown in Fig. 6, 3.5 to 4.0 m³/day till November 1983, and then increased to 6 m³/day thereafter as planned initially. The annual consumption of rainwater from September 1983 till August 1984 was 1,774m³, which corresponds to a daily average of 4.8 m³. The annual precipitation in this period was 1,060 mm, which was 73% of the average rainfall of 1,460 mm, and the condition was unfavorable for the rain water utilization facility.

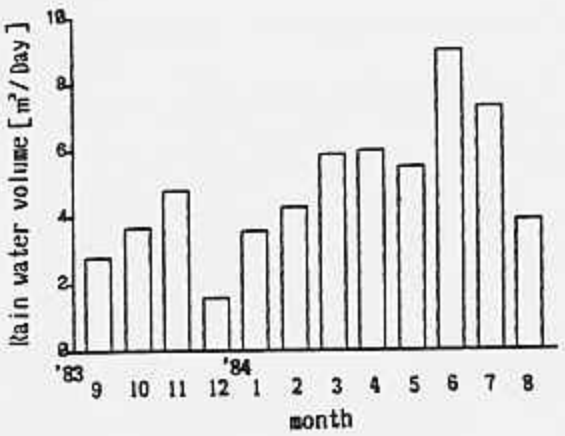


Fig.6 Daily used volume of rainwater

In this rainwater facility, the quality of rainwater is measured periodically (pH, COD, dry residue, SS, and electric conductivity). The results are shown in Table 9, in which it is found that the rain water is lower in the organic matter and inorganic ion concentrations as compared with the recycled water and is sufficiently applicable as the toilet flush water or cooling tower makeup water.

Table 9. Quality of rainwater

		NO. of data	Average
pH	—	33	7.5
COD_{Mn}	mg/ℓ	17	2.5
Dry residue	〃	20	71.6
SS	〃	20	1.3
Electric conductivity	μs/cm	21	121.6

(in the rain water tank)

5. Water manufacturing cost

Table 10. Items of running cost

		Daily consumption	cost [¥/Day]
Water recycle plant	Electric charges	305 kWh	8,418
	NaOH	5.0 kg	700
	Disinfectant	1.7 kg	1,360
	Disposal of sludge	0.47 m³	6,460
	Activated carbon (odor)	0.6 kg	369
	Water analysis	——	3,333
	Personnel expenses	——	6,667
	Article of consumption	——	426
		Total	27,733
		Cost per vouse	173.3 ¥/m³
Drinking water model plant	Electric charges	40 kWh	1,121
	Methanol	2.6 ℓ	666
	Activated carbon	0.5 kg	300
	Disinfectant	1.0 kg	70
	Water analysis	——	3,333
	Personnel expenses	——	3,333
		Total	8,823
		Cost per volume	1,102.9 ¥/m³
Rainwater utilization plant	Electric charges	9.6 kWh	265
	Disinfectant	0.17 kg	137
		Total	402
		Cost per volume	67.0¥/m³

The manufacturing cost of recycled water, drinking water and rainwater was calculated from the running cost and fixed cost (the depreciation of the construction cost). The breakdown of the running cost is shown in Table 10.

The fixed cost was culculated by the capital recovery method, assuming the term of depreciation of 7 years, annual interest of 10% and remaining value of the facility of 10%, with respect to the machinery and construction cost excluding the water tanks and other structural building costs. Table 11 shows the water manufacturing cost of each plant calculated from the running cost and fixed cost. In this calculation, the treating capacity was supposed to be 160m³/day for recycled water, 8m³/day for drinking water, and 6m³/day for rain water.

Table 11. Cost of water

	Recycled Water	Drinking water (from model plant)	Rain water
Depreciation [¥/m³]	337.7	2693.9	149.3
Running cost [¥/m³]	173.3	1102.9	67.0
Total cost [¥/m³]	511.0	3796.8	216.3

These costs are compared with the city water and sewage treatment service

fares. The manufacturing cost of the recycled water is less than the total water service cost of 670 yen/㎥ as of December 1984. By contrast, the manufacturing cost of the drinking water is more than ten times that of city water rate, partly because of the small capacity of 8㎥/day.

Furthermore, in order to study the economy of recycled water, the total cost required for obtaining the recycled water (=constructions cost +running cost) was compared with the municipal water service charge using the city water. In this trial calculation, the consumption of recycled water was assumed to be 100 and 160㎥/day, and the conditions are as shown in in Table 12. The results are shown in Fig.7 which shows that the economical advantage of the recycled water facility comes out in 6.5 years at consumption of 100 ㎥/day and in 4 years at 160 ㎥/day.

Table 12. Condition of calculation

		Case 1	Case 2
Water use		160 ㎥/Day	100 ㎥/Day
Water recycle plant	Use of recycled water	Toilet flush water, pond Cooling tower	Toilet flush water
	Initial cost	¥ 106,653,000.	
	Runnig cost	173.3¥/㎥×160 ㎥/D ×300 D/Y	
	Inflation rate of running cost	5 %/Year	
Service water and sewage fee	Water rate	Service water 375 ¥/㎥ Sewage 295 ¥/㎥ (Total 670 ¥/㎥)	
	Inflation rate of fee	10 %/Year	
annual operation days		300 Days	

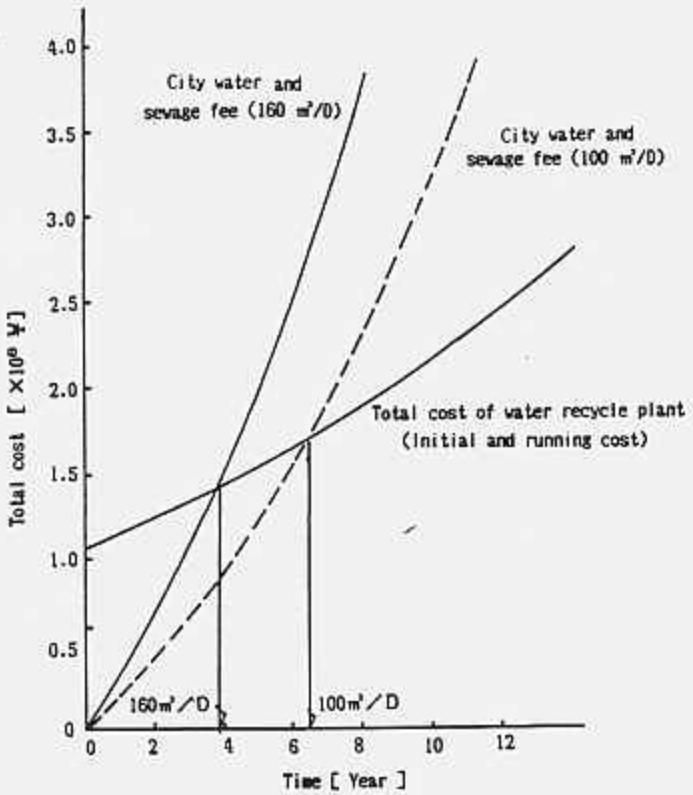


Fig.7 Comparison of total cost

(recycled water and city water•sewage fee)

6. Conclusion

According to the operation records for a year and a half with this water recycling facility, the following facts have been found out.

1) While the water recycling plant consists of only the biological treatment processes, the quality of the treated water is as clean as the limit expected with the biological treatment. The treated water is sufficiently clean to use as the toilet flush water and/or the pond refill water.

2) The drinking water model plant has turned out to have sufficient and stable performance to obtain clean water which satisfies the city water quality standard of the City Water Law in Japan.

3) The amount of water used through the rainwater utilization plant was as much as expected initially.

4) The cost of manufacturing water from waste water by this facility turned out to be lower than the fare of the city water and the sewage treatment service in Tokyo.

[Reference]

1) Tokyo Metropolitan Bureau of Waterworks : Water Quality Annual Report 1982.

CIB

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Automatic Control of Water Reutilization

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AUTOMATIC CONTROL OF WATER REUTILIZATION

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WATER SUPPLY AND DRAINAGE FOR BUILDINGS
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Summary

The pH in the aeration tank can be regarded as an index precisely showing the state of the progress of treatment, when waste water incuding nitrogen compounds is subjected to biological treatment. It has been found that the automatic control method in activated sludge method on the basis of pH is very advantageous. This automatic control method is especially efficient in the water reutilization system in buildings which is characterized by the followng points:

(1) The stability of the treated water quality is particularly required.

(2) As a matter of practice, the availability of a competent specialist to manage a treatment plant is limited.

Résumé

Le pH dans le réservoir d'aération peut être regardé comme un index qui montre précisément l'état de progrès du traitement, quand l'eau d'égout contenant une solution d'azote est assujettie à un traitement biologique. Il a été prouvé que la méthode de contrôle automatique par le méthode de schlamms activée sur le principe pH est très avantageuse. Cette méthode de contrôle automatique est spécialement efficace pour le système de réutilisation de l'eau dans des bâtiments qui sont caractérisés par les points suivants:

(1) La stabilité de la qualité de l'eau traitée est particulièrement requise.

(2) La disponibilité d'un spécialiste compétent pour gérer l'installation de traitement est limitée.

Zusammenfassung

Der pH-Wert im Belüftungstank kann als ein Index angesehen werden, der genau den Zustand des Fortschritts der Behandlung zeigt, wenn Stickstoffverbindungen enthaltenes Abwasser biologischer Behandlung unterworfen wird. Es ist gefunden worden, daß die automatische Regelungsmethode in der Aktivschlamm-Methode auf der Grundlage des pH-Wertes sehr vorteilhaft ist. Diese automatische Regelungsmethode ist besonder wirksam in einem durch die folgenden Punkte charakterisierten Wasserwie-derverwendungssystem in Gebäuden:

(1) Stabilität der Qualität des behandelten Wassers ist besonders erforderlich.

(2) In der Praxis ist die Verfügbarkeit eines kompetenten Spezialisten für die Verwaltung der Aufbereitungsanlage begrenzt.

1. Introduction

Recently reutilization of water in buildings, has been hilighted, because of shortage in water resources and the capacity of drains and sewers.

Usually the treatment quantity for such reutilization is within the range of 50 to 1,200 m^3/day. Therefore the long time aeration activated sludge method is adopted especially when the biological treatment is employed. This method is able to give the effuluent quality in the order of BOD 8 to 10 mg/l as long as the treatment plant is well managed by competent specialists. Generally it is often made a practice not to employ such a specialist or to manage the treatment system by depending on a special who visits it occasionally particularly in the case of a water reutilization plant.

Under these circumstances automatic control which does not need special techniques and knowledge is desired earnestly, since such control is anxiously expected in order to secure satisfactory and stable effluent quality.

We report the results of tests that have been carried out since 1981 and still continued.

2. Comparison of this automatic control method with usual ones

The outline of the usual automatic control methods is described in the following:

(1) The method which controls dissolved oxygen (DO) in an aeration tank at a uniform concentration.

(2) The method which controls the total sludge weight in the system or sludge concentration under a uniform condition.

(3) The method which controls the aeration volume for the aeration tank in proportion to the waste water quantity.

Among these the first method is most usual and have a great deal of records. However, this method involves such problems as trouble due to the DO sensor being dirtied, misoperation, and there being the cases where the object of maintaining the treatment in good condition is not always effected. The other methods, though having advantages and disadvantages, involve the common defects of poorly coping with the variation in the concentration of the raw water.

The automatic control method which here we propose controls the rate of digestion of sewage filth ingredients by means of the extent of oxidation of the nitrogen in raw waste water as a substitute charateristic.

Comparison of this method with constant DO control method, which has been used commonly, is shown schematically in Fig. 1.

The constant DO control method aims at controlling DO in an aeration tank at a uniform concentration in spite of variation of concentration or quantity of raw water, so it is an open control system without a feed-back circuit whereby the effluent quality and the conditions of activated sludge are kept constant in good order. In contrast this control method establishes the control system tied with the ultimate purpose that the rate of digestion of organic compounds is sustained at a constant degree by the nitrification degree, which can be represented by PH. The maintenance of pH within a certain range eventually leads to keeping the activated sludge in good order as explained later.

Generally nitrogen is included in sewage in the form of organic nitrogen or NH_4^+-N. The behavior of nitrogen through nitrogen through biological treatment is shown in Fig. 2.

As such biological treatment makes progress, the greater part of organic nitorgen included in sewage is converted into NH_4^+-N by

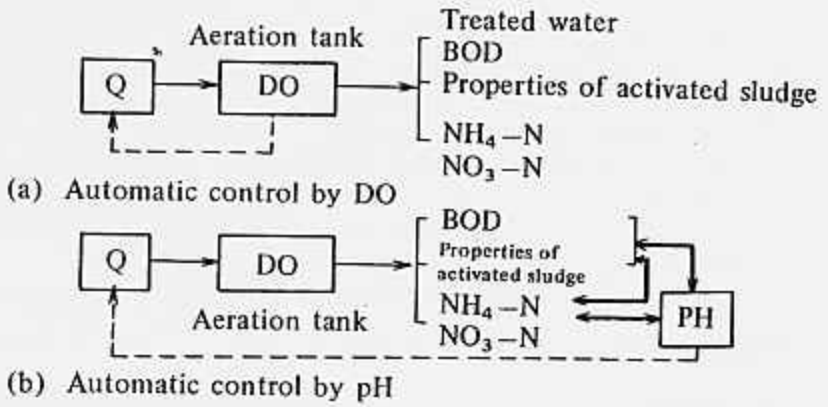


Fig. 1 Comparison of this method with automatic control by DO

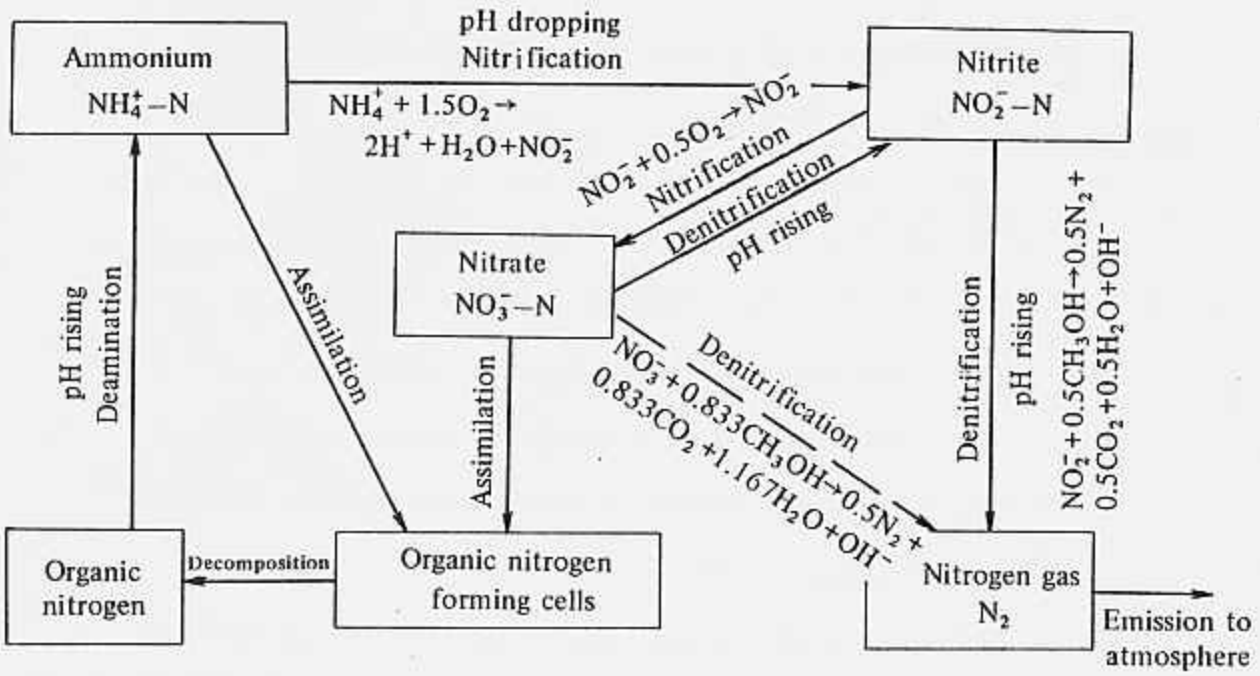


Fig. 2 Behavior of nitrogen through biological treatment

deamination reation, and NH_4^+-N is oxidizend into NO_3^--N by way of NO_2^--N through the working of nitrifying bacteria. As the bacteria. As the nitrification progresses alkalinity is consumed according to the Equations 1 and 2 and pH in treated water drops. Since deamination hardly occurs, in the aerobic condition, the more the removal reaction of BOD and nitrification proceed, the more pH drops, because of the conbined factor of the
generation of CO_2 due to the decomposition of filth.

More exactly speaking, the reduction in alkalinity is closely related to the decomposition of organic nitrogen, the synthesis and degradation of cells; for which Equation 3 represents the actual phenomena in a more actual manner.

There is nitrogen in sewage more than is consumed to synthesize cells and removed as excessive sludge. Usually the consumption of alkalinity is actually 5 to 7 mg/l per NO_3^--N.

$$NH_4^+ + 2O_2 + 2HCO_3^- \longrightarrow NO_3^- + 2H_2CO_3 + H_2O \quad \cdots\cdots\cdots\cdots (1)$$

$$pH = pK_1 - \log (H_2CO_3/HCO_3^-) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (2)$$

$$\Delta \text{ Alkalinity} = 3.57 (N_1 - N_2 + N_3) - 7.14(\Delta NO_3\text{-N}) \quad \cdots\cdots (3)$$

Where N_1 : Decomposed organic nitrogen

N_2 : Nitrogen which is used for synthesizing cells

N_3 : Nitrogen which is formed as a result of degradation of cells

The removal reaction of BOD and nitrification reaction are competitive reactions with each other, but the former takes place earlier. In order for the BOD removal reaction to finish almost completely, the deamination of organic nitrogen should have almost come to an end and the nitrification should have made progress to some extent.

If nitrification reaction proceeds to an excessive extent and pH in treated water drops and the condition of excessive aeration takes place, the activity of purification by micro-organisms drops, and the properties of activated sludge become poor at the same time. Moreover activated sludge is taken to pieces in a extreme case and effluent quality becomes worse. The relations between aeration quantity and phenomena which occur in biological treatment as a result of the variation of the aeration are shown in Fig. 3. It can be seen from Fig. 3 that excessive or insufficient aeration leads to the deterioration of the effluent.

Manipulated variables in the case of treatment by the activated sludge method are as follows:

(1) Aeration quantity for an aeration tank

(2) Sludge quantity which is held in the system

(3) Return sludge volume (return sludge ratio)

(4) BOD loading (being capable of only partial control)

(5) Sludge age which is related to (1), (2) and (4)

Particularly important is the aeration quantity as a basic factor. Excessive aeration is apt to occur as the result of a blower which would do for maximum BOD loading being installed.

Paying attention to the fact as described above, this automatic control system intends to control aeration quantity on the basis of pH; various control methods are thought of as shown in Fig. 4. The method (a) represents the most basic control system.

In this figure, 1 is an aeration tank in which biological treatment is carried out by controlling by the indicating controller as described below. One or more blowers (2) and a pH meter (3) to detect the value of pH in the aeration tank or the sedimentation tank are set. In addition the control circuit (4) is provided to control

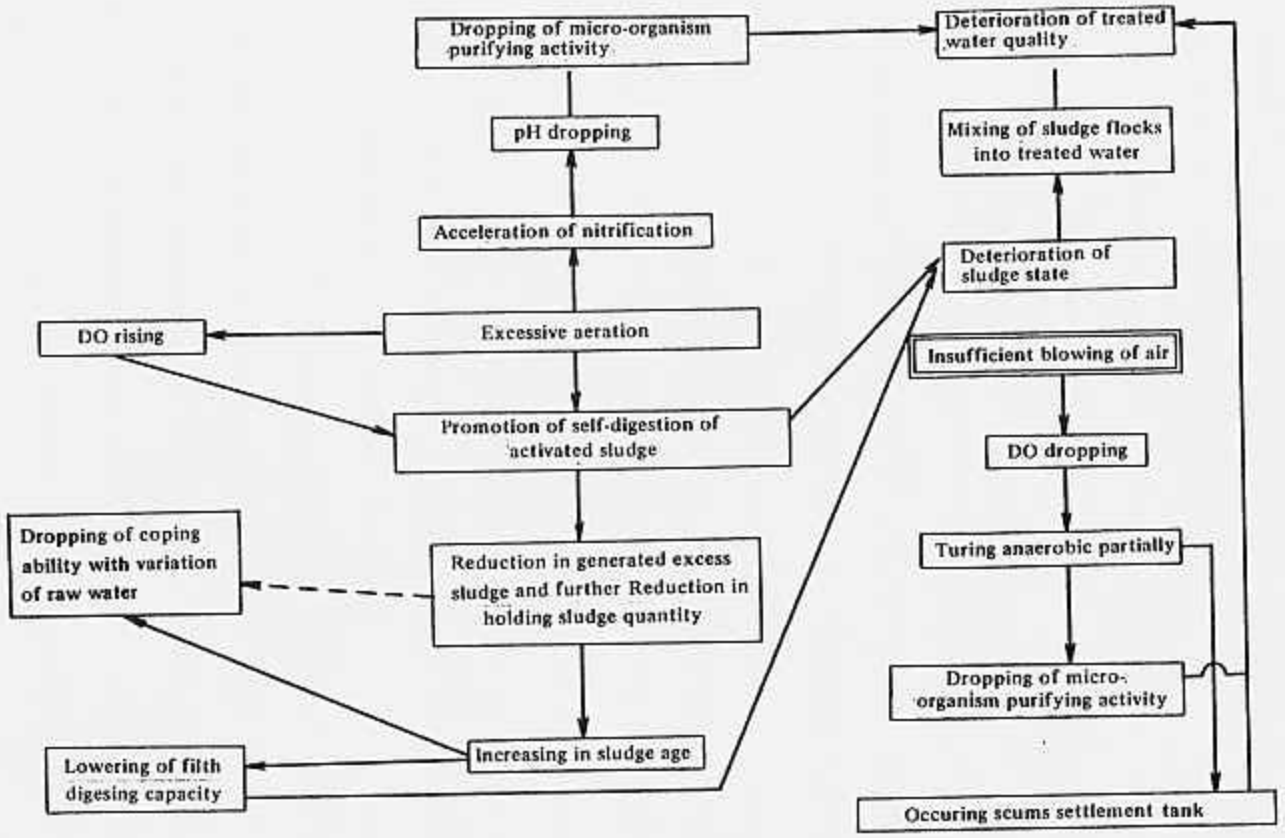


Fig. 3 The relations between aeration quantity and phenomena which occur in biological treatments

the aeration quantity by the pH value and the pH changing velocity.

The control of the aeration quantity is effected as shown in the following:

(1) The control of the number of operated blowers.

(2) The method of controlling air volume emitted from a blower by using an adjustable speed motor

(3) The method of controlling the aeration quantity for the aeration tank by means of adjusting the opening of a powered valve provided in an air bypass.

(4) The combination of the methods of (1) to (3) above.

If the pH value in the aeration tank is higher than the setting pH, the aeration quantity is increased to accelerate the reaction of Equation 1 and as a result pH is controlled. On the other hand, if the pH is lower than the setting pH, the aeration quantity is decreased to suppress the reaction of Equation 1 and pH is likewise controlled. The state of treatment is kept well by the above-mentioned control method, and at the same time treatment efficiency is kept high.

In the method (b) in Fig. 4, the ratio relay is used as a supplementary instrument for the indicating controller. In this case the mesurement of the raw water volume without cease is necessary. The control method (c) in Fig. 4 shows how the aeration quantity is automatically controlled by both the values of pH and DO. This theory is especially efficient for the waste water in which the content of nitrogen and alkalinity is likely to vary hourly to a great extent. That is, the basic volume of aeration for the aeration tank is controlled by the pH value and the changing velocity of pH; and the aeration quantity in excess of the basic one is controlled by the DO detected in the aeration tank with an DO meter.

Since remarkable results have been obtained by the most basic method

(a), here we report the outline of the results from this method.

A summary of our theory forming the premises is shown below:

(1) The value of NH_4^+-N or NO_3^--N/(NH_4^+-N + NO_3^--N) is closely connected with pH

(2) Kjeldahl nitrogen concentration is fairly proportional to organic filth compounds concentration.

The higher Kjeldahl nitrogen concentration, the higher is the alkalinity.

(3) BOD removal reaction precedes nitrification of NH_4^+-N slightly.

The idea as discribed in the above is formed with the intention of producing effectiveness with the long time aeration activated sludge method rather than the other methods. Ordinally retention time in the standard activated sludge method is far shorter than in the long time aeration activated sludge method. Accordingly, as nitrification reaction does not proceed enough, pH is in the range from 6.8 to 7.3 Also a short sludge age ranging from 3 days to five days does not produce enviroment suitable for the increase of nitrifying bacteria. Furthermore, pH dropping is occasionally not enough to apply this control method when waste water has high alkalinity. Accordingly, it poses a problem whether the Fig. 4 (a) method, which is considered mainly on the basis of nitrification (40 $\sim$ 80%) having proceeded to some extent takes effect for those cases.

Thereupon we suggest the control method that takes effect for those conditions as stated in Fig. 5. This method has been devised by developing further the theory (automatic control method by pH) as shown in Fig. 4 (a). That is, this method as shown in Fig. 5 (b) has the intention to control aeration quantity for the aeration tank by the pH, which is detected by a pH meter set in the pilot aeration tank.

The above pilot aeration tank is provided to promote nitrifying reaction by reaerating the mixed liquor taken partially from the aeration tank.

Also the treated water which is separated from sludge is reaerated in Fig. 5 (a) with the same intention as Fig. 5 (b). Both control methods are based on the same theory. The drop of pH is too insufficient to control aeration quantity by pH as the result of insufficient nitrification in the standard activated sludge method: so that both the systems are controlled by pH which is detected by a pH meter set in the pilot aeration tank in order to control the aeration quantity in sensitive range of pH. The difference between the two systems is that the undesirable effect for nitrification due to short sludge age is excluded in the Fig. 5 (a) method. The capacity of a pilot aeration tank e.g. in the range of 10 to 20 l is enough to work properly.

3. Experimental equipment, control system and experimental conditions

3.1 Treatment plant and control system

The schemes and specifications of the automatic control system and waste water treatment plant are shown in Fig. 6, which shows the automatic control system for standard activated sludge method. The output signal from the pH meter equiped in the pilot aeration tank is led to the indicating controller, and the aeration quantity is controlled by means of adjusting the opening of a powered valve for air bypass, through the PID operation. Also the same automatic control system is applied to the long time aeration activated sludge method with the exception that a pH meter is set directly in the aeration tank. DO meter is equiped in the aeration tank, but this is not used as a part of the control system but used as a supplementary instrument.

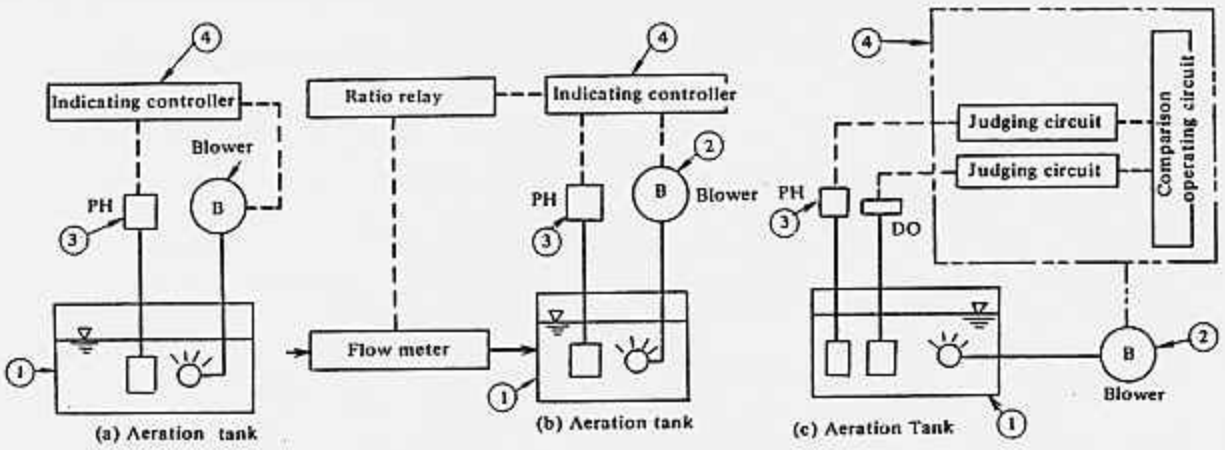


Fig. 4 Automatic control methods for aeration on the basis of pH

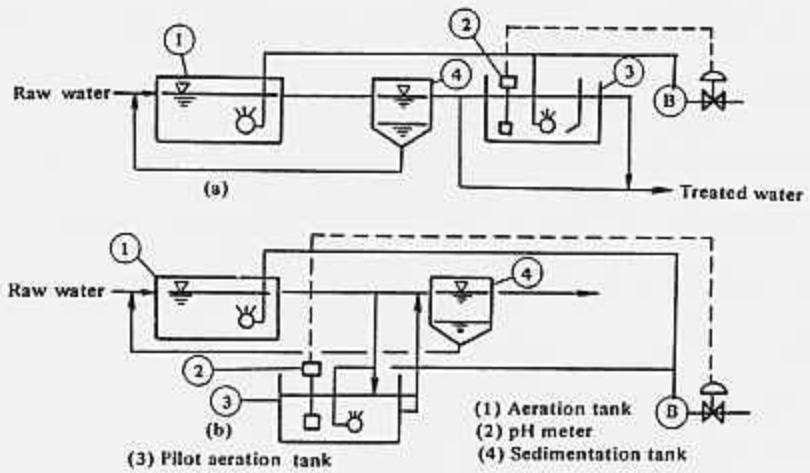
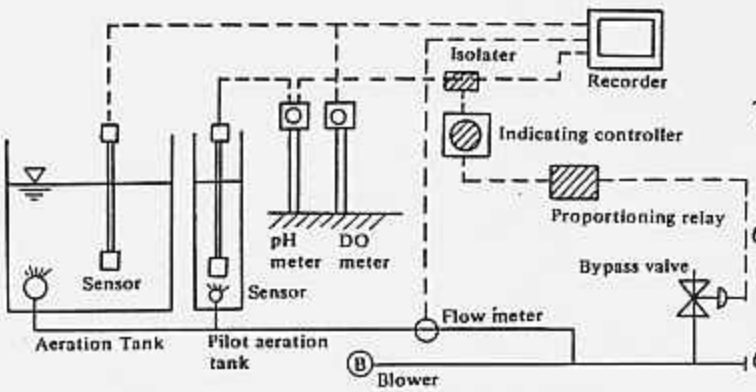


Fig. 5 Automatic control method in standard activated sludge method



Aeration tank	Turning method	Sedimentation tank	Hopper
	Volume 54.9m³		4.1m x 3.2m x 3.5m
	Specification 5.8mx3.2mx3.5m		
Pilot aeration tank :volume 10l			

Fig. 6 Simplified control flow diagram and treatment plant specification

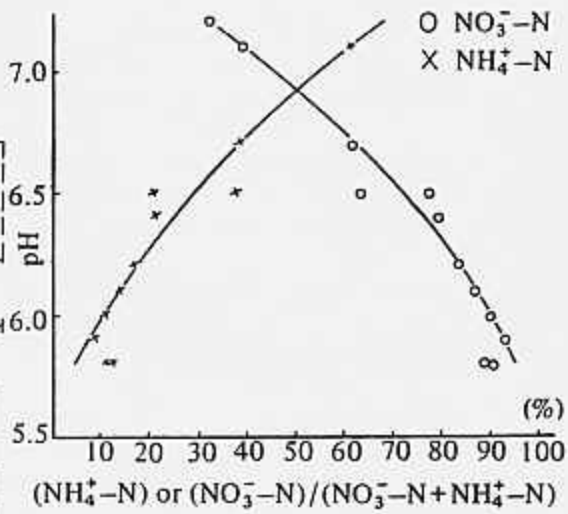


Fig. 7 Variation of pH in aeration tank with the content of NH_4^+–N and NO_3^-–N

3.2 Treatment conditions

The main treatment conditions which have been used are as follows:

(1) Biological treatment type: Long time aeration activated sludge method and standard activated sludge method

(2) MLSS in aeration tank: Various conditions were adopted in the region of 1,000 to 3,500 mg/l

(3) Return sludge quantity: Various return sludge rate were taken within the range of 75 to 150%

(4) Setting pH for control: The pH for control was set variously within the range of 5.8-7.2

(5) Raw waste water: The total waste water from the building including a discharge from kitchens, sundry waste water, and waste water from toilets

4. Results of control by this automatic control method

4.1 Relations between pH in an aeration tank and nitrification rate

A strong correlation was found between pH and the content of NH_4^+-N and NO_3^--N in the aeration tank from the results of analysis, as shown in Fig. 7, when the standard raw waste water flowing into this treatment plant was treated. As the total nitrogen concentration in the raw water varies, an exact correlation between the absolute concentration of NH_4^+-N or NO_3^--N and pH in the aeration tank was not observed. However, a adequate correlation was observed between (NH_4^+-N or NO_3^--N)/(NH_4^+-N+NO_3^--N) and pH, because the alkalinity in raw water is high in proportion to the nitrogen concentration in the raw water. If the aeration quantity is controlled by setting pH within the range of 6.3 to 7.0, both the effluent quality and properties of activated sludge are kept stable in a good state as described below.

That is, the above-mentioned pH values correspond tothe ratio of NO_3^--N/(NH_4^+-N+NO_3^--N) from 40% to 80%.

4.2 Considerations in the case of long time aeration activated sludge method

(1) Situation under the steady-state operation

PH, DO, and aeration quantity are shown in Fig. 8 under the steady-state operation. The operation condition is indicated in Fig. 8, which shows that pH, Do and aeration quantity are nearly constant. DO also is almost constant as a result, though it is not controlled in this system.

(2) Operation situations when MLSS concentration changed suddenly.

Fig. 9 shows the state of operation in which MLSS concentration is suddenly changed by taking out excess sludge from the system changing the concentration from 3,200 to 1,700 mg/l. Though the necessary amount of aeration is reduced in proportion to the change, it becomes almost constant soon after. Also it was found that the pH, DO in aeration tank and the effluent quality hardly changed, as shown in Fig. 9.

(3) State of operation under low MLSS concentration

Usually it is known that the control of aeration quantity by manual operation is very difficult under a low MLSS concentration when the quality of raw water changes.

However as Fig. 10 explains, this control system is found to have the advantage of keeping a good operation under a low MLSS concentration, that is, this enables low energy consumption.

(4) Relation of effluent quality with setting pH

It is shown in Fig. 11 how effluent quality varies as setting pH is changed in the range from 6.0 to 7.3 by using transparency as an

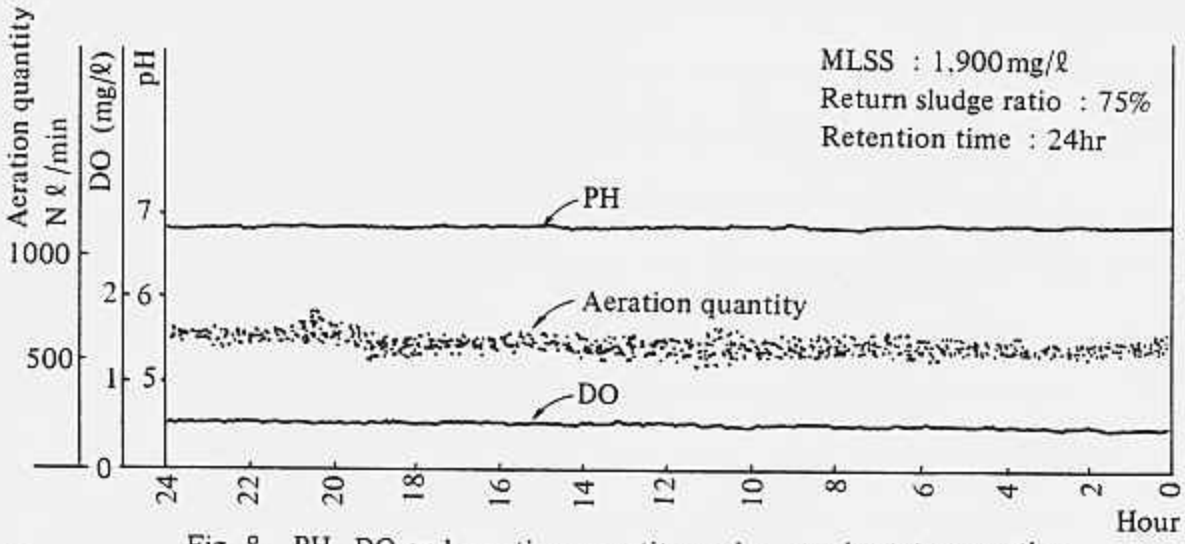


Fig. 8 PH, DO and aeration quantity under steady-state operation

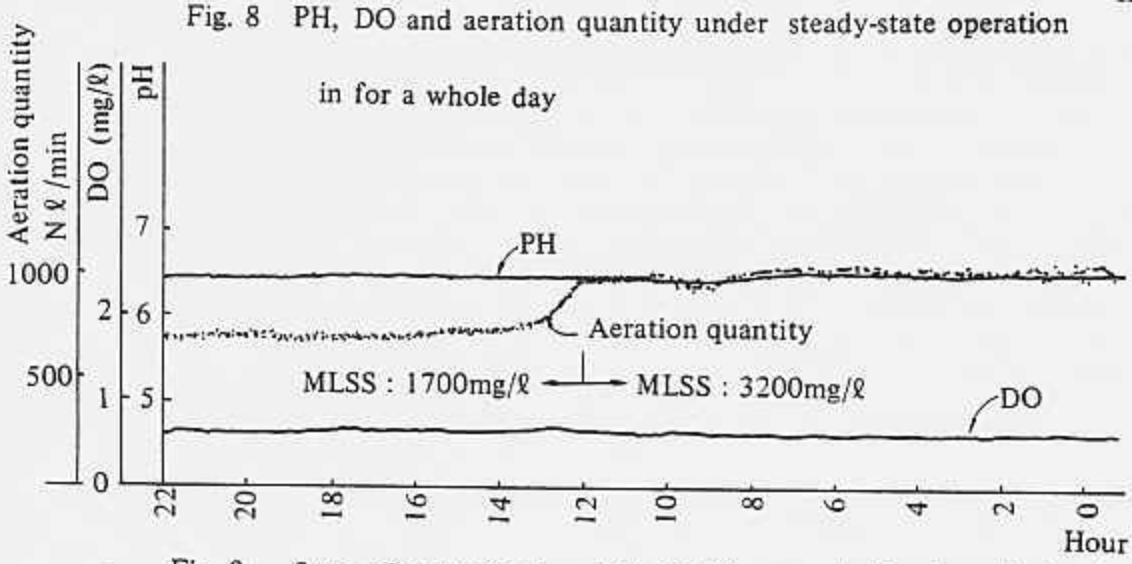


Fig. 9 State of operation in which MLSS concentration is suddenly changed

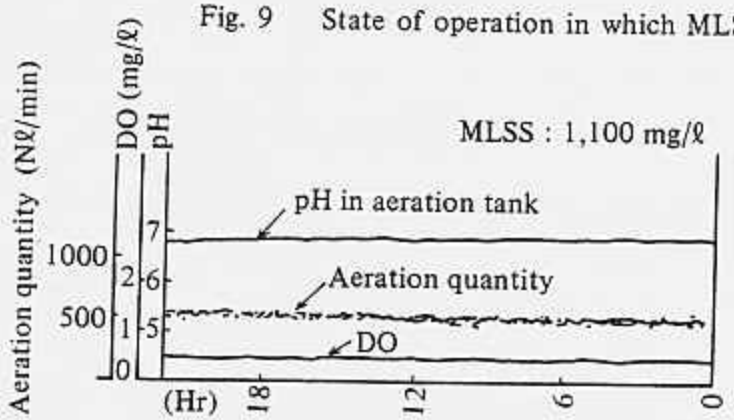


Fig. 10 State of operation under low MLSS concentration

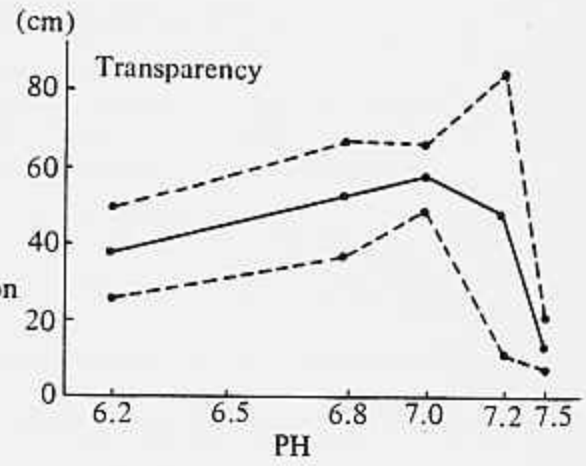


Fig. 11 Variation of effluent transparency with setting pH

index. The data are arranged from the mesurements for two years; the upper dot line shows $+1.96\sigma$ and the lower -1.96σ. If the setting pH is too low, small flocks are apt to occur and then effluent quality becomes worse, because fine sludge flocks are mixed with the effluent. On the other hand, if the setting pH is too high, the effluent becomes a little opaque as the result of the imperfect digestion of the organic compounds, and the control is likely to be unsteady.

(5) Step response character and the production of excess sludge

Fig. 12 shows the result of the response of the analysis values of DO, pH, NH_4^+-N, NO_3^--N, COD and alkalinity and the amount of aeration amount of aeration when a processing system under a steady-state operation condition with the pH value set at 6.5 is changed in steps from the setting pH of 6.5 to 5.9 with the pH intervals of 0.2.

The pH in the aeration tank reaches the setting value in 1 to 3 hours. As was expected, NO_3^--N was observed to increase, but Kjeldahl nitrogen was not observed to decrease corresponding to an increase in NO_3^--N. On the other hand the total nitrogen increased. This indicates that NH_4^+-N is created bythe digestion of sludge and that a part of the NH_4^+-N is nitrified. Consequently such facts suggest that the production of excess sludge is little if the operation is kept at a lower setting pH. Actually tHis was recognized from long period continuous operation at various setting pH values. At the setting pH value of 6.8 the production of the excess sludge is 45-50% of the BOD of influent, in which case nitrification percentage is about 50%. On the other hand the production of excess sludge is 33% at the setting pH value of 6.2, in which case nitrification percentage is 85%.

But the necessary amount of aeration is high when the setting pH is low, and the amount is less in the case of a high setting pH, as shown in Fig. 13. This shows that necessary electric power varies extremely according to the setting pH value and the target nitrification percentage. When nitrification reaction and BOD removal reaction are brought to completion, there are advantage as well as disadvantage as described below. The advantage is that the digestion of sludge proceeds and the production of excess sludge is reduced. But there is the disadvantage that power consumption increases. As described before, in the water reutilization plant the scale is small generally. Accordingly the excess sludge is often delivered to special firms dealing with it. Therefore the cost of disposal of sludge accounts for a great part of the running cost. Generally the restriction of the production of excess sludge is hoped for by many parties concerned. But the most suitable operation method is determined naturally from the scale of the treatment plant, the kind and the quality of raw water, target effluent quality, and economical efficiency.

Fig. 13 shows relations between setting pH values and aeration quantity. From this it is known that necessary aeration volume decreases as the setting pH value is increased and that the width of variation of the aeration volume increases at the same time. The necessary aeration quantity is subject to Equation 4.

$$O_2 = a \times \text{removed BOD} + b \times \text{MLSS} + c \times \text{digested MLSS} - d \times \Delta NH_4 - N \quad \ldots(4)$$

Here, a and b are general coeficients. C is the coefficient multiplying O_2 consumed in digestion of sludge, and d is the coefficient multiplying O_2 consumed in nitrification.

If NH_4-N is completely nitrified in seawage, the values of first and fourth terms reach the same level. As the sludge in the system is

reduced, the necessary aeration volume is reduced too, as known from Fig. 9 and Equation 4. Especially, digestion activity of sludge is accelerated under low MLSS and low sludge age, so that the consumption of O_2 regarding the second and the third terms in Equation 4 is reduced.

(6) Comparison of effluent quality between automatic control operation and manual operation

The data of effluent quality which were taken in both this control operation and manual operation for two years, were arranged statistically and observed. The results are shown in Table 1. They indicate that automatic operation far excels manual one in terms of the averages and standard deviations of BOD, COD and SS.

4.3 Application to standard activated sludge method

In the standard activated sludge method, usually the nitrification of the nitrogen ingredients does not make so much progress as the case of the long time aeration method party because of the short retention time. When the pH value is set at high points ranging from pH 7 to 7.3 and the control is effected, it is considered that the control tends to become unstable because of the following reasons:

(1) The buffer action of the sludge against the pH is strong.

(2) The pH in the aeration tank is apt to vary according to a slight variation of the pH of the raw water.

In trying to control the system in the standard activated sludge method by the control on the basis of pH, the automatic control has been able to be made adequately if the setting pH is 7. However, as the following conditions were realized, the control tended to lack stability, and deviation from the setting pH took place.

(1) MLSS concentration in the aeration tank is low. (The BOD-MLSS loading is high.)

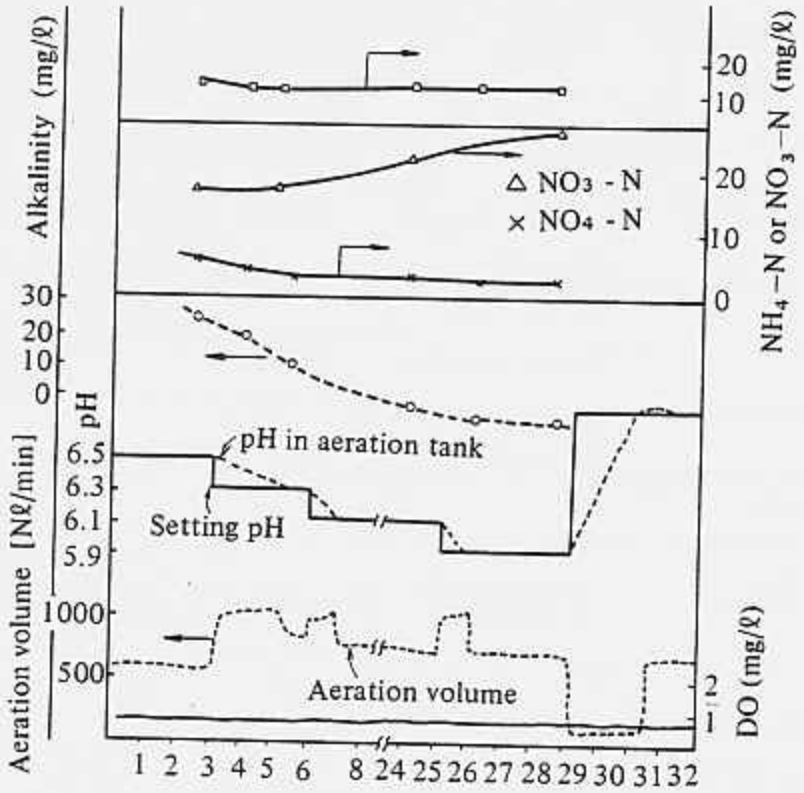


Fig. 12 Step response character

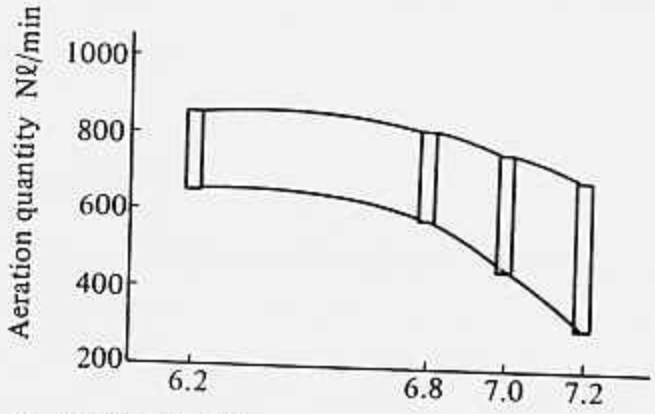


Fig. 13 Variation of the amount of aeration with setting pH

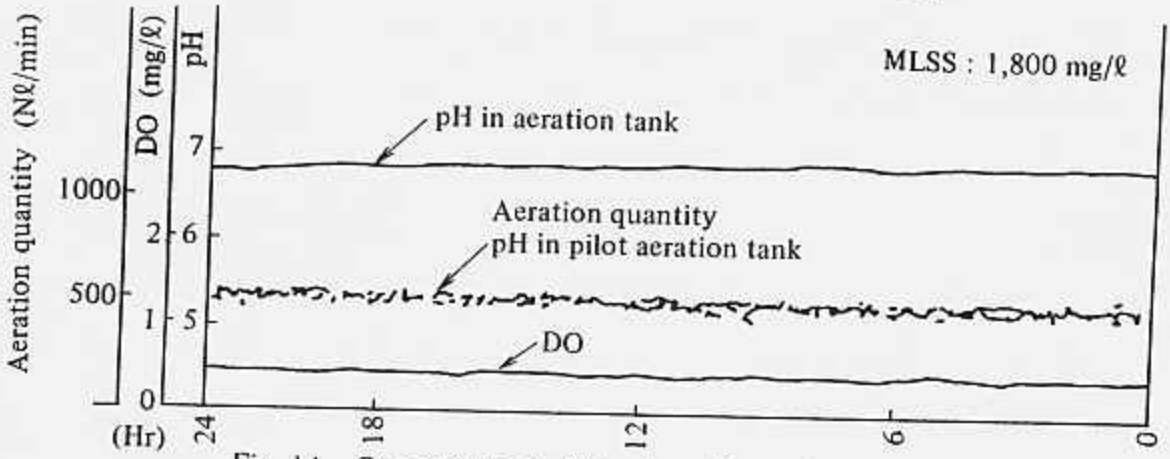


Fig. 14 Comparison of effluent quality under automatic control operation with under manual operation

Table 1 Comparison of effluent quality in automatic control operation with in manual operation.

(mg/ℓ)

		BOD	COD	SS
Average	Manual operation	13.70	17.15	13.60
	Automatic control operation	8.43	15.35	9.19
Standard deviation	Manual operation	6.24	3.95	10.08
	Automatic control operation	4.36	4.02	6.95
No. of samples		44	50	44
$t = \frac{X_1 - X_2}{S\sqrt{n-1}}$	Automatic control operation	8.01	3.16	4.21
Evaluation of effect from automatic control operation		t BOD > t (0.01) Significant	t COD > t (0.01) Significant	t SS > t (0.01) Significant

Table 2 Treatment results by standard activated sludge method

(mg/ℓ)

	Waste water (1)	Aeration tank (1)	Pilot aeration tank (1)	Raw water (2)	Aeration tank (2)	Pilot aeration tank (2)
NH_4^+–N	34.5	22.5	7.16	36.1	21.3	8.73
NO_2^-–N	ND 0.01 >	0.66	0.05	ND	0.35	0.04
NO_3^-–N	0.5 >	13.9	35.2	0.5 >	13.6	30.3
M- alkalinity	211	126	9.9	213	131	27.4

(2) The concentration of raw waste water is high and the quality varies.

So it was found that the operation aiming at check of nitrification under severe conditions is liable to be unstable. An example of the result of the automatic control of the aeration amount according to Fig. 5 (b) is shown in Fig. 14. The quality of raw water, treated water and mixed liquor in a pilot aeration tank are shown in Table 2 as examples. As both the results show, the nitification in the aeration tank proceeds to the extent of 38 to 40% with the pH remaining at 7.05 to 7.08 under the condition shown in Fig. 14. But the nitrification in the pilot aeration tank proceeds to 80% with the pH being kept at the constant value of 6.2 which is the setting pH. Furthermore, both the aeration quantity and DO are almost constant. The values in the above, indicate that this automatic control method can be applied to the standard activated sludge method.

5. Conclusion

A summary of the findings is described below:

(1) The pH in the aeration tank can be regarded as an index precisely showing the state of the progress of treatment, and the automatic control method in activated sludge method on the basis of pH is very advantageous. Especially, the effect by this control method is very remarkable in the water reutilization system in buildings in which the long time aeration activated sludge method is usually adopted.

(2) The aeration quantity is automatically controlled by the value of the setting pH in both the standard activated sludge method and the long time aeration activated sludge method on the basis of the same theory; in the former the pH meter is set in the pilot

aeration tank in which a part of the mixed liquor from the aeration tank is reaerated, while in the latter the pH meter is set directly in the aeration tank. It has been found that the method of controlling aeration quantity by pH yields very good quality of the treated water and keeps the properties of the activated sludge stable. Since the operation at a low DO concentration can be achieved, this realizes low energy consumption.

(3) This control system has been found to have the advantage of keeping a good operation at a low MLSS concentration, under which the control of aeration quantity by manual operation is very difficult.

(4) Since the self-digestion of sludge can be controlled by varying the setting pH, as a result the production of excess sludge can be controlled to some extent.

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CIB

CIB-W62 SYMPOSIUM

Investigation of Water Consumption from Recycling Water System at Newspaper Office Building

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April 9,~10, 1985

TOKYO, JAPAN



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12th CIB-W62 SYMPOSIUM - TOKYO -
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10, 1985 : KEMCHIKU KAIKAN

Zusammenfassung

Untersuchungen wurden in einem Zeitungsverlag durchgeführt, in dem ein System für mittelreines Leitungswasser installiert wurde, um den Gesamtverbrauch an reinem und mittelreinem Leitungswasser, die anfallende Menge des Abwassers, das dann für die Aufbereitung des mittelreinen Wassers verwendet wird, die Produktion von mittelreinem Wasser und den Wasserverbrauch klassifiziert nach Anwendungszweck zu erfassen. Um die Anzahl der Beschäftigten zu untersuchen, wurde alle fünf Minuten eine Zählung durchgefürht; der gesamte Wasserverbrauch wurde durch Überwachung des Wasserstandschwankungen in allen Wassertanks erhalten, wobei der nach Anwendungszweck klassifizierte Wasserverbrauch stündlich direkt von den Anzeigen der Wasserzähler abgelesen wurde.

Analysen über den Zusammenhang zwischen der Personal-Fluktuation und dem nach Anwendungszweck klassifizierten Wasserverbrauch bzw. dem Gesamtwasserverbrauch wurden durchgeführt. Weiters wurde eine Zeitstudie durchgeführt, um den Wasserfluß von reinem Leitungswasser über das Abwasser bis zur Produktion von mittelreinem Leitungswasser klarzustellen.

Als Ergebnis konnten Daten erhalten werden, die den Trend im Wasserverbrauch und den Wasserverbrauch für pro Einheit aufzeigen. Die Zeitstudie stellte klar, daß das für bestimmte Zwecke eingesetzte Wasser jeweils unterschiedliche Hauptperioden aufwies, und dies zusätzlich zu den über einen 24-Studen-Zeitraum in Abhängigkeit von der Personal-Flukuation auftretenden Schwankungen; zwischen dem Verbrauch von reinem Leitungswasser und dem Abwasser konnte aus den 1-Studen-Daten keine Diskrepanz abgeleitet werden, wogegen eine solche Diskrepanz zwischen den beiden verbrauchswerten aus den 5-Minuten-Daten festgestellt wurde.

1. Introduction

Several investigation[3)-6)] on the water consumption of buildings have been published up to now, and standard values for planning of sanitary have been accumulated. However there is very little data available to all kinds of buildings. Furthermore, although it is necessary that the flow from potable water to recycling system should be clear on the planning of recycling water system, information on the flow is still not enough.

Knowledge of the pattern and quantities about water consumption is required for the most appropriate planning of sanitary, including recycling water system.

On the basis of this view point , the object of this paper is to provide the consumption data for various uses and in various units in the newspaper office for which there is very little data on the water consumption and to suggest the characteristics of the flow of water in buildings.

2. Outline of Investigation

2.1 Outline of Building

The outline of the building studied is shown in Table.1. This building is the head office of a newspaper publishing company, and it has printing facilities and all functions for the company including editing, management, and so on. The rooms for the printing machines and delivering section are situated on the basement floors. The rooms for editing and forming section are situated on the lower floors, and the rooms for office and management section on the higher floors.

The flow chart of water supply system in this building is shown in Fig.1. This system is separated to two sub-systems. One is used for the lower floors (B4F-9F) and the other for the higher floors (10F-16F). Flow meters are privided for every route in each sub-system. Table.2

shows the number of plumbing fixture in this building.

The recycling water system introduced in this building is an one-passing system, in which the recycling water before the treatment is the waste water from wash basins, bath tubs, flushing water for photographies and kitchens. After the treatment the recycling water has come into use for such purposes as a makeup water to cooling towers, flush water of toilets and sprinkling. After these uses it is drained to the sewer pipe.

2.2 Method of Survey

The survey was conducted from Aug.31(Mon.) to Sep.6(Sun.), 1981. The following is the items of this survey.

1) The total water consumption of potable water and recycling water
2) The quantites of waste water and recycling water
3) The local water consumption used for various purposes of potable water and recycling water
4) The number of persons in the building
5) The investigation of the number of plumbing fixtures, etc. based upon the drawings and hearing information

For the survey of the total water consumption and the quantities, a vessel with a pressure transducer was submerged in a tank, and water level in the tank tranduced to a signal of the pressure were registered by the recorder (Fig.2). The total water consumption and the quantities were calcilated by reading the record every one hour and every five minutes.

The local water consumption was determined by reading the flow meters provided every routes in the sub-systems.

The number of persons was counted at the entrance of this building

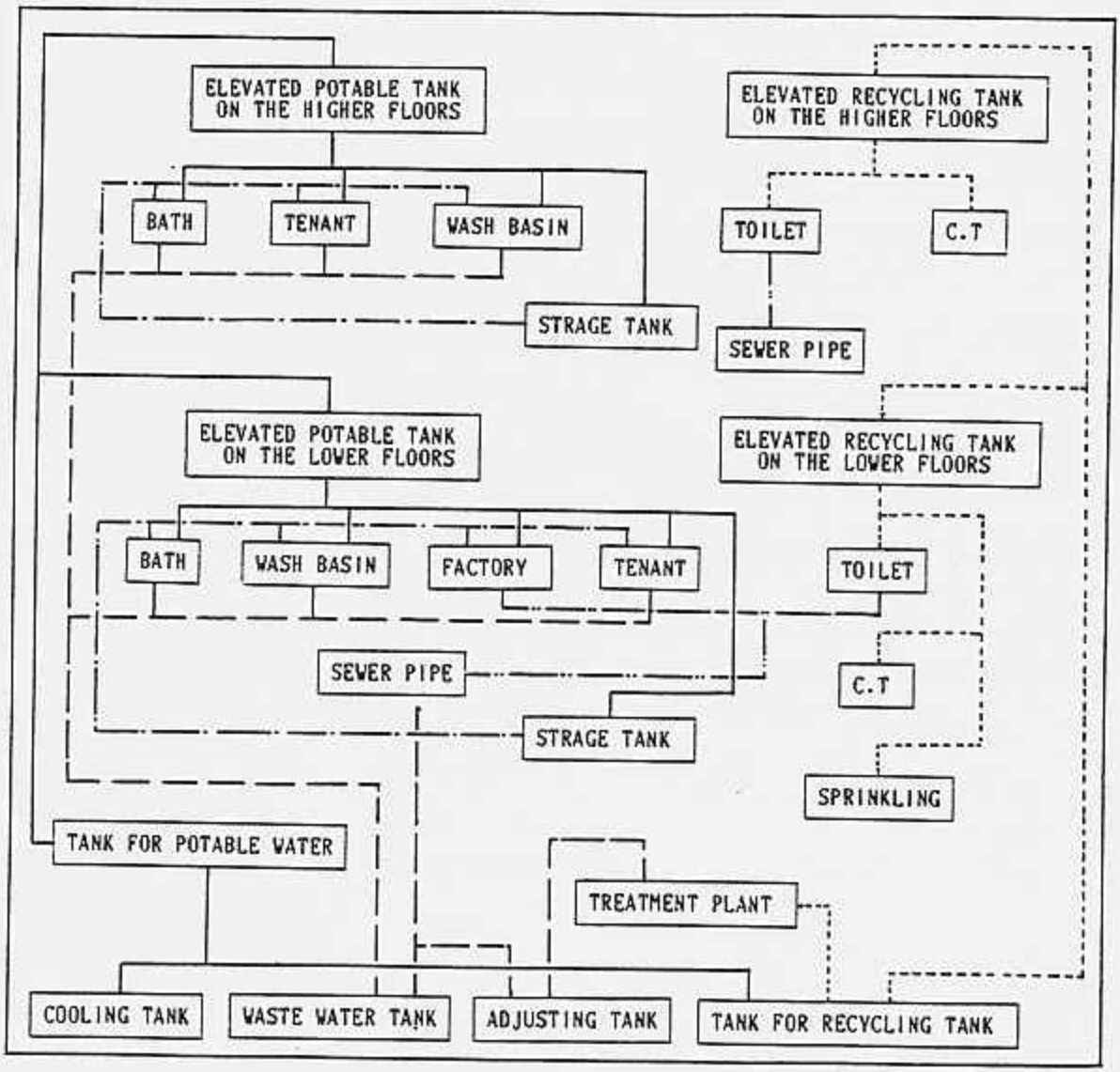


Fig.1 Flow of water supply system

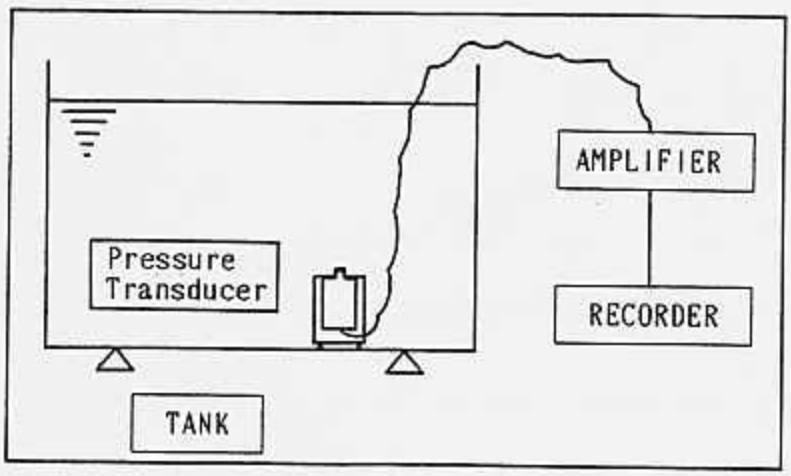


Fig.2 Survey of the total water consumption and the quantities

Table.1 Outline of the building

COMPLECTION		DEC.25,1979	
TOTAL FLOOR SPACE		66300 M^2	
REGISTERED PEAPLES		2948	
		POTABLE	RECYCLING
RECIEVED TANK		336m^3x2	232m^3x1
LIFT PUMP		4	4
ELEVATED TANK	HIGH	25m^3x2	10m^3x1
	LOW	20m^3x2	15m^3x2
WASTE WATER TANK		15m^3x2	
HOT WATER SYSYTEM		CENTRAL AND LOCAL	
REFECTORY		1	
RESTAURANT		1	
TEAROOM		1	
BARBER		1	
BATHROOM		2	

Table.2 Number of plumbing fixture

CLOSET	FV: 175 , LOW TANK: 3
URINAL	AUTOMATIC:147,MANUAL:1
LAVATORY COCK	15(4),MIXING:179(4)
SLOP SINK	51
ELECTRIC WATER HEATER	31
FAUCET	294(8)
FAUSET FOR BATH	54
SWING FAUCET WITH AERATOR	34(30)
MIXING SHOWER	6
SPRINKLING VALVE	69
EYEWASH VALVE	1

notes: The values of () are for the number in the kitchens

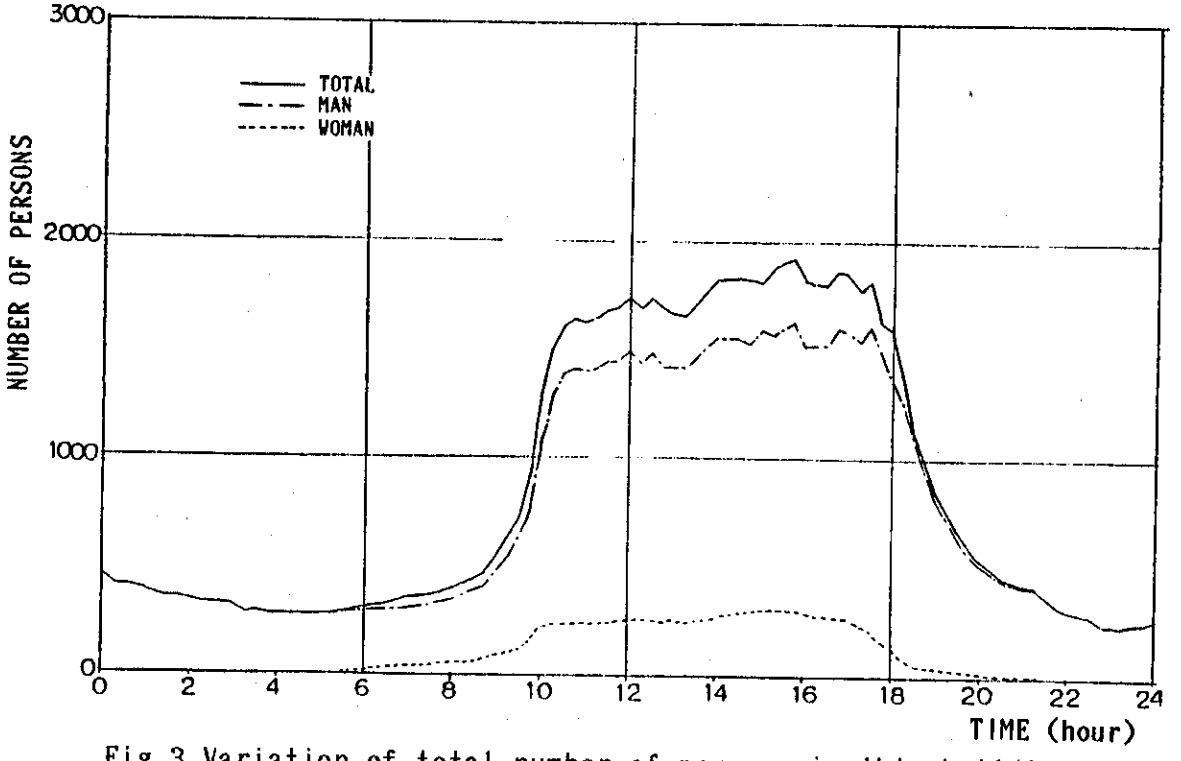


Fig.3 Variation of total number of persons in this building

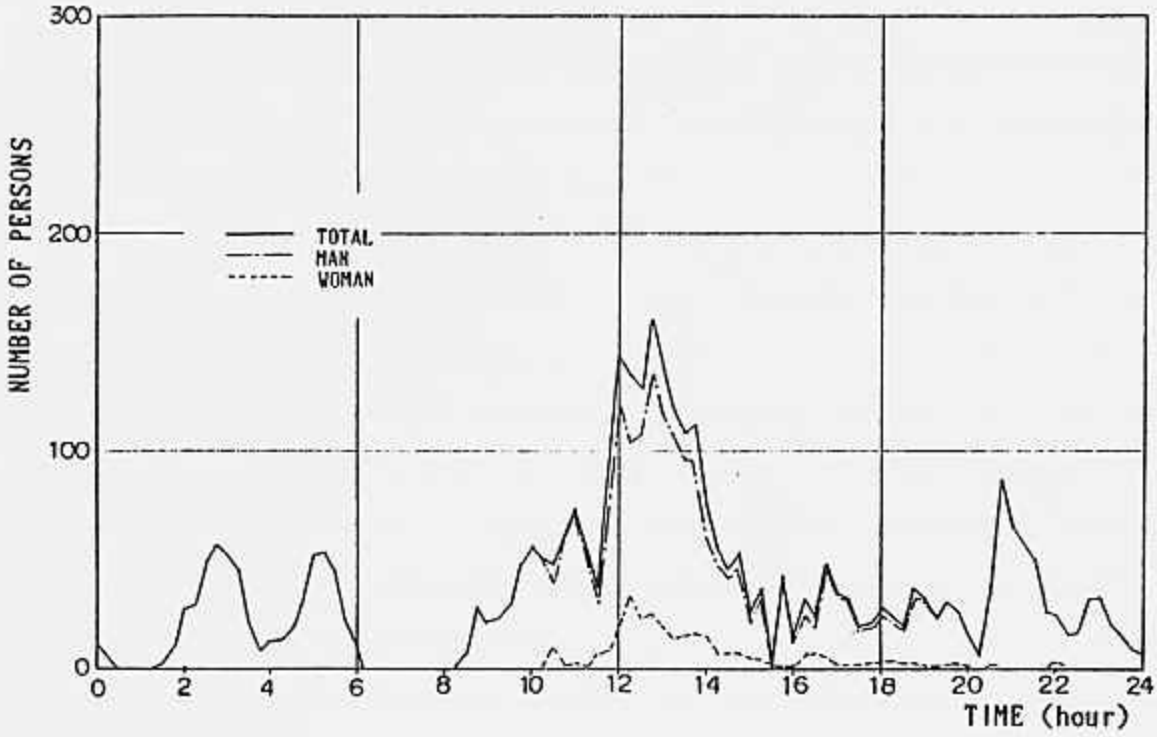


Fig.4 Variation of the number of persons in the refectory

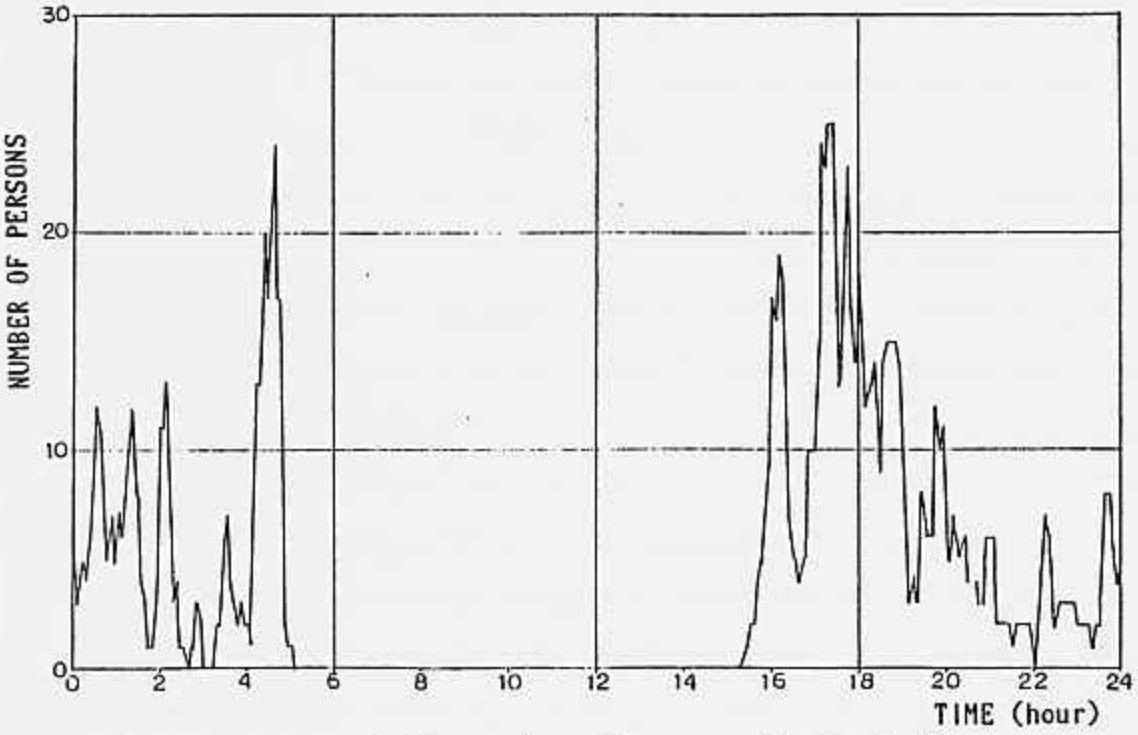


Fig.5 Variation of the number of persons in the bath room

and the refectory, the bath rooms and stores in this building every five minutes for only one day of the survey period from 0 hour to 24 hour.

3. Findings and Discussions

3.1 The number of persons

Fig.3 shows a variation of total number of persons in this building. The starting time and quiting time were one hour late in comparison with the ordinary office buildings, but the pattern of variation was similar to that of the ordinary office buildings.

The rate of the mean number of persons(10:00-19:00) to the registered person in this building was about 56% and the peak number of persons was about 1.14 times as large as the mean number of persons. The rate of the registered person to the total floor space was 0.0445 persons/m^2. These values are smaller than those reported before[5], 75%, 1.25-1.30 and 0.0636 persons/m^2, respectively.

This difference may be attributed to the combined parposes of the building and printing facilities in the building.

Fig.4 shows a variation of the number of persons in the refectory. Peaks appeared at 3 and 5 o'clock for drink, noon for lunch and about 21 o'clock for midnight snack.

Fig.5 shows a variation of the number of persons in the bath room. Two peaks appeared at about 4 and 17 o'clock for the use after works of the printers.

3.2 The Total Water Consumption

Fig.6 and Fig.7 show the total water consumption of potable water and recycling water, respectively.

Both curves have a similar pattern. In the case of potable water, the curve has the two peaks at 13 and 18 o'clock by the water consumed in the kitchen and the bath room. In the case of recycling water

considerably much water consumption was found even at night. This may be mainly attributed to the automatic flush water of toilet and makeup water to cooling tower used all day. There is a higher peak on Wednesday and Thursday than that other days. This would be due to the water sprinkled to the garden at the peak time.

3.3 The Quantities of Waste Water and Recycling Water

Fig.8 and Fig.9 show the quantities of waste water and drainage water from the waste water tank to a sewer pipe directory. Fig.10 and Fig.11 show the quantities of transfer from the waste water tank to an adjusting tank and recycling water.

The pattern of variation of waste water was much the same as that of potable water. As for the quantities of transfer and recycling water, the patterns were similar to those of waste water, while the larger number of peaks were found compared with that of waste water.

The quantites of drainage water was about 83m^3/day on average. It means that the original water of recycling water is not utilized effectively.

3.4 Results by Time Series Analysis

Fig.12 shows the power spectrums for potable water, waste water, transfer water and recycling water. The characteristics af all power spectrums are affected by some peculiar cycle, as well as 24 hour-cycle. The cycle in the potable water and waste water is dependent on the movement of persons. On the other hand the some peculiar cycles in transfer water and recycling water may have been caused by the adjusting tank.

Fig.13 shows the coherence between potable water and waste water, and between transfer water and recycling water. The value of coherence is high at the above-mentioned cycles.

Fig.14 and 15 show the correlation between the potable water and the

waste water. The former is based on the data every one hour and the latter every five minutes. The correlation appeared every 24 hour and the time lag do not exist in Fig.14. While there exist the time lag of five minutes in Fig.15. Therefore, it can be said that the potable water is drained immediately after the use.

Fig.16 shows tha correlation between the quantities of transfer and that of recycling water. No noticeable correlation was found between them.

This may be explained by the assumption that the adjusting tank acts as a buffer.

3.5 Local Water Consumption used for Various Purposes

Fig.17 to 20 show typical examples of local water consumption used for various purposes.

The variation of water consumption in the kitchen in Fig.17 is similar to that of the person in the refectory. (refer to Fig.4). The peak at 9 o'clock is caused by breakfast, at noon for lunch, at 18-19 o'clock for supper and at 22 o'clock for the midnight snack.

The two peaks of the water consumption in the bath room in Fig.18 may be caused by the use after printing, since the time of printing is 8:00-16:00 for evening paper and 20:00-4:00 for morning paper.

It can be seen in Fig.19 that the water of the wash basin on the higher floors is mainly consumed in the daytime. Indeed, very few persons use the higher floors (office and management), at night.

While as seen in Fig.20, the recycling water of tiolet on the higher floors is consumed through all day. Especially the water consumption is constantly at night, because the flushing system of urinal is automatic.

Fig.21 and 22 show the water consumption used for various purpose every day of the week. The former is for the total water consumption and the latter only for the recycling water consumption. The values in bars

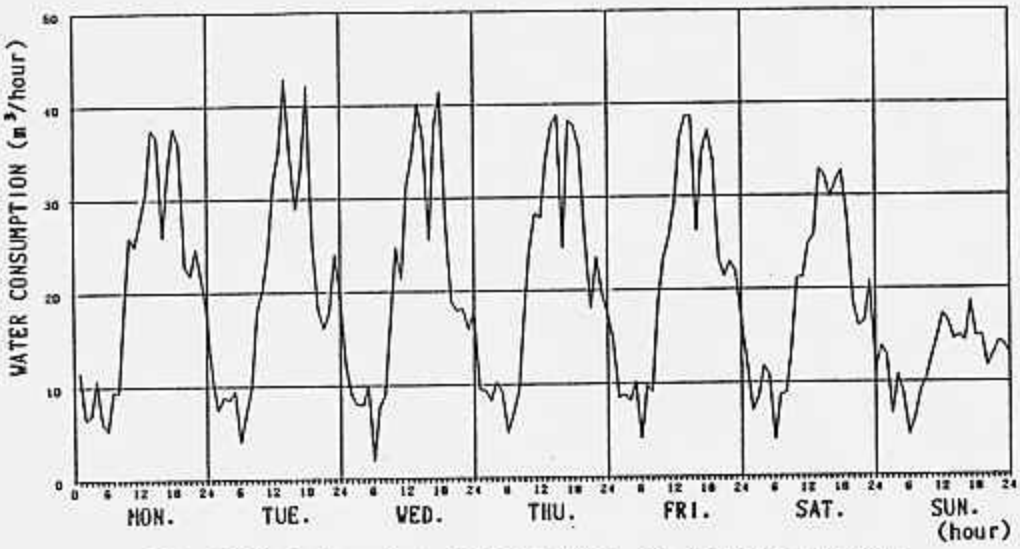


Fig.6 Total water consumption of potable water

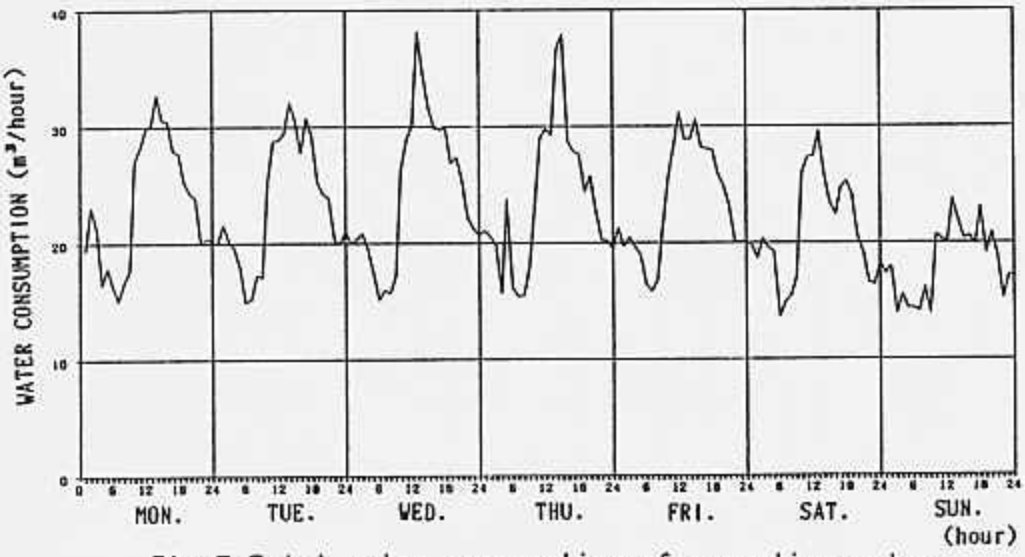


Fig.7 Total water consumption of recycling water

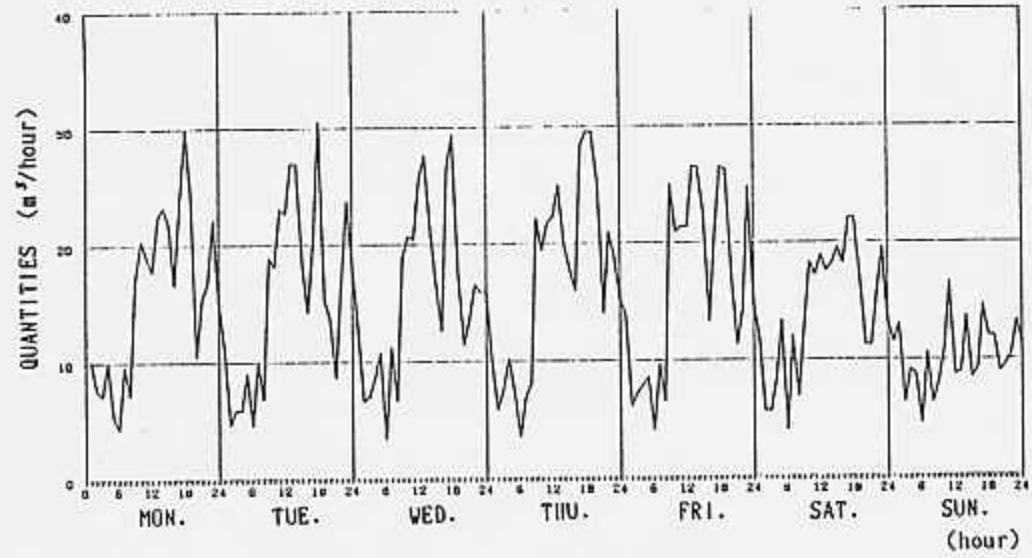


Fig.8 Quantities of waste water

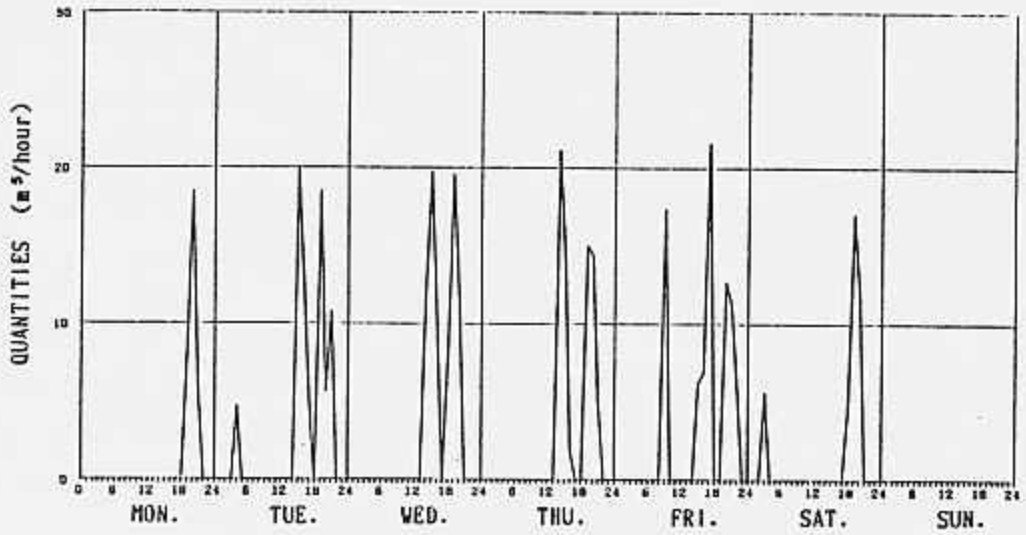


Fig.9 Quantities of drainage water from the waster water tank to the sewer pipe

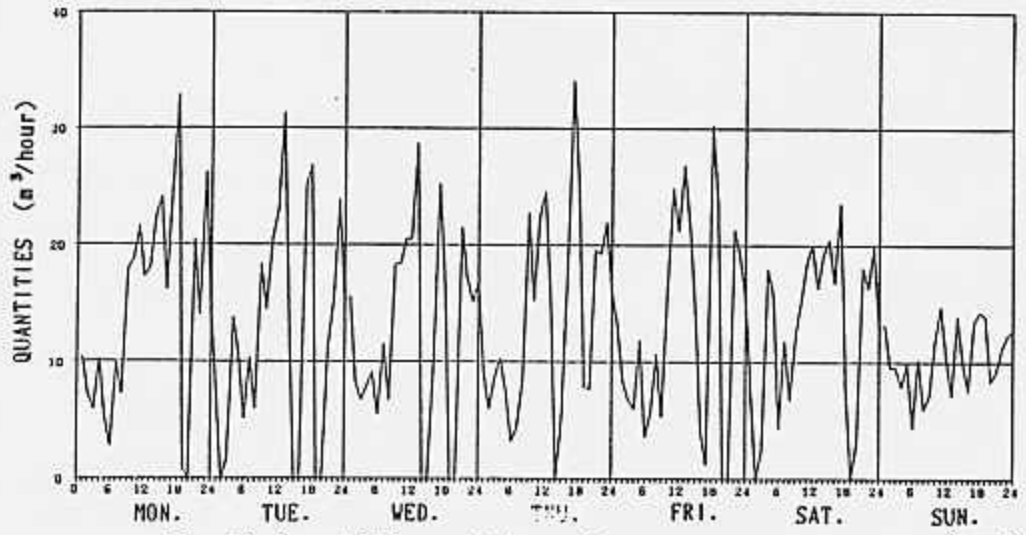


Fig.10 Quantities of transfer from the waste water tank to the adjusting tank

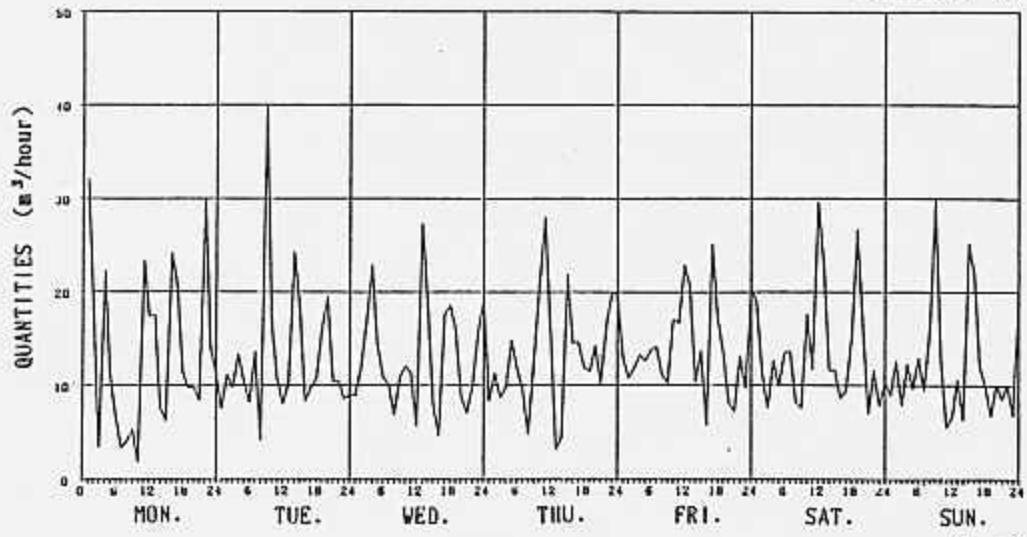
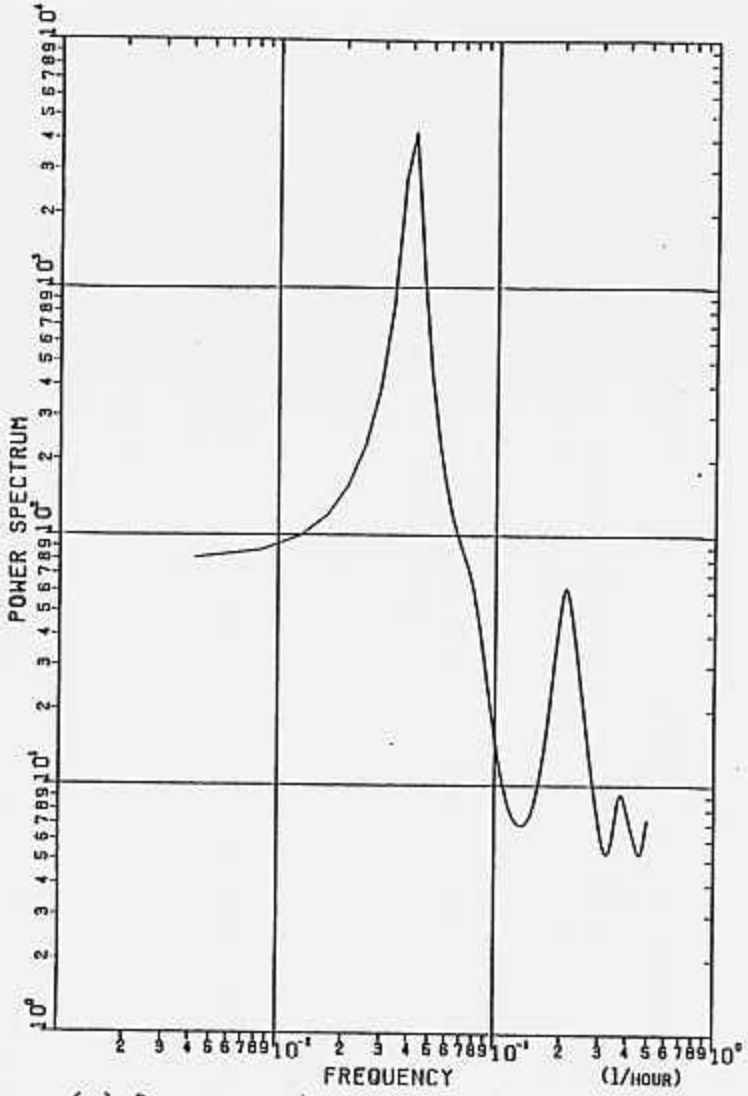
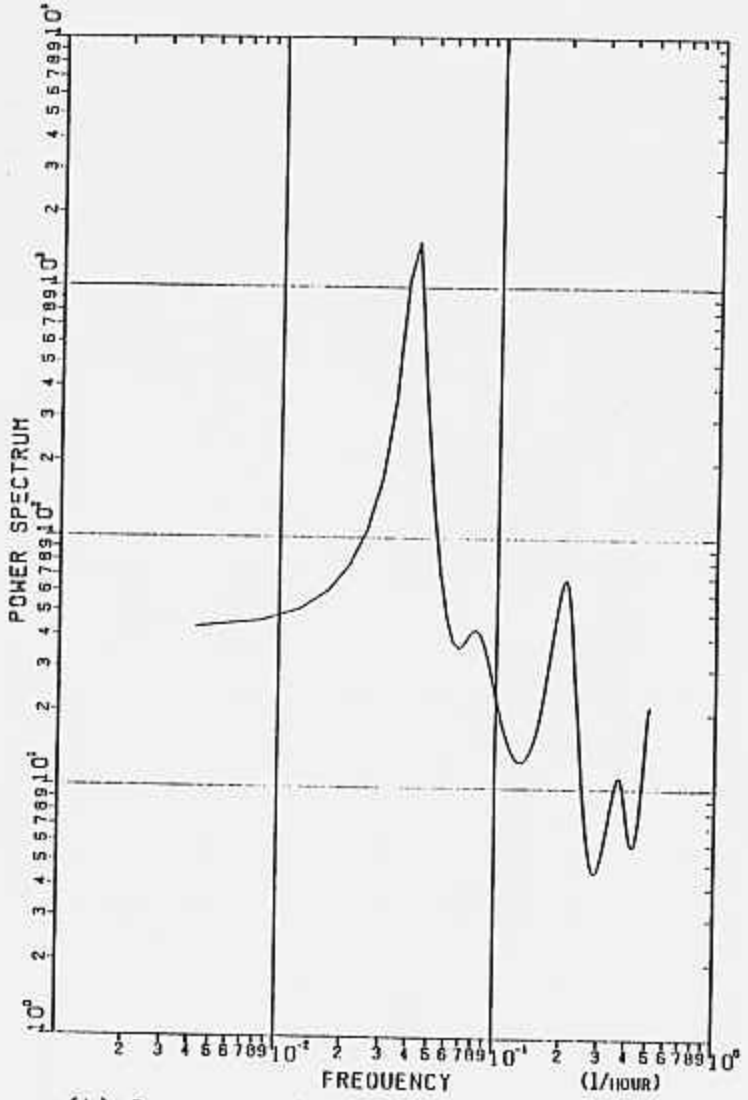


Fig.11 Quantities of recycling water

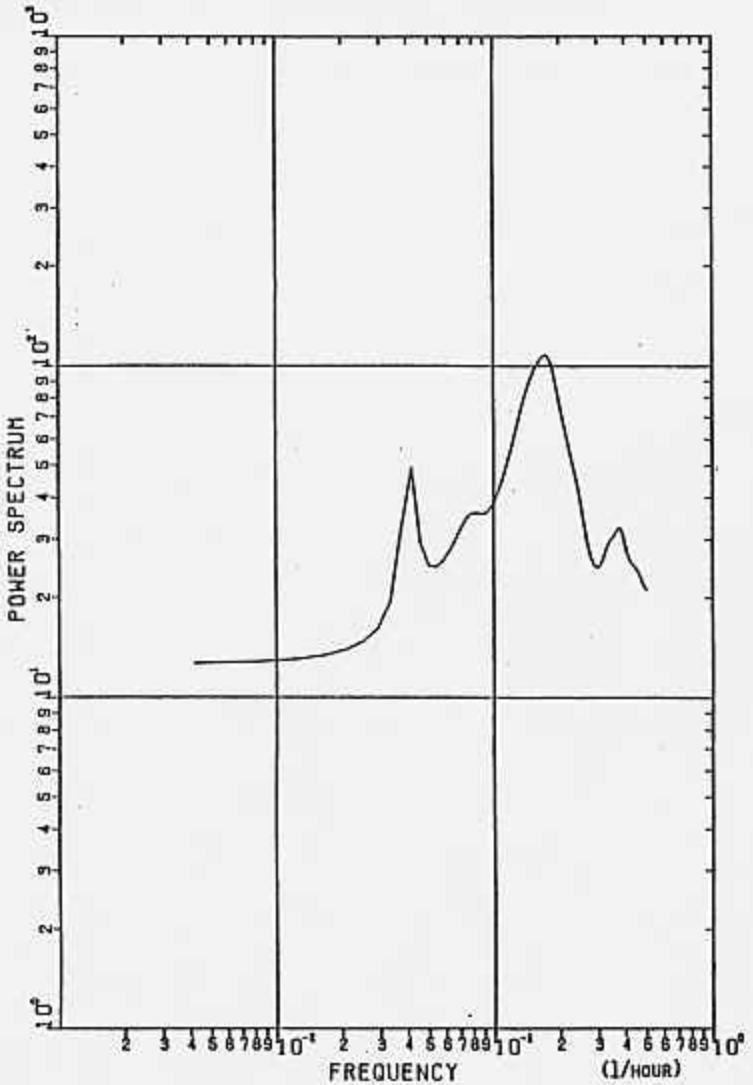


(a) Power spectrum for potable water

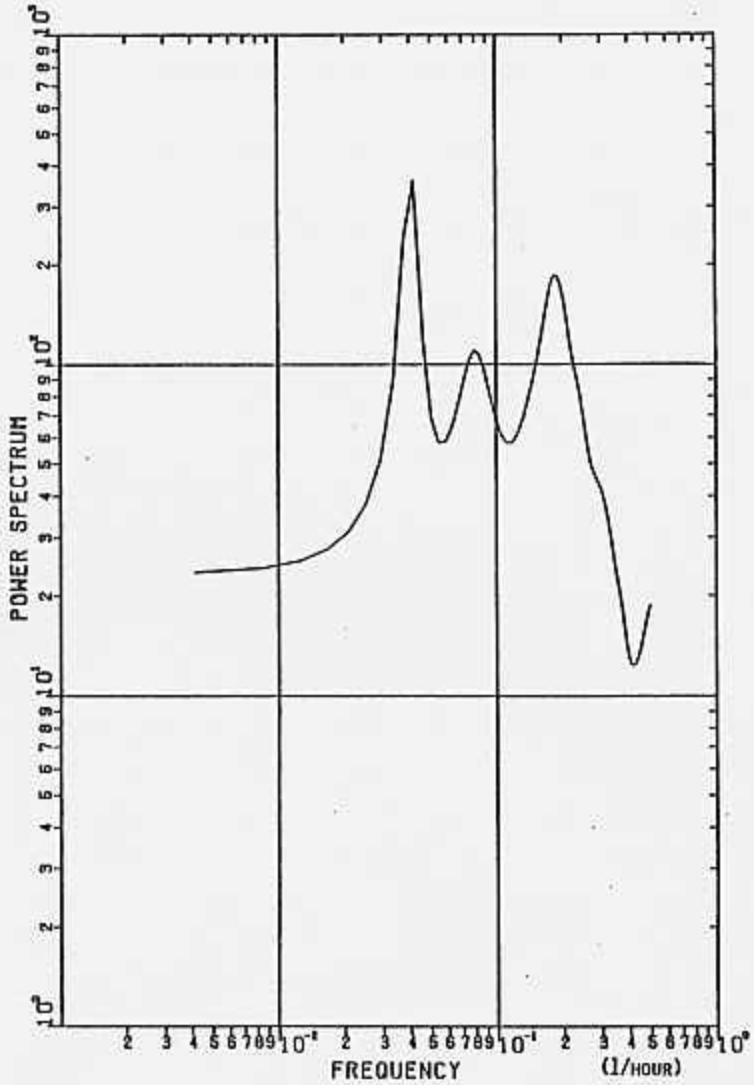


(b) Power spectrum for waste water

Fig.12-1 Power spectrums for potable water, waste water, transfer water and recycling water

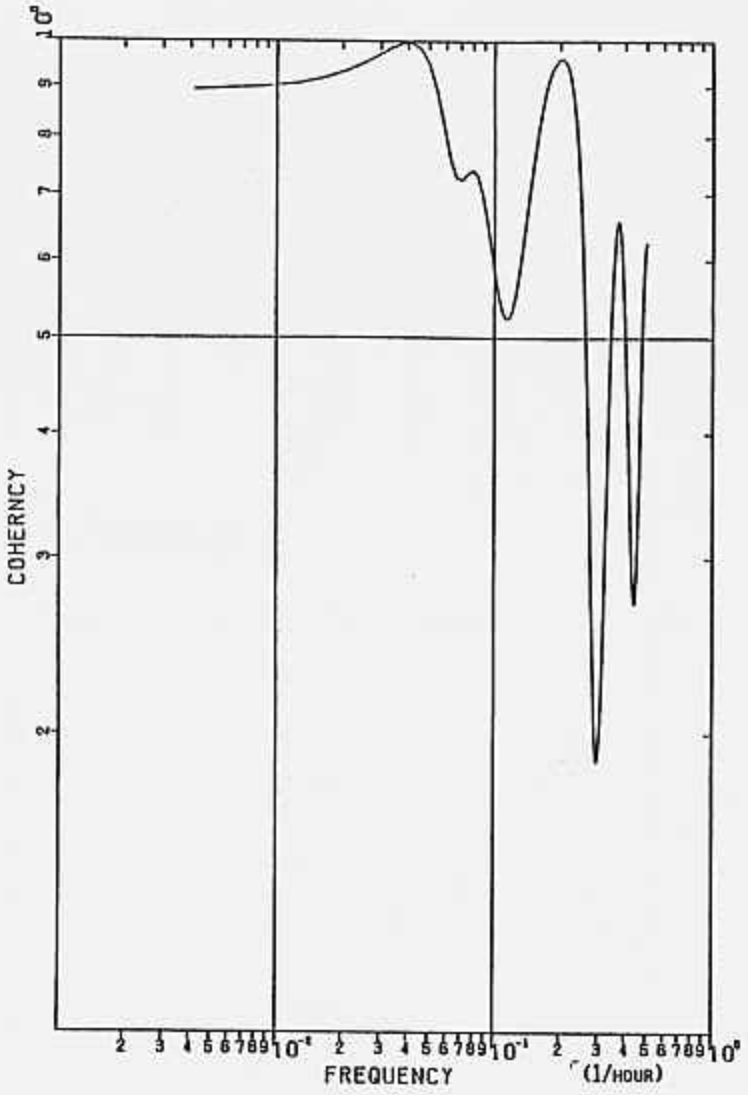


(c) Power spectrum for transfer water



(d) Power spectrum for recycling water

Fig.12-2 Power spectrums for potable water, waste water, transfer water and recycling water



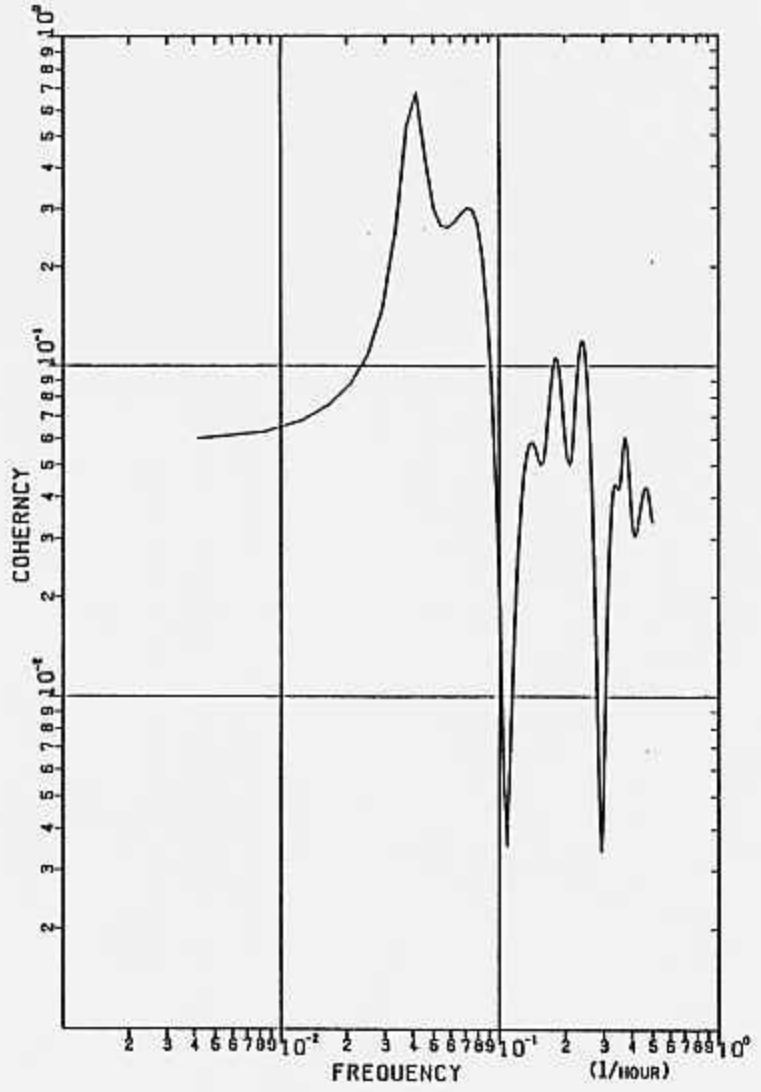


Fig.13 Coherence between potable water and waste water, and between transfer water and recycling water

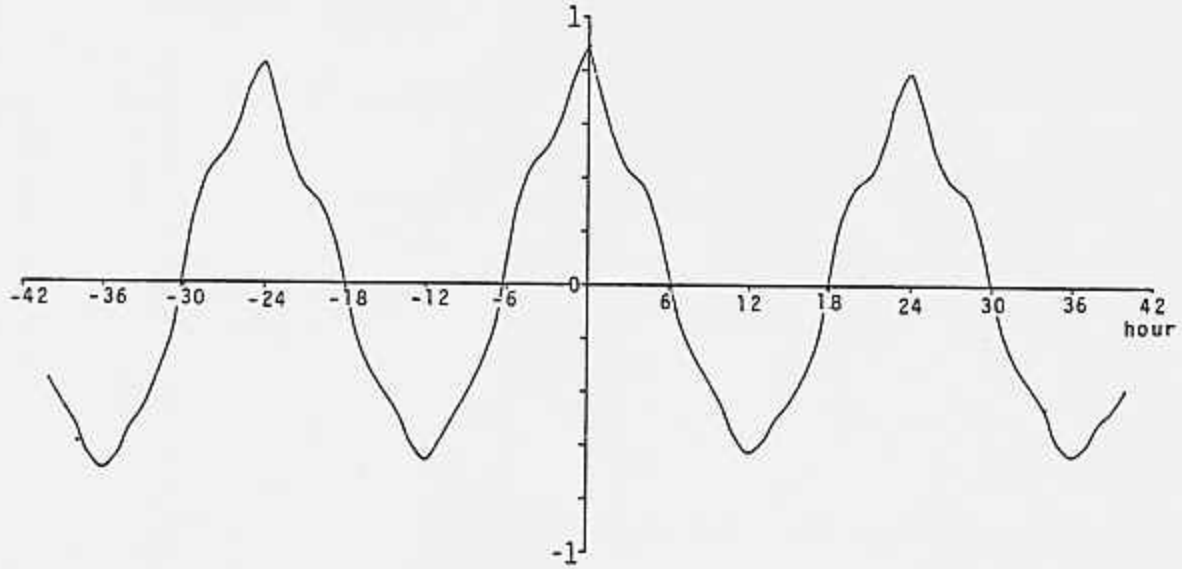


Fig.14 Correlation between potable water and waste water based on the data every one hour

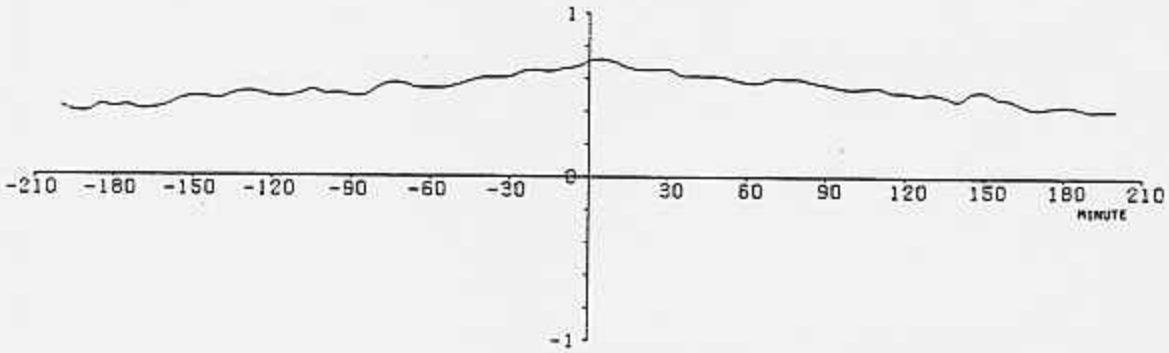


Fig.15 Correlation between potable water and waste water based on the data every five minutes

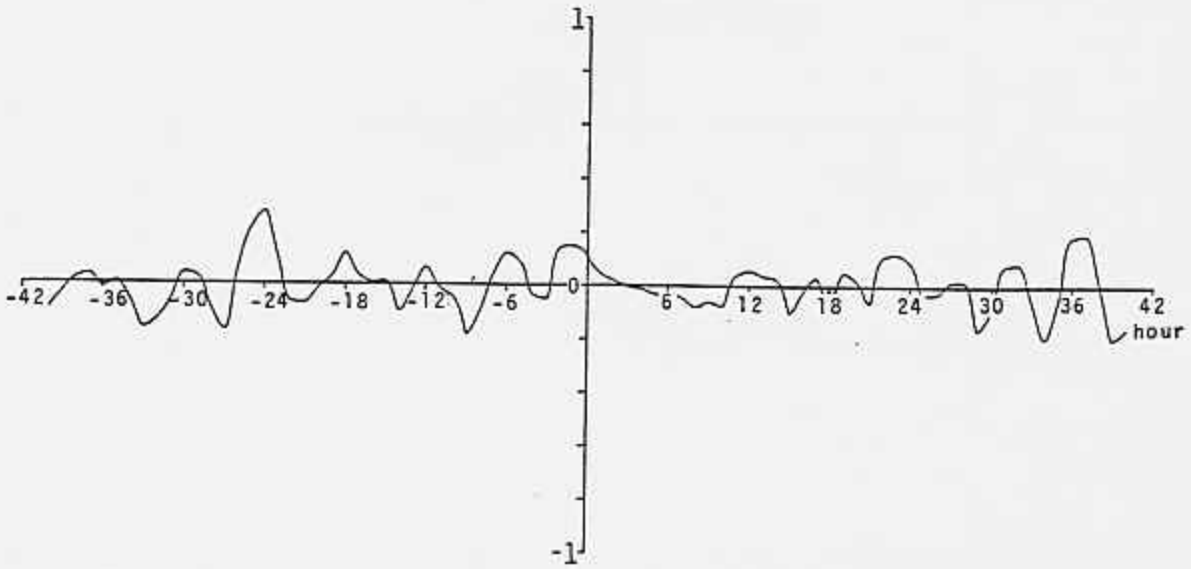


Fig.16 Correlation between quatities of transfer and that of recycling water

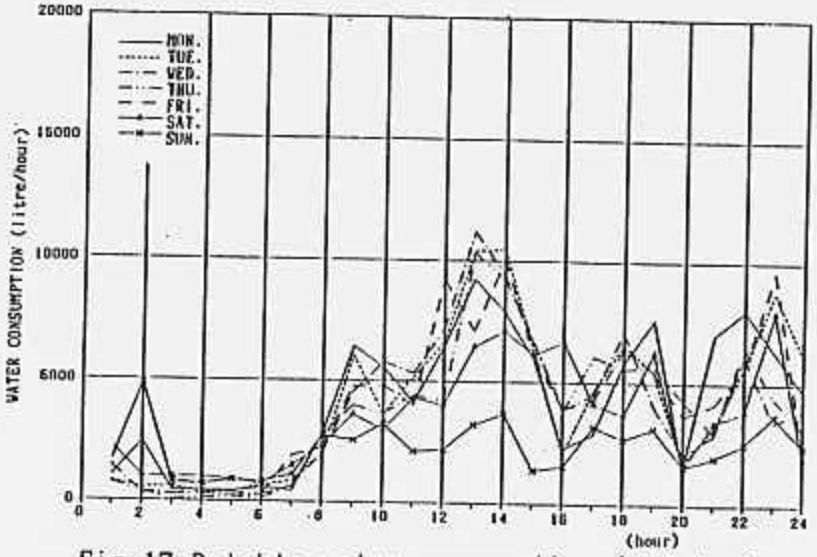


Fig.17 Potable water consumption (Kitchen)

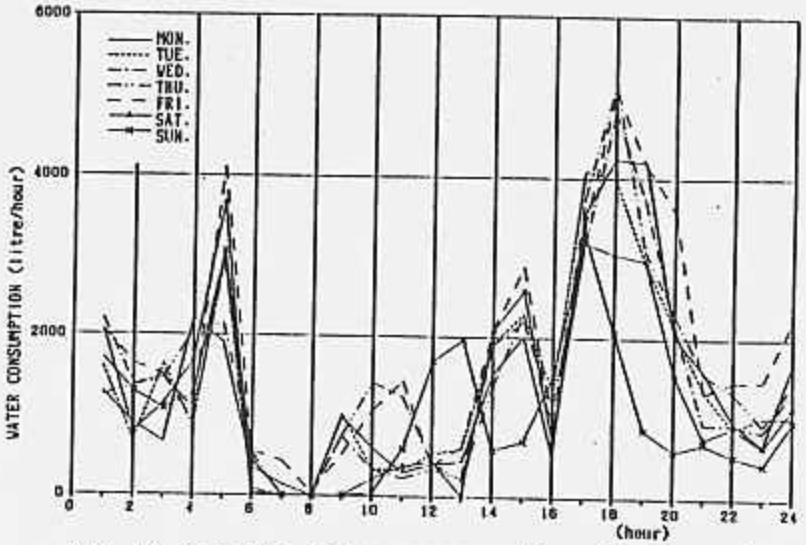


Fig.18 Potable water consumption (Bathroom)

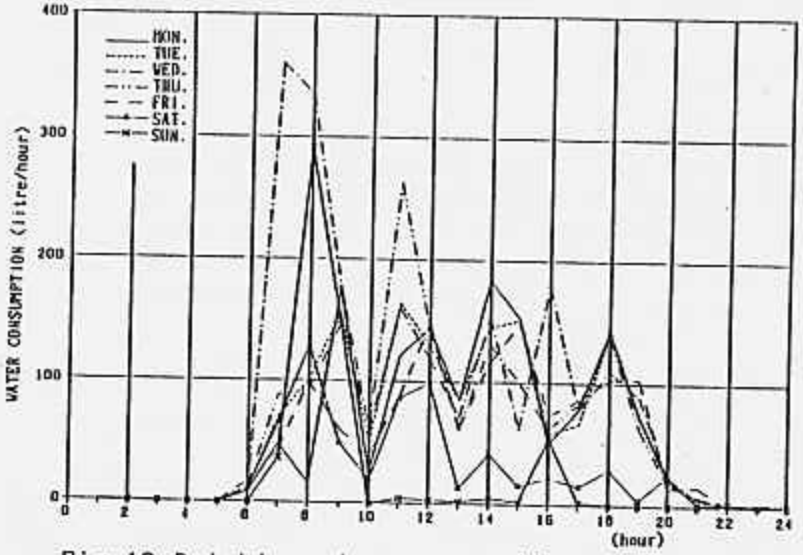


Fig.19 Potable water consumption
(Wash basin:higher floors)

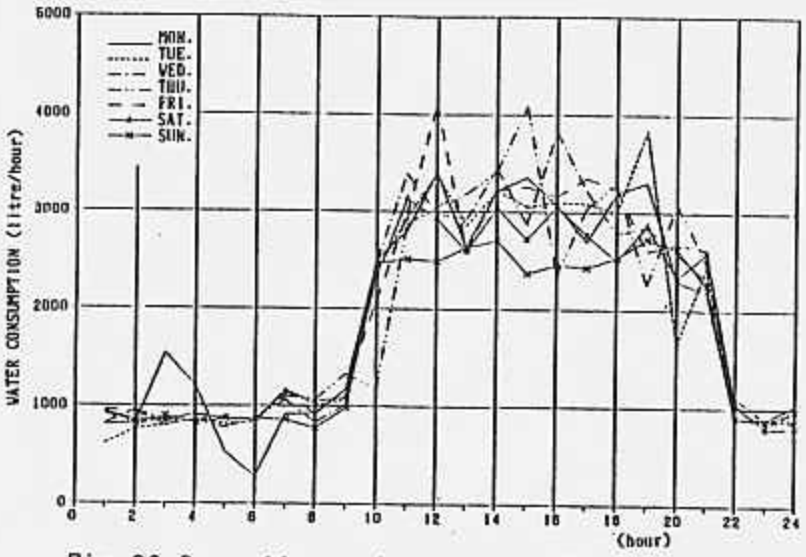


Fig.20 Recycling water consumption
(Toilet:higher floors)

in these figures show percentage to the total water consumption of the day. Much more makeup water to recycling water is used compared with the design values shown by the left side bar. As for the recycling water, especially much flush water of tiolet is used on lower floors. This may be attributed to the short interval time of automatic flushing system of urinal.

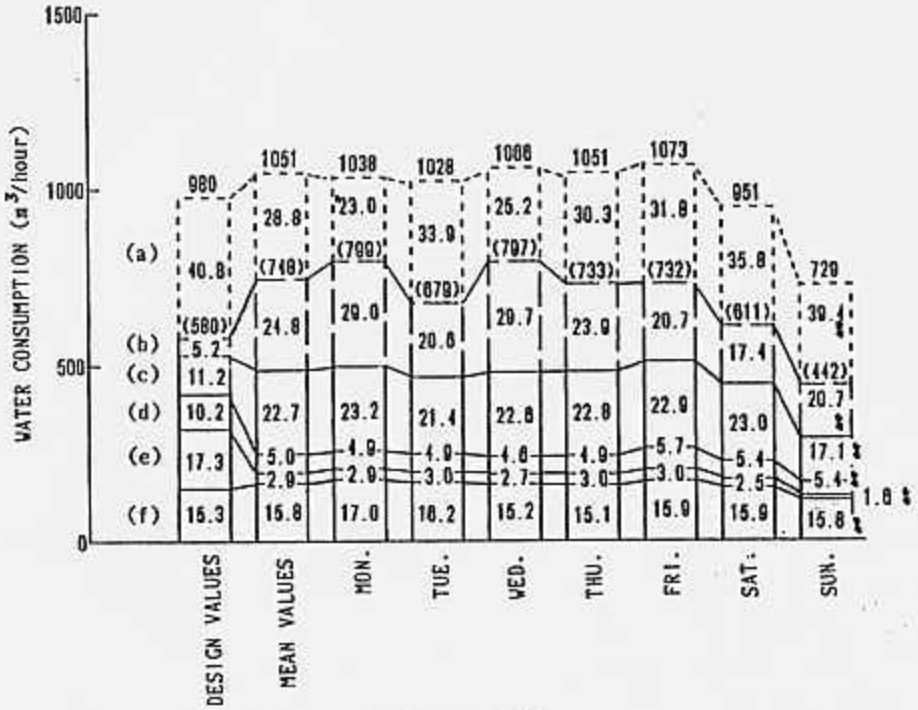
As mentioned in 3.3 the quantities of drainage water is about 83 m^3/day on average, it is necessary to consider more effective recycling water system.

Table.3 and 4 show the water consumption in various units. The former shows for the total water consumption and the latter for the local water consumption used for various purposes.

The data in these table generally coincide to the data reported before, except for the data of refectory.

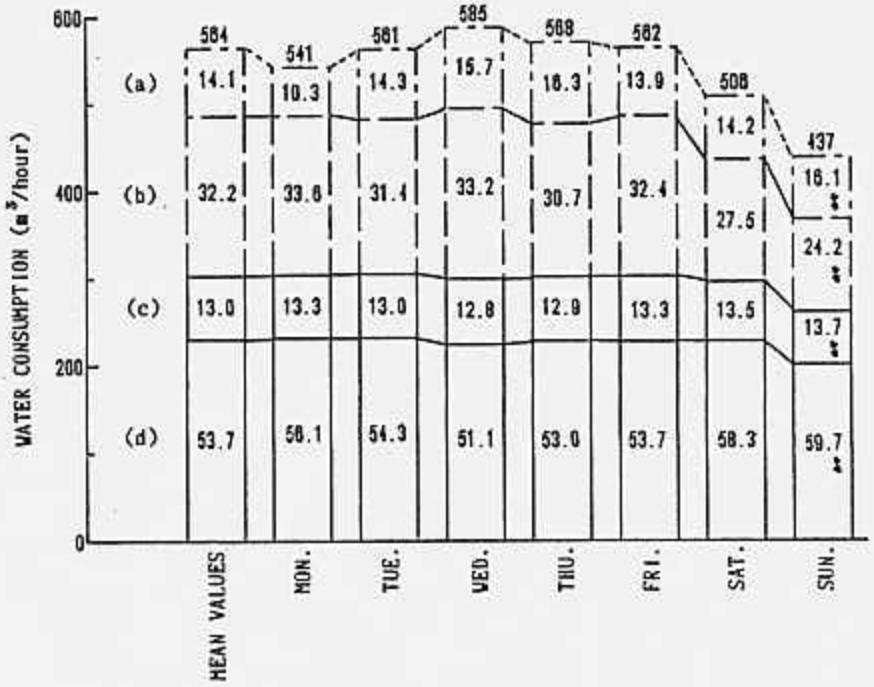
Acknowledgment

The program named TIMSAC (Time Series Analysis and Control) of the Institute of Statistical Mathematics was used for the analysis of data, and help given the Institute is greatly appreciated.



(a) RECYCLING WATER CONSUMPTION
(b) MAKEUPWATER TO RECYCLING WATER
(c) POTABLE WATER CONSUMPTION IN THE BASIN, TENANT, AND SO ON
(d) POTABLE WATER CONSUMPTION IN THE BATH
(e) FLUSHING WATER FOR PHOTOGRAPHIES
(f) POTABLE WATER IN THE KITCHEN

Fig.21 Total water consumption used for various purpose every day of the week



(a) WATER CONSUMTION FOR SPRINKLING, AND SO ON
(b) MAKEUP WATER TO COOLING TOWERS
(c) FLUSH WATER OF TOILET ON THE HIGHER FLOORS
(d) FLUSH WATER OF TOILET ON THE LOWER FLOORS

Fig.22 Recycling water consumption used for various purpose every day of the week

Table.3 Total water consumption in various units

	POTABLE WATER		RECYCLING WATER	TOTAL	REMARKS
	COLD	HOT			
PER HEAD BASED ON THE REGISTERED PEAPLES (litre/person・day)	112.4	56.2	205.5	374.1	
PER HEAD BASED ON THE TOTAL NUMBER OF PEAPLES (litre/person・day)	36.6	18.3	66.8	121.6	＊ 91.2
PER SPACE BASED ON THE TOTAL FLOOR SPACE (litre/㎡・day)	4.8	2.4	8.8	16.1	
PER FIXTURE UNIT (litre/F.U・day)	72.5	36.3	132.5	241.3	

＊ Total water consumption for 8 hour a day

Table.4 Local water consumption used for various purposes in units

		POTABLE WATER		TOTAL	REMARKS
		COLD	HOT		
REFECRORY	PER ONE CUSTOMER (litre/person・day)	35.2	25.8	61.0	
	PER ONE MEAL (litre/person・day)	33.4-31.2	24.5-22.9	57.9-54.1	
TEAROOM	PER ONE CUSTOMER (litre/person・day)	4.9	58.1	63.0	1.85litre/person・15minutes
BARBER	PER ONE CUSTOMER (litre/person・day)	60.0	12.7	72.7	2.14litre/person・15minutes
BATHROOM	PER ONE USER (litre/person・day)	85.4	15.96	101.3	

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CIB

CIB-W62 SYMPOSIUM

WC Flushing Cisterns

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April 9,~10, 1985

TOKYO, JAPAN



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WC flushing cisterns

12th CIB-W62 SYMPOSIUM -TOKYO-
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10,-1985 : KENCHIKU KAIKAN

Summary

In 1984 a new edition of the standard for flushing cisterns has been published in Germany. In order to save water now it is allowed to disign flushing cisterns in a way, that the custumer can interrupt the flushing process. An other aspect is the development of a new generation of WCs, which need only 6 l of water per one flush instead of 9 l. Flushing cisterns have to operate with both types.

Résumé

1984 en Allemagne on a publié une edition nouvelle de la norme des réservoirs de chasse. Pour économiser de l'eau, on peut construer les réservoirs de chasse, où le processus peut être interompé. Un autre point de vue est le développement d'un génération nouveau de WCs, qui marchant avec 6 litres au lieu de 9 litres. Les réservoirs des chasse sont tenus de travailler avec les deux volumes.

Zusammenfassung

Im Jahr 1984 erschien in Deutschland eine neue Ausgabe der Norm für Spülkästen. Um Wasser sparen zu können, dürfen sie jetzt so konstruiert werden, daß der Spülvorgang vom Benutzer unterbrochen werden kann. Ein weiterer Gesichtspunkt ist die Entwicklung einer neuen Generation von Klosettbecken, die mit 6 l Wasser statt mit 9 l gespült werden können. Spülkästen müssen auf beide Volumen einstellbar sein.

1. Situation of flushing devices and WCs in Germany

With a population of about 62 millions people in the Federal Republic of Germany there are about 25 millions of WCs, wash out and wash down type, while the syphonic type is nearly not important. About 50 per cent are supplied by flush water from flushing valves, the other 50 per cent from flushing cisterns. You will find also some combinations, i.e. WC bowl combined with a flushing cistern, which is fixed upon the WC. Among the flushing cisterns this are about 10 - 15 per cent. The water supply system consists of pressure pipes up to 10 bar. The performance requirement for WCs therefor ist that they have to be suitable both for flushing valves and flushing cisterns (except combinations). Otherwise they would not be fully interchangable in practice, what is a strong demand by the plumbers association.

The technical specifications for WCs itsselves are layed down in some standards containing only measures, while the performance requirements are given in principles for contruction and testing (BPG), edited by the Institute for civil engineering (IfBt). In 1985 they will be published as a draft DIN 1385.

The technical specifications for flushing valves are layed down in DIN 3265, edition of 1966. Now this standard is in revision.

The technical specifications for flushing cisterns are given in DIN 19 542. The first edition of this standard from 1970 now has been replaced by the new one of october 1984 (see annex 1).

The average service life of a flushing cistern could be estimated of about 20 years, so the volume of the market may be about 0,6 million flushing cisterns per year.

Until today the amount of flush water for a wash out or wash down closet was 9 l generally. During a long time research work Prof. Knoblauch and others found out, that it was possible to reduce this figure to 6 l under the additional condition for the design of closets that the excreta are followed by at least 2,5 l of water. If there are no excreta, it is admittable to flush with about 3 l. These figures are the outlines for the new functional requirements both for flushing valves and for flushing cisterns.

2. Water saving aspects of the new standard DIN 19 542 for flushing cisterns

The old edition of the standard DIN 19 542 from 1970 didn't allow any interruption of the flushing process. In each flush event 9 l of water left the flushing cistern. All WCs which are now installed, were designed for this amount of flush water and received an official approval when they met in a mandatory test the functional and hygienical requirements based upon this figure. Although there is in general no lack of water in Germany it has been required to save water by reducing the flush volume. Last not least the problem received a political dimension by the activity of politicians and those who thaught to be politicians which were the most active. One of biggest arguments was that there is no need to use 9 l of water for each flush, it is only necessary in case of excreta. Per person in average there are five flushes a day, but only in one case you need 9 l, while in the other four to five cases one should use only 3 l. So one could save 4 x 6 = 24 l per capita and day out of 5....6 x 9 $\cong$ 50 l per capita and day. And a boom in offerts of water saving equipments for installed flushing cisterns was observed in the market, especially in the

do-it-yourself area.

The technical guidance for those operations is given in the new standard (see 3.2.4), and this reads as followes:

"Devices for reducing the flush water volume or for the interruption of the flushing process are admitted. The guide value should be at least 3 l. The devices have to be designed to allow the interruption of a started flush by an operation of the customer (by hand) or automatically after a minimum flush volume of 3 l. In all cases the flow rate has to be the same as for a full flush and the cistern has to be refilled immediately. When interrupted by operation of the customer (by hand) the refilling has to start within 1,5 s after the beginning of the flushing process."

The time limit for refilling a volume of 6 l is 120 s and for 9 l it is 180 s.

The discussions about pro and contra in the technical expert groups started about three years ago. Nowadays you will find nearly all the new developed flushing cisterns with the possibility for interruption. But as already mentioned, it will take about 20 years until the new generation of flushing cisterns is installed everywhere.

This is understood as lasting too long. So it will be accepted also to change the behavior of installed flushing cisterns by replacing part of their elder interior equipment by newer ones. But such a new equipped old cistern then has to do its job like a new one, otherwise this equipment would not receive an approval. Until the end of the year 1984 no official aprrovals were given for those equipments.

3. Flushing cisterns for testing WCs

For testing WCs there are designed two types of test cisterns. One is for floor standing WCs, the other for wall hanging WCs. They are shown in annex 2 and 3. These test cisterns also are in discussion within the relevant committee of CEN to become test cisterns for all countries in Western Europe as far as the national standards institutions are members of CEN. While the old type 9 l WCs are tested not so severely as the water saving type of the future with only 6 l the distance between surface of the bowl and bottom of the cistern is either 185 mm (9 l) or 120 mm (6 l). This is found the most critical test situation, so no other plumbing situations are simulated yet.

DK 621.647.7 : 696.141.1 : 644.68 : 001.4 : 620.1 DEUTSCHE NORM Oktober 1984

Spülkästen für Klosettbecken

Bau- und Prüfgrundsätze

DIN 19 542

Flushing cisterns; principles for construction and testing

Réservoirs de chasse pour WC; principles de construction et d'essais

Ersatz für Ausgabe 03.70

ANNEX 1

Maße in mm

Inhalt

Seite

1 Anwendungsbereich 1
2 Begriffe 1
3 Baugrundsätze und Anforderungen 4
4 Prüfgrundsätze 6
5 Kennzeichnung 12

1 Anwendungsbereich

Diese Norm gilt für Spülkästen für Klosettbecken. Sie legt Bau- und Prüfgrundsätze fest und regelt die Kennzeichnung.

2 Begriffe

2.1 Benennungen und Erklärungen

Benennung	Einheit	Erklärung (Definition)
Abflußstutzen		Verbindung zwischen Spülkasten und Spülrohr
Ablaufventil		Ventil zum Öffnen und Schließen der Ablauföffnung im Spülkastenboden
Absperrventil		Ventil zur Trennung des Füllventils von der Wasserleitung
Betätigungsvorrichtung		Einrichtung, die das Öffnen und gegebenenfalls das Schließen des Ablaufventils bewirkt
Einbauteile		Teile, die aus einem installierten Spülkasten mit einfachen Mitteln ausgebaut werden können, z. B. Füllventil, Betätigungsvorrichtung, Ablaufventil
Energiehöhe	mm	Abstand zwischen dem Nennwasserstand im Spülkasten und der horizontalen Achse des Spülrohres
Fließdurck	bar	Statischer Überdruck in der Wasserleitung vor dem vollständig geöffneten Füllventil
Füllventil		Ventil, durch das der Spülkasten bis zu einem vorgegebenen Wasserstand selbsttätig gefüllt wird
Füllzeit	s	Zeit, in der das Füllventil den Spülkasten vom Restwasserstand bis zum Nennwasserstand füllt
Funktionsfeld		Das für den Spülstrom zulässige Toleranzfeld, abhängig von den geometrischen Gegebenheiten von Spülkasten und Spülrohr sowie von der Prüfhöhe

Fortsetzung Seite 2 bis 14

Normenausschuß Wasserwesen (NAW) im DIN Deutsches Institut für Normung e.V.

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Vertr.-Nr. 0010

Benennung	Einheit	Erklärung (Definition)
Montagehöhe	mm	Abstand zwischen Oberkante Klosettbecken und Unterkante Spülkasten
Nennwasserhöhe	mm	Abstand zwischen Restwasserstand und Nennwasserstand
Nennwasserstand		Lage des Wasserspiegels beim erforderlichen Spülwasservolumen
Prüfhöhe	mm	Abstand zwischen der Achse des horizontalen Teils des Spülrohres und der Unterkante des Spülkastens (entspricht der Montagehöhe plus 45 mm)
Restwasserstand		Lage des Wasserspiegels nach abgeschlossenem nicht unterbrochenem Spülvorgang bei geschlossenem Füllventil
Restwasservolumen	l	Wasservolumen, das nach abgeschlossenem Spülvorgang ohne Unterbrechung und bei geschlossenem Füllventil im Spülkasten vorhanden ist
Ruhedruck	bar	Statischer Überdruck in der Wasserleitung vor geschlossenem Füllventil
Sicherheitsabstand	mm	Abstand zwischen höchstem Nennwasserstand und Überlaufhöhe
Spülkasten		Gegenstand zum Spülen von Klosettbecken, der das über ein Füllventil zugeführte Wasser speichert und es nach Bedienen einer Betätigungsvorrichtung an das Klosettbecken abgibt
Spülrohr		Rohr zwischen Spülkasten und Klosettbecken
Spülstrom	l/s	Das aus einem Spülrohr mit Spülstromdrossel zeitbezogen stationär austretende Spülwasservolumen
Spülstromdrossel		Drosselstück am Ende des waagerechten Schenkels des Spülrohres, um dessen Vollfüllung sicherzustellen
Spülwasservolumen	l	Während eines Spülvorganges abfließendes Wasservolumen
Überlauf		Sicherung gegen Überlaufen des Behälters
Überlaufhöhe	mm	Höchstmöglicher Wasserstand im Spülkasten

2.2 Funktionsschema eines Spülkastens

Bild 1 zeigt beispielhaft die vereinfachte zeichnerische Darstellung eines Spülkastens.

Andere Funktionsprinzipien, die den Anforderungen nach Abschnitt 3 entsprechen, sind zulässig.

1 Behälter
2 Ablaufventil mit Überlauf
3 Spülrohr nach DIN 3268
4 Füllventil mit Schwimmer
5 Absperrventil [1)]
6 Deckel
7 Betätigungsvorrichtung

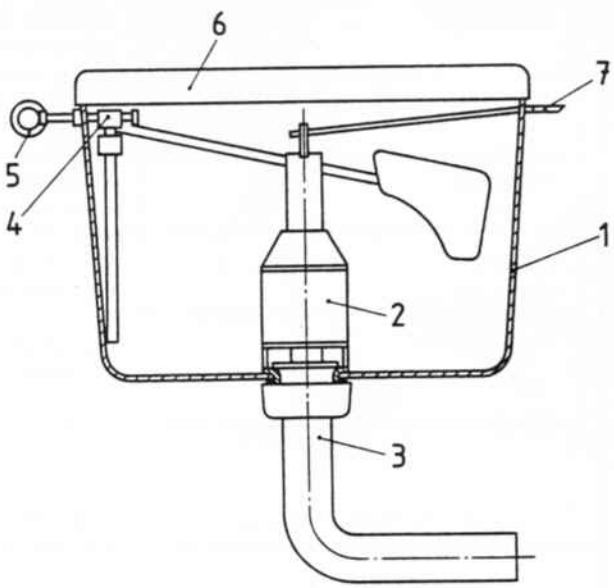


Bild 1. Funktionsschema eines Spülkastens

1) Wird durch diese Norm nicht erfaßt.

2.3 Ausführungsarten

a)		Tiefhängender Spülkasten
b)		Wandeinbau-Spülkasten
c)		Halbhochhängender Spülkasten
d)		Hochhängender Spülkasten
e)		Zweistückanlage, Spülkasten aufgesetzt
f)		Einstückanlage, Spülkasten angeformt

Bild 2. Beispiele von Ausführungsarten

3 Baugrundsätze und Anforderungen

3.1 Prüfhöhen und hydraulische Anforderungen

Spülkästen sind auf die hydraulischen Werte entsprechend Tabelle 1 auszulegen.

In Tabelle 1 werden folgende Kurzzeichen verwendet:

TB Tiefspülklosett, bodenstehend
TW Tiefspülklosett, wandhängend
FB Flachspülklosett, bodenstehend
FW Flachspülklosett, wandhängend
AB Absaugeklosett, bodenstehend
AW Absaugeklosett, wandhängend

Tabelle 1.

Lfd. Nr	Klosettart	Ausführungsart	Prüfhöhe mm		Spülwasservolumen l	Spülstrom mit Spülstromdrossel Grenzwerte l/s
1	TB TW FB FW	tiefhängender Spülkasten	165	295	6 bis 9	2,2 bis 2,9
2	AB AW	tiefhängender Spülkasten	165	295	6 bis 14	2,2 bis 2,9
3	TB TW FB FW	Wandeinbau-Spülkasten	165	295	6 bis 9	2,0 bis 2,6
4	AB AW	Wandeinbau-Spülkasten	165	295	6 bis 14	2,0 bis 2,6
5	TB TW FB FW	halbhochhängender Spülkasten	545	745	6 bis 9	1,7 bis 2,2
6	TB TW FB FW	hochhängender Spülkasten	1345	1545	6 bis 9	1,7 bis 2,2
7	TB TW FB FW	Zweistückanlage	–	–	6 bis 9	wird nicht geprüft
8	AB AW	Zweistückanlage	–	–	6 bis 14	wird nicht geprüft
9	TB TW FB FW	Einstückanlage	–	–	6 bis 9	wird nicht geprüft
10	AB AW	Einstückanlage	–	–	6 bis 14	wird nicht geprüft

Im Hinblick auf den Einbau in Altbauten muß bei Spülkästen nach der lfd. Nr 1, 3, 5 und 6 die Einstellung auf 9 l Spülwasservolumen möglich sein, für Spülkasten der lfd. Nr 2 und 4 die Einstellung auf 14 l.

3.2 Allgemeine Anforderungen

3.2.1 Lebensdauer

Die verwendeten Werkstoffe sowie die Art der Konstruktion müssen bei bestimmungsgemäßem Gebrauch eine angemessene Lebensdauer erwarten lassen.

3.2.2 Geräuschverhalten

Spülkästen müssen hinsichtlich ihres Geräuschverhaltens mindestens der Armaturengruppe II nach DIN 4109 Teil 5 (z. Z. Entwurf) entsprechen.

3.2.3 Füllvorgang

Spülkästen müssen sich selbsttätig füllen.

3.2.4 Wassersparen

Vorrichtungen zur Verringerung des Spülwasservolumens oder zur Unterbrechung des Spülvorganges sind zulässig. Dabei sollte als Spülwasservolumen mindestens 3 l (Richtwert) gewählt werden. Vorrichtungen zur Unterbrechung sind so auszubilden, daß der eingeleitete Spülvorgang entweder durch eine Betätigung unterbrochen werden kann oder selbsttätig nach Ablauf eines Wasservolumens von mindestens 3 l unterbrochen wird. In allen Fällen muß der Spülstrom entsprechend Tabelle 1 eingehalten werden und die Wiederauffüllung des Spülkastens bis Nennwasserstand sichergestellt sein. Im Falle der Unterbrechung durch eine Betätigung der hierfür vorgesehenen Vorrichtung muß die Wiederauffüllung spätestens 1,5 s nach Auslösung des Spülvorganges begonnen haben; ist jedoch konstruktionsbedingt eine Unterbrechung erst nach einer längeren Zeit als 1,5 s möglich, so muß die Wiederauffüllung vor dem Zeitpunkt der möglichen Unterbrechung begonnen haben.

3.3 Füllventil

3.3.1 Wasserzuleitung

Das Wasser ist dem Spülkasten über ein Füllventil zuzuleiten.

3.3.2 Trinkwasserschutz

Bei höchstmöglichem Wasserstand im Spülkasten (Überlaufhöhe) und einem negativen Überdruck von 0,8 bar in der Zuleitung darf es beim Spülkasten, der an eine Trinkwasserleitung angeschlossen werden kann, zu keiner Rücksaugung des im Spülkasten befindlichen Wassers kommen.

3.3.3 Ausbau

Das Füllventil muß so angeordnet sein, daß es ohne Lösen des Spülkastens aus diesem ausgebaut werden kann.

3.3.4 Anordnung

Das Füllventil muß unabhängig von der Anschlußsituation im Spülkasten so montiert sein, daß die Anforderung nach Abschnitt 3.3.2 erfüllt ist. Die Befestigung des Füllventils im Spülkasten ausschließlich an eine flexible Anschlußleitung ist unzulässig.

3.3.5 Werkstoff

Die für das Füllventil verwendeten Werkstoffe müssen eine hohe Alterungs- und Korrosionsbeständigkeit aufweisen. Nicht hinreichend korrosionsbeständige Werkstoffe müssen korrosionsgeschützt sein. Diejenigen Teile des Füllventils, die mit Trinkwasser in Berührung kommen, dürfen das Trinkwasser in seiner Qualität nicht beeinträchtigen. Bei Verwendung von nichtmetallischen Werkstoffen, die mit Trinkwasser in Berührung kommen, ist der Nachweis der hygienischen Unbedenklichkeit nach den KTW-Empfehlungen (Bereich Ausrüstungsgegenstände) *) zu führen, falls die verwendeten Werkstoffe in der Positiv-Liste der KTW-Empfehlungen nicht aufgeführt sind und die Prüfstellen diesen Nachweis verlangen.

Das Füllventil muß einen Gewindeanschluß nach DIN ISO 228 Teil 1 und Teil 2 (z. Z. Entwurf) für DN 10 aufweisen.

3.3.6 Einstellvorrichtungen

Vorrichtungen zum Einstellen des Spülwasservolumens sind so herzustellen, daß sie allen vorkommenden Beanspruchungen genügen und ein selbsttätiges Verstellen ausgeschlossen ist.

3.3.7 Füllzeiten

Bei einem Fließdruck von 0,5 bar dürfen die in Tabelle 2 angegebenen Füllzeiten nicht überschritten werden:

Tabelle 2.

Volumen in l	Füllzeit in s
6	120
9	180
14	280

3.3.8 Druckbeanspruchung

Alle druckbeanspruchten Teile des Füllventils müssen mindestens 10 Minuten lang einem Prüfdruck von 16 bar standhalten. Sie müssen dabei dicht bleiben und dürfen danach keine Formveränderung oder sonstige Mängel erkennen lassen.

3.3.9 Funktionsfähigkeit

Das Füllventil muß ohne Nachregulierung bei einem Fließdruck von 0,5 bar bis zu einem Ruhedruck von 10 bar funktionsfähig sein. Bei beiden Überdrücken muß das Füllventil schließen. Der Überlauf des Spülkastens darf dabei nicht ansprechen.

3.3.10 Druckstöße

Das Füllventil darf beim Schließen keine Druckstöße erzeugen, die den Ruhedruck um mehr als 2 bar übersteigen.

3.3.11 Wasseranschluß

Wird der Wasseranschluß für das Füllventil unterhalb der Überlaufhöhe durch den Spülkasten geführt, so muß das Zuleitungsrohr im Spülkasten aus korrosions- und alterungsbeständigem Werkstoff bestehen. Eine sichere und dauerhafte Abdichtung beim Durchführen der Wasserzuleitung durch den Spülkasten muß sichergestellt sein.

Der Wasseranschluß für Wandeinbauspülkästen muß oberhalb der Überlaufhöhe angeordnet sein.

3.4 Behälter

3.4.1 Wandungen

Die Behälterwandungen müssen so formstabil sein, daß die bei fachgerechter Montage und bei Betätigung auftretenden Kräfte weder Verformungen bewirken noch die Funktion des Spülkastens beeinträchtigen.

*) Herausgegeben vom Bundesgesundheitsamt, Corrensplatz 1, 1000 Berlin 33 (zu beziehen durch Carl Heymanns Verlag KG, Gereonstraße 18–22, 5000 Köln 1).

3.4.2 Deckel

Der Behälter muß mit einem abnehmbaren Deckel versehen sein, der gegen Abgleiten gesichert ist. Wandeinbauspülkästen müssen eine Öffnung mit abnehmbarer Abdeckplatte aufweisen. Diese Öffnung muß so groß sein, daß die Funktion des Spülkastens und die mit dem Spülkasten nicht fest verbundenen Einbauteile jederzeit überprüft und letztere erforderlichenfalls verstellt oder ausgewechselt werden können.

Auf einen Deckel kann dann verzichtet werden, wenn der Spülkasten Bestandteil eines vorgefertigten WC-Elementes ist oder in einem Möbelelement integriert ist und diese Elemente eine Abdeckung aufweisen, die den Spülkasten-Deckel ersetzt.

3.4.3 Überlauf

Jeder Spülkasten muß einen Überlauf haben, der das über das Füllventil zulaufende Wasser bei einem Ausgangs-Ruhedruck von 10 bar sicher ableitet. Nicht wasserdicht verschlossene Ausschnitte, Bohrungen und sonstige Öffnungen im Spülkasten müssen so weit oberhalb der Überlaufhöhe angeordnet sein, daß kein Wasser austreten kann.

3.4.4 Sicherheitsabstand

Zwischen dem höchsten Nennwasserstand und der Überlaufhöhe muß ein Sicherheitsabstand von mindestens 20 mm vorhanden sein (siehe Bild 3). Der jeweilige Nennwasserstand ist entsprechend den Spülwasservolumen nach Tabelle 1 im Spülkasten deutlich und dauerhaft zu markieren. Die Markierung im Spülkasten darf bis 5 mm über bzw. unter dem Nennwasserstand liegen.

3.4.5 Nachfüllvorrichtung

Spülkästen für Absaugeklosetts sind mit einer Nachfüllvorrichtung auszurüsten. Das Nachfüllwasservolumen muß bei einem Fließdruck von 0,5 bar mindestens 2,0 l betragen. Von dieser Anforderung sind die Spülkästen ausgenommen, die ausschließlich auf ein Absaugeklosett mit Nachfüllvorrichtung (z. B. eine Tasche) fest montiert werden können.

3.4.6 Spülrohranschluß

Der Anschluß für das Spülrohr muß lösbar und so ausgebildet sein, daß eine Längentoleranz des Spülrohres bis 10 mm ausgeglichen werden kann.

3.4.7 Abflußstutzen

Der Abflußstutzen ist so auszubilden, daß die Verbindung mit einem Spülrohr nach DIN 3268 erfolgen kann, von dieser Anforderung sind Spülkästen für Klosettkombinationen ausgenommen.

3.5 Ablaufventil

3.5.1 Ausführung

Das Ablaufventil muß aus dauerhaftem Werkstoff hergestellt und leicht zu betätigen sein. Sitze und Führungen müssen eine korrosionsbeständige Oberfläche aufweisen. Sämtliche Teile sind so anzuordnen, daß sie, mit Ausnahme des eventuell angeformten Sitzes, ohne Lösen des Spülkastens ausgebaut werden können.

3.5.2 Schließfunktion

Das Ablaufventil muß den Spülkasten nach jedem Spülvorgang selbsttätig und sicher abschließen.

3.5.3 Dichtung

Die Dichtung des Ablaufventils muß formbeständig und auswechselbar sein.

3.6 Kombination von Spülkästen mit Lüftungsanlagen

Beim Einbau von Lüftungsanlagen in Spülkästen zum Zwecke der Entlüftung von WC-Räumen muß sichergestellt sein, daß die Abluft aus den Klosettbecken nicht mit dem Raum über der Wasseroberfläche des Spülkastens in Verbindung tritt. Hierbei ist die Abluft als Fortluft abzuführen. Die allgemein anerkannten Regeln der Lüftungstechnik, insbesondere DIN 18017 Teil 3, bleiben hiervon unberührt. Die elektrische Anlage muß den VDE-Bestimmungen entsprechen.

4 Prüfgrundsätze

4.1 Prüfunterlagen

4.1.1 Zeichnungen und Werkstoffangaben

Vom Hersteller oder Auftraggeber sind der Prüfstelle für die Prüfung in vierfacher Ausfertigung in deutscher Sprache mitzuliefern:

a) Dauerhafte Zeichnungen (z. B. Lichtpausen) – Format nach DIN 823 und gefaltet nach DIN 824 – mit Datum und rechtsverbindlicher Unterschrift, Schriftfeld mit Angabe des Antragstellers, gegebenenfalls auch des Herstellers, der Benennung des Antragsgegenstands und einer Typ- und Zeichnungsnummer.

Die Zeichnungen sollen mindestens enthalten:

- Darstellung der Ansicht des Spülkastens einschließlich aller beantragten Varianten,
- Schnittdarstellung des Füll- und Ablaufventils,

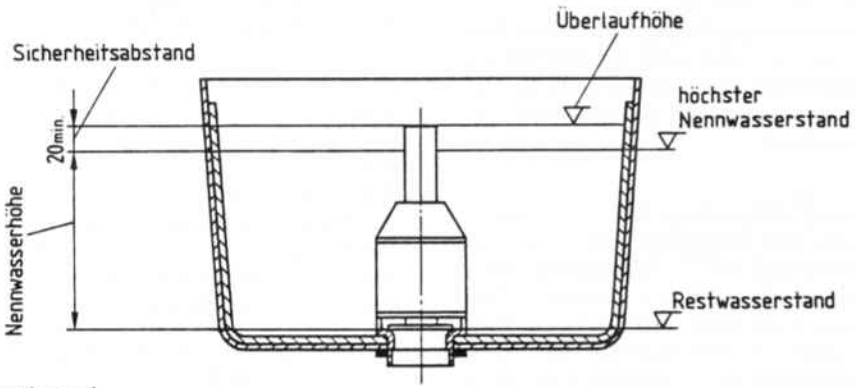


Bild 3. Sicherheitsabstand

- wesentliche Baumaße des Spülkastens,
- Stückliste mit Angabe der Werkstoffe (keine Markennamen, keine Leerfelder),
- Stelle, an der beabsichtigt ist, den Spülkasten mit dem Herstellerzeichen und dem DIN-Prüf- und Überwachungszeichen mit Registernummer zu kennzeichnen; das Herstellerzeichen ist darzustellen.

b) Eine Funktionsbeschreibung, soweit erforderlich.

4.1.2 Prüfstücke

Die Prüfstücke – ein kompletter Spülkasten und zwei weitere Füllventile – sind der Prüfstelle zur Verfügung zu stellen und für die Gültigkeitsdauer der Zeichengenehmigung zu überlassen.

4.2 Prüfumfang

Die Übereinstimmung der Prüfstücke mit den eingereichten Prüfunterlagen und den Anforderungen nach Abschnitt 3 ist zu prüfen. Die Prüfung ist, wenn mehrere Spülkastenmodelle vorgelegt werden, an jedem Typ durchzuführen.

Bei Verwendung desselben Füllventils in mehreren Spülkastenmodellen gelten Spülkästen mit anderen Abmessungen oder verschiedenen Anschlußarten und Betätigungseinrichtungen als Varianten desselben Typs. In diesem Fall kann die Prüfstelle nach eigenem Ermessen auf nicht mit der Prüfung des Füllventils zusammenhängende Prüfungen verzichten. Eine erneute Prüfung nach den Abschnitten 4.4.7, 4.4.8, 4.4.9 und 4.4.11 ist nicht mehr erforderlich, wenn ein Füllventil bereits im Zusammenhang mit einem anderen Spülkasten geprüft wurde und das Prüfergebnis positiv war.

Eine erneute Prüfung des Geräuschverhaltens nach Abschnitt 4.4.24 ist nicht erforderlich, wenn das Füllventil in einem anderen Spülkasten bei einem Fließdruck von 3 bar einen Gruppengrenzwert $L_{AG} \leq 17$ dB(A) bzw. $L_{AG} \leq 27$ dB(A) nachweislich erreicht hat.

Die Prüfung der Wiederauffüllbereitschaft nach Unterbrechung (siehe Abschnitt 4.4.4) ist 5mal durchzuführen. Der Spülstrom (siehe Abschnitt 4.4.2) ist als Mittelwert aus 10 Messungen anzugeben. Alle übrigen Prüfungen sind einmal durchzuführen. Alle Prüfungen müssen bestanden sein.

4.3 Verfahrensgang

4.3.1 Typprüfung

Die Übereinstimmung von Spülkästen mit den Anforderungen dieser Norm ist durch eine Typprüfung nachzuweisen. Die Typprüfung umfaßt die Prüfung nach Abschnitt 4.4; sie ist nach 5 Jahren zu wiederholen. Die Typprüfung kann auch als Ergänzungsprüfung nach Abschnitt 4.3.2 durchgeführt werden.

4.3.2 Ergänzungsprüfung

Eine Ergänzungsprüfung dient der Feststellung, ob und gegebenenfalls welche Einflüsse durch Änderungen an bereits typgeprüften Spülkästen hinsichtlich der seinerzeit erzielten Prüfergebnisse hervorgerufen werden. Die Ergänzungsprüfung wird als Typprüfung nach Abschnitt 4.3.1 durchgeführt, jedoch können im Ermessen der Prüfstelle die Teile der Prüfungen wegfallen, auf deren Ergebnisse die Änderung keinen Einfluß hat.

4.3.3 Prüfstellen

Die Typprüfung erfolgt durch eine von der DGWK anerkannte Prüfstelle [2]; Anträge sind vom Antragsteller bei einer der für die Funktionsprüfungen anerkannten Prüfstelle einzureichen. Diese leitet die Prüfgegenstände nach abgeschlossener Funktionsprüfung an eine für die Prüfung des Geräuschverhaltens anerkannte Prüfstelle nach Wahl des Antragstellers weiter, die die bei der Prüfung des Geräuschverhaltens ermittelten Prüfergebnisse der erstgenannten Prüfstelle mitteilt. Diese erstellt den Gesamtprüfbericht.

4.3.4 Prüfbericht

Die für die Funktionsprüfung anerkannte Prüfstelle faßt die Prüfergebnisse der Funktionsprüfung und der Prüfung des Geräuschverhaltens in einem Prüfbericht zusammen, der mindestens folgende Angaben enthalten muß:

a) Auftraggeber
b) Hersteller des geprüften Gegenstandes
c) Beschreibung des geprüften Gegenstandes
d) Prüfergebnisse
e) Feststellung der Normgerechtheit
f) Prüfdatum und Unterschrift des Prüfers.

4.4 Durchführung der Prüfungen

4.4.1 Spülwasservolumen und Nennwasserhöhe

Die Nennwasserhöhen sind in Abhängigkeit vom Spülwasservolumen nach Tabelle 1 durch Auslitern des Spülkastens zu ermitteln. Zur Ermittlung der Nennwasserhöhen wird der Spülkasten zunächst gefüllt. Das Füllventil ist auf den jeweiligen Nennwasserstand einzuregulieren. Danach ist das Füllventil zu arretieren. Nach anschließender Auslösung des Spülvorganges ist der sich einstellende Restwasserstand zu markieren. Wird bei dieser fünfmal durchzuführenden Prüfung ein unterschiedlicher Restwasserstand festgestellt, ist der höchste Restwasserstand maßgebend. Anschließend werden die Nennwasserstände durch Auslitern mit einem geeichten Meßgerät (z. B. Meßglas) ermittelt und markiert.

4.4.2 Spülstrom

4.4.2.1 Gesamtes Spülwasservolumen

Der Spülstrom nach Tabelle 1, Spalte 6, wird entsprechend den Ausführungsarten bei beiden Prüfhöhen nach Tabelle 1, Spalte 4, ohne nachgeschaltetes Klosett und ohne gleichzeitigen Zulauf über das Füllventil gemessen (siehe Bilder 5 bis 8). Er wird wie folgt ermittelt:

Dem Restwasservolumen werden 2,5 l Wasser hinzugefügt; der so erreichte Wasserspiegel ist Meßpunkt für die untere Meß-Sonde. Nach Zugabe von weiteren 3 l Wasser wird in Höhe des dann erreichten Wasserspiegels die obere Meß-Sonde plaziert.

Dann wird der Spülkasten bis zum höchstmöglichen Nennwasserstand gefüllt, die Auslösevorrichtung betätigt und die Zeit gemessen, während der der Wasserspiegel vom oberen zum unteren Meßpunkt sinkt. Der Mittelwert der Spülströme muß Tabelle 1 entsprechen und sich im zugehörigen Funktionsfeld nach Bild 4 befinden.

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2) Auskunft erteilt die Deutsche Gesellschaft für Warenkennzeichnung GmbH (DGWK), Burggrafenstraße 4–10, 1000 Berlin 30.

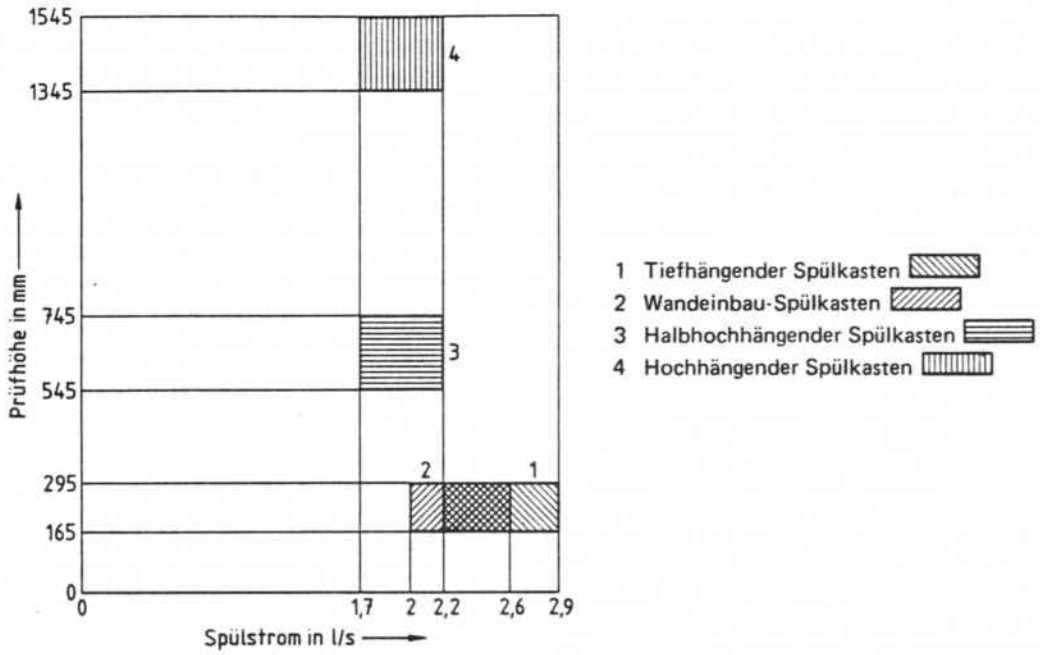


Bild 4. Funktionsfelder

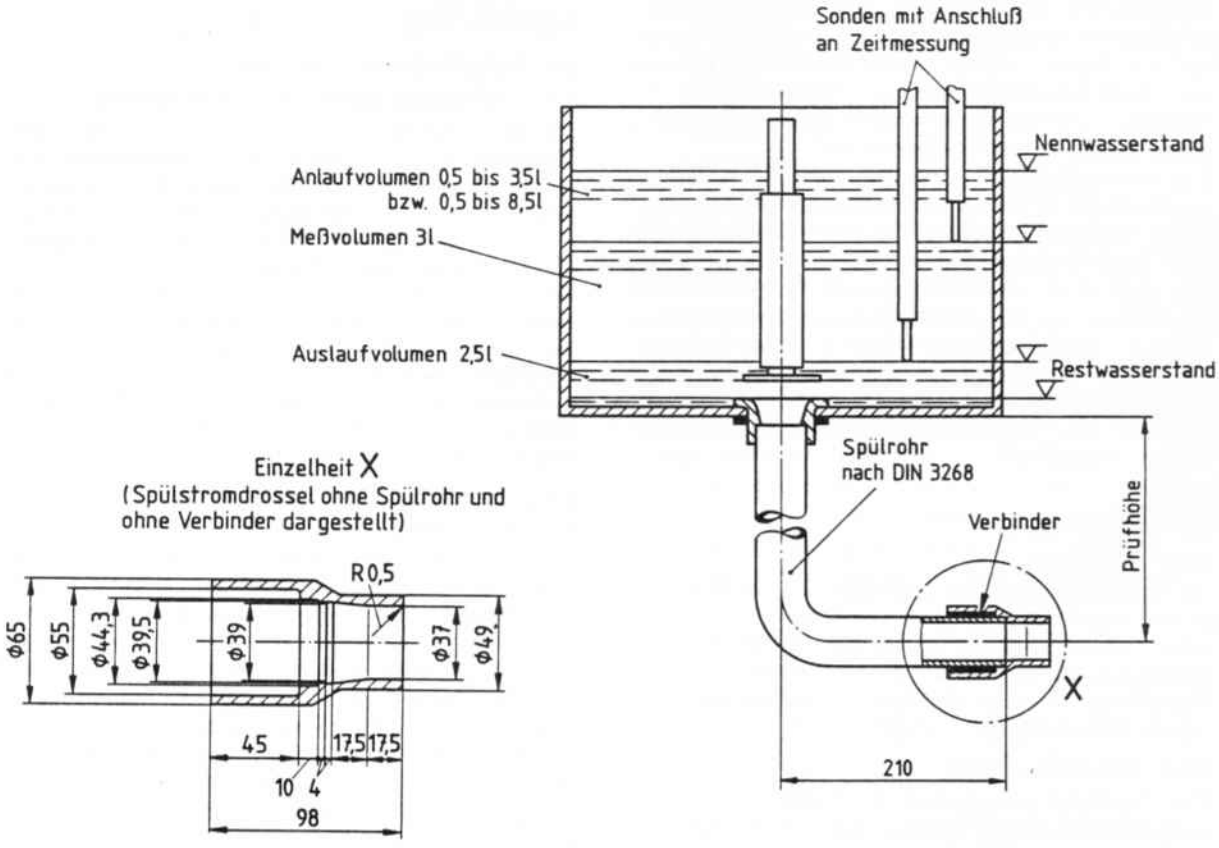


Bild 5. Meßanordnung für die Ermittlung der unteren und oberen Grenzwerte der Spülströme für tiefhängende Spülkästen

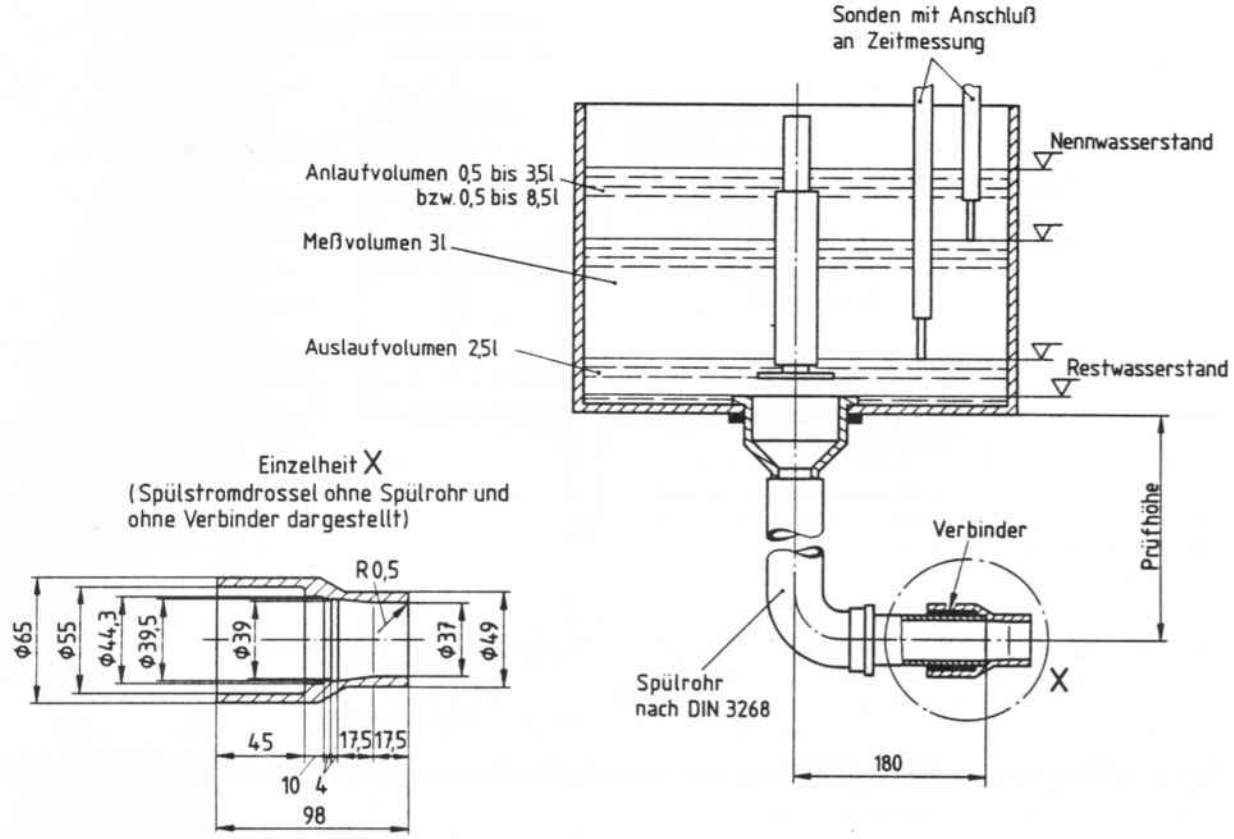


Bild 6. Meßanordnung für die Ermittlung der unteren und oberen Grenzwerte der Spülströme für Wandeinbau-Spülkästen

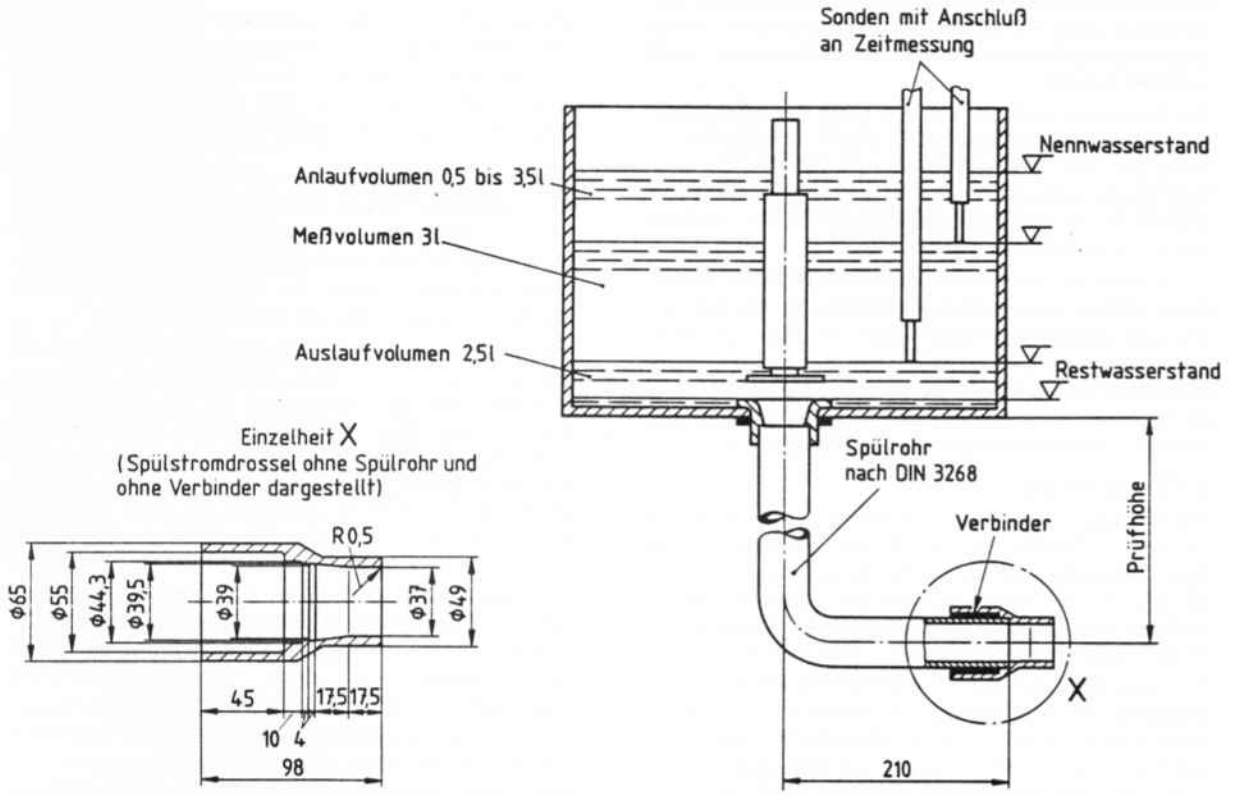


Bild 7. Meßanordnung für die Ermittlung der unteren und oberen Grenzwerte der Spülströme für halbhochhängende Spülkästen

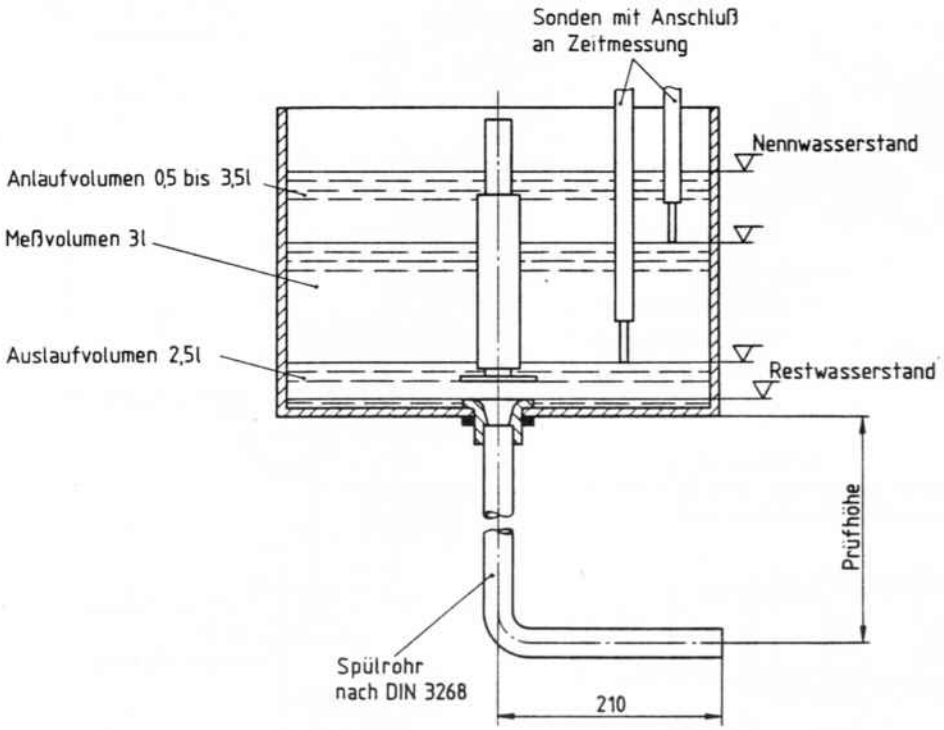


Bild 8. Meßanordnung für die Ermittlung der unteren und oberen Grenzwerte der Spülströme für hochhängende Spülkästen

4.4.2.2 Verringertes Spülwasservolumen

Beim Spülkasten mit selbsttätiger Unterbrechung des Spülvorganges wird zusätzlich der Spülstrom beim Abfluß des Mindestspülwasservolumens (siehe Abschnitt 3.2.4) wie folgt geprüft:

Der Spülkasten wird bis zum niedrigsten Nennwasserstand gefüllt. Danach werden 0,5 l Wasser entnommen. In Höhe des dann erreichten Wasserspiegels wird die obere Meß-Sonde plaziert. Nach Entnahme von weiteren 2 l Wasser wird in Höhe des dann erreichten Wasserspiegels die untere Meß-Sonde plaziert.

Dann wird der Spülkasten bis zum niedrigsten Wasserstand gefüllt, die Auslösevorrichtung für das Mindestspülwasservolumen betätigt und die Zeit gemessen, während der der Wasserspiegel vom oberen zum unteren Meßpunkt sinkt. Der Mittelwert der ermittelten Spülströme muß Tabelle 1 entsprechen und sich im zugehörigen Funktionsfeld nach Bild 4 befinden.

4.4.3 Spülvorgang

Der Spülkasten ist bis zum niedrigsten Nennwasserstand zu füllen. Danach ist der Zufluß abzusperren und durch einmaliges Auslösen der Betätigungsvorrichtung (Dauer 1 s) zu prüfen, ob das Spülwasser vollständig ausläuft. Dies ist dann der Fall, wenn der Wasserspiegel im Spülkasten bis zum Restwasserstand absinkt.

Bei Spülkästen mit Vorrichtung zur selbsttätigen Unterbrechung des Spülvorganges ist zusätzlich das bis zur selbsttätigen Unterbrechung abgegebene Spülwasservolumen zu ermitteln. Hierzu ist der Spülkasten bis zum niedrigsten Nennwasserstand zu füllen, der Zulauf abzusperren und danach die Betätigungsvorrichtung für die Abgabe des Mindestspülwasservolumens zu bedienen (Dauer 1 s). Mit Hilfe der bei der Ausliterung des Spülkastens angebrachten Markierungen (siehe Abschnitt 4.4.1) ist das abgegebene Spülwasservolumen festzustellen. Es müssen mindestens 3 l Spülwasser ausgelaufen sein. Sofern eine Ermittlung über die Markierungen nicht möglich ist, wird das auslaufende Wasser aufgefangen und danach ausgelitert.

4.4.4 Wiederauffüllung nach Unterbrechung des Spülvorganges

Bei Spülkästen mit unterbrechbarem Spülvorgang ist die Wiederauffüllbereitschaft des Spülkastens nach unterbrochenem Spülvorgang wie folgt zu prüfen:

Spülkästen mit einer Vorrichtung zur Unterbrechung des Spülvorganges sind bei einem Fließdruck von 0,5 bar bis zum höchsten Nennwasserstand zu füllen. Nach einer Wartezeit von 60 s ist der Spülvorgang auszulösen und nach weiteren 1,5 s die Vorrichtung zur Unterbrechung des Spülvorganges zu betätigen. Der Spülkasten muß sich anschließend selbsttätig innerhalb von 120 s wieder bis Nennwasserstand auffüllen. Die Zeiten sind mit der Stoppuhr zu ermitteln.

Der nach Wiederauffüllung erreichte Wasserspiegel darf vom Nennwasserstand Abweichungen von ± 5 mm aufweisen. Eine eventuelle Abweichung ist durch Messen zu ermitteln.

Spülkästen mit Vorrichtung zur selbsttätigen Unterbrechung des Spülvorganges sind bei einem Fließdruck von 0,5 bar bis zum niedrigsten Nennwasserstand zu füllen. Nach einer Wartezeit von 60 s ist die Betätigungsvorrichtung für das Mindestspülwasservolumen zu bedienen. Nach Ablauf eines Wasservolumens von min-

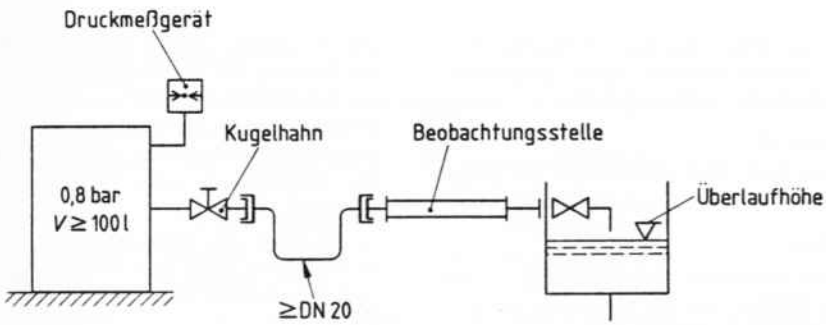


Bild 9. Prüfaufbau für Rücksaugeprüfung

destens 3 l muß sich der Spülkasten innerhalb von 120 s wieder bis zum Nennwasserstand auffüllen. Die Zeiten werden mit der Stoppuhr gemessen. Der nach Wiederauffüllung erreichte Wasserspiegel darf vom Nennwasserstand Abweichungen von ± 5 mm aufweisen. Eine eventuelle Abweichung ist durch Messen zu ermitteln.

4.4.5 Rücksaugung

Die Prüfung gegen Rücksaugung ist bei einem negativen Überdruck von 0,8 bar in der Zuleitung durchzuführen, der Spülkasten ist hierzu bis zur Überlaufhöhe zu füllen (siehe Bild 9). Für die Prüfung ist die Abdichtung des Füllventils unwirksam zu machen, das Füllventil ist vor der Prüfung zu trocknen. Bei mehreren Anschlußmöglichkeiten des Füllventils ist diejenige auszuwählen, die der tiefstmöglichen Einbaulage des Füllventils entspricht. Die Prüfung ist bestanden, wenn kein Wasser in die Anschlußleitung zurückgesaugt wird.

4.4.6 Ausbau des Füllventils

Es ist zu prüfen, ob das Füllventil bei praxisgerecht montiertem Spülkasten ohne Lösen des Behälters ausgebaut werden kann.

4.4.7 Vorrichtung zum Einstellen des Spülwasservolumens

Während der Durchführung der gesamten Spülkastenprüfungen ist durch Inaugenscheinnahme zu prüfen, ob sichergestellt ist, daß ein selbsttätiges Verstellen der Vorrichtung zum Einstellen des Spülwasservolumens ausgeschlossen ist.

4.4.8 Füllzeit

Die Füllzeit ist bei einem Fließdruck von 0,5 bar zu ermitteln. Das Füllventil ist auf den höchsten Nennwasserstand einzuregulieren. Danach wird der Zufluß gesperrt und der Spülkasten bis zum Restwasserstand entleert. Anschließend wird der Zufluß freigegeben. Die Zeit der Auffüllung vom Restwasserstand bis Nennwasserhöhe wird mit der Stoppuhr gemessen.

4.4.9 Druckprüfung des Füllventils

Die druckbeanspruchten Teile des Füllventils sind bei einem Prüfdruck von 16 bar 10 Minuten lang zu prüfen. Dabei ist das Füllventil gegebenenfalls in Verschlußposition zu arretieren. Anschließend wird festgestellt, ob die druckbeanspruchten Teile dicht sind und sich Formveränderungen eingestellt haben.

4.4.10 Funktion des Füllventils bei unterschiedlichen Druckbereichen

Der Spülkasten wird zunächst bei einem Fließdruck von 0,5 bar bis zum höchsten Nennwasserstand oder bis zur höchsten Wasserstandsmarkierung – falls diese höher liegt – gefüllt. Anschließend ist ein Ruhedruck von 10 bar einzustellen, der Spülkasten durch Bedienung der Betätigungsvorrichtung zu entleeren und beim sich danach einstellenden Fließdruck wieder zu füllen. Das Füllventil darf weder verstellt noch nachreguliert werden. Die Beurteilung erfolgt durch Inaugenscheinnahme.

4.4.11 Druckanstieg

Bei bis zum höchsten Nennwasserstand gefülltem Spülkasten und geschlossenem Füllventil ist ein Ruhedruck von 6 bar einzustellen. Danach ist der Spülkasten zu entleeren und anschließend zu füllen. Die Prüfung wird an einer Kupferrohrleitung 15 mm × 1 mm, 5000 mm lang, durchgeführt. Die Druckdifferenz zwischen Ruhedruck und dem maximalen Schließdruck darf 2 bar nicht überschreiten.

4.4.12 Wasseranschluß für Wandeinbauspülkästen

Es ist durch Inaugenscheinnahme und erforderlichenfalls durch Messen zu prüfen, ob der Wasseranschluß bei Wandeinbauspülkästen oberhalb der Überlaufhöhe angeordnet ist.

4.4.13 Behälterwandungen

Während der Durchführung der gesamten Spülkastenprüfungen ist zu prüfen, ob die Formstabilität der Behälterwandungen gegeben ist und keine Anlageteile in der Funktion beeinträchtigt werden.

4.4.14 Deckel und Öffnungen

Der Deckel ist auf den Behälter zu montieren. Danach ist zu prüfen, ob der Deckel gegen selbsttätiges Abgleiten gesichert ist. Bei Wandeinbau-Spülkasten ist durch Inaugenscheinnahme zu prüfen, ob die vorgeschriebene Öffnung mit abnehmbarer Abdeckplatte vorhanden ist. Durch Ausbau der mit dem Spülkasten nicht fest verbundenen Einbauteile ist zu prüfen, ob diese herausgenommen werden können.

4.4.15 Überlauf

Bei gefülltem Spülkasten ist das Füllventil vollständig zu öffnen. Der sich dabei einstellende Fließdruck darf 8,5 bar nicht unterschreiten. Die Prüfung dauert 60 s.

4.4.16 Sicherheitsabstand

Es ist zu messen, ob der vorgeschriebene Sicherheitsabstand eingehalten ist.

4.4.17 Nachfüllvorrichtungen bei Spülkästen für Absaugeklosetts

Bei einem Fließdruck von 0,5 bar ist zu ermitteln, ob das während der Füllzeit nach Abschnitt 3.4.5 vorge-

schriebene Nachfüllwasservolumen zur Verfügung steht. Dazu ist das nach abgeschlossenem Spülvorgang nachlaufende Wasser aufzufangen und auszulitern.

4.4.18 Spülrohranschluß

Es ist zu prüfen, ob beim Spülrohranschluß der vorgeschriebene Längenausgleich bis 10 mm möglich ist.

4.4.19 Abflußstutzen

Durch Montage eines Spülrohres nach DIN 3268 an den Abflußstutzen des Spülkastens ist zu prüfen, ob eine ordnungsgemäße Verbindung möglich ist.

4.4.20 Ausbau des Ablaufventils

Es ist zu prüfen, ob das Ablaufventil ohne Lösen des Behälters ausgebaut werden kann.

4.4.21 Ablaufventil

Während der gesamten Spülkastenprüfung ist festzustellen, ob das Ablaufventil den Spülkasten nach jedem Spülvorgang selbsttätig und tropfdicht abschließt.

4.4.22 Dichtung des Ablaufventils

Es ist zu prüfen, ob die vorgeschriebene Austauschbarkeit der Dichtung möglich ist.

4.4.23 Kombination von Spülkästen mit Lüftungsanlagen

Die Anforderung nach Abschnitt 3.6 ist durch Inaugenscheinnahme gegebenenfalls zusätzlich durch Inbetriebnahme der im Spülkasten befindlichen Lüftungseinrichtungen zu prüfen.

Die elektrische Anlage ist nach VDE 0720 Teil 1 in Verbindung mit VDE 0730 Teil 1 zu prüfen.

4.4.24 Geräuschverhalten

Die Prüfung ist nach DIN 52218 Teil 1 und Teil 2 durchzuführen. Danach ist der Spülkasten entsprechend seinem Armaturen-Geräuschpegel in die Armaturengruppe I oder II nach DIN 4109 Teil 5 (z. Z. Entwurf) einzustufen.

5 Kennzeichnung

5.1 Normenkonformität

5.1.1 Gesamter Spülkasten

Die Übereinstimmung von Spülkästen mit den Anforderungen dieser Norm wird mit dem DIN-Prüf- und Überwachungszeichen zum Ausdruck gebracht. Anträge auf Erteilung des Zeichens sind bei der Deutschen Gesellschaft für Warenkennzeichnung GmbH (DGWK), Burggrafenstraße 4–10, 1000 Berlin 30, zu stellen.

Die Erteilung des DIN-Prüf- und Überwachungszeichens durch die DGWK erfolgt nach bestandener Typprüfung. Die Berechtigung zur Zeichenführung gilt für die Dauer von 5 Jahren, jeweils gerechnet ab Datum des Prüfberichts über die erste Typprüfung. Soll die Berechtigung zur Zeichenführung über den Gültigkeitszeitraum hinaus erhalten bleiben, ist rechtzeitig vor Ablauf der Genehmigung eine Verlängerung bei der DGWK zu beantragen. Die Verlängerung setzt einen erneuten Konformitätsnachweis voraus.

Änderungen des Spülkastens, für den eine Zeichengenehmigung erteilt ist, erfordern eine Ergänzungsprüfung nach Abschnitt 4.3.2.

5.1.2 Einzelne Bauteile

Ein Hinweis auf die Normenkonformität einzelner Bauteile des Spülkastens (Füllventil, Ablaufventil) ist nur zulässig, wenn durch ein Prüfzeugnis einer Prüfstelle nach Abschnitt 4.3.3 die Einhaltung der Anforderungen nach Abschnitt 3 nachgewiesen wird und von der DGWK ein Registrierbescheid über die Berechtigung zum Führen einer Registernummer erteilt worden ist. Anträge auf Erteilung des Registrierbescheides sind bei der DGWK zu stellen. Für die Erteilung des Registrierbescheides gelten die Bestimmungen nach Abschnitt 5.1.1 entsprechend.

5.2 Anbringung der Kennzeichnung

5.2.1 Gesamter Spülkasten

Spülkästen sind mit folgenden Angaben deutlich sichtbar und dauerhaft zu kennzeichnen:

a) Herstellername bzw. -zeichen

b) Typbezeichnung

c) DIN-Prüf- und Überwachungszeichen mit Registernummer



Reg.-Nr. . . .

Die Kennzeichnung der Armaturen-Geräuschgruppe mit I oder II erfolgt durch Zusatz zur Registernummer.

5.2.2 Einzelne Bauteile

Der Hinweis auf die Normenkonformität von Bauteilen von Spülkästen ist wie folgt vorzunehmen:

a) Herstellername bzw. -zeichen

b) DIN 19542

c) Registernummer

Für Füllventile, für die der DVGW [3] eine Registernummer erteilt hat, kann anstelle vorgenannter Kennzeichnung eine Kennzeichnung wie folgt vorgenommen werden:

a) Herstellername bzw. -zeichen

b) DVGW und Registernummer

[3] DVGW Deutscher Verein des Gas- und Wasserfaches e.V., Postfach 5240, Frankfurter Allee 27–29, 6236 Eschborn 1.

Zitierte Normen und andere Unterlagen

DIN ISO 228 Teil 1	Rohrgewinde für nicht im Gewinde dichtende Verbindungen; Gewinde-Kurzzeichen, Maße und Toleranzen
DIN ISO 228 Teil 2	(z. Z. Entwurf) Rohrgewinde für nicht im Gewinde dichtende Verbindungen; Prüfung mit Grenzlehren
DIN 823	Technische Zeichnungen; Blattgrößen
DIN 824	Technische Zeichnungen; Faltung auf Ablageformat
DIN 3268	Spülrohre für Spülkästen
DIN 4109 Teil 5	(z. Z. Entwurf) Schallschutz im Hochbau; Schallschutz gegenüber Geräuschen aus haustechnischen Anlagen und aus Betrieben; Anforderungen, Nachweise und Hinweise für Planung und Ausführung
DIN 18017 Teil 3	Lüftung von Bädern und Spülaborten ohne Außenfenster, mit Ventilatoren
DIN 52218 Teil 1	Bauakustische Prüfungen; Prüfung des Geräuschverhaltens von Armaturen und Geräten der Wasserinstallation im Laboratorium; Meßverfahren und Prüfanordnung
DIN 52218 Teil 2	Bauakustische Prüfungen; Prüfung des Geräuschverhaltens von Armaturen und Geräten der Wasserinstallation im Laboratorium; Armaturenanschluß und Druchführung der Prüfung
VDE 0720 Teil 1	Vorschriften für Elektrowärmegeräte für den Hausgebrauch und ähnliche Zwecke; Allgemeine Vorschriften
VDE 0730 Teil 1	Bestimmungen für Geräte mit elektromotorischem Antrieb für den Hausgebrauch und ähnliche Zwecke; Allgemeine Bestimmungen
KTW-Empfehlung	Kunststoffe und andere nichtmetallische Werkstoffe für den Trinkwasserbereich

Weitere Normen

DIN 1986 Teil 1	Entwässerungsanlagen für Gebäude und Grundstücke; Technische Bestimmungen für den Bau
DIN 1986 Teil 2	Entwässerungsanlagen für Gebäude und Grundstücke; Bestimmungen für die Ermittlung der lichten Weiten und Nennweiten für Rohrleitungen
DIN 1986 Teil 3	Entwässerungsanlagen für Gebäude und Grundstücke; Regeln für Betrieb und Wartung
DIN 1986 Teil 4	Entwässerungsanlagen für Gebäude und Grundstücke; Verwendungsbereiche von Abwasserrohren und -formstücken verschiedener Werkstoffe
DIN 1988	Trinkwasser-Leitungsanlagen in Grundstücken; Technische Bestimmungen für Bau und Betrieb

Frühere Ausgaben

DIN 19542: 03.70

Änderungen

Gegenüber der Ausgabe März 1970 wurden folgende Änderungen vorgenommen:

Norm vollständig überarbeitet (siehe Erläuterungen).

Erläuterungen

Die im März 1970 erschienene erste Ausgabe von DIN 19542 enthielt verschiedene Festlegungen, die zum Teil durch neuere Erkenntnisse in Frage gestellt wurden. Dies machte eine Überarbeitung der Norm erforderlich. Forschungsarbeiten zeigten, daß es z. B. möglich ist, das Gesamtspülwasservolumen für Klosettspülungen ohne Beeinträchtigung der hygienischen Sicherheit bis zu einem Drittel zu verringern. Eine entsprechende technologische Öffnung der Norm wurde daher vorgenommen. Ferner wird die Unterbrechung der Spülung durch den Benutzer ermöglicht. Sie wird als eine bewußte Handlung des Benutzers verstanden. Für Spülkästen, die mit Vorrichtung zur Wassereinsparung nach Abschnitt 3.2.4 ausgestattet sind, kann ab 1.1.1985 – vorbehaltlich der Entscheidung der Jury Umweltzeichen – das Umweltzeichen des Bundesministers des Innern beim RAL Deutsches Institut für Gütesicherung und Kennzeichnung, Bornheimer Straße 180, 5300 Bonn 1, beantragt werden.

Umrüstsätze zur Unterbrechung des Spülvorgangs bei bereits installierten Spülkästen, mit deren Hilfe Wasser gespart werden soll, werden in der vorliegenden Norm nicht behandelt. Sie entsprechen jedoch der Norm sinngemäß dann, wenn durch Prüfung in einer Prüstelle (siehe Fußnote 2) festgestellt wurde, daß damit dafür vorgesehene und bezeichnete Spülkästen die Anforderungen der Norm erfüllen. Den Umrüstsätzen ist eine Einbauanweisung beizugeben, aus der auch die dafür geeigneten Spülkastenmodelle ersichtlich sind. Es wird noch geprüft, ob auch für solche Umrüstsätze eine Kennzeichnungsmöglichkeit mit dem Umweltzeichen vorgesehen werden sollte.

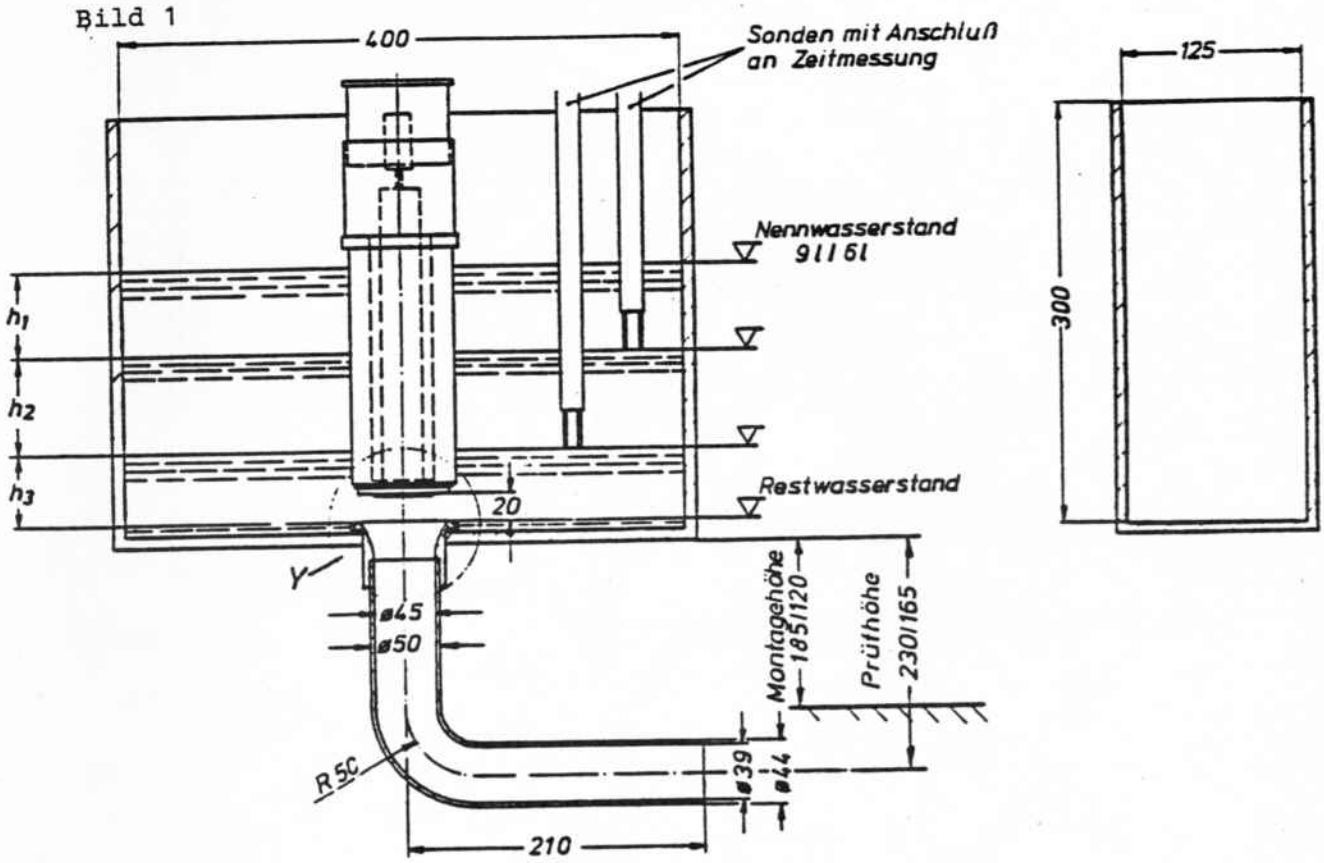
Die Norm erhielt zugleich den Charakter eines Performance-Konzepts, d. h. jede Anforderung soll mit Hilfe des zugehörigen Prüfverfahrens so überprüfbar sein, daß ein Ermessensspielraum bei der Bewertung des Prüfergebnisses nicht vohanden, sondern eine klare Ja- oder Nein-Entscheidung möglich ist. Allein das Prüfzeugnis soll ausweisen, ob ein Spülkasten der Norm in allen Punkten entspricht, so daß weitere Eignungsbescheinigungen entbehrlich sind. Dies wird eine Verwaltungsvereinfachung im Bereich der bauaufsichtlichen Prüfpflicht ermöglichen, der Spülkästen zur Zeit noch unterliegen. Es ist vorgesehen, in Kürze den Musterentwurf der Verordnung über prüfpflichtige Baustoffe, Bauteile und Einrichtungen (Prüfzeichenverordnung) zu novellieren. Dabei sollen unter anderem die Spülkästen von der Prüfpflicht freigestellt werden, so daß vom Institut für Bautechnik ein Prüfzeichen nicht mehr erteilt zu werden braucht.

Internationale Patentklassifikation

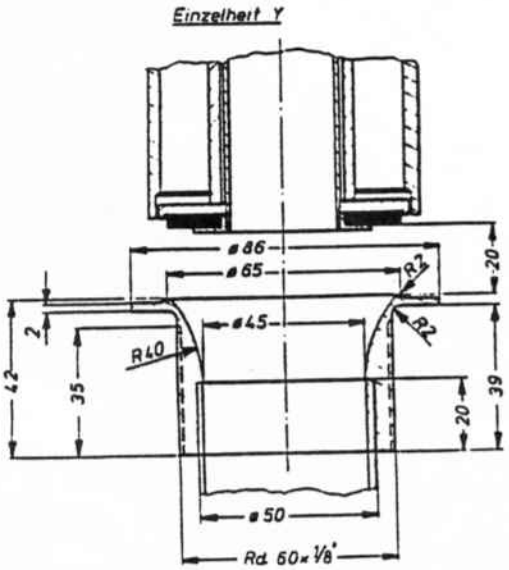
A 47 K 17-02

Prüfspülkasten für bodenstehende Klosettbecken ANNEX 2

Bild 1



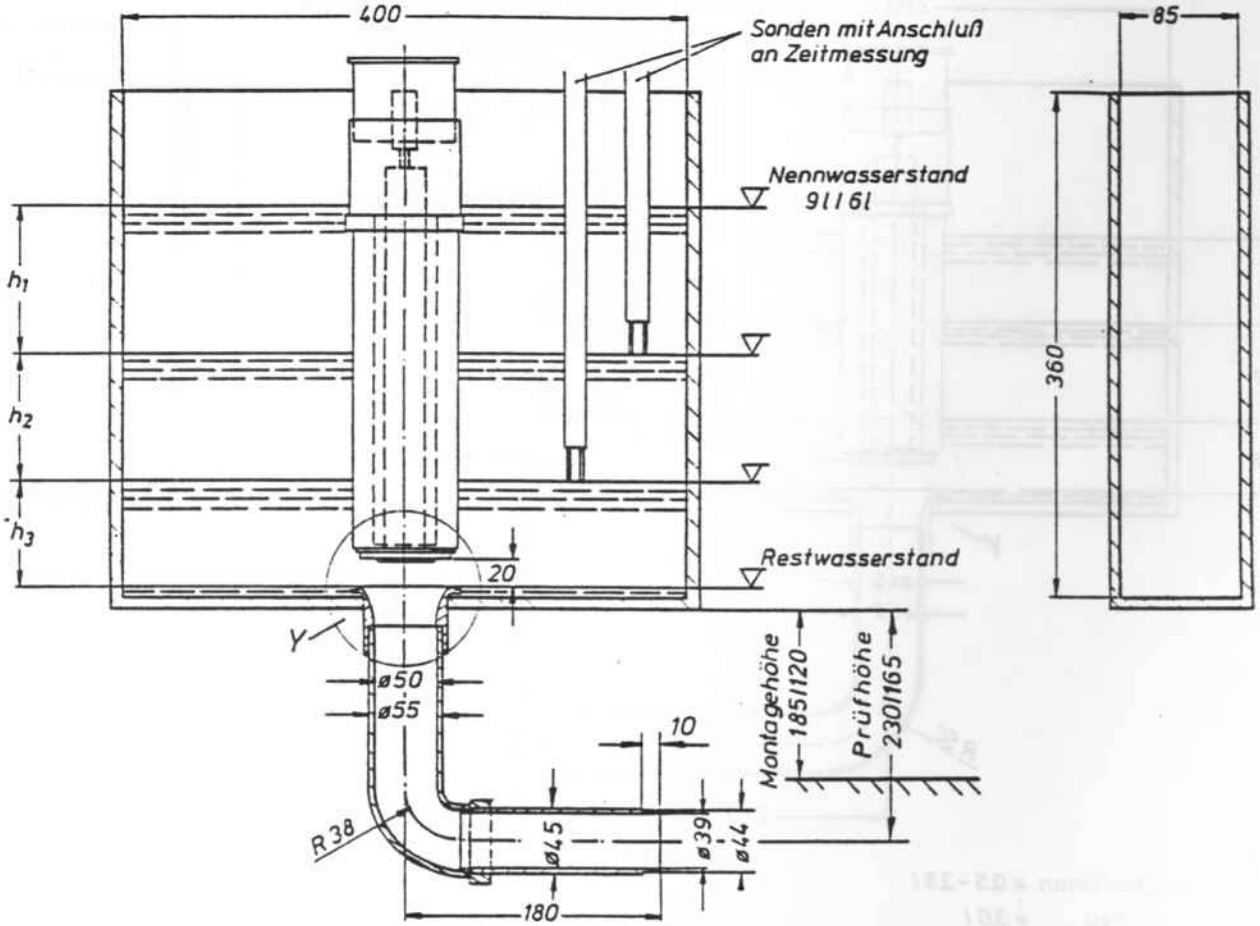
h_1 ≙ Anlaufvolumen = 0,5 - 3,5 l
h_2 ≙ Meßvolumen = 3,0 l
h_3 ≙ Auslaufvolumen = 2,5 l
$h_1 + h_2 + h_3$ = Gesamtspülwasservolumen



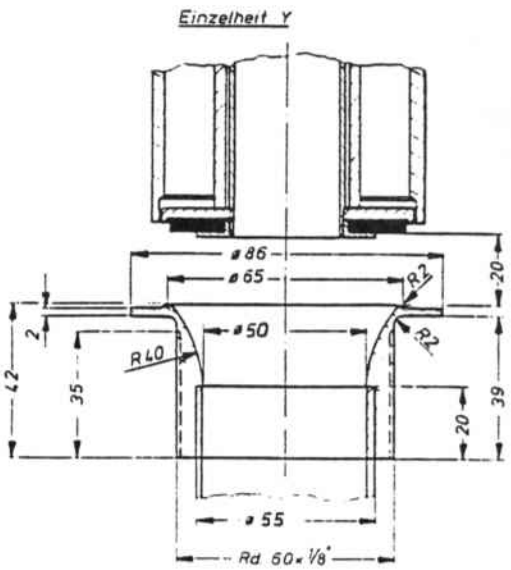
Prüfspülkasten für wandhängende Klosettbecken

ANNEX 3

Bild 2



h_1 ≙ Anlaufvolumen = 0,5 - 3,5 l
h_2 ≙ Meßvolumen = 3,0 l
h_3 ≙ Auslaufvolumen = 2,5 l
$h_1 + h_2 + h_3$ = Gesamtspülwasservolumen



CIB-W62 SYMPOSIUM

Special Drainage Equipment for Saving Water

Eskil Olsson

April 9,~10, 1985

TOKYO, JAPAN



Mr Eskil Olsson (speaker)
The National Swedish Institute for Building Research

Mr Lennart Lindvall (joint author)
The National Swedish Institute for Building Research

SPECIAL DRAINAGE EQUIPMENT FOR SAVING WATER

12th CIB-W62 SYMPOSIUM - TOKYO -
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10,-1985 : KENCHIKU KAIKAN

Summary

Research and development work on water-saving drainage methods has been carried out in Sweden for several years. Water-saving methods comprise WC systems with flushing volumes of 1.5 - 3.5 litres, and showers and sinks producing mean flows of 0.1 - 0.2 l/s.
This form of water saving calls for new components in our waste water systems, so that both the units themselves and the connected piping systems are still flushed clean. Standard requirements and test methods have been evolved, making it possible to develop new units and adapt existing ones. In order to increase the flushing put of piping systems, collecting tanks have been installed which utilize a siphoning effect to produce intermittent flushing without any mechanical arrangements. Models for the calculation of water traps affect the choice of dimensions and thus make it possible to increase the flow velocity in the system without sucking out or breaking through the water trap (sanitary nuisance). This approach has also enabled the development of water-saving technology for installation in developing countries, incorporating a flushing volume of 1.5 litres or flushing from a holding tank of c. 15 litres.

Résumé

Depuis un certain nombre d'années se poursuivent en Suède la recherche et le développement de la technique d'assainissement économique. Par technique d'assainissement économique on entend le système des WC avec un volyme de tirage de 1.5 à 3.5 litres d'eau et le flux moyen de douche et de mélangeur pour évier de 0.1 à 0.2 l/s.
Cette forme d'épargne de l'eau demande de nouveaux composants dans not systèmes d'assainissement où les effets de lavage et nettoyage de l'appareil et le système suivant de canalisation sont conservés. En présental les besoins et les méthodes de test on a pu permettre un développement et une adaptation des appareils respectivement nouveaux et connus. Pour augmenter l'effet de nettoyage dans le système de canalisation, il a été installée une cuve-collecteur dont l'écoulement est intermittent selon le principe de siphon et sans dispositifs mécaniques.

Des modèles de calcul du siphon influencent le choix des dimensions et donnet par cela la possibilité d'augmenter la vitesse d'écoulement dans le système sans que le siphon soit aspiré och percé (inconvénient sanitaire). La facon de voir les choses a aussi donné possibilité à un développement de la technique d'assainissement économique pour l'installation dans les pays en voie de développment d'un volyme d'écoulement de 1.5 litres/écoulement d'un "holding tank" d'environ 15 litres.

Zusammenfassung

In Schweden wird seit ein paar Jahren Forschung und Entwicklung über wassersparende Abfluss-Technik betrieben. Mit wassersparender Technik meint man WC-Systeme mit Spülvolumina von 1.5 - 3.0 l und mittleren Flüssen von Duschen und Spülen von 0.1 - 0.2 l/sek.
diese Form des Wasserhaushaltes stellt grosse Forderungen an neue Komponenten in unseren Abfluss-Systemen, wobei Ausspülungs- und Sauberspülungseffekte von Armatur und nachfolgender Leitung beibehalten werden müssen. Forderungen und Testmethoden haben die Entwicklung und Anpassung neuer respektive bekanter Armatur möglich gemacht. Um den Sauberspülungseffekt im Leitungs-System zu vergrössern, hat man Sammelbecken installiert, die intermittent nach dem Heberprinzip und ohne mechanische Anordnungen spülen. Berechungsmodelle für Wasserverschlüsse beeinflussen die Dimensionswahl und erlauben die Strömungsgeschwindigkeit im System zu erhöhen, ohne dass der Wasserverschluss abesogen oder durschbrochen würde (sanitäre Unannehmlichkeit). Diese hat auch die Entwicklung Auffassung wassersparender Technik für die Installation in U-Ländern ermöglicht, wobei Spülvolumina von 1.5 l pre Spülung aus einen "Holding Tank" von zirka 15 l ausreichen.

SPECIAL DRAINAGE EQUIPMENT FOR SAVING WATER

1.0 BACKGROUND

Water consumption and the trends in this field in different countries exhibit major variations as regards consumer categories, type of society and water quality; the availability of water also affects the consumption. Technically, the water consumption can be divided into consumed and non-consumed water. Thus the requirements can be considered as graded: up to certain minimum values as regards quality and quantity, the water requirements are absolute in order to support life. The limit is 3/4 litre per person per day. Consumption over and above this value can be considered as meeting more or less strongly-expressed wishes, which are usually lumped together under the heading of "standard of living".

In some countries, including Sweden, a systematic analysis is in progress to investigate the possibilities of reducing the amounts of water consumed, principally in the home. These analyses are directed towards proposals for measures which would reduce the amount of water consumed in specified activities, e.g. WC flushing, showering, washing up etc. Thus the proposals lead to considerable reductions in the amount of water used at the various tapping points. For example, the water used by a WC is reduced from 9 l to 6 l to 3 l, or even down to 1.5 l. The mean flow through a mixer tap for a kitchen sink is reduced from 0.2 l/s to 0.10 l/s and that in a shower from 0.4 l/s to 0.20 l/s. This obviously affects the dimensioning of the waste water system, which is to a great extent a question of assessing the combined quantities of water which accumulate in a waste water system. The statistics available for this assessment of the accumulated quantities must be regarded as meagre at present. To a large extent it is a question of what flows are necessary, which overloading periods are accepted, etc. There is also the question of the condition of the piping system after 5, 10, 20, 30 and 50, even up to a hundred years. About this we know very little. However, one thing we do know is that our older systems of 20 years and more have begun to deteriorate more and more. The hydraulic function has got worse, and there is a need for major investments. The magnitude is often considerably greater than the economic resources available for relaying. New solutions and ideas are called for. With this approach,

people are beginning to look at special arrangements for the waste water systems for e.g. increasing the flow through the horizontal sections of our piping systems.

2.0 CURRENT LAWS AND REGULATIONS IN SWEDEN - GRAVITY FALL SYSTEMS

The primary function of the waste water systems is to remove waste water as rapidly as possible without giving rise to a sanitary nuisance. The dimensioning regulations which apply at present include directions and instructions about the design of the systems as well as limiting values. These limiting values include minimum pipe fall in horizontal collecting pipes, see Figures 1 and 2, and the minimum pipe dimension after a WC which is 100 mm.
Another limit that has been set is the volume of flushing water from a WC. Less than 6 l is not permitted since it is anticipated that otherwise there would be accumulations of sludge which would reduce the capacity. Pipes with dimensions less than 100 mm may not be connected to a WC because it is expected that otherwise the pressure variations in the vertical parts of the system would be too great, having regard to the requirements for the shut-off depth of the water traps.
From the above it is evident that there are two important factors in the waste water systems which set limits on new ideas, namely the flow of liquid, i.e. the accumulated value, and the shut-off depth in the water traps. It also follows that in order to improve the systems or find better technical-economical solutions, other components must be introduced into the systems which have the ability to both increase the accumulated amount of water and maintain the pressure variations in the systems within limits so that no sanitary nuisances arise. Sanitary nuisances refer principally to the escape of odour from the sewerage system and overflows due to overloading.

3.0 BASIS FOR RESEARCH AND CRITERIA

Research has been based on tests carried out in full-scale models. Test methods have been evolved which reproduce the largest probable loads that can be expected to occur in a waste water system.
Earlier studies in the SIB water and drainage laboratory have shown

that the WC is the discharge unit that causes most difficulties in a waste water system. Tests have shown that the largest pressure oscillations can be recorded on the level immediately below the two highest storeys in a building where the WCs are flushed simultaneously, see Figure 3. In order to reduce the flushing volume in existing WC models while retaining the flushing effect, it is not enough to simply adjust the ballcock valve downwards and imagine that this will give a satisfactory result, as many people do in order to save water. In such cases there is a great risk of blockages in the system. The WC must be designed for the flushing volume used.

In Sweden, WC models have now been developed with flushing volumes as little as 3 l and the same flushing energy, i.e. the same as for flushing volumes of 6 and 9 litres. A number of studies have been carried out in Denmark which together showed that WCs with flushing volumes as low as 3 l set the following limits on the system:

a) Vertical pipe from the highest WC, 6 m.

b) Horizontal collecting pipe, max. 22.

c) The horizontal collecting pipe must have a pipe fall of at least 50 o/oo over its entire length.

d) Pipe dimension 100 mm.

In Sweden we have studied how a reduction of the volume of water in WCs affects the subsequent piping system. These investigations indicate the need for information about the effects of a reduced accumulated flow in the collecting pipe, not only inside the building but also outside, in the local networks.

Norwegian investigations have been carried out with respect to the transport capacity in networks from pipes with dimensions of 40 - 75 mm, and with a total pipe length of 20 m and variable fall of 20 o/oo to 50 o/oo. The conclusion drawn from these investigations is that they indicate that the transport capacity from a 3 l WC connected to a pipe with 63 mm diameter is better than that from a 6 l WC connected to a 110 mm network.

4.0 NEW COMPONENTS

At present there is no clear picture of the significance of a reduced accumulating effects; studies are therefore still in progress, principally as regards local networks. With these considerations in mind, new units have been evolved which are designed to reinforce the flushing-out capacity and transport capacity in the horizontal parts of the systems.

4.1 WCs

WCs with a flushing volume of 3 litres have been equipped with arrangements (see Figure 4 for the principle) that maintain flow characteristics which are comparable to those for flushing volumes of 9 and 6 litres, see diagram in Figure 5.

4.2 Siphon

In order to increase the flushing and flushing-out capacities of the piping systems, they have been equipped with collecting vessels that are emptied intermittently by means of a siphoning effect. No mechanical arrangements are needed. Figure 6 illustrates the principle.

5.0 NEW SYSTEMS

In spite of the current limits imposed by Swedish building codes, a start was made in Sweden with the development of WCs having a flushing volume of 3 litres. Parallel with this, a siphoning technique was developed that gives an acceptable flushing out of the waste water network in spite of the lower flushing volume from the WC. By intergrating the two components in the system, namely the WC and the siphon, it was possible to fulfil the requirements specified. Tests on full-scale models plus a number of field tests have shown that it is quite possible to achieve comparable results to those in conventional systems with WCs having flushing volumes of 6 and 9 litres. The results of the flushing out measurements show that the effect is often better than in the older systems. The pressure variations which normally occur in installations are considerably lower.

5.1 Siphon method

The siphon method involves, briefly, finding a suitable volume for storage in the collecting tank and finding the minimum value of inflow which will activate the siphon so that it flushes out the stored volume. Since the siphon can be compared with a water trap, it is necessary to have a passage of air past the lock. By combining the permitted quantity of air, siphon resistance and siphoning effect it is possible to design siphons of different sizes, depending on the number of person equivalents connected to them. Suitable design criteria could be:

- the minimum loading value in l/s which is needed in order to achieve a satisfactory functioning of the siphon ($0.3 \leq Q \leq 4.5$ l/s).
- the pipe diameter, length and fall of a horizontal pipe connected before the siphon which are needed in order to achieve a satisfactory functioning of the siphon.
- the minimum working height or siphoning height which is required in order to obtain a satisfactory transport function after the siphon.
- suitable system constructions which are adapted to the siphon action.

A number of calculations and experiments have been carried out with the aim of finding a suitable system combining WC and siphon and a suitable piping system. Examples of this work are shown in Figures 7 and 8.

The piping between the WC and the siphon was tested as follows:
The system was loaded from one connected WC. The matter flushed out comprised paper, sanitary napkins and natural sponges. Five tests were carried out with each type of flushed material.

Transport in the piping system after the siphon was tested as follows:
The siphon tank was filled to the brim. Flushing material was placed in the siphon tank and the WC was activated.

In all the tests, the material was flushed out of the system after two activations (flushings) of the WC or siphon.

The water velocity in the piping system before and after the siphon gives a good picture of the way in which the system functions, see Figure 9.

In this case the system was loaded with a continuous flow of water 10 m before the siphon. The flow was varied from 0.2 - 0.8 l/s. Figure 10 can be used to find the limiting value between the siphon and the system. All values which fall within the sector A are satisfactory.

5.2 Dimensioning directions

On the basis of the above test series, dimensioning directions have been formulated, see example Appendix 1.

5.3 Design of water trap

Piping systems with pipe diameters of less than 100 mm lead to increased pressure differences in the downpipe and a risk of air breakthrough or sucking out of the water traps. In a number of comparative tests between systems with and without siphon, it has been shown that a pressure reducing effect is obtained with the siphon.
Full-scale tests have been carried out in three different system arrangements with pipe dimensions Ø 75, Ø 83 and Ø 90. 12 different types of water trap have been studied in parallel. A calculation model has been formulated for the evaluation of the relationship between pressure variations P and water trap losses Hf. It is anticipated that this model will be of great assistance in future development work on low flushing volume waste systems. The method is based on the relationship between water trap loss and pressure as a function of time, according to the equation

$$Hf/P = K$$

The relationship between pressure and water trap loss has been found by calculating the ratio between water trap loss (Hf) and pressure/sec (P/t). The water loss in a water trap is not solely caused by the magnitude of the underpressure; the loading time also has a great effect on the water loss. For example, if a water trap is subjected to a max underpressure of - 25 mmVp for a period of 0.1 sec, earlier flow tests have shown that the water trap is not affected to any

significant extent. On the other hand, with the same max underpressure and a duration of 1 to 2 sec, the water trap is affected and a measurable water loss results. It has therefore been decided to give the relationship between underpressure and water trap loss by determining the pressure level which has a lasting effect on the water trap during a given time, see diagram in Figure 11.

6.0 MINIMIZATION OF WATER CONSUMPTION

In the introduction, one cause of variation in water consumption was given as being the type of society. In a development project for World Bank/TAG, we have determined the smallest water volume for a low volume flushing cistern in an upgraded squat plate system. This work was carried out for application in developing countries. Here again, the water cycle in a community must be considered as a whole. This in turn means that it is not sufficient to consider only technical solutions, but that combined technical and socio-economical aspects must be considered. There are also cultural practices in some countries which have to be taken into consideration. In the end it is the consumer who has to understand and be able to use the new systems. In this case, the sub-systems which together comprise a water cycle are the water supply system, the water-borne excreta disposal system, treatment systems and transport back to the drainage fields, see Figure 12.

High-volume WCs make large demands on the water supply and drainage systems, and also produce large quantities of polluted waste water. It is therefore most important to develop WC systems which make only small demands on the water supply systems, and where the effluent can be discharged on-site and absorbed in drainage fields which only take up a small area.
Upgradable squat-plate or pedestal systems developed in Sweden have taken the following factors into consideration, among others:

- the minimum quantity of water required for correct operation
- the hydraulic and technical efficiency
- specific requirements, checked by different test methods.

The following sections illustrate examples of suggestions for limiting requirements.

6.1 Property of flushing

Figure 13 show a test system for checking the hydraulic conditions. The maximum volume will be 1.5 litres/flush. The test method uses sanitary napkins to yield information about the flushing effect.

6.2 Property of cleaning

To check the cleaning effect by the use of sawdust sprinkled onto the surface of the pan. They are must be cleaned to at least 90 %.

6.3 Transport to the pit

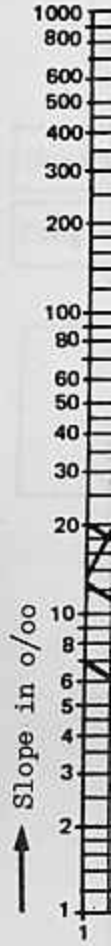
Tables 1a and b, shows a method of testing the transport ability. The matter to be flushed out of the system consists of sanitary napkins. With this method, it was found that a minimum requirement is a transport length of at least 10 m with a pipe dimension of 75 mm and a slope of 1:100. For larger transport distances it is possible to change the slope from 1:100 to 1:50 or 1:20, depending upon the depth of the pit (ground water level).

7.0 NON-GRAVITY SYSTEMS

Non-gravity systems already developed are:

I Vacuum systems (Fig 14)
II Pressure outflow systems (Fig 15).

A combination of these two systems plus the gravity fall system is being tested, in order to achieve an optimal technical-economic system.



Figure

Q= —

Q = fl
h = vo
d = in
J = gr
k = fr

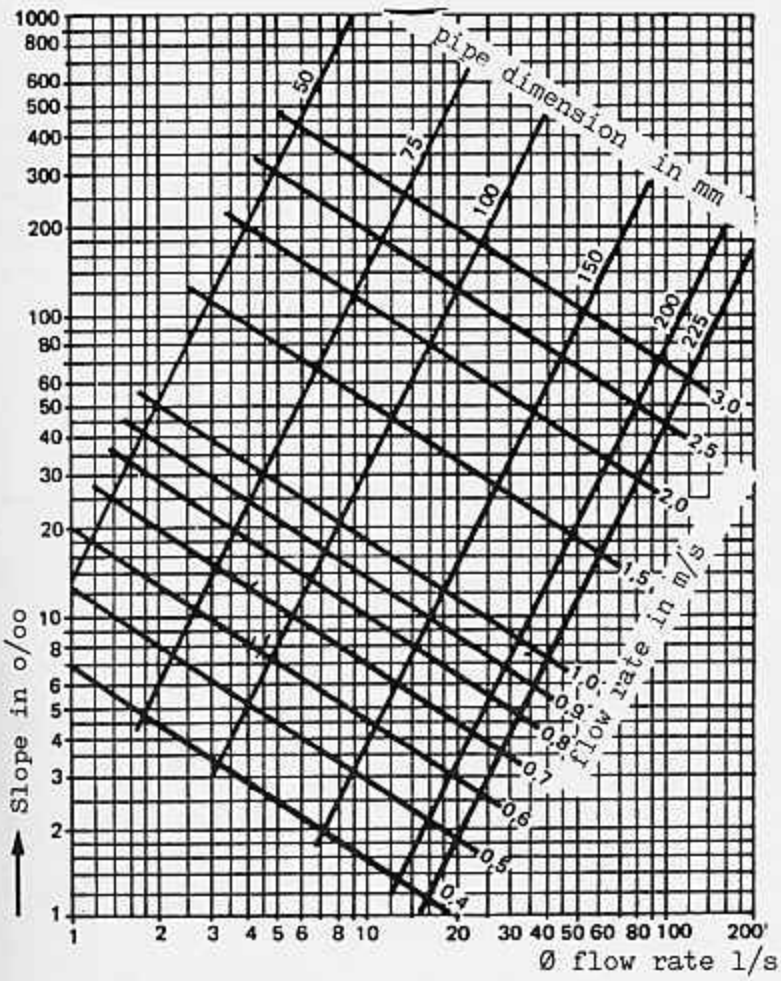


Figure 1. The slope in a horizontal pipe as a function of the probable flow rate and pipe dimension.

$$Q = -6{,}75 \log \left[\frac{0{,}74}{d \cdot \sqrt{d \cdot J} \cdot 10^{6}} + \frac{k}{3{,}71\, d} \right] d^{2} \cdot \sqrt{d \cdot J}$$

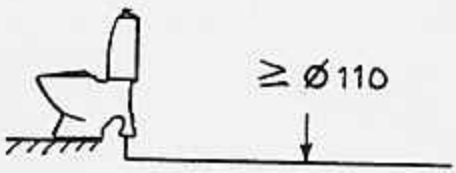
Q = flow rate in a fulfilled pipe (m^3/s)

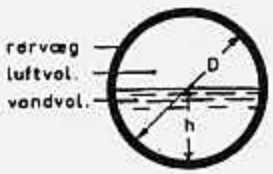
h = volume hight in (m)

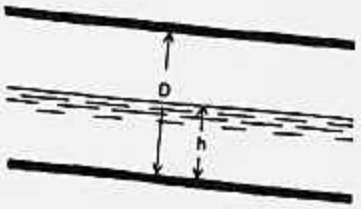
d = inside diameter (m)

J = gravity fall (m/m)

k = frictions koefficient in this case 0.001 m







Relativ vanddybde = $\frac{\text{vanddybde} \sim h}{\text{ledningsdiameter} \sim D}$ = max. 0,5

horizontal pipe

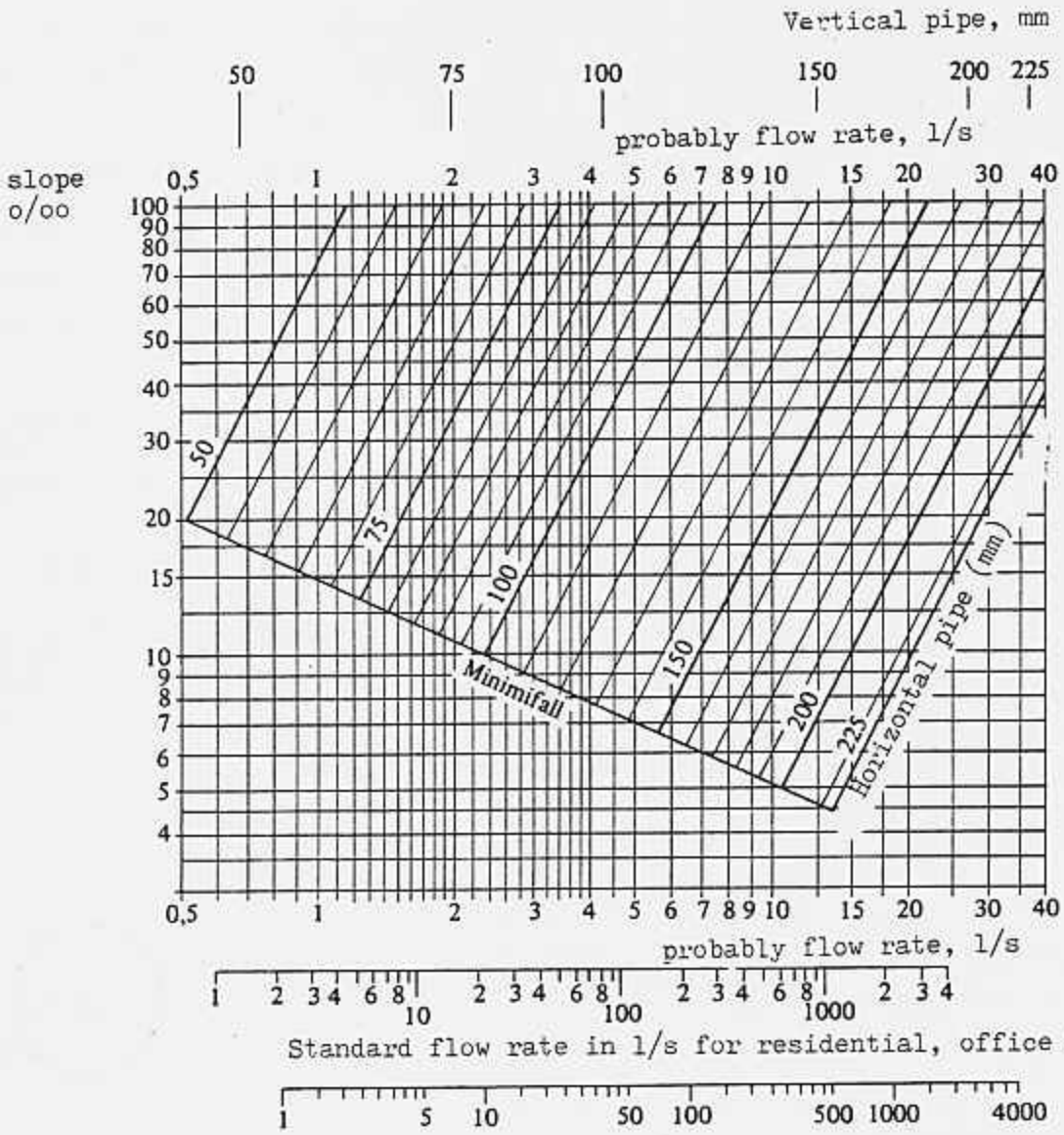


Figure 2. Simplification of the dimension.

CHECK OF FUNCTION

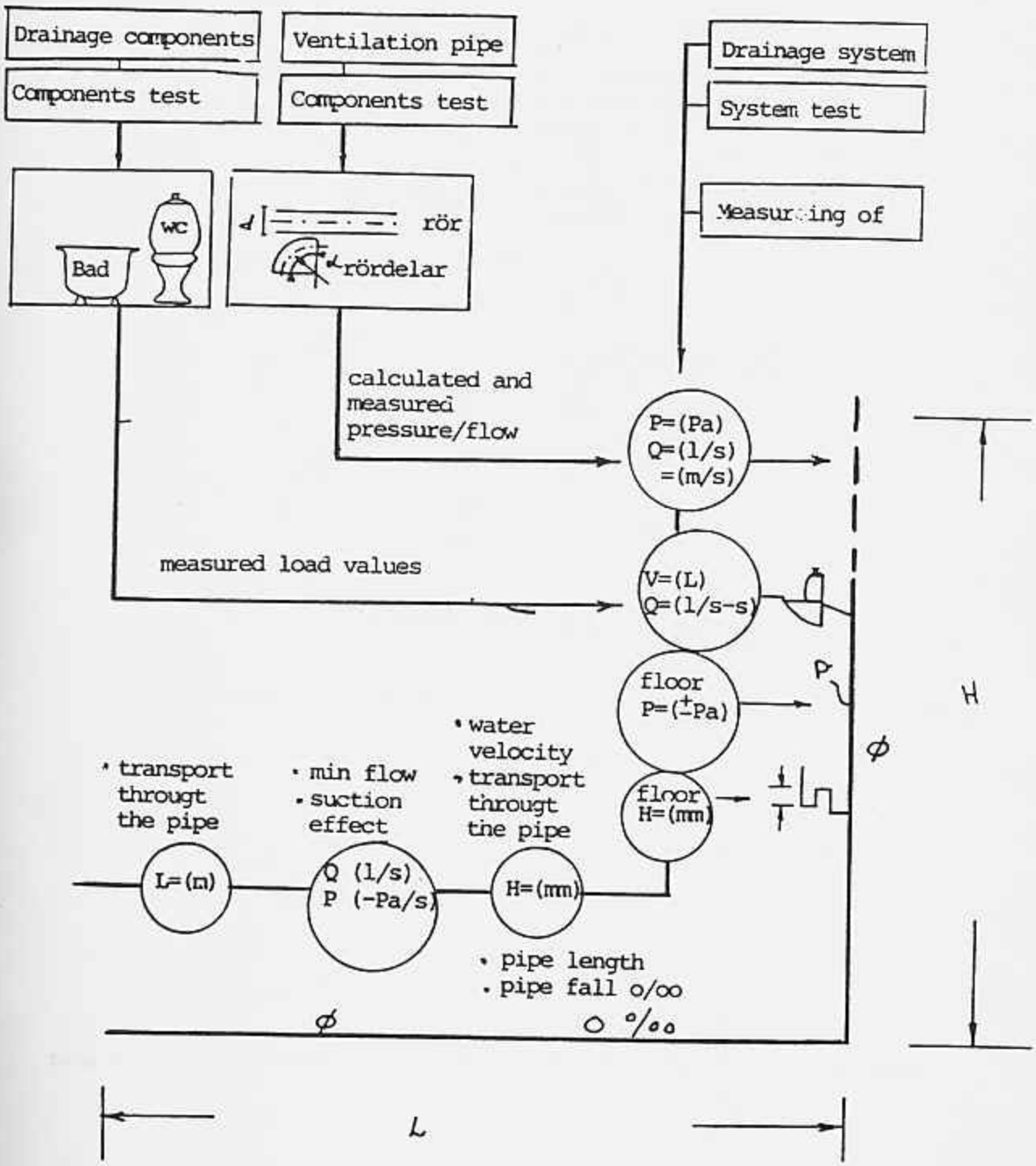


Figure 3.

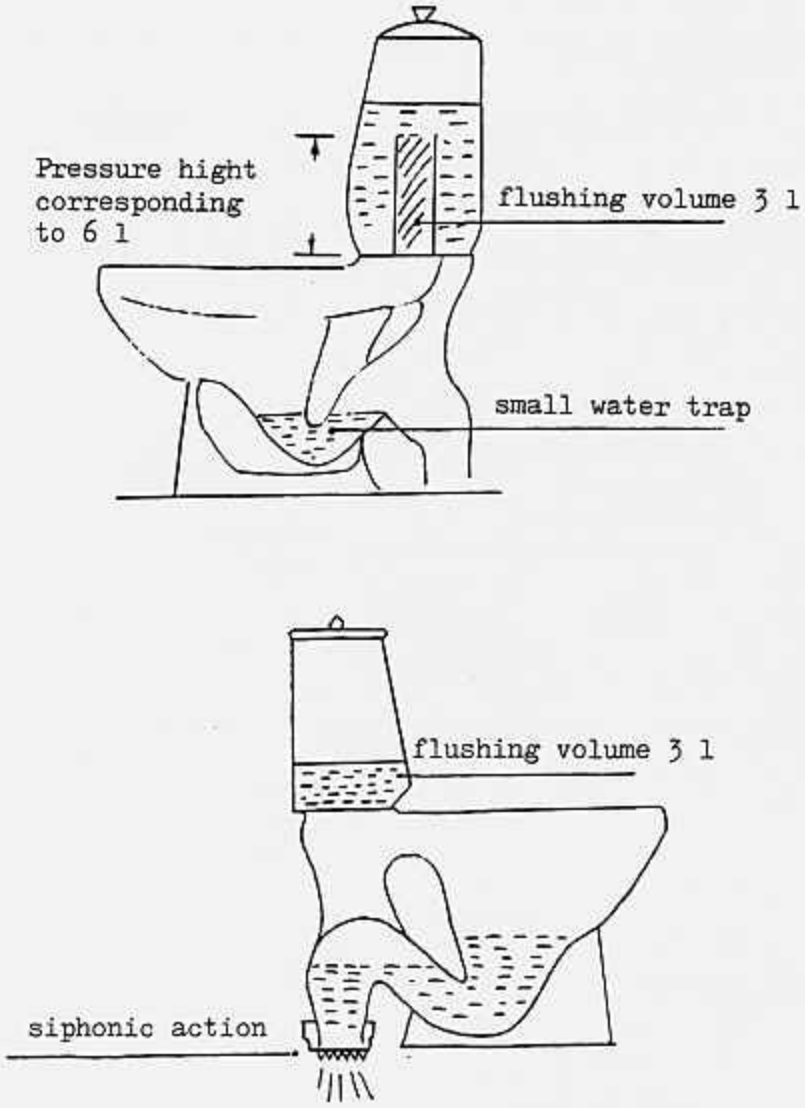


Figure 4. WC with 3 litres volume. The princip for to maintain a good flow rate.

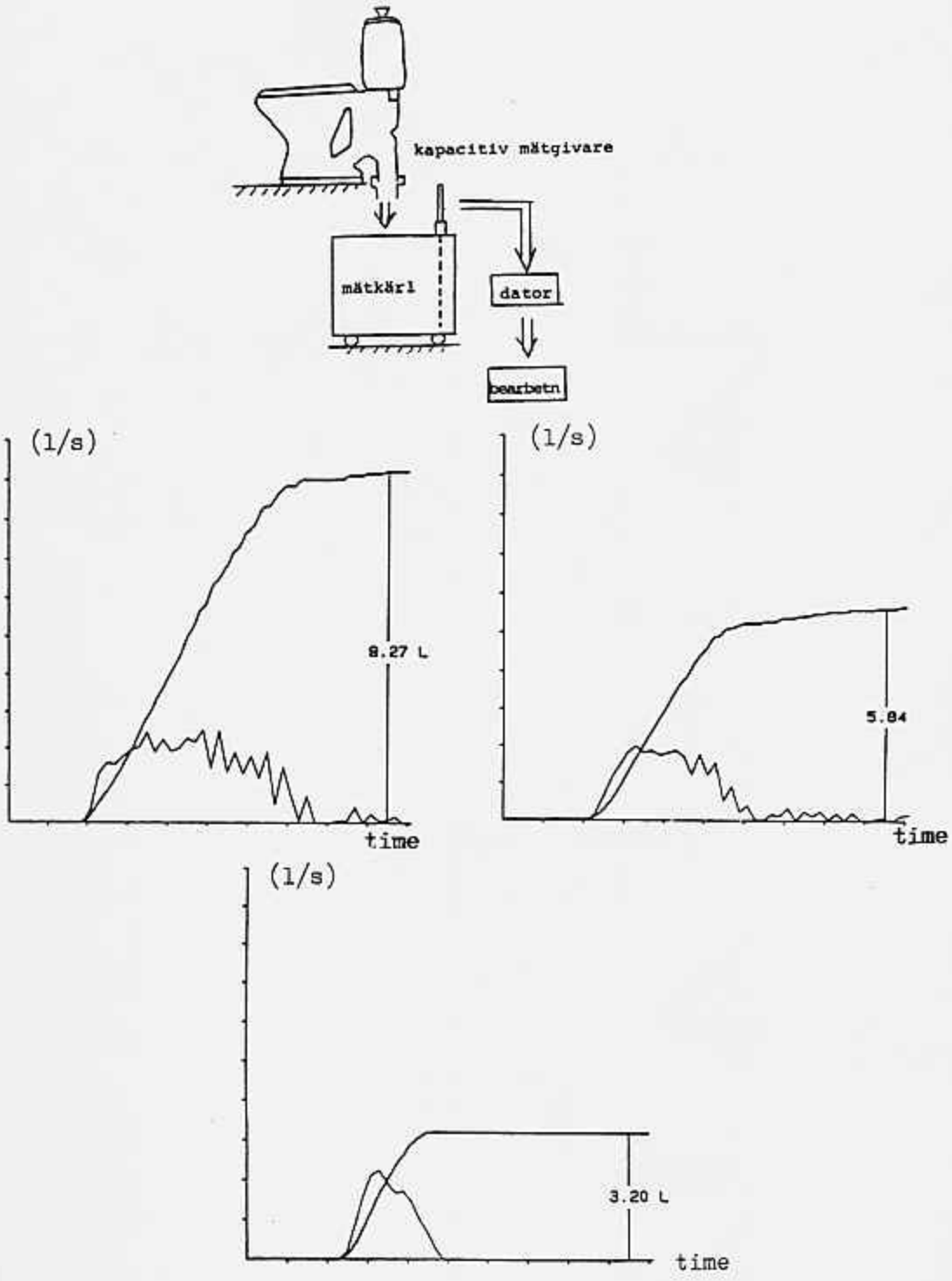


Figure 5. Characteristic function for different volume 9.27 l, 5.84 l and 3.20 l.

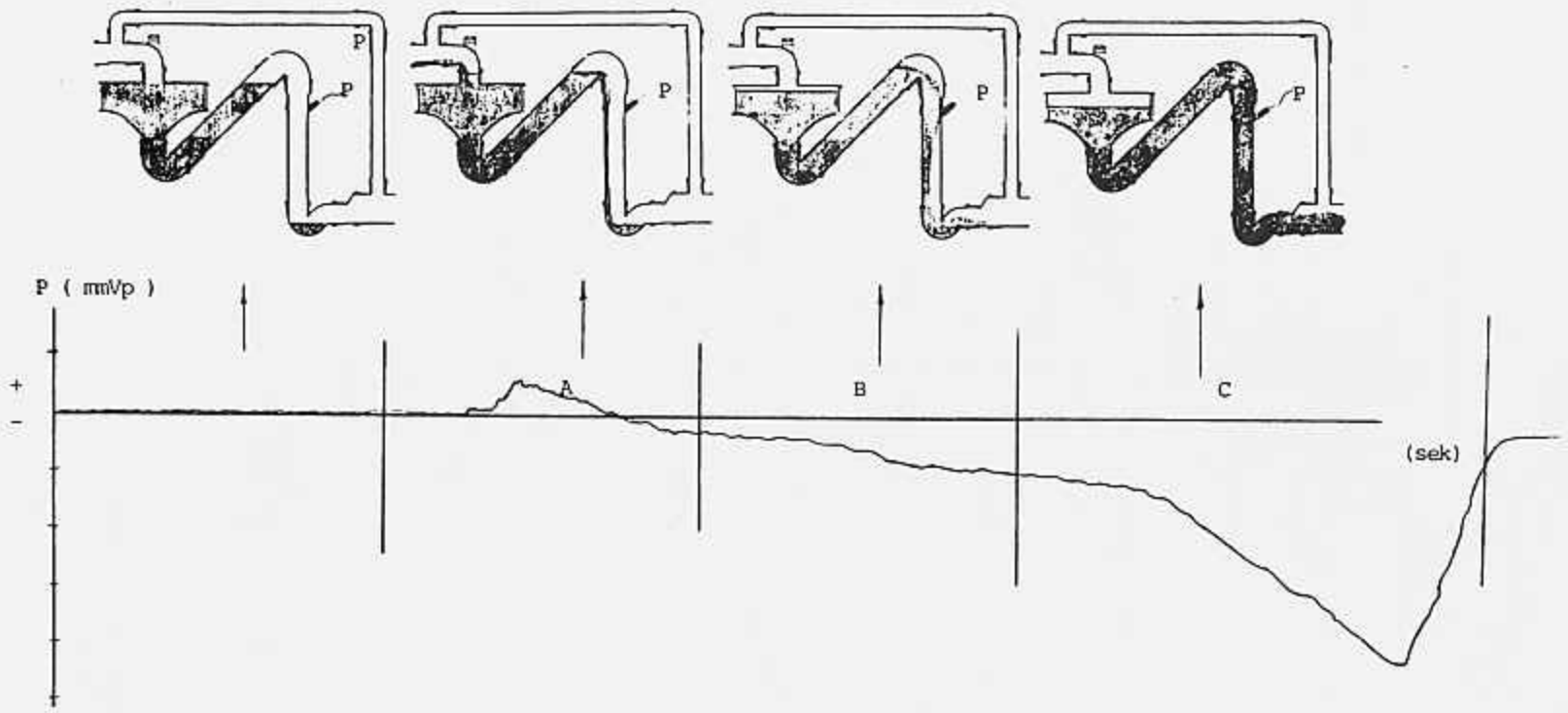


Figure 6. Principal drawings - siphon

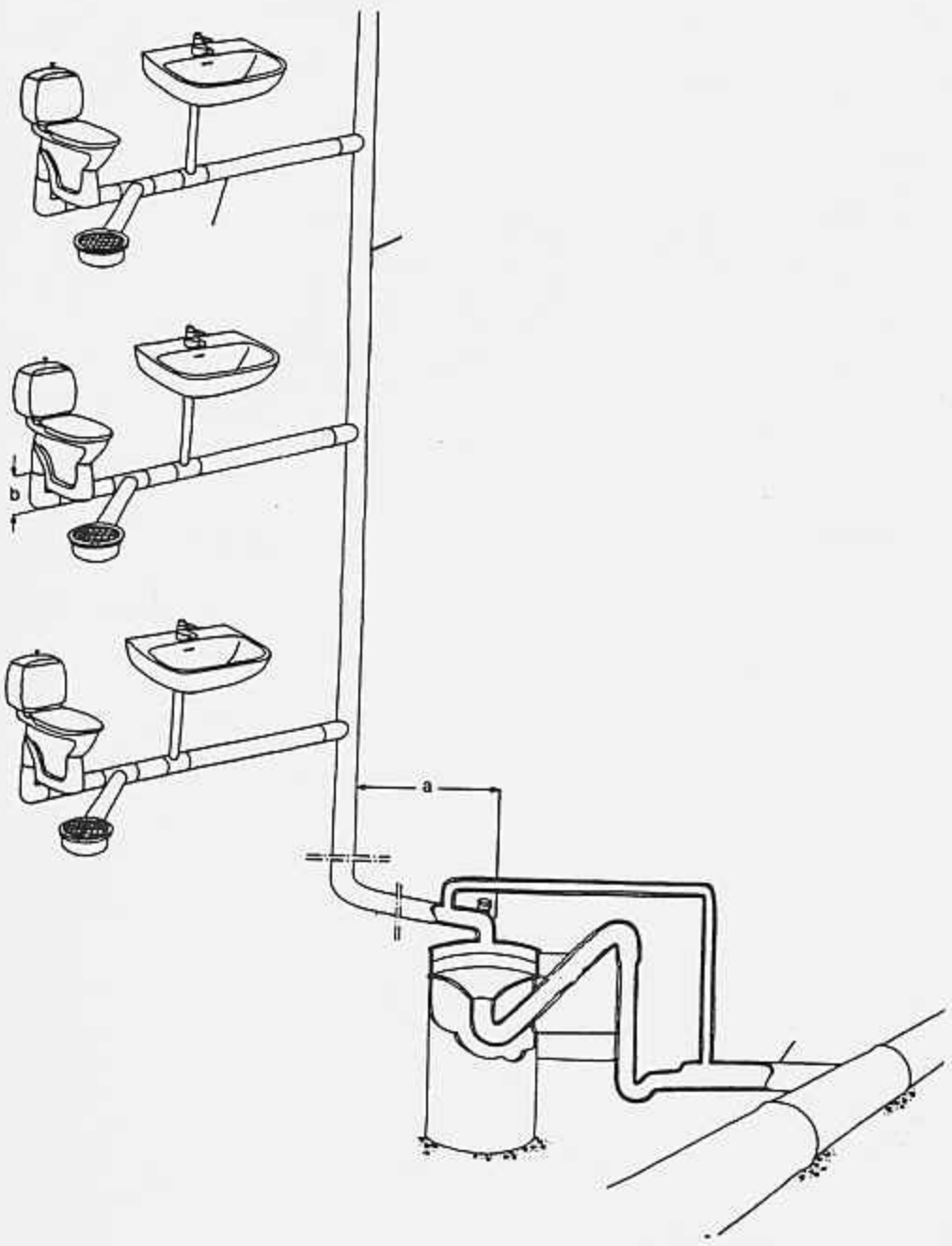


Figure 7. Principal drawings - siphon system

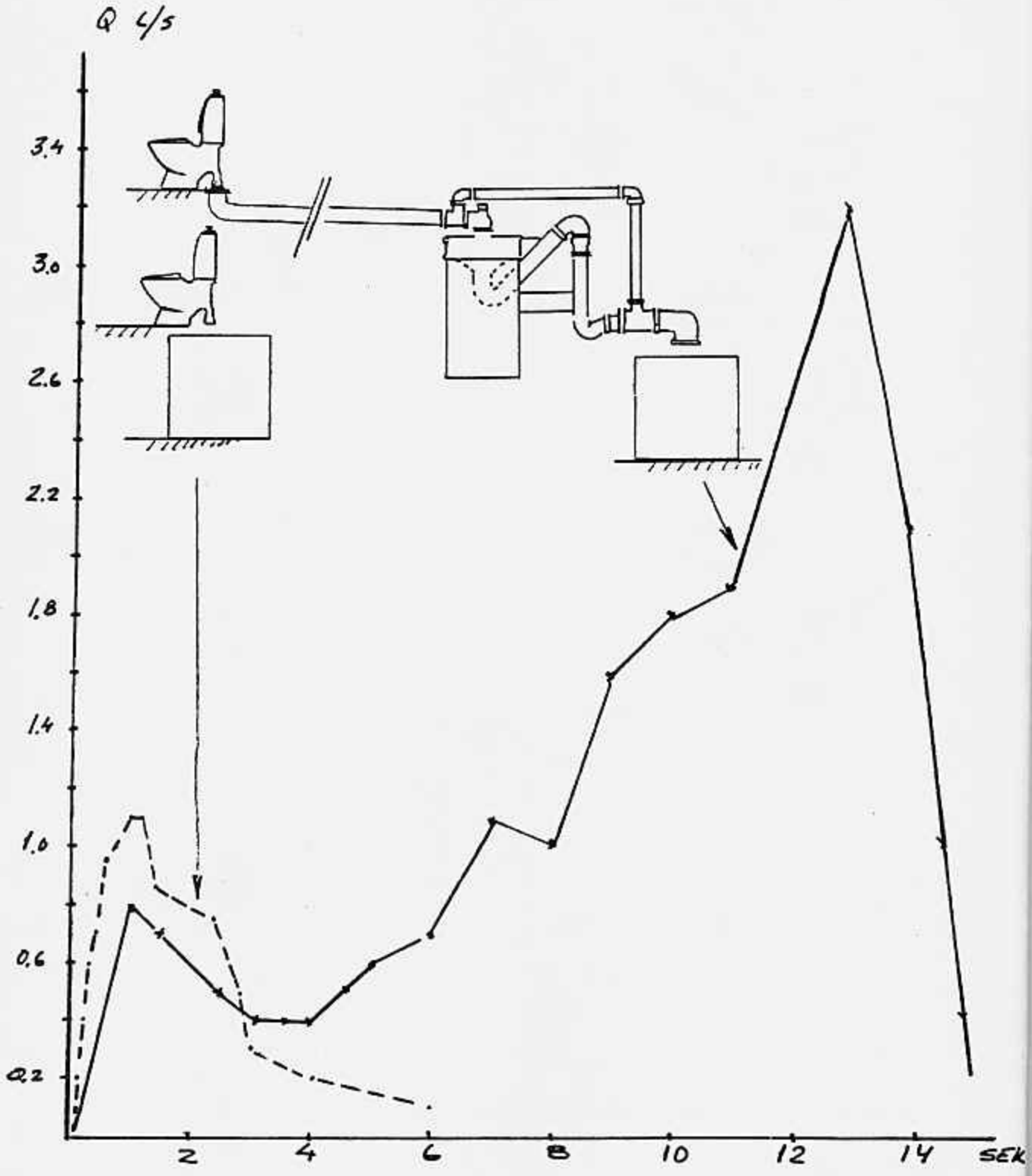
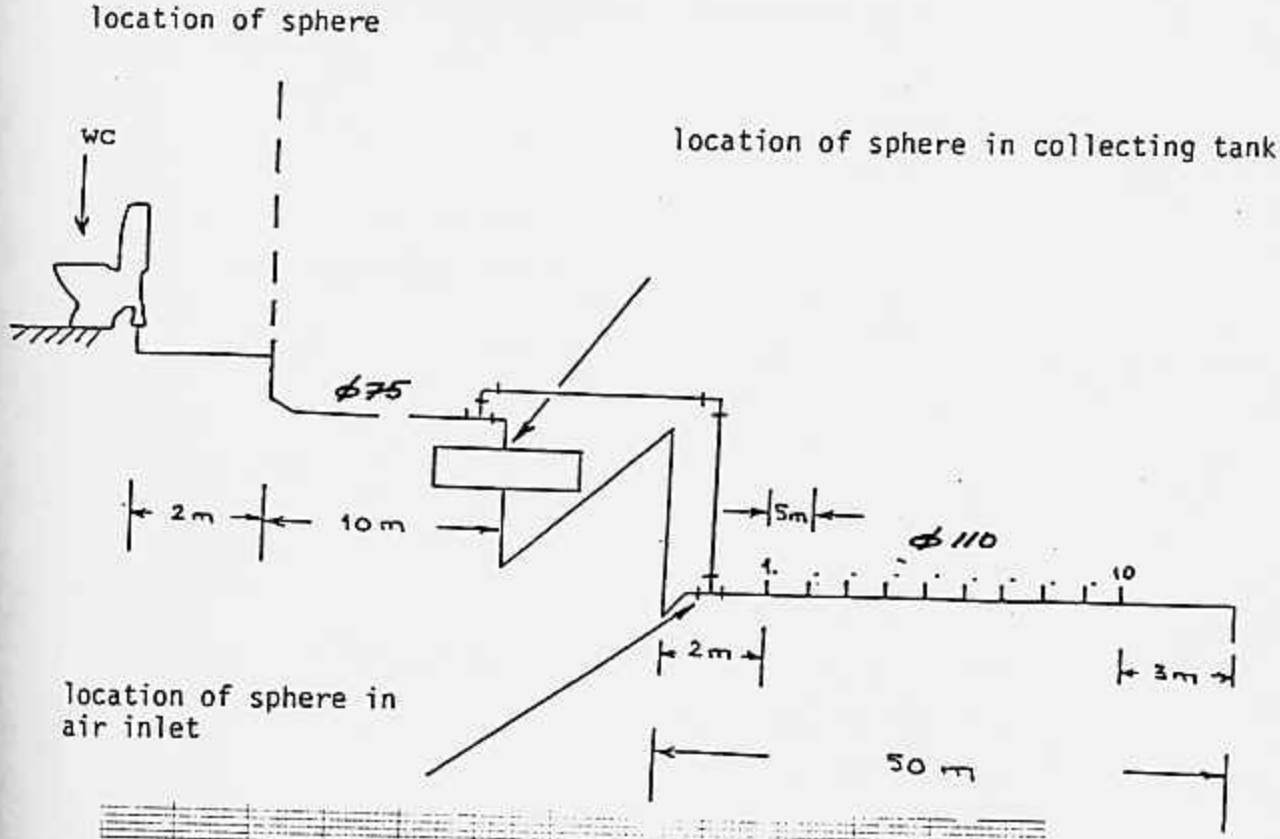


Figure 8. Flow rate characteristic - WC and siphon



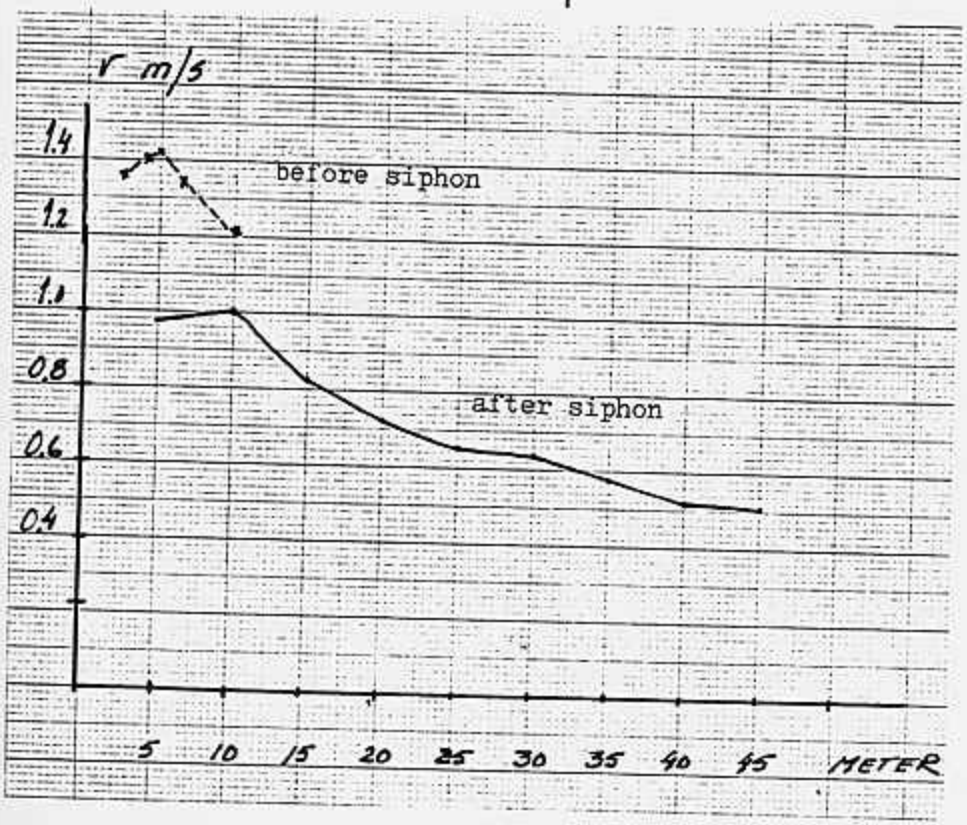
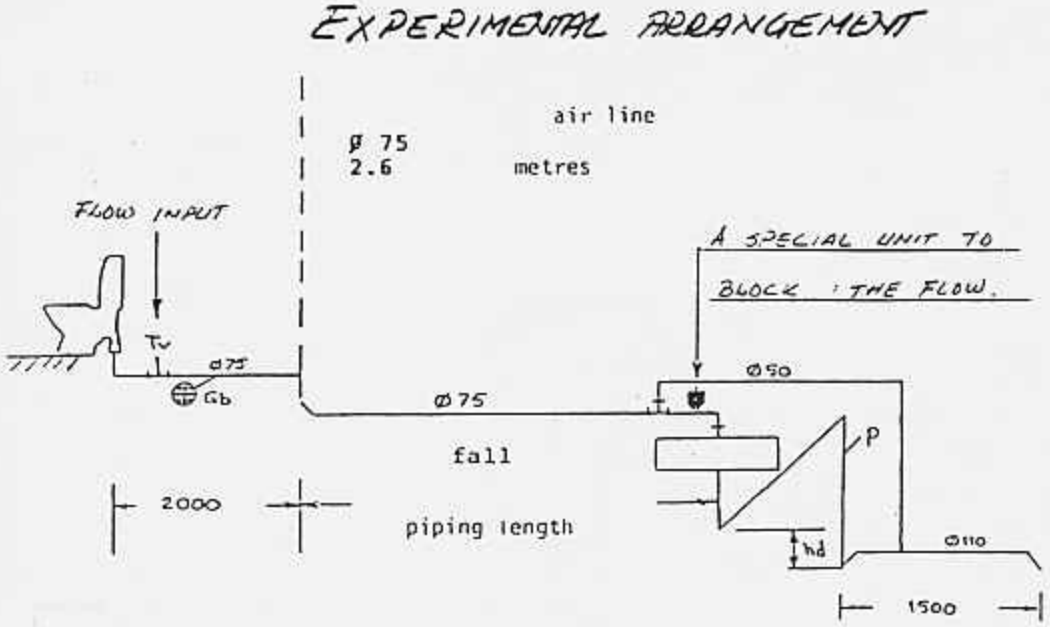


Figure 9. Water velocity in the system before and after siphon



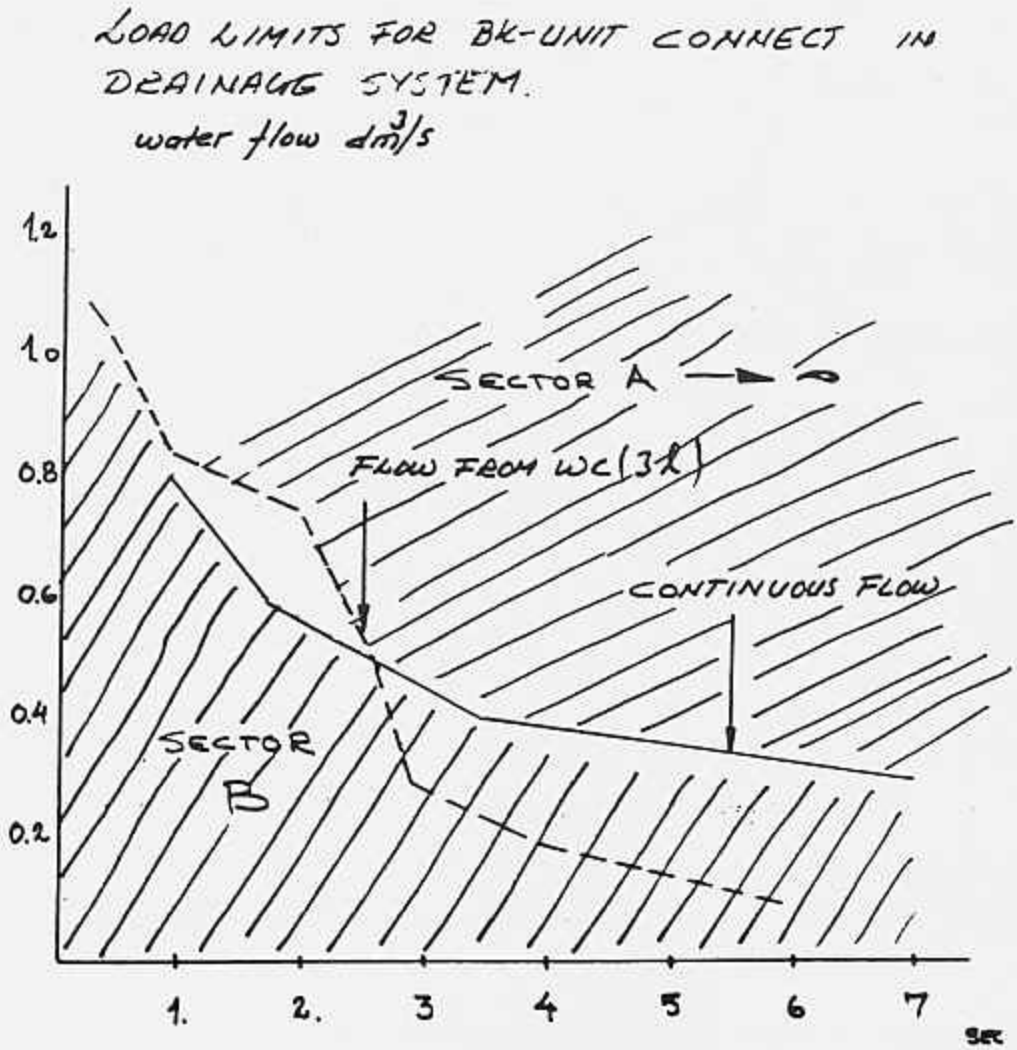


Figure 10. Experimental arrangement - WC - siphon

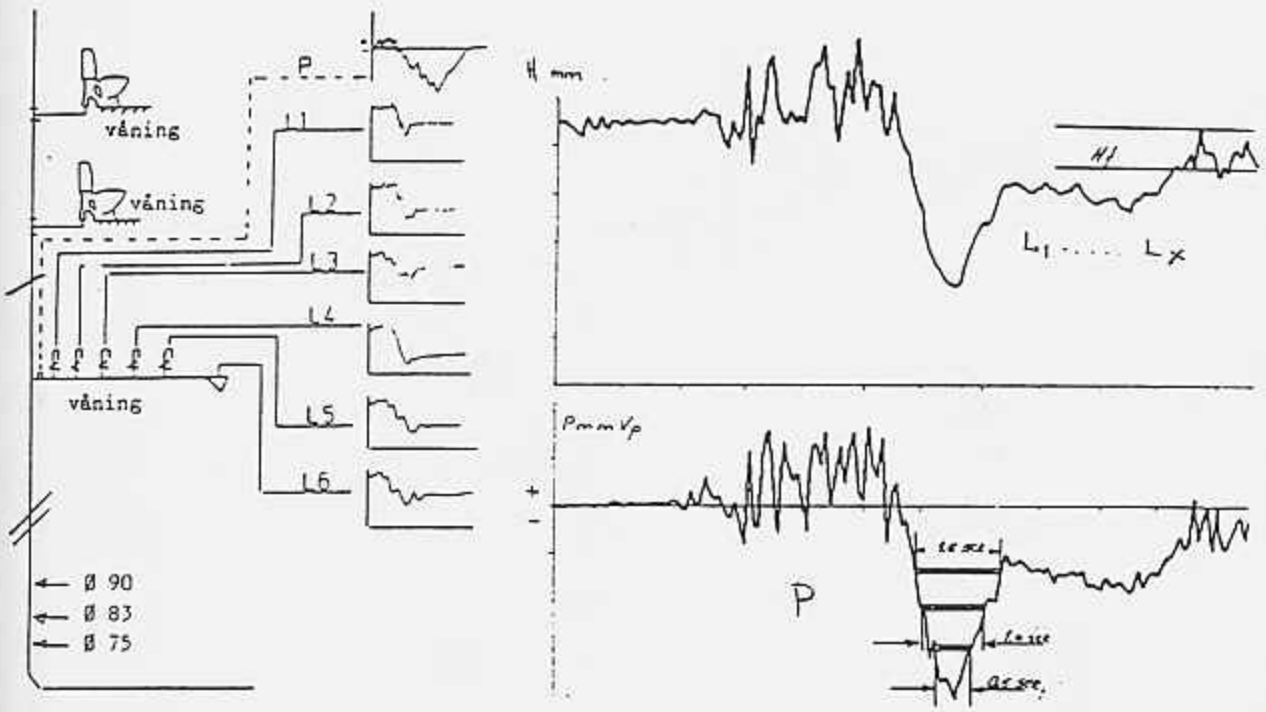


Figure 11. The figure show relation between loss of water in the trap and the pressure.

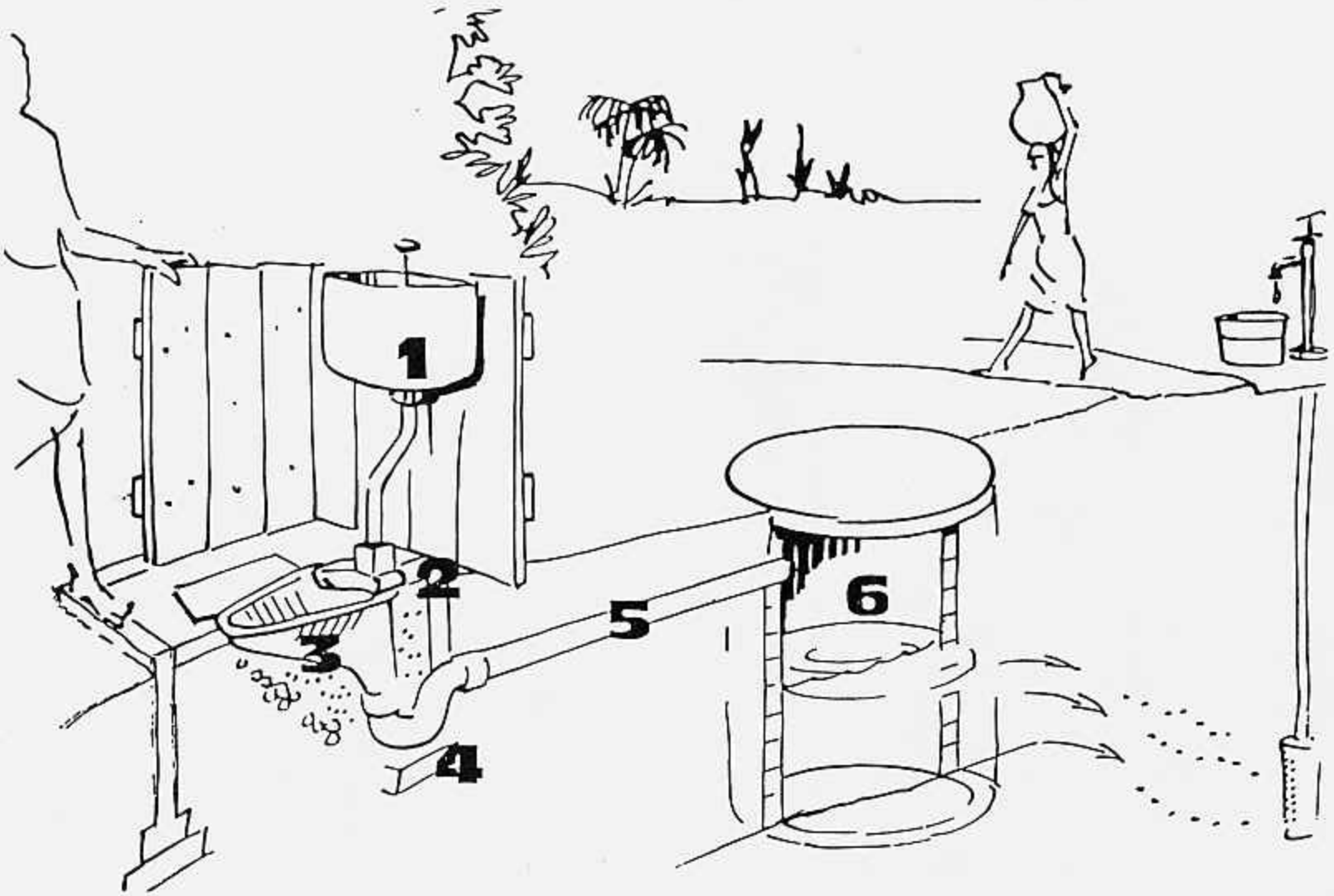


Figure 12. The figure show the 6 sub-systems which together comprise a water cycle in a system.

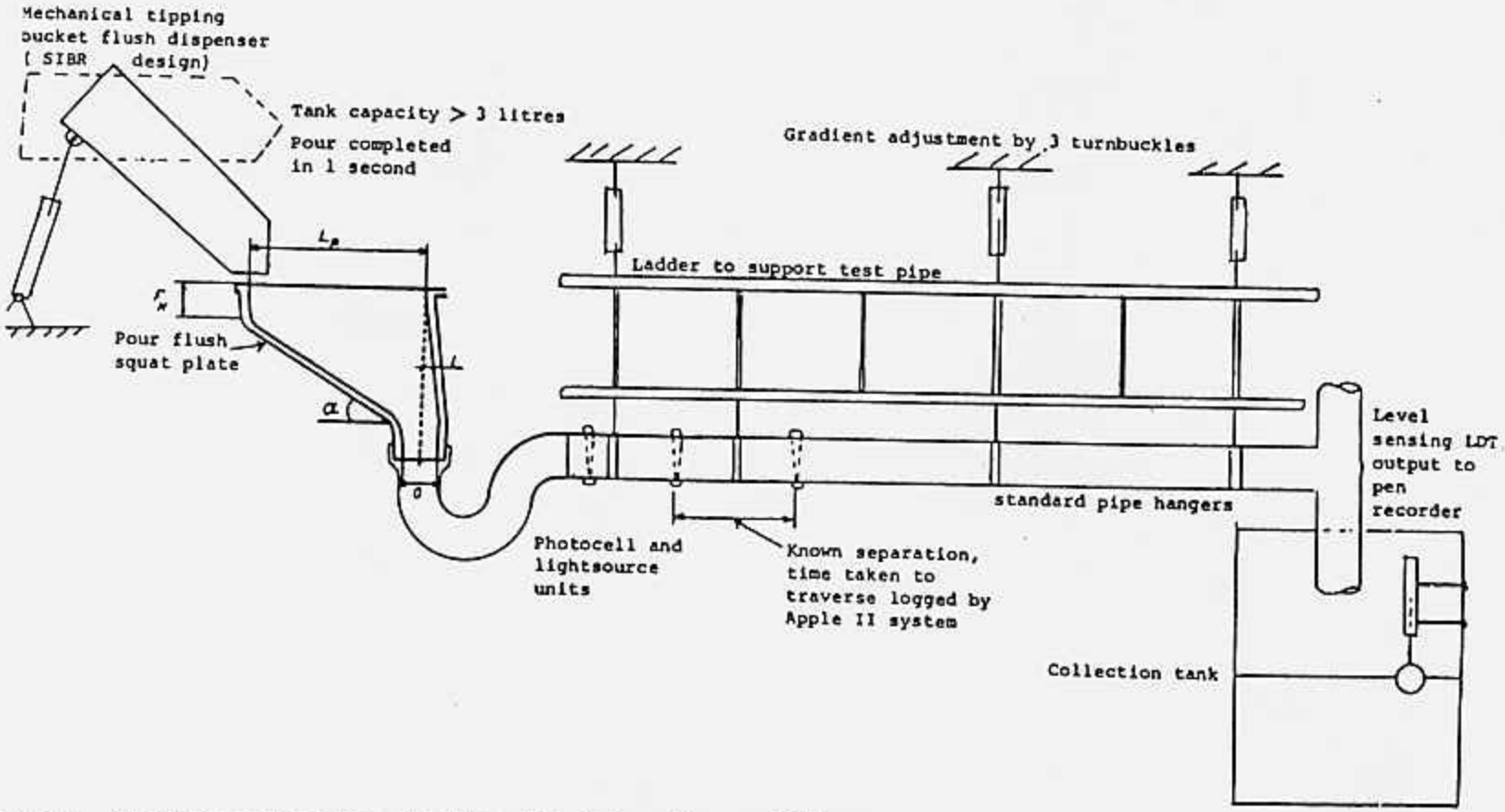
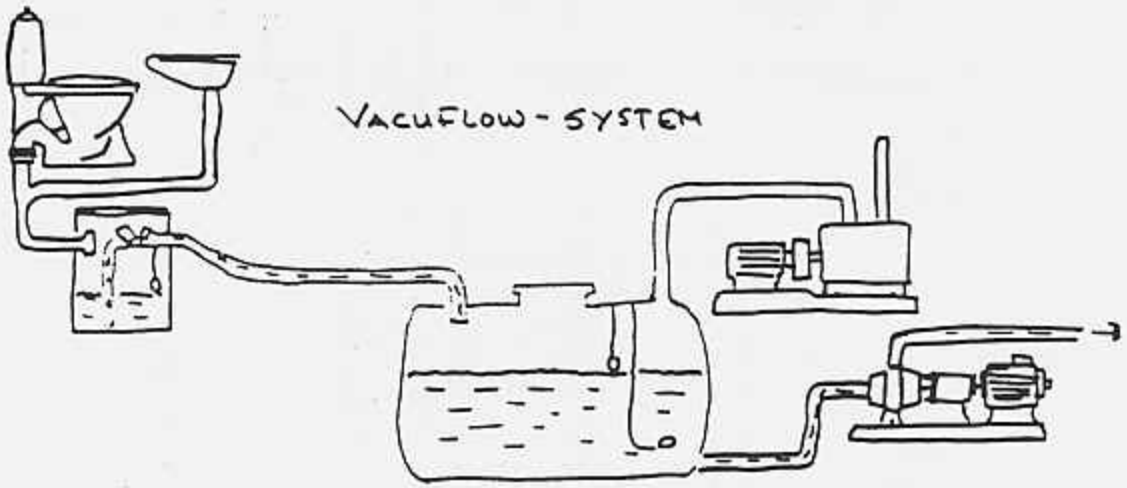


Figure 13. Testing system for checking the hydraulic conditions



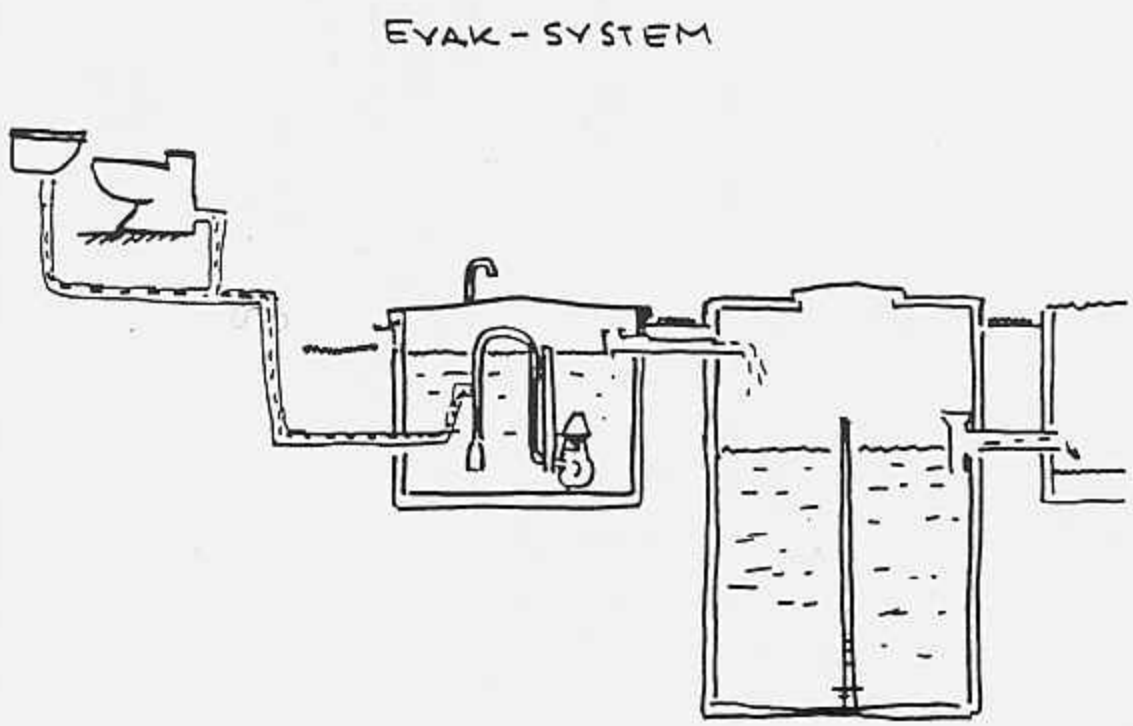


Figure 14. Vacuum flow system

TRYCKAVLOPPSSYSTEM LPS

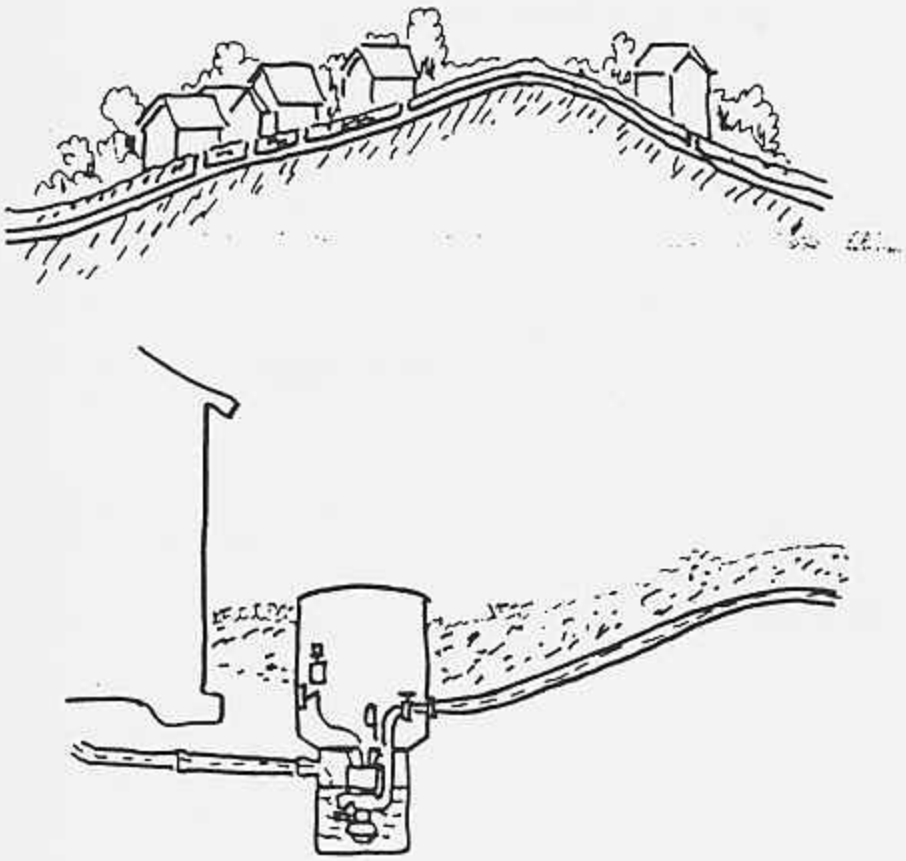


Figure 15. Pressure system (LPS)

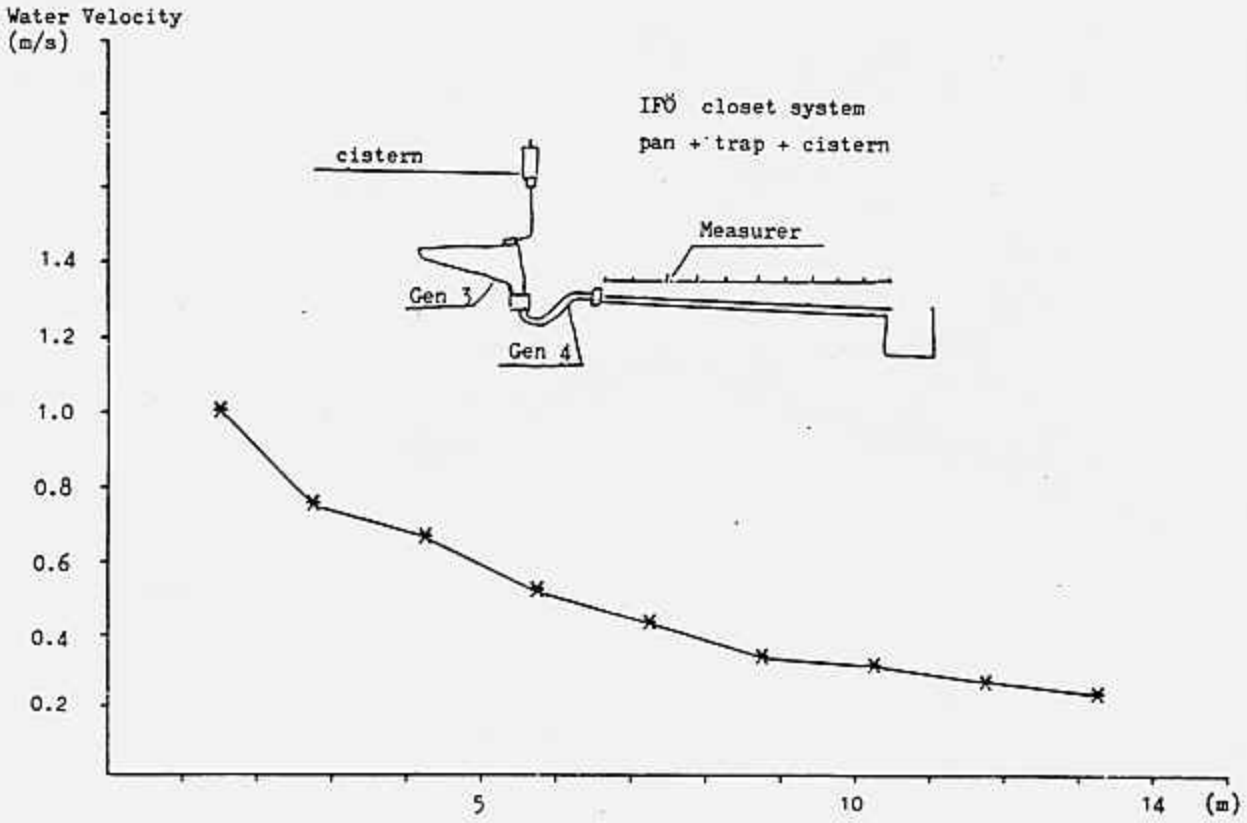


Figure 16. Water velocity test

FLUSHING TEST	MEASURED LENGTHS TOTAL 15 M (A-E) SOLIDS - SANITARY TOWEL								NUMBER SANITARY TOWEL	TRANSPORT M/FLUSH AVERAGE M
	1	2	3	4	5	6	12	OUT		
1	A								A 6	2.5 M
2			A						B 8	1.87
3	B			A					C 6	2.5
4		B		A					D 6	2.5
5	C		B			A			E 4	3.75
6			C		B			A		
7	D				C	B				
8	D				C	B				
9	E	D			C	B				
10			ED					BC		
11				D	E					
12								DE		

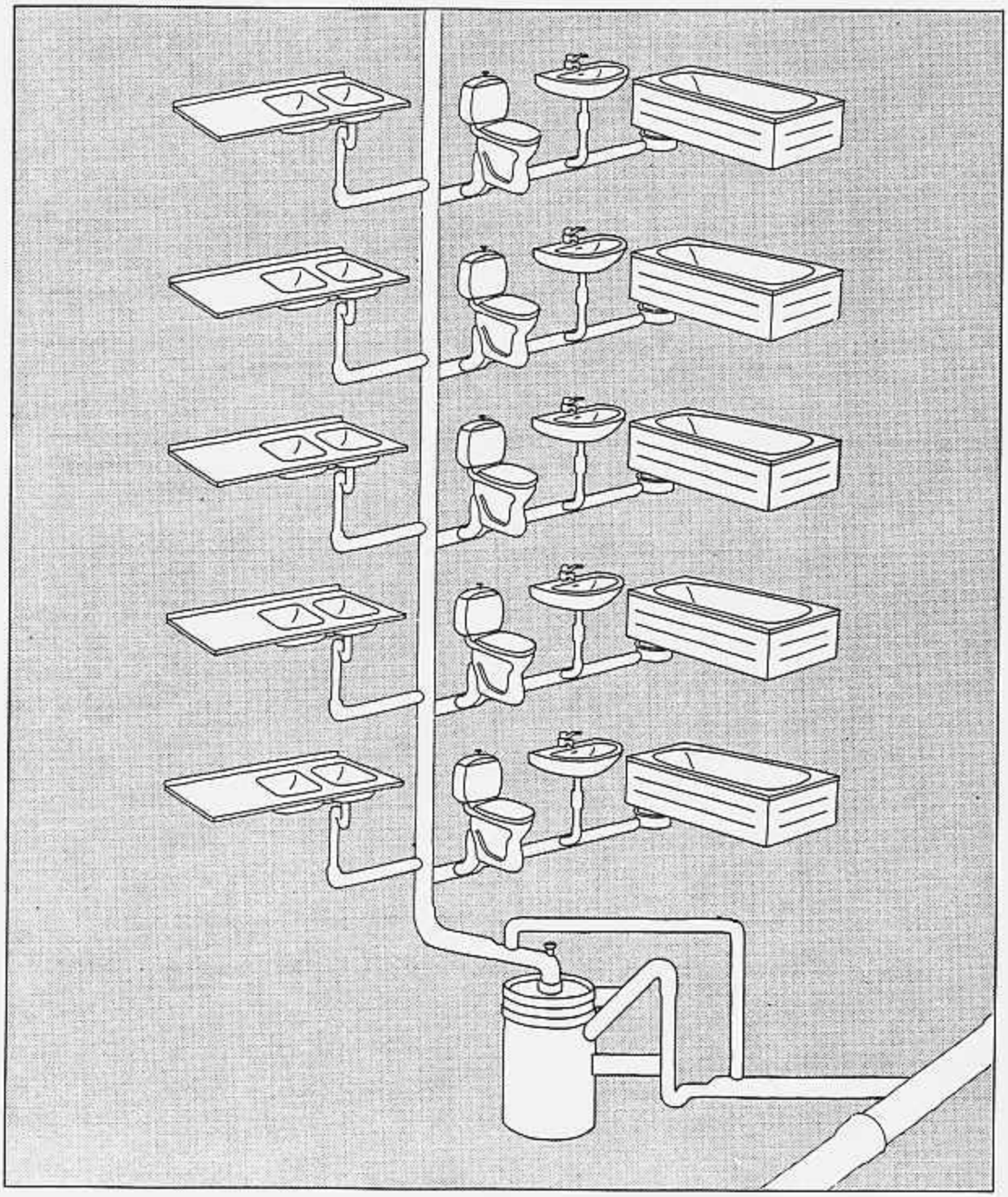
Table 1 a. Transport test (10 flushing - first with sanitary towel second without third with etc) on handflush system

FLUSHING TEST	MEASURED LENGTHS TOTAL 15 M (A-E) SOLIDS - SANITARY TOWEL								NUMBER SANITARY. TOWEL	TRANSPORT M/FLUSH AVERAGE M
	1	2	3	4	5	6	12	OUT		
1	A								A 6	2.5 M
2			A						B 4	3.75
3	B				A				C 3	5.0
4				B			A		D 4	3.75
5	C					B	A		E 4	3.75
6					C			AB		
7	D							C		
8				D						
9		E			D					
10			E					D		
11					E					
12								E		

Table 1 b. Transport test on upgrading cistern system. Flushing is equal to table 1 a.

Gustavsberg's Water Saving System — WSS

General description, pages 2—3
Dimensioning and installation directions, pages 4—5
Planning for housing schemes, pages 6—7
Scale drawings, page 7
Example with 90 mm dimensions, page 8



General description of WSS

It doesn't matter what kind of WC system you are using at present—you are flushing away quite unnecessarily large amounts of fresh, life-giving water. With the Gustavsberg Water Saving System you can save large quantities of water and still have a first-rate WC standard. Each flushing only uses about 3 litres of water, and yet the system can be connected to the municipal sewage network.

The system is based on the principle of gravity, and in its externals it is very similar to a conventional system. It includes WCs, washbasins, showers, bathtubs, kitchen units etc.

The siphon is the heart of the WSS system

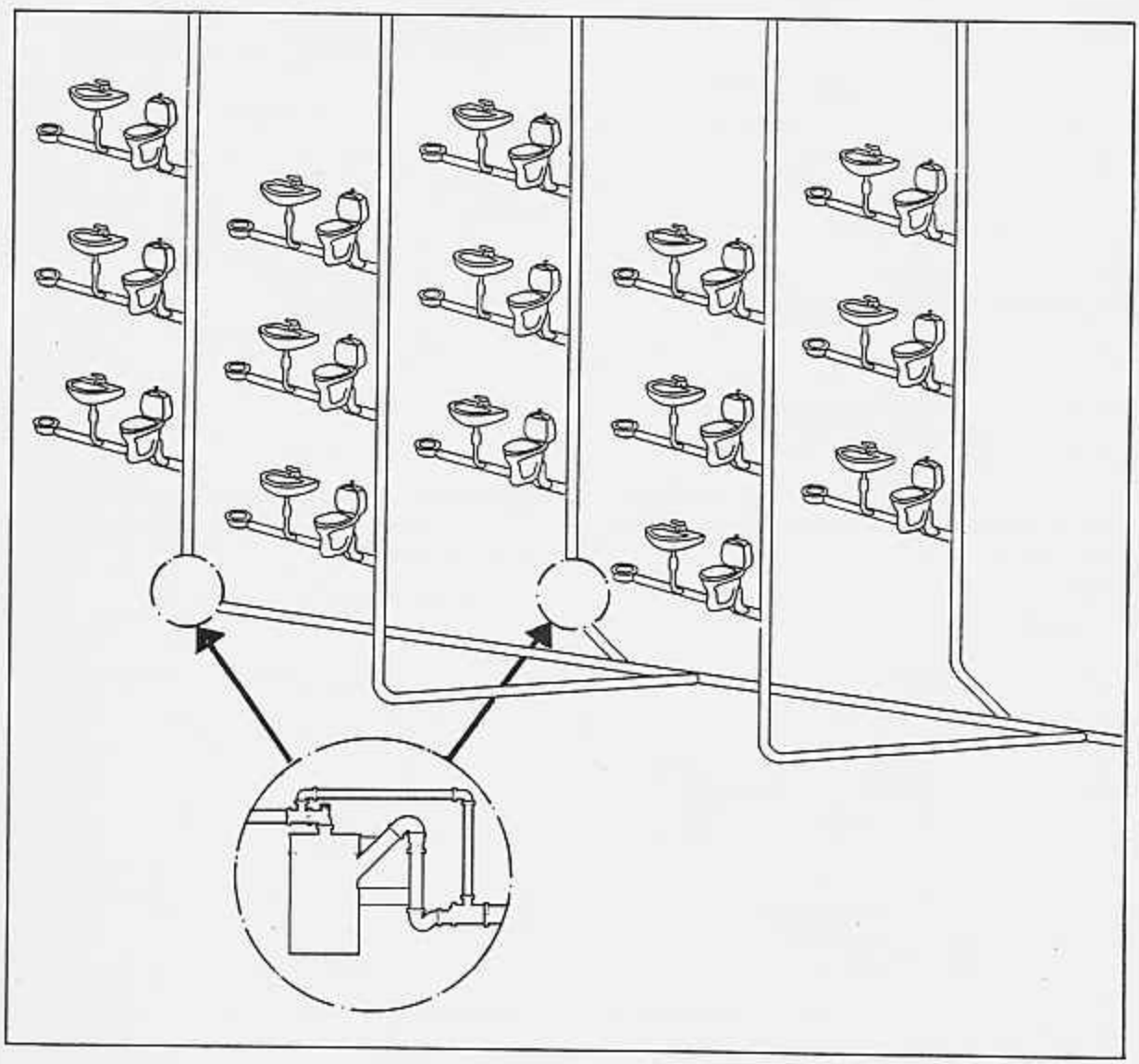
Until now it has not been possible to connect WCs with such a low flushing volume as three litres to the ordinary sewage system. This volume is too small to give an efficient self-cleansing in pipes that are laid in the ground. In the siphon, a large quantity of waste water is accumulated and then flushed out all at once.

The siphon can thus be regarded as an automatic cleansing device, which functions without any external power supply.

Indoors, the piping system consists of conventional waste water pipes. In branch lines and down pipes with connections to WCs, the pipe dimensions used are mostly 90 and/or 110 mm. The number of siphons and their positions are arranged so as to guarantee self-cleansing in the bottom pipe.
NOTE: There are certain special requirements as regards pipe dimensions; these are described on pages 4 and 5.

Thus it is now possible to connect water-saving WCs to the ordinary sewage system and still get an efficient water transport through the pipes.

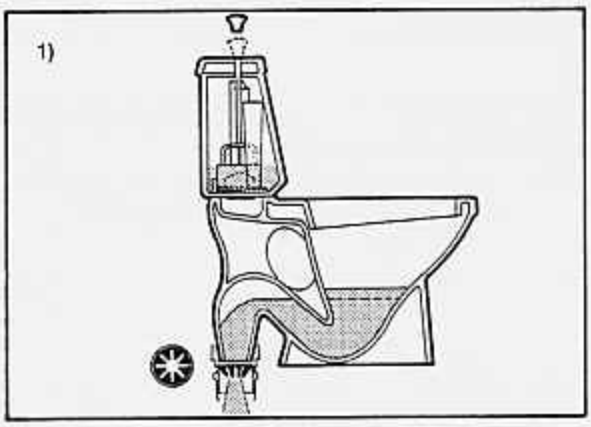
When fitting new units or modernising older buildings, it is usually possible to keep the old downpipe.



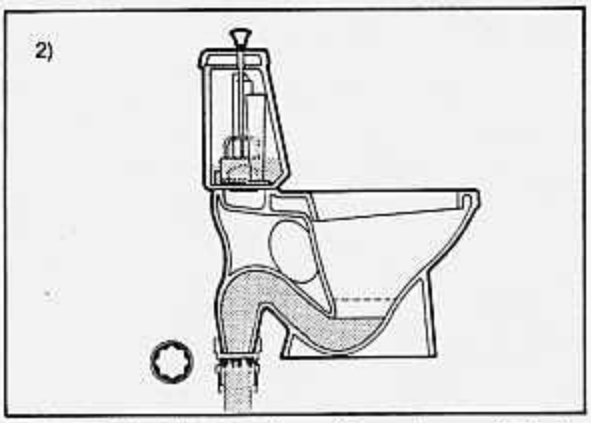
This is how the most important components work

WC 366

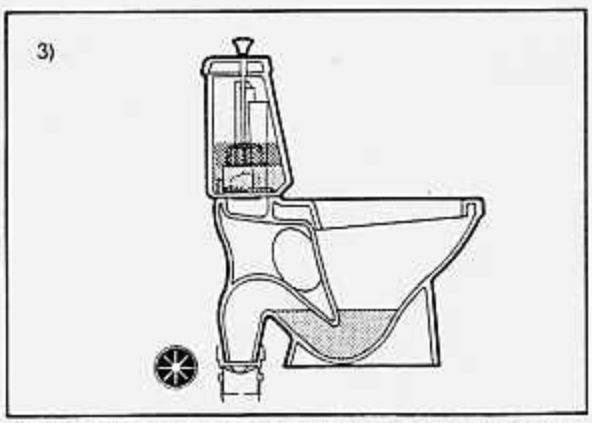
The WC is the first important component. It is flushed out with 3 to 3 1/2 litres. Special fittings in the cistern plus a patented diaphragm in the outlet produce an extra push during the flushing sequence, which can be divided into three phases.



A delaying action



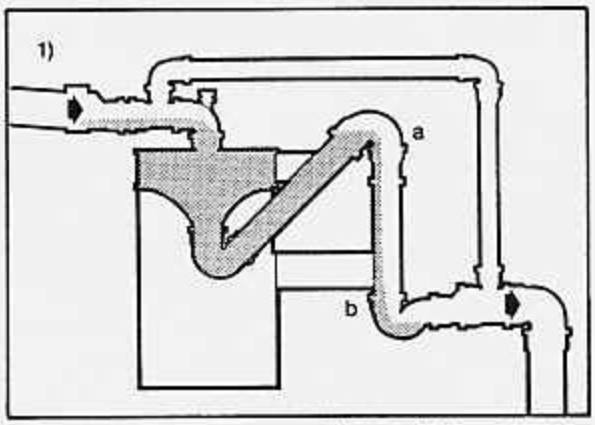
Flushing with siphoning effect. "Secondary ventilation" takes place via the WC.



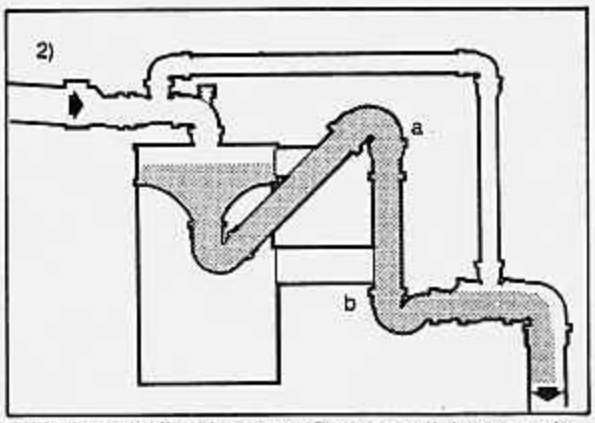
Refilling of water trap and cistern. The WC 366 gives the same flushing efficiency, hygienic conditions and convenience as a conventional WC.

WSS siphon

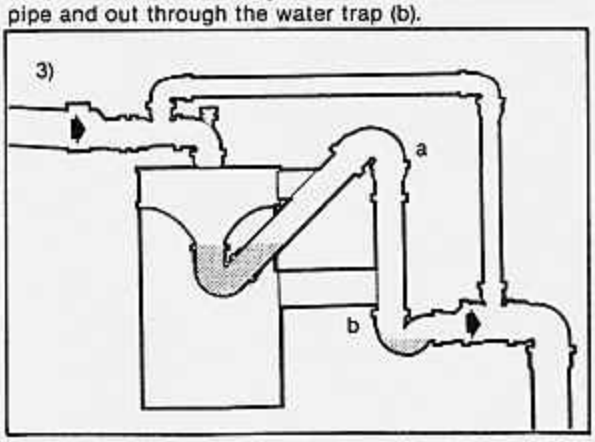
This patented siphon or new pipe section accumulates about 20 litres of waste water from the sanitary fixtures, und when a new flushing from a WC comes into the siphon the whole volume is emptied out into the horizontal pipe, which is thus self-cleansing.



Water from all the sanitary appliances (WC, washbasin, shower etc) flows in through the inlet pipe. The tank and the riser are filled up to the overflow level (a).



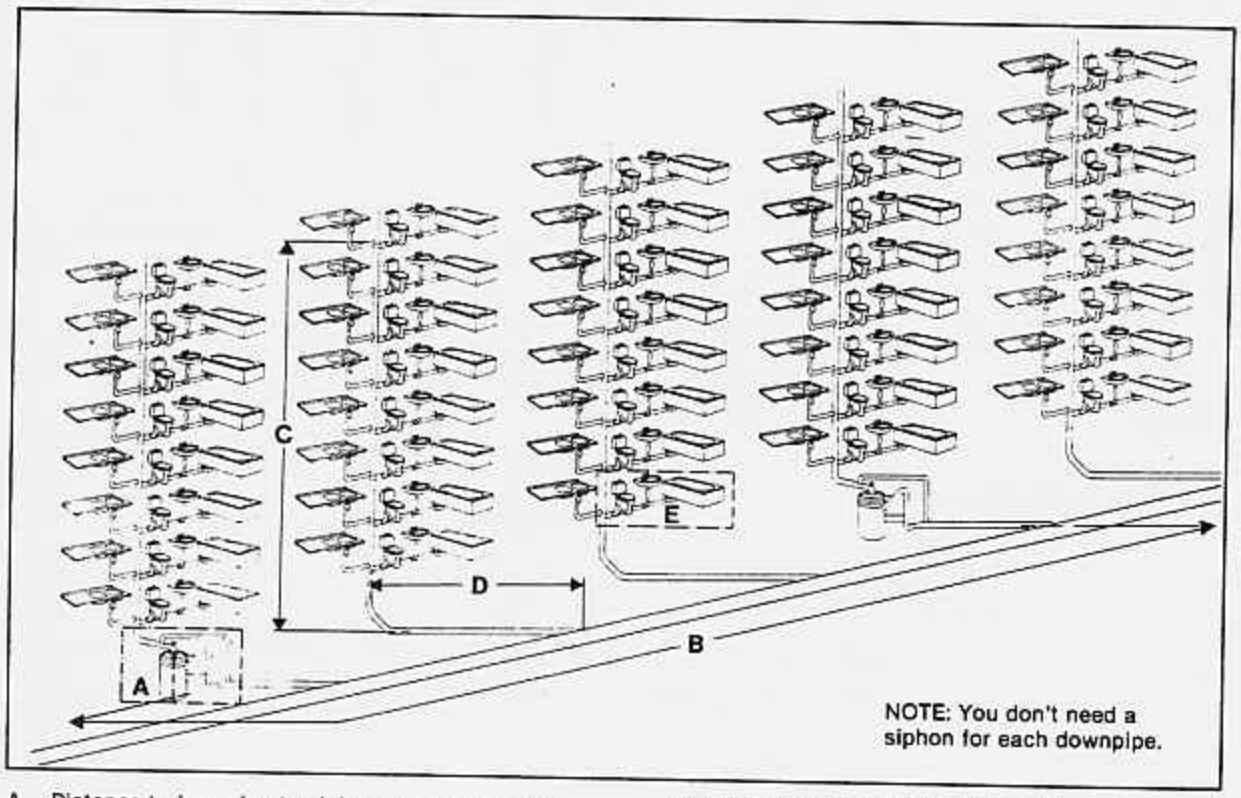
With the next flushing or outflow, a partial vacuum is created in the vertical pipe, so that a new plug of water is formed at (b). The water column becomes continuous, from the tank through the riser and the vertical pipe and out through the water trap (b).



The siphon is now ready for the next cycle.

Dimensioning

Dimensioning is in accordance with the Swedish standards given in SBN 80 chap. 51 (Swedish Building Standards), with the following exceptions.



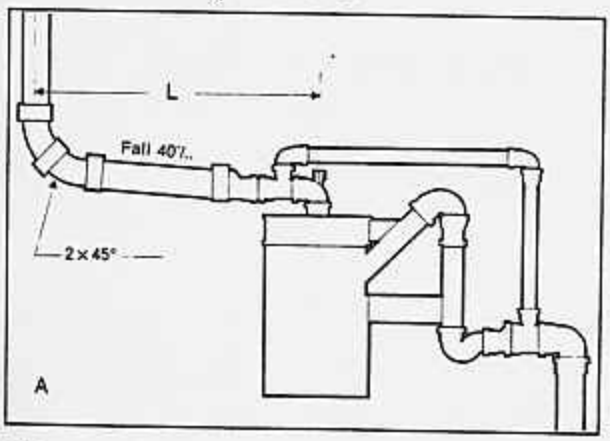
A. Distance L downpipe to siphon with 110 mm dimensions and 40 ·/.. fall = max 3 m.
Distance L downpipe to siphon with 90 mm dimensions and 40 ·/.. fall = max 10 m.

B. Distance with 110 mm dimensions and 10 ·/.. fall = max 50 m.
Distance with 160 mm dimensions and 10 ·/.. fall = max 25 m.

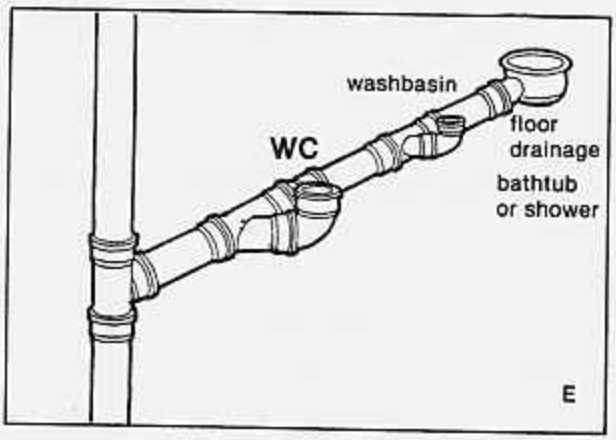
C. Maximum no of floors with 110 mm dimensions = 14 floors, total $_{q}$N max 90 l/s.
Maximum no of floors with 90 mm dimensions = 7 floors, total $_{q}$N max 40 l/s.

D. Pipe without siphon: dimensions 110 mm L = max 3 m with min 20 ·/..fall; 10 m with min 40 ·/.. fall.

E. Pipe length between downpipe and WC with 110 mm dimensions, max 3 m with min 20 ·/.. fall.
Pipe length between downpipe and WC with 110 mm dimensions, max 10 m with min 40 ·/.. fall.
Pipe length between downpipe and WC with 90 mm dimensions, max 10 m with min 10 ·/.. fall.



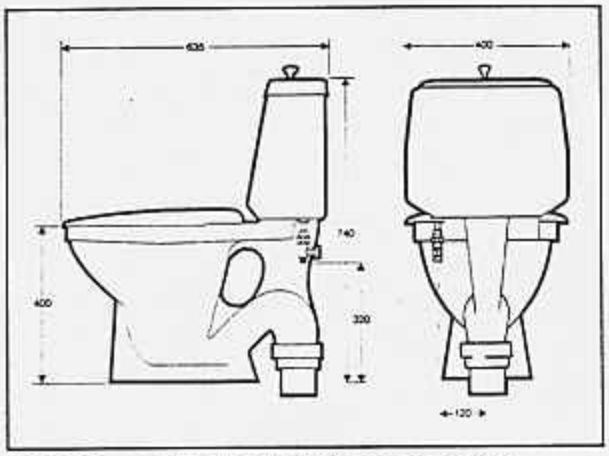
Distance and slope between downpipe and siphon.



Length of pipe between downpipe and WC.

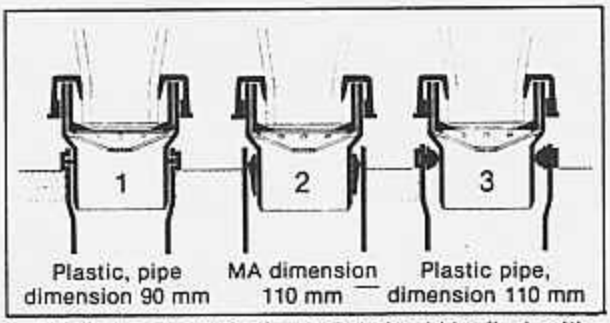
NOTE: Siphon must be placed so that adequate self-cleansing is obtained in the whole installation.
All dimensions above are referred to external diameters.

WC 366



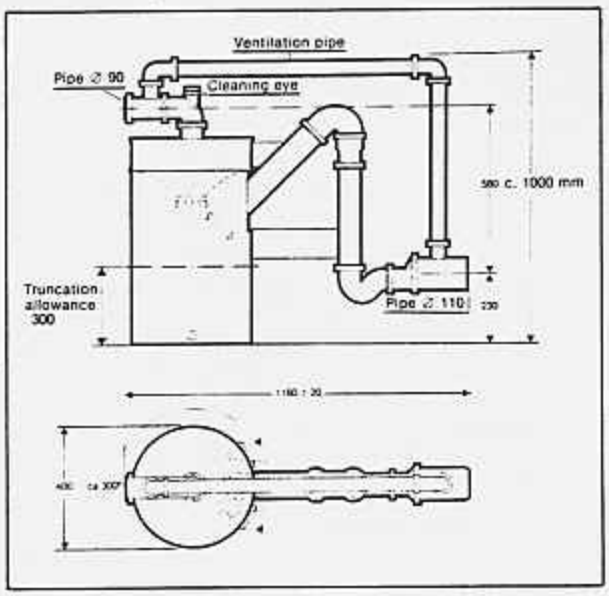
NOTE: Connecting piece with 90 mm dimensions.

Connection of WC 366

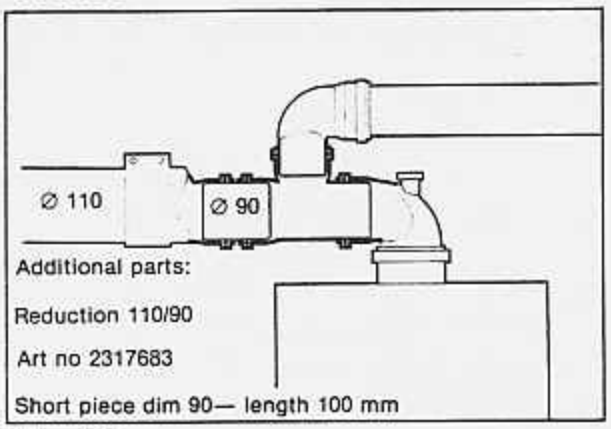


1. The O-ring groove in the socket should be flush with the floor.
2. MA straight end max 20 mm above floor level; sealing ring art. no. 2316883.
3. The O-ring groove in the socket should be flush with the floor; sealing ring art. no. 2316875.

WSS siphon



Connection of WSS siphon 110/90



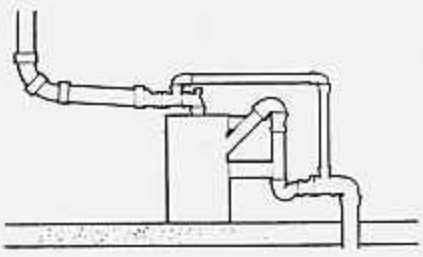
Marking

Gustavsberg

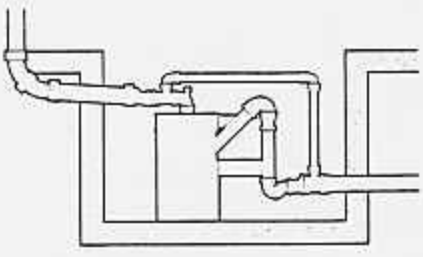
Water Saving System — WSS

Typgodk. nr 3868/82

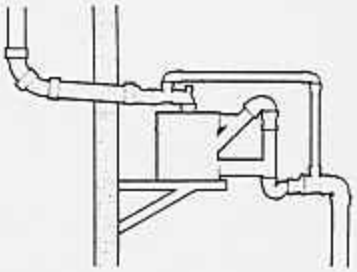
Alternative placings for WSS siphon.



Floor mounting



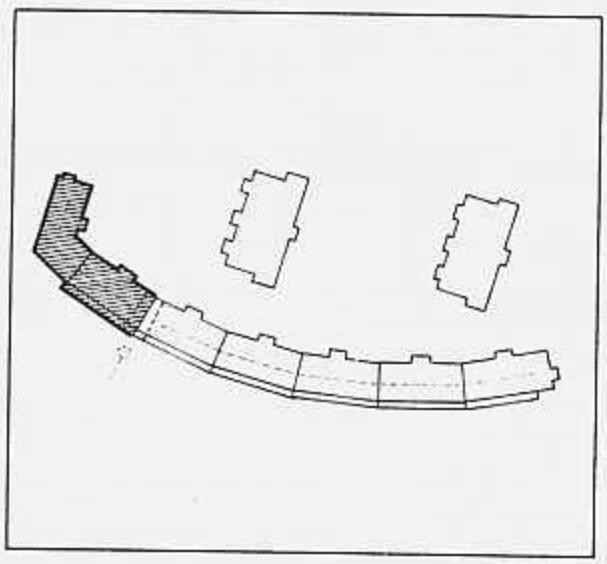
Mounting in well



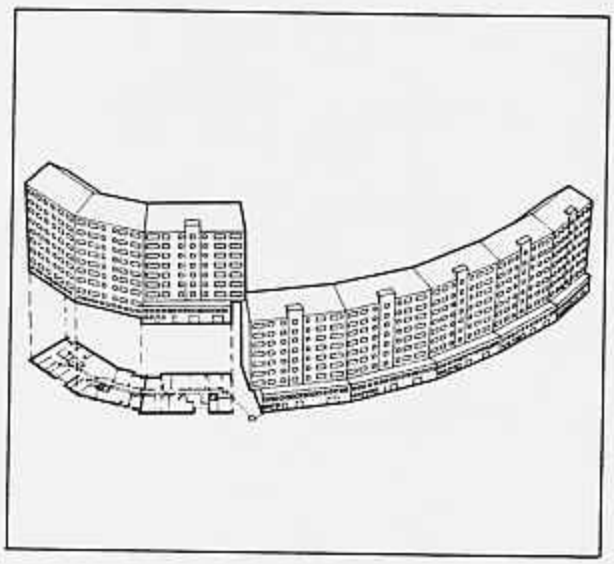
Mounting on wall

Example for housing scheme:

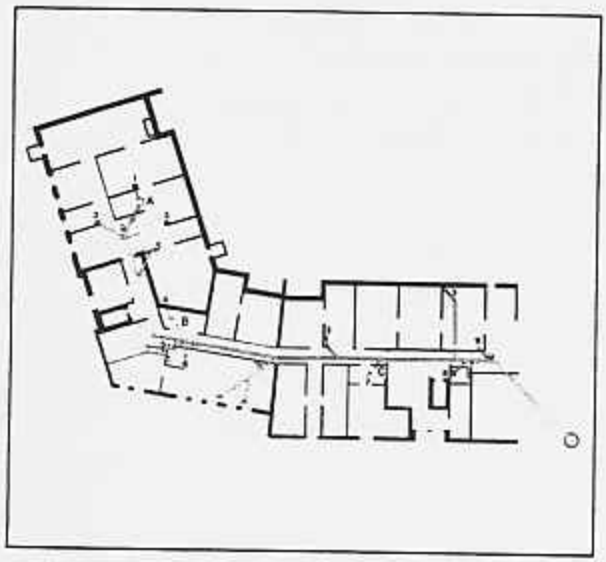
It is advisable to consider systems which can conserve resources while new housing schemes are still on the drawing board. WSS is a conventional gravity system which has been supplemented with a number of siphons. These are included in order to keep the main pipes free of blockages in spite of the reduced flows of water.



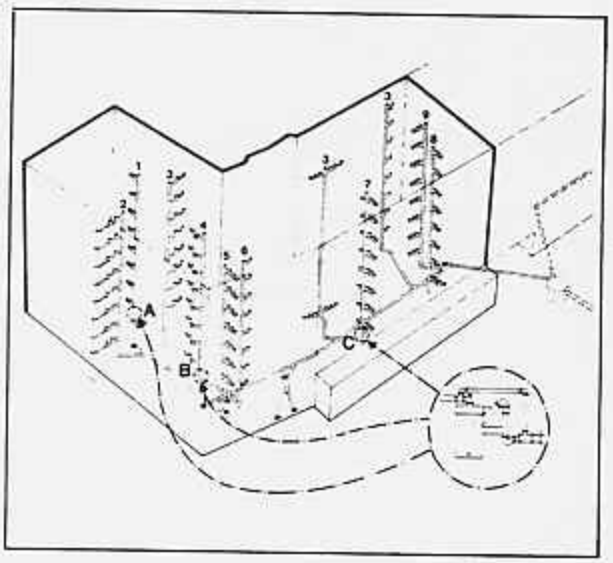
Waste water often has to be transported over long distances.



With small flows, the risk of blockages is great.



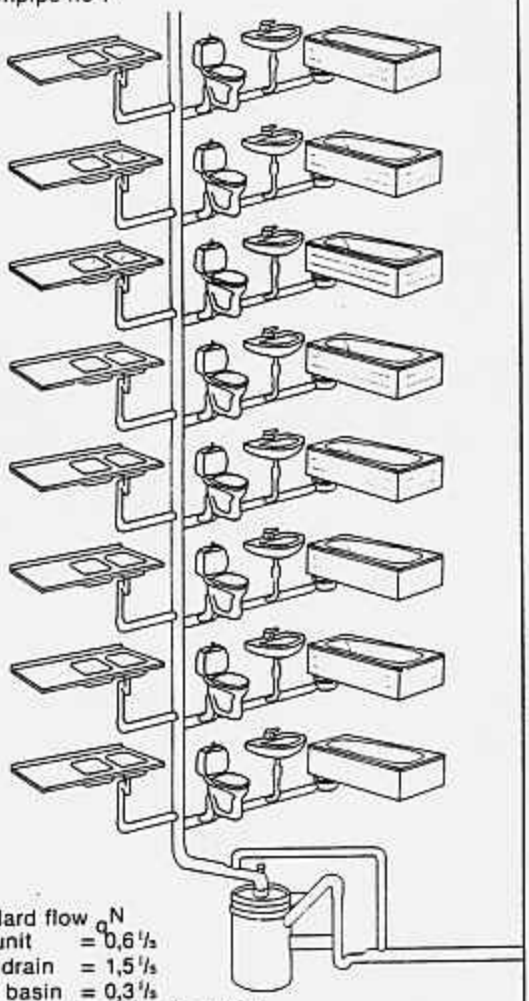
About 40 % of the WC waste passes through siphons. This is to ensure that the siphon is emptied sufficiently often, so that the pipes are flushed out completely.



Only a few siphons are required.

See page no 4

Downpipe no 7



Standard flow $_qN$
Sink unit = 0,6 l/s
Floor drain = 1,5 l/s
Wash basin = 0,3 l/s
WC 366 = 1.2 l/s for WSS

Add together the standard flows in the usual way, remembering that in the WSS system, $_qN$ for the WC 366 is 1,2 l/s.

Downpipe	WC	Basin	Sink	* Bath	q^N	q^S
1	8	8		1	13,5	
2	8	8	8	8	28,8	
3	KITCHEN					
4	7	7		7	21	
5	7	7		7	21	
6	8	8	8	8	28,8	
7	8	8	8	8	28,8	
8	7	7	7	7	25,2	
9	8	8	1	6	21,6	

Max loading for siphon $_qS$ = 4.5 l/s, corresponding to c. 20 flats with dimension 110.

To be noted when using WSS

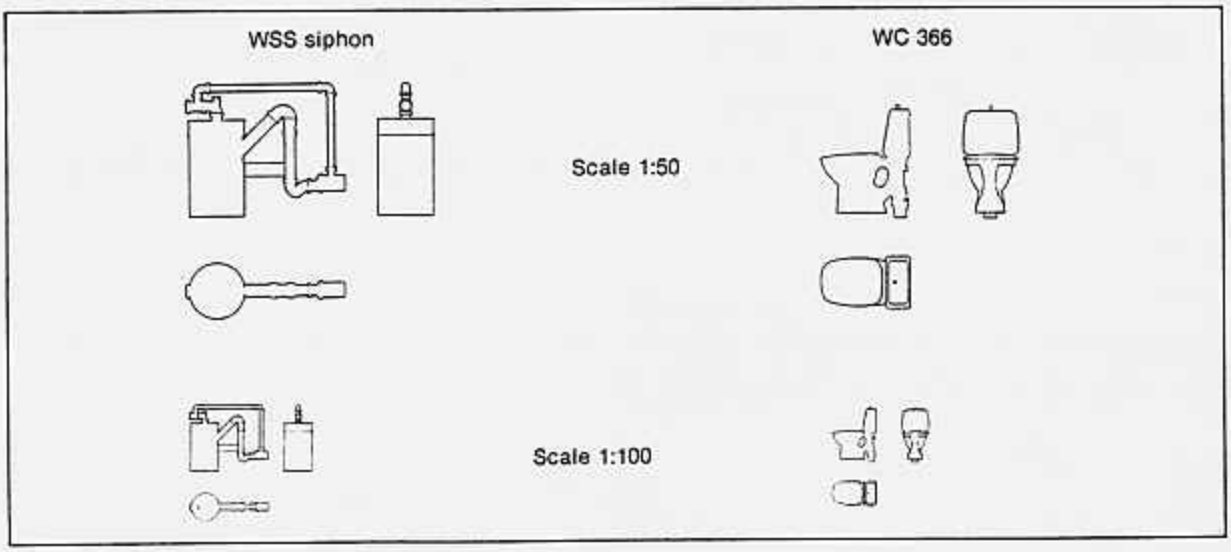
For the architect:
See that there is room for the siphons.

For the planner:
See that the siphons are sited so that there is adequate flushing out of the bottom pipe, and that c. 40 % of the WCs in the building are connected to the bottom pipe via siphons. The standard flows connected to the siphons may not exceed the values which are permitted according to directions.

See that the drawing shows a sufficient fall, and that the maximum distances which apply have been adhered to.

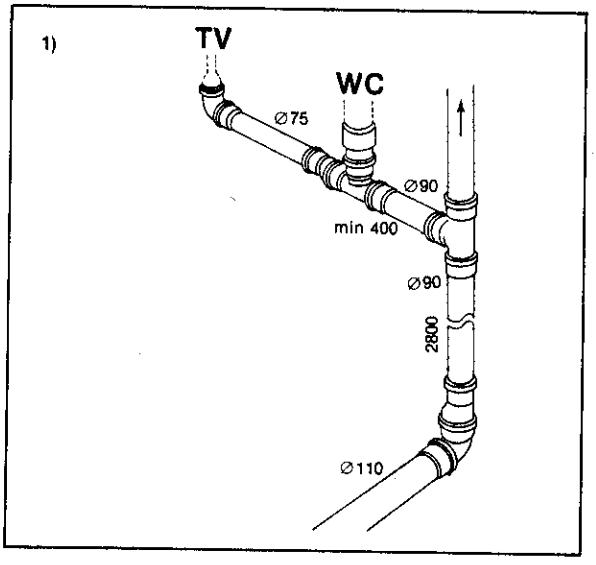
For the pipe fitter:
See that there are no large impurities in the piping system before the siphon is connected up.
The prescribed distances and minimum fall must be adhered to.
WCs are connected according to directions.
The siphon is placed horizontally.

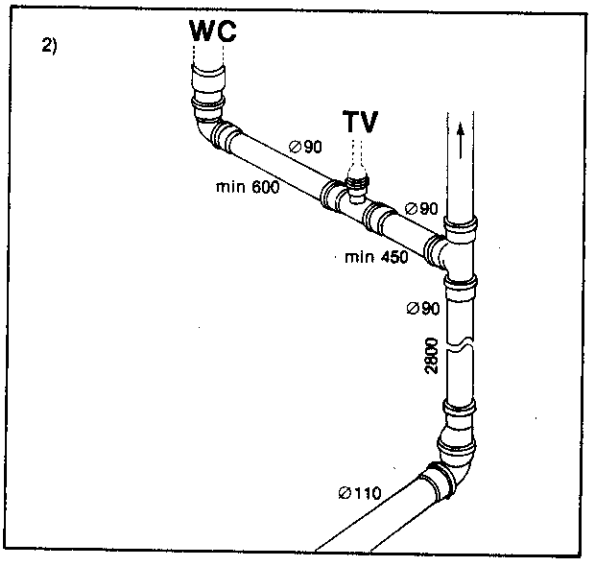
Scale drawings

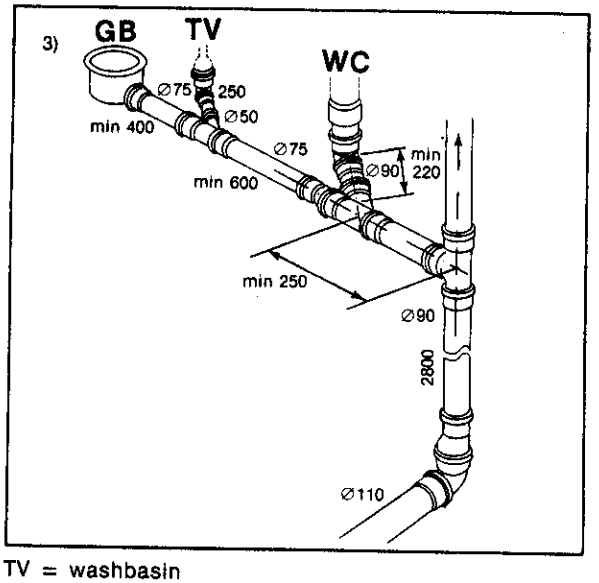


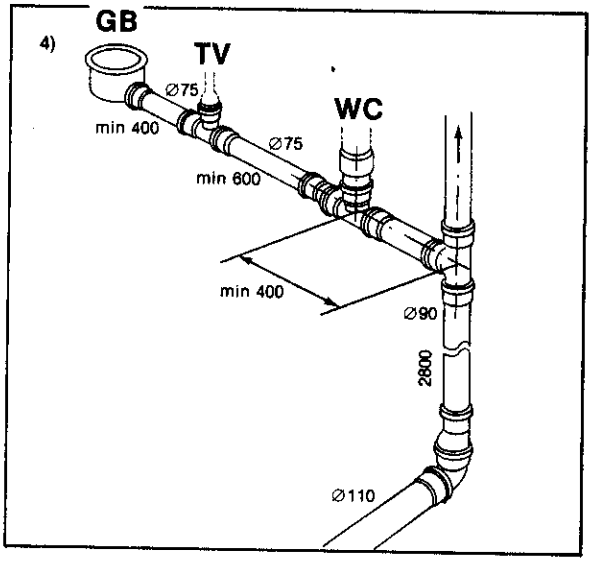
Examples of piping connections with 90 mm dimensions

Non-vented **vertical** collecting pipes with 90 mm dimensions are not permitted.
Non-vented **horizontal** collecting pipes with 90 mm dimensions are permitted only if connected as shown in the figures.









TV = washbasin
GB = floor drainage, bathtub or shower

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CIB-W62 SYMPOSIUM

A Study on the Dynamic Relations Between the Pressure Variations and the Flow Quantities, and the Friction Loss in a Pipeline for a Water Supply.

Yoshiharu Asano

April 9,~10, 1985

TOKYO, JAPAN



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Shinshu University,Faculty of Enginnering,Department of Architecture and Building Engineering.

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12th CIB-W62 SYMPOSIUM - TOKYO -
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10, 1985 : KENCHIKU KAIKAN

Summary

The maximum load for the water supply was occured after using the water closet, and the pressure variations in a pipeline gave the influences upon the water quantities, which were flowed out from the flush valves. When the many flush valves were simultaneuosly used in the supply system, the quantities flowed out varied under interference each other. In this report the relations between the pressure variations and the flow quantities were analyzed

The state of use of the water closet was simulated by the micro computer, and the flush valves were actually operated under the program.The arrival interval and the preesed seconds of the flush valve were calculated by the Monte carlo method. The pressure variations and the flow quantities were measured with the computer system. The spectra analysis were practiced, and the frequency transfer functions between the pressure variations and the flow quantities were obtained. The friction loss in a pipe under the unsteady flow were measured, and compared with the usual values in steady state.

Résumé

La charge maximale d'alimentation en eau est apparu après l'utilisation des toilettes, et les variations de pression dans une canalisation ont influencé les quantités d'eau évacuées par les valves de vidange. Lorsque de nombreuses valves de vidange ont été utilisées simultanément dans le réseau d'alimentation, les quantités évacuées ont varié d'une façon interactive. Dans ce rapport, les relations entre les variations de pression et les quantités écoulées ont été analysées.

L'état d'utilisation des toilettes a été simulé à l'aide d'un micro-ordinateur, et les valves de vidange ont réellement été mises à l'épreuve lors de cette expérience.

L'intervalle d'arrivée et les secondes écoulées aux valves de vidange ont été calculés par la méthode Monte-Carlo. Les variations de pression et les quantités écoulées ont été mesurées à l'aide de l'ordinateur. On a effectué une analyse spectrale, et on a obtenu des fonctions de transfert de fréquence entre les variations de pression et les quantités écoulées. On a mesuré le taux de frottement dans une canalisation sous écoulement non-constant, et celui-ci a été comparé aux valeurs habituelles à écoulement constant.

Zusammenfassung

Die Maximalbelastung der Wasserversorgung wurde nach Benutzung des Wasserklosetts gemessen, und die Druckveränderungen in der Wasserleitung zeigten die Einwirkungen der Wassermengen, die aus den Spülventilen flossen. Wenn viele Spülventile innerhalb des Versorgungssystems gleichzeitig benutzt wurden, variierte die ausfließende Wassermenge durch gegenseitige Interferenzeinwirkung. In diesem Bericht wurden die Beziehungen zwischen Druckveränderung und Flußqualität untersucht.

Die Wasserklosett-Gebrauchsituation wurde mittels Mikrocomputer simuliert, und die Spülventile wurden durch das Programm betrieben. Der Ankunftsintervall und die Betriebssekunden der Spülventile wurden mittels der Monte Carlo Methode durch das Computersystem gemessen. Eine Spektralanalyse wurde durchgeführt, und die Frequenzübertragungsfunktionen zwischen Druckvariationen und Flußmengen wurden gemessen und mit den Normalwerten im Ruhezustand verglichen.

1. INTRODUCTION

There are many studies on the problems in the piping system for water supply such as the flow quantities of water and the friction loss in the pipe. But there are little studies on the transient phenomena such as the water hammer in shutting or opening the fixtures.

In this study, the variations of the pressure and the flow quantities were analysed. The fixtures for these experiments are flush valves generally provided in the buildings for water supply.

When more than two fixtures are used at the same time, the pressure in a pipeline varies quickly and the flushed water quantities from each fixture decrease. The relations between the pressure variations and the flow quantities were analysed.

The simulation analysis were practiced about the occupations of the water closets and the use of the flush valves by the Monte Carlo meathod. The periods of the occupations of the water closets and the pressed time of the flush valves were obtained, and the time procession of the use of the flush valves were made by the micro computer.

The flush valves, which were set on the pipeline, were used in this procession under the micro computer controlls. And the pressure variations and the flow quantities were measured, and the resistance coefficients of the flush valves was calculated. Still more the spectrum analysis were practiced by the pulse responce test method and FFT method, and the frequancy transmit functions were obtained.

2. METHOD OF THEORETICAL ANALYSIS

The model of the transmission from the pressure variations to the flow quantities against the test pipeline is shown as Fig.1. This model illustrates that the influences of the flowout caused by the valve open arrine at the main pipe and the branches, and the pressures in each part of pipeline vary. The power spectrum and the cross spectrum of the variations of the pressure and the flow quantities, which recur periodically, were calculated by FFT method. The frequency transmit functions $G(j\omega)$ as the mono pulse were calculated by pulse respons method, which is shown as eq.(1).

$$G(j\omega) = \frac{\int y(t)\exp(-j\omega t)dt}{\int x(t)\exp(-j\omega t)dt} \qquad (1)$$

3. EXPERIMENT

3.1 OUTLINE OF THE EXPERIMENTAL SETUP

Water supply system is shown as Fig.3, and the test pipelines are shown as Fig.4-6. The electro magnetic flow meters are installed at point(P1),(P2), and the pressure transducers are installed at point(A)-(D).

3.2 EXPERIMENTAL METHOD

For making the practical pressure variations in the pipeline, the time to arrive at the lavatory, the occupated minutes of water closet and the pressed seconds of flush valve were calculated by the micro computer with the Monte Carlo method. The process is shown as Fig.7, and the conditions for the calculations are shown as Table 1.

The simulation and the experiments were practiced in real time with the internal clock of micro computer in accordance with the calculated results. The signals from the micro computer operated the relay switches, and the solenoid, connected to the relay, made open the flush valve for the calculated seconds.

The situations of the occupation of water closets were displayed on the monitor of micro computer.

3.3 MEASUREMENT METHOD

The measurement system are shown in Fig.8. The variations of the pressure were measured with the pressure transducer, connected to the dynamic strain amplifier. The flow quantities were measured with the electro-magnetic flow meter. These data were recorded with the data recoder, and the data passed through the A/D converter to the another micro computer.

4.ANALYSIS

The resistant coefficients of flush valve were calculated by the following equation.

$$\zeta = \frac{2g \cdot P \cdot A}{\gamma \cdot Q} - 1 \qquad (2)$$

ζ : The resistant coefficient of flush valve
P : The effective pressure
A : The sectional area
Q : The flush out flow quantity

The energy frequency transfer function between the pressure variations and the flow quantities were calculated with the pulse responce test method by the micro computer. In using the two flush valves at the same time, the spectra analysis were practiced with the FFT method.

5.RESULTS OF EXPERIMENT AND INVESTIGATION

5.1 The decrease of the quantities flowed out from the flush valves in the simultaneous uses

When two flush valves were used in a few seconds, the decreased quantities flowed out from the first flush valve were measured. The drop rate(%) against the muximum quantities flowed out were calculated, and the relations between the drop rate and the supplied pressure at point(A),(B) were showed in Fig.36 and Fig.37. The drop rate became larger in the low supplied pressure, because the muximum quantities decreased, but the decreased quantities did not vary so much.

5.2 The resistant coefficient of flush valves

Experiments were practiced in five times under the different conditions in Table 1. Three waves of the quantity by three flush valves open were piled up in the test pipe at the same time, and this is the case of the maximum flow quantity. The registant coefficients of flush valves in the case of two uses at the same time were different from in the case of the use of only a flush valve. When the flush valve at point(A) was opening, another flush valve at point(B) was used. The pressure variations are shown in Fig.11, and the flow quantities in the test pipe is shown in Fig.12, and the registant coefficients of the flush valves at point(A)&(B) are shown in Fig.15. The pressure variations of flush valve at point(A) was influenced from the flush valve at point(B) which was used after point (A), and the registant coefficients became smaller momentarily.

5.3 The relations between the pressure variations and the flow rates.

Fig.17 and Fig.19 are the results of analysis under the conditions based on the No.4 and No.5 on table 1. The pressure variations and the flow quantities at point(a) in the main pipe are shown. The power spectrum, the cross spectrum and the coherence were calculated.

The power spectrum of the pressure variations in the case of No.4 is shown in Fig.21, and the maximum values appeared at 0.01Hz and 0.025Hz. The power spectrum of the flow quantitiesis shown in Fig.22, and the maximum values appeared at 0.025Hz. The cross spectrum between the pressure variation and the flow rate is shown in Fig.23, and the maximum values at 0.025Hz is remarkable. Then, the cycle of the pressure variation was equal to the mean arrival period shown in Table 1.

5.4 The pressure variations in the test piping system under the simultaneous loads.

The Gain-Frequency diagram of the frequency transmission function at point (b) is shown in Fig.24, when the flush valve at point(A) was used. In the case that two flush valves were used in point(B) after point(A), the Gain-Frequency diagram at point (b) is shown in Fig.25, and one at point (a) is shown in Fig.26. In the csae that three flush valves were used in order points(C)-(A)-(B), the Gain-Frequency transfer function at point(b) is shown in Fig.27, and one at point (a) is shown in Fig.28.

The large variation of the gain values did not appear in Fig.24, and this is similar in the case of point (a). In Fig.25 the peak appears at 0.13Hz remarkably, in comparing to Fig.24. Fig.26 shows the rerations between the pressure variations and the flow quantities in the main pipe, and the influences to the pressure variations at point(a) by using the flush valve at point(C) was large, because point(A) was already flushing out and the pressure variations were piled up. On the other, the influence to the pressure variations at point(b) was little, and the diagram was similar to Fig.24. There are remarkable peaks at approximately 0.01Hz and 0.25Hz in Fig.27, because the pressure variations occured point(A) was influenced from the valve open at point(B) and the valve close at point(C). Fig.28 is similar to Fig.19, and the influence in the main pipe was less than the pipe end. However, in comparing to Fig.27, it is clear that there are small peaks which show the influences of valve open and valve close at each point.

When three flush valves were used at same time, the maximum values at point(a) appeared in lower frequencies than the case that two valves were used at same time. The reason is that the water flow in the water supply piping system is not continuous and the time of the water flowing becomes longer in the case of the simultaneous use of the prural flush valves.

5.5 The transmitted time of the pressure variations

The original wave patterns of the pressure variations are shown in Fig.29. The pressure variations occured at point(A) were transmitted to point(B),(C),(D) in decreasing. The power spectrum at point(A) is shown in Fig.30, and the cross spectrum of the pressure variations between at point(A) and at point(B) in shown in Fig.31. The peaks appeares near at 21.9 Hz in these figures. The phase at point(D) is shown in Fig.32. The precipitous discrepancy of the phase appears from 20.9 Hz to 22.9 Hz. Then, the periodic time of the principal component wave of the pressure variations is about 0.04 second, and it indicated that the pressure waves reflected at the header of the experimental piping system.

5.6 The friction loss in a pipe

When the constant quantities were flowed out at point(E) in

3kg/cm supplied pressure, the flush valve at point(A) was just used. The non dimensional flow rate and the non dimensional friction loss were shown in Fig.38. In the case that the flush valves at point(A) and (B) were used one by one, those were shown in Fig.39. The non dimensional friction loss varied with the flow rate in each supplied pressure is shown in Fig.40. The relations between the non dimensional friction loss and the differentiated non dimensional flow rate were shown in Fig.41. The relations between the measured data of the hydraulic gradient and the flow quantities were shown in Fig.42. The straight line in Fig.42 is illustrated the experimental equation in the case of the constant flow quantities When the flow quantities vary, the friction loss is different from the values which have been used in usual.

6.CONCLUSION

In this study, the pressure variations, the flow quantities and the friction loss were measured in the unsteady state, and the relations of them were analyzed.

Then th following results were made clear:

(1) This experiment contorolled under the micro computer were reappearable.

(2) The pressure variations were closely related to the frequency of using the water closets.

(3) The friction loss was different from the values which have been used in usual.

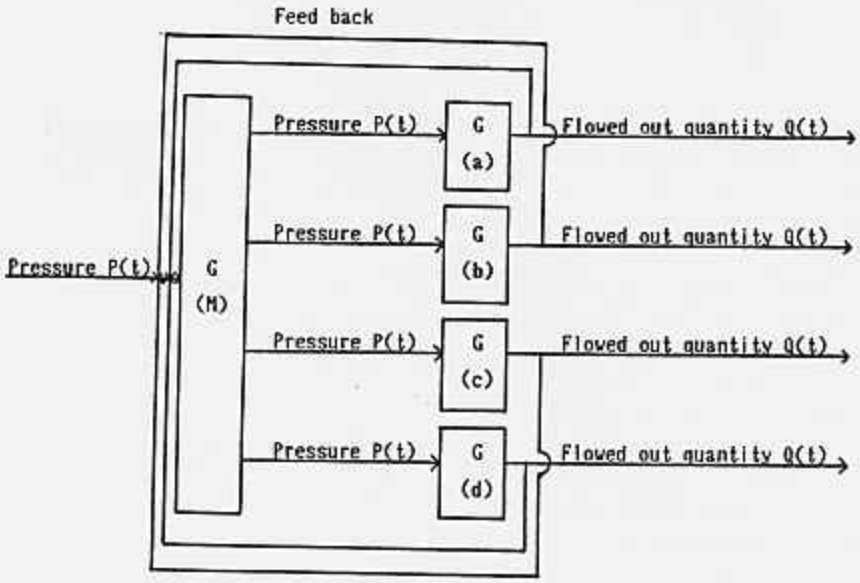


Fig.1 The transmission model in an supply piping system

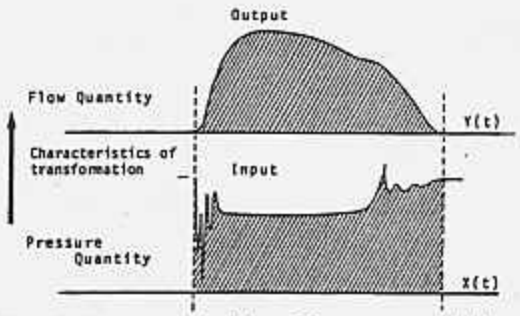


Fig.2 Model of the flow quantities and the pressure variations

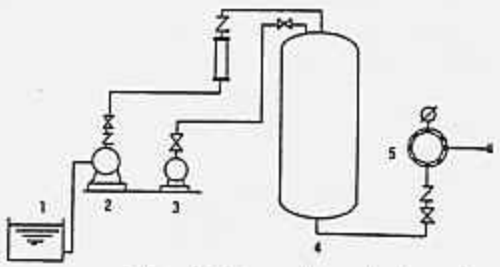


Fig.3 Experimental setup

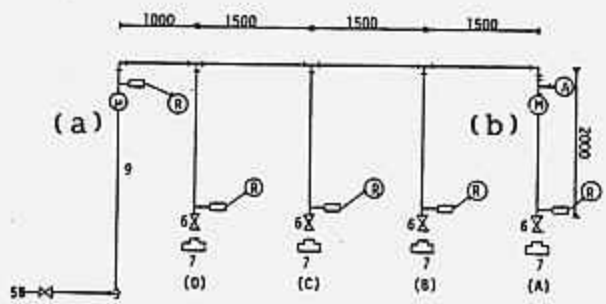


Fig.4 Test piping system(4 branches)

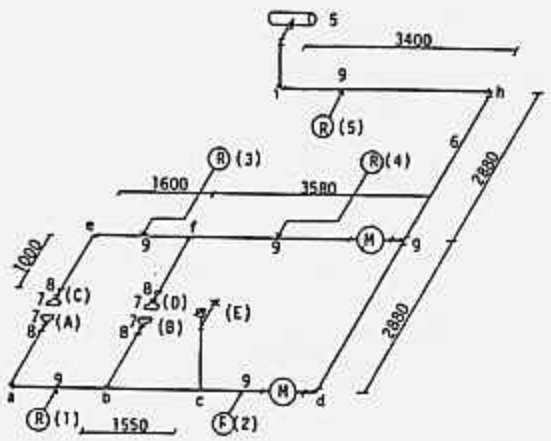


Fig.5 Test piping system(2 branches)

1.Tank
2.Pump
3.Compressor
4.Pressure tank
5.Header
6.Steel pipe
main pipe :50A
branch pipe:25A,50A
7.Solenoid
8.Flush valve
9.Pressure transducer

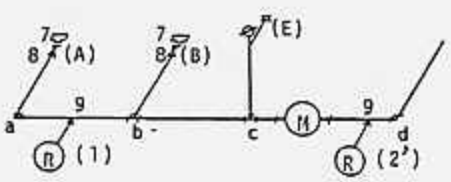


Fig.6 Test piping system(for the friction loss)

Table 1 Input conditions for simulation

	No.1	No.2,3	No.4	No.5
The number of users(persons)	170	190	220	250
The mean arrival rate(1/min.)	$6.8\sharp10^{-3}$	←	←	←
The mean arrival interval(sec.)	50	45	40	35
The mean utilization time(min.)	1.56	←	←	←
The mean traffic density(P)	$10.65\sharp10^{-2}$	←	←	←

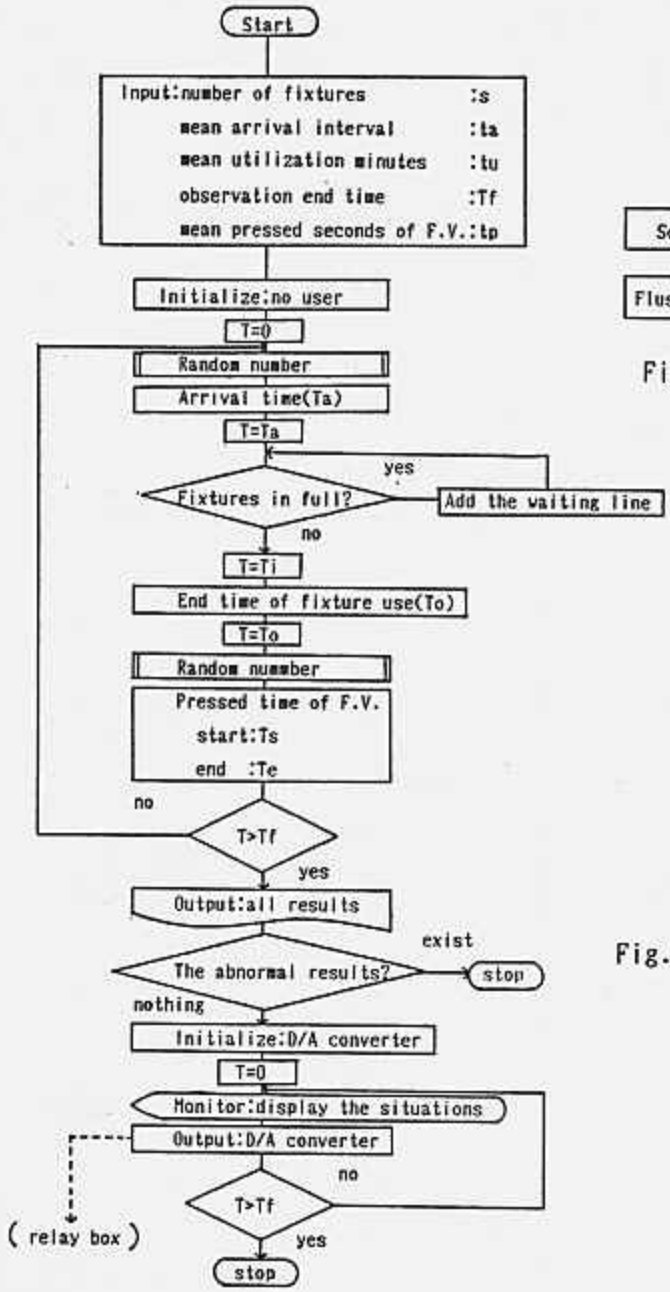


Fig.7 Flow chart for simulation

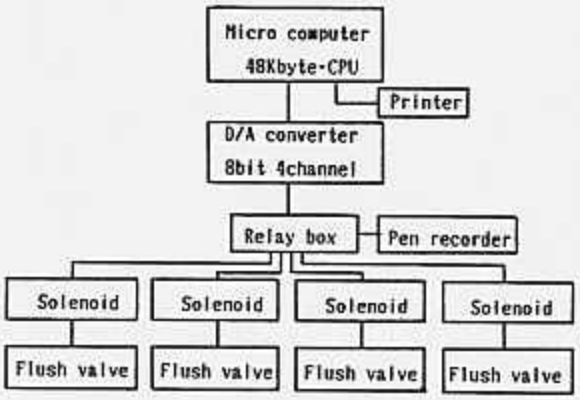


Fig.8 Block diagram for measurement

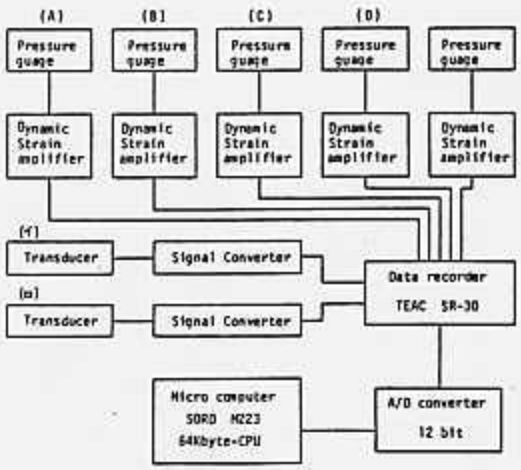


Fig.9 Block diagram for operation system

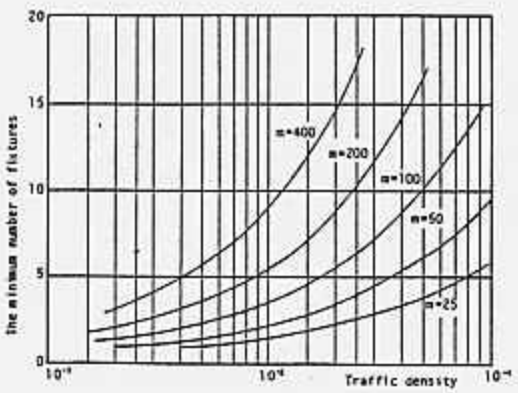


Fig.10 The minimum number of fixtures

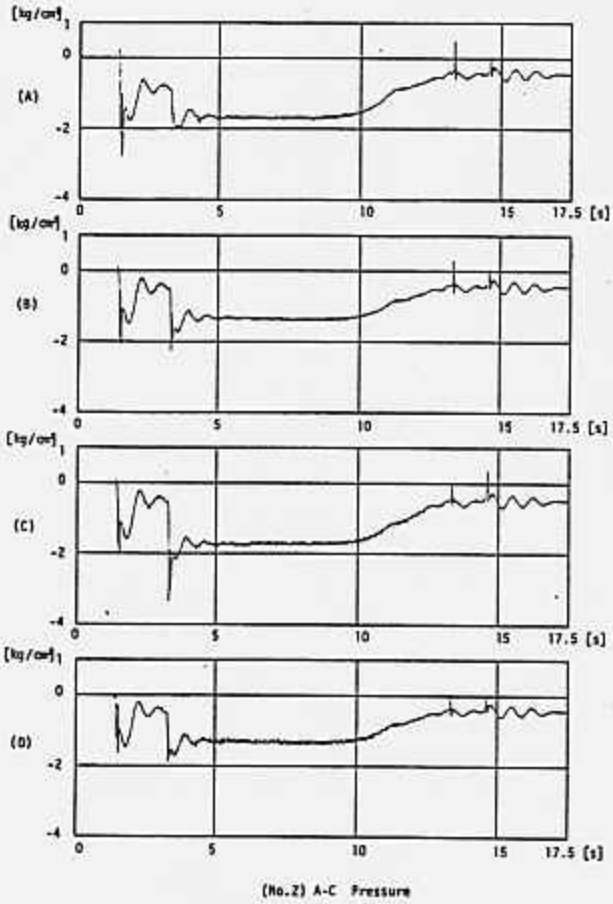


Fig.11 The pressure variations

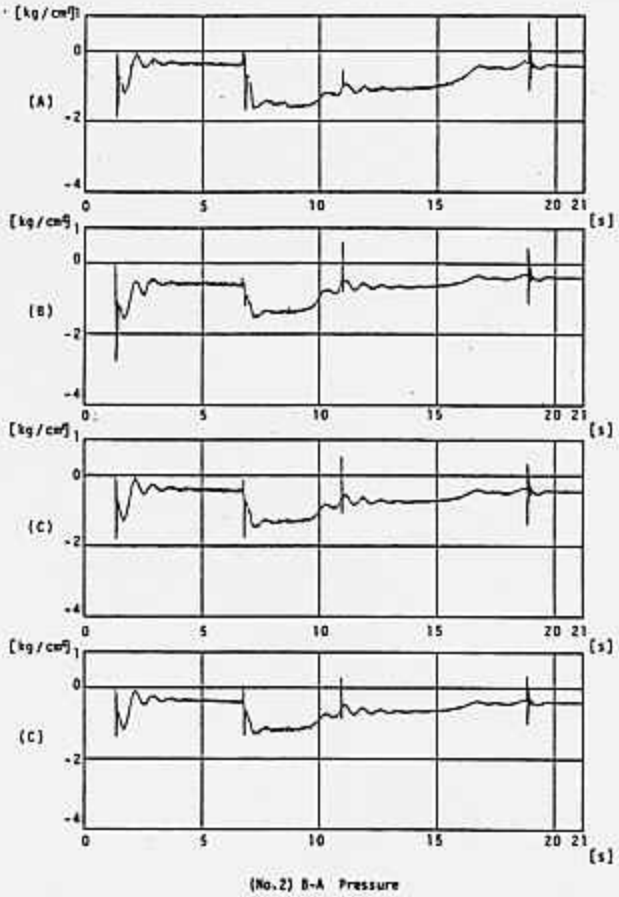


Fig.13 The pressure variations

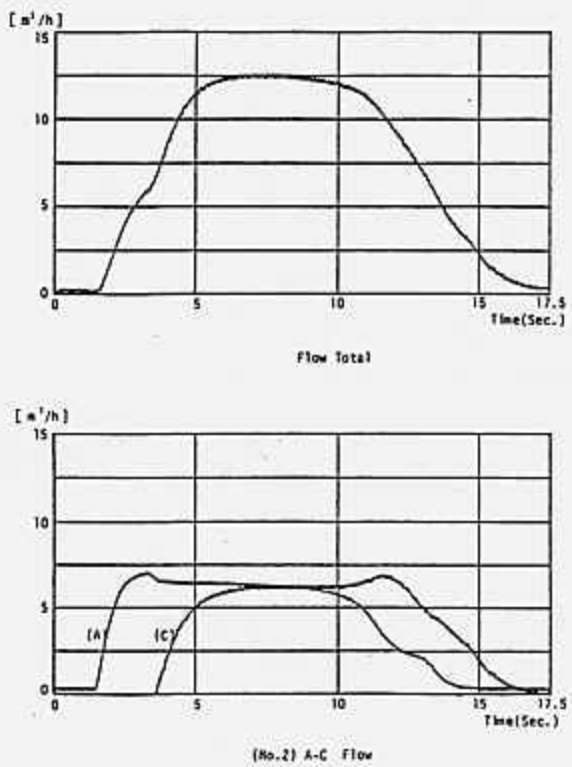


Fig.12 The flow quantities

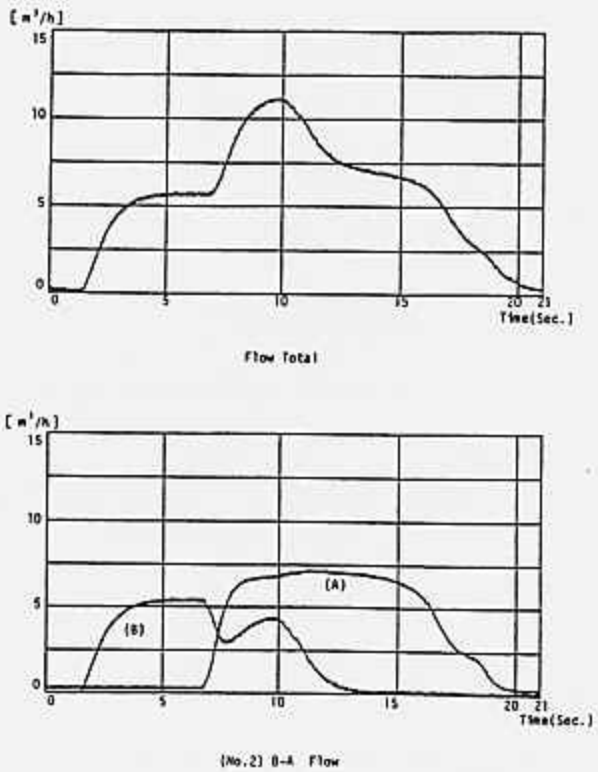


Fig.14 The flow quantities

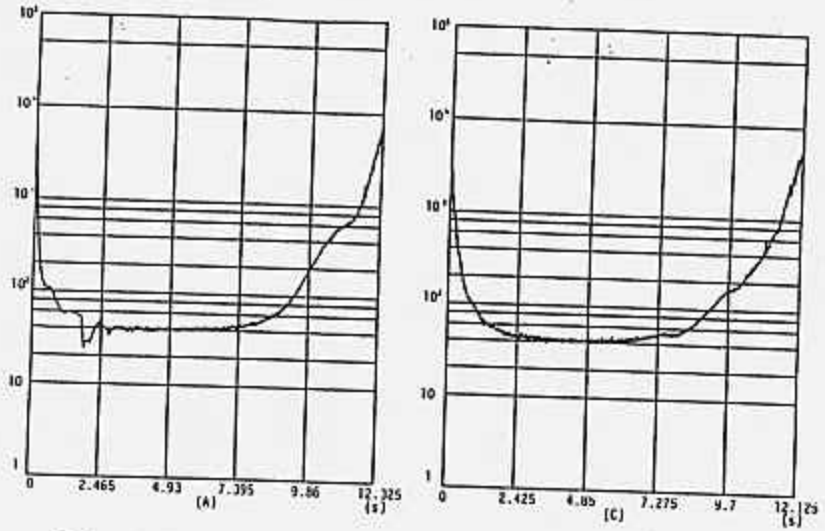


Fig:15 The resistant coefficient of flush valve

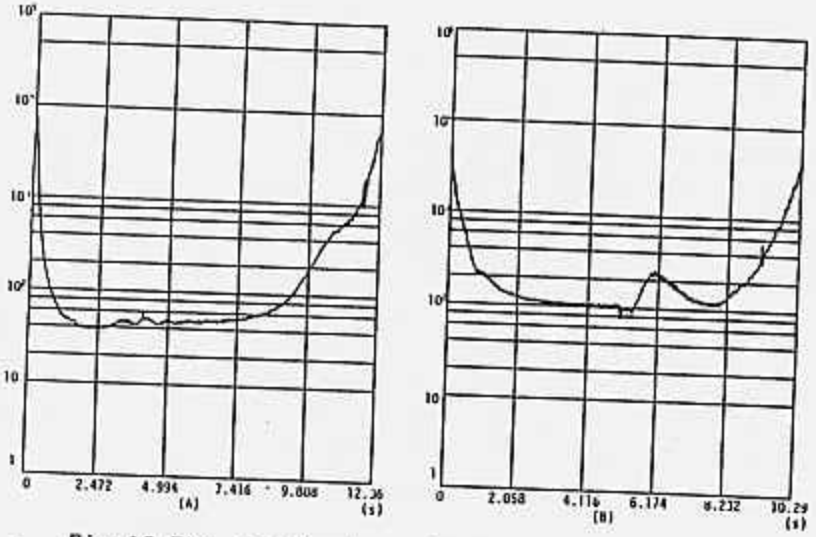


Fig.16 The resistant coefficient of flush nalve

top:W.C.& F.V. bottom:discharged time

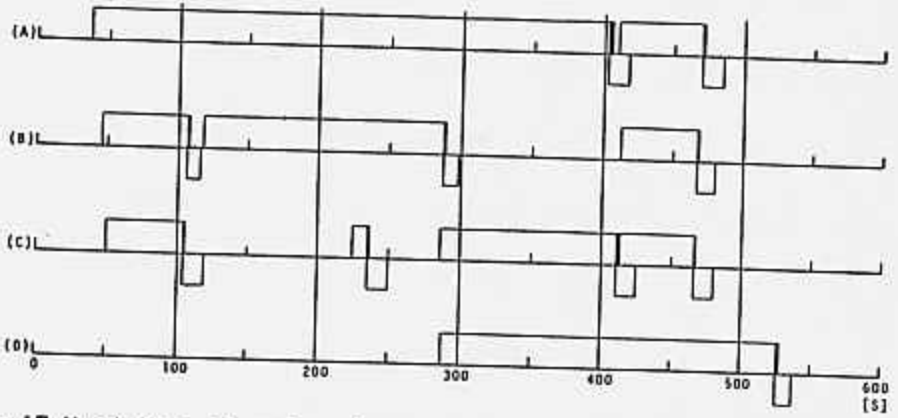


Fig.17 Used time of water closets ,pressed time of flush valves and discharged time from flush valves(in the case of No.4)

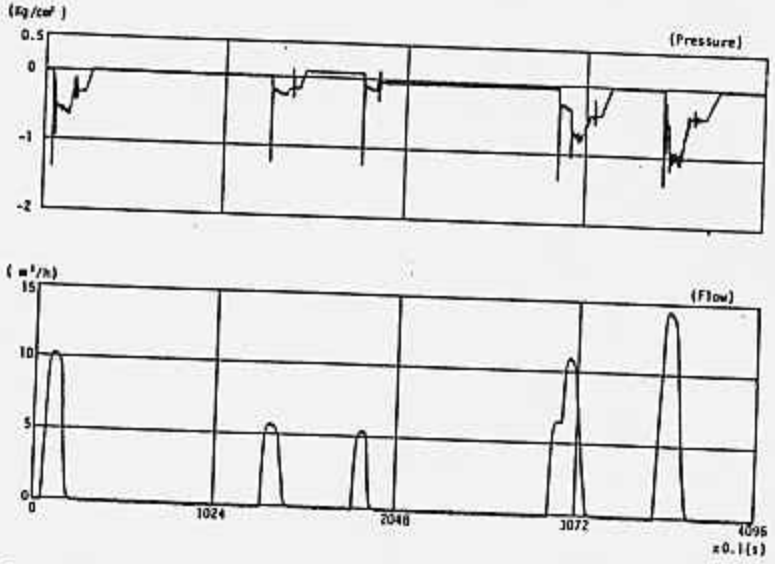


Fig.18 Pressure variations and flow quantities(in the case of No.4)

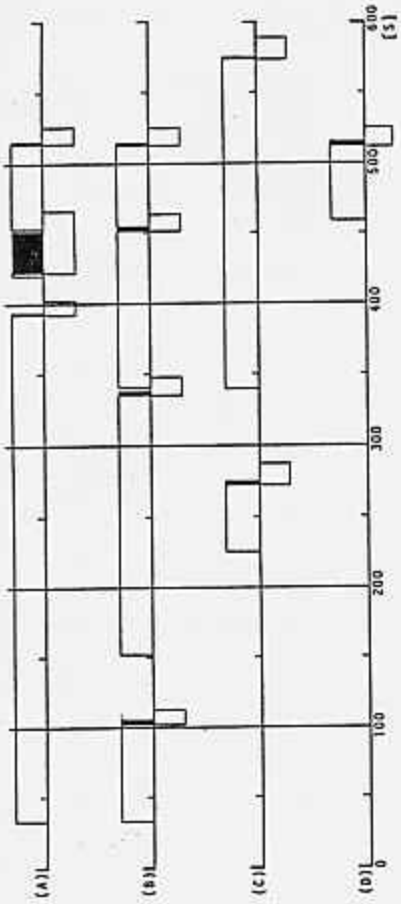


Fig.19 Used time of water closets, pressed time of flush valves and discharged time from flush valves(in the case of No.5)

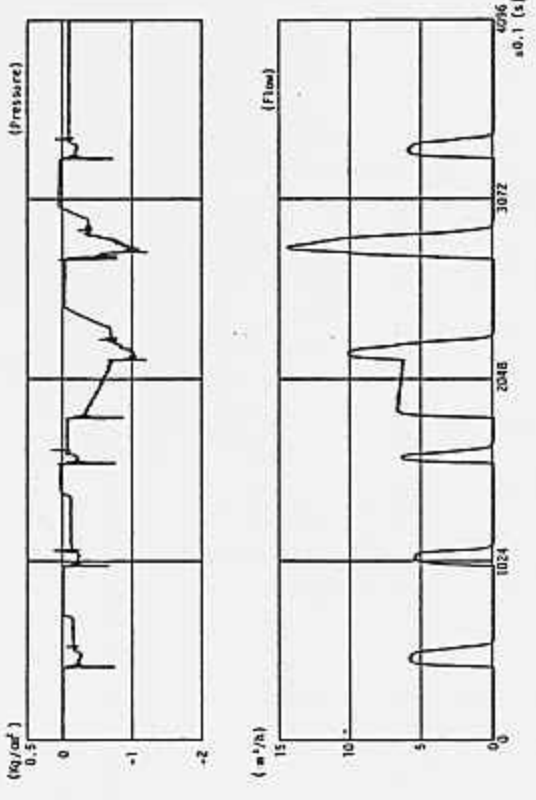


Fig.20 Pressure variations and flow quantities(in the case of No.5)

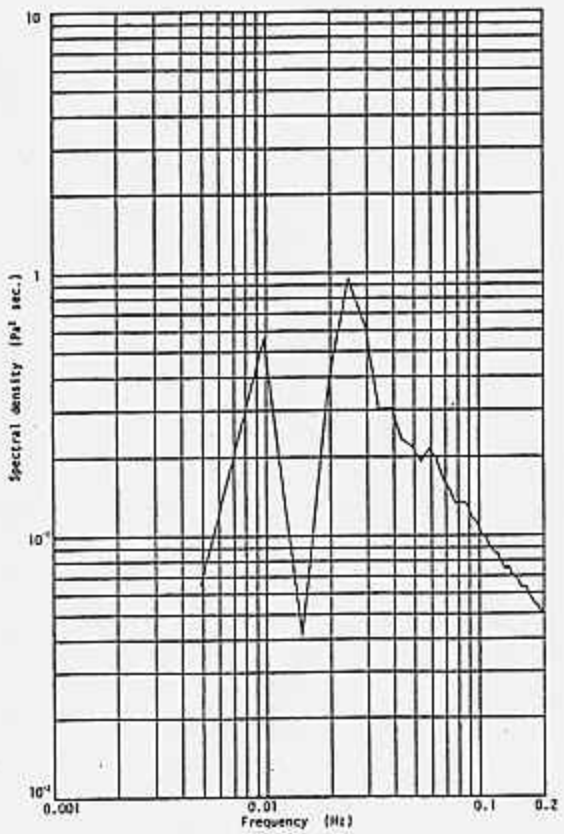


Fig.21 Power spectrum of pressure variations (in the case of No.4)

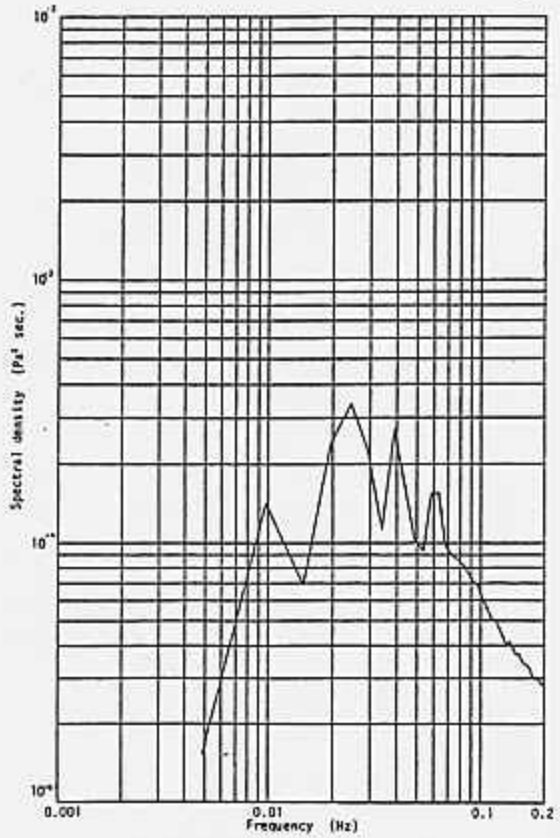


Fig.22 Power spectrum of flow quantities (in the case of No.4)

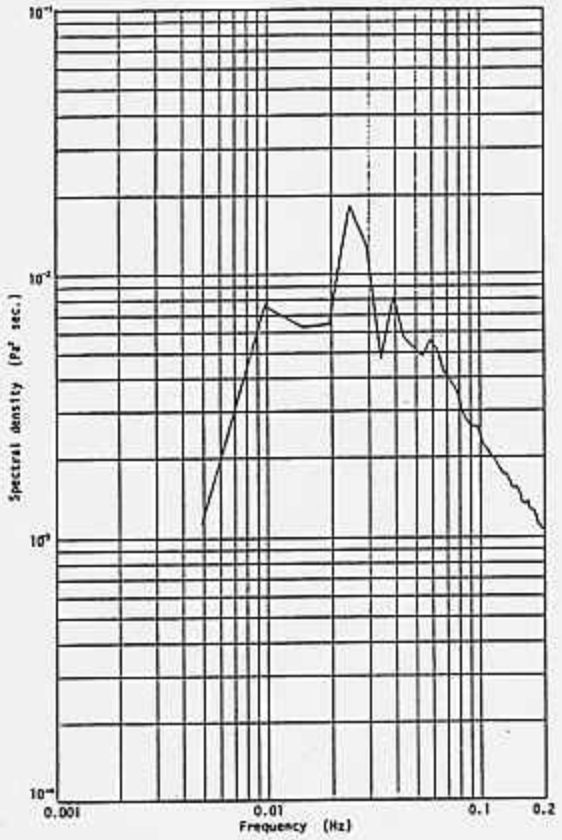


Fig.23 Cross spectrum(in the case of No.4)

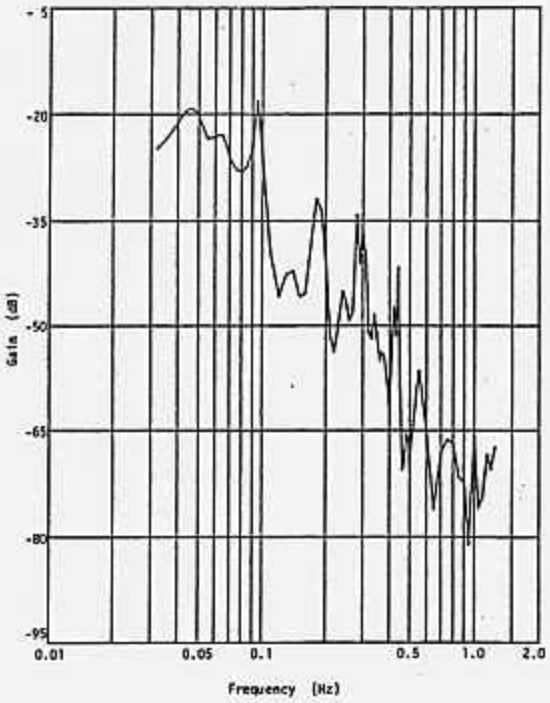


Fig.26 Frequency transfer function at point(a) in open points A-C

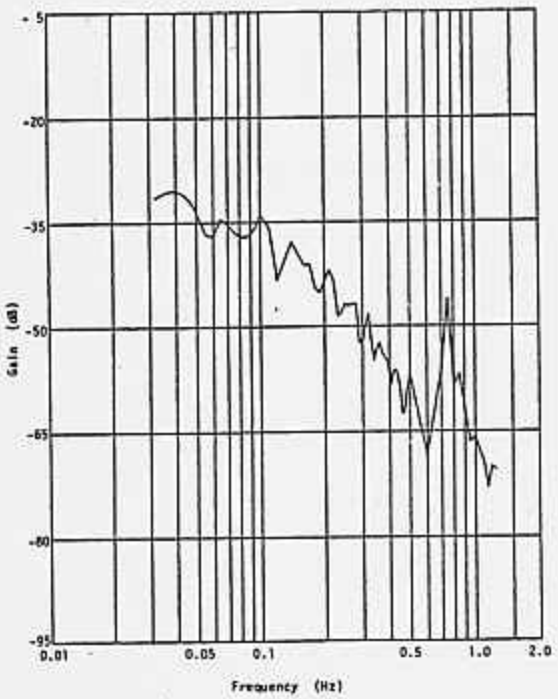


Fig.24 Frequency transfer function at point(b) in open point A

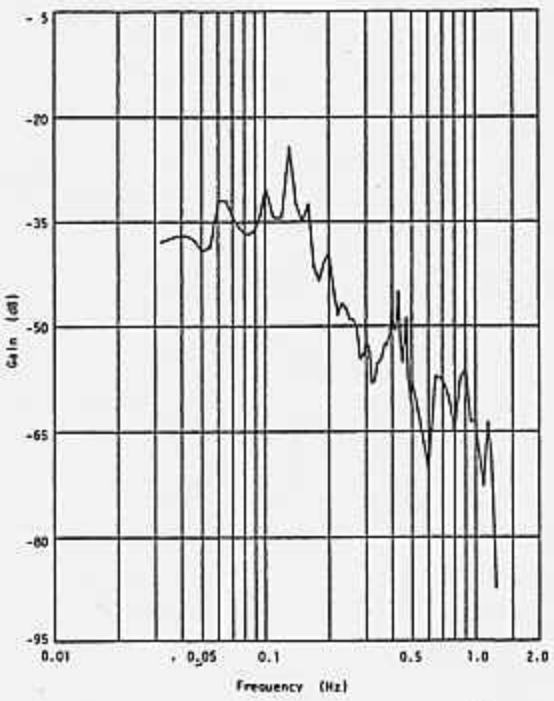


Fig.25 Frequency transfer function at point(b) in open points A-C

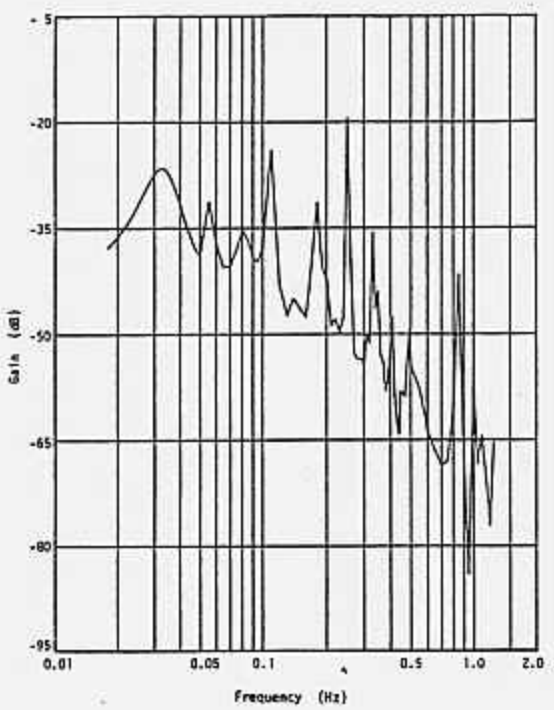


Fig.27 Frequency transfer function at point(b) in open points C-A-B

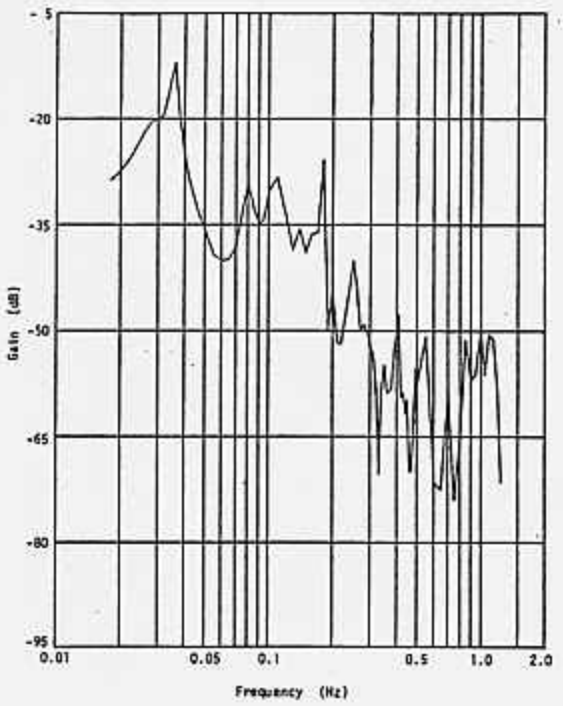


Fig.28 Frequency transfer function at point(a) in open points C-A-B

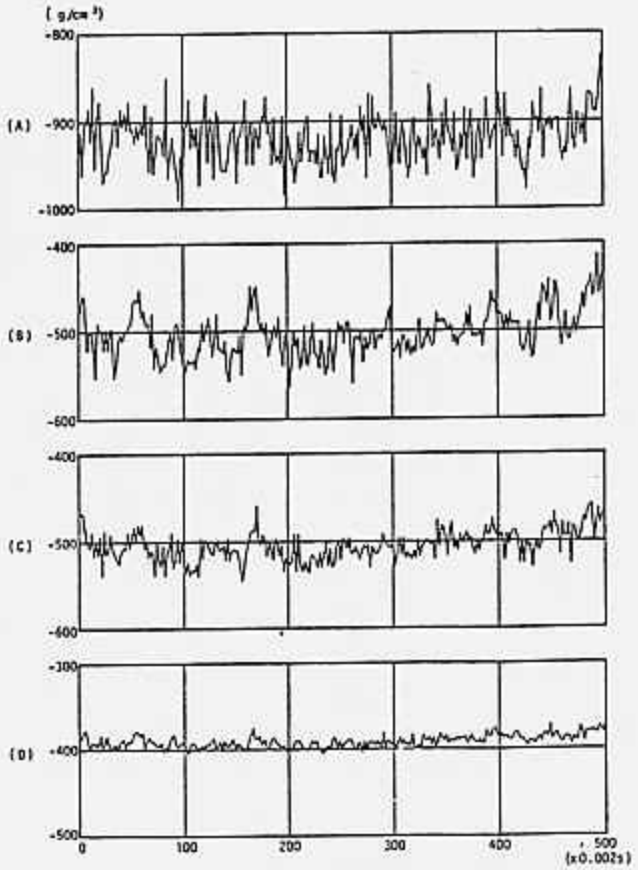


Fig.29 Pressure variations at 4 points

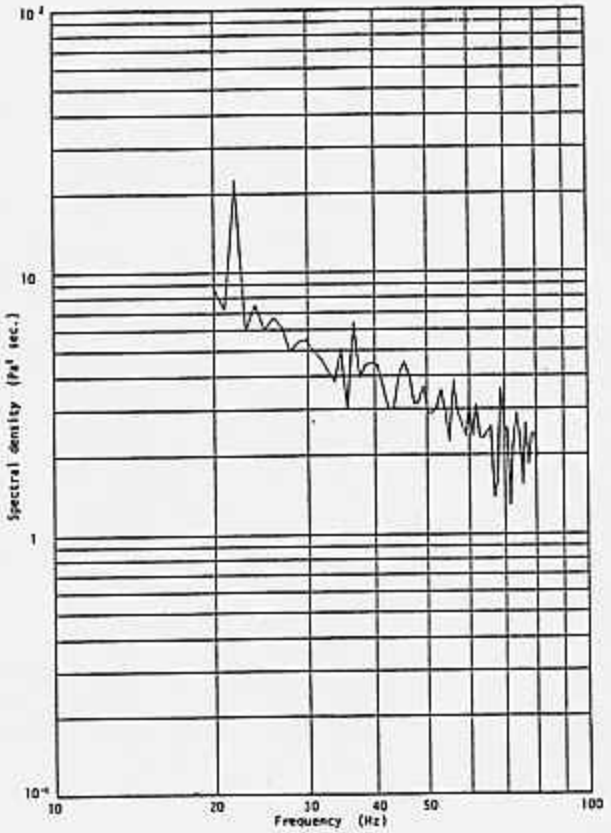


Fig.30 Power spectrum of pressure variations at point A

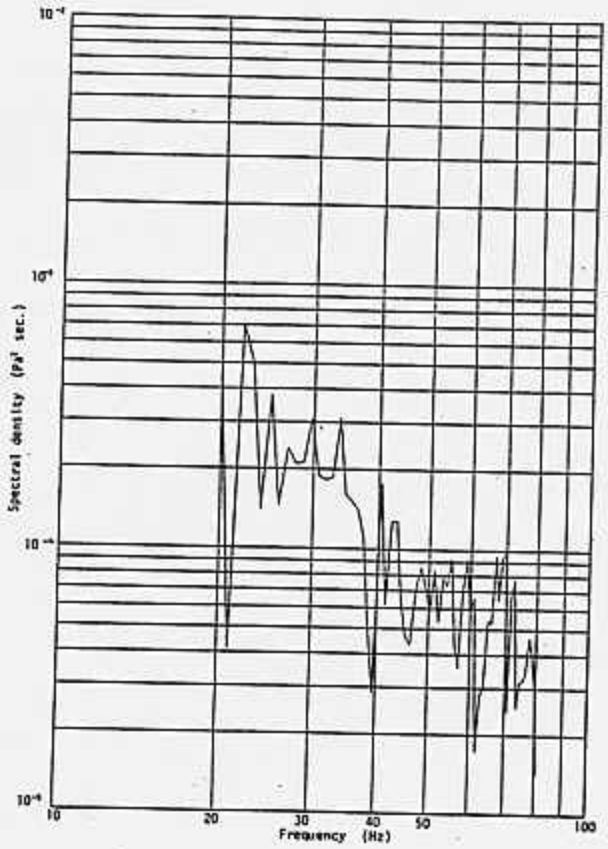


Fig.31 Cross spectrum of pressure variations between point D and point A

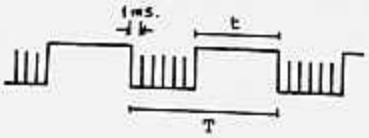
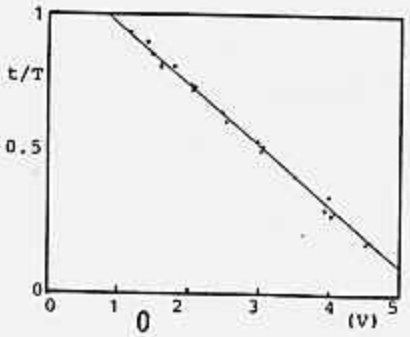


Fig.33 Pulses from electro magnetic flow meter



0 10 m/h

Fig.34 Calibrated results of electro magnetic flow meter

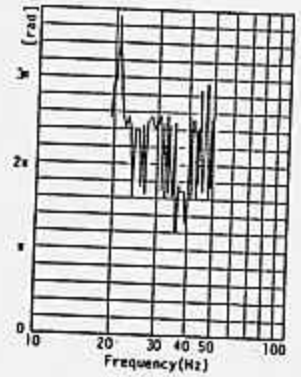


Fig.32 Phase between point D and point A

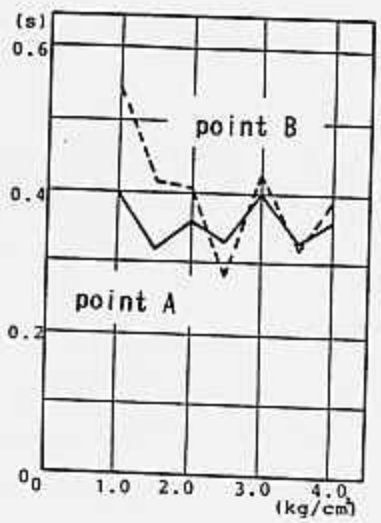


Fig.35 Time to approach 80% value of the maximum of flush valve

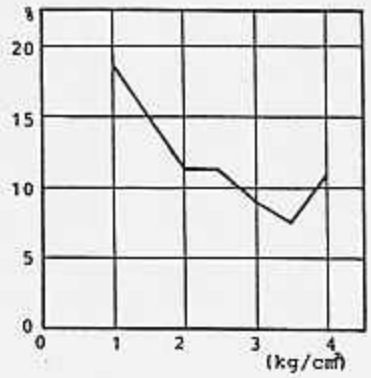


Fig.36 Drop rate(%) of flow quantities in the case of A-C (2 branches)

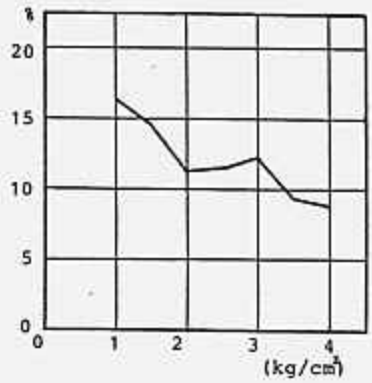


Fig.37 Drop rate(%) of flow quantities in the case of B-C (2 branches)

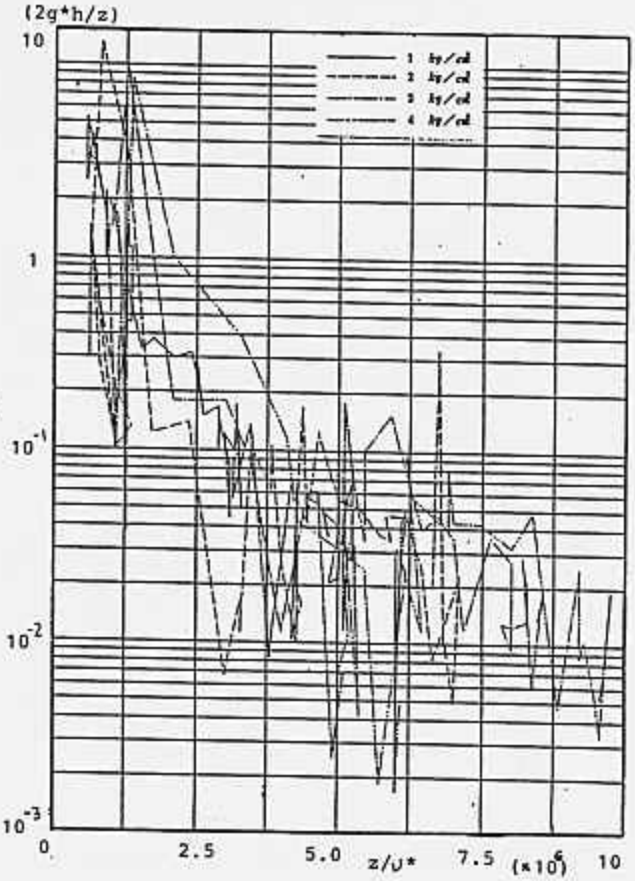


Fig.38 Non dimensional friction loss in each supply pressure

Notations

v:velocity (m/s)

D:diameter (m)

T:time (s)

z:non dimensional velocity; $z=v^{*}T/D$

ν:viscosity (m^2/s)

ν^{*}:non dimensional viscosity

Re:Reynolds number $Re=z/\nu^{*}$

h:friction loss (mAq/m)

g:gravity acceleration

g^{*}:non dimensional gravity acceleration

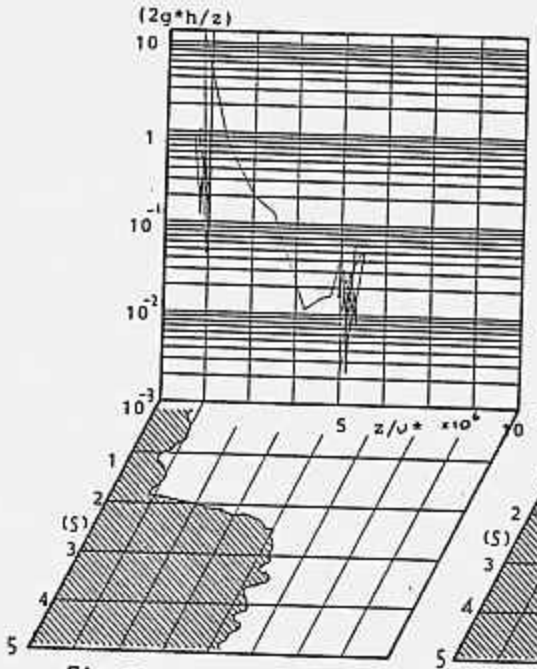


Fig.39

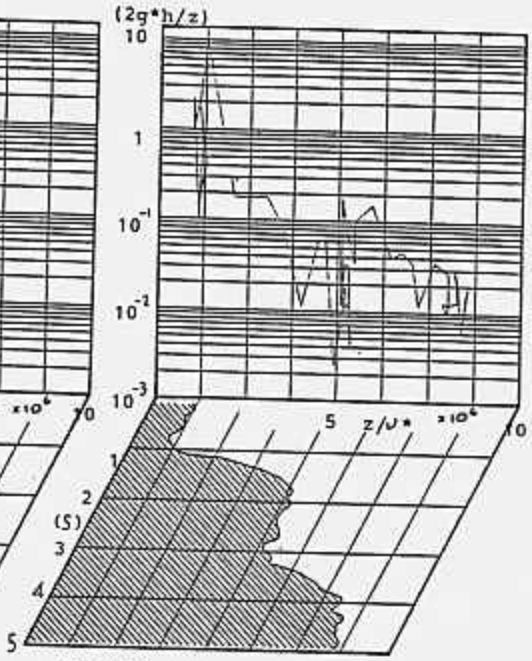


Fig.40

Relations between non dimensional friction loss and non dimensional flow quantities

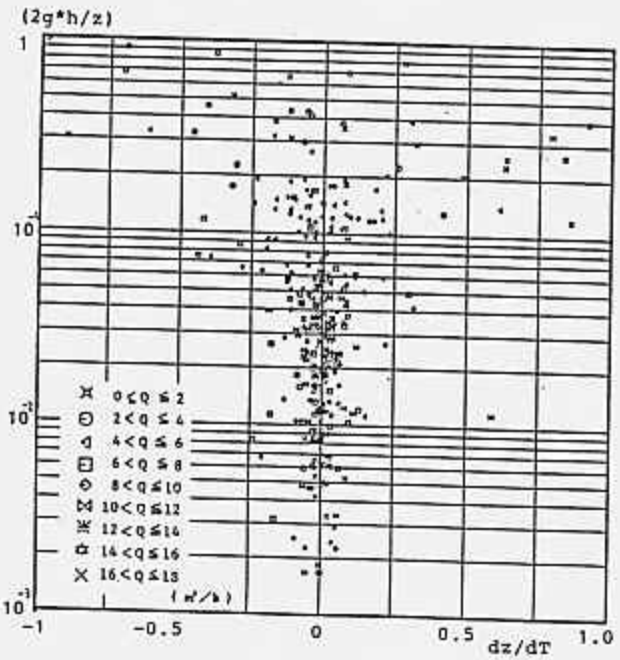


Fig.41 Relations between non dimensional friction loss and the differential flow quantities

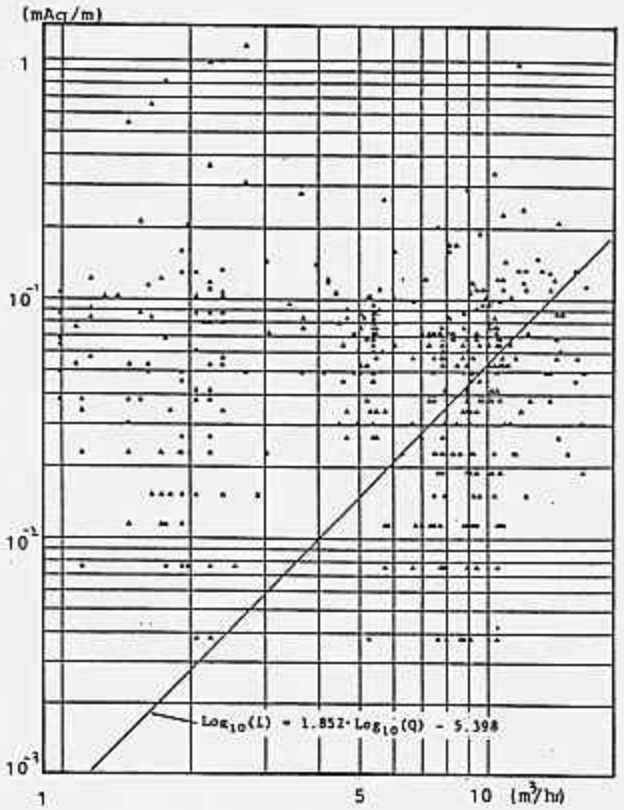


Fig.42 Relations between frictionn loss and flow quantities in the unsteady flow

CIB

CIB-W62 SYMPOSIUM

Basic Study for Performance Test and Theoretical Calculation System

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April 9,~10, 1985

TOKYO, JAPAN



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Basic Study for Performance Test and Theoretical Calculation System

12th CIB-W62 SYMPOSIUM — TOKYO —
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10, 1985 : KENCHIKU KAIKAN

Summary

The most important system function in designing drain pipe networks in buildings is to carry disposals smoothly, and the trap seal should not be broken by the preasure variation inside pipe by the flow.
In Japan, however, the pressure variation inside drain pipe itself has not been clarified systematically enough, and the dynamic characteristics have not been shown in the drain pipe system design thus hindering the deduction at troubles or at the designing of various drain systems.
Under the circumstances, we have conducted the following experiments for the pressure variation characteristics inside pipe based on the relation between the drain flow rate.

1) Based on the pressure variation under steady flow drain, an experimental device of which height is limited to 30m above the ground have been prepared. With the device, a basic experiment was conducted under our original method to find possibility to evaluate the drain performance of several hundreds height highrise buildings.
2) An experiment was conducted on the characteristics of pressure variation inside drain pipe at the vertical converging flow using ST(sanitary tee) fitting loaded from binary floors, consisting of steady and fixture drain flows.

Résumé

La fonction la plus importante des réseaux de tuyau d'écoulement dans les bâtiments consiste à évacuer les déchets de façon continue. Par ailleurs, il est important que la garde d'eau ne soit pas brisée à cause des variations de pression dues à l'écoulement a l'interieur du tuyau.
Au Japon neanmoins, les variations de pression a l'interieur du tuyau d'ecoulement en tant que tel, et les caractéristiques dynamiques n'ont pas fait l'object d'études systématiques, ce qui n'a pas facilité la détection des malfonctionnements, et par là-même, la conception de differents systèmes d'écoulement.
Nous avons effectué les expériences suivantes afin d'étudier les caractéristiques de variations de pression à l'intérieur des tuyaux, en se basant sur la relation entre le taux d'écoulement et la limite de pression négative générée à l'intérieur du tuyau.

1) En se basant sur la limite de pression négative, à débit d'écoulement constant, on a mis sur pied un dispositif expérimental dont la longueur au-dessus du sol a été limitée à 30m. A l'aide ce dispositif, on a effectué une expérience de base permettant d'évaluer les caractéristiques d'écoulement de tours de plusieurs centaines de mètres.
2) On a effectué une expérience sur les caractéristiques de variations de pression à l'intérieur des tuyaux d'écoulement à un débit combiné d'écoulement binaire, à débit constant.

Zusammenfassung

Die wichtigste Systemfunktion beim Entwurf von Abflußrohrleitungen in Gebäuden besteht darin Abwässer ungehindert abfließen zu lassen, wobei die Dichtungsklappe nicht durch Druckunterschiede, hervorgerufen von der Fließkraft im Inneren der Rohre, Unterbrochen weden sollte.
In Japan jedoch, wurde ein Druckunterschied im Inneren der Rohre nie systematisch ausgeglichen und die Druckeigenschaften bei der Konstruktion von Rohrleitungssystemen nicht berücksichtigt, was diw Erkennung der Störungsursachen und die Konstruktion geeigneter Abflußsysteme erschwert hat.
Under den gegebenen Umständen führten wir folgende Versuche bezüglich der Druckeigenschaften im Inneren der Rohre durch, basierend auf dem Verhältnis der Abflußrate und des, in den Rohren erzeugten maximalen Negativdrucks.

1) Basierend auf dem maximalen Negativdruck bei stetigem Abfließen, wurde versuchsweise eine Vorrichtung installiert, deren Höhe auf 30m über Boden begrenzt ist. Mit dieser Vorrichtung wurde ein Experiment durchgeführt, mit dem Ziel Möglichkeiten zur Erkennung und Bewertung der Abflu effektivität bei Hochhäusern zu erfassen.
2) Ein weiteres Experiment wurde Hinsichtlich der Merkmale des Druckunterschieds im Inneren der Rohrleitungen unter kombiniertem Binärabflu bei stetigem Durchflu durchgeführt.

1. Foreward

The most important system function in designing drain pipe network inside buildigns is to carry disposals smoothly, and the trap seal should not be broken by the pressure variation inside pipe generated by the flow in the vertical pipe. The foundation of drain pipe network designing method in our country is based on the National Plumbing Code in U.S., however, the Code does not provide a systematic calculation method to obtain the pressure variation inside pipe itself.

This situation remains unchanged upto now even though the single stack systems such as Sovent and Sextia systems developed to minimize pressure variation inside pipe in Europe have been popularized. Only the number of fixtures of which flow may be accepted by each drain pipe can be obtained. Therefore, as the dynamic characteristics of each part does not appear in the design, which is the most special feature as well as faulty point, it is extremely difficult to forcast the result of design method employed for unconventional buildigns or usages.

It is natural that various sanitary fixtures will be manufactured. The using frequency which supports the Code will be different and buildings having unconventional usages will appear. If a trouble should happen in such buildings, countermeasures to be taken is difficult to find. This study aims at a new design method by clarifying the pressure variation inside pipe under the relation of pipe diameters and load flows based on the consideration that the maximum pressure breaking trap seal is caused by the piston operation when a mass of water falls down in vertical pipe. In future, we wish to develop a software enabling the designing of drain pipe network in any kind by using a computer. This paper reports the result of the basic experiment conducted for the purpose mentioned above.

2. Existing studies in Japan and positioning of this study

Taking this opportunity, we wish to introduce the studies on flow charact-

eristics inside drain vertical pipes and pressures inside pipes as listed on the REFERENCES. The number of such study is not so many and the most of them have appeared recently.

(Flow characteristics) A. Asano et.al.[1979] analyzed mainly the terminal length and velocity by using their original annular drain model. In addition, the equation of Willy-Eatons was examined. N. Tsukagoshi and others [1977] measured the velocity distribution of water flow inside drain pipe by employing salt water tracer method, in addition to the classification of flow characteristics inside pipe per flow rate.

(Pressure distribution inside pipe and various traps) M. Ishihara et.al.[1971] proposed a calculation formula for the maximum minus pressure inside drain pipe and a method to solve vent system by network calculation. The target of this study is the mot similar to that of the authors. M. Kamata et.al. [1981] obtained the relation between the trap seal loss values of various traps connected with systems and the pressure (min.) inside drain pipe. The authors [1983—1984] expressed the evaluation of systems with the amount of trap seal loss, and compared the result of fixture drain load and that of steady flow rate load to clarify the relation. K. Sakaue et.al.[1982—1984] analyzed the pressure variation inside pipe of various drain systems with frequency, and studied various influences to trap seal loss caused by the pressure variation. Regarding to the special waste pipe system by single stack, the study on the Sovent system by A. Abe et.al. is popular[1971] in our societies, and several kinds of drainage contractors develop their original systems. When observing these studies, the pressure variation inside pipe has not been clarified enough theoretically as pointed out at the top of this paper. Although they are all precious studies, it is insufficient to deduct the drain system design for higher buildings, for example. The study by M. Ishihara and others is based on the minus pressure with flow at a single floor, and the flow converging from other floors is obtained only by the resistance of air vent, which sometimes hinders to express the correct pres-

sure increase caused by the converging flow. The relation of the pressure variation inside pipe and trap water level variation studied by M. Kamata does not contribute to the precise analysis for future since the expression of pressure variation inside pipe has not been standardized yet. The authors hope that our experiment will contribute to each of the studies.

3. Method of experiment

3.1 Experiment site

An experimental device is installed in the "highrise residential experimental tower" having a height of 30m located in Engineering Dpet., Science University of Tokyo (Noda, Chiba Pre.) The appearance and main scales are shown in Fig.1.

The first problem for our new experiment method was how to grasp the piston operation of a mass of water under nonpressured flow dynamically and quantitatively and whether the problems relating to higher buildigns having a height of several hundreds meters can be deducted by using the "experimental tower" with a limited height (30m). The authors consider that our experiment conducted was successful to solve such problems.

The experiment method is as indicated below. When similar methods can not be found inside and outside of Japan, the authors wish to call this experiment method under the name of the originator, namely, 'SUT SAITO'S METHOD'.

3.2 Kinds of test piece

For the test drain vertical pipe in this experiment, polyvinyle-chloride pipe of ø100mm is used. For the branch pipes that of ø75mm are used (JIS Products). The system schematic diagram of this experiment is shown in Fig.2.

A) Single stack system is adopted. As shown in the figure, the intervals between horizontal branch pipes are 1.5m from the bottom to first floor (which is exposed to atmosphere), 3.0m each for first to nineth floor, 2.5m between nineth and tenth floor, and the stack vent pipe is extended straight-

ly to 2.5m height from the highest floor's horizontal branch pipe. At the top end of the stack vent pipe, a suction nozzle (bell mounth) (JIS 38330) is provided. The ends of each horizontal branch pipe are closed. At fifth floor, various types of trap shown in Fig.3 are installed. The kinds of type of trap are shown in Table-1.

B) An orifice plate with a diameter of 6cm is attached on the stack vent pipe of the test piece A.

C) A large size basin is mounted at the test piece A. The surrounding gap between the pipe and the basin is sealed tightly, and an orifice plate with a diameter of 6cm is mounted at the top of the basin.

D) An orifice same with B is mounted simultaneously on the test piece C.

The above items are called Type A, B, C and D experiment respectively.

4. Measured items and measuring instruments

4.1 Pressure variation inside pipe; P

The pressures P are measured at 0.45m below the bell mouth top of the stack vent pipe, 0.5m above the center of horizontal branch pipe of the load floor and 0.25m above of other floors, and recorded by a pen recorder through small pressure converters and amplifiers.

4.2 Trap seal water level variation; H

The water level variation of traps in two kinds selected from traps in six kinds installed on the horizontal branch pipe of fifth floor is recorded by a pen recorder through a water level meter and amplifier.

4.3 Suction air velocity variation of stack vent pipe; Qa

Suction air velocity v(m/s) is measured at the stack vent pipe top with a hot wire anemometer. The measured value is multiplied by the bell mouth area A(m^2) and the coefficient 0.82 to obtain Qa. $Qa = 0.82\ Av$(ℓ/s)

4.4 Drain water volume variation at vertical pipe bottom; Qw

The integrated volume of water reached the bottom through the vertical pipe is measured with a water pressure meter mounted to the large basin. The

measured value is time-differentiated with a differential analyzer to obtain the status of variation. The values obtained are recorded by a pen recorder.

5. Load applying method

Load is applied in three ways as mentioned below:

No.1) Steady drain flow from one floor

No.2) Steady drain flow from two floors (Binary steady flow)

No.3) Steady drain flow from one floor and fixture drain flow from another floor (Binary steady flow and fixture drain)

The details are explained below:

No.1) The load floor is lowered from the top floor (9th floor) to the lowest floor (1st floor) separately in order. The load flow rate is applied with an interval of 0.5 (ℓ/s) from 0.5 (ℓ/s) to 4.0 (ℓ/s). The trap water level variation at 5th floor is recorded for each time. However, the trap is closed when the water seal is broken to continue the experiment since the pressure variation inside pipe is a target of this study.

No.2) One of the two load floors is fixed on 9th floor, and steady flow load from 0.5 (ℓ/s) with an interval of 0.5 (ℓ/s) is applied. For the other load floor, a steady flow rate same for 9th floor is applied starting from the lowest floor in order. The same measuring method is adopted for trap water level variation as explained in No.1.

No.3) One of the two load floors is fixed on 9th floor, and steady flow rate is applied with an interval of 0.5 (ℓ/s) starting from 0.5 (ℓ/s) to 2.0 (ℓ/s). From the other floor which is 8th, 6th or 3rd floor, water closet load (T-Company, C417) is applied. Same procedures are adopted to measure the trap water level variation as No.1.

6. Experimental results and consideration

6.1 Steady drain flow from one floor

By Type A experiment

An example of the suction air flow Qa(ℓ/s) of stack vent pipe, the pressure variation P(mmAq) inside horizontal branch pipe, and the water level variation of trap H(mm) installed at 5th floor when the steady flow rate of 2.0(ℓ/s) applied from each floor from 9th to 1st is shown in Fig.4 (in case of 9th floor). The air velocity mean value Aℓ(mmAq) corresponding to the pressure variation P(mmAq) at each point indicated at the right side of Fig. 4 can be arranged as shown in Fig.5. Fig.6 shows how to read Fig.5.

Area ① : Status of the entering of air from the upper part by piston operation (minus pressure) caused by load applied

Area ② : Minus pressure generated by the flow from horizontal branch pipe

Area ③ : A part when the maximum minus pressure is generated at the floor which is situated by one floor lower from the load floor

Area ④ : A part where pressure inside pipe changes linealy down to the bottom end

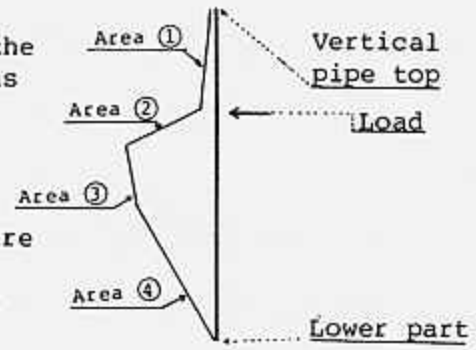


Fig.6 How to read Fig.5

According to the fact the minus pressure ② is almost same even if the load floor is located at from 9th to 6th, however, it is relatively small enough comparing when the load floor locates below 5th floor. Therefore, it can be assumed that the test towers height over six floors is sufficient for the evaluation of drain vertical pipe performance. Consequently, the pressure difference between ① and ③ (called "pressure difference ②" hereafter) can be regarded as minus pressure caused by the converging flow from branch pipes. And, the relation between the load flow rate and the minus pressure can be shown as in Fig.7(a).

By Type B experiment

The pressure difference ② with a resistance (6cm orifice) provided at the upper part of the test piece and load 2.0(ℓ/s) applied is shown in Fig.5(b) and Fig.7(b).

By Type C experiment

The pressure difference ② with a resistance (6cm ofifice) provided and the load of No.1, 2.0(ℓ/s) applied is shown in Fig.5(c) and Fig.7(c).

By Type D experiment

The pressure difference ② with a resistance provided to both upper and lower parts of the test piece, and the load of No.1, 2.0(ℓ/s) applied is shown in Fig.5(d) and Fig.7(d).

No significant difference is found when the results of Type B and A experiments are compared with (a) and (b) in Figs.5 and 7. Therefore, at the upper part of drain vertical pipe, the minus pressure generating inside the drain pipe can be regarded as not significantly changes even though vent resistance is generated at the upper part of load floor. The difference between Type C and Type A corresponds to that the drain vertical pipes extended to the lower part. The maximum minus pressure corresponding to the pressure difference ② is minimized when compared to the difference between Type A and Type B, namely, that between (a) and (b) of Fig.5 and Fig.7. The above may be caused by that the drain water leaving from the pipe wall formed in water drip falls down to generate difference in air resistance. This assumption can be obtained by observing the difference of the pressures P and water volume Qw in Fig.4. To clarify this, more detailed analysis such as the frequency analysis of the water drip may be adapted. It is noticeable that the pressure distribution shape obtained by the Type C experiment is very similar to that obtained from the experiment with house drain conducted by the authors in REFERENCES (8) and (9). Consequently, the authors expect to conduct the performance test of a drain system containing horizontal main pipe in the future with SUT SAITO'S METHOD.

6.2 Steady drain flow from two floors (Binary steady flow)

The suction air flow of stack vent pipe Qa(ℓ/s), the pressure variation P (mmAq) inside horizontal branch pipe, and the water level variation H(mm) of trap installed at 5th floor, for reference, with the drain of steady

flow 2.0(ℓ/s) from 9th floor and that of steady flow in same volume from the other floor (8th – 1st floor) applied are shown in Fig.8(a) and (f). (a): 9th + 8th, (f): 9th + 3rd.

The mean value Aυ of pressure variation at the converging flow 4.0(ℓ/s) from each flow 2.0(ℓ/s) can be arranged as in Fig.9(a) – (g). The broken line in the figure indicates the pressure distribution at the independent drain of 2.0(ℓ/s) from each floor. The maximum minus pressure ② does not change significantly when the height difference of two floors is less than that of three floors. (Refer to Fig.9(a)～(c)). Meantime, the maximum minus pressure ② is suppressed lower by converging with steady binary flow of each 2.0(ℓ/s) than by steady flow from one floor of 4.0(ℓ/s). However, the load of the height exceeding four floors is applied, the increase by converging flow plays as minus rather than to say the trend is remarkable. Namely, back pressure will be generated. (Refer to Fig.9(d)～(g)). The minus pressure can be lowered depending on the using manners. Such phenomenon is generated when a new drain at lower velocity is converged with drain flowing down at high velocity inside a pipe. Especially at the terminal velocity of the original drain, when the water drips fall down with extremely high velocity, the mass of drain water with lower velocity converging from horizontal branch pipe blocks them, which may generate the back pressure.

The special pipe employing joints to lower water velocity is assumed to be developed based on the consideration to lower the minus pressure inside pipe.

6.3 Steady drain flow from one floor and fixture drain flow from another floor (Binary steady flow and fixture drain)

This experiment was conducted as an immediate measure to clarify the peak of load as in the case of fixture drain. The back pressure is generated also at the converging flow of fixture drain, of which reason can be considered same with that for 6.2.

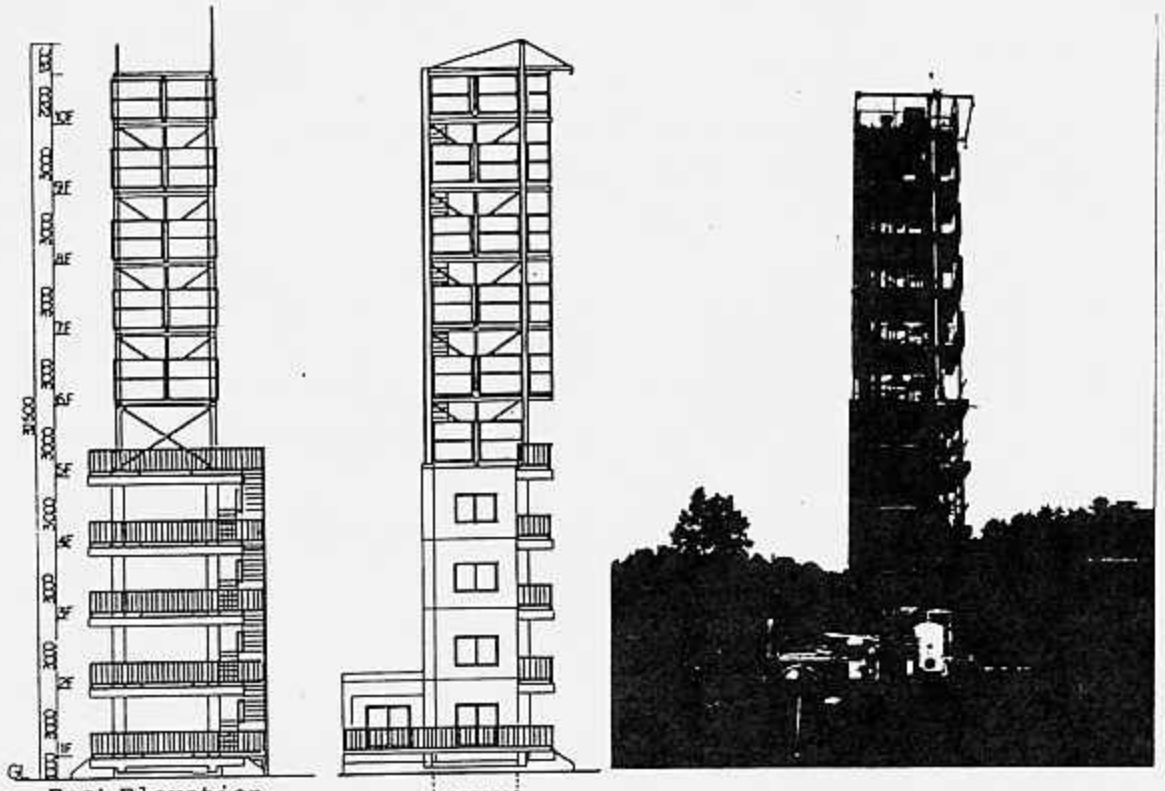


Fig.1 Elevations and appearance of experimental tower

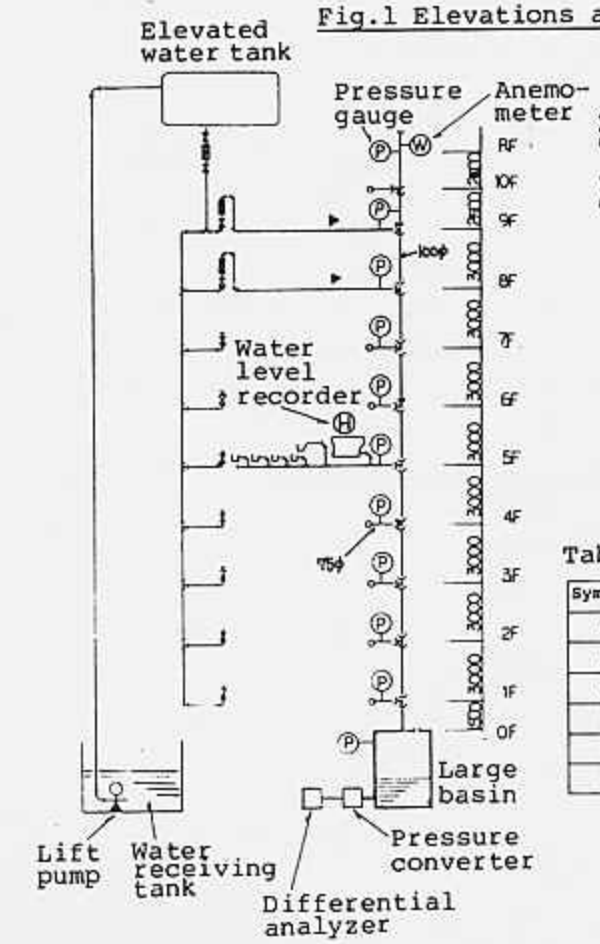


Fig.2 Experimental drain system schematic diagram

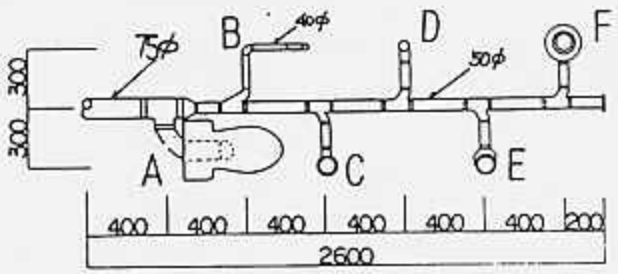


Fig.3 Traps installed appearance of experimental tower

Table-1 Type of traps

Symbol	Kind of trap	Model No.	Jis No.
A	Closet trap	T-made C417	JIS A5207
B	Lavatory P-trap	T-made TL-524F3PR	JIS A5514 Type P
C	Floor drain P-trap	H-made C-50	JIS A4002 Type C
D	Laundry pan P-trap	H-made P-50	JIS A4002 Type P
E	Floor drain P-trap	K-made KT-BL	—
F	Floor drain P-trap	H-made D-50	JIS A4002 Type D

※characteristic values of six kinds of traps ommitted

Measured by;
T. Iso
M. Ohtsuka
Y. Kikuchi
H. Sakaguchi
T. Nakamura

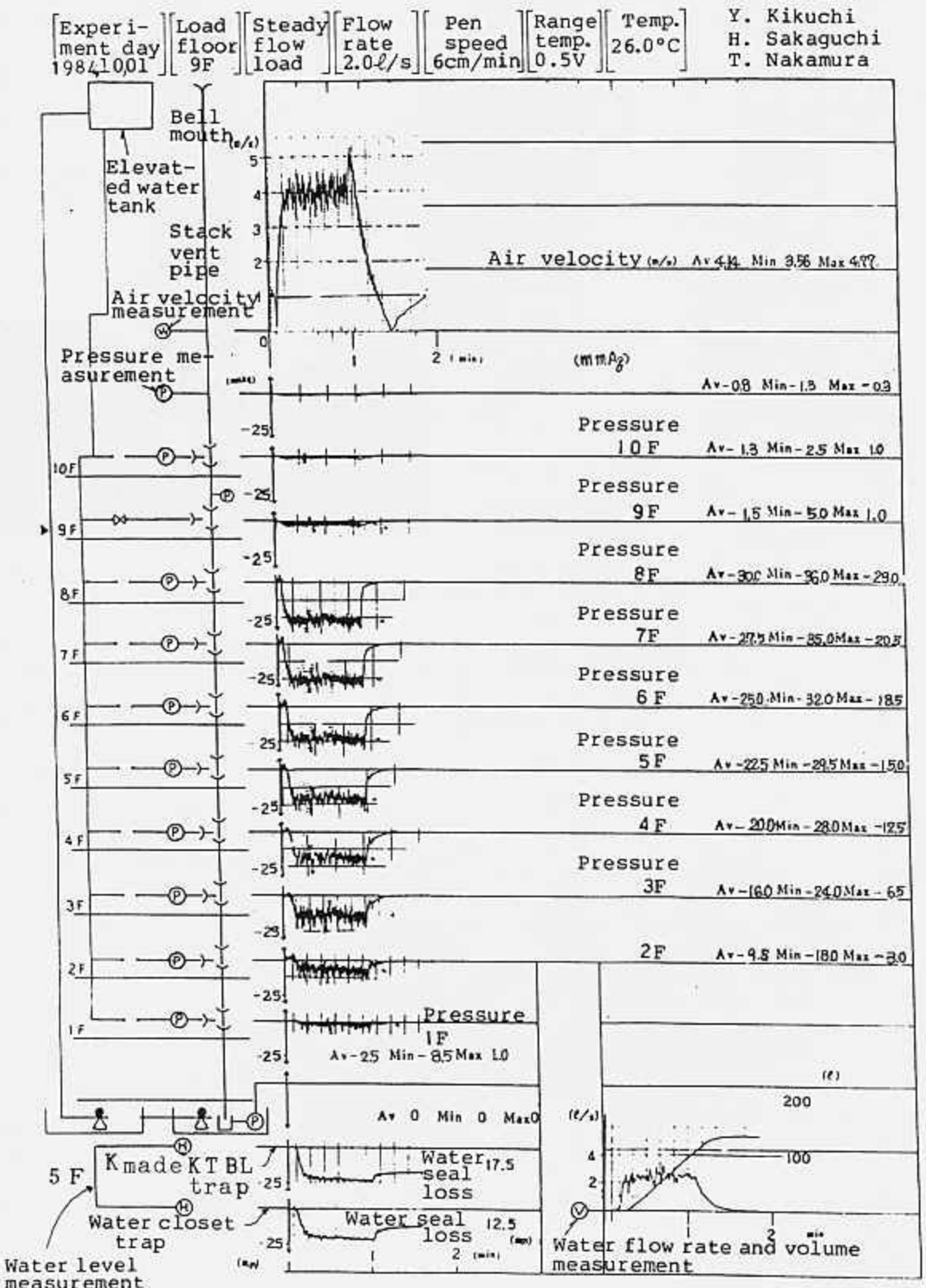
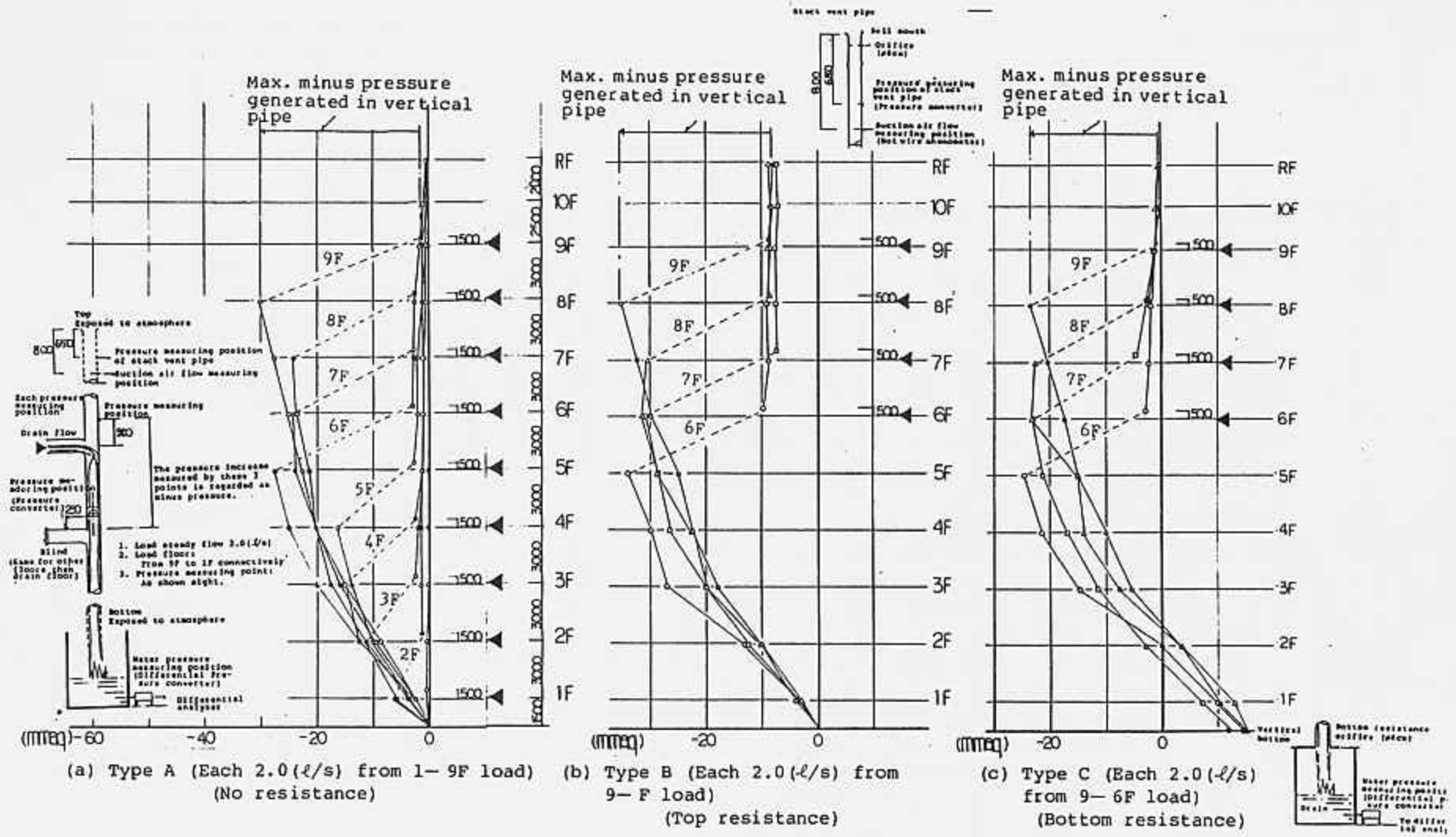


Fig.4 Example of variation of pipe pressure, air velocity, trap water level and drain water volume under steady flow load

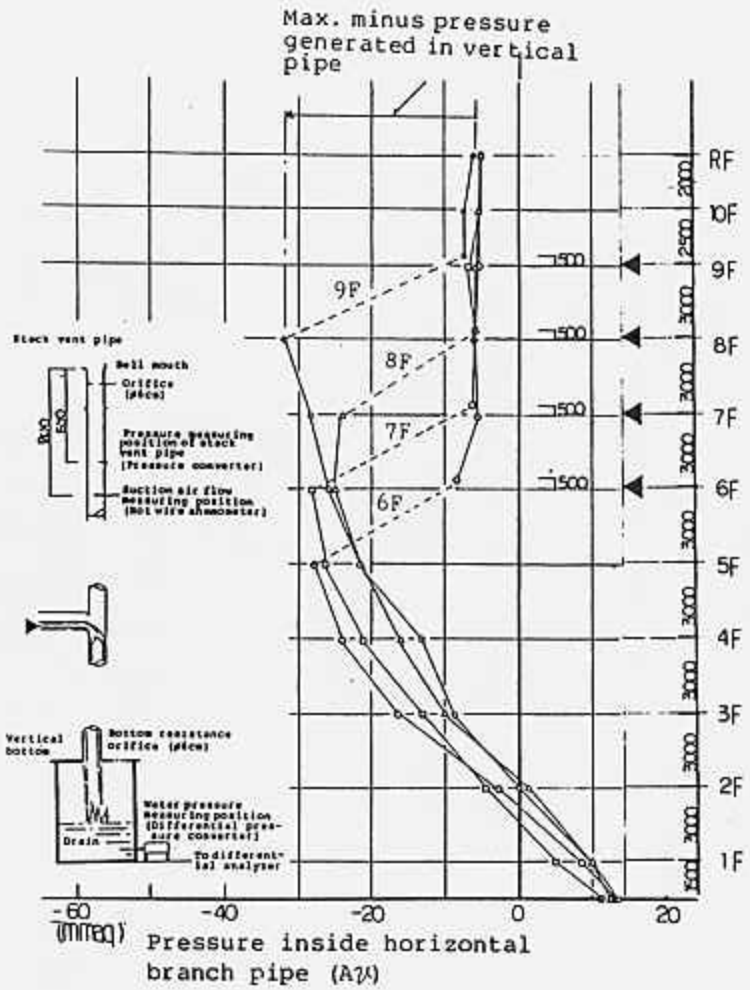


(a) Type A (Each 2.0(ℓ/s) from 1— 9F load) (No resistance)

(b) Type B (Each 2.0(ℓ/s) from 9— F load) (Top resistance)

(c) Type C (Each 2.0(ℓ/s) from 9— 6F load) (Bottom resistance)

Fig.5 Distribution of pressure inside pipe at steady flow load (No.1 experiment)



(d) Type D Experiment (Each 2.0 ℓ/s from 9–6F load)
(Top and bottom resistance) (Orifice dia.6cm)

Fig.5 Distribution of pressure inside pipe at steady from load (No.1 Experiment)

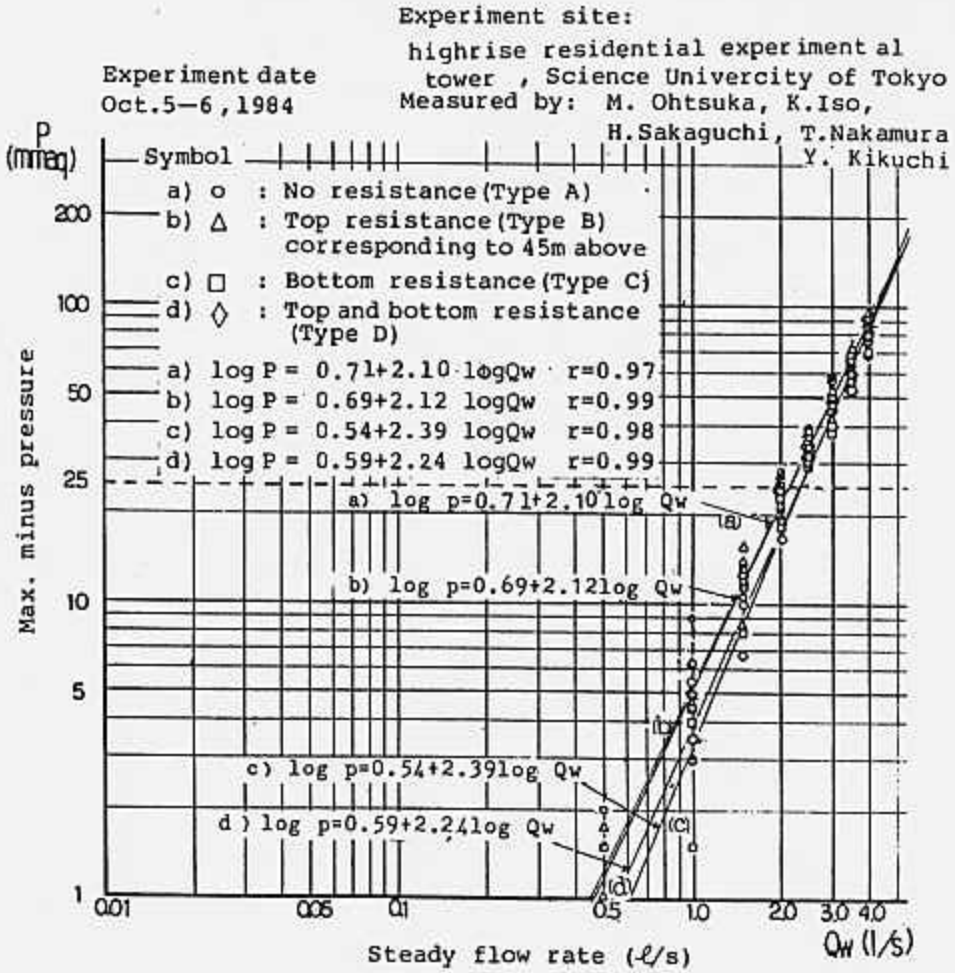


Fig.7 Relation between minus pressure and flow rate generated in vertical pipe caused by converging flow from horizontal branch pipe (No.1 Experiment)

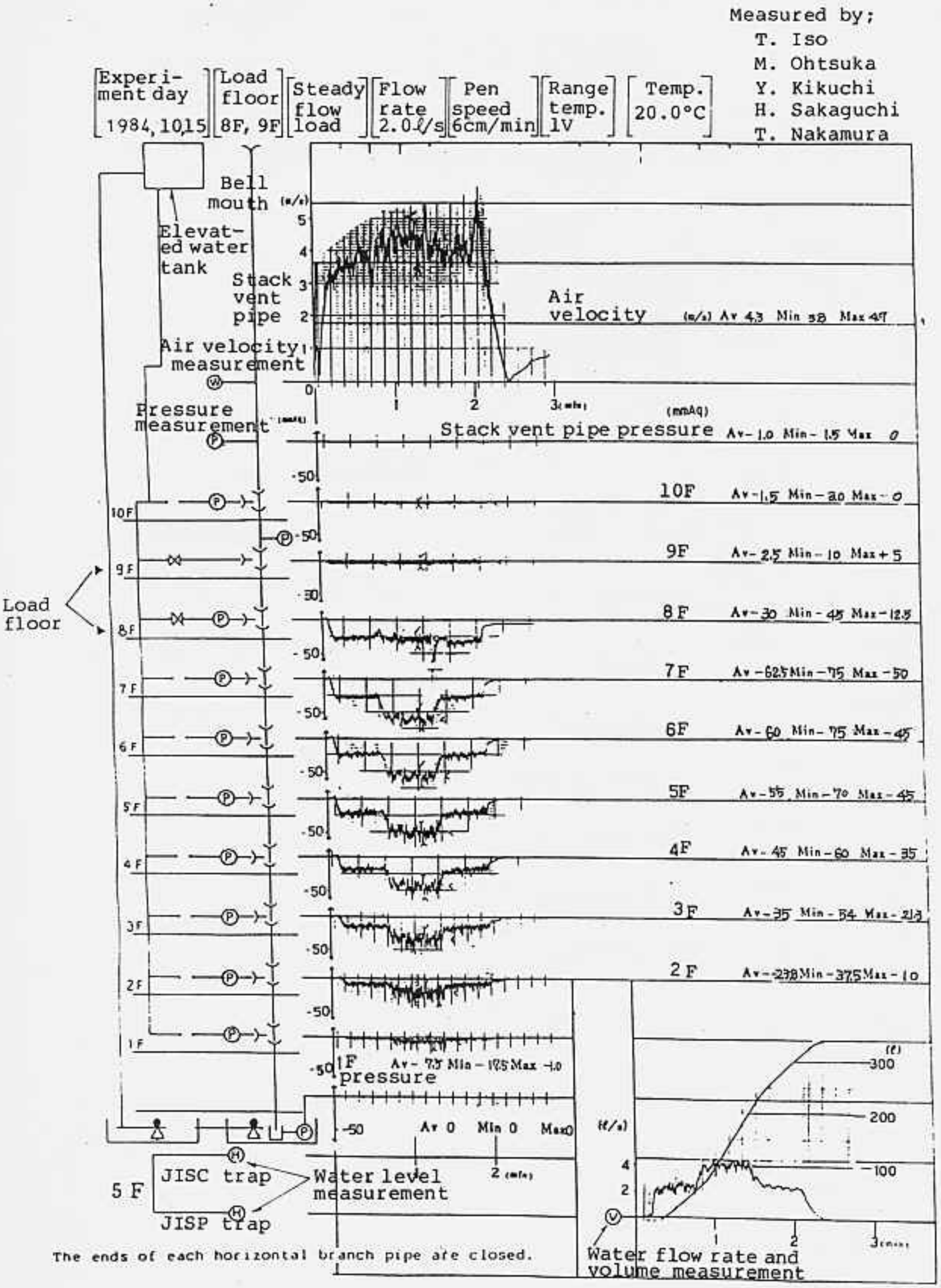


Fig.8(a) Example of variation of pipe pressure, air velocity, trap water level and drain water volume under converging flow of binary steady flow load
(9F + 8F) (Each 2.0ℓ/s) No.2 Experiment (Binary steady flow)

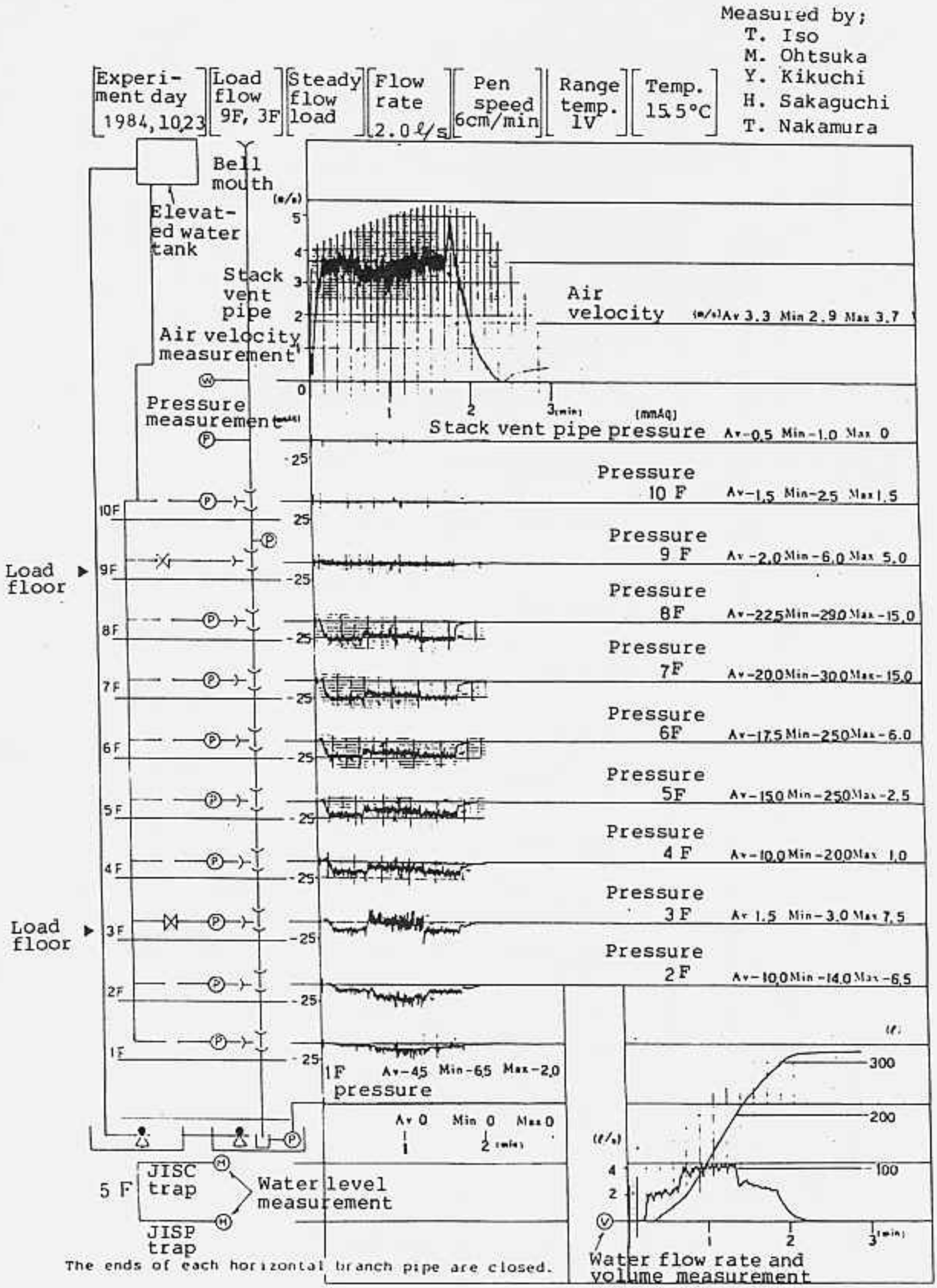


Fig.8(f) Example of variation of pipe pressure, air velocity trap water level and drain water volume under converging flow of binary steady flow load (9F + 3F) (Each 2.0 ℓ/s) No.2 Experiment (Binary steady flow)

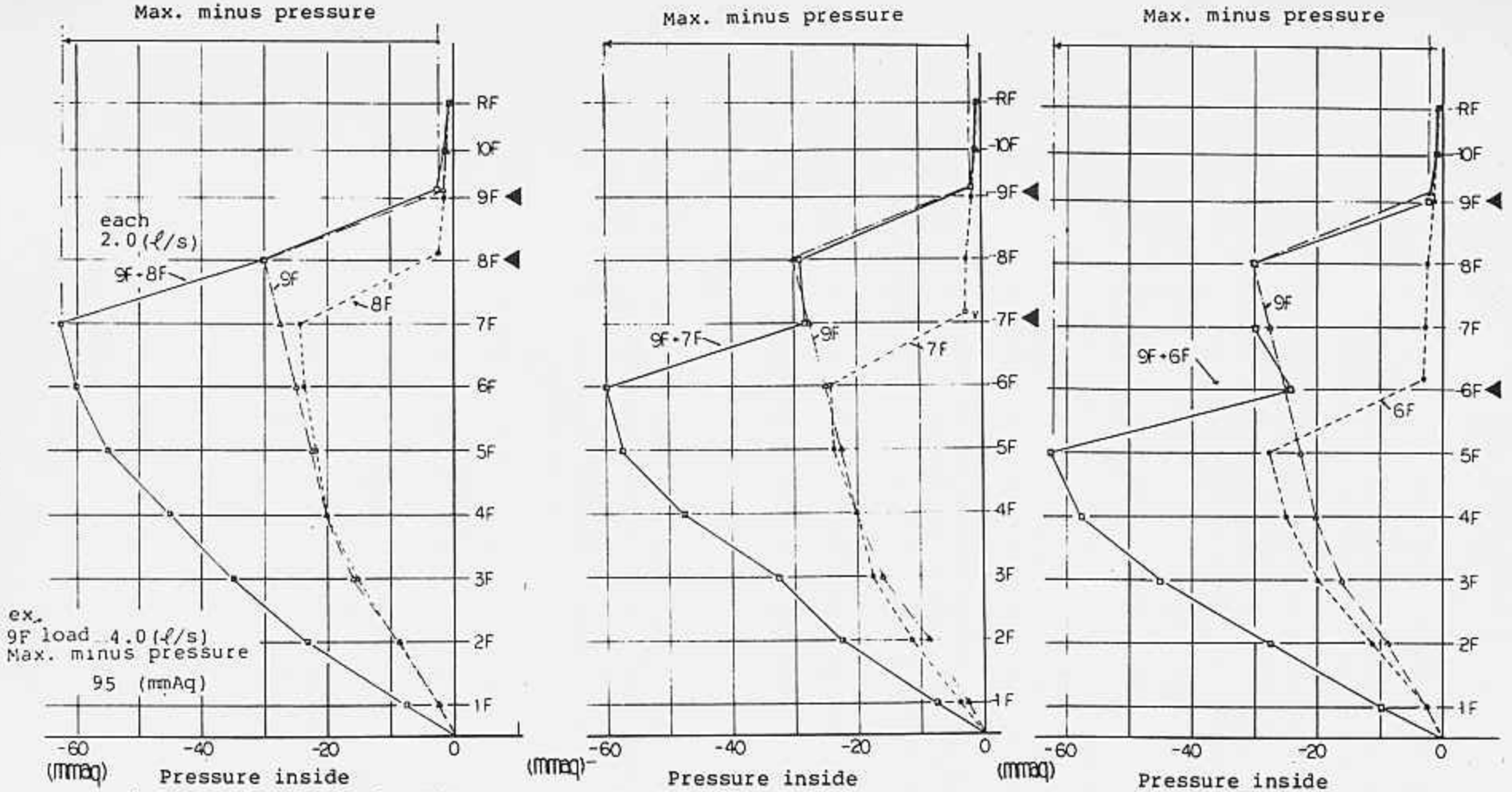


Fig.9 Pressure inside pipe at converging flow from binary steady floor load
(Each 2.0ℓ/s) No.2 Experiment

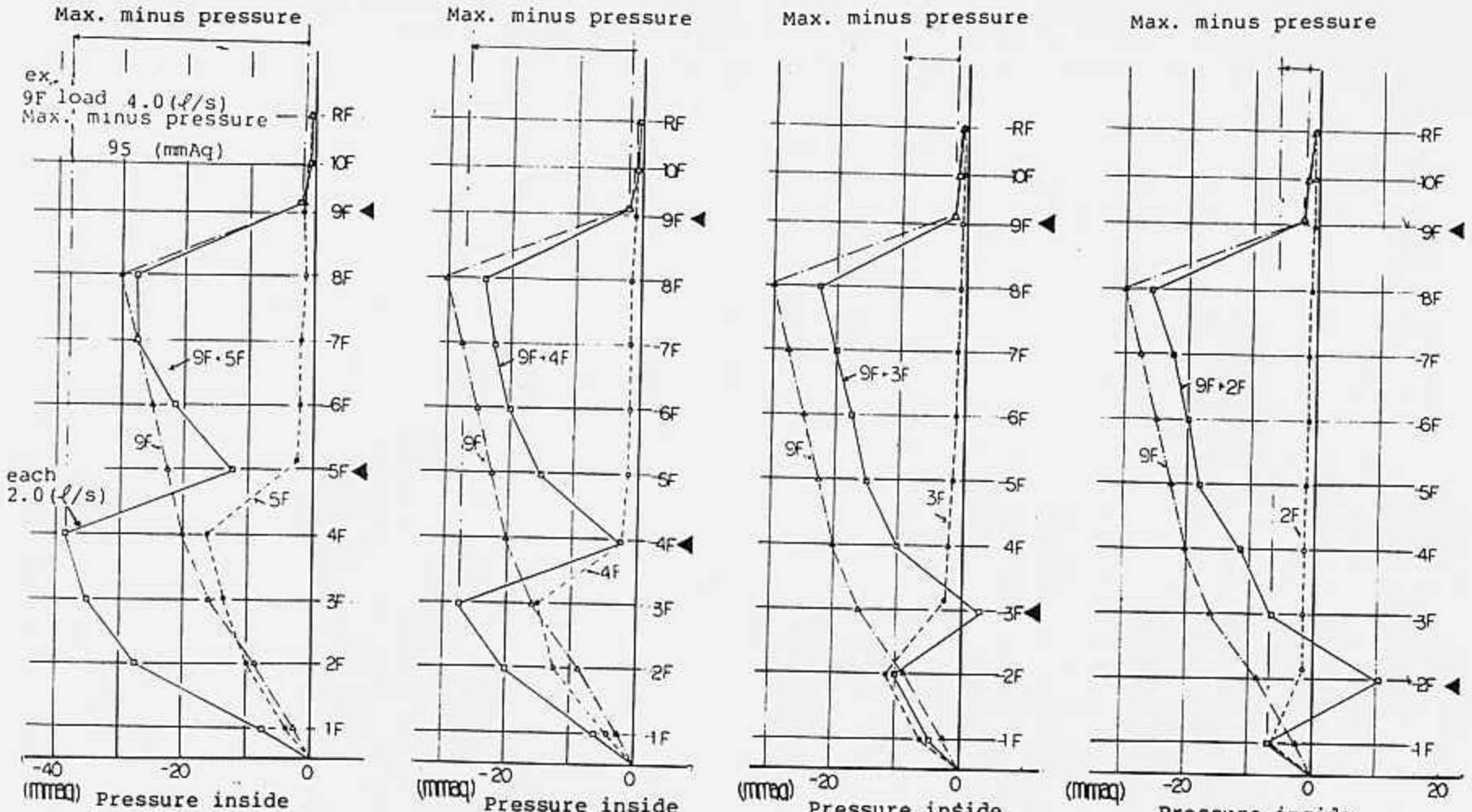


Fig.9 Pressure inside pipe at converging flow from binary steady floor load
(Each 2.0ℓ/s) No.2 Experiment

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Pressure Resistance Performance of Traps

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TOKYO, JAPAN



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12th CIB-W62 SYMPOSIUM -- TOKYO --
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
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Summary

The drainage-vent system are designed not to break the seal water of trap. Regarding the induced siphonage, which is considered as the most important cause to break a seal, the permissible values of pressure in drains are defined as safety standards for breaking a seal, and the permissible flow rates of drainages according to the pipe diameters are established in Japan. On the other hand, however, the performance standard of a trap has not been provided except for the maximum and minimum seal depth. But, it is indicated that the performances of pressure resistance of traps are greatly influenced by not only a seal depth but also other elements of a trap shape, in particular, a ratio of sectional area of legs (sectional area of outlet leg / sectional area of inlet leg). Therefore, it is considered that the permissible values of pressure and flow rates based on only hte seal depth presently adopted may change relatively, if the performance of pressure resistance of traps depending on the seal depth and other elements of a trap shape should differ from them. In order to establish the accurate design methods of the drainage-vent system, first of all, it is necessary to clarify and standardize the performance of pressure resistance of traps.

Under the circumstances, we conducted tests on the typical traps presently used in Japan in 7 types and 7 model traps having different basic shapes applied with steady dischange flow rates by using an actual-sized experimental device for discharge tests, and examined the pressure resistance performance of these traps.

Résumé

Les systémes d'évacuation/dégagment sont conçus pas affecter la garde d'eau des siphons. En ce qui concerne le siphonage induit, qui est considéré comme la cause la plus importante de modification de garde d'eau, les valeurs admissibles de pression dans les conduites sont définies comme normes de sécurité de rupture des gardes d'eau, et les débit d'évacuation admissibles en fonction des diamétres des tuyaux sont établis au Japon. Néanmois, les normes fonctionnelles des siphons ne sont pas indiquées, sauf en ce qui concerne la profondeur maximale et minimale de la garde d'eau. Mais, il est indiqué que les caractéristiques de résistance à la pression des siphons sont généralement influencées non seulement des branches du siphon. En conséquence, il se peut que les valeurs admissibles de pression et de débits d'écoulement basées uniquement sur la profondeur de la garde d'eau, valeurs adoptées actuellement, soient relativement modiffiées si les caractéristiques de résistance à la pression des siphons en fonction de la profondeur et des autres éléments du siphon sont différentes. Afin d'établir des méthodes précises de conception des réseaux d'évacuation dégagement, il est tout d'abord nécessaire de clarifier et standardiser les caractéristiques de résistance à la pression des siphons.

Dans ces conditions, nous avons effectué des tests sur les siphons typiques utilisés actuellement au Japon: 7 types et 7 modéles de siphons ayant différentes formes de base et sur lesquels on a appliqué des débits d'écoulement constants. On a utilisé des dispositifs expérimentaux de grandeur réelle et on a examiné les caractéristiques de résistance à la pression de ces siphons.

Zusammenfassung

Drainage-Lüftungssysteme sind nicht zur Beeinträchtigung der Wirksamekeit des Dichtungswassers von Geruchverschlüssen ausgelegt. Die induzierte Absaugwirkung betreffend, die als wichtige Ursach zur Zerstörung eines Geruchverschlusses angesehen wird, werden die zulässigen Druckwerte in Drainageröhren als Sicherheitsnormen zum Zerstören eines Geruchverschlusses definiert, und die zulässigen Flußraten von Abwasserröhren entsprechend dem Röhrendurchmesser werden für Japan aufgestellt. Andererseit werden die Leistungswerte für Geruchverschlüsse nicht gegeben, abgesehen von Maximal- und Minimal-Verschlußtiefe. Es wird aber dargestellt, daß die Leistung des Druckwiderstandes von Geruchverschlüssen nicht nur durch die Verschlußtiefe sondern auch andere Faktoren wie Verschlußformgebung, insbesondere durch das Verhältnis der Querschnitte der Verschlußein- und auslässe stark beeinflußt wird. Darum wird angenommen, daß die zulässigen Werte für Druck und Flußraten, die zur Zeit nur auf der Verschlußtiefe basieren, sich relativ ändern können, wenn die Leistung des Druckwiderstandes von Geruchverschlüssen je nach Verschlußtiefe und anderen Faktoren sich davon unterscheidet. Um akkurate Designmethoden für Drainage-Lüftungssysteme zu entwickeln, ist es in erster Linie efforderlich, die Leistung im Hinblick auf Druckwiderstand von Geruchverschlüssen zu klären und zu normieren.

Unter den beschriebenen Bedingungen führten wir Versuche an typischen in Japan verwenderten Geruchverschlüssen durch. Dabei wurden 7 Typen und 7 Modellverschlüsse mit verschiedenen Grundformen mit ständigen Ablauf-Durchflußraten unter Verwedung einer Expermentiervorrichtung in Originalgröße verwendet und die Druckwiderstandsleistung diesser Geruchverschlüsse untersucht.

1. Introduction

The drainage-vent systems are designed not to break the seal water of a trap. Regarding the induced siphonage, which is considered as the most important cause to break a seal, the permissible values of pressure in drains are defined as safety standards for breaking a seal, and the permissible flow rates of drainages according to the pipe diameter are established in Japan. On the other hand, however, the performance standard of a trap has not been provided except for the maximum and minimum seal depth. But, it is indicated that the pressure resistance performance of traps are greatly influenced by not only a seal depth but also other elements of a trap shape, in particular, a ratio of sectional area of legs (sectional area of outlet leg / sectional area of inlet leg). Therefor, it is considered that the permissible values of pressure and flow rates based on only the seal depth presently adopted may change relatively, if the pressure resistance performance of traps depending on the seal depth and other elements of trap shap should differ from them. In order to establish the accurate design methods of the drainage-vent systems, first of all, it is necessary to clarify and standardize the performance of pressure resistance of traps.

As the existing studies of the pressure resistance performance of traps, the process of seal water loss is analyzed through mathematical models by H.Matsudaira et al.[1], the author et al.[2)3)], and Y.Asano et al.[4], the performance of traps by shape is compared by model pressure generators by J.Christiansen[5], A.Schlag et al.[6], and the author et al.[7] and the performance is examined by using actual systems by L.Asplund et al.[8], M.Kamata et al.[9], and author et al.[10)11)12)]. Although the

considerable numbers of the study have been conducted as mentioned above, futher experimental data on the actual drainage-vent systems are required to evaluate the performance of traps presently used generally.

From the above point of view, the author et al. installed the typical traps being used in Japan in 7 types, and 7 model traps having different basic shapes to an actual sized drain experimental device in 7 story scale, conducted drain experiments applied with stationary flow rate drain load, and examined the pressure characteristics inside pipe and the pressure resistance performance of these traps.

2. Experiment method

2.1 Test traps

The shapes of the test actual traps in 7 types are shown in Fig.1, and their measurement are shown in Table 1. These traps have the typical shapes presently used in Japan. T-1 ∿ T-6 are cast iron made traps for floor drain, while T-7 is brass made for wash basin.

The shapes of the 7 test model traps made of chloride vinyl are shown Fig.2, and their measurement are in Table 2. As the shape elements to give influences on the pressure resistance performance of traps, the horizontal fixture branch length(T-B), seal depth(T-C), seal water length(T-D, T-E) and a ratio of sectional area of legs(T-F, T-G) against the standard trap(T-A) are taken into consideration here.

2.2 Experimental device

The entire drainage-vent system for testing is outlined in Fig.3. It constitutes a circulation system where waste

water flown down from the stationary drain device at the top through drain stack flow into the bottom drain tank through horizontal drain pipe, and is lifted to the top water tank by a pump. In this system, the horizontal drain branch pipe to be installed with traps shown in Fig.4 are mounted at the 1st, 3rd and 6th floors. For stack-vent system, vent-stack system and loop-vent system, basic drainage-vent system (S-1, S-2), and drainage-vent systems mounted with drain branch pipe at 1st, 3rd and 6th floors (S-3 ∿ S-8) are prepared as test systems (refer to Fig.5).

2.3 Measurement method

The pipe pressure was measured at 5 points (point a ∿ point e) shown in Fig.4 in order to discriminate a difference by measuring points at same floor. For the measuring instrument, a diffused junction diode type pressure converter (natural frequency ; 600Hz) was used. The vent flow of the stack vent pipe was converted from the air velocity inside the pipe measured by a hot wire anemometer. These measured value were stored in a data recorder, processed by A/D converter and personal computer, and recorded in a plotter printer or pen recorder. The level fluctuation of trap seal water was measured by a resistance water level indicator, and recorded by a pen recorder. The phenomena of bubble passing and seal water blow-out, and the seal water loss level were confired visually.

2.4 Experiment conditions

1) Experiment relating to pipe pressure characteristics

The pipe pressure was measured at the measuring point a ∿ e in the system S-1 ∿ S-8, without installing a trap to the horizontal drain branch pipe. The drain load flow rate was

varied from 1.0 l/s ∿ 4.0 l/s by adding 0.2 l/s in step.

2) Experiment relating to pressure resistance performance of traps

The drain load flow rate was varied until the water seal is broken by increasing 0.2 l/s in step, and the pipe pressure was measured at point d of the horizontal drain branch pipe. For the actual traps, S-3 ∿ S-8 systems were adopted, while for the model traps, S-5 and S-6 systems were used.

3. Experiment results and consideration

3.1 Pipe pressure characteristics and vent characteristics

The variations of pipe pressure and vent flow rate against the drain load flow rates by system are shown in Fig.6 ∿ 15. Fig.6 and Fig.7 show the result of the system S-1, and they indicate almost same trend except for the values of the 1st floor. Fig.8 and Fig.9 for the system S-2 appear in almost same variation regardless of the measuring points. Fig.10 ∿ 15 show the results of the system S-3 ∿ S-8. Due to the above facts, the following were found as the characteristics of pipe pressure in this system. Namely, the positive pressure increases along with the increase of drain load flow rate up to 3.4 l/s, the increasing ratio is larger at the lower floors, and a difference is scarcely caused by the measuring points of horizontal drain branch pipe.

Fig.16 shows the vent flow rate at each system. In the case of the stack-vent system, the vent flow rate increases in proportion to the drain load flow rate, however, it decreases in the vent-stack system and loop-vent system contrarily proving that the effect of air circulation in the vent-ctack

and loop-vent system.

3.2 Pressure resistance performance of traps

1) Data processing method

To investigate the relation between the pipe pressure and seal water loss level, and that between the drain load flow rate and seal water loss level, the data were processed by following the methods below.

An example is shown for the system S-6, trap T-4 and drain load flow rate of 3.0 l/s. The upper drawing of Fig.17 shows the variation of pipe pressure along with the lapse of time which was recorded by a pen recorder. The maximum value (A) and minimum value (B) obtained from the above, and the relation with the seal water loss level generated are plotted with the point A and B in the lower drawing. Each drain flow rate plotted in same way can be shown as the lower drawing. When seal water loss level is below a half of the seal depth, a high correlation between the maximum or minimum value of pipe pressure and the seal water loss level generally, of which relation can be approximated by regression line. In this case, 0.84 was obtained for the maximum value, and 0.92 was for the minimum value. On the other hand, when the seal water loss level is larger than a half of the seal water depth, bubble passing or blow-out phenomenon is generated, and no correlation is found in the relation. In the same way, the relation between the drain load water flow rate and seal water loss level is plotted in Fig.18.

2) Pressure resistance performance of actual traps

Fig.19 ∿ Fig.21 show the regression of the pipe pressure at the systems S-4, S-6 and S-8 for which high correlation

coefficient over 0.8 was observed and the seal water loss level of the actual traps. Fig.22 ∿ Fig.24 show the regression of the drain load water flow rate and the seal water loss level. In the systems S-3 and S-6 where the pipe pressure is almost positive pressure, and S-8 where the positive pressure is eminent over the negative pressure, no correlation was found between the pipe pressure and seal water loss level (correlation coefficient ; 0.3 approximately).

In the system S-4 and S-6 where both positive and negative pressure were increased, clear correlation between them is observed (correlation coefficient ; 0.9 approximately). The phenomenon of bubble passing differs depending on the ratio between the positive and negative pressure. For example, bubble passing was generated at the fluctuation range of pipe pressure 55 ∿ 100mmAq in the system S-4 having the ratio of 3:1 approximately, while it was generated at 30 ∿ 55mmAq in the system S-6 of 3:2 approximately. When bubble passing is considered as a phenomenon to break seal water, and ±25mmAq is assumed as the permissible value of pipe pressure, the traps T-6, T-4, T-5 and T-7 in the system S-4, and T-7 in the system S-6 can be judged to satisfy the permissible value (refer to Fig.10 and Fig.20). In addition, the pressure resistance performance of the traps T-6 and T-4 can be evaluated more excellent than that of other traps. This can be identified from the relation between the drain load flow rate and seal water loss level shown in Figs.22 and 23. In the system S-8 where the negative pressure is more eminent than the positive pressure, bubble is passed below ±25mmAq at all traps. Regarding seal water loss, the seal water loss level of trap

T-4 is smaller than that of others.

3) Pressure resistance performance of model traps

Fig.25 shows the regression of the pipe pressure and the seal water loss level of the model traps in the system S-6, and Fig.26 shows the regression of the drain load flow rate and the seal water loss level. In order to investigate the influence to be given to the pressure resistance performance of traps by the shape difference, the traps were compared by making the trap T-A (horizontal fixture branch length ; 250mm, seal depth ; 60mm, seal water length ; 199mm, ratio of sectional area of legs ; 1.0) as a standard.

(1) Influence by horizontal fixture branch length

The trap T-B has a long horizontal fixture length of 500mm designed by taking return water into consideration. With the trap T-A approximately by 20% representing the effect of return water.

(2) Influence by seal depth

The trap T-C has a deep seal depth of 100mm, however, the seal water loss level is almost same with that of trap T-A, for which the influence by the depth can not be found. However, the deep depth gives favorable effect to the phenomenon of bubble passing or blow-out, and makes the pressure resistance performance excellent due to the increased residual seal depth.

(3) Influence by seal water length

The seal water length of the traps T-D and T-E are designed long to 288 and 331mm respectively to increase the seal water volume enabling to prolong the natural period.

(4) Influence by ratio of sectional area of legs

When the trap T-F having a large effluent leg sectional

area (ratio ; 1.56) and T-G having a large inffluent leg sectional area (ratio ; 0.69) are compared, the seal water loss level of the trap T-G is almost same with that of the trap T-A, however, that of the trap T-F is smaller by 50% approximately. Due to the above, it can be clarified that the ratio of sectional area of legs gives significant effect to the pressure resistance performance, and provides excellent performance when it exceeds 1.0.

4. Conclusion

As described above, actual traps in 7 types and 7 model traps were installed to stack-vent system and loop-vent system (or vent-stack system) by using an actual sized drain experiment device, and the pipe pressure characteristics and the pressure resistance performance of traps were examined. The results can be summarized as follows.

(1) The pressure of horizontal drain branch pipe is almost same regardless of the position, and that of drain stack is also same with the above except for the 1st floor.

(2) The vent flow rate of stack vent pipe increases in proportion to the drain load flow rate in the stack-vent system, however, it decreases in the loop-vent system (or vent-stack system) reversely.

(3) Regarding the relation between the pipe pressure and the seal water loss level of traps, high correlation is found when the pressure fluctuates over pisitive and negative range, however, no correlation is found with positive pressure mostly.

(4) Similar trends are observed for the relation between the

drain load flow rate and the seal water loss level.

(5) When the pressure resistance performance of the actual traps in 7 types are compared, P-trap for floor drain (T-6) is significantly excellent at high positive pressure, while contrary bell trap (T-4) is at high negative pressure. In view of the residual seal depth, the pressure resistance performance of P-trap for wash basin (T-7) having deep seal depth is extremely excellent.

(6) Based on the experimental results of the model traps, it was clarified that the ratio of sectional area of legs, and nextly, the length of horizontal fixture branch, give the most significant influence to the seal water loss level among the shape elements of traps. Especially, it is that more larger value is more effective when the value exceeds 1.0.

Acknowledgements

This study was conducted as one of the activity of Experiment Working Group (K.Sakaue, N.Tsukagoshi, N.Ichikawa), Subcommittee of Drainage in Buildings (Chief, K.Maejima), Plumbing Code Committee (Chairman, T.Shinohara), SHASE, Japan in 1982. The author wishes his thanks to the relative committeemen who gave precious advices, Ina Seitoh Company Limited who assisted in improving the experiment device, and the graduate and seminor students who cooperated to the experiment.

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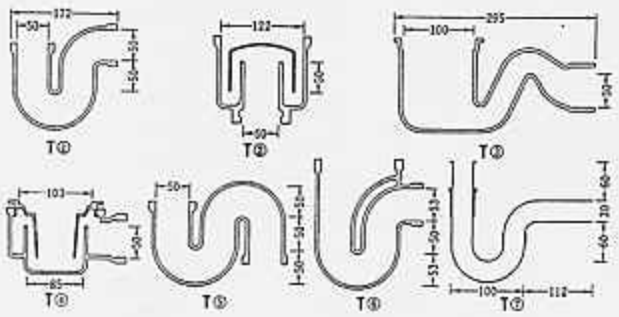


Fig.1 Test trap (actual trap)

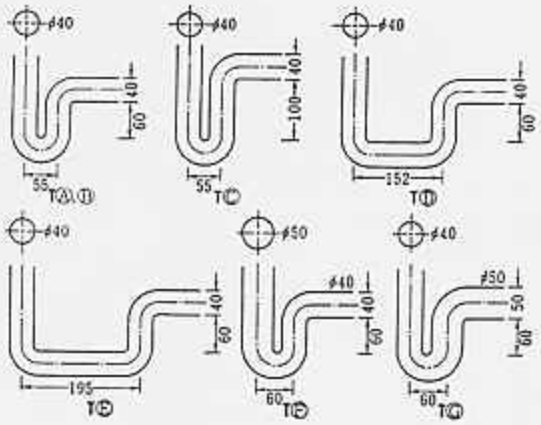


Fig.2 Test traps (model trap)



copper pipe 8φ

for floors without horizontal branch pipe

measuring points : a, b, c, d, e

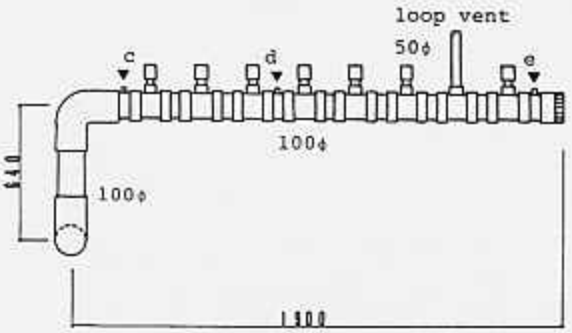


Fig.4 Horizontal drain branch pipe

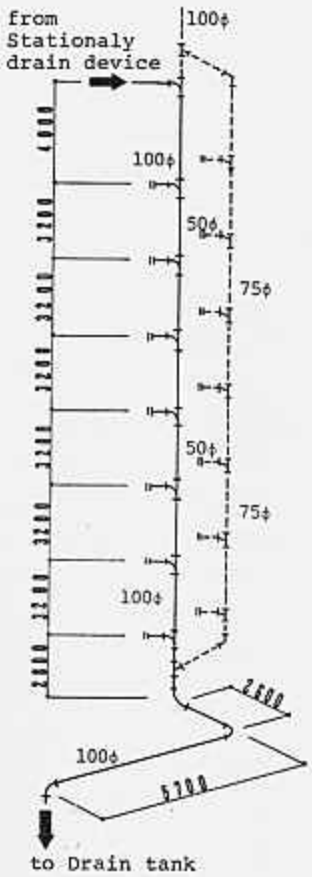


Fig.3 Outline of drainage-vent system for testing

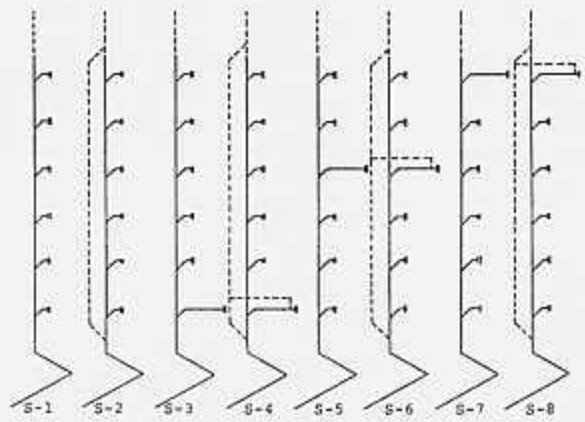


Fig.5 Test systems

Table 1 Measurement of actual traps

Type of trap	T-A	T-B	T-C	T-D	T-E	T-F	T-G
Passing part depth* (cm)	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Sectional area of inlet leg** (cm^2)	12.6	12.6	12.6	12.6	12.6	12.6	19.6
Sectional area of outlet leg** (cm^2)	12.6	12.6	12.6	12.6	12.6	19.6	12.6
Ratio of sectional area of legs***(-)	1.0	1.0	1.0	1.0	1.0	1.56	0.64
Seal depth (cm)	6.0	6.0	10.0	6.0	6.0	6.0	6.0
Seal water volume (cm^3)	250	250	346	360	420	310	315
Seal water length (cm)	19.1	19.1	27.1	28.8	33.1	19.5	19.5
Horizontal branch length** (cm)	250	500	250	250	250	250	250

* vertical distance between top dip and bottom dip of trap
** mean value
*** sectional area of outlet leg / sectional area of inlet leg
** include horizontal pipe of trap

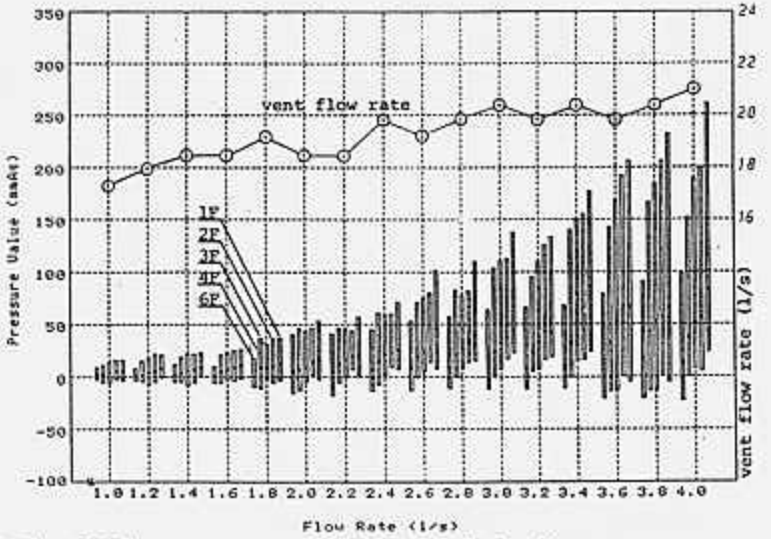


Fig.6 Pipe pressure (S-1, point a)

Table 2 Measurement of model traps

Type of trap	T-1	T-2	T-3	T-4	T-5	T-6	T-7
	P	Bell	Changed P	Contrary Bell	S	P	P
Passing part depth* (cm)	5.3	1.4	3.7	1.9	5.0	4.7	3.2
Sectional area of passing part (cm)	22.1	37.2	38.5	31.9	19.6	40.7	8.0
Sectional area of inlet leg** (cm)	22.1	40.3	86.1	22.1	19.6	37.9	8.0
Sectional area of outlet leg** (cm)	22.1	12.7	38.7	24.5	19.6	37.9	8.0
Ratio of sectional area of legs***(-)	1.0	0.3	0.4	1.1	1.0	1.0	1.0
Seal depth (cm)	5.0	5.0	5.0	5.0	5.0	5.0	6.0
Seal water volume (cm)	450	430	1003	358	420	690	164

* vertical distance between top dip and bottom dip of trap
** mean value
*** sectional area of outlet leg / sectional area of inlet leg

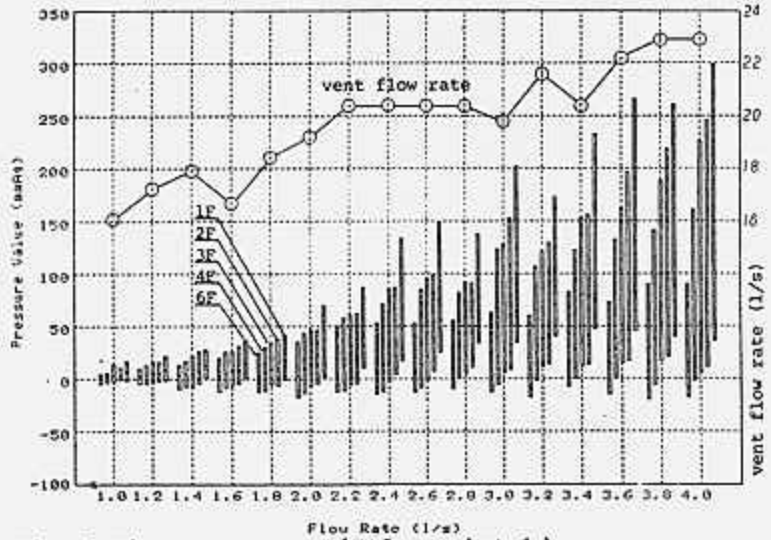


Fig.7 Pipe pressure (S-1, point b)

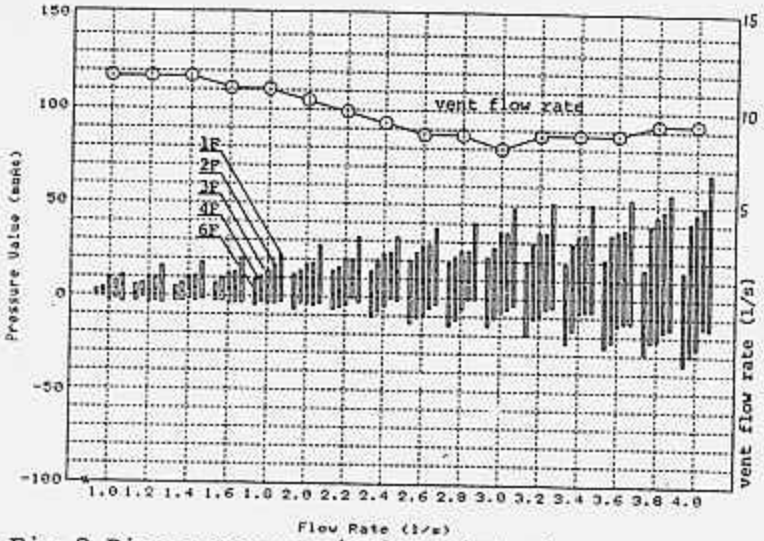


Fig.8 Pipe pressure (S-2, point a)

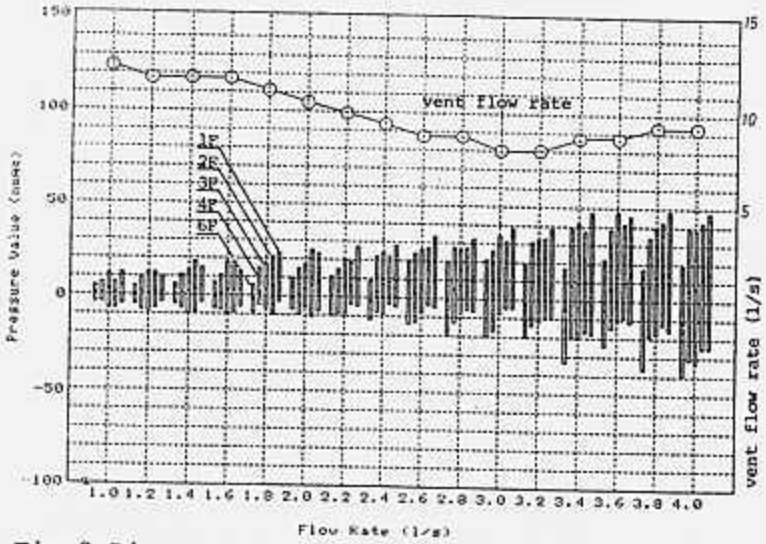


Fig.9 Pipe pressure (S-2, point b)

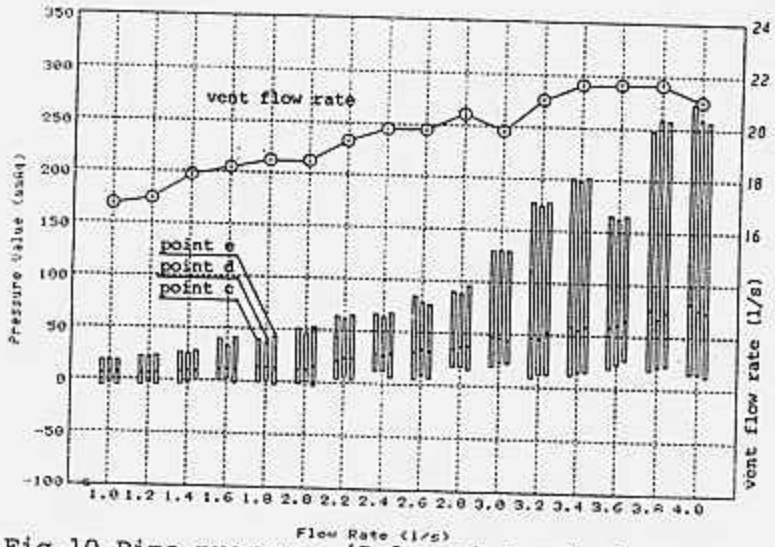


Fig.10 Pipe pressure (S-3, point c,d,e)

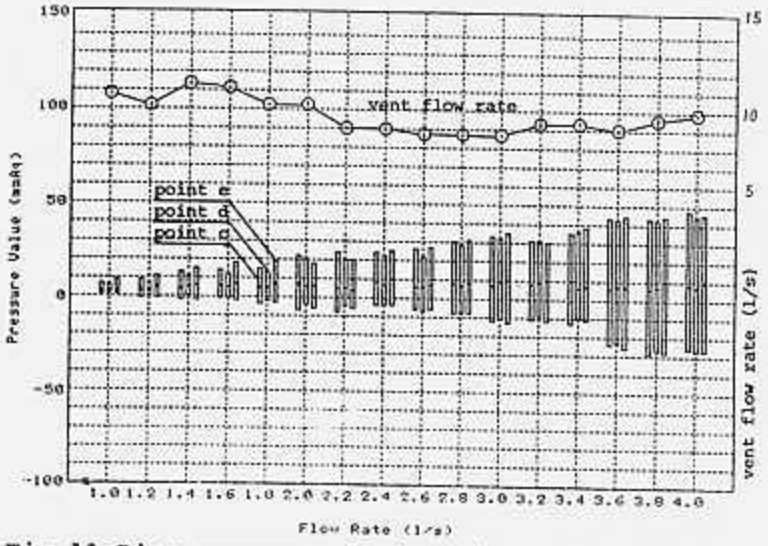


Fig.11 Pipe pressure (S-4, point c,d,e)

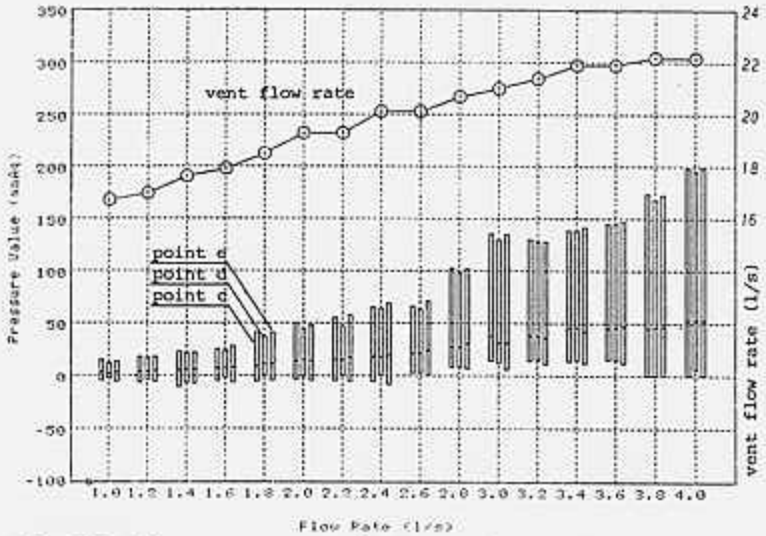


Fig.12 Pipe pressure (S-5, point c.d.e)

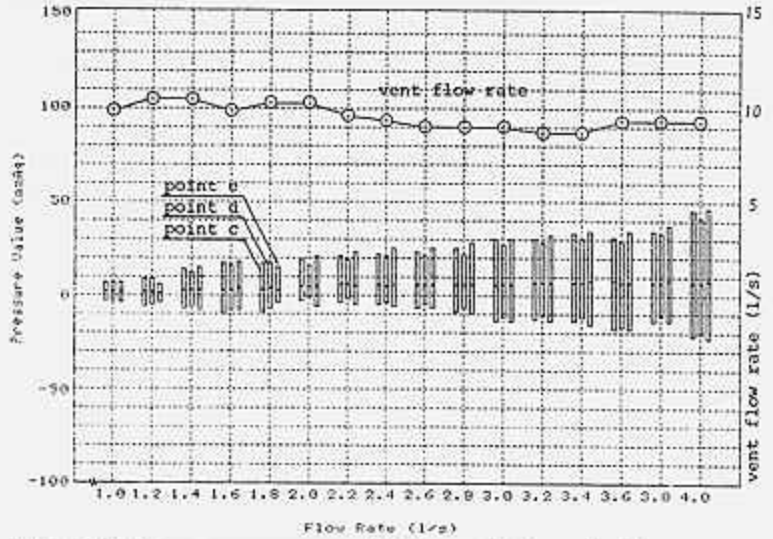


Fig.13 Pipe pressure (S-6, point c,d,e)

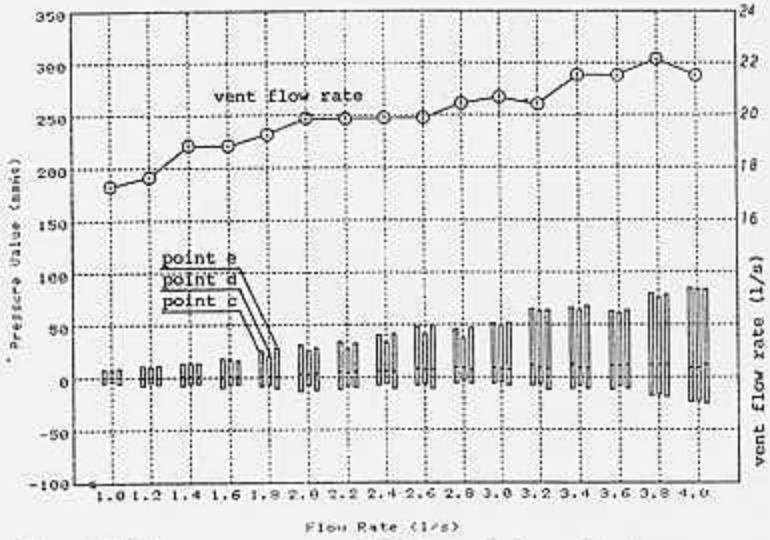


Fig.14 Pipe pressure (S-7, point c,d,e)

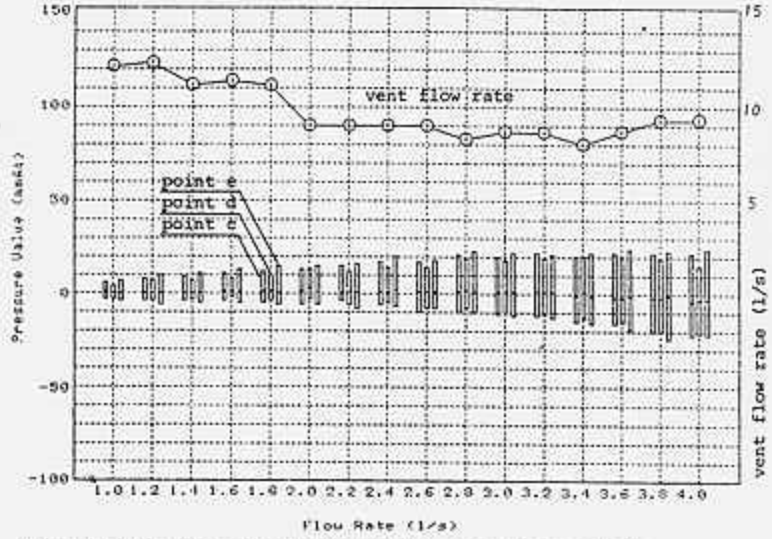


Fig.15 Pipe pressure (S-8, point c,d,e)

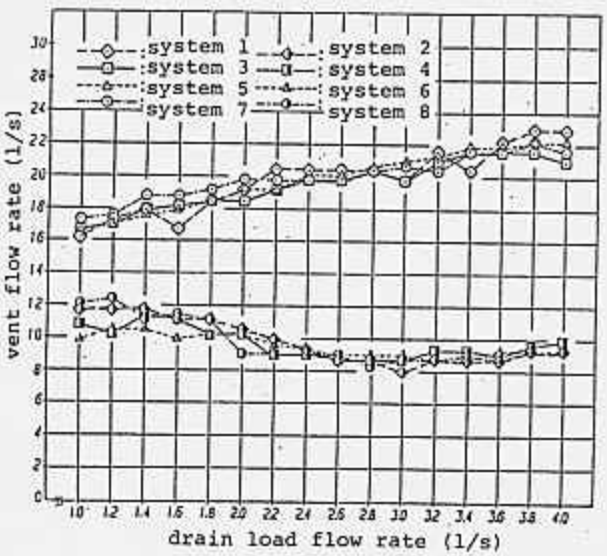


Fig.16 Vent flow rate in stack vent

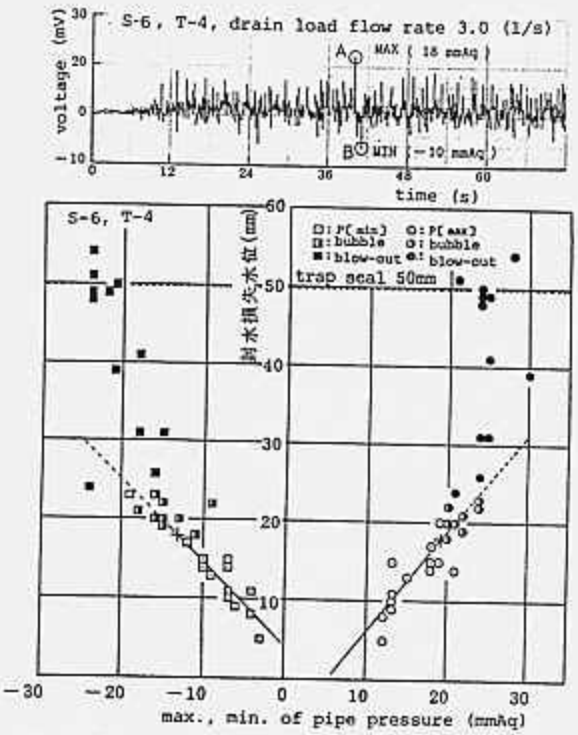


Fig.17 Example of data processing method

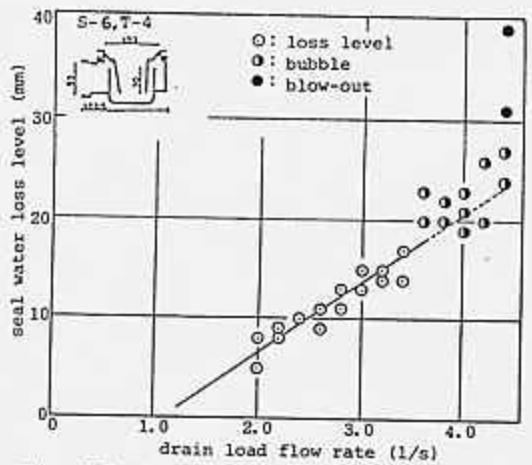


Fig.18 Example of correlation between drain load flow rate and loss level

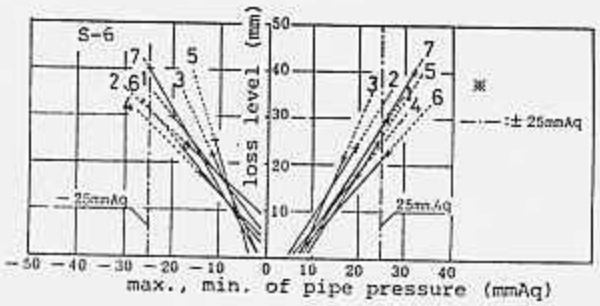


Fig.20 Regression of pipe pressure and loss level (S-6, actual traps)

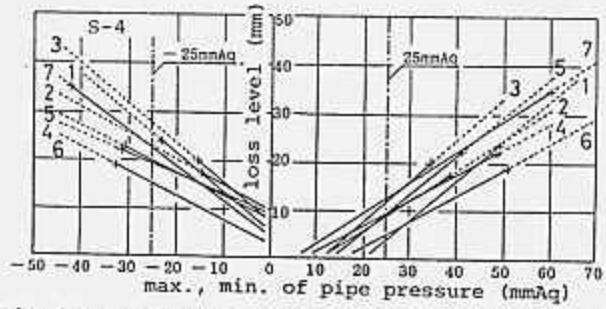


Fig.19 Regression of pipe pressure and loss level (S-4, actual traps)

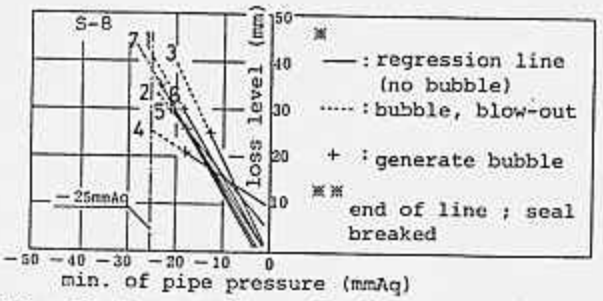


Fig.21 Regression of pipe pressure and loss level (S-8, actual traps)

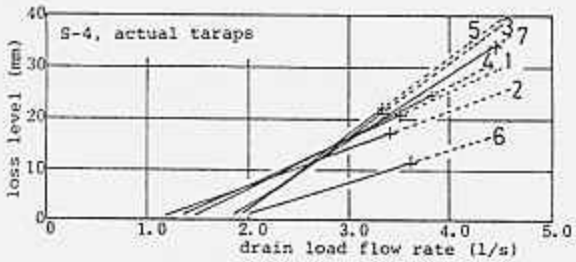


Fig.22 Regression of flow rate and loss level (S-4, actual traps)

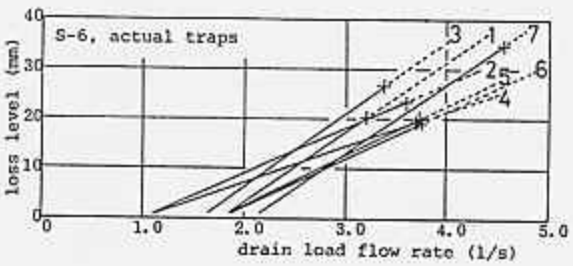


Fig.23 Regression of flow rate and loss level (S-6, actual traps)

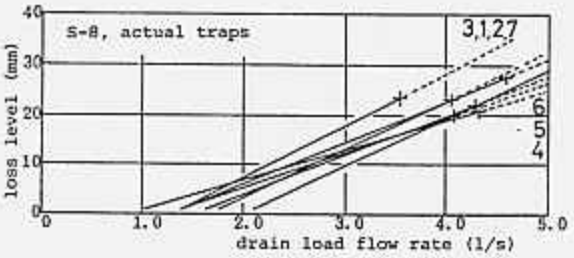


Fig.24 Regression of flow rate and loss level (S-8, actual traps)

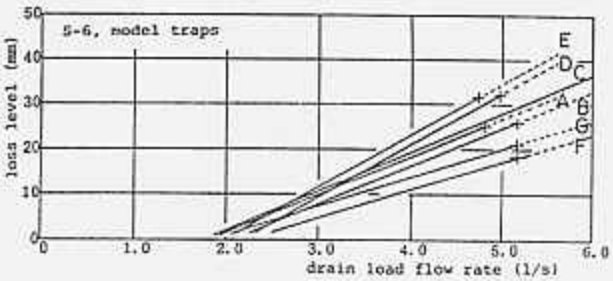


Fig.25 Regression of pipe pressure and loss level (S-6, model traps)

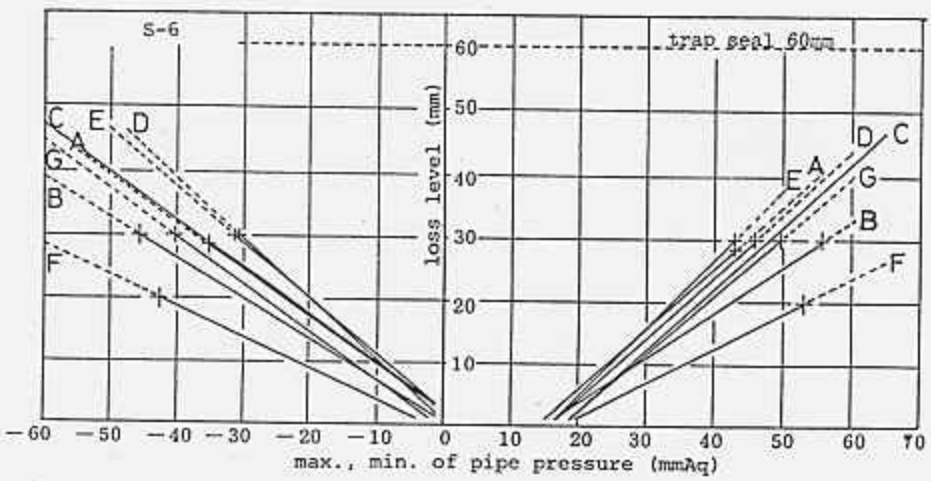


Fig.26 Regression of flow rate and loss level (S-6, model traps)

CIB

CIB-W62 SYMPOSIUM

Hydraulics of Horizontal Pitched Drains Based on Vertical Stack to Drain Entry Condition

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April 9,~10, 1985

TOKYO, JAPAN

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HYDRAULICS OF HORIZONTAL PITCHED DRAINS BASED ON VERTICAL STACK TO DRAIN ENTRY CONDITION

12th CIB-W62 Symposium, Tokyo
Water Supply and Drainage for Buildings
April 9, 10, 1985: Kenchiku Kaikan

Summary

A model for entry condition from the vertical stack annular downflow to the horizontal drain entry condition was developed. The condition for the turning elbow and energy loss coefficient, from stack to drain, was derived as a function of the annular flow thickness terminal velocity and stack diameter. The computer program for the finite difference based method of characteristics model for unsteady partially filled pipe flow was extended to provide numerical solutions for the entire stack and horizontal drainage system. The hydraulic solutions link the branch drains, fittings, vertical soil stack and building drain. Combinations of drainage load patterns can be analyzed from simultaneous, overlapping or sequence of discharge events through the established computer based design procedure.

Résumé

On a développé un modèle de conditions d'entrée à partir d'un conduit vertical annulaire à courant descendant vers une vidange horizontale. Les conditions de coude de et du coefficient de perte d'énergie, entre le conduit et la vidange, ont été dérivées en fonction de l'épaisseur du flux annulaire, de la vitesse finale et du diamètre du conduit. On a étendu le programme informatique de modèles caractéristiques de flux irrégulier par tuyaux partiellement remplis, modèles basés sur la méthode de différence finie, à la recherche de solutions numériques pour un système complet de conduits et de vidanges horizontales. Les solutions hydrauliques tiennent compte des vidanges secondaires, des garnitures, des conduits d'épuration verticaux et de la vidange principale. A partir de cas d'évacuation simultanées, chevauchées ou en séquence, on peut analyser des combinaisons de modèles de charge de vidange à travers la procédure établie par l'ordinateur.

Zusammenfassung

Ein Modell für den Eingangszustand vom vertikalen Sammel-Durchfluß zum vertikalen Ableitungs-Eingang wurde entwickelt. Der Zustand des Winkelstücks und der Energieverlust-Koeffizient von Sammelröhre zu Abwasseröhre wurde als Funktion der ringförmigen Flußdichtengeschwindigkeit und des Sammelröhrendurchmessers erhalten. Das Computerprogramm für die Grenzunterschied-Methode des charakteristischen Modells des schwankenden, partiell gefüllten Röhrendurchflusses wurde erweitert, um numerische Lösungen für den gesamten Stapel und das horizontale Drainagesystem zu liefern. Die hydraulischen Lösungen verbinden die Zweigeinleitungen, die Dichtungen, vertikale Erd- und Gebäudeleitungen. Kombinationen von Drainagelastmustern können aus simultanen, überlappenden oder nachfolgenden Auslaßvorgängen durch die eingeführte computerbasierte Designmethode analysiert werden.

SYMBOLS

A	flow area (m^2)
C	Chezy coefficient ($m^{1/2}/s$)
D	pipe diameter (m)
E	flow specific energy (m)
E_B	bulk annular flow specific energy (m)
e	incremental annular flow specific energy (m)
f	friction factor, resistance coefficient
g	acceleration due to gravity (m/s^2)
h	depth (m)
h_o	entry depth (m)
h_n	normal depth (m)
K	entry loss coefficient
k	pipe roughness coefficient (usually ratio of roughness height to pipe diameter)
L	pipe length (m)
m	hydraulic radius (m)
n	Manning's loss coefficient ($m^{-1/3}s$)
Q	flow rate (/s)
Q_s	stack flow rate (/s)
Re	Reynolds number
S	slope energy grade line
S_o	pipe slope
T	water surface width (m)
t	thickness of annular layer (m); time (s)
V	mean velocity (m/s)
V_o	entry flow velocity (m/s)
V_t	stack annular flow terminal velocity (m/s)

Z_o	pipe elevation (m)
θ	angular displacement (radians)
λ	Colebrook White loss coefficient
ν	kinematic viscosity (m^2/s)
ρ	density (kg/m^3)
τ_o	wall shear stress (kg/m^2)
ΔL	pipe length increment (m)

1. FUNDAMENTAL STACK TO DRAIN CONSIDERATIONS

The unsteady flow equations defining partially filled pipe flow may be solved by means of the finite difference method of characteristics. Programs to utilize this technique have been developed and fully described in previously published papers [1, 2, 3] and reports to CIB W62.

The development of the basic equations and their application in finite difference form to describe unsteady partially filled pipe flow [2] is illustrated in figure 1. In common with the differential equation for finite difference applications, the methods require establishment of both initial and system boundary conditions to allow the solution to proceed. For a single pipe system as shown in figure 1, under supercritical flow conditions (Froude number greater than unity) the exit boundary is supplied by the C^+C^- characteristics from the preceding upstream section. The inlet boundary may be prescribed by steady or unsteady flow profiles or determined from (upstream) vertical annular flow transition profiles at entry into the drain. In addition to the boundary conditions, the finite difference solution also requires knowledge of the initial flow depth and velocity along the pipe length at the start of the simulation. Normally, a small steady flow is assumed along the whole pipe length prior to the introduction of the drain load profile.

For initial studies, the flow profiles entering the drain may be assumed. For example, a high energy steady inflow will become progressively deeper along the length of the pipe as its energy is dissipated. The flow depth will eventually reach the normal steady uniform flow depth. The distance

required, however, will depend on the entry energy, the flow rate and pipe parameters such as diameter, roughness, slope, etc.

In this report, the derivation for the entry condition to the drain based on the inflow conditions resulting from annular flow upstream of the entry section is presented. Fully developed terminal velocity of vertical stack flow entering the horizontal pitched drain is assumed. Determination of initial entry flow depth profiles as a function of time into the horizontal drain is based upon the inflow energy and a loss coefficient for the turning/mixing of the flow.

2. DEVELOPMENT OF THE VERTICAL STACK TO HORIZONTAL DRAIN MODEL

2.1 ENTRY ENERGY BASED ON FULLY DEVELOPED VERTICAL STACK FLOW

Figure 2 illustrates the annular nature of vertical stack flow under fully developed flow conditions [4, 5].

For a section ΔL of the stack, a force balance equation for the falling water may be expressed under steady developed flow conditions, where stress at the air water interface is neglected, as

$$\pi D\ \tau_o(\Delta L) = \rho\pi\ Dt(\Delta L)g \qquad (1)$$

It follows that:

$$\tau_o = \rho\, t\, g \qquad (2)$$

Following Colebrook White for full bore pipe flow it may be shown that the shear stress may be expressed, by:

$$\sqrt{\frac{\rho\, V^2}{8\, \tau_o}} = -\,2\, \log_{10}\left[\frac{k}{3.7\, D} + \frac{2.51}{Re}\sqrt{\frac{\rho\, V^2}{8\, \tau_o}}\right] \qquad (3)$$

Ackers [6] has shown that equation (3) may be applied to partially filled pipe flow if the characteristic length D is replaced by the hydraulic radius, m, defined by

$$m = \frac{\text{Area}}{\text{Wetted Perimeter}}$$

which, for a full bore pipe flow, becomes $m = D/4$.

For Reynolds number $R_e = VD/\nu$ and substituting m for D yields

$$\sqrt{\frac{\rho\, V^2}{8\, \tau_o}} = -\,2\, \log_{10}\left[\frac{k}{14.8\, m} + \frac{2.51\nu}{4\, Vm}\sqrt{\frac{\rho\, V^2}{8\, \tau_o}}\right] \qquad (4)$$

For $t \ll D$, as is the cases here [4, 5], it follows that

$$m = \frac{\pi\, D\, t}{\pi\, D} = t \qquad (5)$$

With the volumetric flow rate, Q, given by

$$Q = \pi\, Dt\, V \qquad (6)$$

where V is the mean annular velocity. Substitution from (2) and (5) into (4) yields an expression for annular thickness, t

$$\left(\frac{Q}{4\pi Dt}\right)\sqrt{\frac{1}{2gt}} = -\log_{10}\left[\frac{k}{14.8t} + \frac{0.3140\nu}{t}\sqrt{\frac{1}{2gt}}\right] \qquad (7)$$

The equation (7) can be solved to yield t for a given Q, and with (6) the annular velocity V. For further discussion of stack flow rates and thicknesses, see [7].

The specific kinetic energy in the uniformly distributed annular downflow then becomes

$$E = \frac{1}{2}\,\frac{V^2}{g}$$

The expressions above apply only to fully developed flow. Previous work [5] has shown that the necessary vertical stack length to reach this condition is about 3m in many design cases, i.e., about the height of one story. In such cases, the derivation above may therefore be utilized. The influence of vertical stack pipe wall roughness for given flow rate Q, upon τ_o follows from equations (7) and (2).

The flow rate in the stack may vary with time due to the imposed load from the branch drain, as sketched, figure 3. With the sufficient height of fall in the vertical stack, the equilibrium terminal velocity, V_t, is attained. For the analysis based upon small time intervals, it may be assumed that the flow rate profile is made up of a large number of fully developed flow sections (incremental time strips) thus allowing the annular thickness and

energy versus time profiles to be developed, as shown. The final downflow profile may (at the turning elbow) then be taken with the derived turning/mixing loss coefficient to develop the upstream drain entry energy profile boundary condition.

2.2 INITIAL CONSIDERATION OF LOSS COEFFICIENT AT ENTRY TO HORIZONTAL DRAIN

Figure 4 illustrates the conditions for derivation of the energy loss at the entry elbow bend to the horizontal drain. It is assumed that within the annular flow the specific energy, e, along "streamlines" of the downflow is represented by the kinetic energy at the terminal velocity condition. Some dissipation of energy is assumed to result from mixing at the bend due to the varying orientation of flow directions from the vertical to horizontal. The assumed equation is

$$e = \frac{V_t^2}{2g}\left(\sin^2 \frac{1}{2}\theta\right) \qquad (8)$$

where V_t is the mean annular (terminal) velocity. The equation (8) indicates at $\theta = 0$ the vertically falling flow loses its entire energy content and only adds mass at the drain inlet, and at $\theta = \pi$ the streamline total energy content is preserved. Then a relation for the specific energy content of the annular mass flow* may be obtained as:

$$\int_0^{2\pi} e\left(\frac{D}{2} - t\right) t \, d\theta = E_B \frac{\pi}{4}\left[D^2 - (D-2t)^2\right] \qquad (9)$$

* The term (D/2-t) includes other losses for annular flow not in contact with the pipe wall. The use of (D-t) 1/2 (in average cross section area formulation for equation (9) leads to a constant energy loss of 50 percent).

where E_B is the annular energy. Substituting for e yields

$$E_B \frac{\pi}{4}\left[D^2 - (D-2t)^2\right] = 2\int_0^{\pi}\left(\frac{D}{2} - t\right) t \frac{V_t^2}{2g}\left(\sin^2\frac{\Theta}{2}\right)d\Theta$$

$$= \left(\frac{D}{2} - t\right)\frac{t}{g} V_t^2 \int_0^{\pi}\left(\sin^2\frac{\Theta}{2}\right)d\Theta$$

$$= \left(\frac{D}{2} - t\right)\frac{t}{g} V_t^2 (\pi/2)$$

Then

$$E_B = \frac{(D/2-t)}{(D-t)}\frac{V_t^2}{2g} \quad \text{i} \quad K = \frac{(D/2-t)}{(D-t)} \qquad (10)$$

For $t \ll D$, $E_B \rightarrow \frac{1}{2}\frac{V_t^2}{2g}$

The model does not apply for $t \rightarrow D/2$ (full bore pipe flow) since the turning losses at an elbow for full bore flow are not represented by comparable mixing phenomena. Flow separation from full bore downflow that develops in a partially filled horizontal drain requires still different physical modeling.

Values of the K-factor modifying the kinetic energy term, $V_t^2/2g$, are indicated below:

Pipe Diameter (mm)	Annular Film Thickness (mm)	Ratio Factor (D/2-t)/(D-t)
100	25.	.33
	12.5	.43
	2.5	.49

Measured values of the annular thicknesses from experiments are difficult to obtain [4, 5]. However, the ranges determined in limited experiments are indicated as much less than 20 percent of the diameter and are a function of flow rate in the vertical stack, the pipe diameter and wall roughness. For t small compared to D, then $(D/2-t)/(D-t) \rightarrow 0.5$. Hence, an energy "loss" term of 50 percent may be a reasonable (constant) assumption for preliminary studies. Conditions other than for terminal velocity should retain the relationship (10) with V_t replaced by the falling velocity as a function of length along the stack.

A study of entry loss effects could naturally include K values greater than unity. That condition would imply that the entry flow energy was higher than that appropriate to gravity driven stack flow, as might be the case if the drain were supplied from a pressurized source. Surge flows generated in tests reported in [5] and discussed in [7] appear to correspond to pumped head conditions. In [5], other elbow losses may also be significant due to the study of shaped orifice elbow entry shapes on the experimental results.

2.3 INITIAL FLOW PROFILES

2.3.1 Steady Flow in Drains

The development of flow depth along the length of the horizontal drain pipe under initial steady flow conditions may be generated by reference to gradually varied flow theory. The basic assumption is that the local head at any section is given by the equivalent steady flow loss equation, either Manning's or Darcy's equation, utilizing the Colebrook White friction factor

expression.

Depth profile predictions by numerical integration are based on that assumption, expressed in figure 5 by

$$\frac{d}{dL}\left[\frac{V^2}{2g} + (Z_o - S_o L) + h\right] = -S \qquad (11)$$

where S is the slope of the energy grade line determined from Mannings equation or from the general Chezy expression:

$$\sqrt{S} = \frac{n\,Q}{A\,m^{2/3}} \text{ (Manning, metric)} \quad ; \quad S = \frac{V^2}{C^2 m} \text{ (Chezy)} \qquad (12)$$

For steady flow Q = VA, then $\frac{dV}{dL} A + V \frac{dA}{DL} = 0$

Also, dA = Tdh, where T is the water surface width (which does not change with L, or changes slowly). Substituting into equation 11 yields the distance along the flow profile, between two depths h_o and h_1, given by

$$L = \int_{h_o}^{h_1} \left[\frac{1 - Q^2\,T/gA^3}{(S_o - S)}\right] dh \qquad (13)$$

2.3.2 Flow Simulations for Steady Flow

In order to numerically evaluate (13), it is necessary to define a boundary depth at the pipe entry. The available flow energy at the horizontal drain entry, assuming no losses, is based on the vertical stack annular specific flow energy,

$$E = h_o + \frac{V_o^2}{2g} = \frac{1}{2}\frac{V_t^2}{2g} \qquad (14)$$

where h_o and V_o are the flow depth and velocity at entry to the horizontal drain. Then

$$\frac{1}{2}\frac{V_t^2}{2g} = h_o + \frac{V_o^2}{2g} = h_o + \left(\frac{Q_o}{A_o}\right)^2 \frac{1}{2g} = F(h_o) \qquad (14a)$$

and solving for h_o, with $V_o = Q_o/A_o$ and $A_o = f(h_o)$ yields the upstream boundary depth.

When energy losses at the elbow (stack flow turning into the drain entry) are introduced in equation (14), the left hand side becomes $K(V_t^2/2g)$. Following the same procedure the entry depth h_o, provides the upstream drain boundary depth.

The downstream boundary may be taken as the flow normal depth, h_n at the distance downstream to be determined from the integration of (13). As the flow is supercritical, the depth may rise gradually to this value with no discontinuity, such as a hydraulic jump.

The choice of dh values in the numerical integration is based on the difference between the control depth, h_o and the downstream "target" depth, h_n. A reasonable integration step size is given by

$$dh = (h_n - h_o)/30 \qquad (15)$$

Once the depth reaches h_n the remaining downstream profile is (assumed) at that constant depth.

For short pipe lengths, or high energy steady initial flows, it may be that the normal depth is not achieved within the available pipe length. In this case, the integration is terminated when $\Sigma\Delta L$ exceeds the pipe length, i.e., $\Sigma\Delta L > L$. A valid flow profile is, however, achieved for this case.

Figures 6 and 7 illustrate the depth profiles along a drain set at slopes of 0.02 and 0.01 and the other identified parameters for a range of initial flow rates. The profiles attain the normal depth at some distance along the pipe, thereafter the flow continues at that depth until discharge at the pipe exit. The pipe length necessary to attain the steady normal flow depth increases for larger values of the steady flows rates, or as the pipe slope is increased. Those results are consistent with [8] where it was shown that more than 100 diameters may be required to reach the peak depth in a drain.

Figures 8 and 9 illustrate the changes in profile for the 8 ℓ/s case in pipes pitched at 1/100 and 1/50 for both decreasing and increasing inlet energy factors. The reduction in entry energy (indicated by the smaller loss coefficient) will steepen the depth profile resulting in normal depths being achieved earlier in the pipe. The determination of the correct flow depth profile for the starting conditions in experiments, or predictive simulation studies, is important since it provides the flow depth condition immediately ahead of time-dependent surge waves superimposed on steady flows.

It will be seen that if the inlet energy is artificially increased for the pumped inlet conditions [8] then the normal flow depth development is delayed. The corollary to this is that a fixed length pipe may be seen to carry rather more flow than suggested by the steady flow calculations of normal depth. For example, with K >1.0, with pipe lengths less than 16m, the depths are less than those which occur with gravity drain conditions; it would be implied that higher flow rates can exist in the pipe without violating (code) permissible half-filled depths. Care should be taken in any experimental work in this area to ensure that the entry energy is appropriate to the system under study. Failure to do this could suggest enhanced carrying capacities in long drains that will not be found in practice. The presence of pipe fittings, such as a junction,will result in substantial energy dissipation and the flow will therefore rapidly increase in depth, could fill the pipe cross section and be improperly interpreted as the hydraulic jump.

Table 1 presents normal depth values for 100 mm diameter pipes at gradients of 1/100 and 1/50.

Table 1. Normal Depths in a 100 mm Diameter Smooth Drain, k = 0.0, Calculated from Colebrook White Friction Loss Expression

Flow Rate l/s	Pipe Gradient 1/100 Normal Depth mm	Pipe Gradient 1/50 Normal Depth mm
1	23.6	19.5
2	33.6	27.5
1.0	41.8	33.9
2.0	49.2	39.5
3.0	56.2	44.8
4.0	63.2	49.7
5.0	70.8	54.5
6.0	79.4	59.3
7.0		64.1
8.0		69.2
9.0		74.7
10.0		81.1
11.0		91.7
12.0		
13.0		

3. SURGE ATTENUATION FOLLOWING STACK DISCHARGE TO A HORIZONTAL DRAIN

3.1 SURGES AND WAVES

The necessary equations and numerical solutions to simulate wave attenuation along the length of horizontal drain pipes were developed [2]. The transition from the time varying downflow in the stack, figure 3, to the horizontal drain may be characterized by the entry energy boundary condition for incremental times described previously. The annular terminal flow condition in the stack was assumed. Initial conditions along the horizontal drain may be set up utilizing the gradually varied flow theory outlined.

The wave formation in the horizontal drain may be viewed as being made up of two separate but superimposed mechanisms. As the surge progresses down the

drain its depth increases as energy is dissipated. At the same time, the wave attenuates due to diffusion, so that the superposition of these two effects results in a peak flow depth downstream of the entry along the pipe length. Figures 10 and 11 indicate the peak flow depths predicted for a range of inflow profiles (defined in the figure). Figures 12 and 13 present the calculated peak flow rates, calculated at each pipe section as the product of velocity and flow area. It is observed that the peak flow rates exceed the maximum inflow rates. That apparent anomaly is explained by the rising inflow surge which generates waves moving with increasing wave speed greater than the mean velocity. The waves "overtake" the preceding flow and hence generate both depths and flow rates in excess of those predicted (incorrectly) by a steady flow analysis.

Also any surge alleviation provided by the reduction in surge flow is only manifested for the shortest time triangular inflow profile. Profiles displaying a plateau at peak inflow rate tend to produce nearly similar maximum depths. This suggests that the increased flow capacity often referred to as a result of attenuating surge flows is applicable only to relatively "sharp", triangular surge inflow rate versus time profiles. In figures 14 and 15, it is noted that the peak flow rate invariably proceeds the location of peak depth in figures 14 and 15. Those figures show the peak depth and flow rate "envelopes" along the horizontal drain at gradients of 1/50 and 1/100. Figures 16 and 17 illustrate the flow depths at three stations along the drain over the duration of the simulation. The peak depths occur at many diameters downstream of the entry.

3.2 COMPARISON OF PREDICTED AND OBSERVED DEPTH PROFILES FOR A HORIZONTAL DRAIN SUPPLIED BY A VERTICAL STACK

Figures 18 and 19 present comparisons between experimentally measured depth versus time profiles in a 75 mm pipe drain at a gradient of 0.06. Surges enter the pipe from a vertical stack supplied by a constant baseflow plus discharges from water closets at higher levels. The results presented were recorded in a dynamics of plumbing system test program [9, 10] previously reported at CIB W62 seminars. A single water closet on the third level and two back-to-back water closets on the second level were simultaneously discharged into the constant downflows in the vertical stack, as noted on the figures.

The idealized water closet flow rate profiles presented on the figures were estimates of the likely water closet flow rate discharge profiles. Those were determined from the measured depth versus time records in the horizontal branch drains at the second and third levels (stories) leading to the vertical stack.

Comparison between the observed and predicted depth variations at a downstream depth tapping are shown. The time scale of the observed results have been adjusted so that the observed and predicted profiles move from the steady base flow condition at the same time. This approximate adjustment may account for some of the time scale deviations. The predicted normal depths with only the steady baseflow (after the surge) are within 2 percent of measured values.

4. CONCLUSIONS AND RECOMMENDATIONS

This report has introduced the concept of an energy entry condition to simulate vertical stack flow entering a horizontal drain. In general, the model has been satisfactory in that no numerical instability problems have been encountered. The predictions of flow depth and flow rate through the stack and drain match the physical mechanisms known to occur for these flow situations. The predictive model provides, for the first time, a comprehensive theoretical basis for explanation of the earlier experiments at NBS to establish the hydraulic capacity of drains.

It may be concluded that the simplified annular stack flow and entry energy model provides the first theoretical basis as a suitable method of linking networks of a number of horizontal drains with a vertical stack which discharges to a lower level pipe, e.g. a building drain. Network horizontal pipe junctions solutions have progressed, in a parallel study [11], so that complex interconnected drainage system analysis is feasible now through combination of the predictive models.

The results presented support the proposed model for the stack to horizontal drain entry model. Improved knowledge of the inflow flow rate profiles developed in vertical stacks and modified by the junction fittings at the upper levels from the horizontal branch drains is required. Further research is necessary to fully account for mixing at entry fittings into the soil stack downflow. There have been few measurements [4, 5] of the velocity profile distribution for annular flow properties in the vertical soil stack;

additional details are required to provide understanding of such gravity driven flow regimes. Investigations of annular flow phenomena indicate that surface waves are observed on vertical falling films. That suggests the superposition of surges on steady soil stack flows may take place with wave velocities greater than the mean falling flow velocities. Consequently, flow redistribution may result beyond the mass addition mixing and momentum exchange at junctions or fittings.

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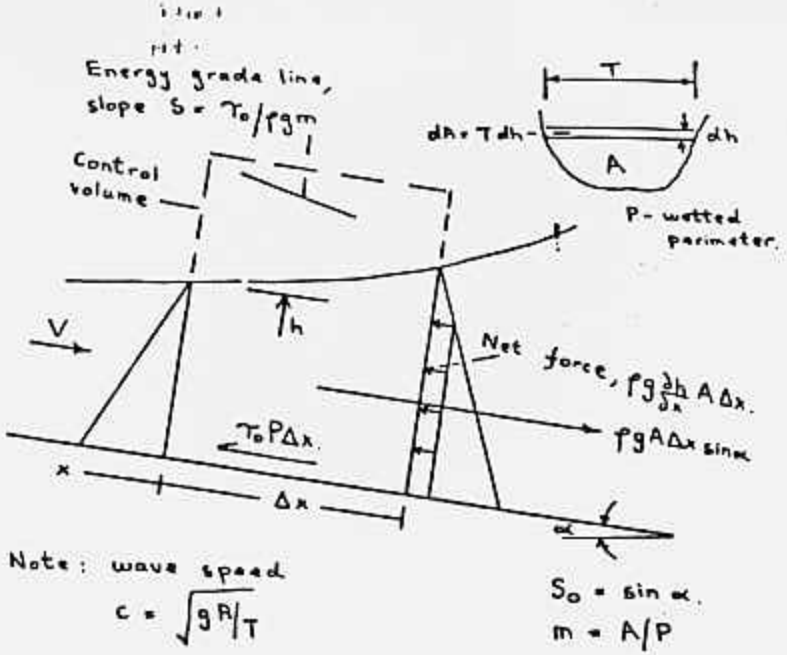
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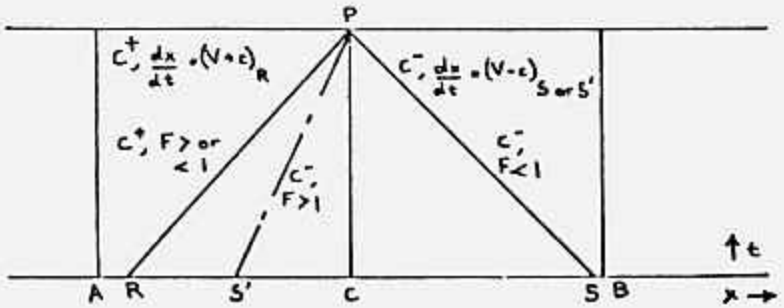
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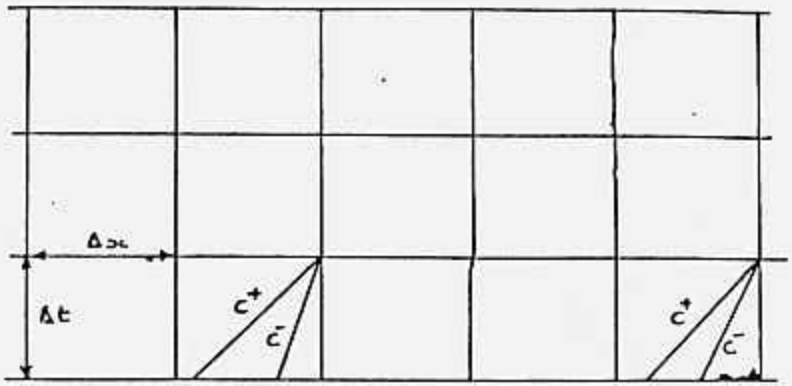


F = Froude N°, < 1 subcritical flow.
> 1 supercritical flow.

Note: if $\frac{dx}{dt} = V \pm c$

then $\frac{dV}{dt} \pm g \frac{dh}{dt} + g(S - S_o) = 0$

Figure 1a Summary of method of characteristics solution of the unsteady partially filled pipe flow equations



Rectangular grid, Δt, Δx arranged so C^+, C^- lines fall within grid as shown.

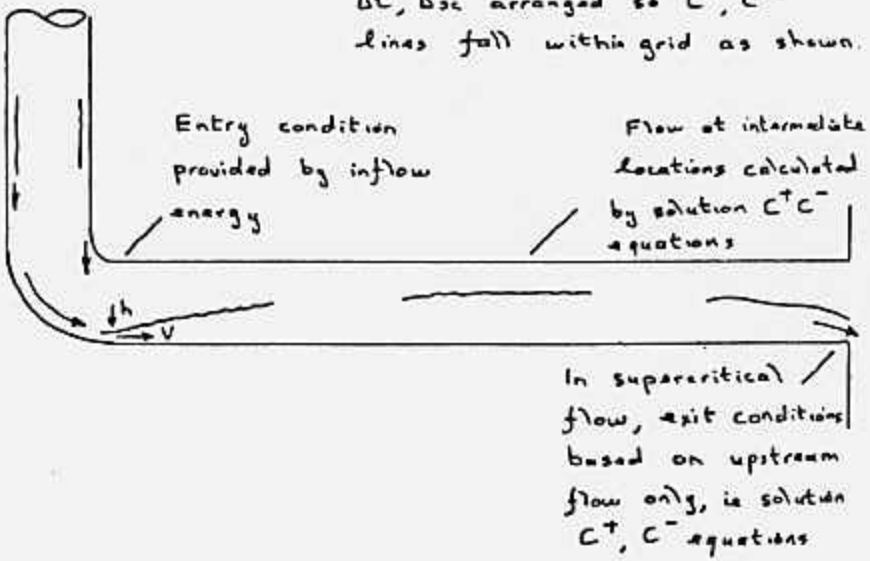
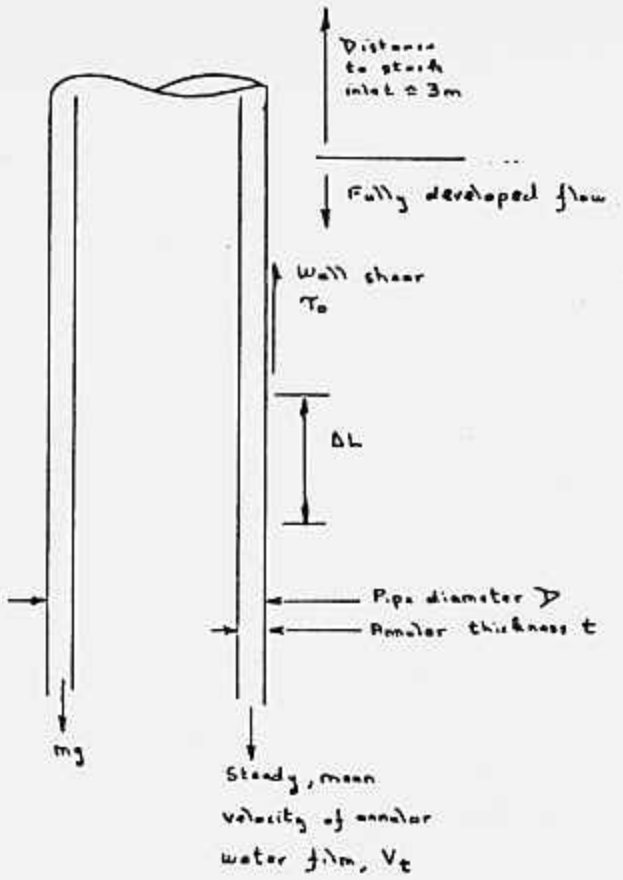


Figure 1b Application of the method of characteristics to unsteady supercritical partially filled pipeflow



Balance of forces over ΔL in developed flow regime yields

$$\pi D \tau_o \Delta L = g\rho\pi D t \Delta L$$

$$\tau_o = \rho g t$$

Figure 2. Fully developed annular flow in vertical stacks

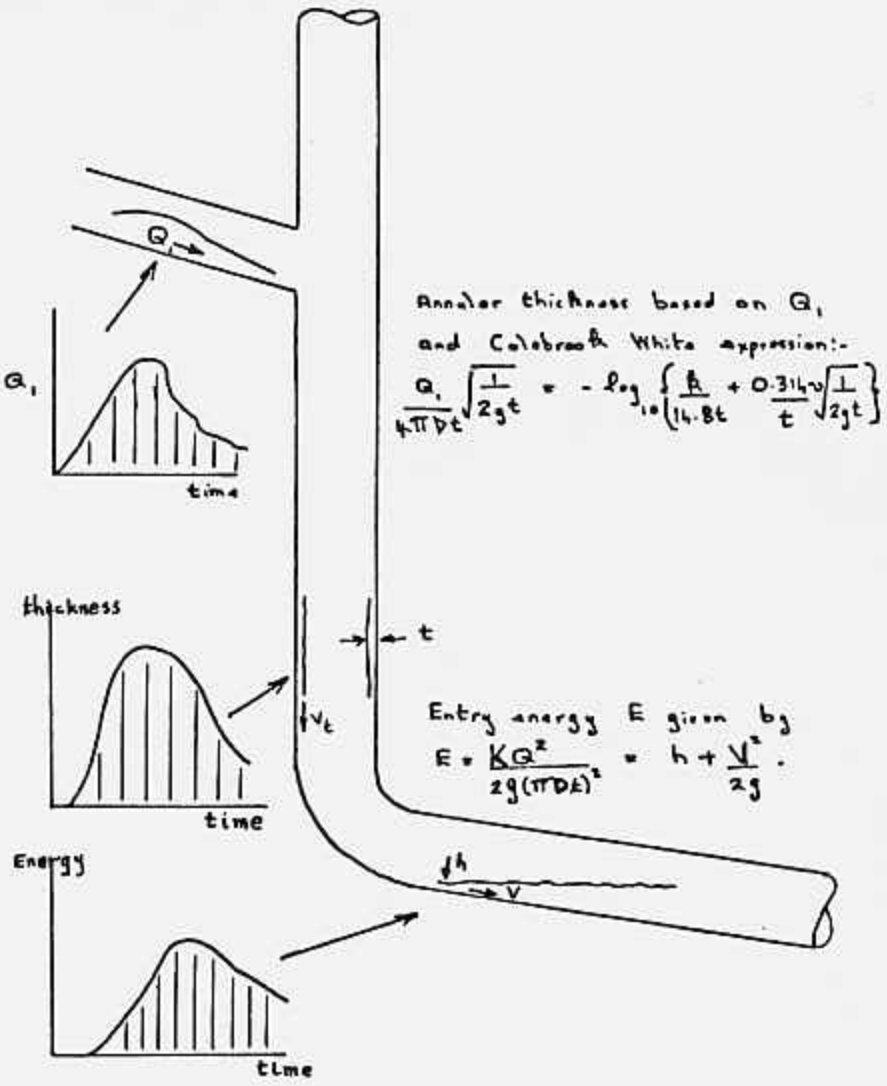


Figure 3. Flow rate vs. time inflow to a vertical stack translated into annular thickness and terminal energy vs. time profiles

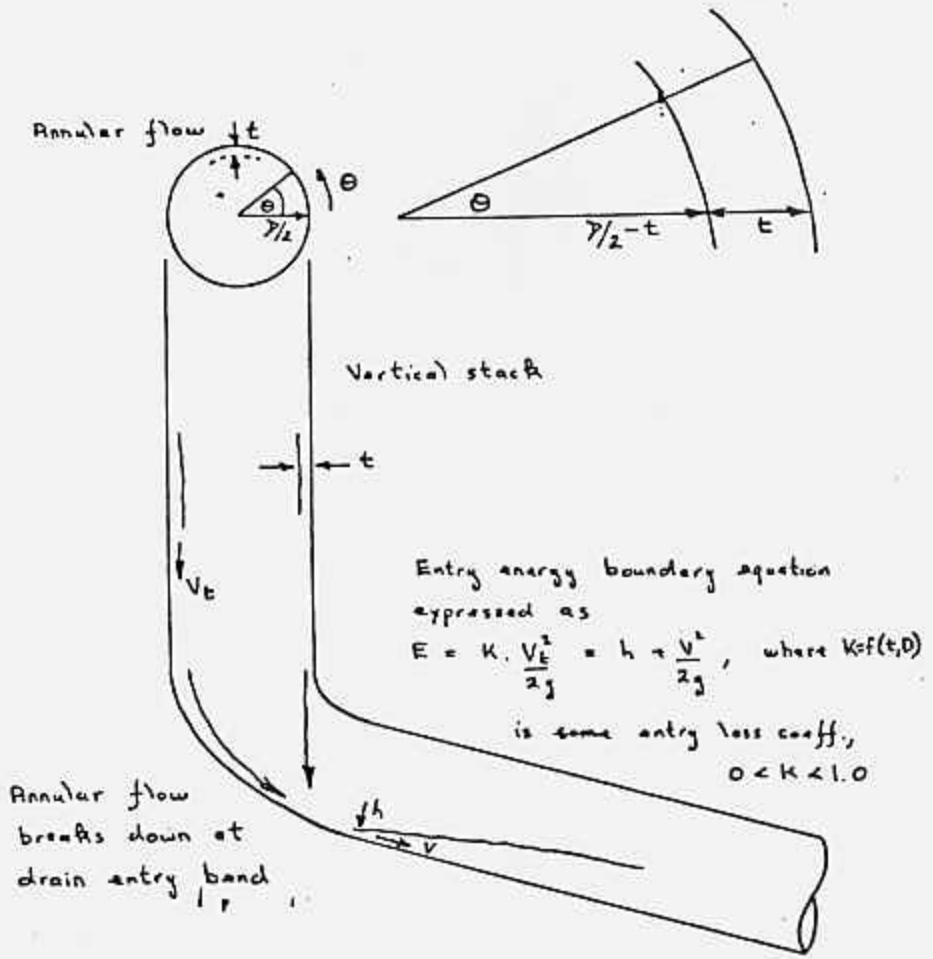
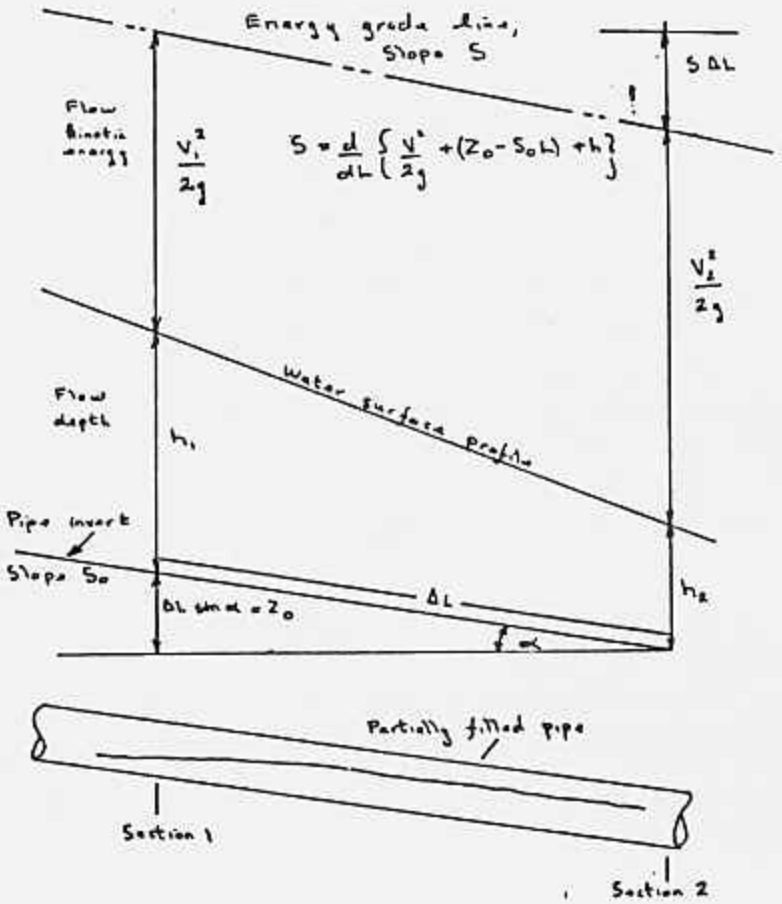


Figure 4. Upstream boundary formed by an entry energy equation



Gradually varied flow analysis based on head loss at any section being equal to the equivalent steady flow loss at that flow rate and other flow parameters

Figure 5. Calculation of the energy grade line for gradually varied flow

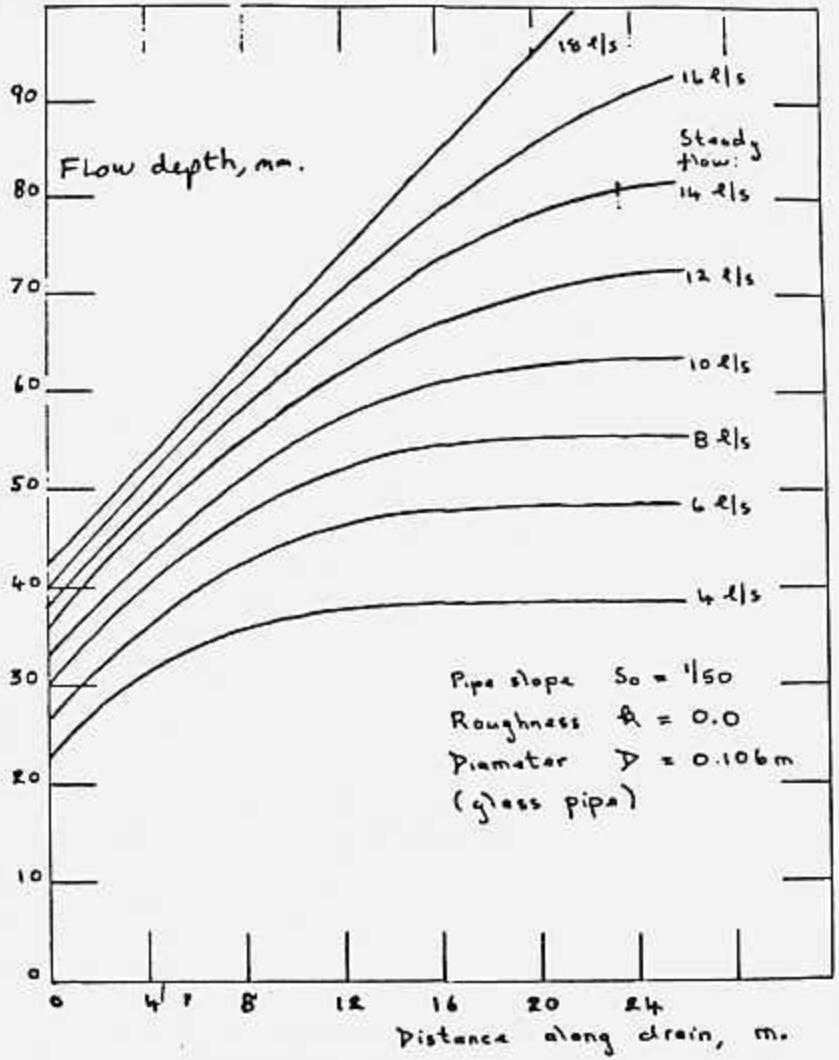


Figure 6. Depth profiles for an initial steady flow along the drain at a 1/50 gradient, no energy loss at entry

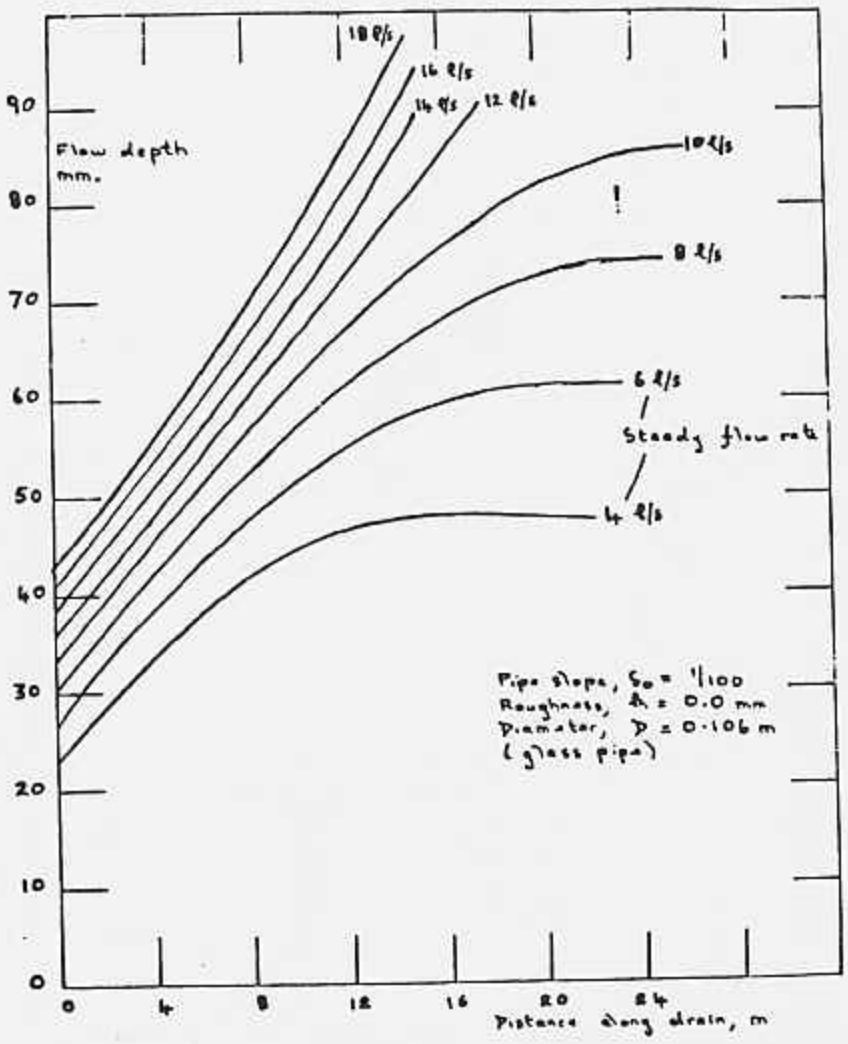


Figure 7. Depth profiles for an initial steady flow along the drain at a 1/100 gradient, no energy loss at entry

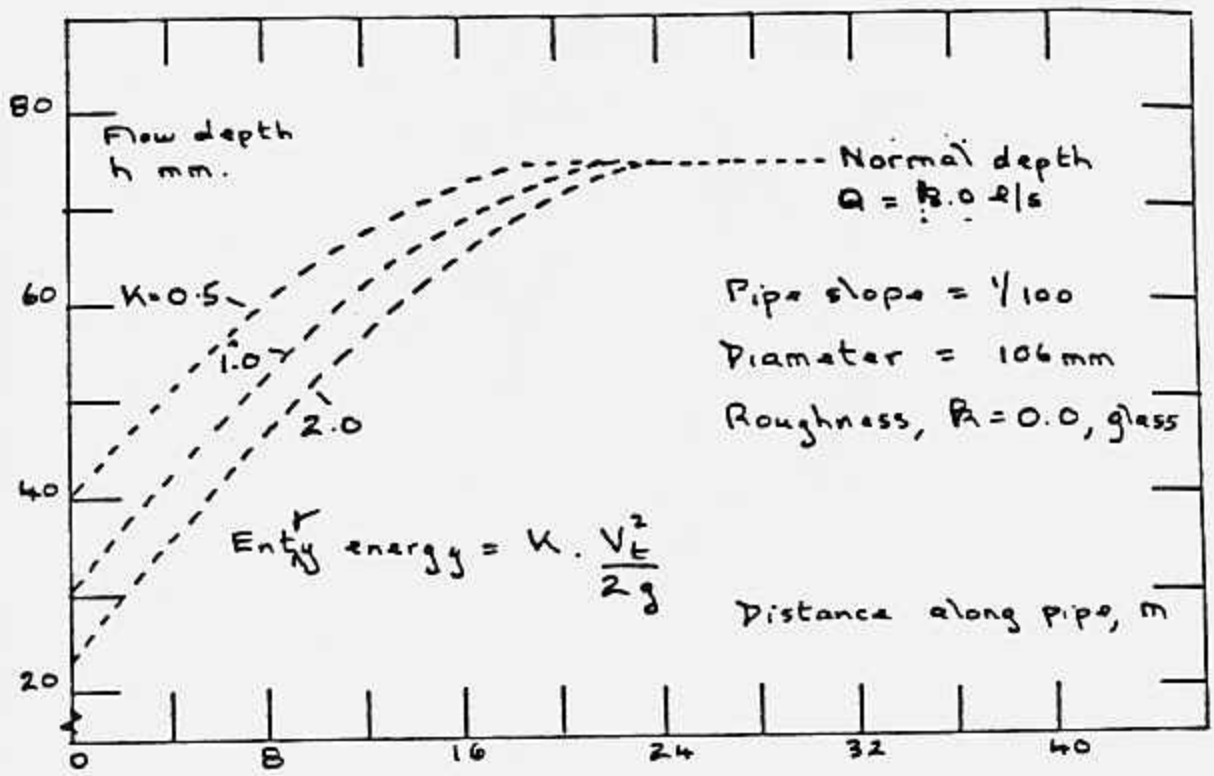


Figure 8. Influence of the entry energy loss coefficient on initial steady flow depth profiles.

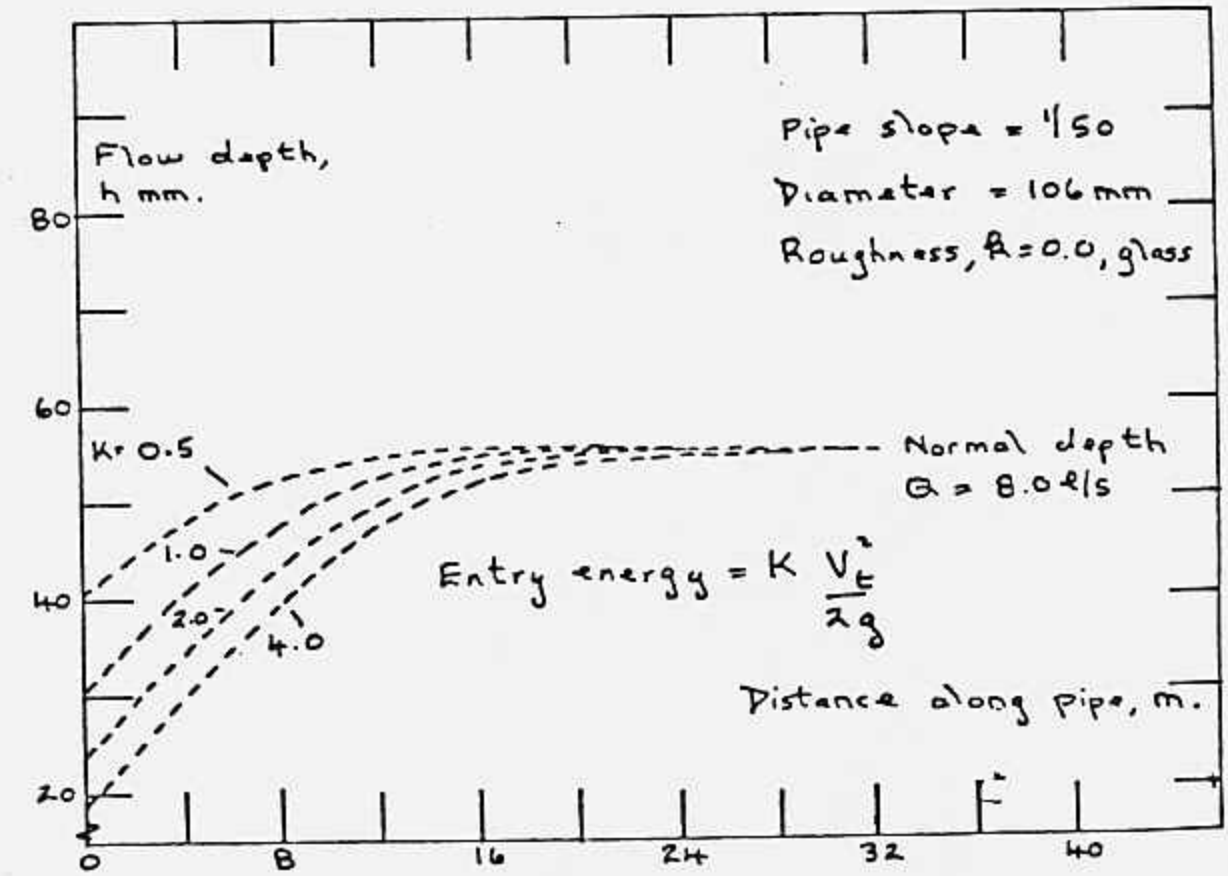


Figure 9. Influence of the entry energy loss coefficient on initial steady flow depth profiles.

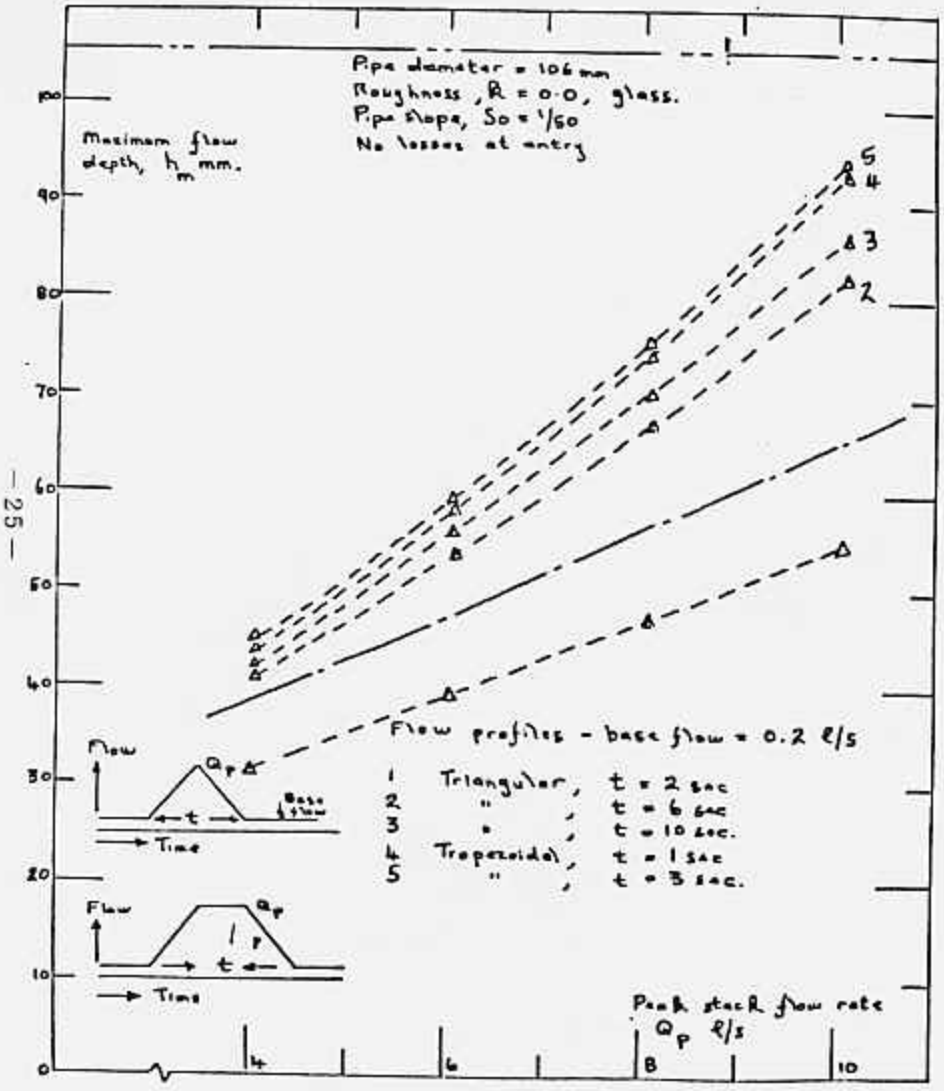


Figure 10. Peak depths predicted along the horizontal drain for a range of inflow profiles (1/50)

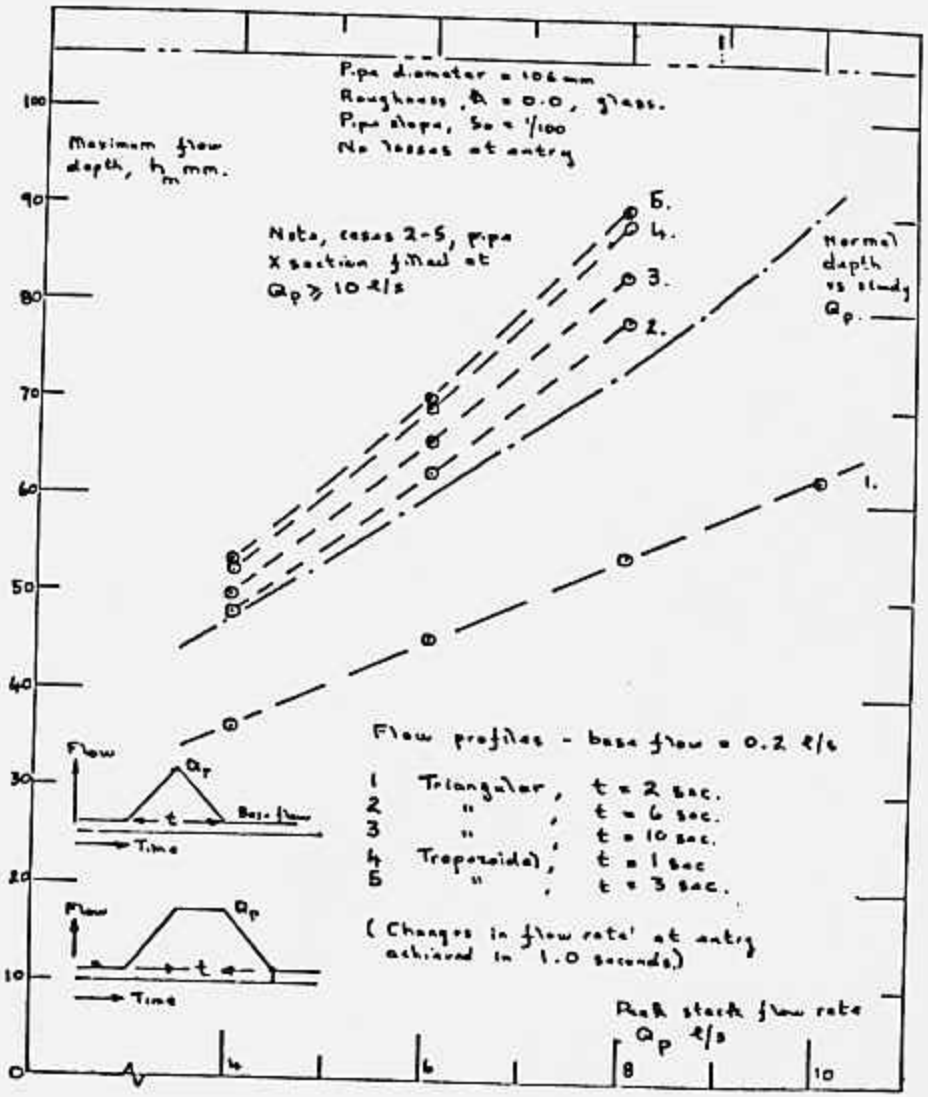


Figure 11. Peak depths predicted along the horizontal drain for a range of inflow profiles (1/100)

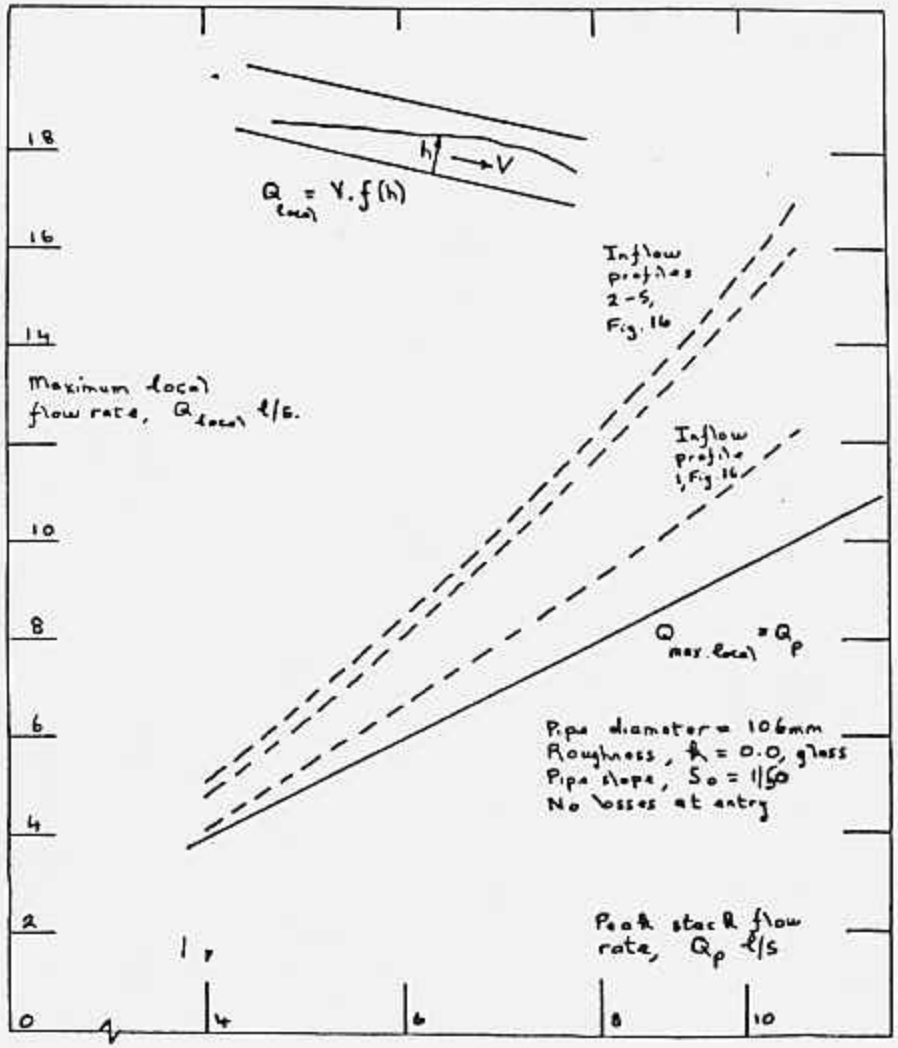


Figure 12. Peak Flow rates predicted locally along the horizontal drain for a range of inflow profiles (1/50)

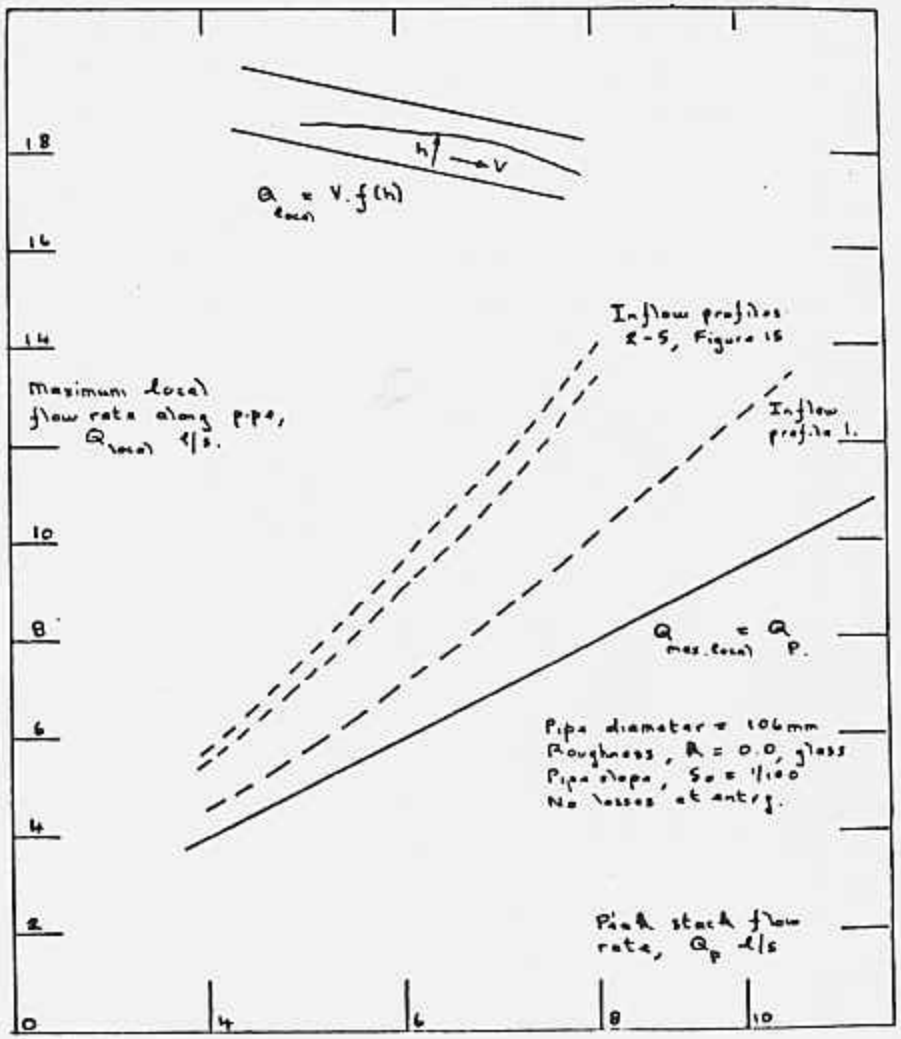


Figure 13. Peak flow rates predicted locally along the horizontal drain for a range of inflow profiles (1/100)

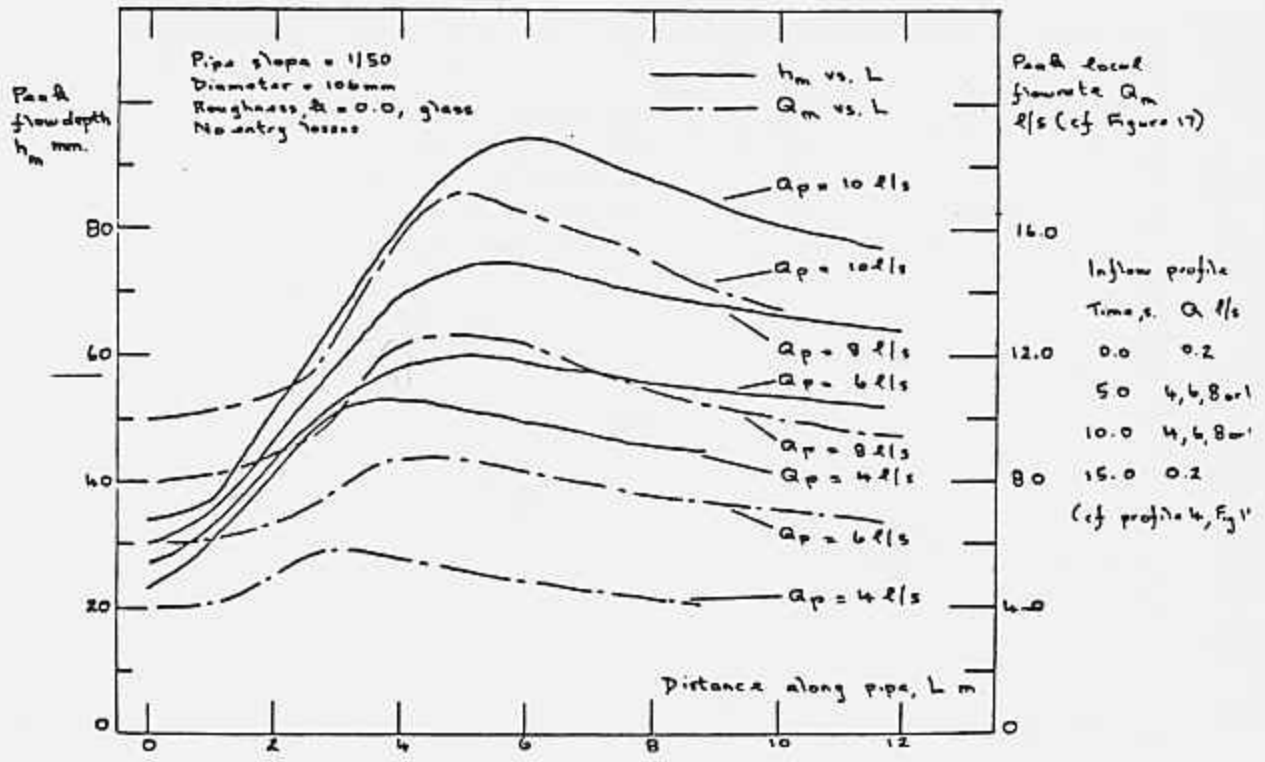


Figure 14. Peak flow depth and local flow rate envelopes along the length of the horizontal drain (1/50)

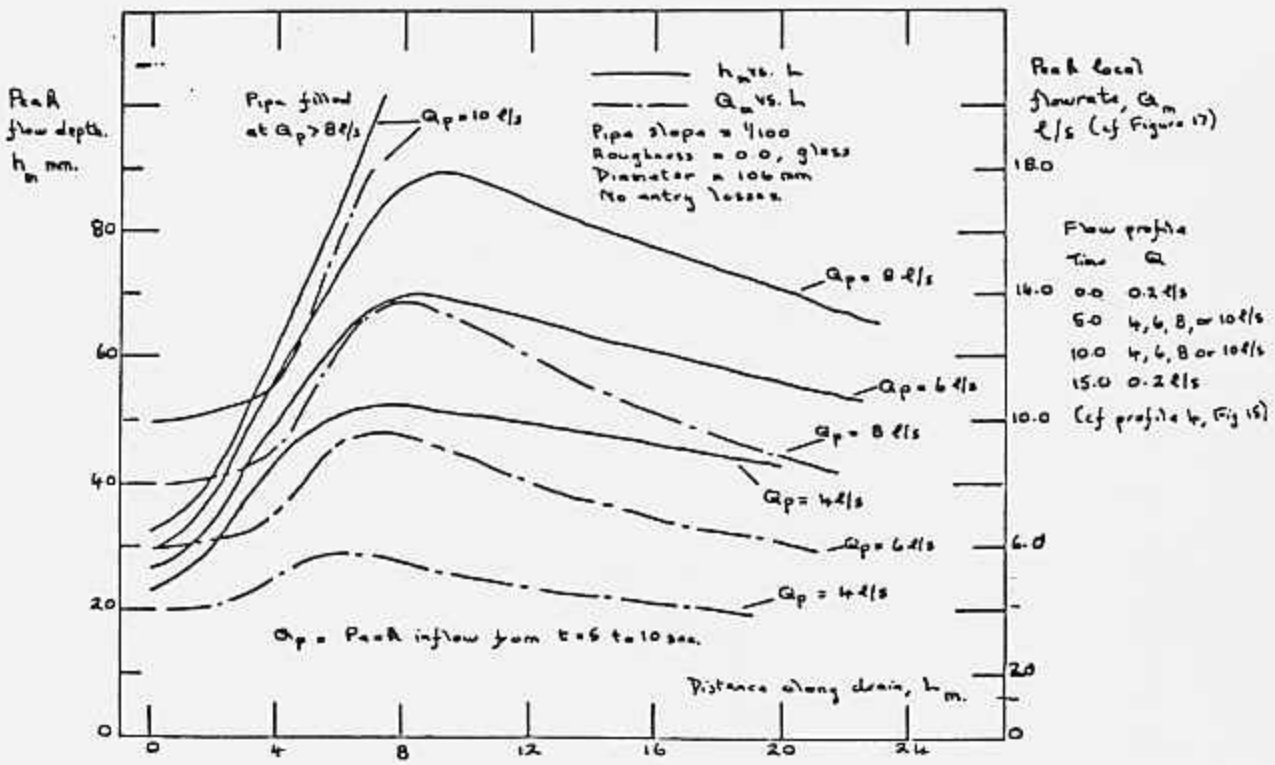


Figure 15. Peak flow depth and local flow rate envelopes along the length of the horizontal drain (1/100)

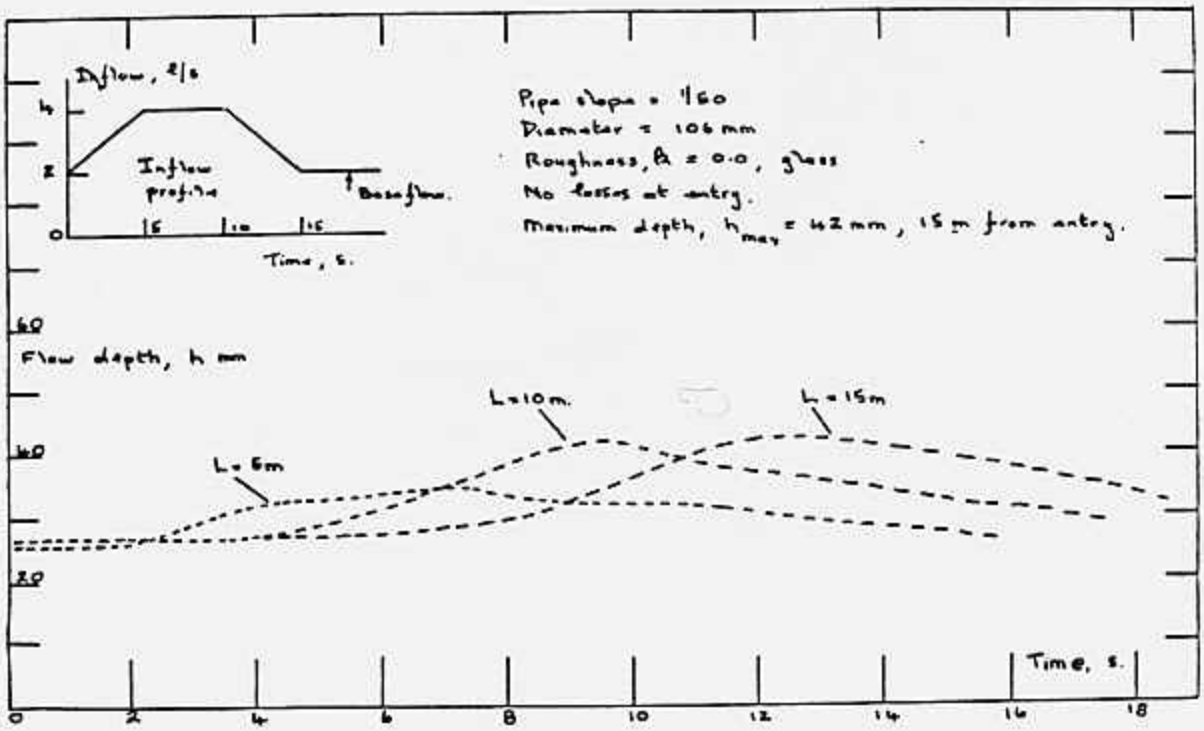


Figure 16. Depth vs. time profiles at a number of stations along the horizontal drain (1/50)

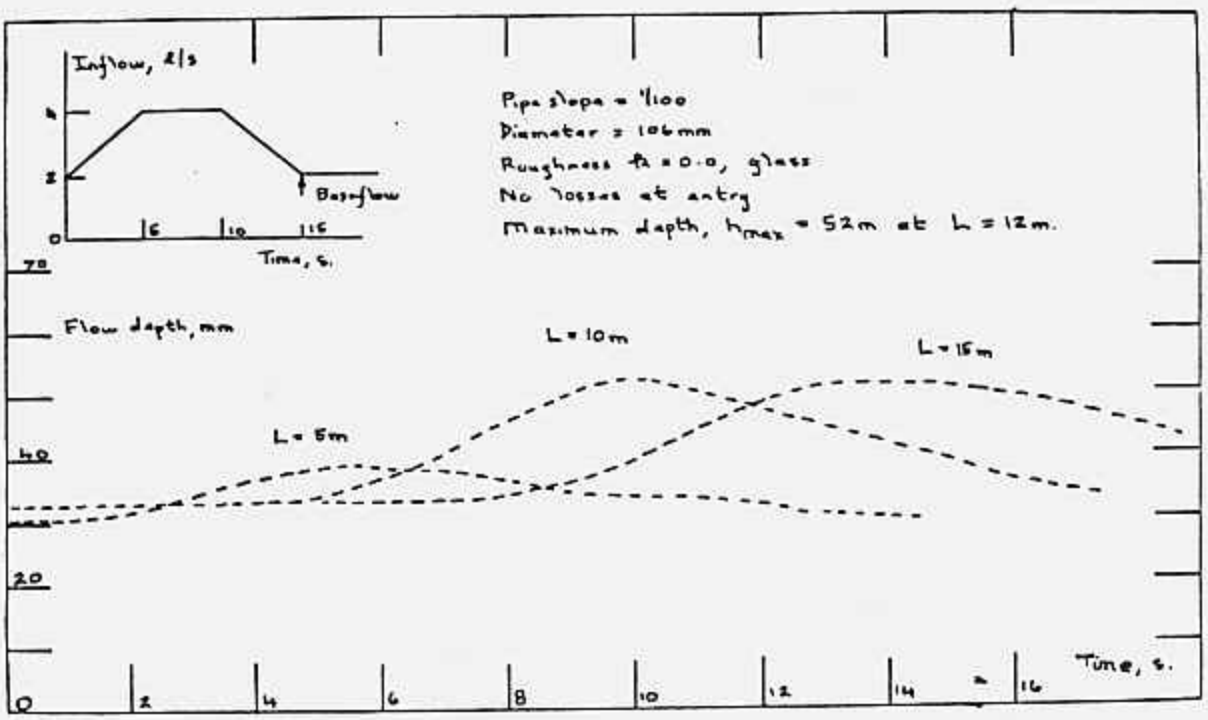


Figure 17. Depth vs. time profiles at a number of stations along the horizontal drain (1/100)

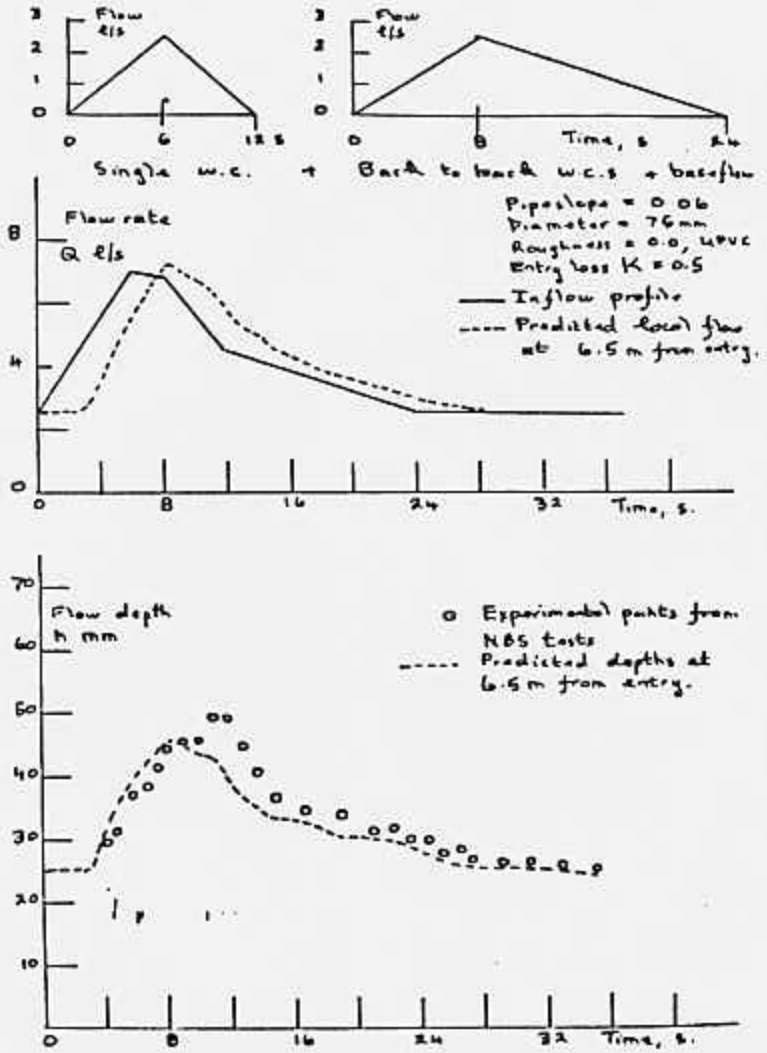


Figure 18. Comparison of observed and predicted surge attenuation downstream of a vertical stack to horizontal drain entry

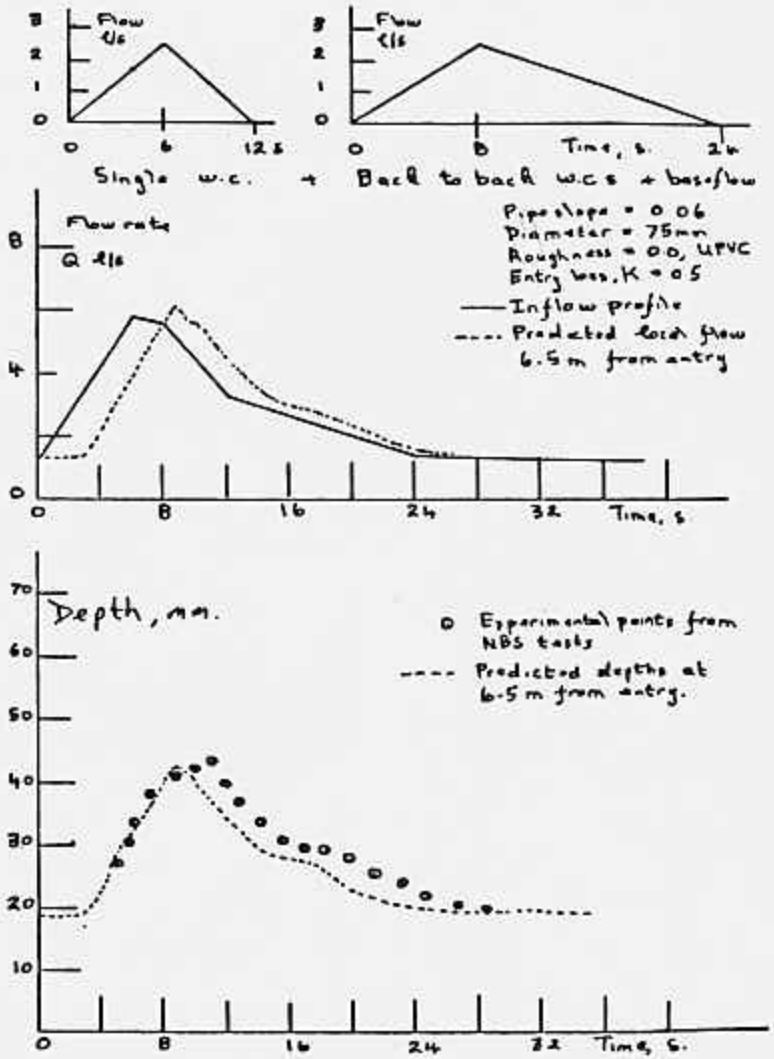


Figure 19. Comparison of observed and predicted surge attenuation downstream of a vertical stack to horizontal drain entry



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Computer Aided Analysis of Unsteady Flow in Multistorey Building Drainage Networks

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COMPUTER AIDED ANALYSIS OF UNSTEADY FLOW IN MULTISTOREY BUILDING DRAINAGE NETWORKS

12th CIB-W62 SYMPOSIUM — TOKYO —
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10,-1985 : KENCHIKU KAIKAN

Summary

The flow in multistorey building drainage networks is identified as free surface unsteady flow and the governing equations are developed. A computer aided analysis, based on the finite difference method of characteristics, is introduced and validated against full scale experimental drainage systems at both Brunel University and NBS CBT. The development and application of a multistorey network unsteady flow model is described and representative model predictions presented.

Résumé

Le flux d'un réseau d'évacuation d'un immeuble de plusieurs étages est identifié comme un flux irrégulier sur surface plane dont les équations correspondantes sont développées. On introduit et vérifie une analyse assistée par ordinateur, basée sur la méthode de différence finie des caractéristiques, sur des systèmes d'évacuation expérimentaux grandeur nature à l'Université de Brunel et au NBS CBT. On décrit le développement et l'application d'un modèle de flux irrégulier dans un réseau de plusieurs étages, et on présente des prévisions pour un modèle représentatif.

Zusammenfassung

Der Fluß in mehrstöckigen Gebäudedrainagenetzen ist als ungleichmäßiger Fluß auf freier Oberfläche definiert worden, und die zugrunde liegenden Gleichungen wurden entwickelt. Eine computerunterstützte Analyse, basierend auf der Grenzwertmethode der Charakteristika, wird vorgestellt und mit experimentellen Abwassersystemen in Originalgröße bei NBS CBT und Brunel University verglichen. Die Entwicklung und Anwendung von Vielstock-Netzmodellen für ungleichmäßigen Fluß wird beschrieben, und repräsentative Modellvorhersagen werden vorgeführt.

Symbols Used in this Article

A	Flow cross sectional area
B^+	Solid path in x-t plane
a	Discharge pipe cross sectional area
C^+ C^-	Characteristic equations in x-t plane
c	Wave propagation speed
D	Pipe diameter
F	Hydrostatic force
F_B	Buoyancy force
F_R	Froude N^o
g	Acceleration due to gravity
i	Pipe number
j	Node number
h	Flow depth
$\bar{h}$	Centroid depth
h_c	Critical depth
h_n	Normal depth
K	Loss coeff. at drain entry
k	Wall roughness, number of inputs to a network
m	Hydraulic mean depth, solid mass
N	Number of junctions in a network
n	Manning's loss coeff.
P	Wetted perimeter
Q	Flow rate
S	Pipe slope, slope energy grade line
T	Surface width flow
t	time

t'	Terminal annular thickness in stack flow
V	Flow velocity
V_s	Solid velocity
V_w	Wave or hydraulic jump velocity
x	Distance along pipe
Δx	Distance increment in model
Δt	Time increment in model
ρ	Fluid density
T_o	Wall shear stress

Application of computer aided analysis and design methods to multistorey building drainage networks

The design of building drainage networks has for the past 40 or so years been largely based upon the "probability of use" model first successfully proposed by Hunter (1940) and later incorporated into both the US and UK "fixture unit" design methods (Konen, 1982, Burberry & Griffiths, 1962). While this technique allows the designer the advantages of diversity by reducing the maximum number of appliances and hence the maximum loading on the system, the actual network design is based on steady flow considerations.

The flow conditions within a building drainage network responding to random discharges from the appliances served may be described as unsteady partially filled pipeflow. The necessary equations defining such time dependent free surface flows have been available since the mid-nineteenth century and the numerical methods required for a network solution well known, (Stoker, 1957). However such calculations were prohibitively time consuming prior to the development of the digital computer as a practical aid to the engineer. Progress in this technology would suggest that design methods utilising full solutions of the unsteady flow equations will become both practical and commonplace within the next decade.

The purpose of this paper is to introduce the necessary unsteady flow equations and to identify the main characteristics of such flows in drainate networks. Progress on the development of a computer based numerical solution and design technique that predicts flow depths and velocities throughout a building drainage network is also presented,

together with the results of full scale validation tests. While the necessary mathematics are presented, it is stressed that the final design package will not require the user to do more than detail the system, its usage pattern and the limits of acceptable flow depths and velocity to be encountered during operation.

Wave attenuation and its implications for system design

Unsteady flow in partially filled pipes is characterised by the fact that waves introduced into the flow change shape as they propagate. The velocity of a wave front communicating changes in flow conditions depends on the wave depth, with deeper points on the wavefront travelling faster than those at a shallower depth, Figure 1.

This variation of wave speed with local wave depth produces a steepening of a rising depth wavefront and a spreading of the wave's trailing edge. As a result of appliance discharge the wave shapes encountered in drainage networks feature both these effects, the net result being a reduction in the peak depth associated with the wave as it moves downstream, with a consequent increase in the wave's length. This phenomenon is termed wave attenuation and clearly affects flow depths and velocities throughout a drainage network. As a numerical example of this effect a UK w.c. discharges 9 litres in about 8 second with a peak flow rate approaching 2 litres/s. At a pipe slope of 1/80 in a 100 mm. diameter drain the length of the observed surge would double within 5 m with consequent reduction in local maximum flow depth (Burberry, 1978).

Wave attenuation is complicated by its dependence on both pipe parameters, i.e. diameter, roughness, slope, and the wave shape itself. Figure 2 illustrates these dependencies, attenuation increasing with both increasing roughness and diameter and decreasing pipe slope or base flow. Peaked inflow profiles attenuate more rapidly than trapezoidal profiles and steeper depth changes attenuate more rapidly than gradually varying profiles. All these relationships depend on the local wave speed effect illustrated in Figure 1.

Design guidelines based on predicted depth or velocity at a point in a network are potentially affected by wave attenuation. The depth of flow in a collection drain serving a number of branches from, for example, dwellings or areas within a complex building form, is dependent upon the attenuation of waves in the branches served. Movement of deposited solids by later discharges is dependent on the wave shape reaching the deposit; clearly attenuation therefore affects self cleansing in drainage networks. Similarly the transport of buoyant solids is affected by grounding in an attenuating wave's trailing edge. These effects can be particularly important in oversized drains or systems retrofitted with low water use w.c's.

Vertical stack discharge from an upper floor enters a horizontal drain with considerable specific energy, resulting in relatively shallow, fast moving flow at the drain to stack entry bend. As the flow moves downstream the flow depth increases in response to frictional resistance. In the case of a surge discharge, rather than a steady flow to the drain, attenuation acts to reduce the peak depth attained downstream. Thus an analysis featuring attenuation prediction could determine the surge carrying capacity of a horizontal, stack fed, drain.

Objectives of the proposed building drainage network model

A computer based finite difference solution of the unsteady free surface flow equations would automatically include the attenuation effects described. Such a model could represent a network in terms of both pipe parameters, i.e. slope, roughness, diameter, junction design, and flow variables, such as frequency of appliance usage and appliance discharge characteristics, Figure 3.

The model should provide information, in terms of flow depth, velocity or local flow rate at any location in the network, on the performance of a drainage network in response to an operator defined range of appliance usage patterns. Similarly the effect of proposed changes in system design, or use, could be studied, with benefits for both the designer and the code committee member wishing to assess the implications of proposed code amendments.

Suitable numerical techniques exist in the study of open channel flows (Price, Wylie and Streeter, Fox). The model presented was based on the method of characteristics, validated by full scale laboratory testing of sections of drainage network.

While the solution for wave motion in long uninterrupted pipe lengths is relatively straightforward, drainage networks feature, in a small area, a large number of pipe boundaries. Examples to be dealt with would include pipe junctions, discharges to a vertical stack and appliance discharge - pipe entry conditions. Similarly a multistorey building model would require a representation of vertical stack annular flow and a summing technique to model flow entry to the lowest level horizontal drain.

The finite difference based model presented includes these features, validated wherever possible by full scale laboratory testing. The model therefore offers an extension to the existing design methods based on "fixture units". While recognising the importance of the existing techniques, the authors feel that the analysis proposed offers considerable advantages both in the design of systems for situations where the likely usage patterns are poorly represented by the fixture unit approach and for the study of the effects of building drainage network design, use or code changes.

Numerical analysis of unsteady drainage pipe flow

Figure 4 illustrates the derivation of the equations of continuity and motion for unsteady partially filled pipeflow

$$g \frac{\partial h}{\partial x} + g (S - S_o) + V \frac{\partial V}{\partial x} + \frac{\partial V}{\partial t} = 0 \quad (1)$$

$$VT \frac{\partial h}{\partial x} + T \frac{\partial h}{\partial t} + A \frac{\partial V}{\partial x} = 0 \quad (2)$$

where the unsteady friction is modelled by the local time equivalent steady flow parameters and friction factor calculated either by use of the appropriate form of the Colebrook White equation, or Manning's 'n' coefficient, (Swaffield and Bridge, 1983).

Equations 1 and 2 may be combined linearly to yield a total differential equation :-

$$\frac{dV}{dt} \pm \frac{g}{c} \frac{dh}{dt} + g (S - S_o) = 0 \quad (3)$$

provided that this relation is confined by the condition

$$\frac{dx}{dt} = V \pm c \quad (4)$$

where $c = \sqrt{gA/T}$ and is the local wave propagation velocity.

Expressing equation 3 as a pair of 1st order finite difference relationships linking conditions at point P at time $t + \Delta t$ to conditions at R and S at time t, Figure 4, yields :-

$$V_P = V_R + \frac{g}{c_R} h_R - g (S_R - S_o) \Delta t - \frac{g}{c_R} h_P \quad (5)$$

or $V_P = K1 - K2.h_P$ when $x_P - x_R = (V_R + c_R) \Delta t$

$$V_P = V_S - \frac{g}{c_S} h_S - g (S_S - S_o) \Delta t + \frac{g}{c_S} h_S \qquad (6)$$

or $V_P = K3 + K4\, h_P$ when $x_P - x_S = (V_S - c_S) \Delta t$

The Courant stability criteria, namely $\Delta t < \Delta x/(V+c)_{max}$, dictates that R and S must both lie within $\pm \Delta x$ of P, thus interpolation is required at each time step to determine these base values from the calculated nodal values at A, B, C.

Equations (5) and (6) are referred to as the C^+ and C^- characteristics respectively. The gradients of these characteristics in the x - t plane depend on the relation V < or > c.

The V > c condition implies that information on downstream conditions cannot propagate upstream as a wave front of velocity c. This flow category is known as supercritical flow and is the normal condition within building drainage networks. In this flow condition it follows, Figure 4, that both the C^+ and C^- characteristics lie upstream of any node point being considered. Subcritical flow, where V < c and waves can propagate upstream, can occur for very shallow pipe gradients or where the flow is restricted, for example by passage through a pipe junction and merging with another incoming flow. In this latter example the subcritical flow may be regarded as artificial or forced and terminates some distance upstream of the restriction in an hydraulic jump, the upstream approach flow reverting to a supercritical condition.

In order for an analysis to prceed it is necessary to not only solve the C^+ C^- equations at each internal node but also to provide solutions across the boundaries formed by pipe entry or exit or by pipe junctions. At such boundaries it is necessary to provide supplementary

relationships either linking, most commonly, flow depth and velocity or alternatively imposing some time dependence on one of these parameters. Moving boundaries may also be encountered along a pipe, provided by, for example, solids in transport or hydraulic jumps formed as a result of flow back up from junctions or restricted pipe exits. Table 1 illustrates a range of such boundary conditions, solved in each case by combining available C^+, C^- equations with appropriate flow relationships.

In common with other applications of the method of characteristics, it is also necessary to define the initial flow depth and velocity along the network.

Model validation

Validation of the proposed model was undertaken at each stage in the development of the analysis. A full scale test pipe, illustrated in Figure 5, was used to compare measured and predicted flow depth along a 14 m drain constructed of either 100 mm or 150 mm diameter glass, UPVC or cast iron pipe, set at a range of gradients from 1/40 to 1/300. Depths at intervals along the drain were scanned by an Apple II based data logging system and passed to the University's Honeywell main frame computer for comparison to predicted values generated in response to the same input wave profile.

Unsteady flow and waves were produced by either a pressure controlled reservoir tank or by the discharge of a variable height cistern, in order to simulate both the situation at a point in the system remote from the entry, i.e. longer duration surge profiles, or close to the pipe entry, i.e. the higher energy and shorter duration cistern discharge.

Figure 6 compares the predicted and measured flow depths along a 100 mm diameter glass drain in response to a pressure reservoir generated inflow wave. The entry boundary condition provided by a flow rate calibrated depth at entry equation yields satisfactory agreement between predicted and observed depths along the drain. Alternative theoretical entry conditions based on the assumption of normal or critical depth at entry are less successful close to the head of the drain, due to the geometry of the vertical riser to drain junction.

Cistern discharge comparisons are presented in Figure 7. In this case the flow entry kinetic energy is considerable and may be equated to the drain entry node specific energy, Table 1. Use of this boundary

condition predicts a maximum depth at some distance along the drain due to the combined effects of flow depth increase, due to frictional resistance, and wave attenuation. Depths further downstream continue to be well predicted. This "entry energy" boundary condition may be utilised for both w.c. discharge to a branch and for vertical stack discharge to a horizontal drain provided an estimate of the flow kinetic energy can be made, Table 1.

In order to develop a network model it was necessary to deal with a junction between two or more drains. As the analysis was primarily directed towards complex in-building drainage networks, junctions were initially confined to level invert designs. Figure 8 illustrates the model representation choosen, drawing on both exit and entry boundary conditions from Table 1 as well as involving a moving hydraulic jump boundary in each inflow pipe to the junction. Laboratory measurements determined a steady flow depth vs combined flow relationship at the junction, Figure 9, for both 45^{o} and 90^{o} cases. Gradually varied flow theory enabled the initial backwater profile from the junction to the upstream hydraulic jump position to be calculated. The combined flow through the junction to the downstream pipe passed through a critical flow depth immediately downstream of the junction, thus providing an entry boundary condition for this pipe, Table 1. Strictly the 1 dimensional flow assumptions do not apply at the junction and this was confirmed by laboratory observation of the flow. However the proposed model yielded satisfactory comparisons between observed and predicted depth variations in the junction region in response to waves arriving along either or both the inflow pipes linked at the junction. Figure 10 illustrates a typical comparison for a 45^{o} junction in 100 mm diameter glass drains. The assumption of a concentrated hydraulic jump is shown

to be reasonable, although in practice the transition from the approaching supercritical flow to the deeper subcritical flow leading to the junction was spread over several pipe diameters. In addition to satisfactorily representing depth profiles, the junction model was also capable of predicting backflow from one supply pipe to the other, dependent upon the relative wave strengths in each flow. This effect was shown by both negative flow velocities in the backflowing pipe and the upstream movement of the hydraulic jump boundary.

The model validation was undertaken with 45^{o} and 90^{o} glass junctions. Alternative junction designs would be easily represented by combined flow vs junction depth relationships, determined under steady flow conditions.

Network model development

The successful analysis and validation of the junction boundary condition enabled the treatment of a single level network to be considered. In this context a network is restricted to a tree shaped array of pipes, connecting sanitary appliances, containing no pipe loops and featuring only one discharge point, the "sink node".

The network description technique proposed by Berthouex et al (1974), was adopted as it accepts an arbitrary list of junction and pipe numbers and translates these into an ordered system. Contours, called drainage or isonodal lines, are superimposed on the network so that they pass through junctions separated from the sink node by the same number of pipe lengths, or "links". A tree of N junctions is completely connected by N-1 links, the number of isonodal lines being (N-1)/k where k is the number of upstream inputs to the network. Isonodal line 1 always passes through the sink node and thus the flow direction is always specified as from a higher to lower isonodal line number.

Figure 11 illustrates this technique applied to a single level network and also presents flow depth profiles at a range of locations through the network in response to both single and repeating appliance discharge. The depth predictions illustrate both the wave attenuation effects and the backflow representation provided by the junction model. The latter effect is clearly illustrated by the arrival in pipe 3, Figure 11 of a wave propagated through the downstream junction with pipe 4 prior to the arrival of waves from upstream due to the discharge to pipes 1 and 2.

These predictions could obviously be utilised in any design considerations of the carrying capacity of downstream pipes. Similarly the self cleansing properties of the network are indicated by the local velocity or flow rate histories provided by the computer model.

Multistorey Building Drainage Model

In order to link individual networks on each floor of a multi-storey building it is necessary to represent the annular flow in the system's vertical stacks. Further the modification to a stack inflow profile that occurs as a result of a vertical drop down the stack must also be represented in some reasonable manner and the summing of flows at each floor handled.

Research in both the UK and US on steady annular flow in vertical stacks (Wise, 1979, Wyly, 1964) established that a modified version of the Colebrook White frictional loss equation could be used to link steady flow, Q, with the annular thickness, t', achieved for a developed flow. The necessary vertical drop to achieve developed flow conditions was found to be as short as 3 to 5 m, or approximately 1 floor height.

Figure 12 illustrates the stack flow model choosen. The discharge to the stack at each level is known and is represented by a series of steady flows. Once in the stack the appropriate terminal velocity for each steady flow plateau is used to represent the steepening of a rising flow profile or the spreading of a decreasing flow profile. This approach is analogous to the wave speed effect described earlier, Figure 1. The modified flow profile arriving at the next floor down the stack may thus be calculated and summed to the inflow at that lower level. This process may then be repeated until the lowest level collection drain is reached.

At entry to the collection drain the flow kinetic energy vs time profile may be determined by reference to both the annular thickness and volumetric floor profiles. From Table 1 it may be seen that equating this energy at any time to the flow specific energy at the

horizontal drain entry provides a suitable boundary condition and allows the unsteady flow calculations to proceed in the lowest level network or collection drain.

An initial validation of this technique is provided by Figure 13, namely a comparison between experimental data from the NBS CBT plumbing tower and model predictions of flow depth 6.5 m downstream of a vertical stack to drain entry. In this case the drain was of 75 mm diameter and slope 0.06, i.e. 1 in 16.

Figure 14 illustrates the application of the full multistorey model, with depth profiles presented in the pipes delivering flow to the stack at each level and in the lowest level collection drain. The lowest level drain could of course be part of a network serving several vertical stacks. The analysis presented obviously contributes to the design and sizing of the collection network in response to discharges throughout the upper floor networks. The model also allows the effect of random user patterns to be investigated and the consequences of pipe sizing decisions to be studied. In addition to depth predictions, both local velocity and flow rate profiles are produced throughout the network, again contributing to an assessment of the self cleansing performance of the system.

Development and application of the computer based model

The development of an unsteady flow analysis technique suitable for use in the design and study of multistorey building drainage networks has been presented. The program is available for use at both Brunel University, England, and at NBS CBT in Washington DC.

In its current state of development the program could, for example, be usefully employed to study the effects of introducing reduced flush w.c's into an existing building drainage network or reducing pipe diameters in response to the lower throughflows arising from the introduction of water conservation procedures.

The information required to undertake an analysis is primarily related to the geometry and sizing of the drainage network. In addition it is necessary to know, or postulate, the appliance usage pattern and the discharge profiles for the various appliances in the system. In view of the changes in w.c. design criteria currently being considered, such data should be readily available in the future as discharge volume vs time profiles (Pink 1973, Wise 1979).

The current model is limited to level invert junctions whose flow characteristics are required in terms of junction depth vs combined supply steady flow rates, Figure 9, (Bridge 1984). As these relationships can be obtained under steady flow conditions, and as they obviously effect junction efficiency regardless of their usefulness in this analysis, their provision should present no major difficulty to manufacturers.

It is stressed that the analysis technique in no way replaces the need for the designer to understand the operation of his system. Indeed this understanding becomes an important part of the analysis as it will be

necessary for the designer to "instruct" later versions of the program as to acceptable flow depth and velocity limits within the system.

Several areas require further work and it is hoped that the investigation of the following topics will form the second stage in the development of this potential design method :-

1. Top entry junctions should be studied, suitable boundary equations developed and validated, and then included in the model.

2. Further tests on vertical stack flows should be undertaken to validate the representation of inflow profile steepening utilised in the current model.

3. The program should be restructured to become both "user friendly" and design based rather than analytical in nature. For example program input could become graphical in nature, various w.c. discharge profiles could be held on file internally, and the program could recalculate appropriate pipe diameters or slopes so that flow depths and velocities come within the designer's stated limits, Table 2 illustrates these objectives.

The research results clearly indicate that improved drainage design methods are feasible and that they will offer the designer greater flexibility in the detailing of his system.

It is hoped that these enhanced analysis techniques will be made generally available so that the building drainage system designer can make full use of both his knowledge and understanding of the subject and

the advantages of computer aided design unhindered by the intractable nature of the solution of the wave equations that define unsteady flow in partially filled pipe networks.

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TABLE 1. Summary of the boundary conditions and appropriate equations included in the network analysis model

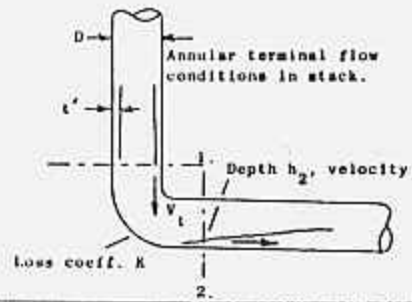
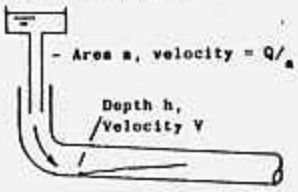
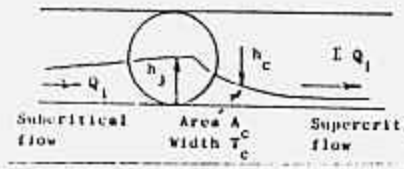
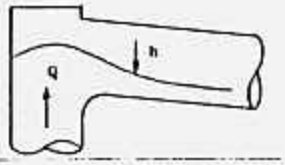
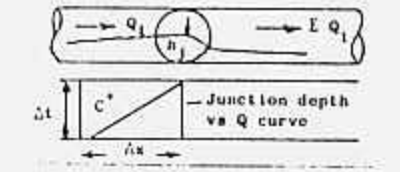
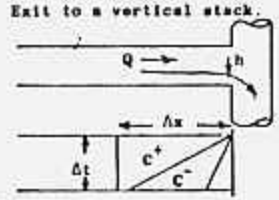
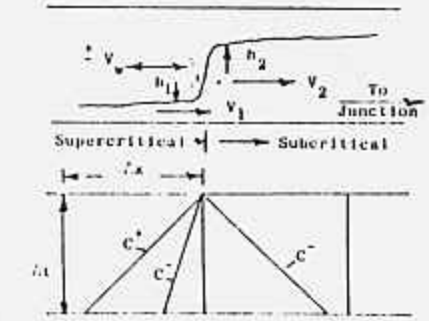
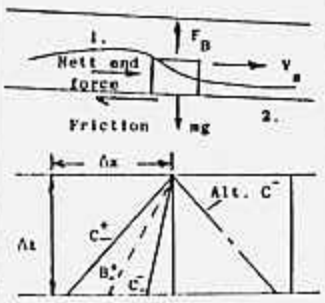
1. Vertical stack to horizontal drain. 	Kinetic energy (K.E) at 1 x an appropriate loss coefficient = specific energy at 2. Assume Q = f(time) known in stack, hence calc. terminal annular thickness, t', as f (time), V_t as f(time) and K.E as f (time). Note tt known from the Colebrook White equation :- $\frac{Q}{\pi D t'} \sqrt{\frac{1}{2gt'}} = -\log\left(\frac{k}{14.8t'} + \frac{0.314}{t'}\sqrt{\frac{1}{2gt'}}\right)$ hence $V_t = Q/\pi Dt'$ and KE = K. $V_t^2/2g$ at each time step. Solve for h_2 at each time step as $K V_t^2/2g = V_2^2/2g + h_2$, where $V_2 = Q(t)/A(h_2)$	2. Cistern discharge 	Assume Q = f(time) known from cistern discharge. Calc. K.E. in discharge tube from : $K.E = Q^2/2g\,a^2$ Equate to specific energy $h + V^2/2g$ at drain entry. $Q^2/2g\,a^2 = Q^2/2g\,A^2 + h$ Solve for h at each time step.
		3. W.c. discharge 	Conditions at 2 described by Q = f(time) for w.c. discharge and K.E = f(time) based on an equivalent discharge tube diameter of = 40 mm. (See 2 above).
4. Entry from a junction. 	Depth h_j in junction is common at exit of all supply pipes. The junction flow restriction imposes subcritical conditions upstream. To return to supercritical downstream the combined flow passes through the appropriate critical depth immediately downstream of the junction. If ΣQ_i is the combined flow at any time step, h_c is given by $f(h_c) = 0 = 1 - \Sigma Q_i^2 T_c/g A_c^3$	5. Laboratory vertical riser entry. 	Assume Q = f(time) known and that h = f(Q) is pre-calibrated at steady flow. Thus h may be calculated at each time step. Alternatively h may be set to normal or critical values dependent on Q : $f(h_n) = 0 = 1 - n\,Q/(A m^{2/3} S_o^{\frac{1}{2}})$ $f(h_c) = 0 = 1 - Q^2 T/g A^3$
6. Exit to a level invert junction. 	Depth h_j at a junction is dependent on combined throughflow. Steady flow calibration yields $h_j = a \Sigma Q_i^b$. Upstream flow is forced subcritical by the junction. Depth at exit from each of the supply pipes by solution of each C^+ equation with $h_j = a \Sigma Q_i^b$ where $\Sigma Q_i = \Sigma V_j A_j$, $A_j = f(h_j)$.	7. Exit to a vertical stack. 	Supercritical flow is "unaware" of the presence of the stack. Solve for depth and velocity at pipe exit directly from the C^+, C^- equations for the final Δx of the pipe.
8. Moving hydraulic jump. 	Supercritical flow approaching a junction becomes subcritical through the mechanism of an hydraulic jump. The jump position relative to the junction depends on junction design, pipe slope and flow rate. The jump moves upstream or downstream dependent on flow conditions. The 5 unknowns across the jump, including V_w, the jump velocity, from available C^+, C^- equations plus momentum and continuity across the jump :- $(V_1 - V_w)A_1 = (V_2 - V_w)A_2$ $\rho g(A_1\bar{h}_1 - A_2\bar{h}_2) = \rho A_2(V_2 - V_w)^2 - \rho A_1(V_1 - V_w)^2$ where $\bar{h}$ is centroid depth.	9. Moving solid 	Similar to moving hydraulic jump example :- 5 unknowns, including solid velocity V_s, solved from available C^+, C^- characteristics, plus continuity of flow, $A_1(V_1 - V_s) = A_2(V_2 - V_s)$, a leakage relationship, $Q = f(V_1, V_s$, solid size, pipe dia.) and the force equation, Hydrostatic - friction + slope = $\frac{d V_s}{dt}$ end forces weight component

TABLE 2: UNSTEADY FLOW NETWORK ANALYSIS

OBJECTIVE OF FURTHER PROGRAM DEVELOPMENT :-

"DESIGN RATHER THAN ANALYSIS"

PROGRAM LAYOUT IN "USER FRIENDLY" FORM.

1. ENTER SYSTEM DESCRIPTION IN FORM SIMILAR TO CURRENT PROGRAM, POSSIBLY INTERACTIVELY.

2. ENTER ACCEPTABLE LIMITS (UPPER AND LOWER) OF MAXIMUM FLOW DEPTH, MINIMUM FLOW VELOCITY.

3. ENTER ACCEPTABLE RANGES FOR PIPE SLOPES, DIAMETERS AND POSSIBLY MATERIALS IN ROUGHNESS FORM.

4. PROGRAM CALCULATES ALL FLOW DEPTHS AND VELOCITIES AND IDENTIFIES ANY NODES FAILING TO FALL WITHIN DEPTH AND VELOCITY LIMITS.

5. RECALCULATE WITH CHANGED SLOPE OR DIAMETER TO BRING FLOW DEPTH AND VELOCITY PARAMETERS WITHIN LIMITS.

6. INFORM USER OF DESIGN OPTIONS AS A RESULT OF THESE RECALCULATIONS.

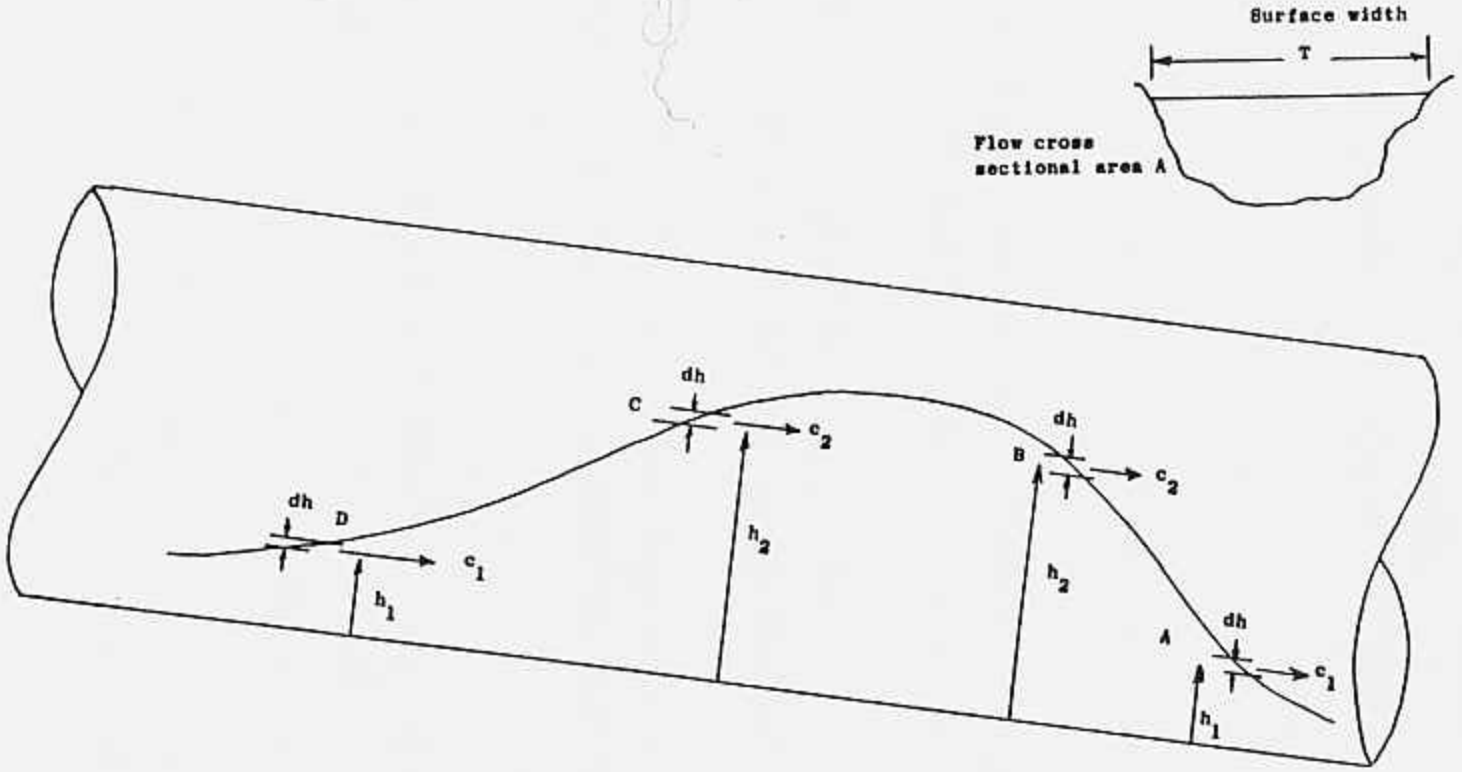


Figure 1 Dependence of wave attenuation on the local wave propagation velocity $c = \sqrt{gA/T}$.

As $h_1 < h_2$, $c_1 < c_2$, ∴ B overtakes A but C outdistances D.

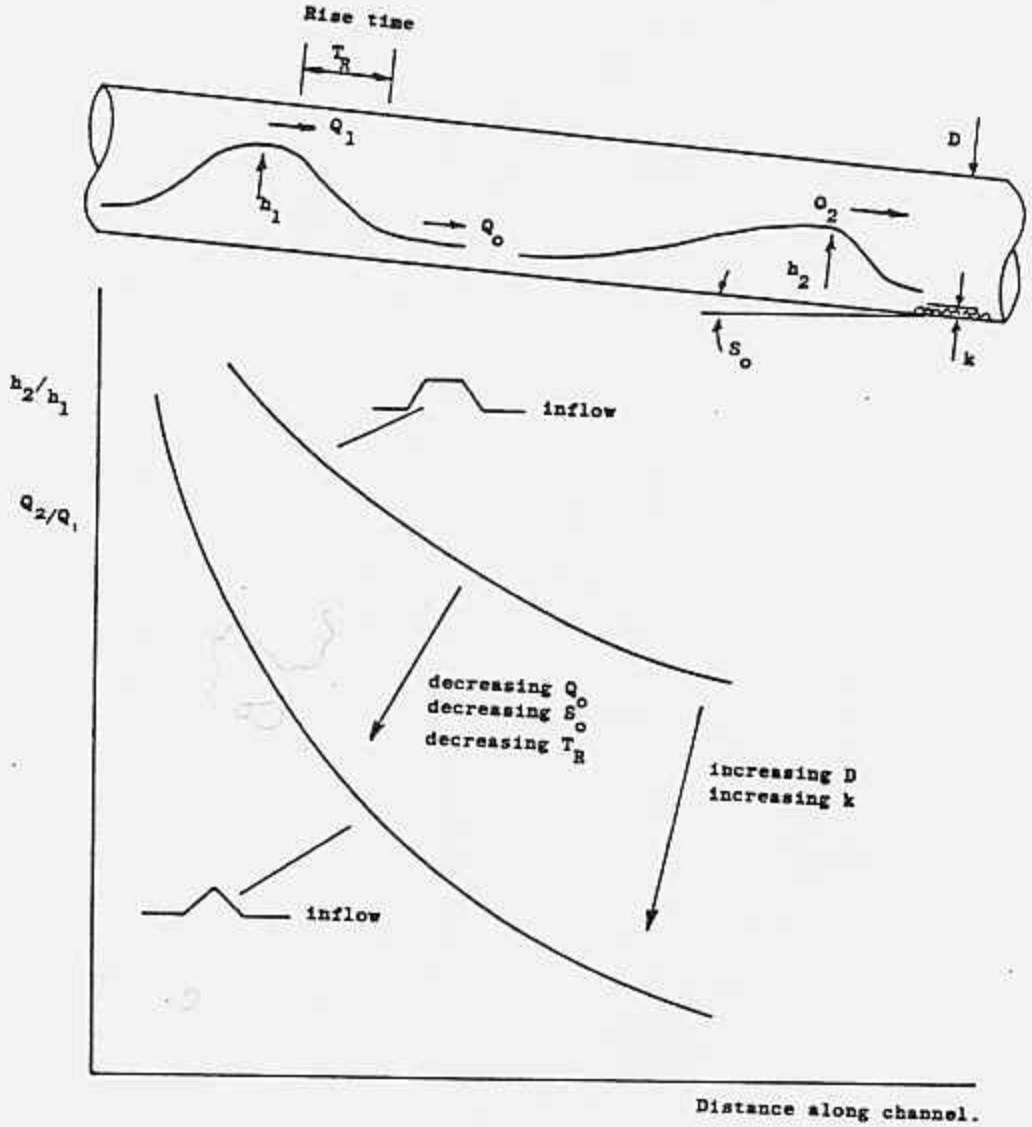


Figure 2. Dependence of wave attenuation on pipe and flow parameters.

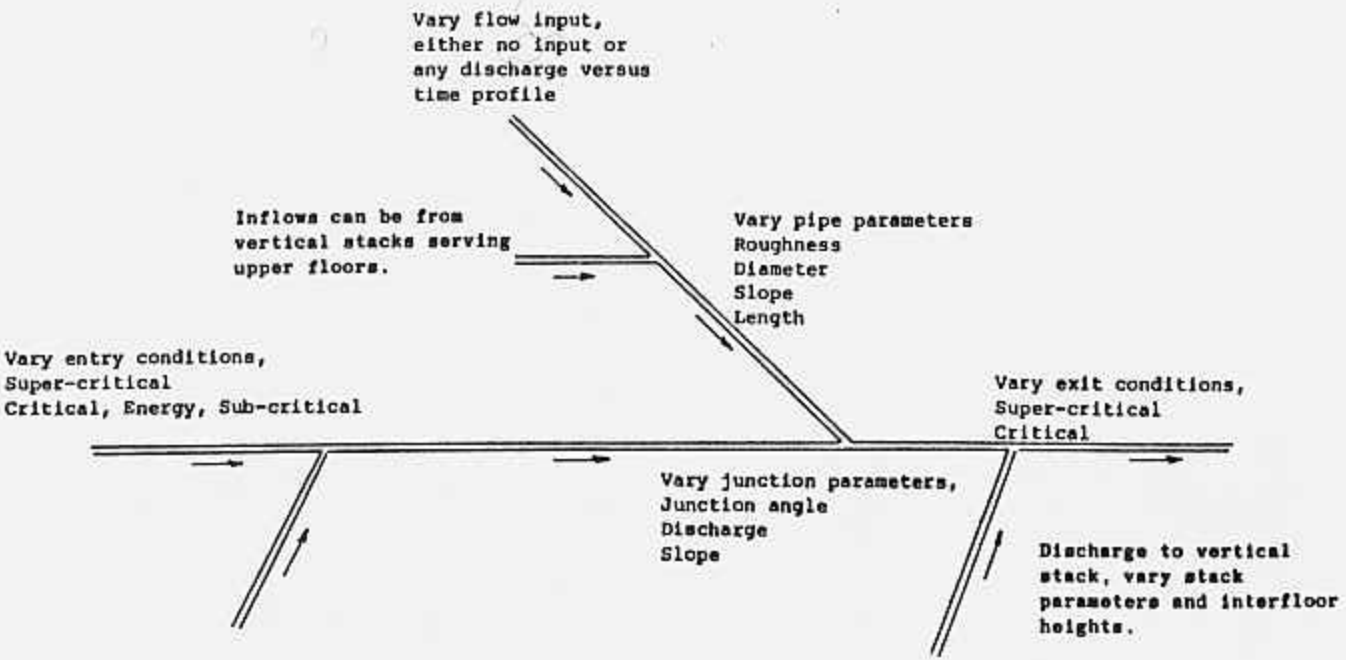
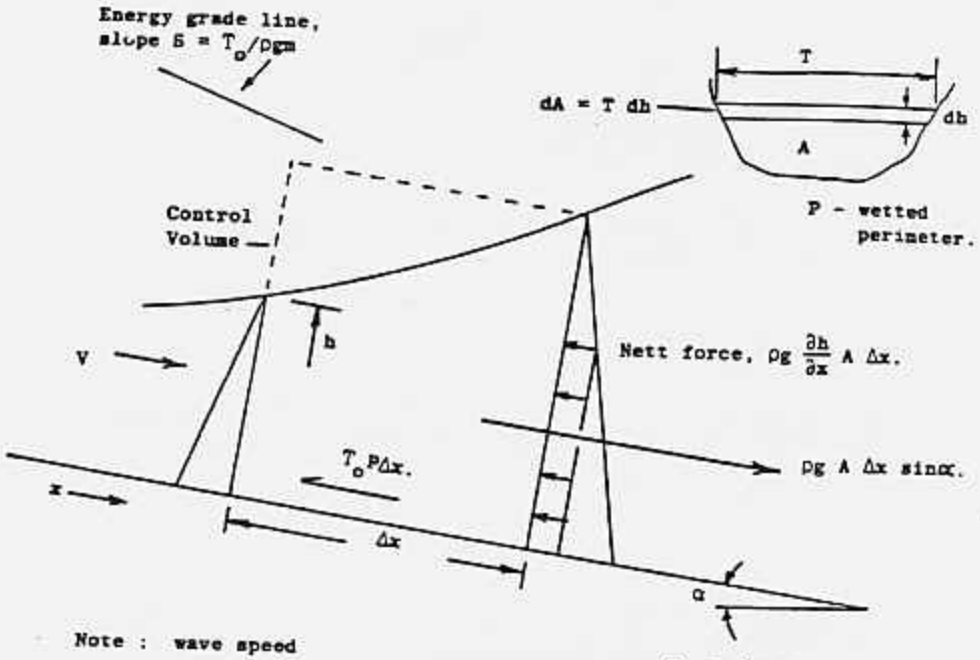


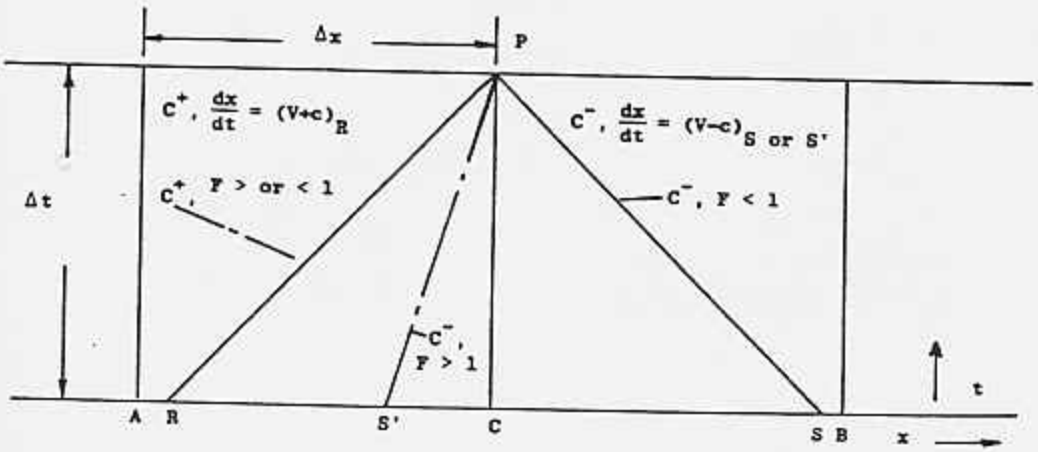
FIGURE 3. Options available in network program. Note that inclusion of vertical stacks as either an inflow or exit boundary yields a multistorey, multinetwork model.



Note : wave speed

$$c = \sqrt{g A/T}$$

Normally $\Delta x = 0.3m$, $c < 1.5$ m/s and
$V < 3$ m/s in a 100 mm bore pipe
$\therefore$ Δt normally $\simeq 0.1$ sec.



F_R = Froude N°, < 1 subcritical flow.
> 1 supercritical flow.

Note : if $\frac{dx}{dt} = V \pm c$

then $\frac{dV}{dt} \pm g \frac{dh}{dt} + g (S - S_o) = 0$

Figure 4 : Summary of Method of Characteristics Solution of the Unsteady Partially Filled Pipe Flow Equations.

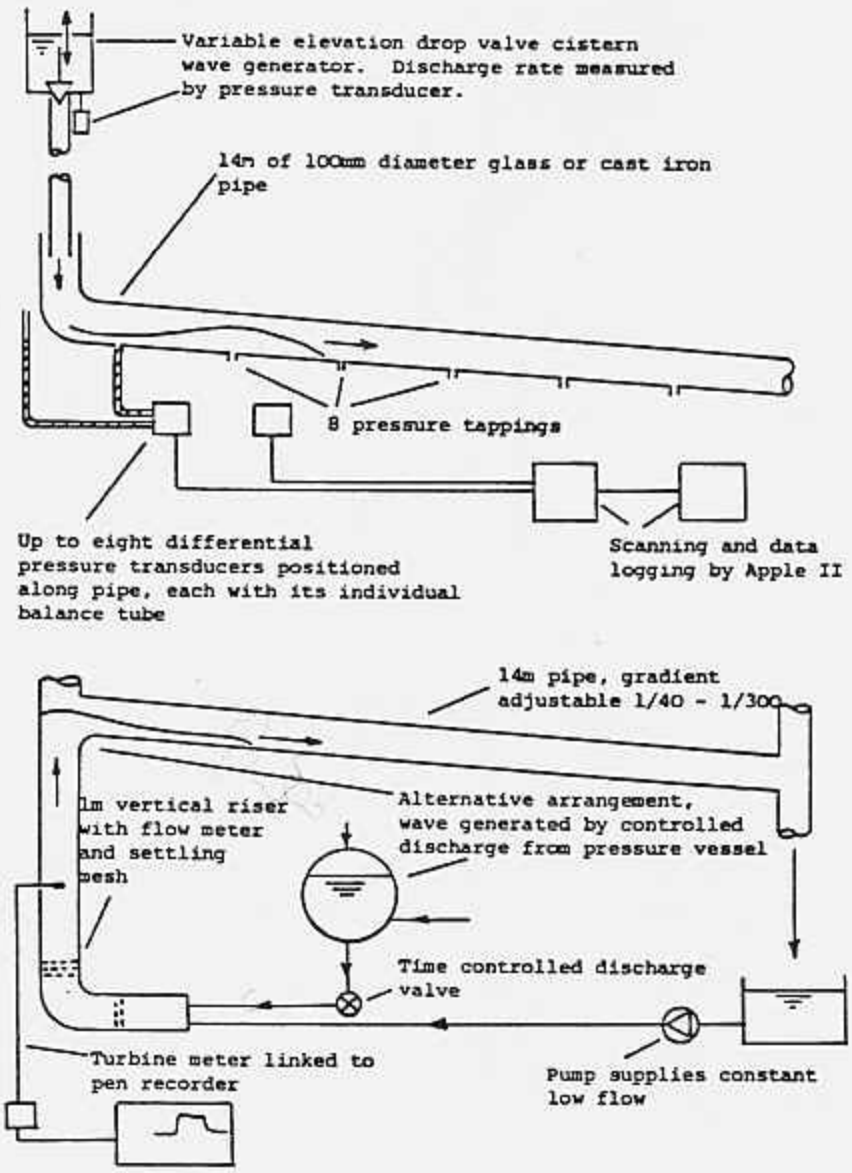


Figure 5, Schematic layout of the Brunel test rig, illustrating instrumentation and wave generating methods

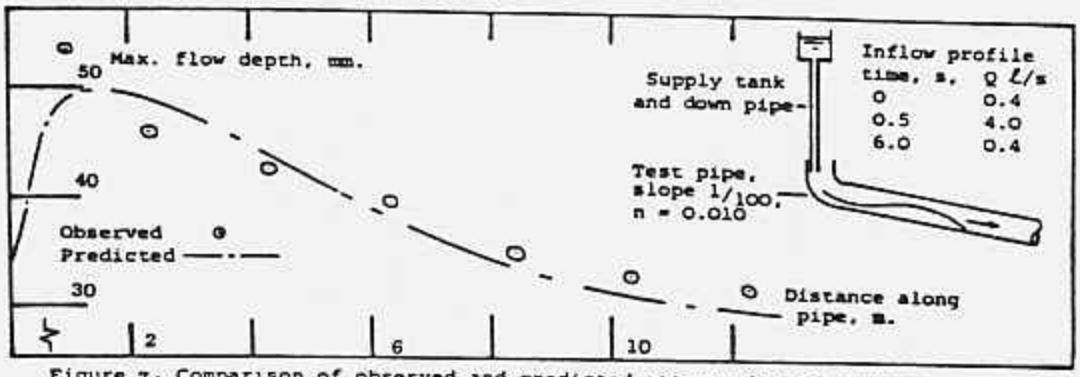


Figure 7: Comparison of observed and predicted attenuation of cistern generated wave, entry conditions based on inflow kinetic energy

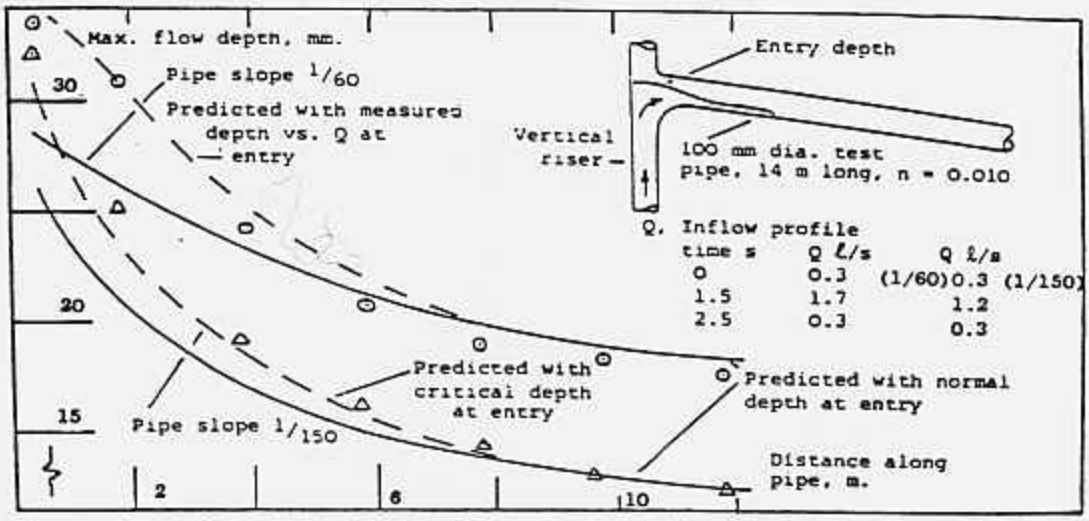


Figure 6: Comparison of observed and predicted attenuation of a pressure vessel generated wave, various entry boundary conditions

Solve at jump:

Upstream	C^+, C^- (super-critical)
Downstream	C^- (sub-critical)
Jump	Flow continuity Momentum eqn.
Yields	V_u, h_u, V_d, h_d, V_{wave}

Solve at junction:

Upstream	C^+ (both inflow pipes)
Depth vs. junction flow eqn.	
Yields	V_{uj}, h_{uj} (both pipes)

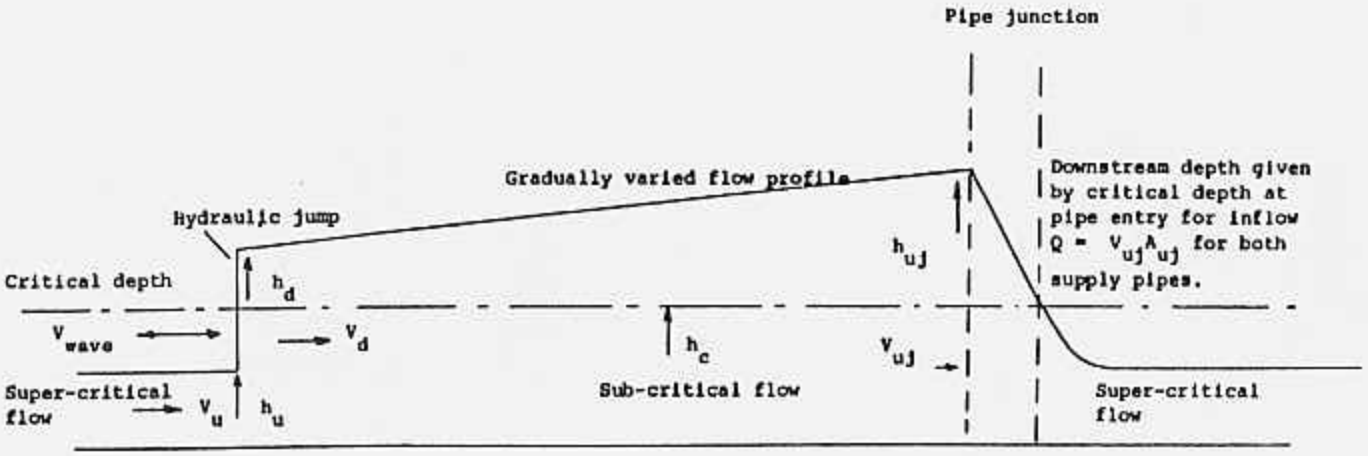


Figure 8 : Schematic of the junction flow model used.

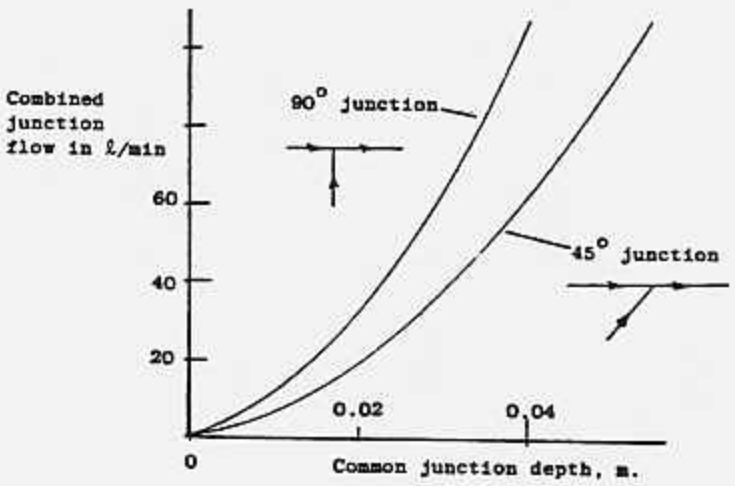


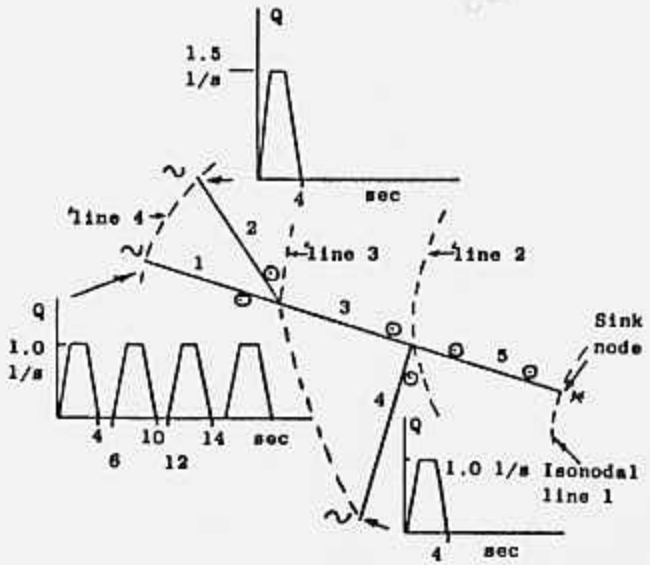
Figure 9 : Depth at a junction in terms of the combined throughflow.

$Q = 0.2918\ h^{1.75}$ (45° junction)

$Q = 0.353\ h^{1.75}$ (90° junction)

Note units m^3/s and m.

Figure 11: Application of program NBSNET to the analysis of repeating inflows to a single level network.

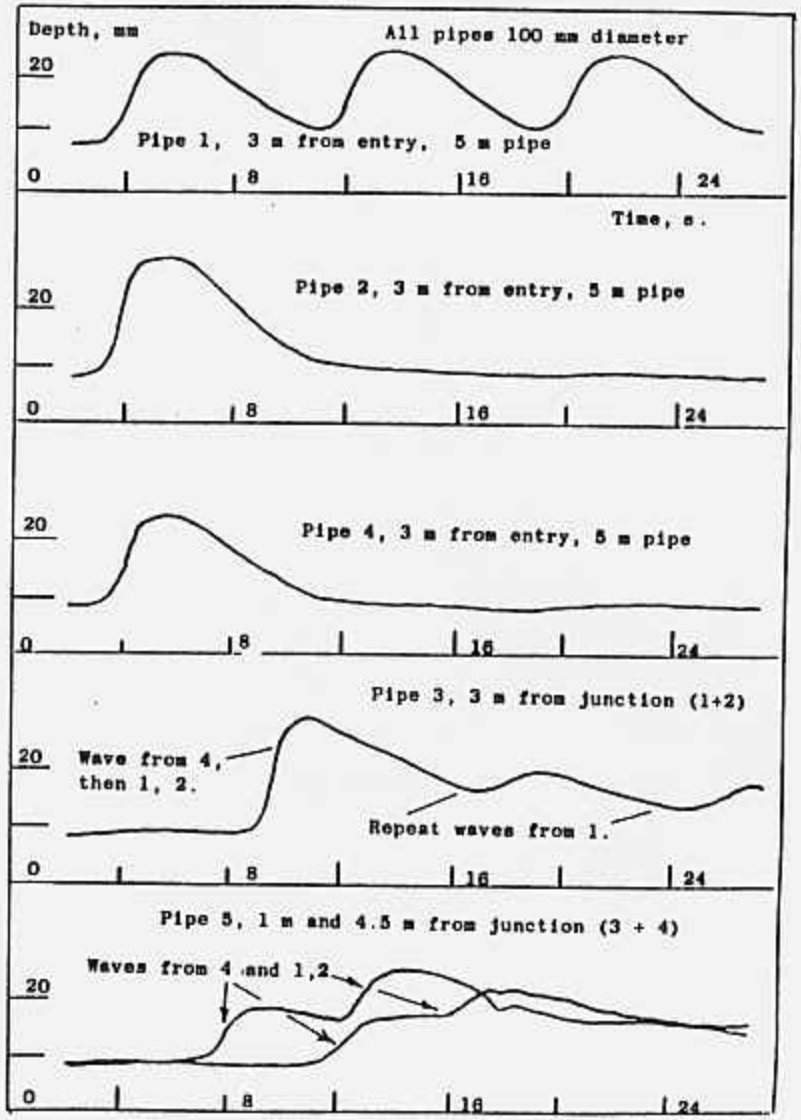


~ Q vs t input flow profiles

⊙ h, v, c output at these points

* Q vs t output at stack connection

- - - - Isonodal lines



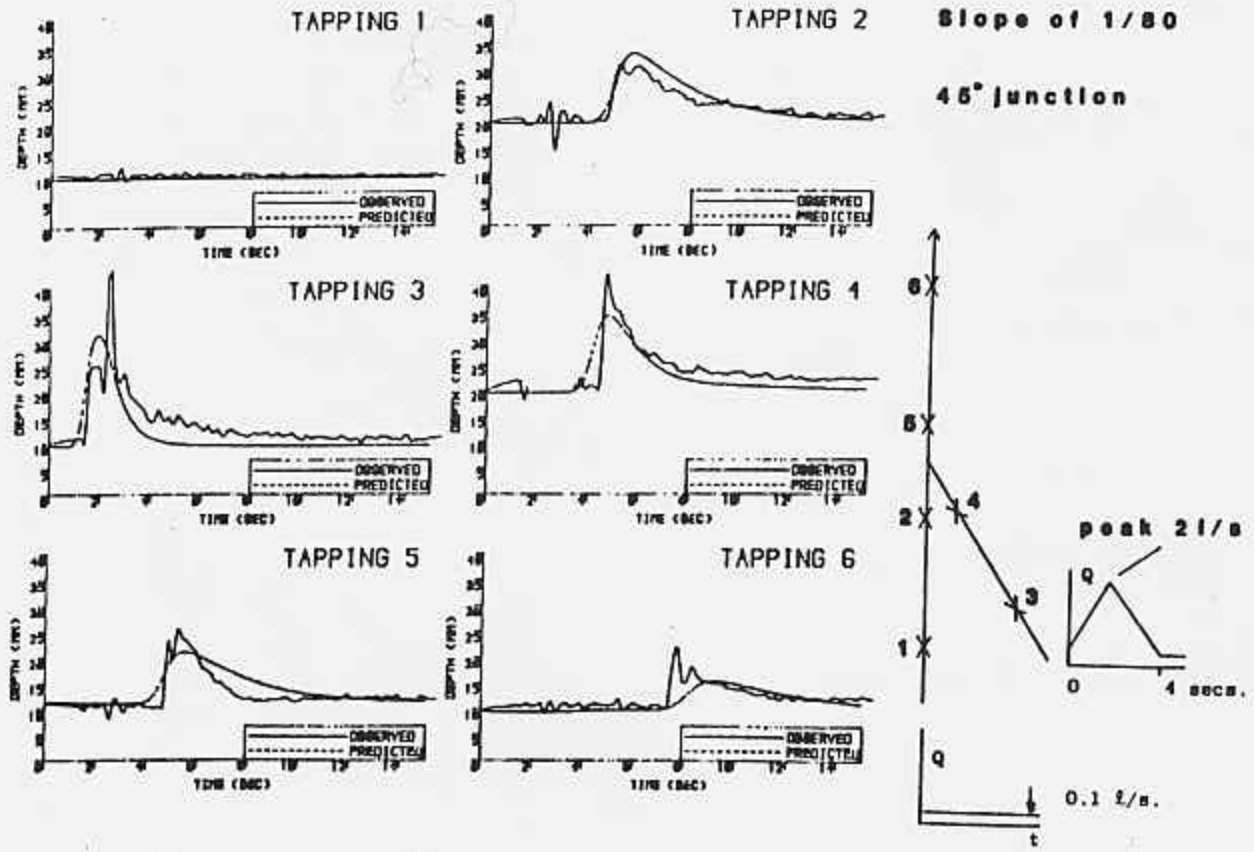


Figure 10: Comparison of predicted and observed depth variations in the region of a pipe junction.

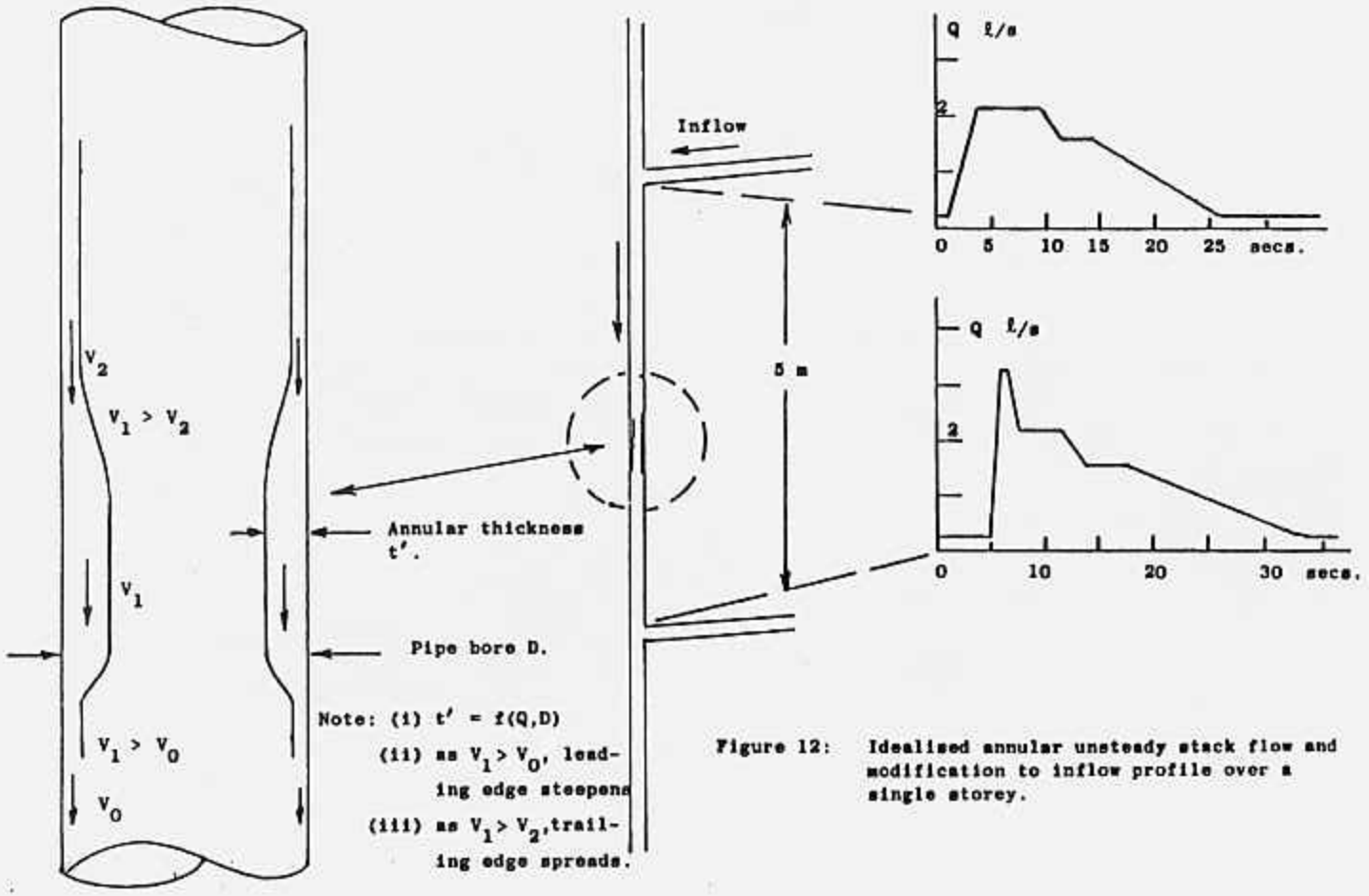


Figure 12: Idealised annular unsteady stack flow and modification to inflow profile over a single storey.

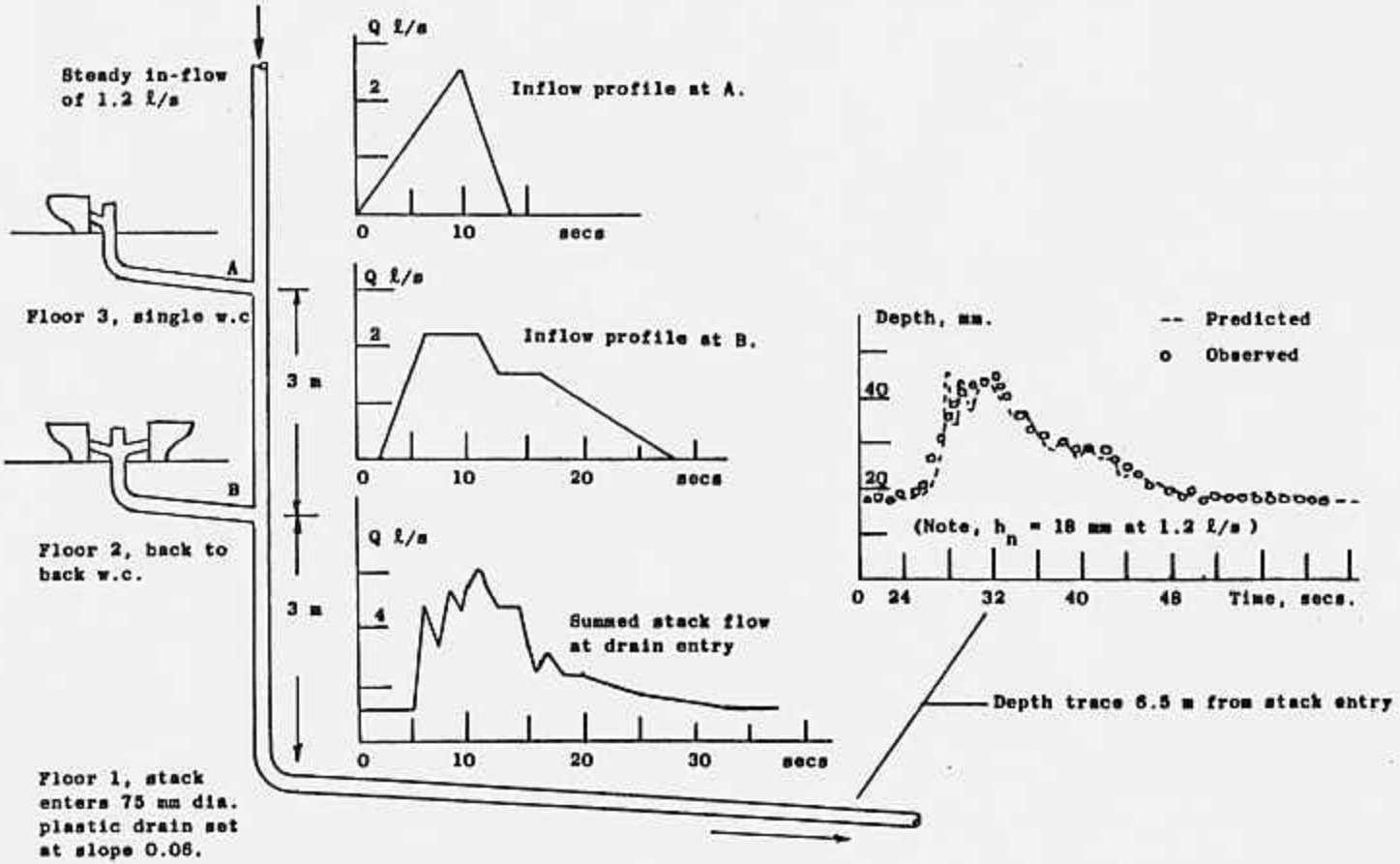


Figure 13: Comparison of model predictions and NBS CBT plumbing tower results as partial validation of stack flow model.

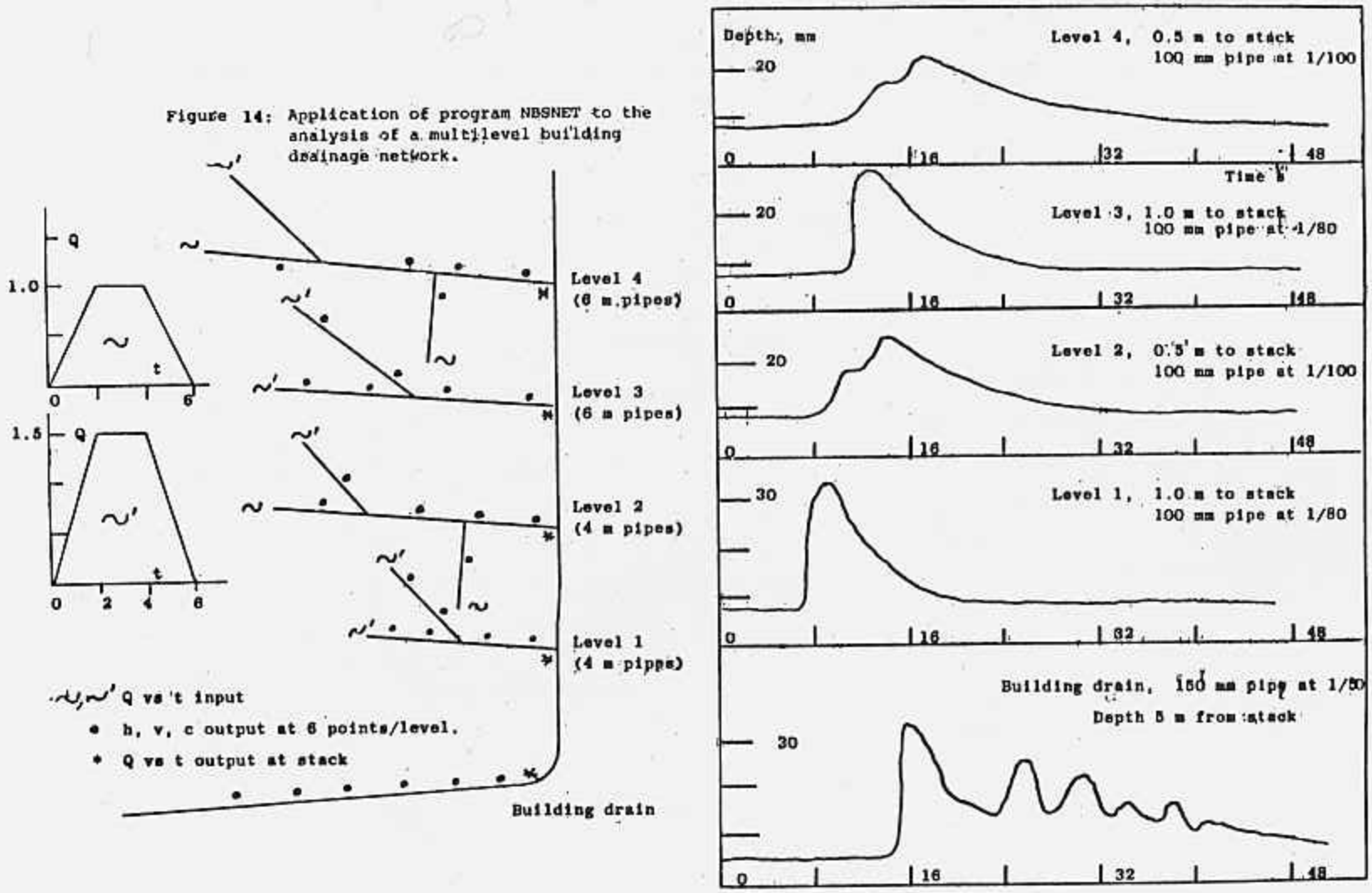


Figure 14: Application of program NBSNET to the analysis of a multilevel building drainage network.

CIB-W62 SYMPOSIUM

Performance Studies on Low Cost Hand Pour Type Squatting Pans and Traps

Sudesh Kumar Sharma

April 9,~10, 1985

TOKYO, JAPAN



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PERFORMANCE STUDIES ON LOW COST HAND POUR TYPE SQUATTING PANS AND TRAPS

12th CIB-W62 Symposium - TOKYO
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10,-1985 : KENCHIKU KAIKAN

Summary

A project has been taken by Swedish International Development Authority (SIDA) in collaboration with World Bank, UNDP and Technology Advisory Group (TAG) on "Low Cost Water Supply and Sanitation Technologies in Developing Countries". Under this programme it was decided to develop low volume water closet systems. The author had an opportunity to work with this group to develop test methods for pour flush squatting pans and traps.

The paper deals with the development of test rig to perform specific test requirements on hand pour flush squatting pans and traps. The major objectives in designing low volume flushing systems have been minimal water requirement for flushing fecal matter, simple in construction and trouble free maintenance.

The tests carried out at IFO and SIBR Sweden revealed that 1.5 litres of flushing water is sufficient to discharge out sanitary napkin through squatting pan and trap. Also studies were conducted on solid transport length through horizontal pipe at Studsvik (Sweden) and Brunel University, U.K. are discussed.

Résumé

La Commission Suédoise au Développement International a formulé, en collaboration avec la Banque Mondiale, l'UNDP et le Comité de Conseil Technologique (Technology Advisory Group, TAG) un projet sur les "Technologies Economiques de Distribution et d'Evacuation d'Eau dans les Pays en Voie de Développement". Le programme de ce projet prévoit le développement de dispositifs sanitaires à volume d'eau réduit. L'auteur a eu l'occasion de travailler avec ce groupe pour le développement de méthodes d'essai de cuvettes sanitaires et syphons à chasse d'eau manuelle (avec brot).

Cette étude traite du développement d'un appareil d'essai répondant aux exigences spécifiques des tests de cuvettes et syphons sanitaires à chasse d'eau manuelle. L'objectif principal fut la conception de systèmes sanitaires permettant d'évacuer les matières fécales avec un volume d'eau minimal, et de construction et d'entretien simples.

Les test effectués à l'IFO et au SIBR en Suède ont montré qu'un volume de 1,5 litres d'eau suffisait pour évacuer une serviette hygiénique par une cuvette et un syphon sanitaires. Cette étude traite également de recherches conduites à Studvik, Suède et à l'Université de Brunel, Grande-Bretagne, sur la longueur de transport solide par tuyaux horizontaux.

Zusammenfassung

Ein Projekt wurde von der schwedischen internationalen Entwicklungsbehörde (SIDA) in Zusammenarbeit mit der Weltbank, UNDP und Technology Advisory group (TAG) über "kostengünstige Wasserversorgungs- und Sanitärtechnologien in Entwicklungsländern" durchgeführt. Im Rahmen dieses Programmes wurde entschieden, Niedrigvolumen-Wasserklosettsysteme zu entwickeln. Der Verfasser hatte Gelegenheit, mit dieser Gruppe zu arbeiten und Testverfahren für Eingieß-Toilettenschüsseln und Wasserverschlüsse zu entwickeln.

Die Studie befaßt sich mit der Entwicklung eines Teststandes zur Durchführung von spezifischen Testerfordernissen bei Handeingieß-Toilettenschüsseln und Geruchsverschlüssen. Die Hauptziele bei der Entwicklung von Niedervolumen-Spülsystemen waren niedrigstmöglicher Wasserverbrauch zum Spülen von Fäkalien, einfache Konstruktion und problemfreie Wartung.

Die Tests wurden bei TFO und SIBR in Schweden durchgeführt und zeigten, daß 1,5 l Spülwasser ausreichten, um Damenbinden durch Sitzpfanne und Geruchsverschluß zu spülen. Desweiteren wurden Studien über solide Transportlänge durch horizontale Röhren in Studsvik (Schweden) und Brunel University, Großbritannien, diskutiert.

1. INTRODUCTION

The United Nations General Assembly, at its 35th Session, in November 1980, formally launched the International Drinking Water Supply and Sanitation decade 1981-1990. During the decade it is aimed to provide safe drinking water and adequate sanitary facilities for all mankind. It is estimated that 32 percent of the population in developing countries have adequate sanitation services. The safe disposal of human waste is essential, as inadequate facilities for excreta disposal causes diseases. The conventional water borne sewerage system is not the only solution for sanitary waste disposal. Alternative technologies should be adopted meeting standard requirements.

A project has been taken up by Swedish International Development Authority (SIDA) in collaboration with World Bank, Technology Advisory Group (TAG) and United Nation Development Programme (UNDP) on "Low Cost Water Supply and Sanitation Technologies in Developing Countries". Under this project it was decided to develop low volume water closet systems for efficient disposal of human excreta with minimum water consumption. Author had an opportunity to work with this group to develop test methods and performance requirements for squatting pans and traps.

The paper deals with the development of test rig to perform specific test requirements on hand pour flush squatting pans and traps. The main objectives in developing low volume flushing systems have been minimal water requirement for flushing fecal matter, simple construction and trouble free maintenance.

The tests carried out at Swedish Institute for Building Research (SIBR) Sweden resulted in development of modified squatting pan and trap using 1.5 litres flushing water. The modified pans and traps would be manufactured by I.F.O. Sanitary-Wares Sweden and sent for field trials in the developing countries.

2. EXPERIMENTAL SET-UP

The low volume water closet system consists of squatting pan, trap, pipe and two pits. The system could be flushed with hand pour flush and also upgraded to cistern flush with little modifications in the connection details. The basic component of the system is squatting pan and trap. The squatting pan and trap shall meet certain performance requirements. Earlier researchers have optimised the dimension of the squatting pan and trap (length 425 mm, breadth 200 mm, water seal depth 15-20 mm)[1]. An ideal squatting pan and trap is shown in Fig.1. These could be manufactured with different materials like ceramic, cement concrete, plastics and metals etc. These pans and traps are used in India with hand pour flush system and normally 2-3 litres of water is used after each operation. The fecal matter from the squatting pan is flushed out through trap to the soak pit even with the hand pour flush. Therefore it was essential to develop a test rig which could be simulated to hand pour flush discharge rate and could be used repeatedly for carrying out test performance on squatting pans and traps in laboratory.

The test rig developed to simulate hand pour flush for repeated test consists of a stand, tipping tank and

pneumatic control valve. The details of the assembly are shown in Fig.2. The pneumatic valve was used to control the tilting speed of tipping tank. The flow rate caused by hand pour flush was measured for different flush volumes (1.0, 1.5, 2.0 and 3.0 litres) and the same was simulated in tipping tank flow rate by adjusting its employing time, the details are shown in the Fig.3.

The flow rate curves for tipping tank are obtained with the help of electronics flow measuring device and recorder. Different volumes of water (1.0, 1.5, 2.0 and 3.0 litres) were discharged from tipping tank at a speed of 200 mm/sec. and the discharge rate curves have been depicted in the Fig.4 to 7.

The squatting pans and traps of different design were made in fibre reinforced plastic by IFO Sanitar, Sweden and their performance was evaluated at the IFO factory as per test methods.

Also test set up was erected to study the solid transport through horizontal drain laid at different slopes (1:20 to 1:100). A transparent plastic of 90 mm outside diameter and 15 metre length was used. Electronic detectors were spaced 1 metre apart to record water velocity profile of the horizontal drain. For solid transportation a sanitary napkin of 150 gm wet weight was used.

3. TEST METHODS

The performance tests on squatting pans and traps shall be conducted by installing a tipping tank rig. The tipping tank shall be placed over the squatting pan such that the top surface of pan touches the tip of the tank

and it falls at a distance of 5 cm from the front of the pan to simulate the flow rate of hand pour flush. The following tests shall be performed using 1.5 litres of water.

(A) Ball Test : The pan shall be filled with water to its nominal water seal level and 30 polyethelene balls of 19 mm diameter and 0.85 specific gravity be placed on the water surface of the pan. It shall then be flushed from tipping tank and number of balls flushed out shall be counted. The test shall be conducted 10 times and average value considered as percentage efficiency. It shall not be less than 80 percent.

(B) Sponge Test : Four natural rubber sponges of size 20 mm diameter and 100 mm length shall be saturated in water and placed on water surface of the pan. It shall then be flushed with the help of tipping tank. The test shall be repeated 5 times and it shall discharge all the four sponges at least four times.

(C) Sanitary Napkin Test : The pan shall be charged with a standard sanitary napkin (wet weight 150 gm). The pan shall be flushed with tipping tank. The sanitary napkin shall flush out at least four times from the 5 tests conducted.

(D) Solid Transport Test : The pan and trap shall be connected to horizontal P.V.C. pipe of inside diameter not less than 75 mm and length 15 metre. The pipe shall be laid at a slope of 1:100. The Pan shall be charged with a sanitary napkin (wet weight 150 gm) over its water surface. The

sanitary napkin shall be flushed out of the pipe at least in 5 flushes. The test shall be repeated three times and it shall pass two times at least.

(E) Odour Control : Normally the squatting pan and trap is connected to the horizontal drain and to protect against sewer gas a water seal of 20 mm is provided. The trap shall have a minimum water seal of 20 mm when put in position.

(F) Tightness against penetration of water : The Pan when sealed at the outlet of the trap shall be capable of holding 1.5 litres of water between normal level and highest possible water level of pan. Also pan and trap joint shall have no leakage at this water head.

4. RESULTS AND DISCUSSIONS

Flushing efficiency tests were conducted on FRP squatting pan manufactured in India and a PVC trap was fabricated at the SIBR, Studsvik (Sweden) using different volumes of flushing water (1.0, 1.5, 2.0 and 3.0 litres). The results are tabulated in the Table-1. These results clearly indicates that the flush volume 1.5 litres is sufficient to perform efficiency tests satisfactorily. The use of 1.5 litres is therefore recommended for further development of modified squatting pan and trap.

IFO Sanitar, Bromolla fabricated two different designs of squatting pans (slope 25^{o} and 29^{o}) and three traps (65 mm, 70 mm outlet) based on studies carried out at SIBR, Studsvik. It was decided to carry efficiency tests on these pans and traps to study their performance and suggest modifications in the design, if any.

Performance tests were carried out on these pans and traps using 1.5 litres tipping tank rig. The results of pan with 29° slope and trap with 70 mm outlet diameter are tabulated in Table-2.

Also it was decided to carry solid transportation test with the developed pans and traps to understand the effect of low volume on horizontal drain*. As necessary facilities were available at Brunel University, U.K., the problem was referred to them for detailed investigation[2].

*Preliminary investigations were carried out using 1.5 litres flush volume through squatting pan. The test results are tabulated in Table-3.

5. CONCLUSIONS

The evaluation of the squatting pans and traps at Studsvik and Bromolla Lead to the following conclusions:

1. 1.5 litres flush volume is sufficient for hand pour flush squatting pans and traps.
2. The horizontal pipe shall be minimum 75 mm inside diameter and slope shall be 1 in 10 to 1 in 100.
3. The hand pour flush system could be upgraded to cistern flush system with minor modifications.
4. FRP pans and traps shall be joined properly to avoid leakage.
5. There is need to develop new jointing techniques for efficient laying of pipe lines.
6. It is proposed to install 1000 units in the field to monitor performance and feed back on the developed units. The units would be supplied by SIDA and monitored by TAG India.

ACKNOWLEDGEMENT

The author is thankful to Mr Eskil Olsson, Project Manager, Swedish Institute for Building Research (SIBR), Sweden for his valuable guidance and encouragement to take up this project.

The work was performed under sponsorship of Swedish International Development Authority (SIDA) Sweden and published with the permission of the Director, Central Building Research Institute, Roorkee (India).

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TABLE 1

Efficiency Test Results with Tipping Tank on FRP Squatting Pans and PVC Traps (Indian Make)

A. 3.0 Litres Water Volume

S.No.	No. of Balls Flushed out of 30	No. of Sponges Flushed out of 4
1	29	4
2	30	4
3	29	4
4	30	4
5	30	4
6	30	
7	30	
8	29	
9	29	
10	30	

B. 2.0 Litres Water Volume

1	29	4
2	30	4
3	28	4
4	27	3
5	29	
6	30	
7	29	
8	27	
9	26	
10	27	

C. 1.5 litres Water Volume

S.No.	No. of Balls Flushed out of 30	No. of Sponges Flushed out of 4
1	25	4
2	25	4
3	24	3
4	22	4
5	26	3
6	24	
7	25	
8	24	
9	23	
10	25	

D. 1.0 Litres Water Volume

1	18	1
2	20	4
3	20	0
4	17	3
5	23	0
6	19	
7	17	
8	21	
9	17	
10	21	

TABLE 2

Efficiency Test Results with Tipping Tank on ITC Squatting Pan and Trap

1.5 Litres Water Volume

S.No.	No. of Balls Flushed out of 30	No. of Sponges Flushed out of 4	Sanitary Napkin Flushed out
1	29	4	Yes
2	30	4	Yes
3	30	4	Yes
4	30	4	Yes
5	28	4	Yes
6	30		
7	30		
8	29		
9	30		
10	30		

TABLE 3

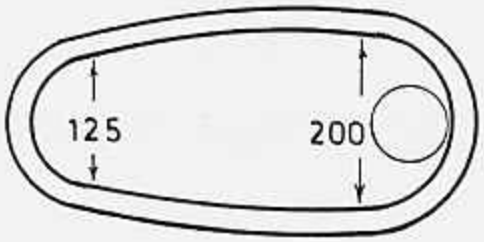
Test Results of Solid Transport Performance

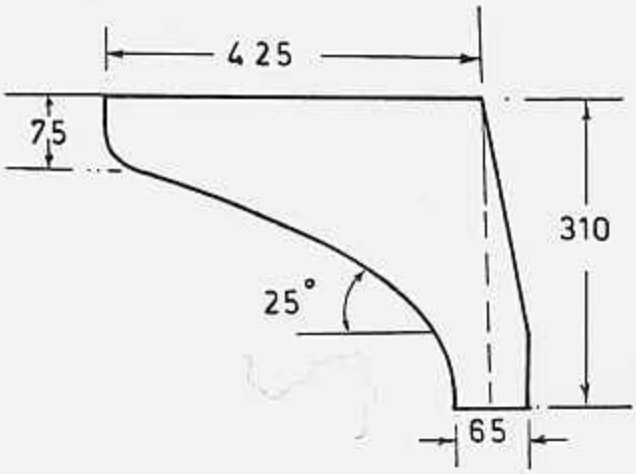
Pipe Diameter - 90 mm (outside)

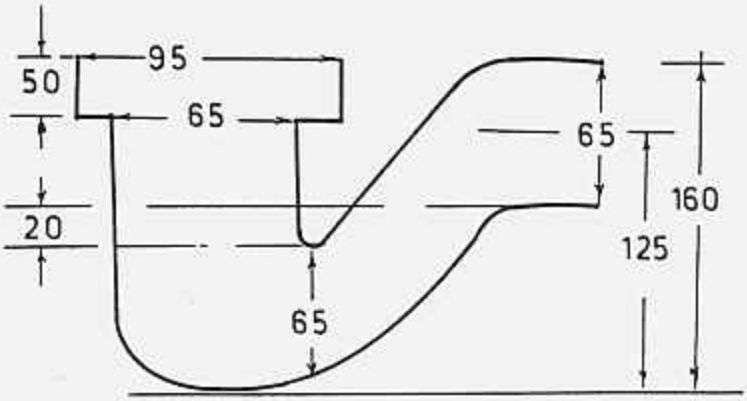
Test Object - Sanitary Napkin (150 gm wet weight)

Slope	Number of Flushes Required to Clear 15 metre length Flush Volume Litres			
	3.0	2.0	1.5	1.0
1 in 100	2	5	5	10
1 in 80	2	3	4	10
1 in 40	1	3	3	8
1 in 20	1	1	1	5

FIG. 1



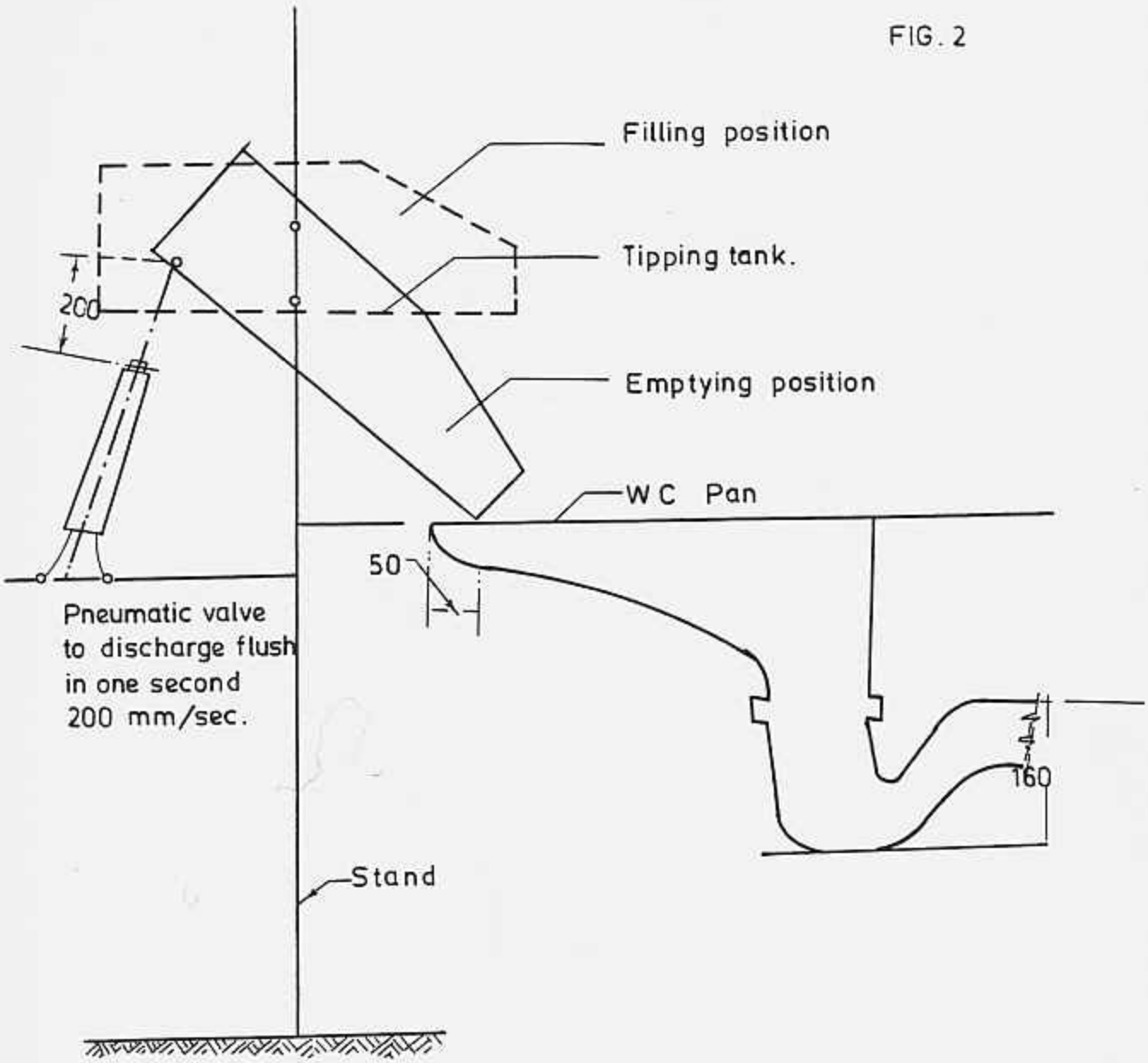




POUR FLUSH SQUATTING PAN AND TRAP

All dimensions are in mm

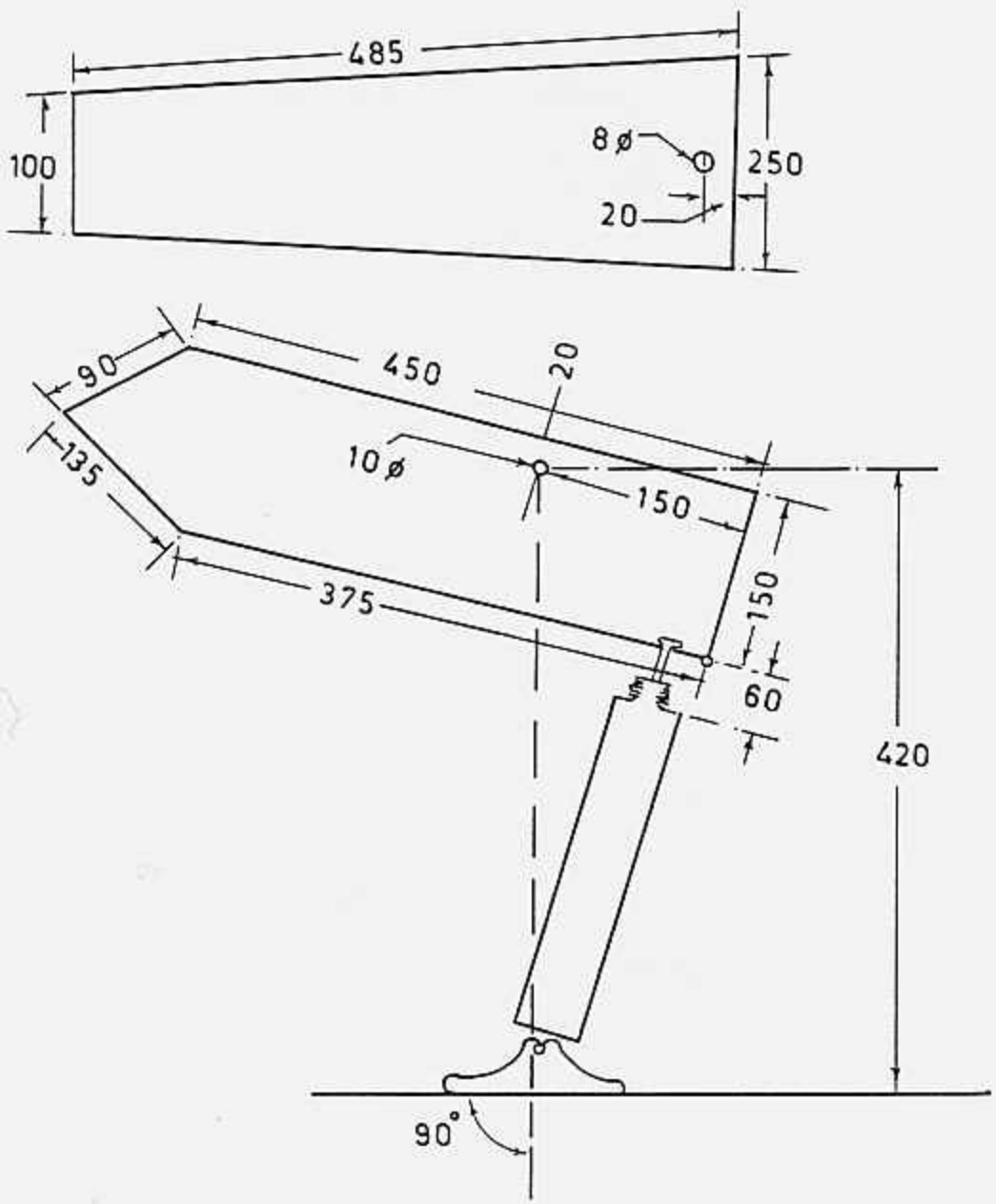
FIG. 2



TIPPING TANK TEST SET-UP

All dimensions are in mm

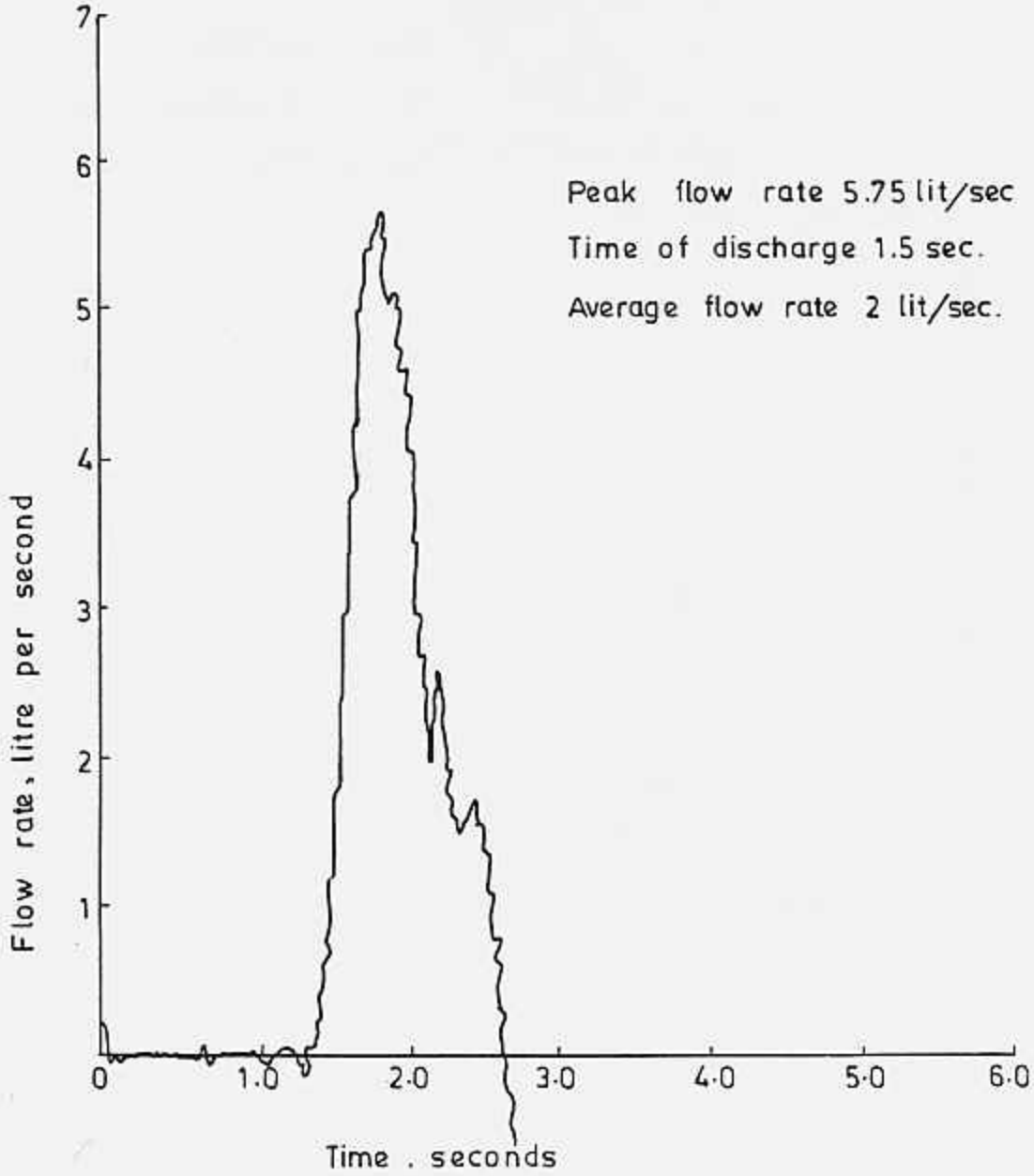
FIG. 3



DETAILS OF TIPPING TANK

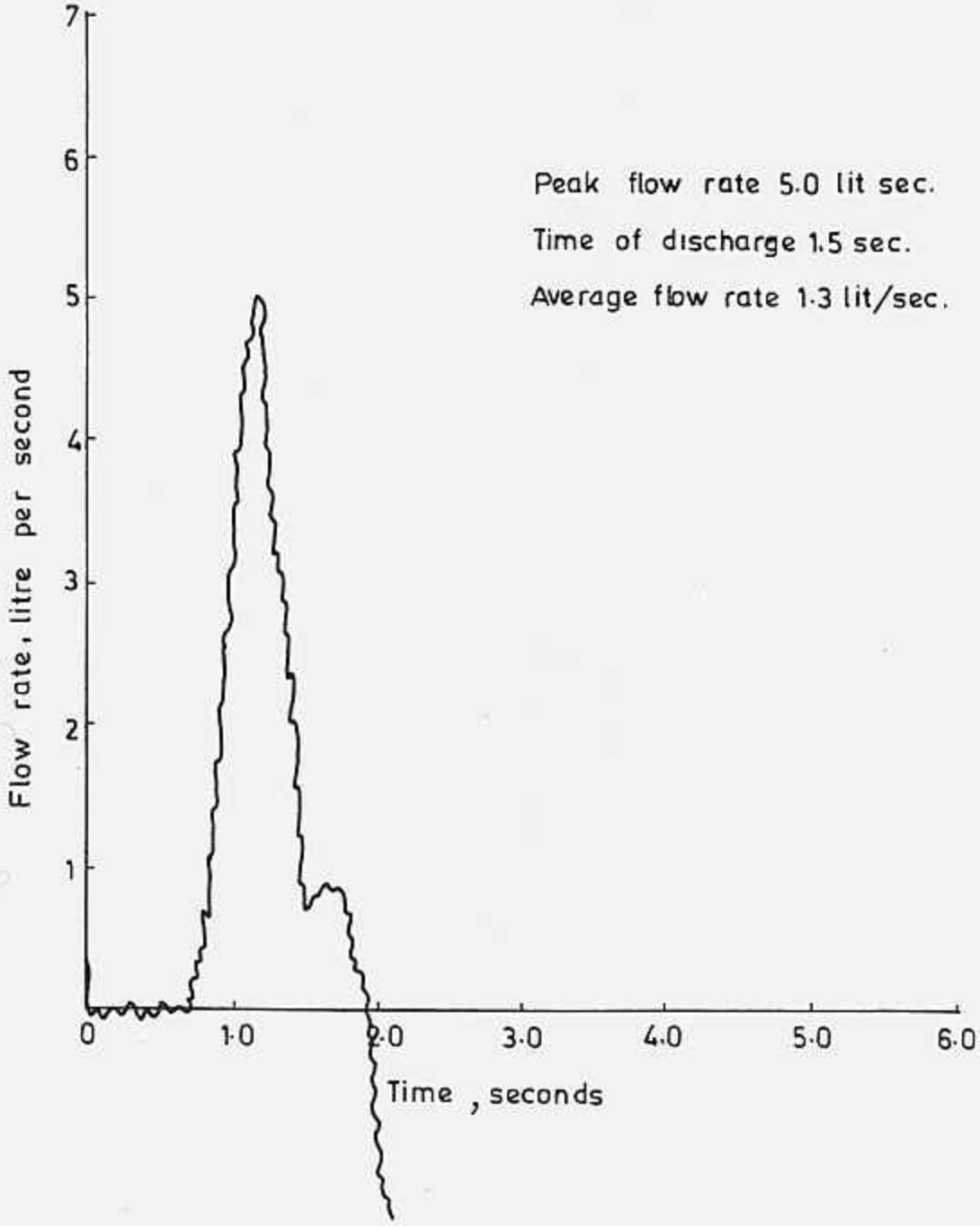
All dimensions are in mm

FIG. 4



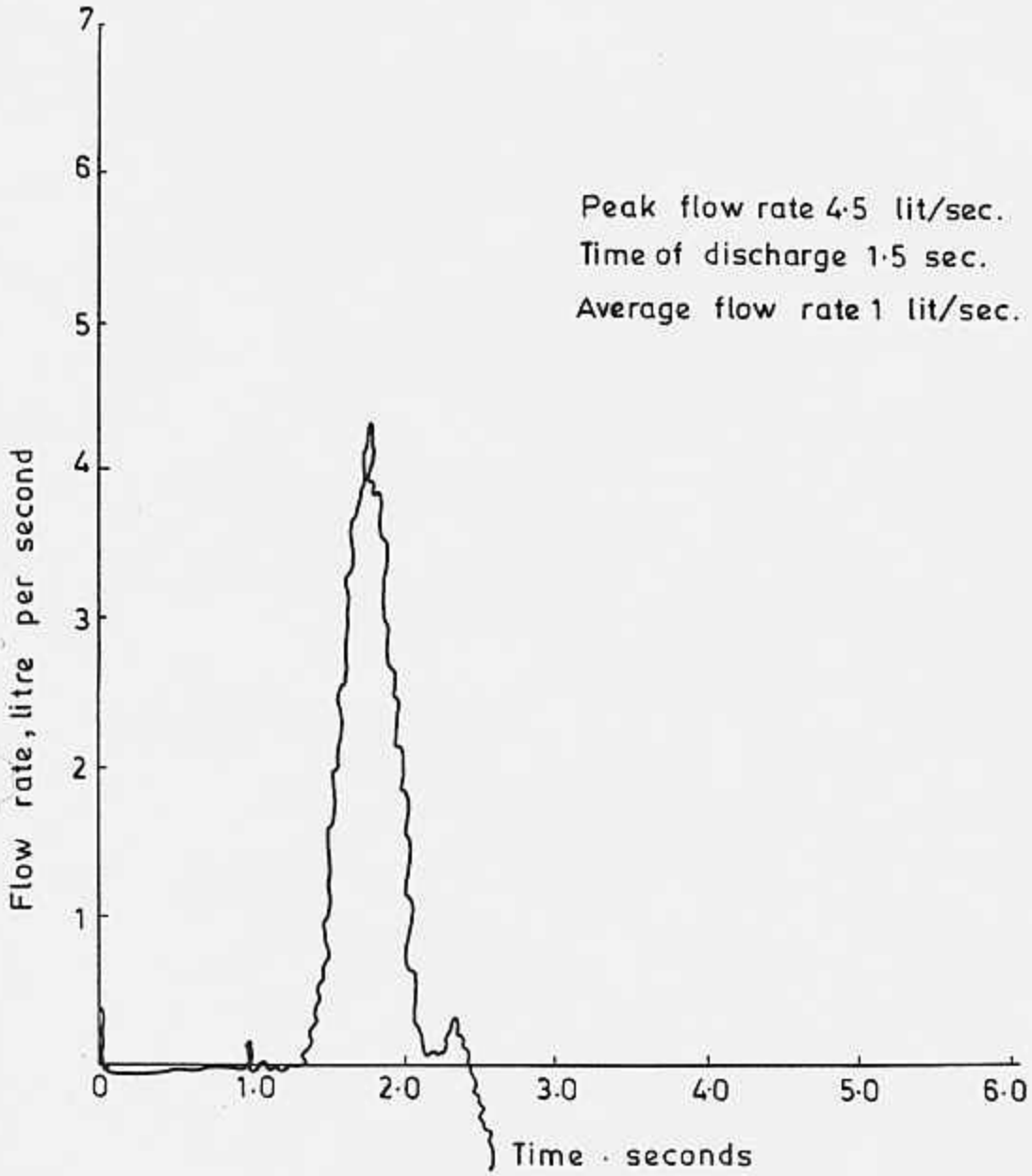
TIPPING TANK FLOW RATE CURVE (3.0 lit.)

FIG. 5



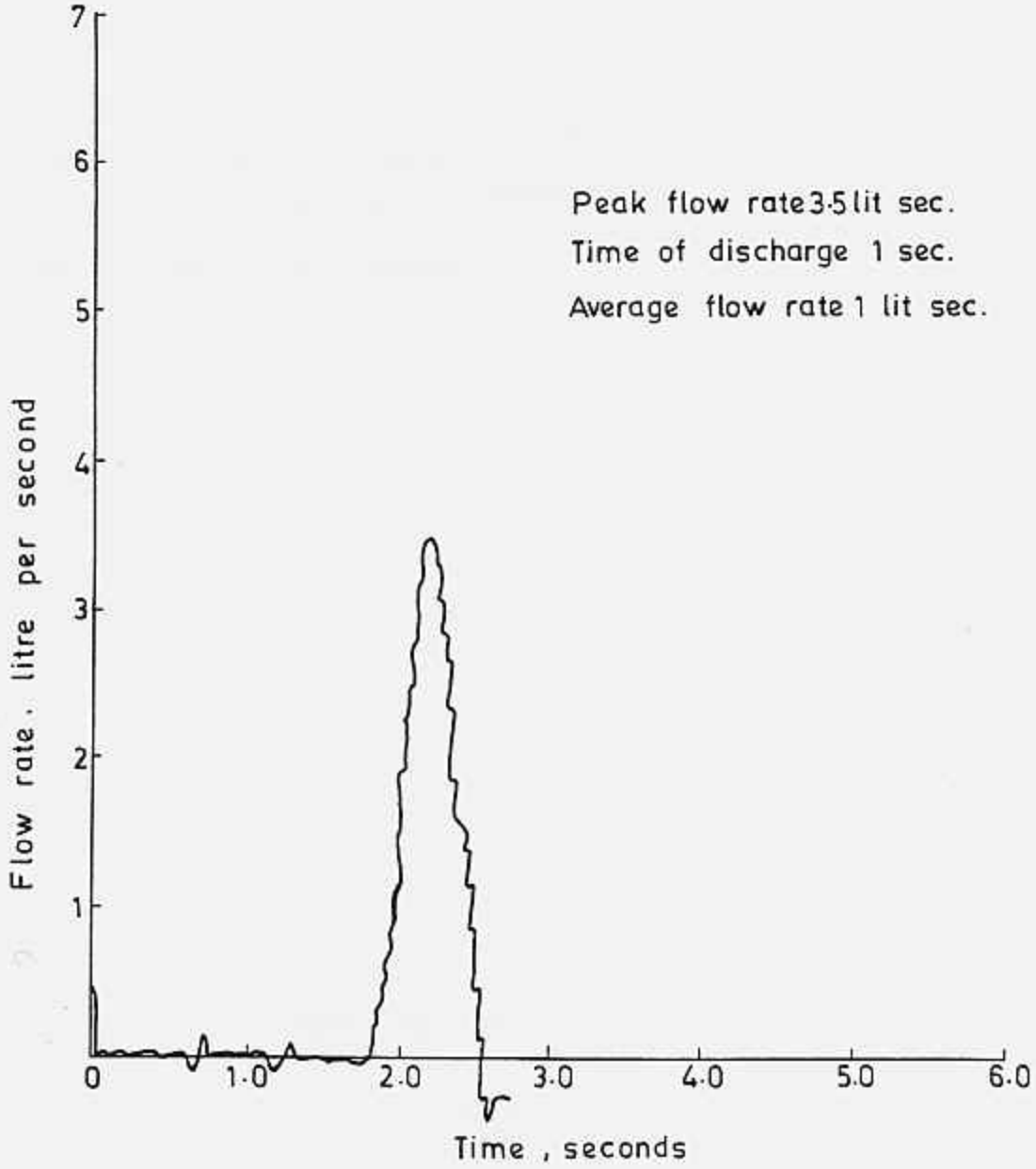
TIPPING TANK FLOW RATE CURVE (2.0 lit.)

FIG. 6



TIPPING TANK FLOW RATE CURVE (1·5 lit)

FIG. 7



TIPPING TANK FLOW RATE CURVE (1·0 lit.)

CIB

CIB-W62 SYMPOSIUM

Study on the Method for Calculating Water Consumption and Water Uses in Multi-Story Flats

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TOKYO, JAPAN



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12th CIB-W62 SYMPOSIUM - TOKYO -
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10,-1985 : KENCHIKU KAIKAN

Summary

Hunter's method utilizing fixture units has been used as the current design procedure to calculate the size of piping. Nevertheless, we cause several problems such as overload for design of piping in using this method.

Therefore, this paper described the water uses in multi-story flats and suggested a method based on the probability theory for calculating water consumption.

We can estimate the water load with the probability distribution of simultaneous uses of water. The probability distribution is derived theoretically by the queuing theory. At the model given with M/M/S types , Kendoll symbol , the probability of simultaneous uses of water is shown as the Erlang formula. Approching S,the number of fixtures ,to infinite,the probability distribution shows the Poisson distribution.

Analysing the water uses of the two multi-story flats, the probability distributions were shown approximately in the Poisson distribution.Therefore, the flow rates in the system equiped with the same and the different types of outlets could be calculated with these probabilities given in the Poisson distribution. These results were shown at small values in comparison with the Hunter's values.

In addition, the relation between loading units and loading curve was shown as a simplified method for the flow rate design of multi-story flats.

Résumé

la méthode de Hunter utilisant des appareils fixes a été utilisée en tant que procédure de conception courante pour calculer la dimension des canalisations. Néanmoins, nous occasionnons plusieurs problèmes tels le surdimensionnement des canalisations en utilisant cette méthode.

Ce document décrit donc l'utilisation de l'eau dans les appartements de bâtiments à plusieurs étages et suggère une méthode basée sur la théorie des probabilités pour calculer la demande en eau.

Nous pouvons estimer la quantité d'eau à l'aide de la densité de probabilité de l'utilisation simultanée d'eau. La densité de probabilité est dérivée de la théorie des files d'attente. Pour le modèle donné par les type M/M/S, selon Kendoll, la probabilité d'utilisation simultanée d'eau est donnée par la formule de Erlang. En faisant tendre S, le nombre d'appareils fixes, vers l'infini, la densité de probabilité tend vers une distribution de Poisson.

En analysant l'utilisation d'eau dans les appartements d'un bâtiment de deux étages, les densités de probabilité sont approximativement des distributions de Poisson. Aussi, les taux de débit dans les systèmes équipés d'appareils fixes de même type ou de types différents peut être calculés a l'aide des probabilités données par la distribution de Poisson. Les résultats se sont révélés être des valeurs plus faibles que celles données par la méthode de Hunter.

De plus, la relation entre les appareils de charge et la courbe de charge se révèle être une méthode simplifiée pour le dimensionnement des taux de débit pour les appartements de bâtiments à plusieurs étages.

Zusammenfassung

Als momentane konstruktionsmethode für die Größenordnung der Rohrverlegung wurde das Hunter-Verfahren gewählt, welches auf Installationseinheiten basiert. Trotzdem ergaben sich eine Reihe von Problempunkten, wie zum Beispiel zu der bei dieser Methode zutreffenden Konstruktionsweise zur Rohrverlegung.

Dementsprechend wird in dieser Studie die Wassernutzung in mehrstöckingen Mietshäusern beschrieben, und eine auf Wahrscheinlichkeitsrechnung basierende Methode zur Berechnung des Wasserbedarfs vorgeschlagen.

Die Wasserlast kann mit der Wahrscheinlichkeitsverteilung des gleichzeitigen Wasserverbrauchs berechnet werden. Die Wahrscheinlichkeitsverteilung wird theoretisch von der Warteschlangentheorie abgeleitet. Bei dem mit M/M/S-Typen, Kendoll-Symbol gegebenen Modell wird die Wahrscheinlichkeit für gleichzeitigen Wasserverbrauch als Erlang-Formel gezeigt. Mit S, der Nummer an Installationen, gegen Unendlich, zeigt die Wahrscheinlichkeitsverteilung die Poissant-Verteilung.

Bie der Analyse des Wasserverbrauchs für die beiden mehrstöckigen Mietshäuser werden die Wahrscheinlichkeitsverteilungen annähernd in der Poissant-Verteilung gezeigt. Deshalb lassen sich die Fließmengen bei Systemen mit identischen Installationen und bei Systemen mit verschiedenen Installationen mit den in der Poissant-Verteilung gegebenen Wahrscheinlichkeiten errechnen. Diese Ergebnisse zeigen sich im Vergleich mit Hunter-Werten als kleine Werte.

Zusätzlich wurde die Beziehung zwischen Lasteinheit und Lastkurve als vereinfachtes Verfahren für die Fließmengenkonzept eines mehrstöckigen Mietshauses dargelegt.

1. INTRODUCTION

The method by Roy B.Hunter(1) for calculating water consumption has been used for the calculation of pipe sizes. However, it is pointed out that we cause several problems such as over loading for design of piping, using this method. In European countries and U.S.A, the factors of the method by Hunter and new methods are studying(2 - 4). In Japan,there have been some studies in the some cases(5 - 10). Recently , the society of heating, air-conditioning and sanitary engineers of Japan proposed the new method for calculating water consumption in HASS 206-1976(11). However, the new method has some problems and the further studies are necessary for working out those problems.

Therefore,this paper suggests a method based on the probability theory for calculating water consumption and shows the results of calculating water consumption in multi-story flats based on the data. Moreover, the relation between loading units and maximum flow rates in flats is shown as a simple method for calculating water consumption, following the Hunter's Method.

2. THE METHOD FOR CALCULATING WATER CONSUMPTION

2.1 The probability of simultaneous uses and the procedure for calculating water consumption

We can calculate the water consumption with the probability distribution of simultaneous uses of water derived by analysing the uses of outlets. The procedure for calculating water consumption is as follows;

1) Decide the scale of a planning building (the number of occupants , the number of flats and so on)

2) Decide the frequency of use and the distribution of the using time in each fixture and water.

3) Decide the probability distribution of simultaneous uses of water.

4) Calculate the loading of systems consisted of same types or different types of outlets by the probability theory.

The probability distribution is introduced theoretically by the queuing theory(12). If the servers (fixtures) s are arranged in a row line, the proba-bility of the customer's arrival frequency is the Poisson distribution (random arrival) and the service time is the exponential distribution, the probability of the number of customers in the systems can be obtained by solving the equations of a state transition. The probabilities p_n being customers n in the systems are represented by equation (1).

$$\left.\begin{aligned} p_n &= \frac{a^n}{n!}p_0 \quad (0 \leqq n \leqq s) \\ p_n &= \frac{a^n}{s!\,s^{n-s}}p_0 \quad (s \leqq n) \end{aligned}\right\} \qquad \cdots\cdots(1)$$

where:

$$p_0=\left\{\sum_{n=0}^{s-1}\frac{a^n}{n!}+\frac{a^s}{(s-1)!\,(s-a)}\right\}^{-1} \qquad \cdots\cdots(2)$$

and:

$a=\lambda_f/\mu_f$ (the average number of simultaneous uses of fixtures)

$\rho=a/s$ (utilization factor, $\rho<1$)

λ_f : average arrival rate ($1/\lambda_f$: average interarrival time)

μ_f : average service rate ($1/\mu_f$: average using time)

Approaching the number of fixtures to infinite, the probability is approximted to the Poisson distribution as follow;

$$p_n=e^{-a}\frac{a^n}{n!} \quad (n\geqq 0,\ a>0) \qquad \cdots\cdots(3)$$

When all fixtures are occupied, the case which makes users return is called as the loss system. In this case there is the Erlang formula as follow;

$$p_n=\frac{a^n}{n!}\Big/\sum_{n=0}^{s}\frac{a^n}{n!} \quad (0\leqq n\leqq s) \qquad \cdots\cdots(4)$$

When $n=s$, p_s is called the probability of loss, the Erlang formula is established in any distribution of using time.

Therefore , if there are many fixtures used at random , the probability distribution of simultaneous uses of fixtures is approximated to the Poisson distribution shown in equation (3). Farthermore, the probability of outlets r being on from a total of such occupied fixtures n is shown in the binominal distribution $b(r;n,\eta)$. Hence, the probability distribution of simultaneous uses of water P_r is the compound distribution in equation (5) and can be expressed the Poisson distribution which includes the parameter $a\eta$.

$$P_r=\sum_{n=r}^{\infty}p_n b(r;n,\eta)=e^{-a}\eta^r\sum_{n=r}^{\infty}\frac{a^n}{n!}\binom{n}{r}(1-\eta)^{n-r}$$
$$=e^{-a\eta}\frac{(a\eta)^r}{r!} \qquad \cdots\cdots(5)$$

where: η = the mean time of water use / the mean time of fixture use

$a\eta$ = the average number of simultaneous uses of water

Equation (5) is derived from the procedure of customers using water after the arrival at a fixture. However, we can be derived the probability distribution in connection with the occurrence of water use, therefore this thought is applied in this paper.

2.2 A method for calculating water consumption

If the probability distribution of simultaneous uses of water is given, the

maximum loading of system, involving same types of outlets, is calculated by an assumed failure rate. At the group A involved same types of outlets, the probability is formularized in equation(6) in the condition that the random variable X takes the number of simultaneous uses x_{ai}.

$$P_A(X=x_{ai})=p_A(i) \qquad \cdots\cdots(6)$$

where: $x_{ai}=0,1,2,\cdots$ (x_{ai} :discrete variable)

$p_A(i)$: probability function

Therefore, the maximum loading of systems,involving same types of outlets, is derived from the value m_a which satifies equation (7) with failure rate K_p.

$$\sum_{x_{ai}=m_a+1}^{\infty} P_A(X=x_{ai}) \leqq K_p \qquad \cdots\cdots(7)$$

The Maximum flow rate $Q_{A\,max}$ in group A is calculated by equation (8) included the average flow rate of outlet q_a in simultaneous uses.

$$Q_{A\,max}=m_a q_a \qquad \cdots\cdots(8)$$

In the other systems involved different types of outlets, the flow rate is derived in term of probabilities with the conbinations of outlets, using the probability distribution of simultaneous uses in each group.

In above mentioned case,if we express the groups of outlets by A,B,C,... and the maximum numbers of simultaneous uses by $m_a, m_b, m_c, \cdots$, the probability distribution of simultaneous uses of systms involved different types of outlets $P_r(I)$ is derived by equation (9) with each outlet used independently.

$$P_r(I)=\{P_A(X=x_{ai})\}\{P_B(X=x_{bj})\}\{P_C(X=x_{ck})\}\cdots \qquad \cdots\cdots(9)$$

$x_{ai}, x_{bj}, x_{ck}, \cdots$ are the numbers of simultaneous uses in group A,B,C ,... and the numbers are discrete independent variables. Therefore, considering the maximum number of simultaneous uses of same types of outlets, the number of the conbination derived by $P_r(I)$ is shown by equation (10).

$$M_r=(m_a+1)(m_b+1)(m_c+1)\cdots \qquad \cdots\cdots(10)$$

The flow rate is calculated by equation (11) in the probability of equation (9).

$$Q_r(I)=x_{ai}q_a+x_{bj}q_b+x_{ck}q_c+\cdots \qquad \cdots\cdots(11)$$

where: $q_a, q_b, q_c, \cdots$ are the average flow rate of each outlet in the same manner as the same types above described.

Therefore, the procedure for caluculating the maximum flow rate in the system involved different types is as follows;

1) The flow rates calculated by equation (11) are selected stepwise from the minimum value upward.

2) $Q_r(I)$ is used for the selected values.

where: $I = 1,2,3,\cdots$ and $Q_r(1)=0$

3) The probability value corresponded to each flow rate is calculated by equation (9), and the values are accumlated.

4) The minimum value n_r is calculated by the accumulated value satisfied equation (12) with critical rate K_r .

5) The flow rate at the minimum value n_r is chosen as the maximum flow rate.

$$1-\sum_{I=1}^{n_r} P_r(I) \leqq K_r \quad (1 \leqq n_r \leqq M_r) \qquad \cdots\cdots(12)$$

In the above mentioned procedure, there is distinction between failure rate K_p and critical rate K_r for deriving the maximum number of simultaneous uses of system involved same types of outlets and the maximum flow rate of system involved different types of outlets. It is suitable for the both rates to take the range from 0.001 to 0.01 in planning.

The above description was developed by the probability theory. If the average values of the simultaneous uses of water are known in some buildings, the water consumption can be calculated with the approximation to the Poisson distribution.

If there are the frequency distribution of water use , the distribution of water using time and the flow rate distribution of outlets , the flow rate which changes everymoment can be calculated by the Simulation method.

3. ANALYSIS OF BASIC DATA FOR CALCULATING WATER CONSUMPTION

3.1 Research of water use in multi-story flats

For collecting of basic data for calculating water consumption , the research for water use was conducted in two multi-story flats, TK and TO. Where, the names are abbreviated. The building scale of TK was one tenement, 4-story house, divided into 24 flats. That of TO was two tenements, 5-story house, divided into 60 flats. Each flat had two rooms and one kitchen-dining in both cases.

The contents of the research were according to the water uses and the amounts of water. The research systems of water and fixture uses are shown in Fig 1. The water using time in each outlet was recorded automatically in the recording room, using the sensor of water use attached to the end of each outlet. The water supply systems for the wash clothes and the WC at TO were recorded by the flow switches installed in pipes. There were five cold water

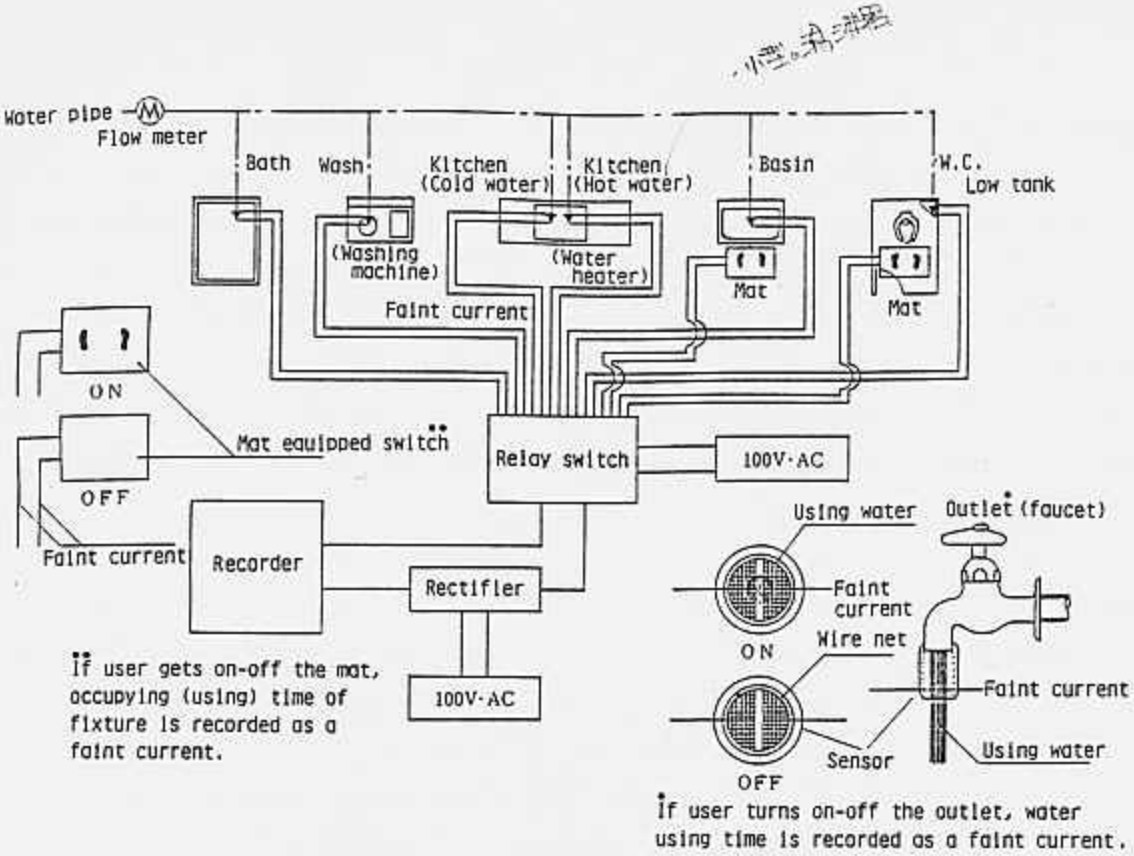
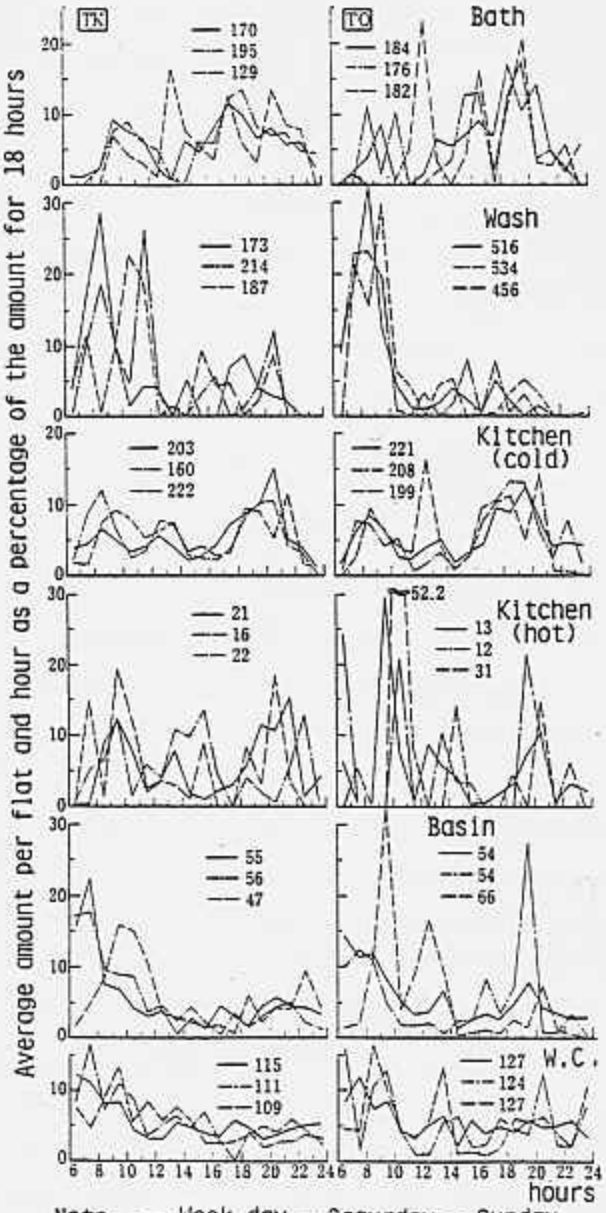


Fig 1. Measurements for using water and fixtures

outlets ; bath, wash basin installed washing machine, kitchen sink , WC and basin, and one hot water outlet; kitchen sink installd instantaneous gas water heater.The amount of water use was recorded by the flow meter of each flat at intervals of 10 minutes from 6:00 to 24:00. 19 flats of TK and 11 flats of TO were chosen as the subject of this research. The average number of occupants in each flat was 3.45 in TK and 3.54 in TO.In the case of TO,the children age took 0-6, and the babies 0-2 occupied for 70.6 per cent of them ; 17 persons. The research was conducted for the three groups and periods; 17-22 July 1974 on 10 flats of TK, 25-29 July 1974 on the other 9 flats and the former one flat of TK and 23-29 July 1975 on 11 flats of TO.

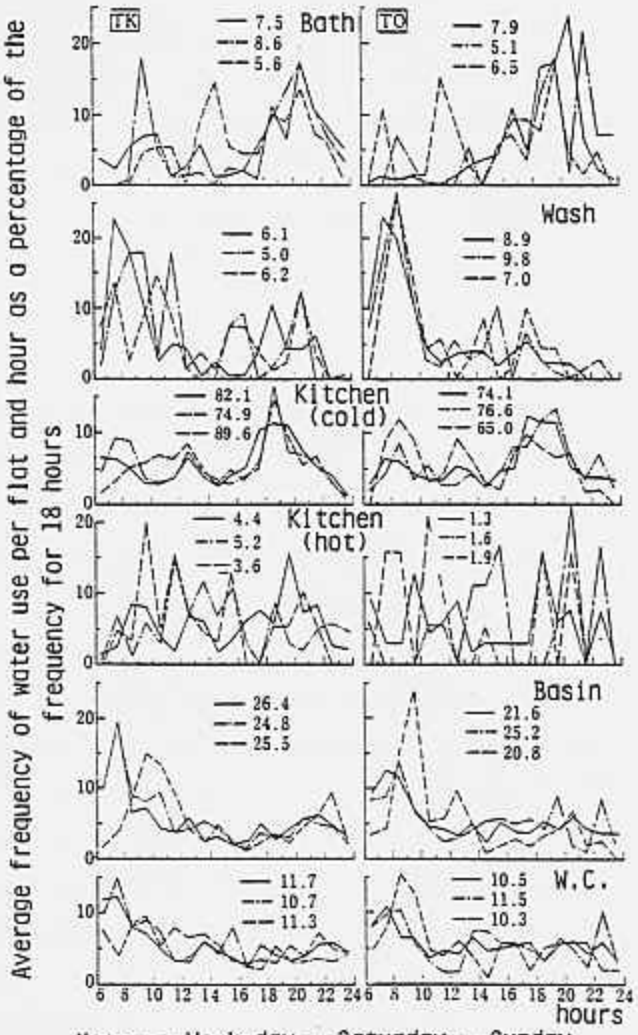
3.2 The water consumption in each water supply system

The average amount of water consumption per flat and hour of each type of outlet as a percentage of the amount for 18 hours (from 6:00 to 24:00) is shown in Fig 2 divided in three cases; on Sunday , Saturday and weekday. In those cases there are large variations in some patterns because of limited sample size. However, the character of each pattern can be recognized. Those characters are related to the occupants' life activities in a day. For example, the characters are recognized in the differences between the peak



Note: —Week day --Saturday --Sunday
The numbers in Figure show average amount consumption from 6:00 to 24:00 h (l/flat· 18 hours)

Fig 2. Average amount of water consumption



Note: —Week day --Saturday --Sunday
The numbers in Figure show average frequency of water use from 6:00 to 24:00 h (frequency/flat· 18 hours)

Fig 3. Average frequency of water use

time occured on weekday morning and that on Sunday morning at the basin and the WC. About the total water consumption in dwellings, there are commonly the largest peak caused by wash clothes in the morning, and the next peak caused by a kitchen and a bath in the evening.

The amount of water consumption per flat and day of each various water uses is shown for each number of occupants in Table 1. There is a large difference between the two multi-story flats in the case of wash clothes. The difference was caused by the number of babies and the way of wash clothes.

3.3 The frequency of water use

The average frequency of use per flat and hour for each type of outlet as a percentage of the frequency for 18 hours (from 6:00 to 24:00) is shown in Fig 3. The frequency of use at the kitchen is the largest and that of use at the basin is the next. The frequency of use of wash clothes in TO is about 1.5 times as many as that in TK. The amount of water consumption in TO is about 3.0 times as much as that in TK. In Fig 6 that gives the average using time of wash clothes per one turned on-off of outlet as mentioned later, the value in TO is about 1.5 times as long as that in TK. In Fig 7 that gives the average flow rate of wash clothes as mentioned later, the value in TO is about 1.2 times as large as that in TK. Therefore, the reason that the amount of water consumption at wash clothes in TO is about 3.0 times as much as that in TK depends on not only the frequency but also the way of wash clothes. The changing pattern of the frequency of water use did not always corresponded to that of the amount of water consumption, and the many differences could be shown at the peak time in the two cases.

The probability distributions of water use are shown in Fig 4 (a), (b) as the examples for the time of high frequency on weekday. The results of the data show that the distribution for each type of outlets is approximated to the Poisson distribution. Hence, the distribution of origination intervals of water use is approximated to the exponential distribution, and we can consider that the water use occured at random.

3.4 The water using time

The tendency of changing pattern of the water using time is approximated to that of the amount of water consumption shown in Fig 2. The mean water using time for each type of outlets is shown in Table 2. The hourly average water using time of turned on-off of outlet as a ratio of the hourly average using time of that for 18 hours (from 6:00 to 24:00) is shown in Fig 5. In the case of the different purpose of water use in same system, there were re-

Table 1. Amount of water consumption in each system of outlets (l/flat.day)

Number of occupants per flat	Name of falts	Each system of outlets						Sum of each system	Number of flats
		Bath	Wash	Kitchen (cold)	Kitchen (hot)	Basin	WC		
2	TK	164	172	187	2	66	115	706	3
		144*	144*	117*	3*	42*	79*	529*	2*
3	TK	157	154	182	7	42	85	627	5
	TO	161	487	178	27	64	137	1054	6
4	TK	172	200	208	31	55	124	790	12
	TO	179	464	250	0.3	37	93	1023	4
5	TO	277	878	305	13	92	220	1785	1

* These values show the amount of water cosumption except one flat which had consumed a great deal of water.

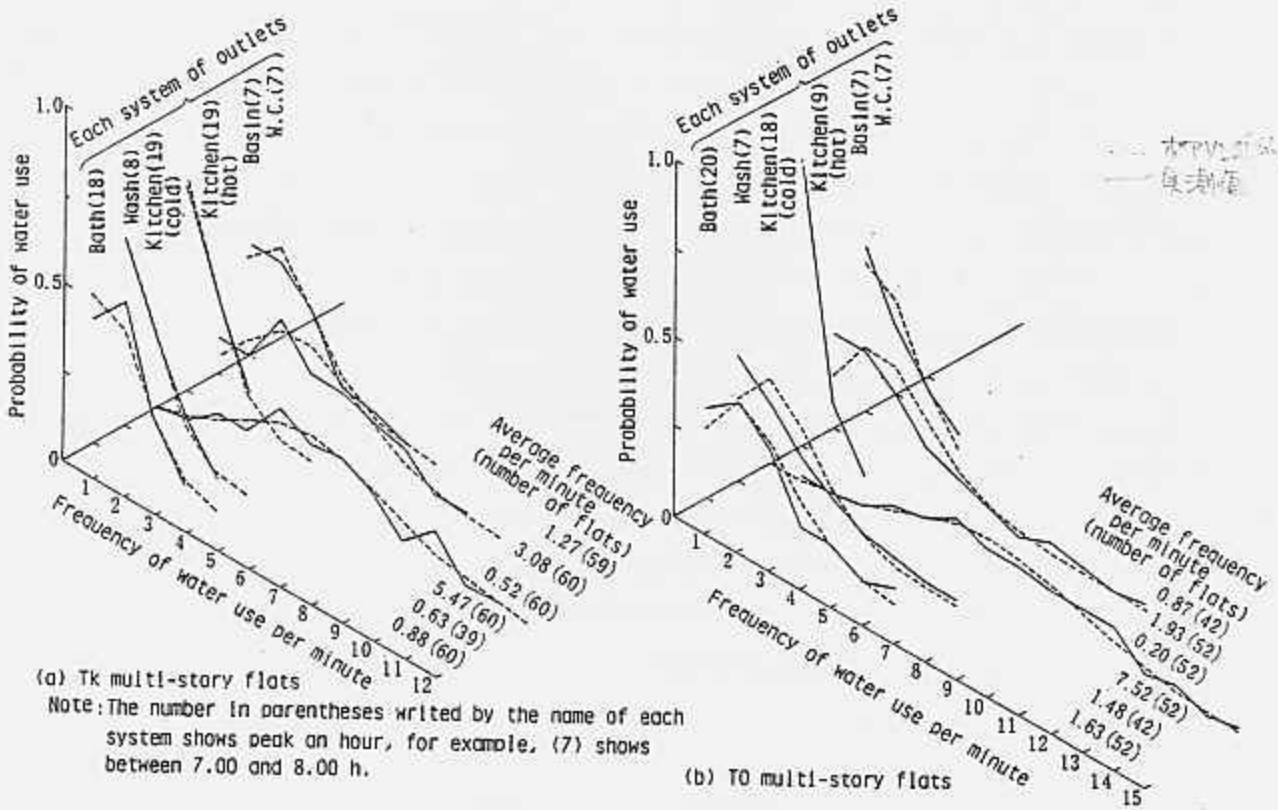


Fig 4. Probability distribution of water use

Table 2. Average water using time (s) per flat in each system of outlets

Each system of outlets	A day of the week	TK multi-story flats				TO multi-story flats			
		6-24	peak an hour			6-24	peak an hour		
		per flat (s/18h)	per flat (s/h)	occured time (h)	peak rate	per flat (s/18h)	per flat (s/h)	occured time (h)	peak rate
Bath	weekday	1102	160	17-18	2.62	1296	227	18-19	3.15
	Saturday	1346	214	17-18	2.85	1621	405	15-16	4.50
	Sunday	719	141	17-18	3.53	1123	264	12-13	4.23
Wash	weekday	1019	306	8- 9	5.41	2189	810	8- 9	6.66
	Saturday	1014	239	8- 9	4.24	2264	641	8- 9	5.10
	Sunday	982	233	10-11	4.26	1698	578	9-10	6.13
Kitchen (cold)	weekday	1702	177	17-18	1.87	1352	165	19-20	2.20
	Saturday	1410	201	8- 9	2.57	1367	179	18-19	2.36
	Sunday	1719	209	21-22	2.19	1119	151	17-18	2.43
Kitchen (hot)	weekday	244	42	21-22	3.09	137	39	9-10	5.12
	Saturday	176	27	9-10	2.76	124	35	6- 7	5.01
	Sunday	225	51	20-21	4.06	284	151	10-11	9.56
Basin	weekday	385	102	7- 8	4.76	377	59	6- 7	2.79
	Saturday	390	81	7- 8	3.73	424	84	19-20	3.57
	Sunday	337	55	10-11	2.96	450	138	9-10	5.54
WC	weekday	914	170	7- 8	3.34	1084	111	7- 8	1.85
	Saturday	667	113	7- 8	3.06	1110	116	8- 9	1.89
	Sunday	789	94	9-10	2.16	1039	164	8- 9	2.84

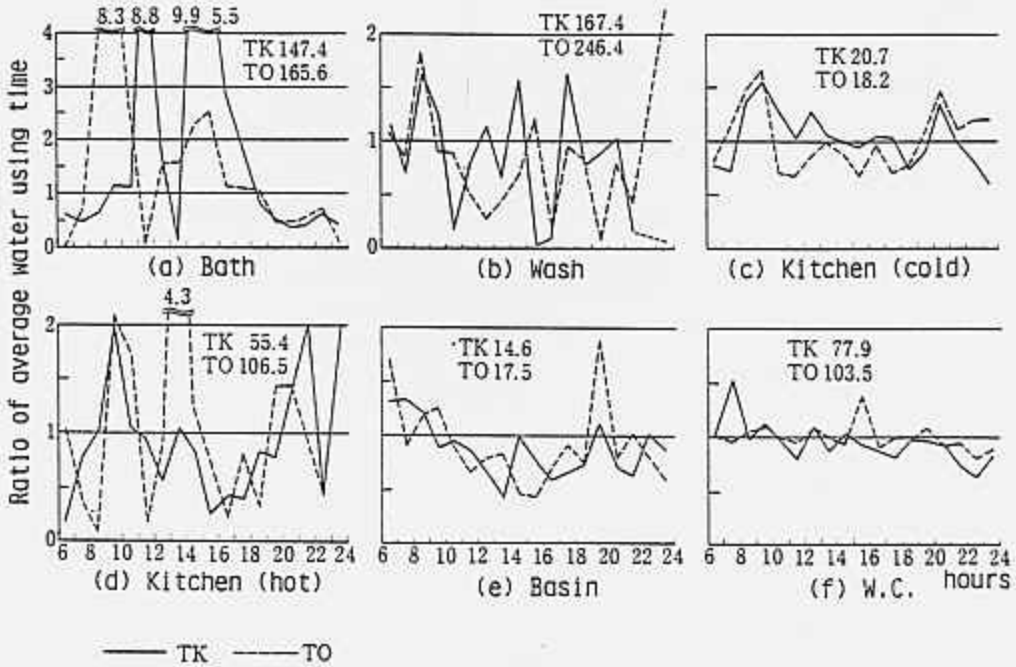
Note peak rate: (Water using time at peak hour) /
(Average using time per hour from 6:00 to 24:00h)

markable differeces between the mean water using time. For example,the using time was long at the time of pouring into the bath, clearing the table in the kitchen and washing face at the basin in the morning. The amount of effluent in the WC changes by selected valve,hence,there are no remarkable differences of hourly values in Fig 5. The cumulative frequency distribution of the water using time for turned on-off of outlet is shown in Fig 6. The distributions are approximated to the exponential distribution or the hyper exponential distribution except the case of WC in TO. However, water using time in the time occured both activities of pouring into a bath and taking a bath is not approximated to the two distributions as shown at the bath in TK. As shown at the WC in TO, if many occupants select the high volume valve, the distribution of water using time is approximated to the Erlang distribution.

3.5 The flow rate of outlet

The flow rate is determined by pressure, pressure loss in pipes,opening of outlets and so on. The user controlls the flow rate by the opening of outlet for each purpose.

The histogram of used flow rate as a percentage of total frequencies recorded for 10 days in TK is shown in Fig 7. The average flow rate of each type of TO is in parentheses of Fig 7. In the cases of hot water supplyer at

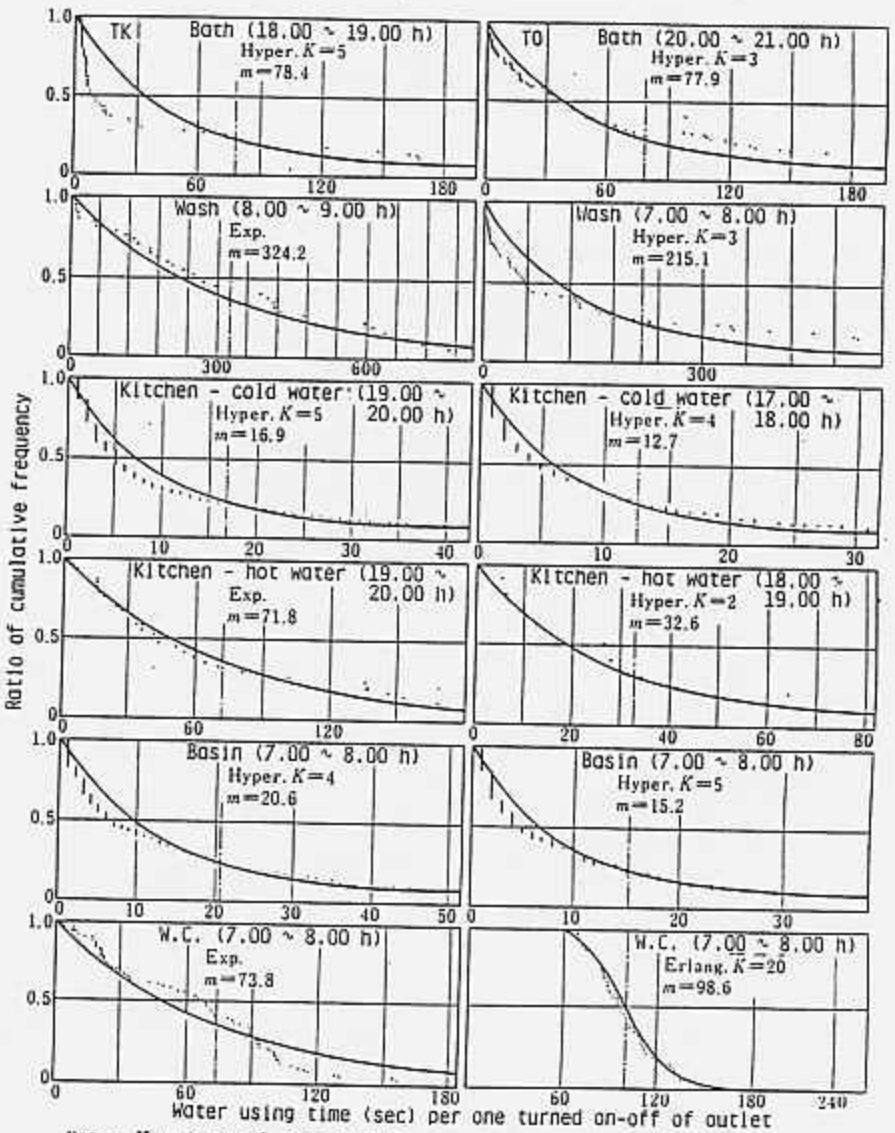


Note: The numbers in Figure show average water using time for turned on-off of outlet from 6:00 to 24:00 h.

Fig 5. Average water using time

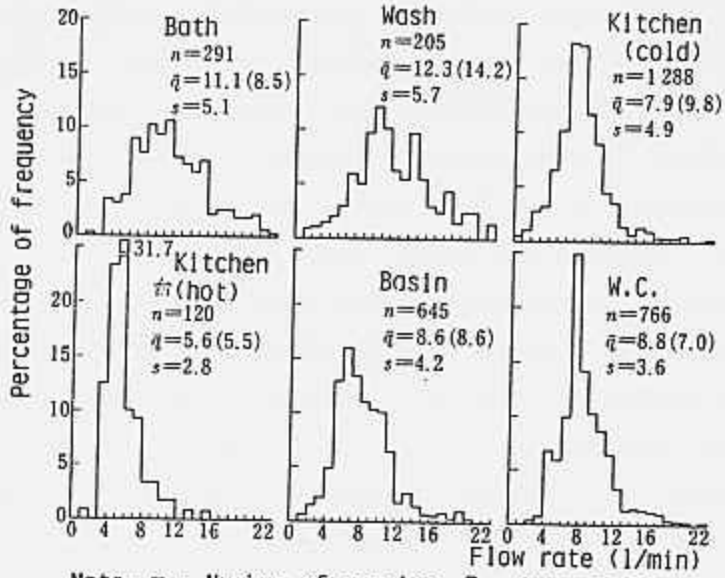
the kitchen and low tank at the WC, the flow rates are limited by the character of the equipments,hence, the variances are smaller than the other cases. Furthermore, flow rates are affectd by the number of simultaneous uses. Fig 8 shows the histogram of flow rates in each case of the number of simultaneous uses at the wash clothes in TO. The controlled range of flow rate is wide in using one outlet, whereas the range and the flow rate are limited with increasing the number of simultaneous uses.

Therefore, the needed flow rate of each type has to be considered in connection with using function , saving water,user's opinion and so on. With the present studies and researches, the author thinks that the flow rate expected in the maximum number of simultaneous uses is required to satisfy the average



Note: K ; phase of distribution, m ; average water using time (sec.) for turned on-off of outlet.

Fig 6. Distribution of water using time



Note: m ; Number of samples, q̄ ; Average flow rate (l/min) the value of TO shows in parentheses, s ; Standard deviation

Fig 7. Histogram of flow rates

Case	Number of simultaneous uses	Number of samples	Average flow rate	Standard deviation
①	1	308	15.9	4.8
②	2	145	27.1	3.9
③	3	72	32.4	2.5
④	4	40	35.2	1.5
⑤	5	8	37.2	1.0

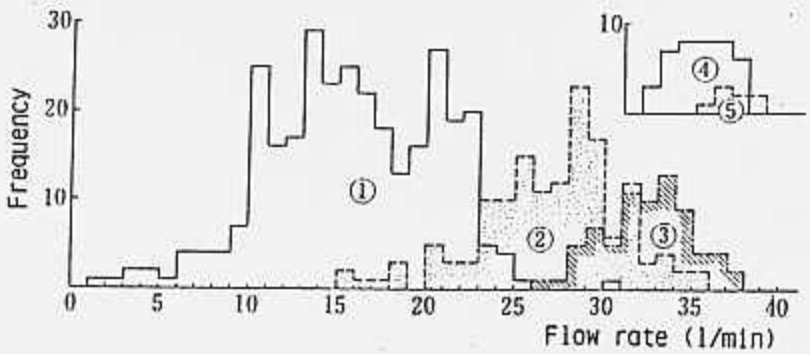


Fig 8. Changes of flow rates by the number of simultaneous uses, wash clothes in TO.

flow rate described in Fig 7 for calculating load.

3.6 The probability distribution of the simultaneous uses of water

Considering the frequency and the using time distribution of water uses, the probability distribution of simultaneous uses of water in peak hour is estimated to be approximated to the Poisson distribution by the queuing theory.The results of recorded data are shown in Fig 9 (a),(b) exampled on weekday. The distribution in each type is approximated to the Poisson distribution. The hourly average number of simultaneous uses of water per flat is shown in Table 3.

4. ANALYSIS AND CALCULATED RESULTS OF WATER LOADING

4.1 Calculated results by the probability method

The calculated results of water loading are shown on the basis of the probability method and the data of water uses in the multi-story flats above mentioned.

The average numbers of simultaneous uses of water were utilized the values shown in Table 3 and the probability distribution was applied the Poisson distribution on the conditions of calculation. The maximum values were selected for the calculation of each type of same outlet within the values

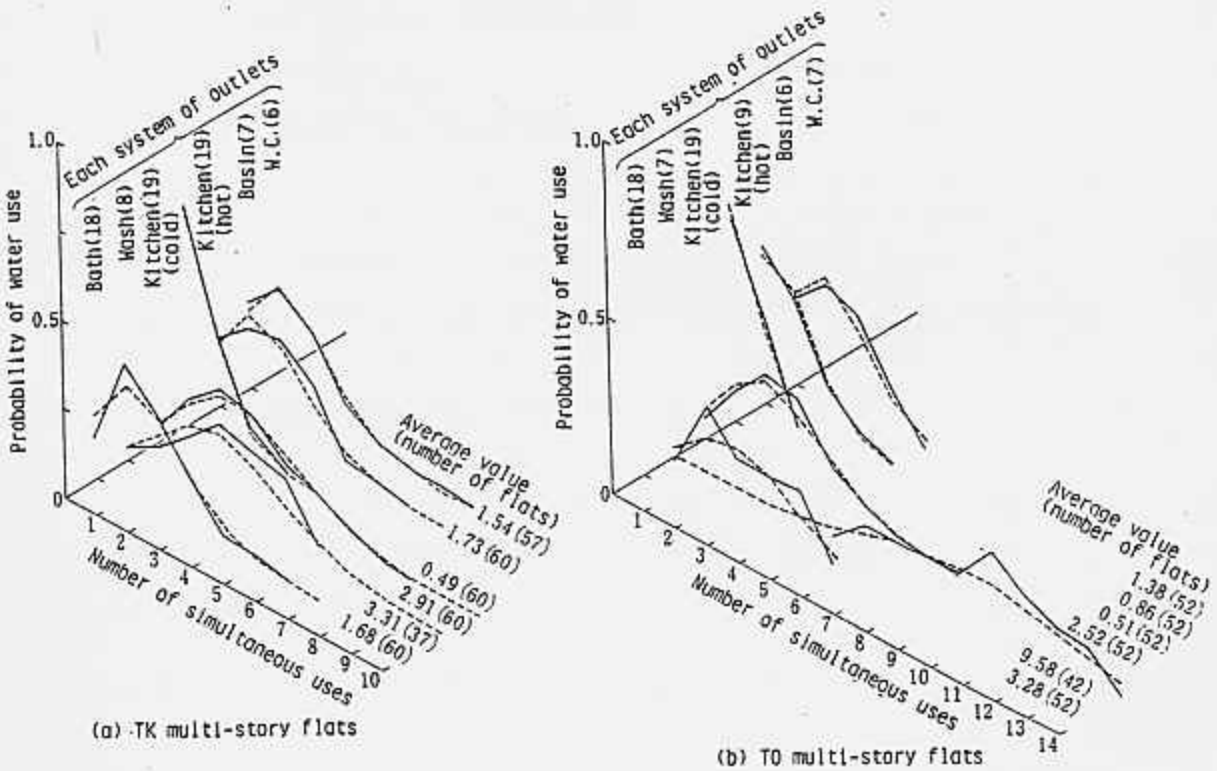


Fig 9. Probability distribution of simultaneous uses of water

Table 3. Average number of simultaneous uses of water

Hours	Name of flats	Each system of outlets					
		Bath	Wash	Kitchen (cold)	Kitchen (hot)	Basin	WC
6 - 7	TK	0.003	0.012	0.031	0.000	0.015	0.027*
	TO	0.000	0.063	0.007	0.002	0.017*	0.026
7 - 8	TK	0.004	0.047	0.026	0.001	0.029*	0.025
	TO	0.001	0.195	0.024	0.000	0.012	0.033*
8 - 9	TK	0.010	0.085*	0.037	0.006	0.009	0.018
	TO	0.010	0.228*	0.028	0.001	0.015	0.022
9 - 10	TK	0.022	0.034	0.022	0.008	0.008	0.017
	TO	0.026	0.061	0.030	0.010*	0.009	0.024
17 - 18	TK	0.036*	0.018	0.036	0.002	0.004	0.012
	TO	0.016	0.036	0.034	0.001	0.004	0.020
18 - 19	TK	0.028	0.024	0.043	0.003	0.002	0.009
	TO	0.063*	0.013	0.035	0.002	0.004	0.014
19 - 20	TK	0.017	0.011	0.048*	0.008	0.005	0.009
	TO	0.028	0.001	0.048*	0.003	0.009	0.022
20 - 21	TK	0.016	0.014	0.047	0.008	0.005	0.009
	TO	0.041	0.011	0.028	0.004	0.005	0.019

* These are the values in peak hours. Peak hour by the kitchen (hot) in TK occured between 21.00 and 22.00h, and the average number was 0.012.

Table 4. Standard flow rate (l/min) in each system of outlets

	Bath	Wash	Kitchen (cold)	Kitchen (hot)	Basin	WC
As to use more than two outlets	12	13	10	5	10	10
As to use one outlet	20	25	15	6	15	15

given in Table 3. Furthermore,the values between 8:00 and 9:00 were selected for the calculation of the total water consumption involved different types of outlets, for the reason that the maximum amount of water consumption was caused mainly at that time zone. The values of the average flow rate of outlets are shown in Table 4. In Table 4 the values of the upper spaces are selected from the experimental values as the average flow rate to be utilizable at the maximum number of simultaneous uses. The fewer the number of simultaneous uses occurs, the wider the controlled range of flow rate will be. The values of the lower spaces give the flow rate used with the one outlet.

Fig 10 shows the maximum flow rate in each type of same outlets. In this case, the criterion of the failure rate K_r is 0.002. The value of wash clothes in TO showed the very larger than that in TK. If we make a decision according to the other investigations, it will be suitable to understand that the value in TK is ordinary. Fig 11 shows the maximum flow rate to 100 flats involved the all same and different types of outlets. In this case, the criterion of the critical rate K_r is 0.002. Moreover, the sum of flow rate which was calculated in each type of outlets to 1000 flats on the time between 8:00 and 9:00 is shown in Fig 11 It is clear that the difference between the value which is calculated with the probability of combination in different types of outlets and the total value which is calculated with the probability in each type of outlets.The loading curve in TO shows large value effected by the wash clothes.In comparison with the values by Hunter's method and Sato's investigation(13), the result of calculation by the probability of combination is simulate approximately to Sato's investigation.

4.2 Calculated result by the easy method utilized loading unit

The method for calculating water consumption by Hunter's Curve is convenience. However, it is clear that the values give the overload for the design of piping size from the above mentioned contents. Nevertheless,the method has valuable contents to be analysed in the process of getting the fixture units. Therefore, in addition to the above mentioned results, new loading units and flow curve are shown nearly the hunter's method.

For determining the loading units in each type of outlets, Fig 10 was utilized. We can consider that the number of outlets is equal to the number of flats in Fig 10, for each of flats equips one outlet of each type. Therefore, the relation between the flow rates and the number of outlets can be gotten. For example, in each flow rate; 0.5,1.0,2.0,3.0 and 5.0 l/s,the ratios of the number of each type of outlets by standardizing the number of basin in TK are shown in Table 5(where; the number of basin in each flow rate of TK set-

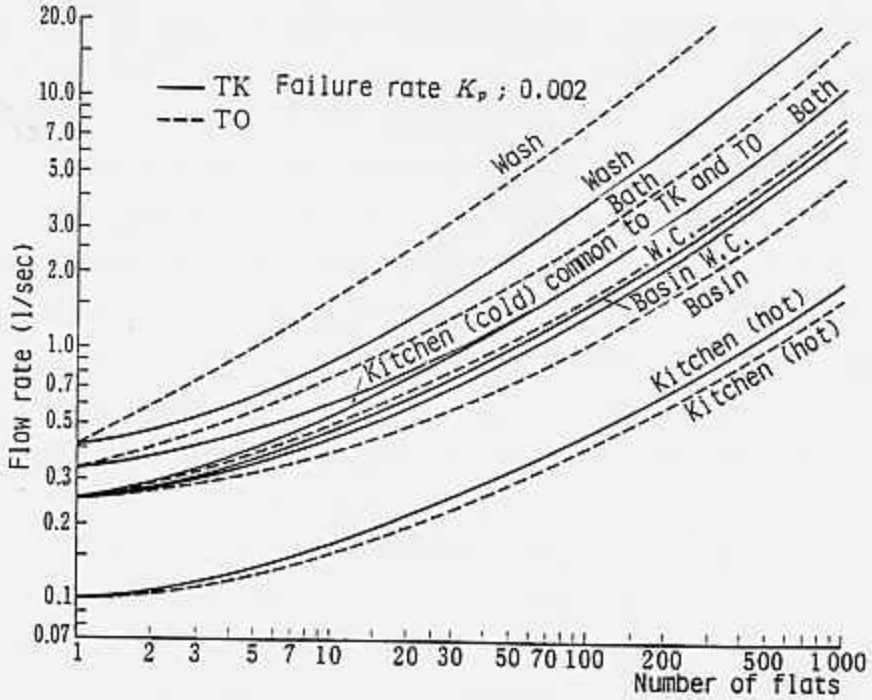


Fig 10. Flow rates in each type of outlets

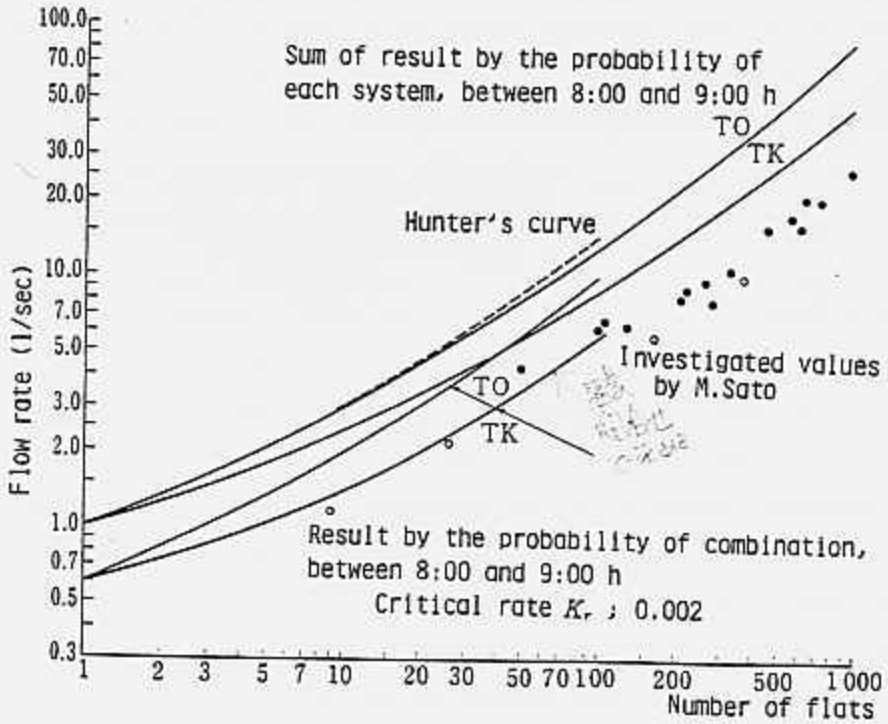


Fig 11. Flow rates involved the same and the different types of outlets

Table 5. Loading units

Flow rate (l/s)	Name of falts	Each system of outlets					
		Bath	Wash	Kitchen (cold)	Kitchen (hot)	Basin	WC*
0.5	TK	2.0	4.6	1.4	0.1	1	0.8
	TO	3.1	8.0	1.4	0.1	0.6	1.2
1.0	TK	1.6	3.9	1.5	0.1	1	0.9
	TO	2.8	10.0	1.5	0.1	0.5	1.1
2.0	TK	1.5	3.9	1.5	0.1	1	0.9
	TO	2.6	10.6	1.5	0.1	0.6	1.1
3.0	TK	1.6	4.0	1.6	0.1	1	0.9
	TO	2.6	10.6	1.6	0.1	0.6	1.1
5.0	TK	1.6	3.9	1.6	0.1	1	0.9
	TO	2.6	10.6	1.6	0.1	0.6	1.1
average	TK	1.7	4.1	1.5	0.1	1	0.9
	TO	2.7	10.0	1.5	0.1	0.6	1.1
loading units		2	4	1.5	0.5	1	1

* Low tank system is equiped at the WC.

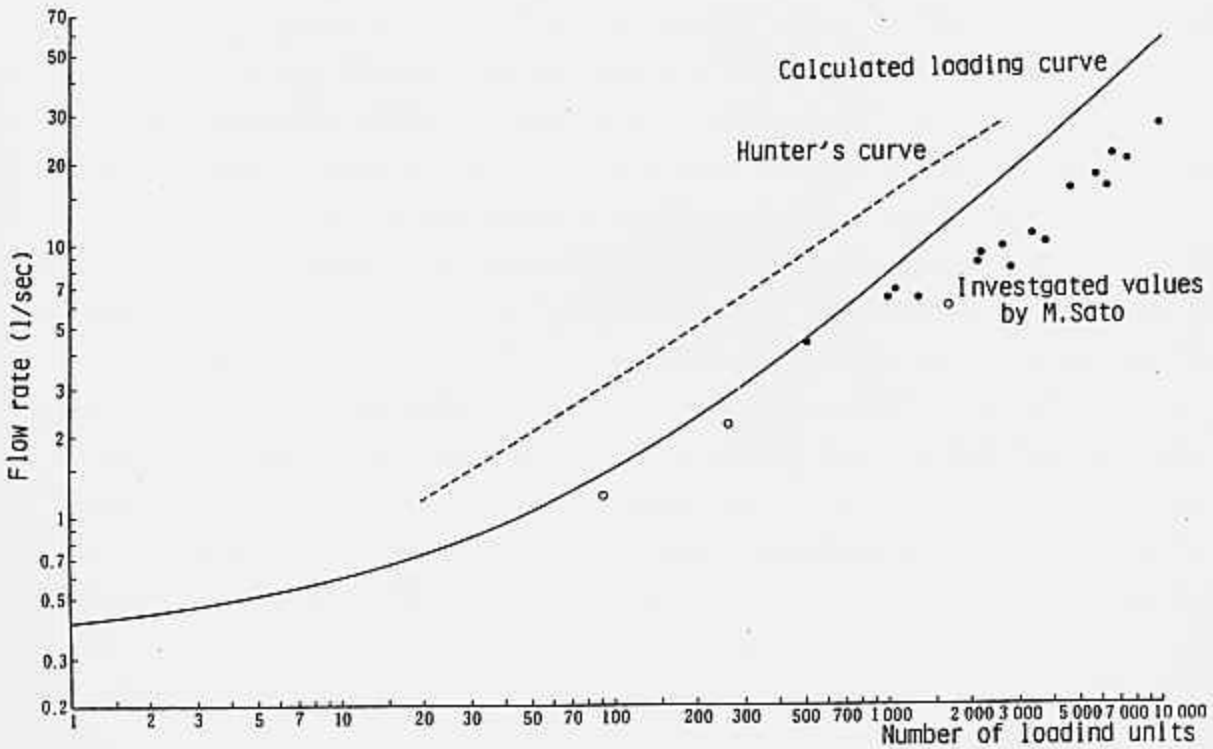


Fig 12. Flow rates based on the number of loading units

tles to unit 1). In this paper the flow rates are settled between 0.5 l/s and 5.0 l/s,however,we can select the flow rate at our pleasure.The values in the same type of outlets are similar in each flow rate, therefore the average values of these for loading unit are shown at the lowest spaces in Table 5. However, the loading unit of wash clothes was calculated from the values of TK because of the values of TO were not considered ordinary. Furtheremore, the loading unit of hot water in the kitchen was settled larger than the calculated average values to be utilized not only in summer but also in other seasons.

The relation between the flow rates and the loading units is shown in Fig 12. In Fig 12 the loading curve less than 6 flats was made some changes in the values. To utilize the loading curve is a easy method for the calculation of water consumption. However, the user has to know that the total maximum flow rate calculated in this method on the time between 8:00 and 9:00 gives more than the expected amount, for the loading units are settled from the maximum flow rates in each type of outlets. Nevertheless , the calculated valules are half as large as Hunter's values.

5. CONCLUSION

This paper described a method for calculating water consumption for designing a pipe size and the results of analysing the water uses in multi-story flats.

The main conclusions from this study are as follows;

1. The probability distribution of the number of simultaneous uses of water can be derived by the queuing theory with using the data ; the intervals between water uses and the distribution of water using time.
2. The amount of water consumption for designing a pipe size can be calculated with the probability distribution of simultaneous uses of water,using a method based on the probability theory.
3. The intervals between water uses can be considered to be occured at random, and the distribution of water using time can be approximated to the exponential distribution or the hyper exponential distribution by the results of water uses in multi-story. Therefore, the probability distribution of simultaneous uses of water can be approximated to the Poisson distribution.
4. The result of calculating water consumption based on the probability theory using the distribution of simultaneous uses of water is a great deal lower than that of Hunter's method.
5. Considering above mentioned results , the relation between loading units and maximum flow rate was shown as a simplified method.

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CIB-W62 SYMPOSIUM

Introduction of Calculation Method of Sanitary Fixtures in Japan

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TOKYO, JAPAN



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WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9. 10. 1985 : KENCHIKU KAIKAN

Summary

In December, 1983, an original quantity estimation method for sanitary fixtures was proposed by the Society of Heating Air-Conditioning and Sanitary Engineering of Japan. The essence of this estimation method is the application of the " queuing theory ", where the access time while the fixtures are " occupied " is utilized as the evaluating factor.

In this paper, the concept of simulation model with the use of GPSS (General Purpose Simulation System) simulation language, which is partly adopted in the above-mentioned estimation method, is introduced, with the relation among design number of persons, quantity of installed fixtures and access time shown through an example on urinals in an office building. As a result, proposed number of fixtures, estimated under NPC or other existing estimation methods, were compared with access time and the service level of each estimation methods were shown.

Résumé

En décembre 1983, une formule d'évaluation du nombre des installations sanitaires originaire du Japon a été proposée par la Société Technologique de Régularisation de l'Air et de l'Hygiène.

L'essentiel de cette formule est constitué par la Théorie de l'Attente en considérant les heures d'attente avant utilisation de l'installation sanitaire comme fonction évaluée.

Ce rapport présente le mécanisme du modèle de simulation avec la langue de simulation du GPSS (General Purpose Simulation System) adoptée partiellement pour cette formule d'évaluation, et indique le rapport entre les heures d'attente et le nombre d'utilisateurs estimé et le nombre d'installations sanitaires en citant comme exemple la cuvette du bâtiment des bureaux.

En conséquence, le niveau de service a été vérifié en comparant les heures d'attente avec le nombre d'installations proposées conformément au NPC (National Plumbing Code) et aux formules d'évaluation déjà existantes.

Zusammenfassung

Im Dizember 1983 wurde von der wissenschaftlichen Gesellschaft der Luft-Reinigung und Hygiene eine für die Japaner eigene Methode der Berechnung für die Geschirr in der Toilette vorgelegt, die die Wartezeit bei der Benutsung der Toilette als Funktion der Schâtzung nimmt - eine Theorie der Wartezit. Dieser Bericht stellte die Gedankenweise des Modells des Systems der Simulation vor, die das Sprache der Simulation von GPSS (General Pursose Simulation System) benutzt. Duses Sprache ist teilweise auch in dieser Methode der Berechnung aufgenemmen.

Der Bericht nahm als Beispiel die Toilette eines Büros und zeigte eine Zusammenhang swischen der geplannten Zahl der Benutser, der Zahl der Geschirr und der Wartezeit. Die vorgelegte Zahl der Geschirr durch die Methode der Berechnung von NPC (National Plumbing Code) oder anderer bestehender wurde im Zusammenhang mit der Wartezeit verglichen. Dadurch wurde das Niveau des Service jeder Methode der Berechnung klargemacht.

Preface

The applicable Japanease standard on quantity estimation of sanitary fixtures is, for the most part, modeled after the National Plumbing Code (NPC) of the United States. This standard, however, does not provide clear definition on the relation between the quantity of installed fixtures and the degree of satisfaction by the user.

In these circumstances, a subcommittee to study the proper quantity of fixtures was formed under the committee on Plumbing Equipment Standards of the Society of Heating, Air-Conditioning and Sanitary Engineering of Japan. After six years of research and investigation, the subcommittee submitted a proposal on the proper quantity of sanitary fixtures for buildings classified according to their intended use (i.e., offices, department stores, dormitories, hospitals, theaters and schools) in December, 1983.

The authors of this paper were able to recreate the utilizing condition of sanitary fixtures by drawing up a mathematical model, based on the simulation language of GPSS (General Purpose Simulation System). The basic data for the simulation were obtained through actual survey on the utilizing condition of sanitary fixtures by those engaged in representative work category in an office building selected as the subject of the survey.

With this method, relation between design number of persons and required quantity of sanitary fixtures can be

obtained with the maximum access time as the parameter.

As a result, service level of proposed quantity of fixtures, as derived by NPC or other estimation methods, were able to be evaluated by access time.

The concept of the above-mentioned estimation method have been partly adopted in the results of the aforementioned committee.

1. Traditional Studies of Sanitary Fixture Evaluation as Compared with This Method

Generally speaking, the number of sanitary fixtures in office buildings is supposed to be determined on the basis of optional use, that is, in view of the cases where people need not wait when they use a sanitary fixture. As regards how to determine the number of sanitary fixtures there have been a variety of evaluation methods so far proposed in Japan[4),5),6)], including the National Plumbing Code (NPC)[2)] and the Enforcement Ordinance on Industrial Safty and Health[3)], where the number of sanitary fixtures is uniformly subject to the proposed number of personnel established.

All the above methods which have been prevailing in Japan, excluding NPC and BOISH, were based on overflow or surplus probabilities, where users' attributes involving their working condition were evenly and uniformly handled, according to the frquency of use on all-day or peak-time basis.

In this study, we turned our attention to the length of access time, which differs accoding to the concentration

of use due to different working conditions of personnel in different office biuldings, we proposed an evaluation method concerning the number of sanitary fixture. Here, the access time functions as a parameter pertaining to the number of fixtures and satisfaction of users, from which the tolerable access time in which the evaluating standards are based on a questionnaire can be evaluated. (Figure 1)

Step 1: An inquiry about how sanitary fixtures are used in existent buildings. The results of this inquiry constitute the basic data.

Step 2: A questionnaire to confirm the tolerable access time pertaining to the use of a sanitary fixture.

Step 3: Assumption of the design number of personnel in a proposed building, based on the basic data from Step 1. Simulation of how sanitary fixtures are being used, based on the General Purpose Simulation System (GPSS), thereby finding the acccess time.

Step 4: Repetition of Step 3 by changing the number of sanitary fixtures, thereby finding the relationship between the number of fixtures and access time.

Find the number of fixtures in which the maximum access time falls below the tolerable access time found in Step 3.

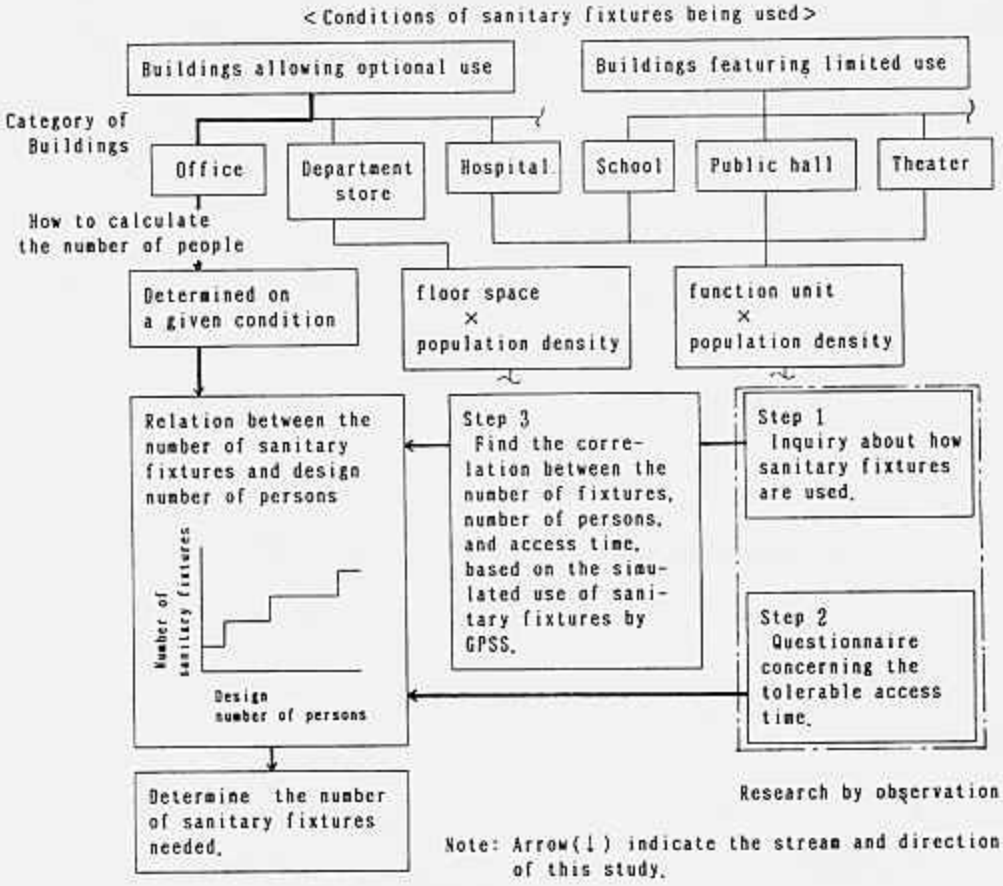


Fig. 1 Sanitary Fixture Evaluation Process

2. Summary and Result of the Questionnaire about the Use of Sanitary Fixtures

2.1 Questionnaire about Use of Sanitary Fixtures

(1) Summary of Questionnaire (including the persons and buildings surveyed)

The questionnaire was conducted for the personnel working in two different office buildings, that is, Bldg. Y (8 stories aboveground and 4 floors underground; 930m² standard floor space) and Bldg. G (7 stories aboveground ; 170m² base floor space). Three floors, i.e. the 3rd and 6th floors of Bldg. Y and the 6th floor of Bldg. G, were selected for this questionnaire. Different works were performed by different persons on these three floors, that is, electronic computing work by clerical-technological personnel on the 3rd floor of Bldg. Y,

designing work by technological personnel on the 6th floor of Bldg. Y, and planning and auditing work by secretarial personnel on the 6th floor of Bldg. G. Table 1 shows the details of the questionnaire itemized by building. To examine how sanitary fixtures are being used in a day, the examiness (persons undergoing the questionnaire) were asked to fill out the questionnaire personnally concerning the following subjects.

1) The length of time for which the examinees stay in their office (in the building or on the floor).
2) The time at which the examinees use a sanitary fixture or for which they occupy it.

Table 1 Details of the Questionnaire Itemized by Building

Building (Standard floor space)	Floor questioned	Number of personnel registered on the floor questioned		Work category	Toilet room space (m²)		Number of sanitary fixtures				
							Male			Female	
		Male	Female		Male	Female	①	②	③	①	③
Bldg. Y (930 m²)	3rd fl.	51	27	T+C	8.9	11.6	2	3	2	3	4
	6th fl.	67	16	T	8.9	8.9	2	3	2	2	2
Bldg. G (170 m²)	6th fl.	14	2	C	4.7	—	1	1	1	—	—

Flushing water supply methods			Date of questionnaire		Number of replies (reply rate)		Remarks
Male		Female	about how sanitary fixtures are used.	about how sanitary fixtures are felt.	Male	Female	
①	②	①					
F	H	F	16 ~ 20 April 1979	4 July 1979	41 (80.3)	25 (92.6)	About how sanitary fixtures are used: 15 men and 10 women among all persons resistered.
F	H	F		3 July 1979	45 (68.2)	9 (64.3)	About how sanitary fixtures are felt: 66 men and 14 women resistered at the time of questionnaire.
F	F	—		4 July 1979	12 (85.7)	—	

Notes: ① Closet ② Urinal ③ Washstand
T : Technological work C : Clerical work
F : Flash valve H : High tank

(2) Result of Questionnaire

1) Analysis of hourly fluctuations in the number of personnel staying on the floor:

Fig. 2 shows hourly fluctuations, on a 5-day average, in the percentage* of male and female personnel staying on each floor.

2) Analysis of how sanitary fixtures used:

Fig. 3 shows the hourly percentage** of sanitary fixtures being used each floor on a 5-day average.

Fig. 4 shows the distribution of toilet arriving time during one hour when the urinal is most crowded, with the horizontal axis standing for the probability density and the vertical axis for toilet arriving time (seconds). The arriving time for urinals is not markedly concentrated on the 3rdfloor of Bld. Y and 6th floor of Bldg. G. On the 6th floor of Bldg. Y, however, 50 percent of the toilet users per hour is concentrated in about 500 seconds after 13:00 (after the end of lunch break). This suggests that, depending on the work categoty of personnel, the use of plumbing fixtures may concentrate in a short time in office buildings, as in the case of schools and theatres.

Note: * Ratio of the hourly average number of personnel actually staying on the floor to the number of registered personnel.
** Hourly frequency of use related to the average number of personnel staying on the floor during regular office hours.

Note: *Daily average percentage of persons staying on the floor and percentages in ( ) indicate the standard deviation during the 5-day period.

	Bldg./Fl.	Symbol	Number of persons questioned	*
Male	Y/3F		15(out of 51)	75.2(16.0)
	Y/6F		57	68.3(2.2)
	G/6F		14	71.8(8.1)
Female	Y/3F		10(out of 27)	92.8(4.3)
	Y/6F		16	81.8(9.2)

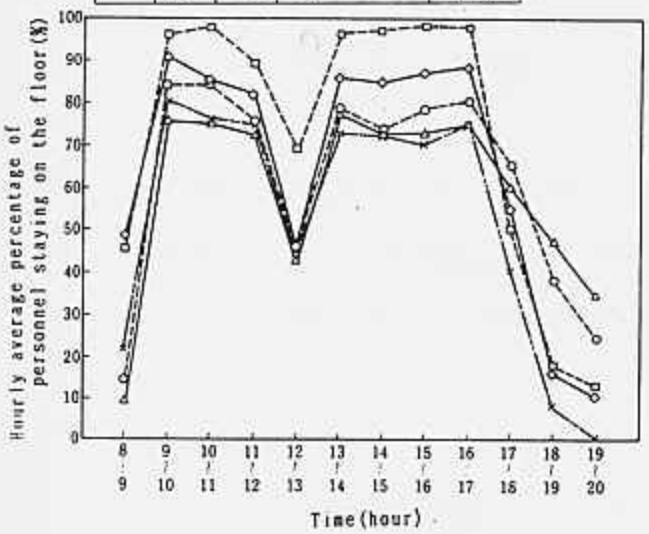


Fig. 2 Hourly Percentage of Personnel Staying on the Floor

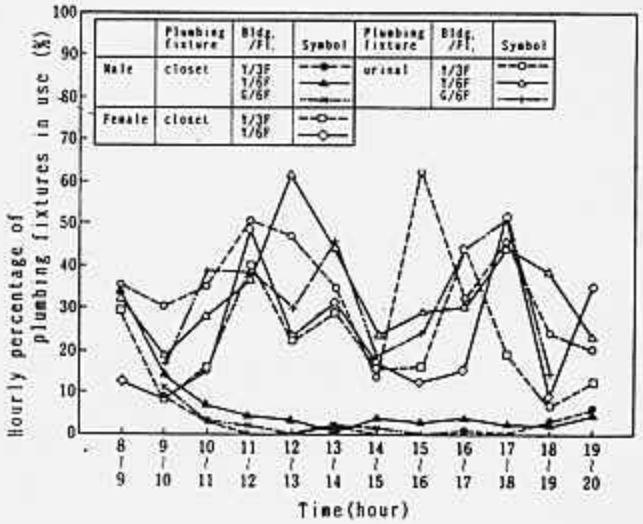
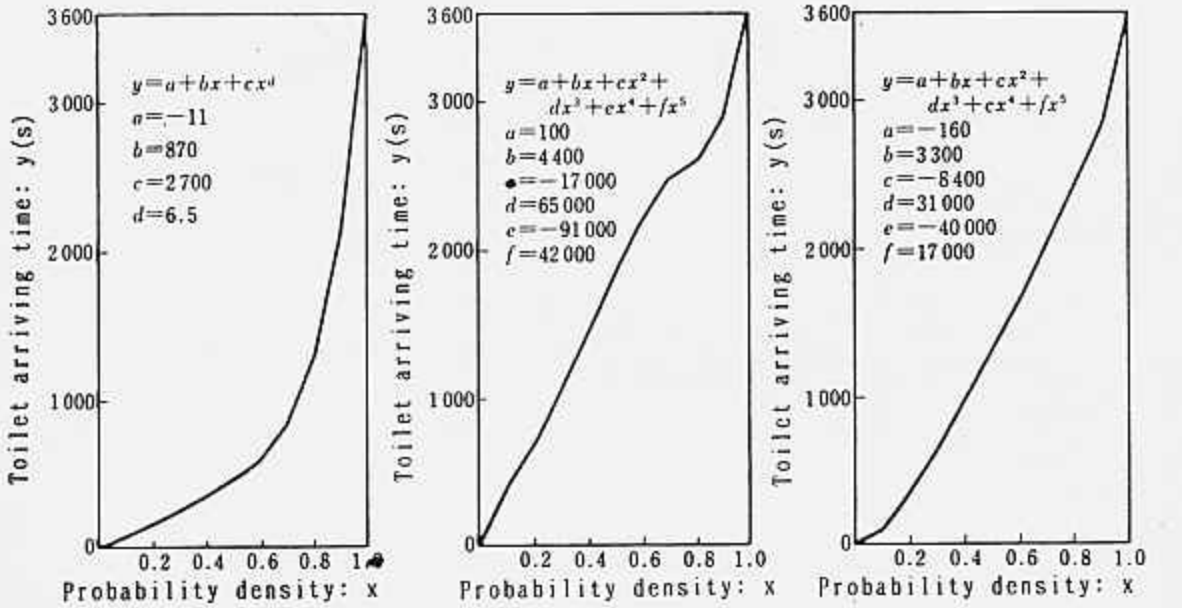


Fig. 3 Hourly Percentage of Plumbing Fixtures in Use



(a) 13:00 ~ 14:00 (Y/6F) (b) 15:00 ~ 16:00 (Y/3F) (c) 13:00 ~ 14:00 (G/6F)

Fig. 4 Functional Approximation of the arriving time

3) Plumbing fixture occupying time:

Table 2 shows the data number, mean value, and Phase-K value (approximate through Erlang's distribution) pertaining to the sanitary fixture occupying time, all of which were calculated on the basis of observation results.

Phase-K value (approximate through Erlang's distribution) pertaining to the sanitary fixture occupying time, all of which were calculated on the basis of observation results.

Table 2 Sanitary Fixture Occupying Time Classified by Floor on Observation Results

Sanitary Fixture	① Mean value of occupying time ② Phase K of Erlang's distribution ③ Data number	Male			Female	
		Bldg. Y 3rd fl.	Bldg. Y 6th fl.	Bldg. G 6th fl.	Bldg. Y 3rd fl.	Bldg. Y 6th fl.
Closet	①	246	225	308		
	②	—	7	6		
	③	10	134	9		
Urinal	①	29	29	30	73	49
	②	13	11	13	6	13
	③	205	661	143	105	135
Washstand (used after fecal discharge)	①	22	21	27		
	②	8	3	13		
	③	10	132	10		
Washstand (used after urinal discharge)	①	12	17	16	17	13
	②	4	3	4	7	2
	③	205	650	138	98	134
Washstand (used for washing hands or face)	①		31			23
	②		4			3
	③		28			42

2.2 Questionnaire Concerning the Use of Sanitary Fixture in the Existent Buildings

(1) Summary of Questionnaire

This Questionnaire is intended to study the reaction of toilet users as well as to tolerable access time in cases where a sanitary fixture is occupied.

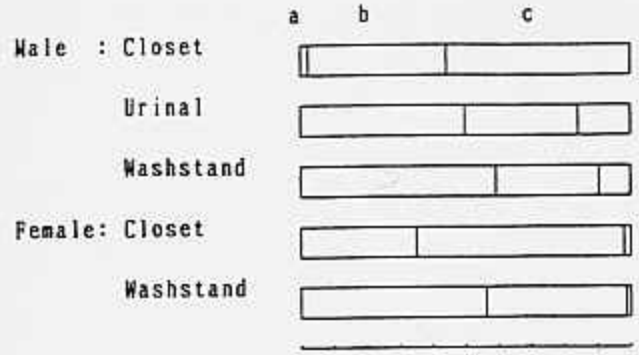
(2) Result of Questionnaire

1) Reaction when a sanitary fixture is occupied:

To the question "What will you do when the toilet you are going to use is occupied ? " there were three different replies: a) "I will wait until it becomes unoccupied."; b) " I will come back again."; and c) "I will go to another toilet." Fig. 5 shows each reply's share of the total number of replies.

2) The length of access time during which no inconvenience or displeasure is felt:

Fig. 6 shows the replies to the question "How long (how many seconds) can you wait without feeling inconvinience or displeasure if the toilet you are going to use is already occupied by another?" Nearly half of the repliers regarded the following access time as tolerable: below 10 seconds in male closet; about 10 seconds in male urinal; about 40 seconds in female closet; about 15 seconds in male washstand;about 30 seconds in female washstand.



Note: a) "wait unit it becomes unoccupied";
b) "come back again" ;
c) "go to another toilet"

Fig. 5 Reaction when a toilet is occupied

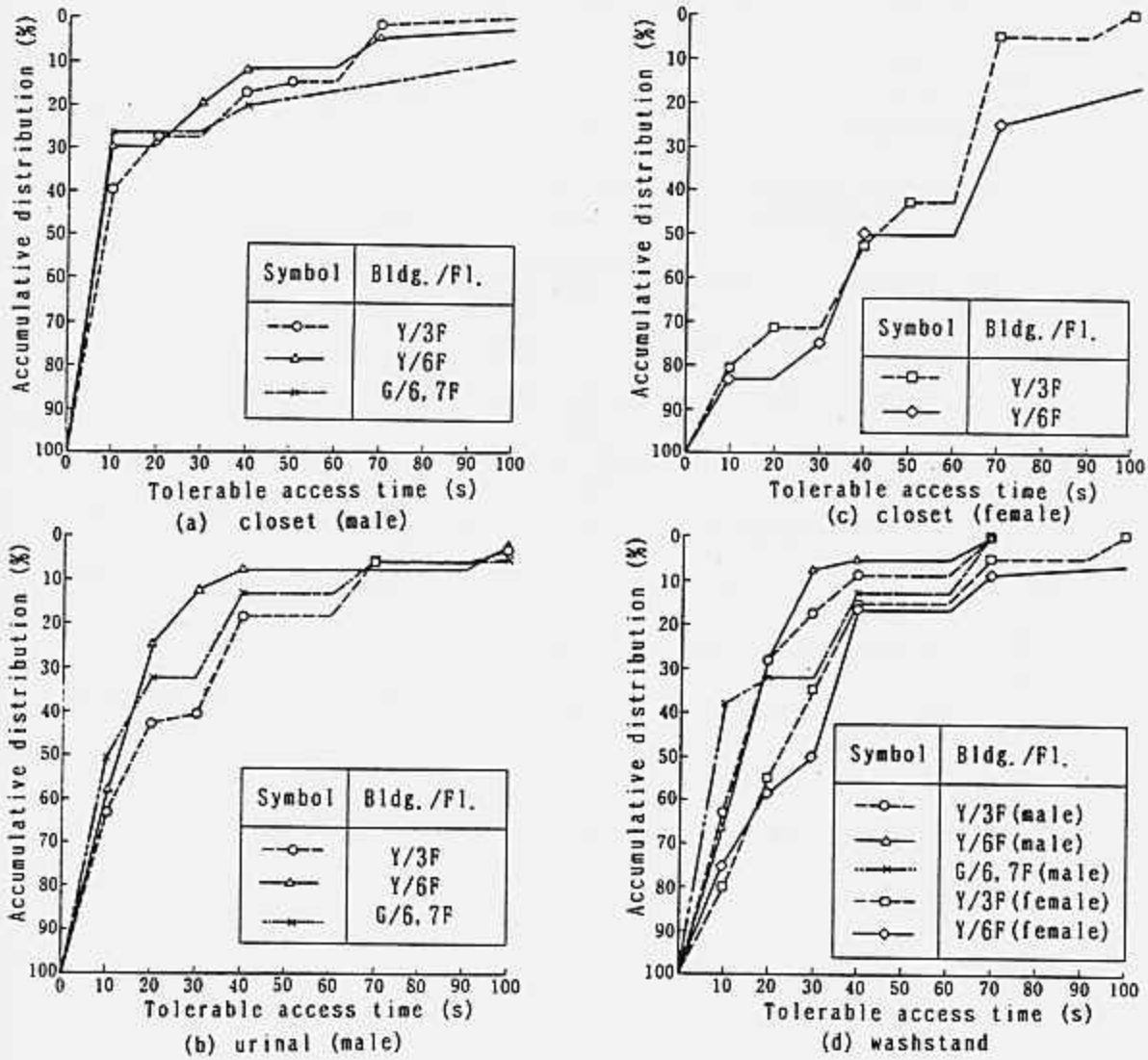


Fig. 6 Tolerable Access time when a toilet is occupied

3. Examples of Calculation Based on Questionnaire Results, as Compared with Traditional Evaluation Methods

3.1 Simulation of Sanitary Fixture in Use and Modelled Use of Sanitary Fixture

Estimated simulation of the sanitary fixtures in use is as illustrated in Fig. 7. In accordance with the questionnaire results, the simulation was performed by means of GPSS (General Purpose Simulation System) based on the data applying to the particular hours when a sanitary fixture was most crowded. This simulation is intended to find the correlation between the proposed number of personnel, needed number of fixture, and maximum access time.
The simulation was accomplished through the modelling processes as detailed below:

(1) Behavior Pattern of Sanitary Fixture Users:

The behavior of people assumed by simulation is divided into five patterns as shown in Fig. 8 (① - ⑤). The symbols x_1 to x_4, written in Fig. 8, indicate the ratio of behavior pattern applying to each sanitary fixture used during the particular hours under simulation.

(2) Modelling of People's Behavior:

People's behavior is categorized into four different models: a) lining up in front of a sanitary fixture; b) occupying the fixture after the previous user leaves it; c) continuing to occupy the fixture; and d) leaving the fixture.

(3) Detemination of Arriving Time:

Against the assumed time of 3,600 seconds under simulation, a polynominal approximation is performed by the

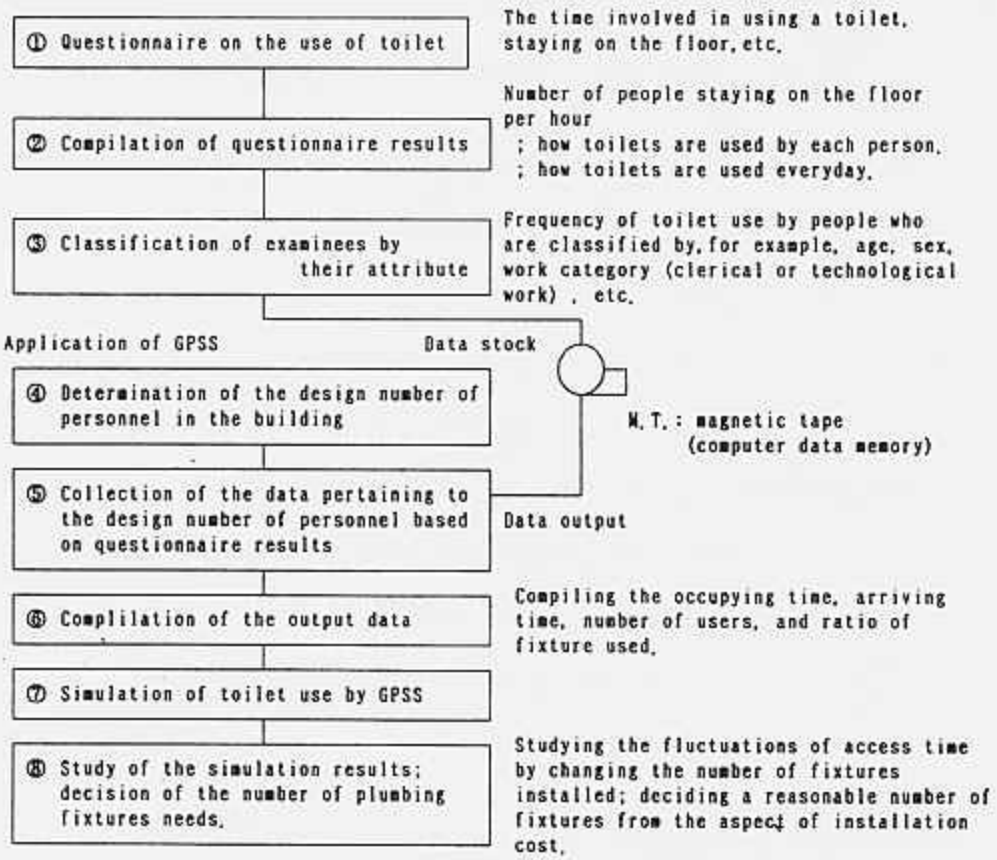


Fig. 7 Simulation by GPSS Based on Questionnaire Results

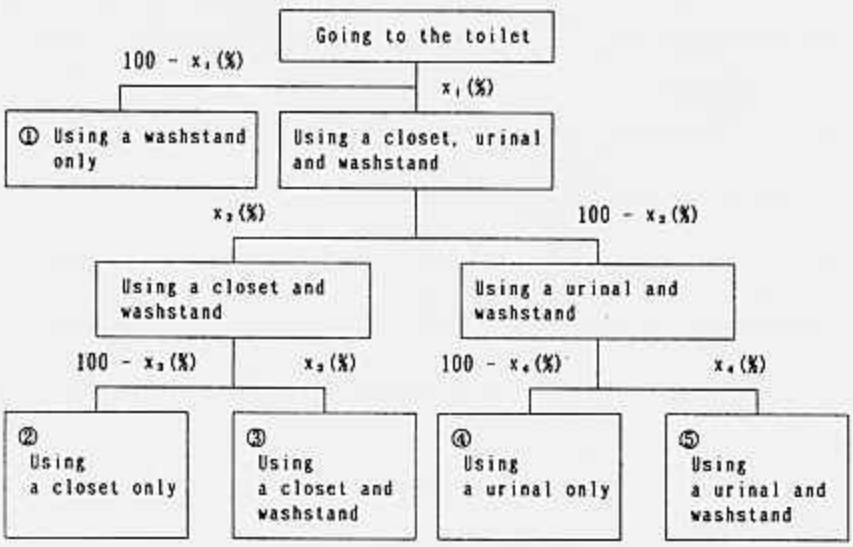


Fig. 8 Behavior Pattern When Using a Plumbing Fixture in the Toilet

function of probability variables (0 to 1) based on the arriving time during the particular hours when each sanitary fixture is most crowded. Based on this relationship, the values pertaining to those probability variables can be found by random numbers. The arriving time is determined by these values which apply to the number of people who used a sanitary fixture during the same houres (see Fig. 4).

(4) Determination of Occupying Time:

Through functional approximation (Erlang's distribution) of the occupying time available from the observation survey, the values pertaining to probability variables (0 to 1) can be found by random numbers, thereby determining the occupying time.

(5) Method of Simulation:

The simulation can be accomplished by the following steps. Within a particular hour applying to simulation, the time involved in the use of sanitary fixtures is established by (3); the behavior pattern is defined by the ratio x_1 to x_4 as explained in (1); then the occupying time is determined by (4).

3.2 Necessary Number of Urinal as Examined by the GPSS Model

Fig. 9 shows the correlation between the number of sanitary fixtures and the maximum access time based on the results of simulation, which was repeated 10 times on each floor under the conditions sanitary fixtures are being used. By means of the GPSS Model as mentioned in Paragraph 3.1, the simulation was conducted during a paticular hour when urinals were most crowded.

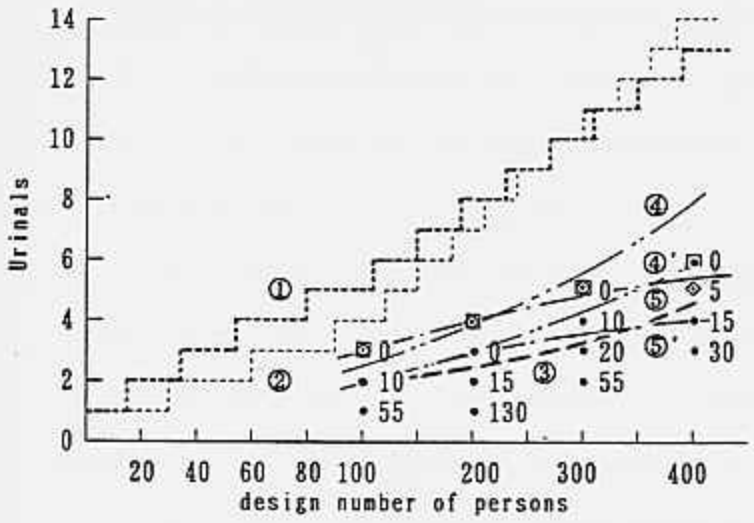
Fig.9 also shows the NPC(closets, thick broken lines), Enforcement Ordinance on Industrial Safety and Health (thin broken lines), surplus rate α = 1/100 and 1/1000 available from the diagram which is based on Yoshitake's α-method (a dot-dash-line), surplus rate α = 2/1000 by Fujii and others (□ mark), and excess probability Kp = 2/1000 basedon Murakawa's excess probability (◇ mark).

The number stipulated by NPC is in the following way, depending on the number of personnel(N):

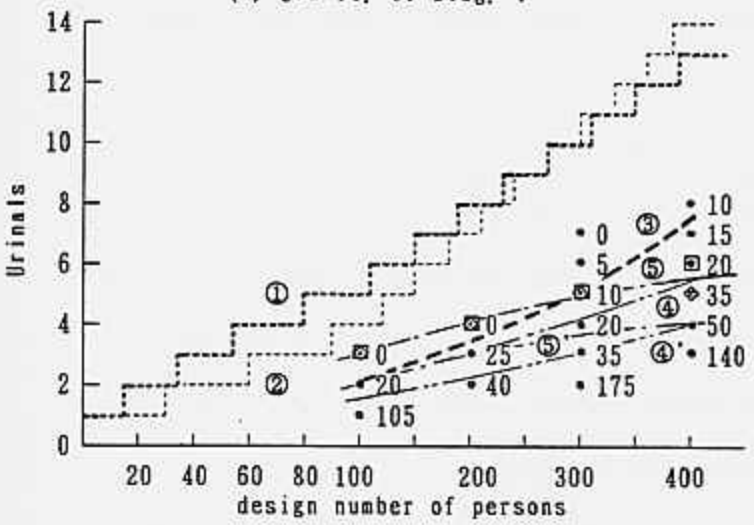
1	in case of $1 \leqq N \leqq 15$	4	in case of $56 \leqq N \leqq 80$
2	in case of $16 \leqq N \leqq 35$	5	in case of $81 \leqq N \leqq 110$
3	in case of $36 \leqq N \leqq 55$	6	in case of $111 \leqq N \leqq 150$

In case where N is 151 or more, 1 fixture is added for each 40 additional persons. And urinal can be substituted for one closet, but the total number of closet shall not be reduced to less than 2/3 of the minimum specified.

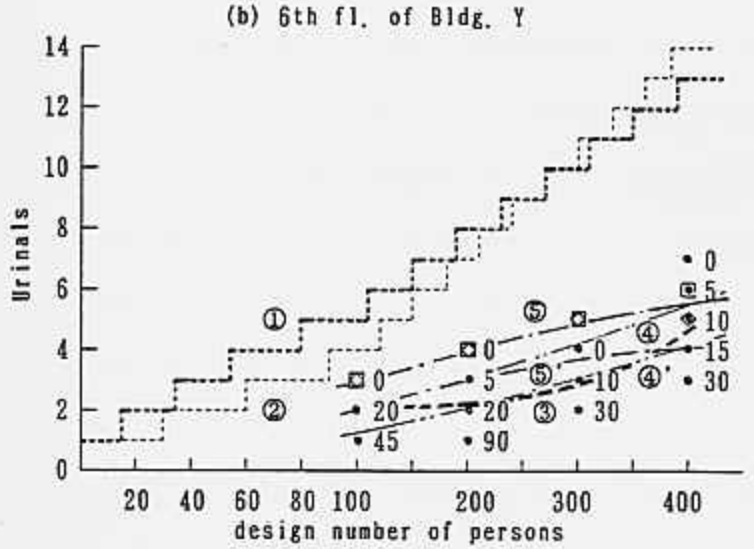
The conditions of calculation applying to the GPSS Model were: the number of users (48, 34, and 36 respectively per 100 assigned persons) during 15:00-16:00, 13:00-14:00, and 13:00-14:00 when urinals are most crowded on each floor; and the distribution of arriving time (Fig. 4). Fig.9 shows the maximum access time in every 5 seconds indixated



(a) 3rd fl. of Bldg. Y



(b) 6th fl. of Bldg. Y



(c) 6th fl. of Bldg. G

① Number of closets according to the NPC

② Number of urinals according to the Enforcement Ordinance on Industrial Safety and Health

③ Number of urinals defined at Ta = 10 sec.

④ Number of urinals by the α-method based on questionnaire results
α=1/1000

④' α=1/100

⑤ Number of urinals based on Yoshitake's diagram
α=1/1000

⑤' α=1/100

□ : Number of urinals defined by Fujii and others

◇ : Number of urinals defined by Murakawa

The numerals indicate the maximum access time(seconds) pertaining to the design number of persons and urinals based on the results of 10 simulations during the peak hour.

Fig. 9 The Number of Urinals and Maximum Access Time

by the simulation which was performed under the condition where urinals are being used by the assumed number (100, 200, 300, and 400) of proposed persons on each floor. Values found by the α- method based on the results of questionnire are also shown with a fine dot-dash-line. The mean values (m = occupying time× average arriving rate) partaining to the number of concurrent users, which are applied to the above calculation, were 0.0039 × N, 0.0026 × N, and 0.0030× N respectively on the 3rd and 6th floors of Bldg.Y and 6th floor of Bldg.G (N represents the total number of users).

(1) In the case where the service level is supposed to involve no access time:

When the service level with no access time is attained, it is evident from Fig.9 (a, b, c) that the necessary number of urinals on each floor increases in the order of 3F/Y, 6F/G, and 6F/Y.

It is clear from Fig.9 (a) that, on the 3rd floor of Bldg. Y (m = 0.0039 × N) where no concentration is seen in the use of sanitary fixtures, the value of α = 1/1000 (brought by the α-method based on questionnaire results) is nearly equal to the number of fixtures based on NPC. The 3rd floor of Bldg.Y thus involves no access time and the number of sanitary fixtures is excessive there.

It has become known that the values of α =1/100 and α =1/1000[4] (which is based on Yoshitake's calculation diagram) are similar to the case of no access time by the GPSS Model. The service level is high in this case.

Also, the values brought by Murakawa, Fujii and others[5),6)] are nearly equal to the value of α =1/1000 by Yoshitake, where the service level with no access time is almost attained.

On the 6th floor of Bldg. Y, on the other hand, where sanitary fixture users concentrate in a short time, the access time reaches 20 to 30 seconds against the design number of 100 to 200 persons, if the value of α =1/1000 is applied. The access time tends to increase as the number of persons increases (to 300 or 400), and therefore it is obvious that this floor features low service level. Such a tendency is also the case with the values values brought by Murakawa, Fujii and others.[5),6)] On the floor with this type of business category, it is necessary to provide almost the same number of sanitary fixtures as required by NPC, if a service level involving no access time must be achieved. However, the NPC-based value may lead to an excess of facilities on a whole-day basis, although it is enough to eliminate the access time during the peak hours.

(2) The number of urinals needed when the service level features the tolerable access time of 10 seconds:

Fig. 9 indicates the necessary number of urinals, shown by a thick broken lines, with the access time being set at 10 seconds, which half of people regard as tolerable. This is based on the results of a questionnaire concerning the tolerable access time (Ta) in the urinal, as already, explained in Paragraph 2.2 (2) 2). On the floor where users do not concentrate in urinals, the service

level can be realized by the value below the surplus rate of α =1/100, and therefore a value similar to Yoshitake's α = 1/100 will be enough to fulfill the necessary number of urinals. On the floor where users concentrate, the value of α =1/1000 by the α-method based on questionnaire results and that of α =1/1000 by Yoshitake will be enough to fulfill users' needs, if the design number of persons is less than 300. However, if the number exceeds 300, the service level satisfactory to users cannot be achieved without a value approximately equal to NPC.

Conclusion

As regards how sanitary fixtures are used in office buildings, we conducted a simulation based on the results of a questionnaire. From the aspect of the access time, we also examined the number of sanitary fixtures defined by NPC or reported from traditional researches. These studies have brought us the following findings.

(1) The questionnaire was performed concerning the persons (personnel) stationed on the three different floors of office buildings. The persons questioned were made up of those engaged in clerical-technological work (3rd floor of Bldg. Y), technological work (6th floor of Bldg. Y), and clerical work (6th floor of Bldg. G). The results of this questionnaire have proved that many people tend to concentrate in a short time when using a sanitary fixture in office buildings, such as the 6th floor of Bidg.Y (technological), where optional use is reportedly prevailing.

(2) We gained the followings as a result of the questionnaire concerning the tolerable access time in case a sanitary fixture is occupied. The access time tolerable for harf of people was: below 10 seconds in male closet; about 10 seconds in urinal; about 40 seconds in female closet about 15 seconds in male washstand; and about 30 seconds in female washstand.

(3) Based on the simulation results, we made a comparison with the traditional number of sanitary fixtures, focusing on a male urinal. There are two different case where urinal users concentrate and do not concentrate in a short time. The necessary number of urinal was calculated according to this difference, with the service level being divided into two instances, i.e. (a) no access time and (b) 10-seconds tolerable access time. The comparison was made betweeen the necessary and traditional numbers of urinals.

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CIB

CIB-W62 SYMPOSIUM

Field Investigations of Flow in Water Supply Networks With the Help of Computers

Sture Holmberg

April 9,~10, 1985

TOKYO, JAPAN



M. Eng. Sture Holmberg (speaker)
The National Swedish Institute for Building Research

(see speaker)

FIELD INVESTIGATIONS OF FLOW IN WATER SUPPLY NETWORKS WITH THE HELP OF COMPUTERS

12th CIB-W62 SYMPOSIUM - TOKYO -
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10, -1985 : KENCHIKU KAIKAN

Summary

As far back as in ancient Rome, a work was produced in the year 97 under the guidance of Julius Frontinus entitled "De aquaeductu urbis Romae", giving rules for how water was to be distributed to houses via conduits. Ever since, there have been many proposals for the laying and dimensioning of water conduits. Starting from the first simple empirical formulae, a number of mathematical/statistical models for the functioning of the conduits have been developed.

Present-day computer technology with its fantastic opportunities for carrying out measurements and storing data has opened new possibilities for a more exact and economically optimized dimensioning. Detailed, continuous measurements have previously provided valuable input data for stochastic dimensioning models, and they now furnish execellent opportunities for simulating the entire sequence of events. With the help of a computer it is also possible to follow the effects of altered operating parameters and system components. This paper is intended to give a picture of the present status of research at the National Swedish Institute for Building Research, Studsvik, Sweden.

Résumé

Déjà dans la Rome Antique, en l'an 97, apparaissait sous la direction de Julius Frontinus l'oeuvre "De aguaeductu urbis Romae" sur les règles de la distribution de l'eau dans les canalisations jusqu'aux habitations. Depuis ce temps, de nombreuses propositions sur la facon dont les canalisations d'eau doivent être installées et dimensionées ont été présentées.

Un nombre considérable de modèles mathématiques et statistiques de la fonction des canalisations a été développé depuis ces premières simples formules empiriques. La technique des ordinateurs actuelle avec ses possibilités fantastique de calculer et d'enmagasiner des informations a permis l'apparition de nouvelles possibilités de dimensionement plus exact et économiquement optimal. En ayant auparavant programmé des données d'entrée précieuses dans des modèles de dimensionement stocastique,

on obtient aujourd'hui, par des calculs détaillés et continus, à avoir d'excellentes possibilités de simulation d'un processus. Avec l'aide de l'ordinateur, on peut aussi suivre les effets dus aux variations des paramètres de commande et des composants de système. Cet article est destiné à donner un apercu sur la situation actuelle de la recherche à l'Institut National de la Reserche en Batiment à Studsvik, Suède.

Zusammenfassung

Schon im alten Rom wurde unter der Leitung von Julius Frontinus im Jahre 97 eine Schrift ausgearbeitet mit dem Titel "De aquaeductu urbis Romae". Sie umfasste Regeln darüber, wie Wasser in Leitungen zu den Wohnhäusern gebitet werden solle. Seitdem hat es viele Vorschläge gegeben, wie Wasserleitungen verlegt und dimensioniert werden sollten. Von den ersten einfachen empirischen Formeln sind eine Vielzahl mathematisch-statistischer Modelle für Leitungsfunktionen entwickelt worden.

Moderne Datentechnik mit phantastischen Möglichkeiten zur Messung und Speicherung von Daten hat neue Wege eröffnet zu einer exakteren und ekonomich optimalen Dimensionierung. Detaillierte und kontinuierliche Messung, die früher werholle Eingaben zu stokastischen Dimensionierungsmodellen geliefert haben, verleihen heute enorme Möglichkeiten, den gesamten Verlauf zu simulieren. Mit Rechnerhilfe kann man heutzutage die Konsequenzen von Änderungen in Betriebsparametern oder Systemkomponenten verfolgen. Der folgende Beitrag soll einen überblick über die augenblickliche Lage der Forschung im Staatliche Institut für Bauforschung in Studsvik, Schweden geben.

1.0 INTRODUCTION

The opportunities for measurement and recording provided by our modern computers have now begun to bear fruit in the form of valuable information about the flow in water supply networks. At the National Swedish Institute for Building Research at Studsvik, many years' experience of field measurements have helped us to develop our own assessment routines, and the computers have both made possible and simplified the total recording of complex events in water supply systems for apartment houses.

The aim of our measurements is to obtain an information base from which future, improved systems can evolve. Present-day issues are economics and comfort. The cost of clean water is increasing, and in a country with a high water consumption the energy involved has become significant during the last few years. In our well-insulated energy-saving buildings, we are no longer prepared to accept that such a large fraction of the energy should be used for heating the hot-water supply. If we so not want to lower our standards of comfort, we must learn to use the water more efficiently.

2.0 MEASURED BUILDING AND MEASUREMENT METHODS

The field measurements described here are being carried out in a six-storey apartment house in Stockholm. The project has been going on for one year, and is a cooperative effort between the trustee, four of Sweden's largest manufacturers of water supply fittings and the Building Research Institute. The building contains a total of 22 apartments, with 11 on each of two staircases. This particular building contains 10 apartments with two rooms plus kitchen, 10 with four rooms plus kitchen and one with five rooms plus kitchen, and it was chosen so as to include both large and small apartments. The water to the apartments is distributed via 12 vertical main pipes, i.e. 6 pairs of mains with hot and cold water. One such pair of mains is shown in Figure 1. The temperature and pressure beside the flowmeters are also measured.

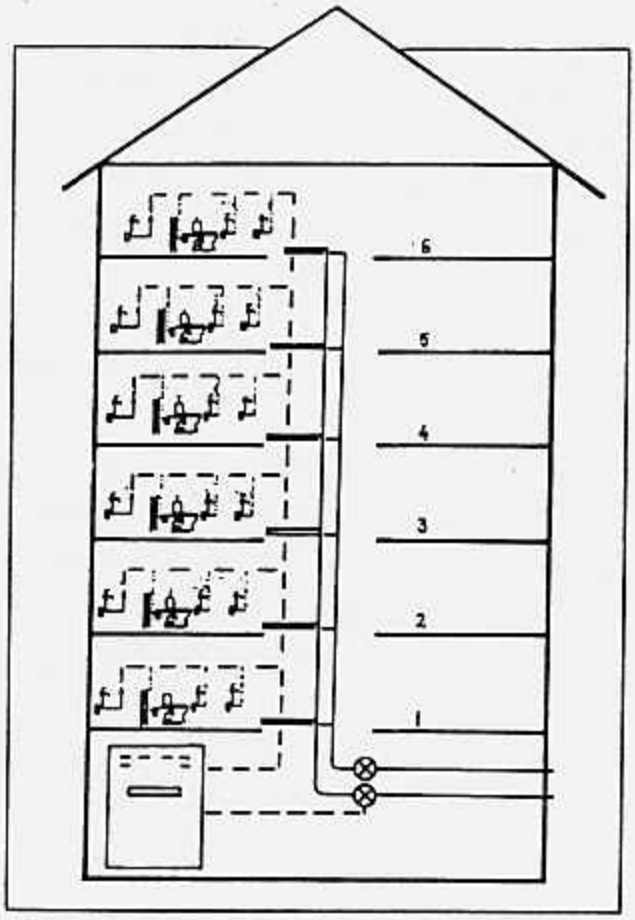


Figure 1. Water supply investigation in Stockholm. Every water tap is connected to the computer.

The basic concept for the measurements is to manage with flowmeters only on the 12 vertical main pipes, and still be able to measure the flows at all 180 outflow points in the apartments. This can be done with the help of computer monitoring from the basement of the building. All the outflow points are equipped with on/off sensors and connected to the computer by signal cables. The computer provides a continuous record of frequency, flow, temperature and pressure for all the sensors. It records the values in accordance with programmed limiting values, and gives the correct figures in real time. All data are recorded on floppy discs. The storage capacity on the double discs is sufficient for a two-week measurement period.

When the discs have been fetched from the measurement building, another mini-computer and suitable software can be used to obtain practically all the information about how the system has functioned. This work is done with the help of a large number of "IF" statements

in the main programme, and small subroutines which insert information about the parameter status into the main programme. For example, it can be said that on average each vertical cold-water main supplies water to 30 outflow points. With the help of a suitable programme it is possible to determine the times when cold water from the main is only being supplied to one particular outflow point, and thus to find the individual flows during these times. In spite of the limitations, a long measurement period gives a large number of occasions when each outflow point is the only one taking water from a particular main. The real-time information means that each event can be located correctly in time - second, minute, hour, weekday and week.

3.0 FLOW AND ENERGY DIMENSIONING

3.1 Background

For amny years, simple empirical formulae have been used for dimensioning the water supply lines to housing. The same formulae have been used for estimating the energy requirements for heating the hot-water supply. A very simple formula which was used formerly in Scandinavia was the square-root formula:

$$Q = q \frac{\sqrt{n}}{2} \qquad (1)$$

where q is the flow from a normal outflow point and n the number of normal outflow points. A version of formula (1) which has been used in Sweden is the somewhat longer formula

$$Q = q \left(n_o + \frac{\sqrt{n - n_o}}{2}\right) \qquad (2)$$

where n_o is the number of outflow points with the largest water consumption. These models were very general and could be used without any detailed information about the projected system.

3.2 Stochastic variables

In order to get a greater freedom and variation in dimensioning, there was soon a demand for better dimensioning formulae. The old formulae cold not, for example, take account of the fact that different installations required different amounts of water.

Further, a better understanding of how the formulae worked would help the users to carry out modifications in them when necessary.
With the advent of mathematical-statistical methods, new dimensioning formulae began to be developed which have held their own up to the present day. It was assumed that the stochastic loading variations of probability theory would apply for the loads on water supply systems, and dimensioning began to be carried out for a probable flow Q_{prob}.

$$Q_{prob} = q_{max} + \Theta(\Sigma q - q_{max}) + A\sqrt{\bar{q}\Theta}\cdot\sqrt{(\Sigma q - q_{max})} \qquad (3)$$

where Q_{prob} = probable flow
q_{max} = the greatest individual water flow
Θ = probability of water being drawn off
Σq = sum of the connected standard flows
A = risk factor
$\bar{q}$ = mean value of the connected standard flows.

Formula (3) is used in the Scandinavian counties.
However, it has been found that the formula for the probable flow (3) imposes rather large demands on the input data if it is to function satisfactorily. Here, our field measurements have yielded valuable information which has replaced the rough assumptions made previously. Formula (3) calls for a knowledge of the water flows q from the individual installations and also of the probability Θ of a mean load. Figure 2 shows measured flows and mean flow times. Figure 3 gives the measured probability Θ that water will be drawn off from a given outflow point.

Water tap	Average flow rate (l/s)	Average duration (s)
Kitchen, hw	0.095	46
Kitchen, cw	0.085	30
Wash basin, hw	0.090	44
Wash basin, cw	0.075	54
WC, cw	0.090	67
Bath, hw	0.140	184
Bath, cw	0.060	141

Figure 2. Average flow rates and durations of single tappings. 11 apartments, hw temp. 45°C, Stockholm 1984.

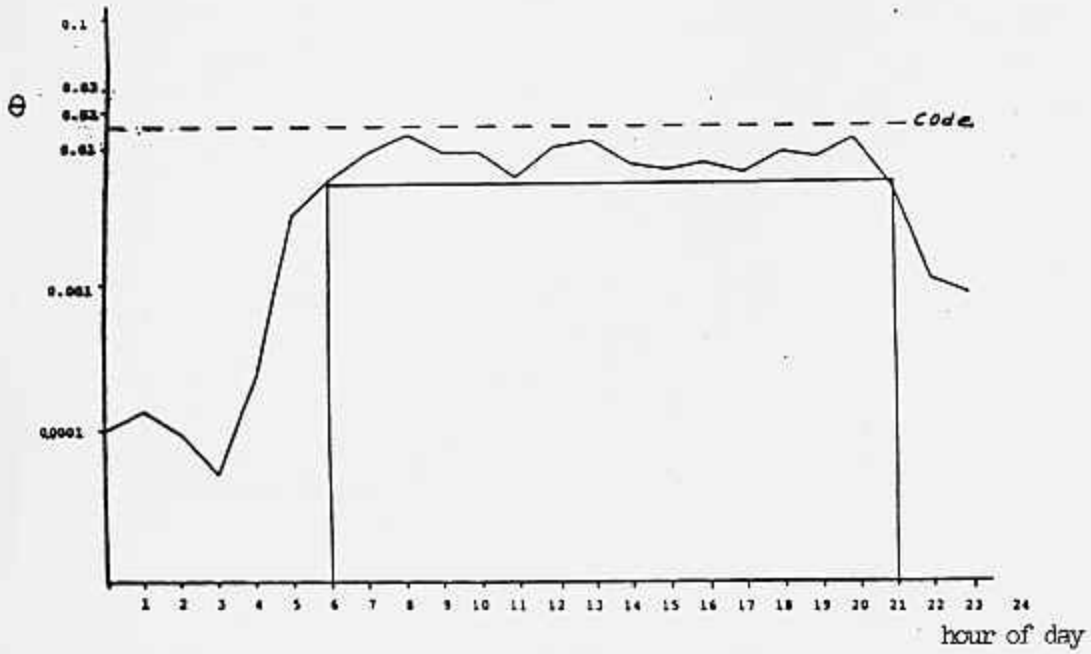


Figure 3. Average probability Θ for a water tap to be used. Norrköping 1981.

3.3 Simulation

No that it is possible to make continuous and accurate computer measurements, it is tempting to begin to simulate the entire loading sequence. The computer can record practically all the facts about what happens in the water supply pipes, so that it ought to have the maximum qualifications for determining the dimensioning parameters. A dimensioning data base simulated on the computer would have the following advantages by comparison with present-day dimensioning: The time parameter would have a greater significance. The peak load periods in the day would be taken better into account, see Figure 4. The time shift between the peak loads for different installations would be taken better into account, see Figure 5.

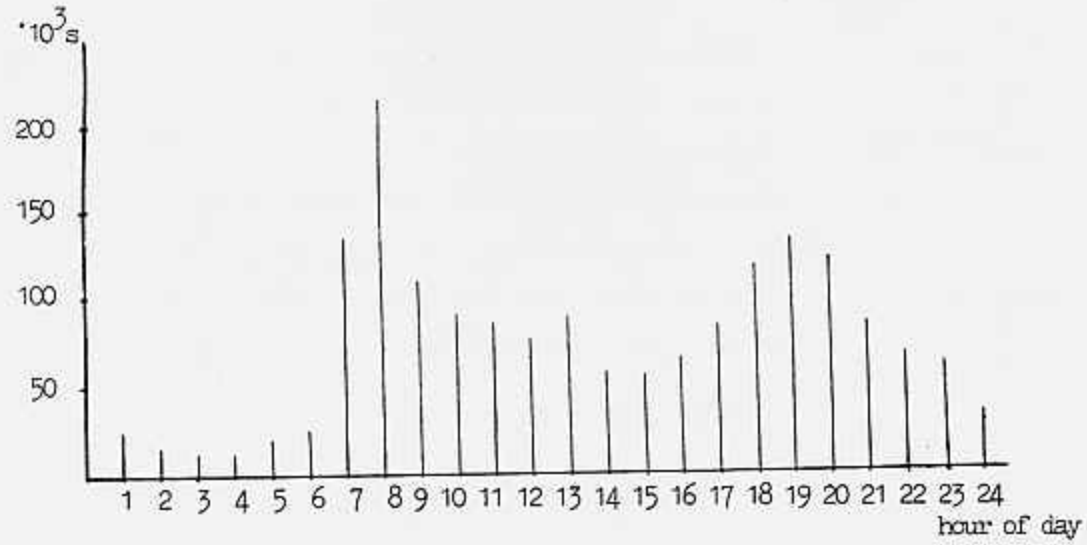


Figure 4. Discrete tapping time distribution for each hour of the day. 11 apartments in Stockholm 1984.

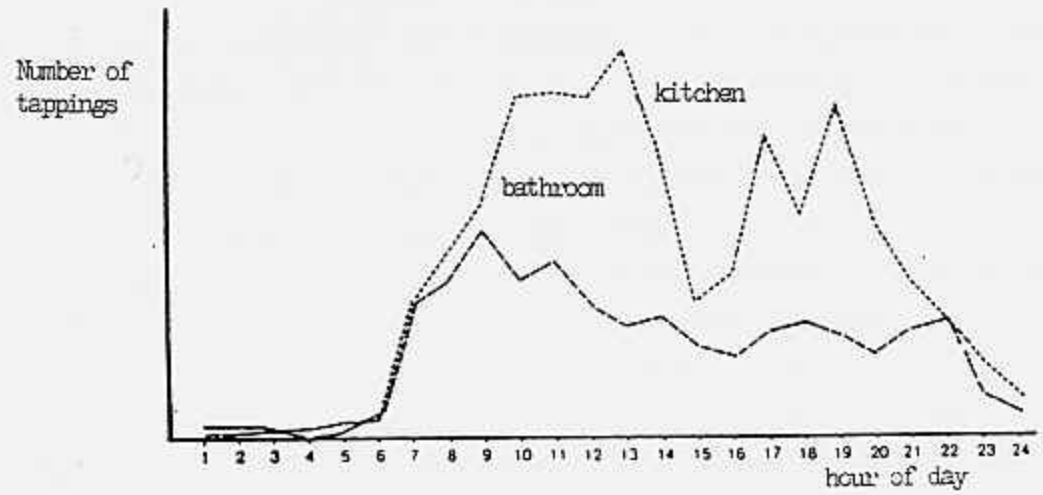
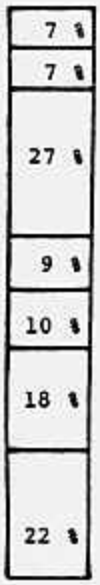


Figure 5. High-load periodes of water use in bathroom and kitchen. Norrköping 1981.

A simulation programme could take into account the fact that the probability of different groups of installations being used is not constant, see Figure 6. In the simulation use could be made of load distributions measured in the field, which are dependent for example on temperature in the case of the hot-water supply, see Figure 7.



Bath, cw

Bath, hw

WC

Wash basin, cw

Wash basin, hw

Kitchen, cw

Kitchen, hw

Figure 6. The distribution of the total time water taps have been used. Norrköping 1981.

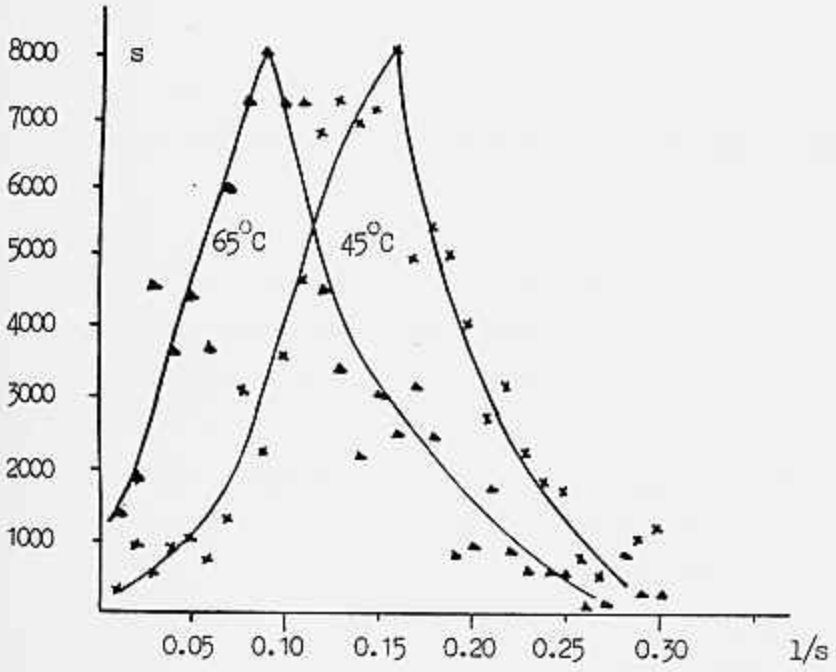


Figure 7. Distribution of used tap water flows from bath (tube + shower) for hot water temperatures 45°C and 65°C. Stockholm 1984.

3.3.1 Simulation process

The following are required in a simulation process:

1. The probability of water being drawn off at the different loading units

   $p_1, p_2 \cdots\cdots p_n$

2. The flow load with its distribution

3. The number of units (persons, outflow points)

4. A computer with random number generator.

The probability p is determined for each hour; it can be defined since the relative time (flow time/total time) stabilizes when measurements are carried out over a long period. In this connection a check should also be made that the probabilities for different groups of installations are independent of each other, which is the case if

$$p_{1\ 2\ ..n} = p_1 \cdot p_2 \cdot \cdot p_n \qquad (4)$$

where $p_{1\ 2\ ..n}$ = probability of simultaneous use of more than one outflow point.

The on/off status of each individual installation and its flow load is obtained with the help of the random number generator. When generating flows, the distribution must also be taken into account, cf figure 7.
In Sweden, the number of units has hitherto been considered to relate to the number of outflow points. In reality it is the persons involved who cause the outflows, so that the number of people should perhaps play a more promintent part in dimensioning.
Nowadays there are computer programmes that generate both uniform (on/off) and distributed (flow) probability frequencies.
The individual loads are summarized to give a total load. In our measurement building, the simulated total load for the different mains can be compared with the duration curves (flow-time) from the flowmeters on the mains.

4.0 WATER AND ENERGY SAVING METHODS

In many cases, our field measurements are designed to find out how water is used in our homes and where the greatest potential lies for saving water and the energy used for heating water. The concept of saving is rather comprehensive, and the division given below is intended to clarify the situation.

4.1 Division into different types of saving

Savings in water and the energy used for heating water are here divided into three groups (a,b,c).

a) Reduced water consumption.

A reduction in the total volume of water consumed means that either
- the fraction of cold water (V_{cw}) has diminished

or - the fraction of hot water (V_{hw}) has diminished

or - the fractions of both hot and cold water have diminished.

b) Reduced energy consumption.

The quantity of thermal energy E supplied in the hot water used is given by the relation

$$E = \underbrace{c_p \cdot \rho}_{\approx \text{ constant}} \cdot V_{hw} \cdot \Delta\vartheta \qquad (5)$$

where c_p = thermal capacity of the water
ρ = density of the water
V_{hw} = quantity of hot water consumed
$\Delta\vartheta$ = number of degrees through which the water has been heated.

A reduction in V_{hw} or $\Delta\vartheta$ or both results in a saving in energy.

c) Reduced losses of water and energy.

Leakages can involve the loss of both water and energy. A hot water system with poor efficiency or poor insulation leads to energy losses.

The methods which have been tried in order to achieve savings within the groups listed above are described in the sub-sections which follow.

4.2 New technology as a changer of consumer patterns

During the last few years there has been a lively discussion about whether new installations can affect the water consumption. Single-handle mixer taps, low-flow mixer taps, thermostatically controlled mixer taps, pressure reducing valves, air mixers, low flushing volume toilets etc have been discussed and brought forward as marketing arguments. In order to obtain a picture of which measures can be taken without neglecting the comfort of the consumers and which favour our water economy, field investigations are needed.

If it is desired to reduce the consumption of water at a given outflow point, one or both of the following two changes must be achieved:

- a reduction in flow
- a reduction in flow time.

Thus the magnitude of the water flow and the length of time during which the water is flowing are parameters that must be known both before and after a change in order to be able to say what the effect of the change has been.

4.2.1 New taps and throttling valves

If a water tap is easy to manipulate, it may be expected that the regulating time, i.e. the time to achieve the desired flow and desired temperature, will be shortened. Consequently the total flow time will also be shortened. Single-handle mixer taps and thermostatically controlled mixer taps are examples of types of tap which have been developed so as to be easy to use.

If in addition the tap is equipped with a high pressure drop, i.e. the outflow of water is throttled, then the resulting tap has good qualifications for being able so save water. In this case, the tap is normally denoted a low-flow mixer of single-handle type. This tap usually has built-in pressure reduction and can also be equipped with an air-mixing nozzle which further reduces the pressure and makes the jet of water softer.

It is still difficult to be certain how great the savings are when a tap is exchanged for a modern appliance. Several investigations have been carried out, but seasonal variations, leakage and other problems have often made it difficult to reach uniform results. In addition, people have widely differing habits. However, it is expected that our

field measurements in Stockholm, which will be ready for their final report at the end of 1985, will yield valuable information about how much the water consumption can be affected. Some results from three investigations carried out in Sweden are given below.

An Investigation [1] in some 100 apartments in the Mora district shows an approximate saving in both hot water and cold water of between 10 and 20 %. The taps at kitchen sinks and washbasins had been exchanged for single-handle mixer taps, and the baths had been equipped with thermostatically controlled mixer taps.

[2] describes a similar investigation carried out in Gothenburg. The article cites the following conclusions:
"By installing flow regulators on both hot and cold water pipes to the taps at kitchen sinks and washbasins, a water saving of 12 % is obtained. If a flow regulator is installed on the hot water line only, a water saving of 10 % is obtained. The saving in energy obtained is c. 3 %. The savings in energy and water give a payoff time of two years.
The savings obtained by regulating the flow on the cold water side also are considerably less. The total payoff time is then 3.5 years. The payoff time for the energy saving alone, when only throttling the flow of water, is c. six years.
By exchanging the taps for low-flow types, a water saving of c. 15 % was obtained. The energy saving in this case was 3 % of the total energy consumption. This corresponded to a total payoff time of 4 - 5 years."

A report [3] from the National Swedish Institute for Building Research shows that with extremely restrictive installations it is possible to achieve even greater savings, at least in individual cases. This report describes a water saving of around 30 %. The case investigated was limited to only 10 apartments.

4.3 Regulation

4.3.1 Hot-water temperature

There has also been much discussion about which hot-water temperature can be considered to be most suitable as regards savings in water and

energy consumption. At the National Swedish Institute for Building Research and other places, measurements have shown that if both the hot-water consumption and the heat losses in the hot-water pipes (including circulation lines) are taken into account, a low hot-water temperature is practically always preferable. Measurements have been carried out in the range 65 - 45°C.

In the investigation described in Table 1, the mean value of all volumes of water drawn off except for WCs has been determined for both hot water (hw) and cold water (cw). This has been done at three different temperatures of the hot water, and the relative amount of energy used for heating the hot water used from 10°C (E) has been determined according to equation (5).

hw temp	cw (l)	hw (l)	E (rel.)
65°C	7.15	6.67	367
55°C	7.23	9.36	421
45°C	5.01	10.43	365

Table 1. Tapped water volumes and relative energy E in tapped hot water (hw) for three hw temperatures, Stockholm 1984.

The table shows that approximately the same relative amounts of energy have been used at hot-water temperatures of 45°C and 65°C. Taking into account the heat losses from the hot-water pipes and the circulation lines for the hot water, the convection losses will follow the formula

$$P = \alpha A(\vartheta_{pipe} - \vartheta_{air}) \qquad (6)$$

where P = convective heat loss
ϑ_{pipe} = temperature of the heat transmitting surface
ϑ_{air} = temperature of the surrounding air
A = size of the heat transmitting surface
α = thermal transfer coefficient

An approximate comparison between the heat losses from hot-water pipes at temperatures 45°C and 65°C gives according to formula (6):

$$\frac{\Delta\ 65^{\circ}C}{\Delta\ 45^{\circ}C} = \frac{55}{35} = 1.57 \qquad (7)$$

This is assuming that the temperature of the cold water is 10°C. According to (7) the losses would be 1.57 times greater with a hot-water temperature of 65°C than for one of 45°C. If it is assumed that the heat losses in the pipes at 45°C are 20 %, the above argument would mean that the losses are 30 % at 65°C. The heat losses due to radiation also have a certain effect. This depends on the ratio between the temperature of the outer layer of the pipes and that of the surrounding material, both raised to the fourth power.

4.3.2 Static pressure

The figure below shows the relationship between the magnitude of the flow drawn off and the static pressure in the piping system. In our measurement building in Stockholm, the mean flow drawn off (for all installations) decreased with height (decreasing static pressure), as shown in Figure 8.

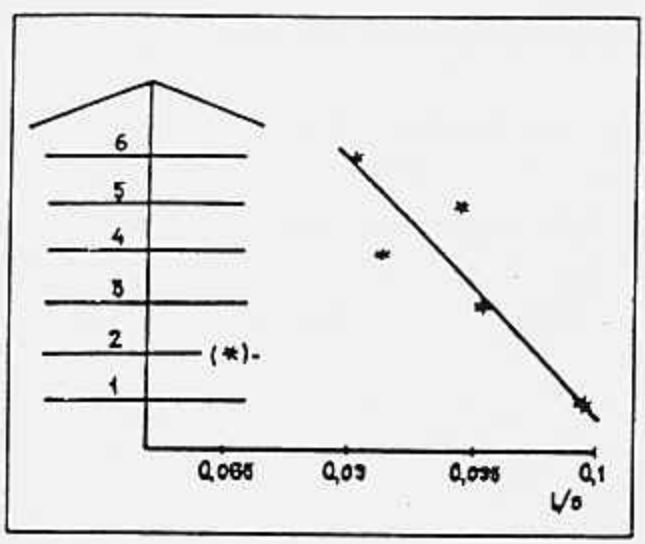


Figure 8. Measured average flow rates (from all tapping points) on each floor, Stockholm 1984.

Thus if in future evaluations we can show that the flow time at the different heights is constant, this will mean that less water is used in the upper stories.

4.4 Some measures and proposals

In order to decrease the heat losses from the hot water in circulation lines, the Swedish building regulations of 1980 direct that circulation lines should be insulated according to the same regulations as apply for hot-water pipes in the heating system. Cold-water pipes are also to be insulated in places where the temperature exceeds 30°C or if they have been installed near to the hot-water lines.
Attention has been drawn of late to leakages in water supply systems. In one article [4], it is said that the losses through leakage have been steadily increasing and by now they often amount to more than 20 % of the quantity of water produced. Searching for leaks is important, and the techniques should be developed. Even small leaks and dripping taps can in time result in large water losses.

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CIB-W62 SYMPOSIUM

Experiment of Macro-Cells Corrosion of Underground Piping

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April 9,~10, 1985

TOKYO, JAPAN



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EXPERIMENT OF MACRO-CELLS CORROSION OF UNDERGROUND PIPING

12th CIB-W62 SYMPOSIUM -TOKYO-
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10 -1985 :KENCHIKU KAIKAN

Summary

Recently water leaks which are caused by concrete-soil macro-cells corrosion pitting are often happening in burried utility pipes (for buildings) within a few years after construction.
So we are performing a project of ministry of contruction, "Development of Techniques for Improving Life Time of Buildings" from 1981 which imcludes field experiments about macro-cell corrosion with steel reinforced concrete blocks (750mm sq. x 1200mm hi.) and steel pipe-specimen.
In this experiment corrosion currents, pipe-soil potentials, soil specific conductance are also measured.
From these results, we estimate (and confirm) as follows;

1. Maximum speed of pitting corrosion are
   0mm/anual in the case of perfect corrosion-prevention pipes,
   0.3mm/anual in the case of semi-perfect,
   1.4≒1.6mm/anual in the case of noprotection.
2. Corrosion current in pipes will be reduce to 1/10-1/16 by the use of insulation fitting (which designed for water domestics).
3. Use of stainless steel pipes under the ground increase the risk of stain of reinforcing rebars by the formation of macro-cells.
4. Combination of stainless steel and ninyle lined steel pipes, cause a very repid corrosion at the joint part, and with in a few months red rust water may occur.

Then we made up a judgement method for macro-cell corrosion and applied it.

Résumé

Les tuyauteries à l'eau en acier enterrées près du bâtiment montrent souvent une rapide corrosion locale en forme de piqûre. Les auteurs ont essayé de clarifier la cause de cette corrosion locale et de trouver quelques solutions contre ceci, dans le cadre d'un grand projet de recherche "technologie pour l'Amélioration de la Durabilité du Bâtiment".
Ce rapport est à présenter une partie intéressante des resultats obtenus dans une série d'essai qui ont été faits dans un chantier d'essai où un bloc en béton (carré de 750mm x 1200mm de haut) a été pose pres duquel les tuyauteries de teste ont été enterrées.

1. La vitesse de corrosion se differe suivant le niveau de protecion traite a la tuyauterie;
   0mm/an: cas de la protection Parfaite,
   0.3mm/an: cas de la protection Non-protégee,
   1.4-1.6mm/an: cas de la protection Non-parfaite.
2. L'application d'un joint isolant pour tuyauterie à l'eau a montré une efficacité à propos de la réduction de la courant électrique de corrosion; celle-ci l'a réduite en 1/10-1/16.
3. Le remplacement de la tuyauterie d'acier galvanisé à la tuyauterie d'acier in-oxidable à montré une risque d'accélerer la corrosion des armatures de renforcement du béton.
4. La tuyauterie en acier enrobée de PVC a montré une corrosion excessive au coin de coupe au point de connexion qui puisse salisser l'eau.

La methóde diagnostique d'estimation du niveau de corrosion causée de la macro-pile electrique établie pour ces essails en basant sur les valeurs cités ci-dessous a montré une utilité importante;
   la courant électrique de corrosion,
   le potentiel électrique entre tuyauterie et sol,
   le potentiel électrique entre deux niveaux de profondeur du sol.

Zusammenfassung

In den letzten Jahnen, die Erdleitung neben einem Gebäude wird oft so beschädigt von den Metallpickelbildung, daß sie in nur zwei oder drei Jahren undicht wird.
Die Verfasser durchführen das Entwicklungsprojekt von den Hallbarkeitsverbesserungstechnik, in dem Experimente in Freien über die Makrozellenkorrosion mit Stahlbetonblöcke (750mm Quad. x 1200mm hoch) und Stahlrohre enthalten sind.
In Diesem Experiment, der Korrosionsstrom, die Potentialdifferenz zwischen dem Rohr und den Erde, der Widerstandskoeffizient von der Erde usm. werden gemessen.
Aus diesen Ergebnissen, wir schließen (bestätigen) folgendermassen:

1. Die maximale Schnelligkeit von der Korrosion ist:
   0mm/Jahr : mit vollkommenem Rostschutz
   0.3mm/Jahr : mit unvollkommenem Rostschutz
   1.4-1.6mm/Jahr : mit keinem Rostschutz

2. Der Korrosionsstrom des Stahlvohr wird durch den Gebrauch von einer Isolierfuge verringert zu 1/10-1/16.

3. Das Rohr vom rostfreien Stahl in der Erde macht die Gefahr der Korrosion der Rundstahl höher durch die Formung der Makrozelle.

4. Die Zusammensetzung von dem rostfneien Stahlvohr und dem Rohr mit einer Vinylchloridauskleidung macht das Korrosionsgefahr der Fuge sehr hoch, und in wenigen Monaten roter Wasser Kann entstehen.

Dann wir eine Diagnostik für die Makrozellenkorrosion verfaßten und probeweise benutzten.

概　要

近年，建物近傍における埋設配管に２～３年という短期間に孔食を生じ漏水に至る事故が多発している。筆者らは鉄筋コンクリートブロックと鉄パイプを用いたマクロセル腐食の屋外実験を含む開発プロジェクト「建築物の耐久性向上技術の開発」を実施している。本実験では腐食電流，管対地電位，土壌比抵抗等を実測している。これらの結果より筆者らは以下の点を推定している。

1. 最大腐食速度は，完全防食の場合で０㎜／年，不完全防食の場合で 0.3㎜／年，無防食の場合で 1.4～1.6 ㎜／年。
2. パイプの腐食電流は絶縁継手の使用により１／10～１／16に低減される。
3. 地中のステンレス管はマクロセル形成により鉄筋の腐食の危険性を増大させる。
4. ステンレス鋼管と塩ビライニング管の組合せは継手部分の腐食危険性を増し，ほんの数ヶ月で赤水が発生する場合がある。

以上によりマクロセル腐食診断案を作成し試行した。

Preface

We know that maximum speed of pitting corrosion in normal conditions is less than 0.1-0.2mm/year even if corrosion occurs intensty. but we hear that speed reachs 1-2mm/year and water leak happens in two or three years after building construction, which is ten times as much as in natural.

These corrosion are caused by not only soil corrosivity, but macro-cells conrrosion force which formed by contact with reinforcing rebars in concrete and underground pipe in soil.

Accessment and repair of underground pipes is so difficult that damage of water leak falls so serious often.

Generally vinyl tape (0.4mm thickness) are used for protection against

corrosion. But when tape tears by die checking or pipe wrenching, macro-cells are formed.

Now technical assessment method of macro-cells and protection method are desired.

We studied and experimented in committiee on macro-cells corrosion so that develop those methods, we report the results in.

This experimental research is a equipment's part of a project which aims to develop a techniques for improving life time of buildings.

Experiments were made to compare and investigate the effects of prevention methods against macro-cells and micro-cells.

Experimental(SPECIMEN)

Tests were made using three sets of piping specimen which has same material and same scale (Fig.1, Table1). Each were buried for 12 months, 24 months or 36 months. Dug up pipes were examined and measured in respect of characteristics of corrosion and maximum corrosion speeds. Test sites are Multi perpose experimental field in B.R.I. (IBARAKI, TSUKUBA) and Nogi factory of Z-company (TOCHIGI, TSUGA).

Specimen consist of piping and reinforced concrete blocks (750mmsq. x 1200mm high) in which about 30m of 16ϕ rebars and 16.4m of 9ϕ rebars are used. Amount of surface area of rebars are 1.98m^2.

Pipes (25A) have 1.8m^2 long and 0.19m^2 surface area, which is about one-tenth of rebars. Pipes and rebars are electrically bineded by cable (8mm sq.CV) and thermit welding. Buring depth are about 600mm (Fig.1).

(MEASUREMENTS)

When bury and dig up , outlook of soil (topography, kind and constitution of soil, drainage and odor), physical and electrical characteristics of soil (density, water content, specific conductance, oxidation reduction potential and curent) and electro-chemical characteristics (PH, conductivity, Cl^- density, SO_4^{2-} density of soil

dissolved solution) of soil on the site are measured and investigated. After buring, measurement of corrosion current, pipe-to-soil potentials, specimen-to-soil potentials, reinforcing rebars-to-soil potentials, ground surface voltage drop and soil conductance are performed every month.

These are showed in Fig.2. Table-1 shows corrosion current which measured at B.R.I. Fig.-2 shows at Z company.

M-1 is bared steel pipe galvanized zinc (SGP-white). In early time of experiment corrosion current reaches several mili amperes, which are seemed to be caused by resolution of zinc on steel pipe to soil. It is proved by the data of soil potential, -0.95V $Cu/CuSO_4$ (steel-to-soil potential is -650mV to $Cu/CuSO_4$).

MT-1 is covered twice by vinyl tape (0.4mm thickness) with half lap and is regarded as perfect protection specimen MT-2 is covered Vinyl tape as like as MT-1 and strip vinyl tape 1cm width along circumference (arrow mark) in Fig.3 as a semi-perfect protection specimen with defect of protection which caused by die checking in threadding or pipe wrenching at connectiong.

Corrosion current of MT-1 were recognized scarecely. Minimum unit of used measuring instrument is 0.001μA.

When specimens dug up, because bared zinc galvanized steel has no rust, then, we judge that recorded currents are caused by concrete soil macro-cells, and that equivalent dessolved quantity may be calculated from total current in a year.

Table-3 shows results of calculated equivalent dissolved quantity.

On MT-1 current increased in second year, paticulary in Z-company, current reached 10 times than first year. These are because of deterioration of sticky paste of tape water invasion in protection layer, and drop of electrical resistance of protection.

Current of M-1 reduced in second year 0.8 times than first year. After buried, much current flew because of dessolving of zinc in early period. In second year, steel rusted and current decreased. Current of MT-2 reduced in second year too.

Table-4 shows current concentration ratio.

Each current density is obtained by deviding the total current by the area without protection of MT-1 by M-1.

The current concentration of M-1 is 12-24 times as much as MT-1.

In the ratio of maximum pitting speed between MT-1 and M-1 in Table 4 is 1 to 5.

These facts mean that stronger protection with protection defect invites more heavy concentration of damage. The specimen MT-2 at B.R.I. made a pitting hole in two years, and rusted at ties as we expected.

We find that taping on complicated place like ties is very difficult for protection, and deterioration runs more rapidly than we thought.

PROTECTION OF INSULATION FITTING

We examined the effect of insulation fitting on corrosion prevention against macro-cells at the site, where specimen were buried 12 months long.

SC-1 without insulation fitting, is compared to piping specimen named IC-10D, IC-20D with insulation fittings which is used intest of corrosion prevention of wather pipes.

Although insulation fitting was used a short insulation gap is able to be jumped current through the water in the pipe. Manifactures specify that distance between metal ends of pipes should be greater than ten times as long as the diameter.We make two specimen with 5-D and 20-D insulation gap fitting and examine the effect of difference of gap length.

Specification of taping are same as MT-2. In this experiment, pips are

filled with water which is city water at Z-company, and in B.R.I. which is adjusted to 1000 S/cm on conductivity by addition of KCl (Karium chloride).

Inner water are changed every month, Fig-4 shows measured data of corrosion current in first year.

In fig.4, white circle is value before water changed, and black circle is value after.

These difference caused by changing of water and different water temperature which rises water cunductivity.

About sequential measuring at B.R.I., the fact are found that current rise at the change of water and then decrease gradually for three days, and go back formar value. The reason is what water tenperature became soil temperature three day later. While water is flowing, corrosion current increases 1.2 times at SC-1 and 1.6 times at IC-10D, IC-20D.

The evaluation for insulation fitting is made by comparing annual amount of currents and depth of pitting. Table-5 shows these results.

The current reduction by use of insulation fitting became 1/16-1/22 in the first year and 1/10-1/22 in two years. Total current of second years almost decrease than first year.

Except is the specimen IC-20D at B.R.I. It is nearly equal to last year.

From this experiment we cannot confirm that the longer insulation gap improve the protection.

Because current of 5 D lenght specimen is nearly equal to current of 10 D and 20 D, and effect of difference on conductivity also not clear.

MACRO-CELLS CORROSION OF STEEL AND STAINLESS STEEL

As a material of water suplly from mains to stop valve, stainless steel is used in case of small diameter.

In other cases, vinyl lined steel pipes are used.This piping system

intenced to long life use.

Fig.-5 shows buried specimen conditions. The material of specimen SU-1 is all stainless, specimen SU-SC is half stainless, half VLP which lapped by vinyl tape.

Specimen SU-IC has insulation fitting added to SU-SC.

These pipes are filled with water which changed every month. The water is adjusted in the same way of test of fitting.

We welded lead lines on each side of insulation fitting of specimen (SU-IC), and measered pipe-to-soil potential each lead line. These measured potentials prove the effects of insulation fitting. Fig.-6 shows measured currents in the first year. RC block which connected with SU-SC has noble potential because formar experiment, large current occured in early times. Corrosion current in soil flew from reinforcing rebars which rusted as we expected. The fact that stainless pipe-to-soil potential is noble to rebar-to-soil potential, proved high durability of stainless steel. The current reduction performed by insulation fitting is about 1/2-1/3.

At the site of Z-company, electric rail way run 200m distant from experiment site and stray current flow out which interfere the valtage drop of ground surface caused by macro-cells.

As the direction of current are changed sometimes, data are not reliable.

When new pipes connect to main pipe of city water, new pipes rusted and old pipes are protected from new pipe by macro-cells. To use stainless pipes for water supply in site will rust main pipes.

Two months later after the experiment starts at the water changing rust red water issued from pipe.

Iron surface contacting to water is only end parts of pipe and its area is little.

Therefore anode area is too small than cathode area (stainless steel), corrosion concentrate at the ends of pipe.

Estimation method about corrosiveness of soil was reported by W. Beackman & W. Schwenk based on N.B.S. corrosion test for buried pipes, consist of 13 indicaters.

At first, from these indicaters we chose 4 which have major infuluence on macro-cells corrosion, and then take in consideration the defect of covering material, and degree of macro-cell consistency, chose 7 indicaters finally.

By this estimation method consist of 7 indicaters evaluated result of the corrosiveness of soil of B.R.I. and Z-company is middle intensity. But corrosion speed of B.R.I. is twice of Z-company.

In experiment, we measured not only macro-cells corrosion potential but also micro-cells. Specimens are SGP-W, SGP-B and SUS pipe. Corrosion potential ofSGP-B pipe in B.R.I. is quite different from Z-company.

To take in consideration of potential of SGP-B pipe is better, we think.

If reinforcing rebars and buried pipe steel perform macro-cells, proposed estimation methods are shown in Fig.7. Criteria figure is 0.5mV/m (Ground surface voltage drops) which is desided after the Stray Current Prevention Code.

To evaluate macro-cells exactly, the way which cut buried pipe which excavated beside buildings and measure the corrosion current and potentials is(rebar-to-soil and pipe-to-soil).

In Table 7, the measured potentials are shown.

From this table, it can be seen tath the potentials of reinforcing rebars which had been 200mV vs, $Cu/CaSo_4$ at first increased to -100mV when the specimen's corrosion prevention was excellent, but decreased to -400mV in the case of poor prevention. In this experiment, the potential of reinforcing rebars changed from -220mV to -100mV or -400mV,

but it is not clear whether or not this change was affected by the shortness of reinforcing rebars. Regarding macro-cells prevention measures, it was confirmed that insulation fitting on piping system near buildings reduces corrosion current to one tenth, but it is still not made clear how long, or how many times of pipe diameter, the insulation gap should be, and how think insulation gap is needed to prevent galvanic corrosion.The concentration of electric current on the end area of pipe cuses corrosion problem. To mitigate this problem, it is necessary to establish a code that gives the slandard on the length of insulation fittings and of water flow speed because wather flow speed affects electric conductivity of water.

To estimate macro-cells corrosion speed we need to know the area and the place of defective protection. The almost only technique available at present for meàsuring macro-cells corrosion is to periodically measure pipe-to-soil potentials and ground surface potential gradient using lead cable (CV cable) thermited on pipes .

This data is just one record obtained by a limited laboratory experiments, therefore collecting field tests data will be valuable to determine the accurate criteria of corrosion prevention, the definition of pitting corrosion speed, the testing method and the acceleration testing method. This will make it possible to develop corrosion prevention techniques, which will eventually result in a rational technical code for macro-cell corrosion prevention.

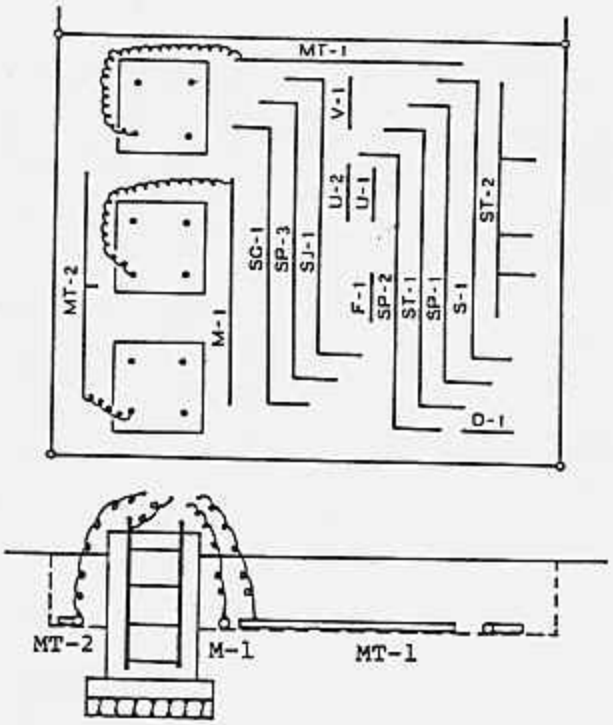


Fig-1 BURIED SPECIMEN ARRAY

Table-1 SPECIMENS LISR

NAME	CODE	SPECIFICATION	FORM
STEEL PIPE WITH FITTING (SGP, WHITE)	S-1 ST-1 SJ-1 SC-1	BARED VINYL TAPED WATER PROOF COVERED JUTE COAL-TARL COATED	25A 2100 30
STEEL PIPE WITH FITTING (SGP PC)	SP-1 SP-2 SP-3	POLYETHYLENE LINED	25A E2 E1 E1 : EPOXY RESIN COATING E2 : POLYETHYLENE LINING
CARSTIRON FOR DRAINAGE COPPER TUBE (TYPE-L) STAINLESS PIPE (SUS304) STAINLESS PIPE (SUS316) VINYL PIPE (VP)	F-1 D-1 U-1 U-2 V-1	SCRATCHED BARED BARED	50 * 400 1' * 400 25SU * 400 25SU * 400 25 * 400
STEEL PIPE WITH TIES (SGP, WHITE)	ST-2	VINYL TAPED	25*1800
STRAIGHT PIPES (MACRO-CELL CORROSION TEST PIECES, SGP, WHITE)	M-1 MT-1 MT-2	BARED VINYL TAPED (PERFECT) VINYL TAPED (SEMI-PERFECT)	25*1800 25*1800 25*1800

Table-2 CORROSION CURRENT(B.R.I)

BURIED PERIOD	SPECIMEN CODE	CURRENT UNIT	5/8 240	5/28 720	6/26 1416	7/29 2208	8/28 2880	9/28 3672	10/28 4392	12/1 5208	12/28 5832	1/27 6576	2/27 7320	3/29 8040	4/27 8736
12 MONTHS	MT- 1	μA	—	—	0.001	0.009	0.18	0.075	0.003	0.004	0.002	—	0.001	0.001	—
	M - 1	mA	7.5	6.6	6.4	5.4	5.7	5.6	4.25	3.6	3.0	3.0	2.95	3.2	3.6
	MT- 2	mA	0.55	0.89	1.0	1.2	1.2	1.05	0.51	0.6	0.525	0.56	0.6	0.68	0.67
24 MONTHS	MT- 1	μA	—	—	0.001	0.009	0.185	0.081	0.003	0.004	0.002	—	—	—	—
	M - 1	mA	10.5	8.2	8.1	6.7	7.4	6.5	5.1	4.2	3.4	3.4	3.2	3.7	4.1
	MT- 2	mA	0.7	1.2	1.25	1.5	1.45	1.2	0.625	0.73	0.62	0.63	0.645	0.72	0.72
36 MONTHS	MT- 1	μA	—	—	—	0.009	0.19	0.09	0.005	0.006	0.003	0.001	0.001	0.001	0.001
	M - 1	mA	10	8.3	8.6	6.2	7.3	6.5	4.95	4.0	3.15	3.0	3.0	3.4	3.75
	MT- 2	μA	—	—	—	0.009	0.19	0.10	0.007	0.01	0.009	0.0075	0.0075	0.001	0.016

A-ZONE (BUILDING RESEARCH INSTITUTE) BURIED IN APRIL 18th

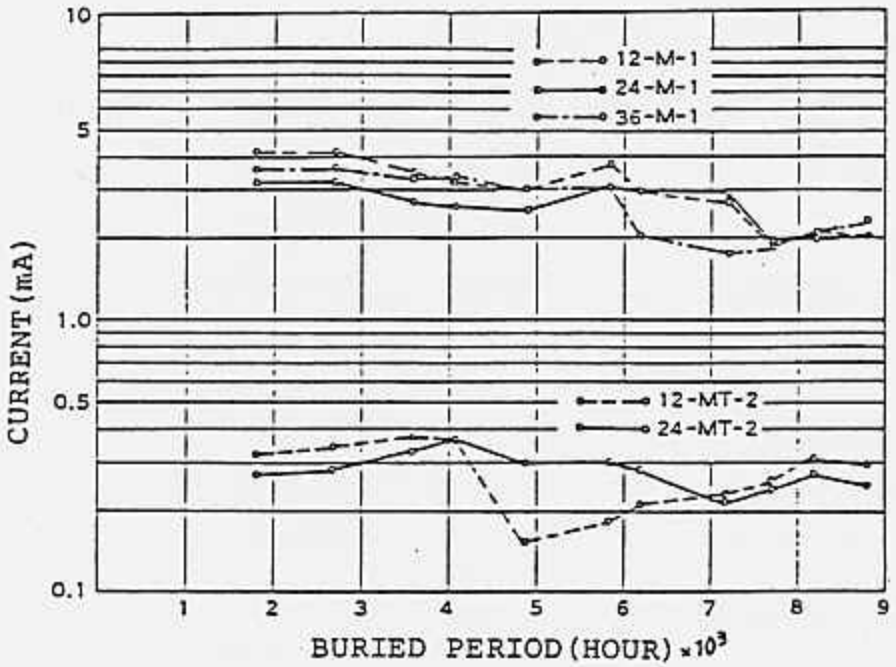


Fig-2 CORROSION CURRENT(Zcomp)

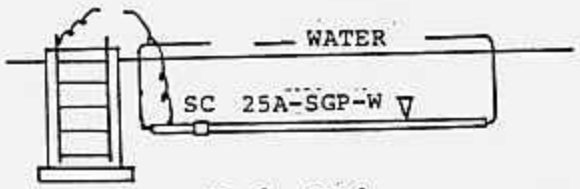
Table-3 COMPARISON OF MACRO-CELLS CORROSION SPEED

BURIED PERIOD			12 MONTHS			24 MONTHS								
SITE	SPECIMEN CODE	SPECIFICATION	TOTAL CURRENT Q YEAR	EDQ	MPD mm	TOTAL CURRENT FIRST YEAR	TOTAL CURRENT SECOND YEAR	Q YEAR TOTAL	EDQ FIRST	EDQ SECOND	EDQ TOTAL	SECOND FIRST	MPD mm	MPS mm YEAR
BRI	MT−1	VINYLE TAPED PERFECT	0.073 *10	0.211mg	—	0.076*10	0.082*10	0.157*10	0.22mg	0.23mg	0.451 mg	1.08	—	0
	M −1	BARED	14.5 *10⁴	41.6 g	0.35	17.3 *10⁴	13.3 *10⁴	30.6 *10⁴	49.7g	38.2g	87.8 g	0.769	0.61	0.33
	MT−2	VINYLE TAPED SEMI-PERFECT	2.45 *10⁴	7.03g	1.89	2.91*10⁴	1.37*10⁴	4.28*10⁴	8.36g	3.92g	12.3 g	0.471	3.15	1.6
Z-COMP.	MT−1	VINYLE TAPED PERFECT	0.052 *10	0.148mg	—	0.144*10	1.45 *10	1.60*10	0.413mg	4.17mg	4.59 mg	10.1	—	0
	M −1	BARED	8.36 *10⁴	24.0 g	0.2	7.24*10⁴	5.93 *10⁴	13.2 *10⁴	20.8 g	17.0 g	37.8 g	0.82	0.68	0.28
	MT−2	VINYLE TAPED SEMI-PERFECT	0.723 *10⁴	2.07g	1.1	0.75*10⁴	0.50 *10⁴	1.25*10⁴	2.16g	1.44 g	3.60 g	0.666	2.75	1.38

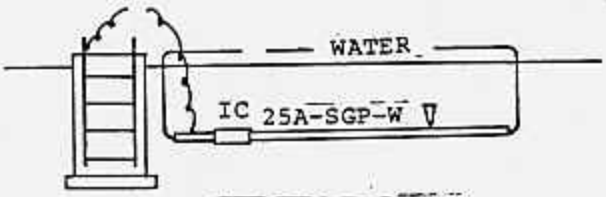
EDQ : EQUIVALENT DISOLVED QUANTITY. MPD : MAXIMUM PITTING DEPTH. MPS : MAXIMUM PITTING SPEED

Table-4 CONCENTRATION OF CURRENT DENSITY

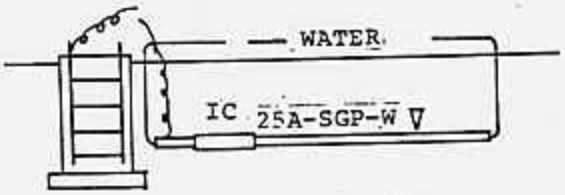
		BURIED 12 MONTHS			BURIED 24 MONTHS			MAXIMUM PITTING SPEED RATIO
SITE	SPECIMEN CODE	TOTAL CURRENT Q/YEAR S	CURRENT DENSITY mA/cm	CONCENTRATION DEGREE	TOTAL CURRENT Q 2YEAR	CURRENT DENSITY mA/cm	CONCENTRATION DEGREE	
BRI	M−1	14.5*10⁴	97	—	30.6*10⁴	204	—	—
	MT−2	2.45*10⁴	2290	24	4.28*10⁴	4010	20	4. 8
Z-COMP.	M−1	8.36*10⁴	56	—	13.2*10⁴	88	—	—
	MT−2	.723*10⁴	67.7	12	1.25*10⁴	1170	20	4. 9



No-1 SC-1



No-2 IC-5D (10D)



No-3 IC-10D (20D)

Fig-3 BURIED SPECIMEN CONDITION

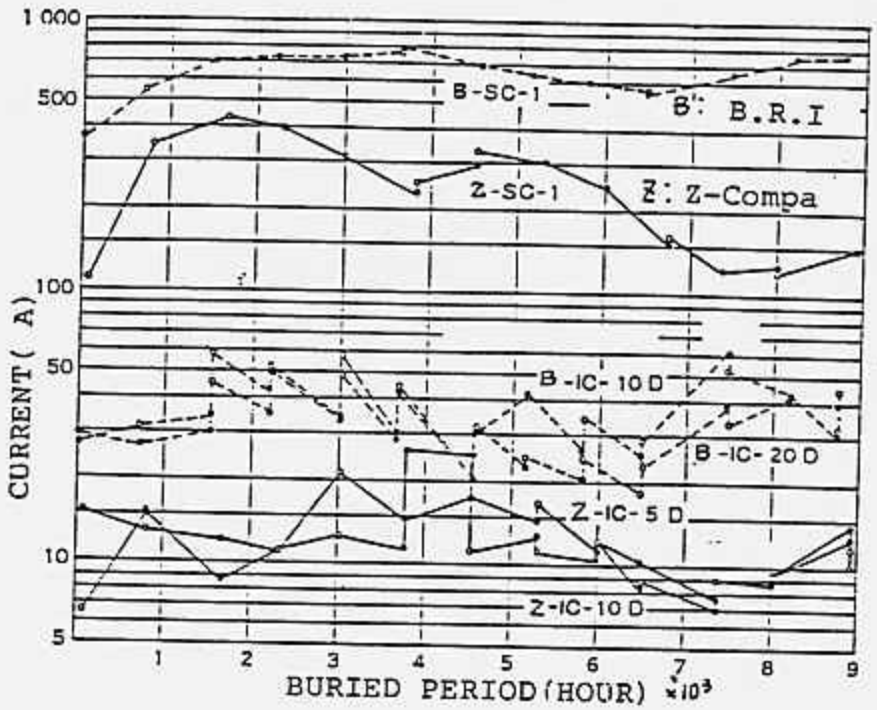
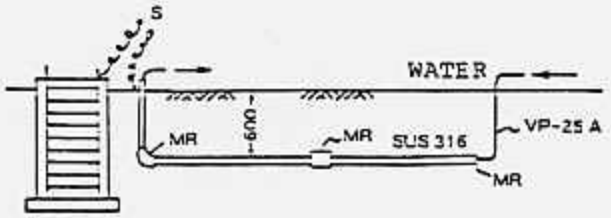
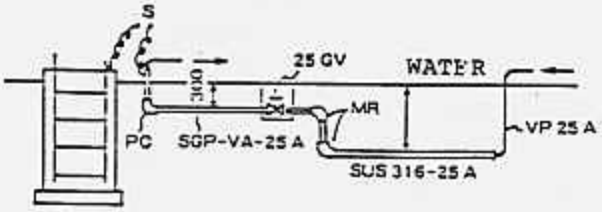


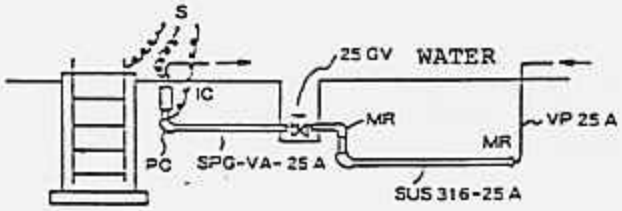
Fig-4 CORROSION CURRENT(INSULATION FITTING)



No. 1 SU-1



No. 2 SU-SC



No. 3 SU-IC

Fig-5 BURIED SPECIMEN CONDITION(SUS PIPES)

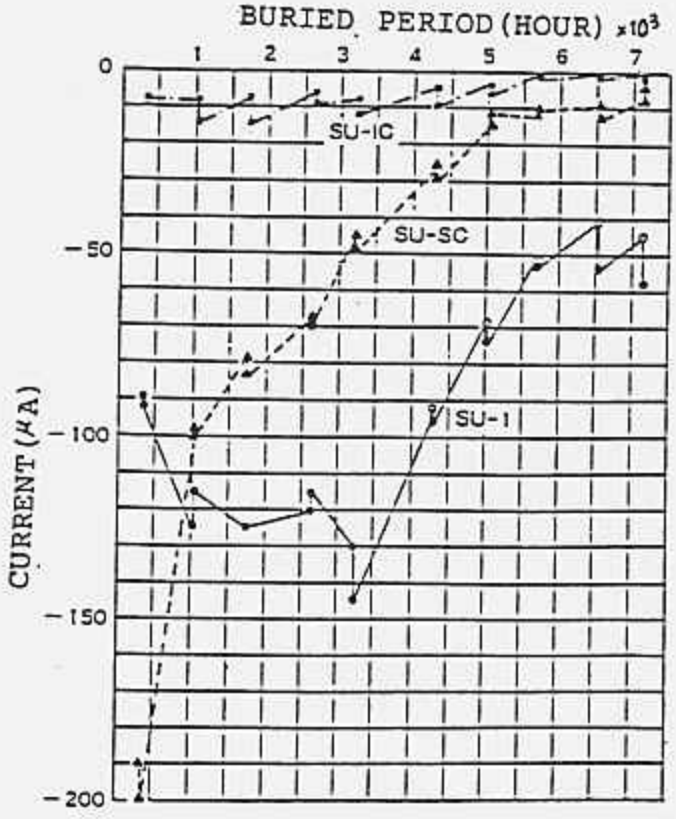
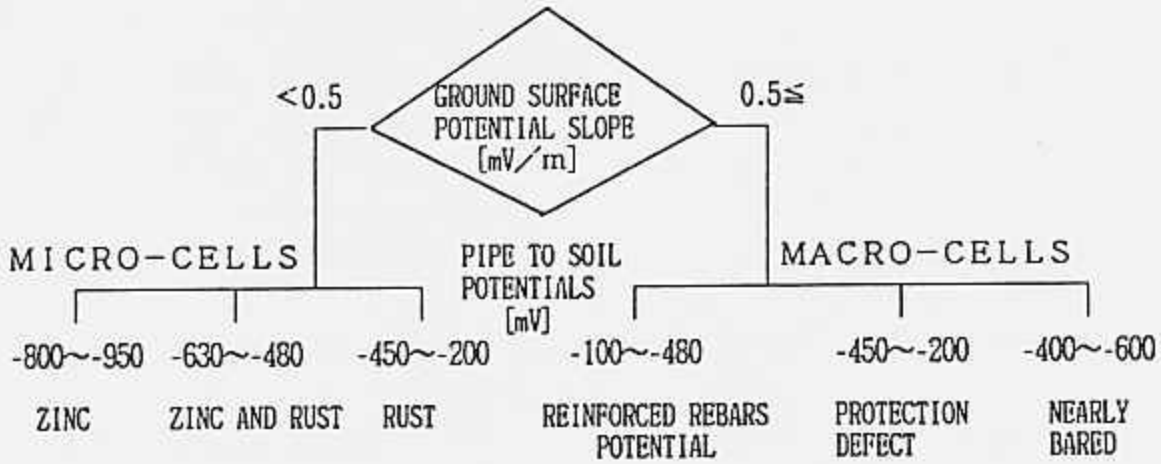


Fig-6 CORROSION CURRENT(SUS PIPES)

Table-5 COMPARISON OF EFFECT OF INSULATION FITTING

SITE	SPECIMEN CODE	FIRST YEAR		SECOND YEAR		TOTAL OF TWO YEARS		REDUCTION RATIO OF INSULATION SECOND/FIRST
		TOTAL CURRENT Q/YEAR	CRR	TOTAL CURRENT Q/YEAR	CRR	TOTAL CURRENT Q/2YEARS	CRR	
BRI	SC-1	19.06 *10³	1/1	15.88 *10³	1/1	34.94 *10³	1/1	83.3%
	IC-10D	1.192*10³	1/16.0	0.710*10³	1/22.3	1.902*10³	1/18.4	59.6%
	IC-20D	0.999*10³	1/19.1	1.017*10³	1/15.6	2.018*10³	1/17.3	101.8%
Z-COMP.	SC-1	8.241*10³	1/1	3.105*10³	1/1	11.345*10³	1/1	37.7%
	IC- 5D	0.426*10³	1/19.3	0.324*10³	1/ 9.6	0.750*10³	1/15.1	76.1%
	IC-10D	0.386*10³	1/22.4	0.286*10³	1/10.9	0.654*10³	1/17.3	77.7%

CRR : CURRENT REDUCTION RATIO



NO.	RATING ITEMS	INDEX				
		0	−1	−2	−3	−4
1	SOIL LECTRIC RESISTIVITY	>10000	10000 ~5000	5000 ~2300	2300 ~1000	1000> [Ωcm]
2	pH	>6	6≧			
3	cl IONS	<100	100≦			[mg/kg]
4	SO SALTS	<200	200 ~500	500 ~1000	1000≦	[mg/kg]
5	PROTECTION OF PIPES	PLP	TAPE JUTE	BARED		
6	GROUND SURFACE POTENTIAL SLOPE	<0.5		5≦		[mV/m]
7	PIPE TO SOIL POTENTIAL-SCE	<-800	-800 ~-650	-650 ~-450	-450 ~-200	-200≦ [mV]

SUM OF INDEX VALUE	DEGREE OF CORROSION
>0	SAFETY
0~−3	SLIGHTLY DANGER
−4~−8	DANGER
<−8	VERY DANGER

Fig-7 JUDGMENT FLOW OF MACRO-CELLS

Table-6 PIPE-TO-SOIL POTENTIALS(B.R.I)

SPECIMEN CODE	DATE	4/28	6/3	7/1	7/29	9/5	9/30	11/14	12/14	1/12	2/15	3/12
SC-1	MACRO-CELLED	267	240	230	240	228	233	238	228	220	225	230
	RC-BLOCK	240	213	210	217	203	213	205	198	195	200	200
	SPECIMEN	502	450	420	435	435	440	450	430	425	420	420
IC-10D	MACRO-CELLED	75	78.5	89	82	76	72.5	65.5	61	54	47.5	52
	RC-BLOCK	89	78	78	71	75.5	82	85	60	52	47.5	53
	SPECIMEN	360	281	350	350	315	355	345	289	275	242	270
IC-20D	MACRO-CELLED	112	107	114	110	100	108	94.5	87	79	79	75.5
	RC-BLOCK	112	102	110	108	100	107	93.5	86.5	81.5	80	76
	SPECIMEN	700	660	620	625	615	610	630	515	485	425	435
SU-1	MACRO-CELLED	120	67	57	56	51	47.5	26	28.6	34	34.5	31.5
	RC-BLOCK	120	70	62	60	55	55	34	36.5	41.5	38.5	38
	SPECIMEN	470	32	18	21	16.1	7.1	13.3	-17	-7.5	-1.7	-6.2
SU-SC	MACRO-CELLED	480	111	53	44.5	26	21.8	10.8	7.0	6.1	5.1	14.7
	RC-BLOCK	339	120	56	46.5	29	23.9	12.8	8.0	8.7	7.95	16
	SPECIMEN	650	41.5	28	24	-14.5	12.2	3.7	8.75	-1.0	6.8	12.2
SU-IC	MACRO-CELLED	165	110	111	106	98	120	88.5	80	71.5	74.5	77
	RC-BLOCK	161	110	110	104	98.5	120	90	78	74	74.5	77
	SPECIMEN	675	14.4	-17	11.8	15.8	7.8	7.7	28.8	98	11.5	103
40-M-1	MACRO-CELLED	112	107	108	112	108	110	94	79	74	75	79
	RC-BLOCK	112	103	118	112	108	110	95	80	75	75	80
	SPECIMEN	480	1020	1030	690	1000	785	760	1030	460	1040	1050
40-M-1	MACRO-CELLED	450	450	460	470	470	470	450	440	420	420	430
	RC-BLOCK	490	375	400	415	410	400	390	360	350	350	375
	SPECIMEN	650	640	640	665	670	685	665	640	615	610	620
40-M-1	MACRO-CELLED	82	70	76	76	67.5	68	47	49	49	43	55
	RC-BLOCK	82	70	76	76	67.5	68	48	49	49	43	55
	SPECIMEN	480	650	77	490	470	450	450	610	410	500	450

CIB

CIB-W62 SYMPOSIUM

Reserch on Corrosion of Pipings in Buildings

Taku Matsumoto

April 9,~10, 1985

TOKYO, JAPAN



TAKU MATSUMOTO
Kajima Corporation

NOBUYUKI KIMATA
Kajima Corporation

RESEARCH ON CORROSION OF PIPINGS IN BUILDINGS

12th CIB-W62 SYMPOSIUM — TOKYO —
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10, 1985 :KENCHIKU KAIKAN

Summary

This report aims to grasp the actual status of the corrosion of pipings in buildings and attempts to find the causes of the corrosion although through an indirect method (questionnaire). In this research, the main purpose was set to grasp the major trends, and the replies from building managements on the status of corrosion and using manners obtained by interviewing were analyzed.

The object in this research was limited to water supply, hot water supply, cooling water and chilled/hot water piping application. At the analysis, a special consideration was taken for the material characteristics of piping systems and the inherent operating environment of building mechanical installation.

When summerizing the results, troubles caused by corrosion were frequently observed on galvanized pipes for water and hot water supply which grows seriousely along with the lapse of time. For hot water piping, a significant difference is observed depending on the operating environment caused by specific building applications. Under severe operating condition shown in hotels and hospitals, the generation ratio of troubles is high even on copper piping although it is lower than that on galvanized piping.

The generation ratio of troubles on cooling and chilled/hot water pipings is lower than that on water and hot water pipings. For cooling water piping, it was high under severe operating condition in terms of period and hour.

Résumé

Ce rapport a pour but d'évaluer l'état réel de corrosion des tuyauteries dans les bâtiments et de tenter de déterminer les causes de cette corrosion par une méthode indirecte (questionnaire). Le but principal de cette recherche était de cerner les principales tendances; pour cela, on analysé les réponses données lors d'interviews de gestionnaires de bâtiments en ce qui concerne l'état de corrosion des tuyauteries et les méthodes employées.

L'objet de cette recherche était limité aux tuyauteries d'alimentation en eau, en eau chaude, en eau de refroidissement et en eau froide/chaude. Lors de l'analyse, une attention particulière a été consacrée aux caractéristiques des réseaux de tuyauterie et aux environnements d'exploitation inhérents aux installations mécaniques des bâtiments.

Pour résumer les résultats, on peut dire que des malfonctionnements causés par la corrosion ont été fréquemment observés dans le cas de tuyaux galvanisés destinés à l'alimentation en eau et en eau chaude; l'ampleur de ces malfonctionnements augmente sérieusement avec le temps. En ce qui concerne les tuyaux d'alimentation en eau chaude, une différence significative a été observée selon l'environnement d'exploitation découlant des applications spécifiques des bâtiments. Dans des conditions sévères d'exploitation trouvées dans des hôtels ou des hôpitaux, le taux de malfonctionnement est plus élevé sur des tuyaux de cuivre bien qu'il soit plus faible sur des tuyaux galvanisés.

Le taux de malfonctionnement sur des tuyauteries d'eau de refroidissement et d'eau froide/chaude est inférieur à celui des tuyauteries d'eau et d'eau chaude. En ce qui concerne les tuyauteries d'eau de refroidissement, ce taux était élevé dans des conditions d'exploitations sévères en termes de durée et d'heures.

Zusammenfassung

Dieser Bericht zielt darauf ab den tatsächlichen Zustand der Korrosion an Rohrleitungen in Gebäuden festzulegen und auf inderektem Wege die Ursachen dafür zu ermitteln (Fragebogen). Der Hauptzweck dieser Studie bestand darin die Grundtendenzen durch eine Analyse der Berichte von Gebäudeverwaltungen hinsichtlich des Zustands der Korrosion und angewandter Methoden, ermittelt anhand von Interviews, festzulegen.

Die Untersuchungen beschränkten sich hierbei auf die Wasserversorgung, bzw. die Versorgungsleitungen für heißes Wasser, Kühlwasser sowie Kalt/Heiß-Wasserrohrleitungen. Man konzentrierte sich besonders auf die Materialeigenschaften der Rohrleitungen und die jeweilige Betriebsumgebung der mechanischen Installationseinrichtungen in den Gebäuden.

Die Ergebnisse zusammenfassend zeigten sich durch Korrosion hervorgerufene Probleme am häufigsten an galvanisierten Rohren für die Wasser- und Heißwasserversorgung, die sich im Laufe der Zeit noch wesentlich verschlimmerten. Bei den Rohrleitungen für heißes Wasser wurden beachtliche Unterschiede bezüglich der verschiedenen Betriebsumgebungen der jeweiligen Gebäude-Installationssysteme festgestellt. Bei besonders hoher Beanspruchung, wie in Krankenhäusern oder Hotels, traten Störungen noch wesentlich häufiger auf und dies selbst an Kupferrohren, obwohl immer noch geringfügiger als an galvanisierten Leitungen.

Die Häufigkeit des Aufretens von Störungen an Kühl- sowie Kalt/Heißwasserrohrleitungen ist geringer als an Wasser- und Heißwasserleitungen. Bei Kühlwasserrohrleitungen war jedoch, bei langer und häufiger Beanspruchung, ein Anstieg von Störungen zu verzeichnen.

1. Purpose of research

The quality of buildings has been remarkably improved under abrupt economic growth after 1960s in Japan. Cooling/heating and hot water supply facilities have been popularized repidly. Before this time, buildings were scarcely provided with such facilities except plumbing facility. In this period, these facilities were constructed in a short period to match the expanding needs without having technical backup causing the presence of various troubles appeared today.

The authors have been impressed to note that piping equipment inside buildings are hindered by corrosion in no small cases through the past trouble investigation. In actual buildings, the clogging of pipes, red suspension and water leakage are generated within an unexpectedly short period in no small cases. On the other hand, no trouble is found on old piping installed over 40 years before, while frequent water leakages are found on new piping installed several years before.

Although the life of pipings for building mechanical installations is shorter than that of building structures generally, it is desired to be durable against the use over 30 years in Japan.

Difficulty to grasp corrosion problems is caused by the complexed factors of corrosion and various conditions generated along with the lapse of time. In addition, the status of corrosion appeared as a result can not be expressed correctly.

Under such circumstances, this research intends to delve into the surveys conducted in the past, as well as to pursue the causes of corrosion with indirect data.

2. Method of research

1) Method of research

Although various methods are available to grasp the status of corrosion,

an extreamely hard work is required to obtain the phsical status of corrosion through actual observation, since the corrosion phenomenon itself tends to appear locally.

Under the circumstances, this research was based on indirect language data through questionnaires for the experiences of building managements on corrosion inside buildings. This research aimed at understanding the major trends by grasping the actual status of corrosion generated on pipings in buildings as well as to investigate the causes of corrosion. This method was basically taken from the epidemiological research.

With the cooperation of the Building-Energy Managers Association of Japan, each building service company under the Association set out questionnaires to the building managements. As a result, replies on 423 examples were collected from the building managements.

As explained, the corrosion of building mechanical installation is generated under complexed mechanism consisting of many factors. Therefore, the analysis was proceeded by taking the relation between the causes and results indicated below into consideration. Especially, a specific corrosion is seriously influenced by the material characteristics of piping systems and the inherent operating environment of facility. In our research, therefore, the combination of facility application and piping material was paid by special attention. Firstly, it was classified and then the influences caused by other factors were studied.

Research items

Relating to major cause

- Pipe material
- Facility application (Water supply, hot water supply)
- Usage (Building application)
- Control method (Inhibitor,

Relating to major result

- Content of trouble (Corrosion, rust suspension, scale, etc.)
- Trouble frequency
- Content of corrosion (Kind, shape, distribution)

blow, etc.)

- Water quality (pH, temperature, bubble, chlorine ion, etc.)
- Time (Operating years, hours, and seasons)
- Jointing with other metal materials
- Location of trouble
- Material in trouble
- Time of trouble generation

2) Object of research

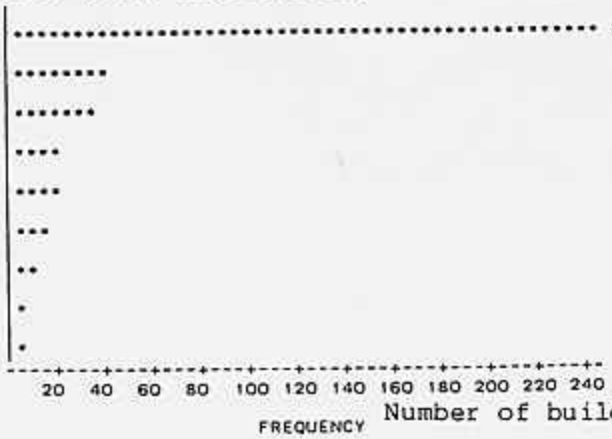
The object of this research was set to water supply, hot water supply, cooling water and chilled/hot water pipings on which many troubles were observed through the past investigations. Underground pipe was excluded from this research. The outlines of the object buildings in this research are shown below. The trends of these buildings indicate that of the buildings managed by the building service companies.

(1) Number of research facilities

Total number of research facilities	423
With water supply piping	423 (100%)
With hot water supply piping	230 (54%)
With chilled/hot water supply piping	365 (86%)
With cooling water supply piping	389 (92%)

(2) Building applications

Building application (Main application) N : 423	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
Office	245	245	57.92	57.92
Other complex building	42	287	9.93	67.85
Department stores	34	321	8.04	75.89
Hotel	21	342	4.96	80.85
Hospital	18	360	4.26	85.11
Office & others	13	373	3.07	88.18
Apartment house	11	384	2.60	90.78
Residence	7	391	1.65	92.43
School	6	397	1.42	93.85
Leave out.				



This chart shows that office buildings hold a majority of the total number of buildings, followed by department stores, hotels and hospitals.

(3) Year of construction

This chart shows that all the buildings distribute after 1926, centering around the years between 1965～1974.

FREQUENCY BAR CHART

MIDPOINT YEAR	N : 419	FREQ	CUM. FREQ	PERCENT	CU PERC
1954	*****	5	5	1.19	1
1955	*	1	6	0.24	1
1956	*	1	7	0.24	1
1957	***	3	10	0.72	2
1958	******	6	16	1.43	3
1959	*******	7	23	1.67	5
1960	*******	7	30	1.67	7
1961	*******	7	37	1.67	8
1962	**********	11	48	2.63	11
1963	**********	11	59	2.63	14
1964	**********	11	70	2.63	16
1965	*******************	19	89	4.53	21
1966	************************	24	113	5.73	26
1967	***************	15	128	3.58	30
1968	************	12	140	2.86	33
1969	**********	11	151	2.63	36
1970	*****************************	29	180	6.92	42
1971	*****************************	29	209	6.92	49
1972	*****************************	29	238	6.92	56
1973	*****************************	29	267	6.92	63
1974	**	41	308	9.79	73
1975	*****************	17	325	4.06	77
1976	**************	14	339	3.34	80
1977	*****************	16	355	3.82	84
1978	*********************	21	376	5.01	89
1979	******************	18	394	4.30	94
1980	*******************	19	413	4.53	98
1981	*****	5	418	1.19	99
1982	*	1	419	0.24	100

5 10 15 20 25 30 35 40

FREQUENCY

(4) Total area of buildings

Large-scale buildings, especially those of 3,000～15,000m^2, predominate in this chart.

FREQUENCY BAR CHART

MIDPOINT AREA	Total area (Midpoint) N : 417	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
1000 m²	**************				
3000	**********	15	15	3.60	3.60
5000	**********	69	84	16.55	20.14
7000	**********	66	150	15.83	35.97
9000	**********	65	215	15.59	51.56
11000	**********	40	255	9.59	61.15
13000	**********	30	285	7.19	68.35
15000	**********	17	302	4.08	72.42
17000	**********	15	317	3.60	76.02
19000	**********	18	335	4.32	80.34
21000	**********	9	344	2.16	82.49
23000	**********	10	354	2.40	84.89
25000	**********	3	357	0.72	85.61
27000	**********	6	363	1.44	87.05
29000	**********	3	366	0.72	87.77
31000	**********	6	372	1.44	89.21
33000	**********	4	376	0.96	90.17
35000	**********	5	381	1.20	91.37
37000	**********	1	382	0.24	91.61
39000	**********	4	386	0.96	92.57
41000	**********	2	388	0.48	93.05
43000	**********	2	390	0.48	93.53
45000	**********	2	392	0.48	94.00
47000	**********	1	393	0.24	94.24
49000 m²	**********	3	396	0.72	94.96
	**********	21	417	5.04	100.00

5 10 15 20 25 30 35 40 45 50 55 60 65

FREQUENCY

(5) Research number by prefectures

There are as many as 19 researched prefectures. Tokyo-to, holding a majority, marks 264 cases (63%), followed by 37 (9%) of Aichi-ken, 32 (8%) of Kanagawa-ken, 14 (3%) of Chiba-ken, 12 of Niigata-ken, and 10 of Osakafu.

Number of buildings by prefectures

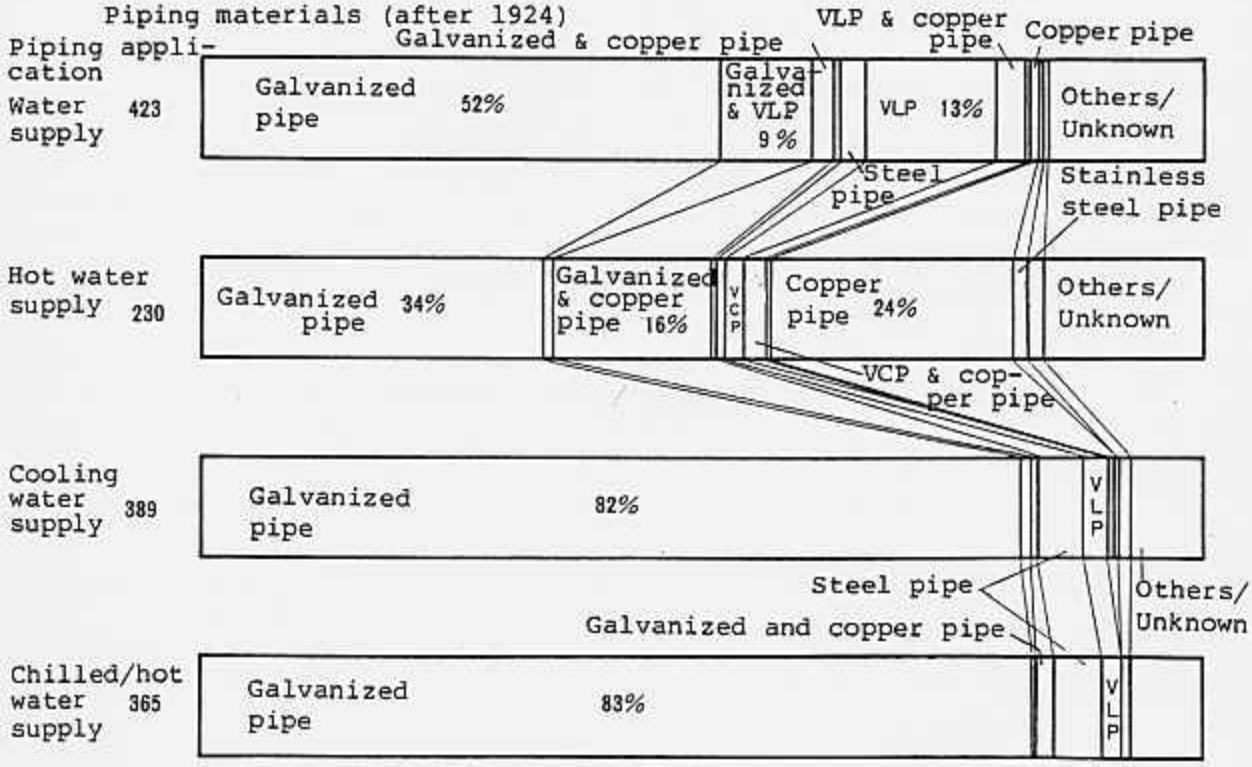
FREQUENCY BAR CHART

PREFEC	N: 421	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
13 Tokyo-to		264	264	62.71	62.71
23 Aichi-ken		37	301	8.79	71.50
14 Kanagawa-ken		32	333	7.60	79.10
12 Chiba-ken		14	347	3.33	82.42
01 Hokkaido		13	360	3.09	85.51
15 Niigata-ken		12	372	2.85	88.36
27 Osaka-fu		10	382	2.38	90.74
07 Fukushima-ken		7	389	1.66	92.40
34 Hiroshima-ken		6	395	1.43	93.82
11 Saitama-ken		6	401	1.43	95.25
22 Shizuoka-ken		4	405	0.95	96.20
17 Ishikawa-ken		4	409	0.95	97.15
28 Hyogo-ken		3	412	0.71	97.86
44 Oita-ken		2	414	0.48	98.34
09 Tochigi-ken		2	416	0.48	98.81
05 Akita-ken		2	418	0.48	99.29
21 Gifu-ken		1	419	0.24	99.52
08 Ibaragi-ken		1	420	0.24	99.76
04 Miyagi-ken		1	421	0.24	100.00

20 40 60 80 100 120 140 160 180 200 220 240 260

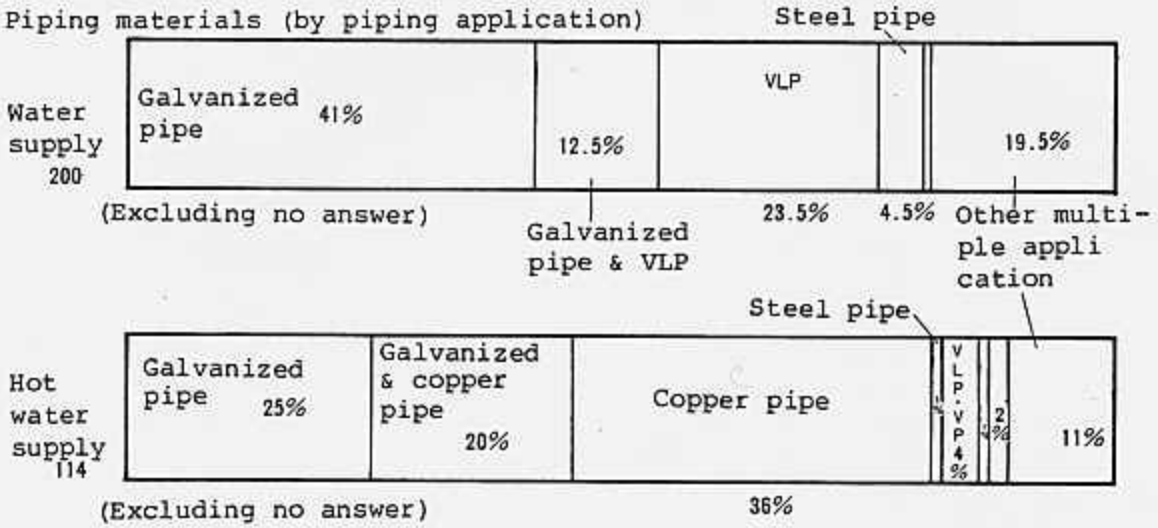
FREQUENCY

(6) Piping materials



As the objects of this research center around the pipes made in the late 60s and early 70s, this chart shows the high usage rate of galvanized pipes (Zinc-plated carbon steel pipes for piping).

A tendency to increase the application of VLP (Vinyl Chloride Lining Pipe) for water supply, along with that of copper pipe for hot water supply, is seen during the last decade.

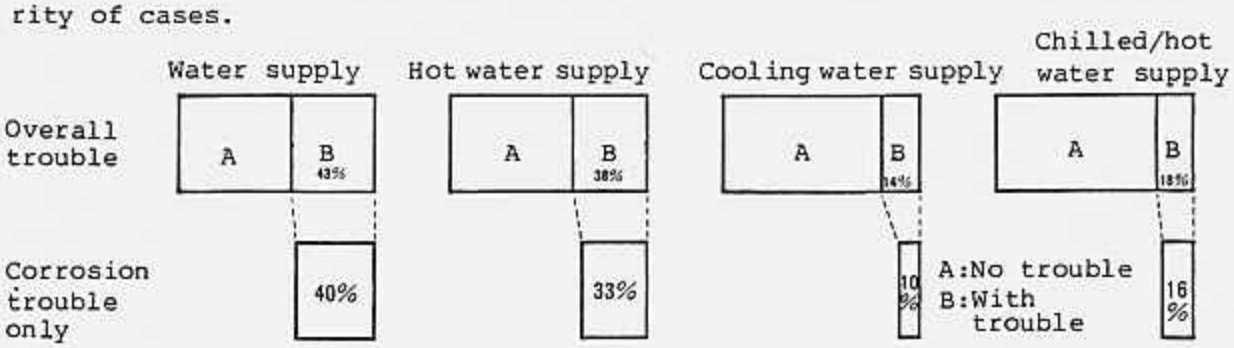


3. Summary of result

(1) Trouble frequency by facilities

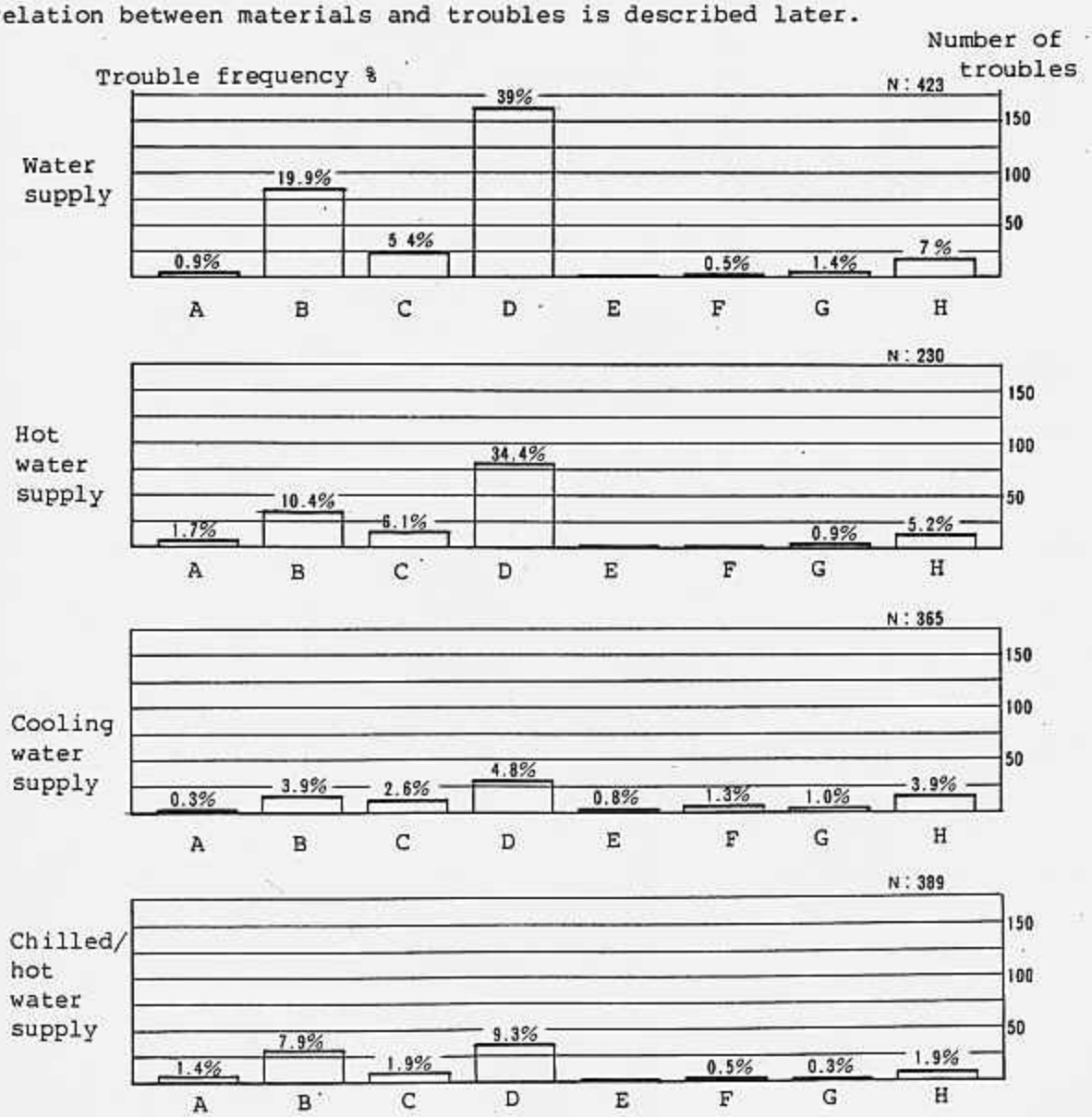
Comparing the troubles occrring among water supply, hot water supply, cooling water supply and chilled/hot water supply, the high frequent ratio of troubles in water supply and hot water supply is brought to light.

This research is made to analyze piping materials which have caused troubles, however, it is also necessary to take secular changes (time elements) into consideration. The trouble is generally caused by corrosion in the majority of cases.



(2) Trouble contents by facility application

This chart shows that chilled/hot water supply and cooling water supply make fewer troubles than water supply and hot water supply do. It also shows a tendency to cause rust suspension and water leakage on account of corrosion. It is necessary to consider the application condition and secular change of galvanized pipes (carbon steel pipes for piping) in the 1960s. As the trouble contents greatly vary with materials (galvanized pipe, vinyl chloride lining pipe, copper pipe, etc.), detailed relation between materials and troubles is described later.



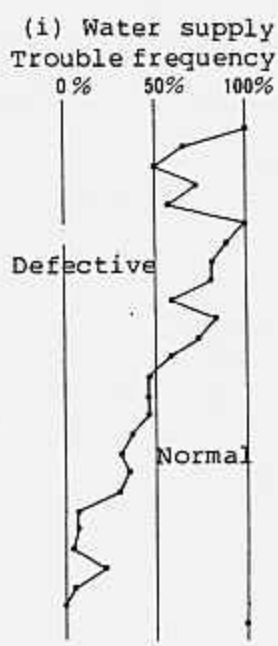
A: Zinc oxide suspension B: Rust suspension C: Clogging by tuberculation D: Leakage by corrosion E: Blue staining F: Clogging by slime G: Inner exfoliation H: Others

(3) Trouble frequency by construction year

The following charts show normal/defective conditions of each piping-water supply, hot water supply, cooling water supply and chilled/hot water supply.

The high defective rate of water and hot water supply facilities is obvious, and will be described later by each of their materials.

(i) Water supply



FREQUENCY BAR CHART

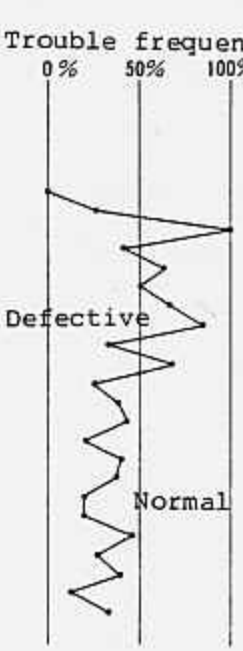
MIDPOINT YEAR	N : 418	FREQ	CUM. FREQ	PERCENT	CU PERC
1954	+++++	5	5	1.20	1
1955	0	1	6	0.24	1
1956	+	1	7	0.24	1
1957	++0	3	10	0.72	2
1958	+++000	6	16	1.44	3
1959	+++++00	7	23	1.67	5
1960	++++000	7	30	1.67	7
1961	+++++++	7	37	1.67	8
1962	++++++++++0	11	48	2.63	11
1963	+++++++++00	11	59	2.63	14
1964	+++++++++00	11	70	2.63	16
1965	++++++++++00000000	19	89	4.55	21
1966	++++++++++++++++++++0000	24	113	5.74	27
1967	++++++++++0000	15	128	3.59	30
1968	+++++++00000	12	140	2.87	33
1969	+++++000000	11	151	2.63	36
1970	++++++++++++0000000000000000	29	180	6.94	43
1971	++++++++++++0000000000000000	29	209	6.94	50
1972	++++++++++0000000000000000000	29	238	6.94	56
1973	+++++++++0000000000000000000	29	267	6.94	63
1974	++++++++++++++0000000000000000000000000000000	40	307	9.57	73
1975	+++++000000000000	17	324	4.07	77
1976	+0000000000000	14	338	3.35	80
1977	+0000000000000000	16	354	3.83	84
1978	+00000000000000000000	21	375	5.02	89
1979	++++000000000000	18	393	4.31	94
1980	+0000000000000000000	19	412	4.55	98
1981	00000	5	417	1.20	99
1982	+	1	418	0.24	100

Legend
+ Defective
0 Normal

5 10 15 20 25 30 35 40

FREQUENCY

(ii) Hot water supply



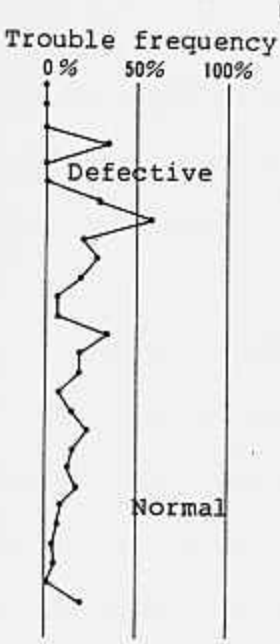
FREQUENCY BAR CHART

MIDPOINT YEAR	N : 226	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
1954		0	0	0.00	0.00
1955	0	1	1	0.44	0.44
1956		0	1	0.00	0.44
1967	00	2	3	0.88	1.33
1958	00	2	5	0.88	2.21
1959	00	2	7	0.88	3.10
1960	+000	4	11	1.77	4.87
1961	+++	3	14	1.33	6.19
1962	++000	5	19	2.21	8.41
1963	+++00	5	24	2.21	10.62
1964	+++000	6	30	2.65	13.27
1965	++0	3	33	1.33	14.60
1966	++++++++++++000	16	49	7.08	21.68
1967	++0000	6	55	2.65	24.34
1968	++++00	6	61	2.65	26.99
1969	+000	4	65	1.77	28.76
1970	+++++++0000000000	18	83	7.96	36.73
1971	++++++++0000000000	18	101	7.96	44.69
1972	+++++00000000000000	19	120	8.41	53.10
1973	++++++0000	10	130	4.42	57.52
1974	+++++++++00000000000000000	25	155	11.06	68.58
1975	++00000000	10	165	4.42	73.01
1976	++00000000	10	175	4.42	77.43
1977	+++++000000	11	186	4.87	82.30
1978	+++00000000	11	197	4.87	87.17
1979	++++000000	10	207	4.42	91.59
1980	++0000000000000	16	223	7.08	98.67
1981	+00	3	226	1.33	100.00
1982		0	226	0.00	100.00

5 10 15 20 25

FREQUENCY

(iii) Cooling water supply



FREQUENCY BAR CHART

N : 385

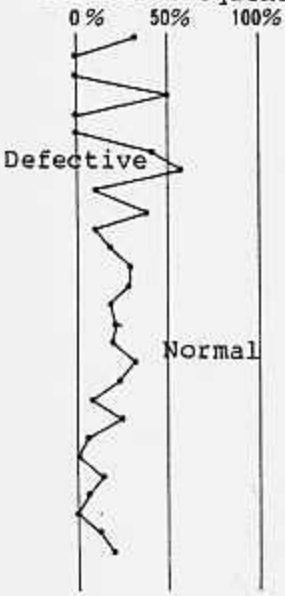
MIDPOINT YEAR		FREQ	CUM. FREQ	PERCENT	CUM PERCE
1954	0000 (Before 1954)	4	4	1.04	1.
1955	0	1	5	0.26	1.
1956	0	1	6	0.26	1.
1957	+00	3	9	0.78	2.
1958	000000	6	15	1.56	3.
1959	000000	6	21	1.56	5.
1960	++00000	7	28	1.82	7.
1961	++++000	7	35	1.82	9.
1962	++000000000	10	45	2.60	11.
1963	+++00000000	11	56	2.86	14.
1964	++00000000	11	67	2.86	17.
1965	+0000000000000000	18	85	4.68	22.
1966	+00000000000000000	19	104	4.94	27.
1967	+++++000000000	15	119	3.90	30.
1968	++00000000	11	130	2.86	33.
1969	++00000000	11	141	2.86	36.
1970	++0000000000000000000000000	29	170	7.53	44.
1971	++++000000000000000000000	27	197	7.01	51.
1972	++++++0000000000000000000	27	224	7.01	58.
1973	++++000000000000000000000	28	252	7.27	65.
1974	++++00000000000000000000000000000000	38	290	9.87	75.
1975	+++000000000000	17	307	4.42	79.
1976	+00000000000	12	319	3.12	82.
1977	+00000000000	13	332	3.38	86.
1978	+0000000000000000	18	350	4.68	90.
1979	++000000000000	16	366	4.16	95.
1980	++00000000000	14	380	3.64	98.
1981	+0000	5	385	1.30	100.
1982		0	385	0.00	100.

Legend
+ Defective
0 Normal

5 10 15 20 25 30 35

FREQUENCY

(iv) Chilled/hot water supply



FREQUENCY BAR CHART

N : 361

MIDPOINT YEAR		FREQ	CUM. FREQ	PERCENT	CUM. PERCEN
1954	+00 (Before 1954)	3	3	0.83	0.8
1955	0	1	4	0.28	1.1
1956	0	1	5	0.28	1.3
1957	+0	2	7	0.55	1.9
1958	000000	6	13	1.66	3.6
1959	00000	5	18	1.39	4.9
1960	+++0000	7	25	1.94	6.9
1961	++++000	7	32	1.94	8.8
1962	+00000000	9	41	2.49	11.3
1963	++++000000	10	51	2.77	14.1
1964	++00000000	10	61	2.77	16.9
1965	+++0000000000000	16	77	4.43	21.3
1966	+++++000000000000	17	94	4.71	26.0
1967	++++0000000000	14	108	3.88	29.9
1968	++00000000	11	119	3.05	32.9
1969	++0000000	9	128	2.49	35.4
1970	+++++00000000000000000000	24	152	6.65	42.1
1971	++++++++0000000000000000000	25	177	6.93	49.0
1972	++++++000000000000000000000	26	203	7.20	56.2
1973	++0000000000000000000000000	27	230	7.48	63.7
1974	+++++++++0000000000000000000000000000000	37	267	10.25	73.9
1975	+0000000000000	15	282	4.16	78.1
1976	0000000000	10	292	2.77	80.8
1977	++000000000000	14	306	3.88	84.7
1978	+0000000000000000	17	323	4.71	89.4
1979	0000000000000000	17	340	4.71	94.1
1980	++000000000000	16	356	4.43	98.6
1981	+0000	5	361	1.39	100.0
1982		0	361	0.00	100.0

5 10 15 20 25 30 35

FREQUENCY

4. Summary of analysis on water supply facility

The trouble frequency of water supply facility accounts for the relatively high ratio of 43% (overall troubles). This is because of the fact that the

galvanized pipe is widely used and that its open circuit makes it easy to find troubles, such as rust suspension.

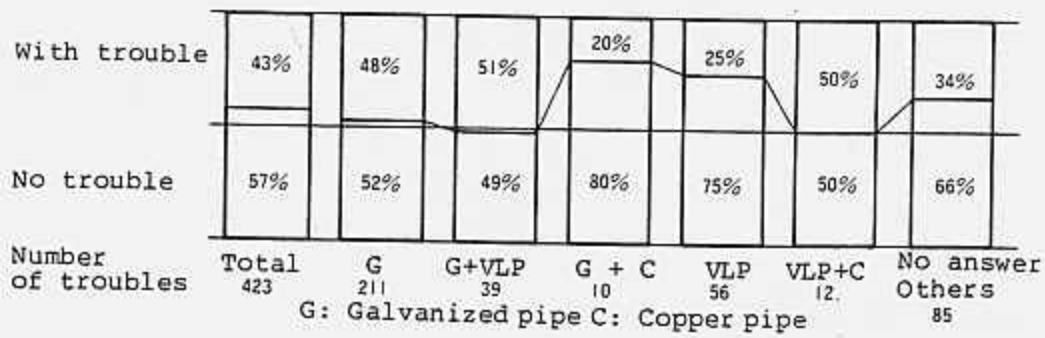
Generally speaking, up to this point, it is almost impossible to prevent the galvanized pipe from total corrosion. Therefore, material selection shifts from the galvanized pipe to VLP (Vinyl Chloride Lining Pipe) which has confirmed a lower corrosion rate.

Installation of VLP, however, continuously causes troubles such as rust suspension and corrosion at the end. Most of these troubles are owning to system arrangements, such as incomplete installation, and contamination by flowing rust from piping system, such as tank, pump, valve or upstream piping. Therefore, it is necessary not only to select right materials but also to arrange right piping with careful execution.

Comparing the galvanized pipe with VLP, the former marks the remarkable corrosion rate over a long term of years. However, statistical analysis does not show the great difference between these two. (It may be necessary to inorease a number of data.)

Water quality control by adding chloride and inhibitor (rust-proof) does not make much difference here. This is because of the fact that only few cases employ chloride and inhibitor and that water quality control may not be conducted with great care.

• Trouble frequency by materials for piping (Water supply: for all troubles)



G: Galvanized pipe C: Copper pipe

• Trouble contents of galvanized pipe and VLP

The following table shows the number of trouble frequency of the two materials.- the galvanized pipe and VLP.

A: Zinc oxide suspension B: Rust suspension C: Clogging by tuberculation D: Leakage by corrosion F: Slime G: Inner exfoliation H: Others

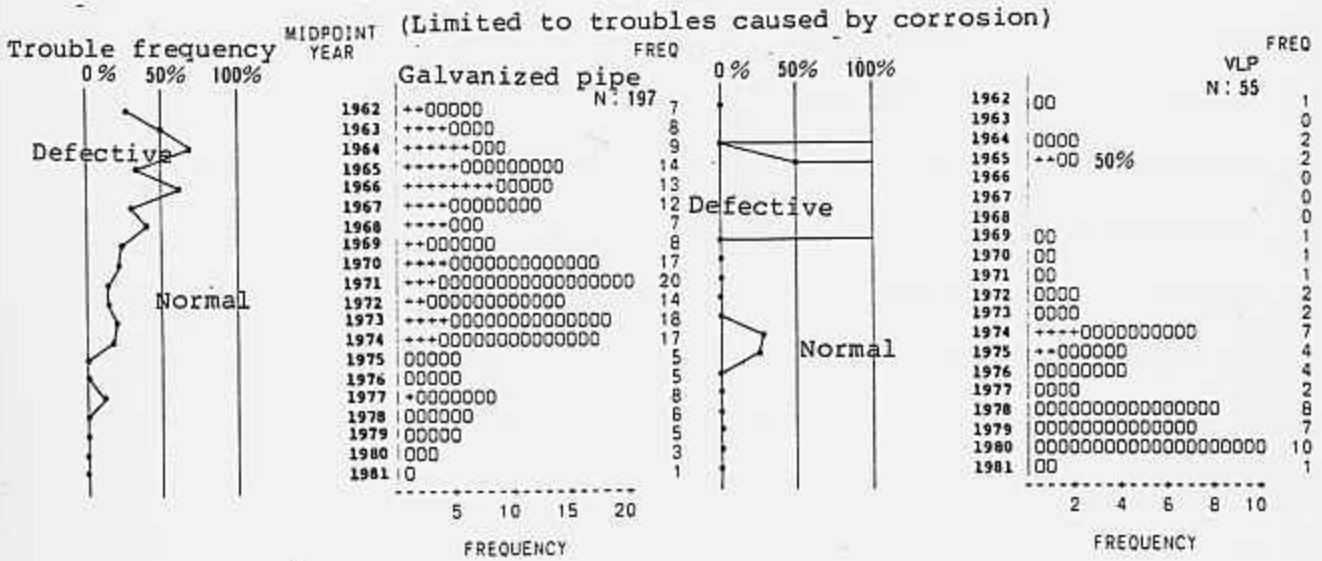
FREQUENCY ROW PCT	A	B	C	D	F	G	H	P	TOTAL
A Galvanized	3 1.28	71 30.34	16 6.84	133 56.84	1 0.43	1 0.43	8 3.42	1 0.43	234
C VLP	1 4.76	4 19.05	0 0.00	9 42.86	0 0.00	4 19.05	3 14.29	0 0.00	21
TOTAL	4	75	16	142	1	5	11	1	255

Some trouble materials are different from those of main in the above report. The next table provides the analysis on pipes which have the same quality in both trouble and main materials.

A: Zinc oxide suspension B: Rust suspension C: Clogging by tuberculation D: Leakage by corrosion F: Slime G: Inner exfoliation H: Others

FREQUENCY ROW PCT		A	B	C	D	F	G	H	P	TOTAL
A Galvanized	5 2.16	3 1.30	69 29.87	16 6.93	130 56.28	1 0.43	1 0.43	5 2.16	1 0.43	231
C VLP	2 9.52	1 4.76	4 19.05	0 0.00	9 42.86	0 0.00	4 19.05	1 4.76	0 0.00	21
TOTAL	7	4	73	16	139	1	5	6	1	252

• Trouble frequency of galvanized pipe and VLP by year of installation (Limited to troubles caused by corrosion)



• Experimental calculation of average trouble frequency n by lapse of years (Water supply)

(i) Galvanized pipe (of buildings built after 1962)

$$n = \frac{\text{Corrosion Trouble Frequency}}{\Sigma(\text{Lapse of Years}) \times (\text{Number of Facilities})} = \frac{84}{2{,}295 \cdot \text{Year}}$$

= 0.0366 Times/Year·Building

(ii) VLP (of buildings built after 1972)

$$n = \frac{\text{Corrosion Trouble Frequency}}{\Sigma(\text{Lapse of Years}) \times (\text{Number of Facilities})} = \frac{6}{356 \cdot \text{Year}}$$

= 0.0168 Times/Year·Building

Above calculation shows that corrosion trouble frequency of the galvanized pipe marks almost twice as much as that of VLP.

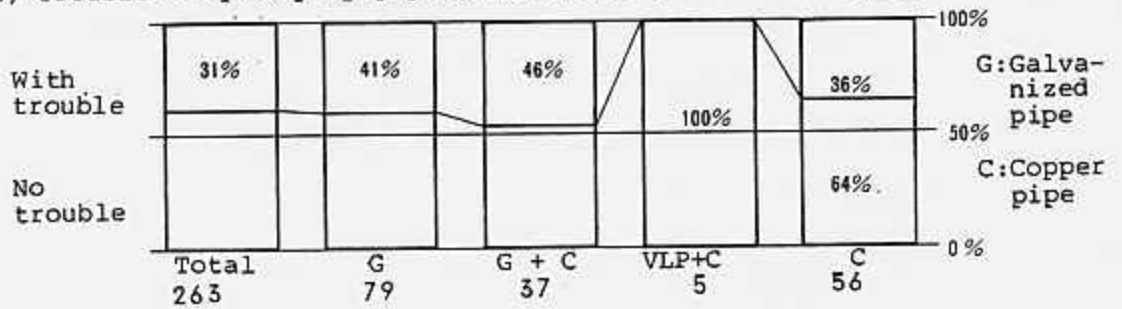
5. Summary of analysis on hot water supply facility

The trouble frequency of hot water supply facility was 38% (corrosion trouble: 33%) which is higher than that of cooling water and chilled/hot water facilities. While it is a little lower than that of water supply facility. Generally, the hot water supply facility is exposed to severe condition due to many bubbles and dissolved oxygen existed and high temperature. While the operating condition adopted is not so severe since the object pipings were mostly installed in office buildings. The above result may be induced by these two adverse condition. For your references, however, the trouble frequency was high in the buildings with hard operating condition such as hotels. According to the past investigation, galvanized pipes tend to be corroded inevitably, our selection of materials are moving to copper pipes and others from galvanized pipes. Although the trouble frequency of copper pipes is lower than that of galvanized pipes, corrosion troubles are observed. The corrosion of copper pipes are frequently found in hotels and hospitals, and are not so frequently in

ordinary office buildings proving that the troubles are caused by continuous operation under severe condition.

Since the present research does not actually check the cross section of corroded copper pipes in details, it has not been clarified enough whether the corrosion was caused by erosion due to excessively high water velocity or by chemical corrosion. Even with copper pipes, rust suspension was generated sometime. This may be caused by flowing rust from the piping or equipment (boiler, etc.) at the upper stream, which requires to consider the entire composition of hot water supply system at design and construction. In this research, the analysis took a special attention to galvanized pipes and copper pipes, however, a significant difference on the troubles between them can not be found statistically.

(i) Trouble frequency by piping materials (Hot water supply: all application)



(ii) Troubles of galvanized and copper pipes

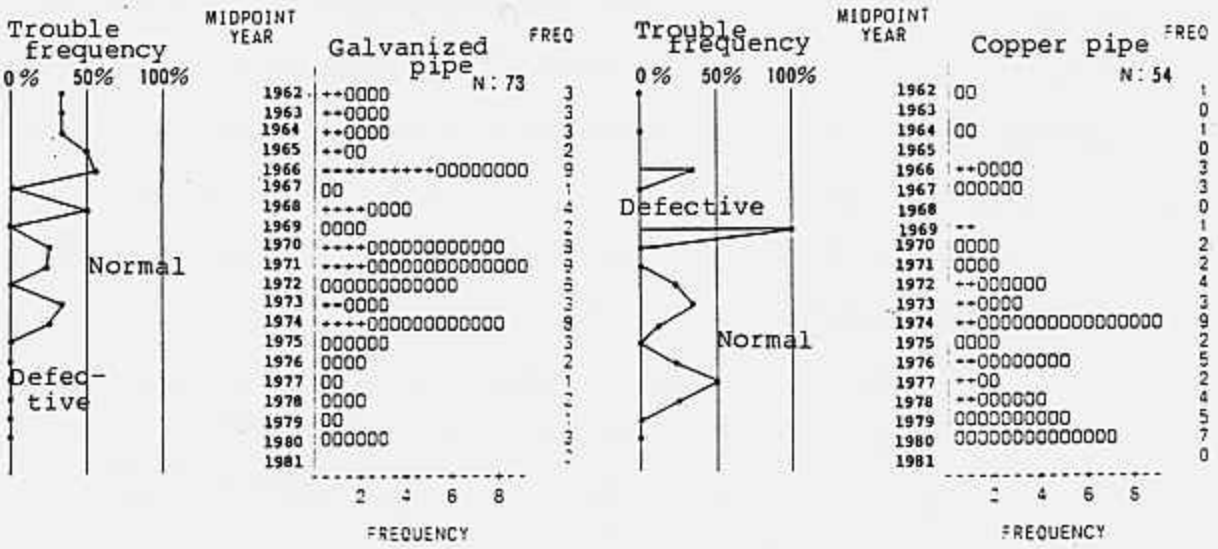
FREQUENCY ROW PCT	A Zinc oxide suspension	B Rust suspension	C Clogging by tuberculation	D Leakage by corrosion	G Inner exfoliation	H Others	TOTAL
A Galvanized pipe	3 4.48	15 22.39	11 16.42	35 52.24	2 2.99	1 1.49	67/84
E Copper pipe	0 0.00	4 9.30	0 0.00	30 69.77	0 0.00	9 20.93	43/62
TOTAL	3	19	11	65	2	10	110

In the table above, the material in trouble includes that other than main material. The next table shows the result obtained by rearranging the above.

FREQUENCY ROW PCT	A	B	C	D	E	F	G	TOTAL
A Galvanized pipe	1 1.54	3 4.62	14 21.54	11 16.92	34 52.31	2 3.08	0 0.00	65
E Copper pipe	2 4.88	0 0.00	4 9.76	0 0.00	27 65.85	0 0.00	8 19.51	41
TOTAL	3	3	18	11	61	2	8	106

A:No answer B:Zinc oxide suspension C:Rust suspension D:Clogging by tuberculation E:Leakage by corrosion F:Inner exfoliation G:Others

(iii) Galvanized and copper pipes



(iv) Influence of operating condition

In the circulation system water supply facility, it is operating condition which has great influence upon trouble occurrence. In other words, under the condition of 24-hour operation, such as in hotels and hospitals, troubles are noticeable. The below table shows the comparison of trouble frequency between 24-hour operation and limited-time operation (classified by galvanized and copper pipes).

• Trouble frequency by operating condition of galvanized pipes

Operating condition / Galvanized pipes	Limited-time operation	24-hour operation	Total
With trouble	21 (44%)	7 (70%)	28
No trouble	27 (56%)	3 (30%)	30
Total	48	10	58

According to this report, the 24-hour operation has more troubles than the other, which confirms the engineering judgement. (However, from the statistical point of view, this datum alone does not show considerable difference.)

• Trouble frequency by operating condition of copper pipes

Operating condition / Copper pipes	Limited-time operation	24-hour operation	Total
With trouble	12 (34%)	11 (73%)	23
No trouble	23 (66%)	4 (27%)	27
Total	35	15	50

According to this report, statistical research confirms that 24-hour operation has more trouble frequency. (Adaptability verification)

(v) Water quality control by hot water supply temperature or inhibitor (rust-proof) does not influence upon trouble frequency remarkably. This result is due to these facts; only few inhibitor application cases are researched and water quality control may not be conducted with great cares.

6. Summary of analysis on cooling water supply system

(i) Trouble frequency of cooling water supply piping is considerably lower, as the ratio of 14%, than that of water supply and hot water supply piping. Compared with cooling/hot water (summer/winter switchover) system cooling water alone system holds the trouble frequency ratio of 13.4%, while the other has 23.8%. This result confirms the engineering judgement considering water quality and operating condition. (However, this result does not achieve to be effective from the statistical point of view.)

(ii) Having analized the influence of open/closed circuit, ambient environment or electric conductivity, we did not find any remarkable difference in this research.

(iii) According to the analysis on operating condition considering these 2points - operating time (operating time per day) and operating term (whole

year operation or seasonal operation), statistically effective difference was confirmed; trouble frequency increases with heavy operation condition.

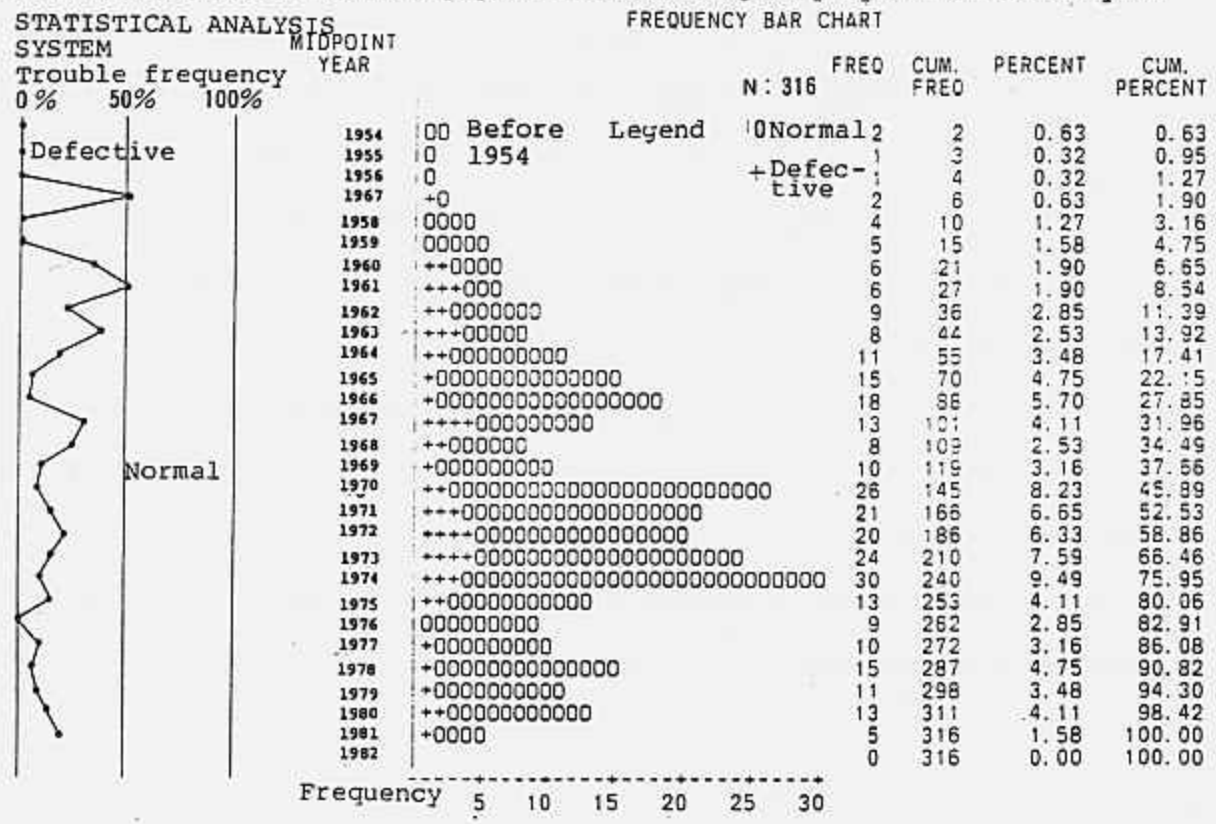
[Seasonal]	Trouble frequency of operating term	{Seasonal operation: 11.9% {Whole year operation: 24.2%
[Daily]	Trouble frequency of operating time	{Limited time operation: 12.3% {Whole day operation: 27.5%

(iv) Analysis on the influence of inhibitor (rust-proof) application and water quality control does not show a remarkable difference in trouble frequency. This result is caused by the respect that water quality control may not be conducted with great care and that it is difficult to grasp the exact control process.

● Trouble frequency by piping materials (after 1972)

FREQUENCY ROW PCT COL PCT	No Answer	Galvanized A pipe	B	C	G	MIX	TOTAL
+ With trouble	2 8.00 25.00	19 76.00 12.67	1 4.00 9.09	0 0.00 0.00	0 0.00 0.00	3 12.00 30.00	25
0 No trouble	6 3.68 75.00	131 80.37 87.33	10 6.13 90.91	7 4.29 100.00	2 1.23 100.00	7 4.29 70.00	163
TOTAL	8	150	11	7	2	10	188

● Cooling water/galvanized pipes: Trouble frequency by construction year



MIDPOINT YEAR	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
1954	2	2	0.63	0.63
1955	1	3	0.32	0.95
1956	1	4	0.32	1.27
1957	2	6	0.63	1.90
1958	4	10	1.27	3.16
1959	5	15	1.58	4.75
1960	6	21	1.90	6.65
1961	6	27	1.90	8.54
1962	9	36	2.85	11.39
1963	8	44	2.53	13.92
1964	11	55	3.48	17.41
1965	15	70	4.75	22.15
1966	18	88	5.70	27.85
1967	13	101	4.11	31.96
1968	8	109	2.53	34.49
1969	10	119	3.16	37.66
1970	26	145	8.23	45.89
1971	21	166	6.65	52.53
1972	20	186	6.33	58.86
1973	24	210	7.59	66.46
1974	30	240	9.49	75.95
1975	13	253	4.11	80.06
1976	9	262	2.85	82.91
1977	10	272	3.16	86.08
1978	15	287	4.75	90.82
1979	11	298	3.48	94.30
1980	13	311	4.11	98.42
1981	5	316	1.58	100.00
1982	0	316	0.00	100.00

7. Analysis on chilled/hot water supply system

(i) Trouble frequency of chilled/hot water supply piping is lower, as the ratio of 18% than that of water supply and hot water supply piping. This result is caused by the fact that water quality in piping is stable and that galvanized pipes (carbon steel pipes), materials used in the most of chilled/hot water supply piping, eliminate the chance to show rust suspension at water and hot water supply.

• Trouble frequency by piping materials (after 1972)

FREQUENCY ROW PCT COL PCT	No Answer	Galvanized A pipe	B	C	H	MIX	TOTAL
+ With trouble	0 0.00 0.00	21 87.50 14.00	2 8.33 18.18	0 0.00 0.00	0 0.00 0.00	1 4.17 16.67	24
0 No trouble	11 6.88 100.00	129 80.63 86.00	9 5.63 81.82	5 3.13 100.00	1 0.63 100.00	5 3.13 83.33	160
TOTAL	11	150	11	5	1	6	184

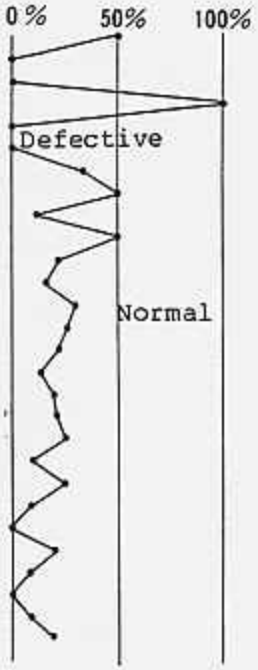
(ii) The analysis on the influence of open/closed circuits and air purge methods does not show a remarkable difference in this research. This result is caused by the respect that it is not easy to grasp closed/open degrees and air purge condition.

(iii) The difference among pipes for chilled water alone, for hot water alone, and usuable for chilled/hot water is influenced by water condition (temperature); chilled water has lower trouble frequency as mentioned below. This result does confirm the engineering judgement but does not fulfil statistical satisfaction.

(Trouble frequency) Chilled water: 7.1% Hot water: 21.2% Chilled/hot water: 20.8%

(iv) The analysis on the influence of inhibitor (rust-proof) application and water quality control does not show a remarkable difference in trouble frequency. This result is caused by the respect that water quality control may not be conducted with great care and that it is difficult to grasp the exact control process.

● Chilled/hot water : Galvanized pipes-Trouble frequency by construction year



S T A T I S T I C A L A N A L Y S I S S Y S T E M
12:53 WEDNESDAY, JULY 28,

FREQUENCY BAR CHART

MIDPOINT YEAR	N : 301	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
1954	+O (29年以前) Legend O Normal	2	2	0.66	0.66
1955	O +Defective	1	3	0.33	1.00
1956	O	1	4	0.33	1.33
1957	*	1	5	0.33	1.66
1958	OOOO	4	9	1.33	2.99
1959	OOOO	4	13	1.33	4.32
1960	++OOOO	6	19	1.99	6.31
1961	+++OOO	6	25	1.99	8.31
1962	+OOOOOOOO	9	34	2.99	11.30
1963	++++OOOO	8	42	2.66	13.95
1964	++OOOOOOO	9	51	2.99	16.94
1965	++OOOOOOOOOO	13	64	4.32	21.26
1966	+++++OOOOOOOOOO	16	80	5.32	26.58
1967	+++OOOOOOOOO	12	92	3.99	30.56
1968	++OOOOOOO	9	101	2.99	33.55
1969	+OOOOOOO	8	109	2.66	36.21
1970	++++OOOOOOOOOOOOOOOO	21	130	6.98	43.19
1971	+++++++OOOOOOOOOOOOO	21	151	6.98	50.17
1972	+++++OOOOOOOOOOOOO	20	171	6.64	56.81
1973	++OOOOOOOOOOOOOOOOO	21	192	6.98	63.79
1974	++++++++OOOOOOOOOOOOOOOOOOOOO	31	223	10.30	74.09
1975	+OOOOOOOOOOO	13	236	4.32	78.41
1976	OOOOOOO	7	243	2.33	80.73
1977	++OOOOOOO	9	252	2.99	83.72
1978	+OOOOOOOOOOOOO	15	267	4.98	88.70
1979	OOOOOOOOOOOOOOO	16	283	5.32	94.02
1980	+OOOOOOOOOOO	13	296	4.32	98.34
1981	+OOOO	5	301	1.66	100.00
1982		0	301	0.00	100.00

5 10 15 20 25 30

FREQUENCY

● Galvanized pipes-Trouble frequency by water temperature

S T A T I S T I C A L A N A L Y S I S S Y S T E M

FREQUENCY BAR CHART

MIDPOINT ONDO Water temp.	N : 271	FREQ	CUM. FREQ	PER
35 ℃	+++++OOOOOOOOOOOOOOOOOO	25	25	
40	++++++++++OOOOOOOOOOOOOOOOOOOOO	34	59	1
45	++++++++OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO	52	111	1
50	++++++++OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO	52	163	1
55	++++++OOOOOOOOOOOOOOOOOOOOOOO	31	194	1
60	++++++++OOOOOOOOOOOOOOOOOOOOOOOOOOOOOO	42	236	1
65	++OOOOOOOOOOO	14	250	
70	++OOOOOOOOOO	13	263	
75	OOOOO	5	268	
80	+OO	3	271	

5 10 15 20 25 30 35 40 45 50

FREQUENCY

8. Table of research items

The items of this research and analysis are listed below.

(1) Objects of reserch

- Number of facilities
- Total area of buildings
- Number of stories
- Facility application
- Construction year
- Number by prefectures

(2) Common items

- Piping materials (after 1926) W, H, C, C/H
- Trouble contents W, H, C, C/H
- Corrosion trouble condition W, H, C, C/H
- Trouble frequency by facilities
- — " — (Limited to corrosion troubles)
- Trouble condition by construction year W, H, C, C/H

(3) Water supply system

- Piping materials (kn the last decade)
- Trouble frequency of galvanized pipes and VLP by construction year
- Trouble contents and condition of galvanized and VLP
- Influence of chloride application, inhibitor application and water quality control
- Trouble frequency by piping materials
- Comparison of trouble frequency between galvanized and VLP (Adaptability verification)
- Galvanized pipes: Influence of water quality control

(4) Hot water supply system

- Piping materials (in the last decade)
- Trouble frequency of galvanized and copper pipes
- Trouble contents and condition of galvanized and copper pipes
- Influence of operating condition (daily and seasonal operation)
- Troubles of whole year operation in hotels
- Trouble frequency by piping materials
- Comparison of trouble frequency between galvanized and copper pipes
- Influence of circulation system
- Influence of temperature
- Influence of inhibitor application and water quality control

(5) Cooling water system

- Difference between cooling water and cooling hot water
- Influence of sites and ambient environment (around cooling towers)
- Influence of inhibitor application and water quality control
- Influence of open and closed circuits
- Influence of electric conductivity
- Influence of operating condition (daily and seasonal operation)

(6) Chilled/hot water supply system

- Difference among chilled, hot and chilled/hot water
- Influence of inhibitor application and water quality control
- Influence of closed and open circuits
- Influence of operating condition
- Influence of water temperature

W: Water supply H: Hot water supply C: Cooling water supply
C/H: Chilled/hot water supply

CIB

CIB-W62 SYMPOSIUM

Prevention of Water Damages due to Plumbing Systems.

Kaj Ovesen

April 9,~10, 1985

TOKYO, JAPAN



Kaj Ovesen
Danish Building Research Institute

Prevention of Water Damages due to Plumbing Systems.

12th CIB-W62 SYMPOSIUM - TOKYO -
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10, 1985: KENCHIKU KAIKAN

Summary

Maintenance of plumbing systems causes normally no problems - when it is carried out regularly. If the maintenance is missing or insufficient there is a risk of damages - not only in the plumbing system itself but also in other parts of the building where damages caused by the leaking water may occur.

In the Nordic countries we have worked with these problems during some years. We know now the number and the character of the damages and we have set up a programme to establish some rules of prevention. In the paper is described some aspects of this work.

Résumé

En général les systèmes de plomberie ne causent pas de problèmes, pourvu qu'ils soient tenus en bon état. Si l'entretien nécessaire n'est pas exécuté régulierement, il y a des risques de dégâts - non seulement dans le systeme de plomberie lui-meme, mais également dans les autres parties du batiment, où des dégâts causés par l'eau pourraient apparaître.

Dans les pays nordiques on a traité ces problèmes pendant quelques années. On en connait bien le nombre et la nature des dégâts, et un programme a été élaboré en vue d'établir des règles de prévention. Cette conférence présente quelques aspects de ce travail.

Zusammenfassung

Indstandhaltung von Wasser- und Abwasserinstallationen ist normalerweise problemlos - eine regelmässige Durchführung vorausgesetzt. Wenn die Wartung nicht befriedigend ist, besteht ein Schadenrisiko - sowohl für die Installationen als für andere Teile des Gebäudes, wo Wasserschäden auftreten können.

Diese Probleme sind einige Jahre hindurch in den nordischen Ländern untersucht worden. Die Untersuchungen haben Information über die bisherige Häufigkeit und Charakter der Schaden gegeben, und ein Programm für Massnahme, um die Schäden zu vermeiden, ist aufgestellt worden. Einige Aspekte von dieser Arbeit werden im Vortrag beleuchtet.

Systems in use

Within the field of drainage water supply system we do our best to ensure a proper function. At the seminars we have heard dozens of lectures dealing with pipe sizing, water demand, and flow resistance, but we have very seldom put the question: what happens to our plumbing system when we have installed it and leave it for normal service?

This question raises a number of other questions:

- what will the lifetime of the system be?
- what might go wrong?
- what can we do to prevent problems?

In that context we do not know very much about our systems.

Water damages

In the Nordic countries we have tried to find the answers of some of the questions. The reason for this activity was in fact that some figures from the insurance companies had surprised us. They told us that in 1980 the bill for water damages in the Nordic countries was about 1.5 billion Danish kroner or 150 million US $.

Research for preventing water damages

It is difficult to say whether this is far too much or not, but at any rate I think that all competent designers were surprised that their careful work could cause problems like that - and no matter whether it is much money or not, we could do a lot of good things, if we could save the money and use it for research, education or just for a better quality of the systems. Unfortunately we have to save the money before we can use it - however, the Nordic Council has been willing to support our efforts to minimize the water damages.

Surprising damaging

In fact it is surprising that we in the Nordich countries could have such problems in spite of the efforts already made in creating proper installations. First of

all we have a common Nordic code of practice and on this basis we have national codes of practice - or rather regulations. They are made on a functional basis and I consider them to be very valuable tools. We have comprehensive guidelines or directions. For all material and components we have an approval system and all work has to be carried out under supervision of authorized plumbers. This system ought to be good but the figures showed us that something was wrong.

Investigations in the Nordic countries

To find the reasons for this situation we made a number of investigations. In Denmark we recorded all damages in this country within a period of 4 months. All damages were analyzed and treated statistically by a computer programme. Similar investigations were made in the other Nordic countries.

Surprising results

The results of the investigations were surprising. We had assumed that the findings would have been: new types of faults and errors, damages due to unknown reasons and some unexpected combinations of well-known errors. However, the results were different - all the damages were caused by well-known and well described errors.

And who was to blame for making the errors? It appeared that all parties in the building proces had been guilty: the building owners, the designing architects and engineers, the contractors and the plumbers, and even the users have given their contribution.

The reasons

What was the reason for making the errors? This is a more problematic question. If we knew the answer we would also know what to do to prevent water damages. However, we have some guessses.

The background

In many countries we have had a building boom during the sixties and the beginning of the seventies. This

period changed many of our concepts. We came from a period with a strong building tradition and went into a period with slogans such as development, industrialization, productivity, new materials and components. If you could get a guarantee of 5 years on a product it was considered as ever-lasting. No wonder that this revolution caused some problems.

In the same period we made even bigger errors than water damages. We have in the western countries a number of building areas where not only the buildings but also the social life has been a failure. The best lessons to learn from this period are: beware of great and rapid changes in traditions - also in building traditions.

Changes in building services

Part of the revolution has taken place within the field of building services. Firstly, we have had a tremendous increase in number and types of installations. Secondly, we have changed the design of the building services - they shall perform but must not be seen.

The situation behind the water damages

On this background it is possible to draw some lines to the water damages. The cry for increased productivity brought forward a number of new labour saving products and new design. The labour saving was necessary because of the increasing wages. The new and non-traditional products combined with a time pressure resulted in a poor execution of the work. Most of the plumbing was hidden in walls, floors and ceilings so that not even the proudness of a good plumbing work could ensure the quality. This attitude may have been reinforced by the belief in future development - what we build to-day will be too small and too old-fashioned to-morrow. Consequently, a short lifetime was no problem.

This is a rough sketch of the situation behind the water damages during found in our investigations. We may

learn a lot by a thoroughly analysis of these phenomena. However, when we to-day try to prevent future damages we have to face a new situation.

A new concept

During the eighties the building sektor - and the rest of the society - has changed the concept. To-day the conservation of energy and other resources is a main issue, but we do not want to pay for conservation - at least not very much. A high productivity is still necessary. The labour cost is still of major importance in spite of unemployment. We still believe in technical development but we also have a growing understanding of the value of traditions. The view of the lifetime of products is also subject to change. We still have many products with an unnecessary short lifetime, but many consumers are no longer fond of the "buy to-day and throw away to-morrow" - mentality. For many years the first cost of a building was the only parameter and no concern was given to the running costs. To-day we can catch a glimpse of a total economy concept.

Measures for preventing damages

On this new background we have sketched up the following measures for preventing water damages - and some other failures - in the future.

It will be necessary to use a wide spectrum of efforts. As well high technology methods as psychological ways should be used as shown in the following examples.

Information and education

One of the most misused tool is information. On all levels we need the right type of information - from the designer to the end user. If we want to continue the development within our field, regulary education is necessary too. What a licensed plumber was taught 30 years ago is a poor background for modern installations.

Research

Research is still the best background for technical development, but maybe the direction has to be turned a little. Our installation systems have in many cases reached the final state of development. Optimalization in order to save a few millimeters of a pipe diameter or of the trap seal height has very little influence. Studies of lifetime and ageing of components could have much more effect.

Design

The type of systems we use and the way we integrate the building and the installations need to be revised. The main reasons for severe water damages is that we hide the piping. In most cases a decent bathroom is still without visible pipes. However, the younger architects have started to find out that some pipes could be a natural part of the room in which water is needed. We have tried to work out some design examples where the pipes are covered in order to give a nice room and where they are not hidden in a way that may cause a tremendous water damages before a leak is discovered.

Design means also right choice of materials. Although we know rather much of corrosion we notice many faults caused by a wrong combination of materials. This is mainly a problem of missing information - or missing receivers of the information.

Execution and control of the work

Quality control on the building site is easy to describe but difficult to carry out. Control functions which can easily be carried out in a factory seem to be impossible to use on the site. We have as well psychological barriers as practical problems. In industrialized buildings it seems to be very difficult to get the plumber to stick to the responsibility and the pride of his work. The "modern" way is to develop fool-proof methods. Another way could be to develop methods for workers' own control. This might involve use of advanced

technology. A missing tool for that type of control is a handy tool which instantly tells the plumber whether a soldering joint is perfect or not. A number of similar tools might improve the quality substantially.

Maintenance

No building services can work without maintenance. Proper maintenance requires maintenance instructions - even for small houses with the user and owner as the only maintenance staff. Normally instructions for plumbing systems are not worked out - and very often the systems are designed and located in such a way that maintenance is nearly impossible. Systems should be designed for maintenance.

Authorities

In the Nordic countries we have regulations for drainage and water supply systems. The structure of regulations and the way of administration can have a heavy impact or water damages. The stiff and prescriptive regulations are no guarantee of quality. A combination of functional requirements - being open to new development - and product approval tests seems to be a far better tool.

Other problems

Water damages is a problem but also a symptom which proves that something is wrong. We have got a new technology in many parts of the building sector but we have not built up traditions for handling the technology in a proper way.

CIB

CIB-W62 SYMPOSIUM

Solar Energy Utilization

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TOKYO, JAPAN



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SOLAR ENERGY UTILIZATION

12th CIB-W62 SYMPOSIUM — TOKYO —
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10, -1985 : KENCHIKU KAIKAN

Summary

The Nippon Telegraph and Telephone Public Corporation (NTT) is currently the sole provider of telecommunication services within Japan. NTT constructed about 30 solar energy systems throughout Japan. The locations ranged from warm climate (Kyushu) to a cold climate (Hokkaido). NTT created a data book on solar energy systems and developed the solar system simulation programs SOLASD(SOLAr system Simulation program for Domestic hot water supply), SOLASH(SOLAr system Simulation program for space Heating). This software is being researched and developed at NTT. NTT's use of solar energy systems, the problems of current systems and the durability of flat plate solar collectors are discussed in this paper.

Résumé

A la Rēgie Japonaise des Tēlecommmunications (NTT), nous faisons usage des mecanismes d'alimentation en eau chaude dans 30 places au JAPON: de la zone froide (HOKKAIDO), a la zone douce (KYUSHU). Pour ces mēcanismes solaire, nous rēdigons des documents originaux, et nous crēons SOLASD(SOLAr system Simulation program for Dometic hot water supply). SOLASH (SOLAr system Simulation program for space Heating) pour examiner ces mēcanisme. Alors, nous rapportons notre usage de ces mēcanismes, des imperfections de ces mēcanisme en marche, et la qualitē rēsistante de panneau solaire.

Zusammenfassung

Nippon Telegraph und Telephone Öffentliche Korporation (NTT) hat etwa 30 Sonnen Energie Systeme eingerichtet für NTT Gebäude überall im Lande von kälte Gegend, Hokkaido und wärme Gegend, Kyushu. Für dem Entwurf von diesem Systeme, NTT hat ein Daten Buch und SOLASD (SOLAr system Simulation program for Domestic hot water supply), SOLASH (SOLAr system Simulation program for space Heating) gemacht. Der Bericht erstatten über der Ansicht für die Benutzung von Sonnen Systeme, die Probleme von lebend Systeme und die Dauer von ebenen Sonnenpllatten ausführlich.

概　要

電電公社では寒冷地の北海道から，温暖地の九州まで，全国で２４局所の太陽熱給湯設備が稼働している．

これらの設計に当っては，社内で独自に設計資料を作成し，またシステムの性能評価に社内で開発した太陽熱給湯システム解析プログラム（ＳＯＬＡＳ－Ｄ）を用いている．

そこで，電電公社における太陽熱給湯システムへの取り組みの考え方と，全国で稼働中のシステムの問題点，及び設置後５年経過した設備の耐久性能（主として平板形集熱器）の詳細について報告を行なう．

1.Hot Water Supply System Utilizing Solar System

NTT's facilities include telephone and telegraph offices.administrative offices, and corporation residential housing. The Facilities Engineering Section designs and supervises buildings and supports equipment. In this regard, the section has adopted solar energy systems to address enviromental and resource conservation problems. This application of solar power was based on the Sunshine Project(1974) established by the Japanese government. NTT is currently reseaching energy reduction systems. Consequently, a data book was created to obtain information on solar energy utilization systems and the hot water volume required in several types of buildings. This book outlines solar energy utilization concepts. described below.

Solar energy systems function much more effectively in locations which receive large amounts of solar radiation. As a result, NTT has developed solar energy systems based on the quantity of solar radiation and snowfall. This is shown Table 1.

At NTT, hot water supply systems are used in several types of buildings. These systems supply non-potable water. As a result,an index to evaluate an energy reduction is necessary from an economic viewpoint. The data book contains a coefficient of energy saving of over 50 per cent. This coefficient is derived using the following equation.

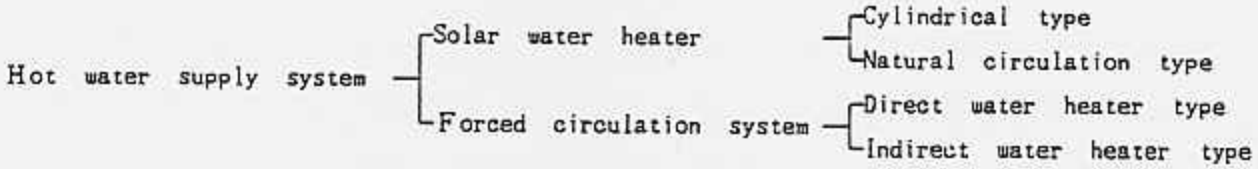
$$\text{Coefficient of energy saving}(\%)=\left(1-\frac{\text{annual energy consumption of solar energy system}}{\text{annual energy consumption of system not utilizing}}\right)\times 100$$

NTT uses the payback period as an economic index. The target value was initially 10 years, but has now been reduced to 7 years.

2.Load

The uses for hot water in NTT buildings and the hot water volume generally used at NTT are shown in Table 2. When the volume is determined, the hot water mix ratio is applied. The lineman center is used by field construction telephone crews. Frequency of use per day and the utilization ratio for each building are shown in Tables 3 and 4. This data was obtained by monitoring the facilities.

3.Hot Water Supply System



A solar water heater is used, when a low volume of hot water exists. For high volume, a forced circulation system is applied. A solar collector must have a efficiency of over 45 per cent. Solar collectors generally face to the south. they are tilted a maximum of 15 degrees to the west or east. The angle from the horizon is set at the local latitude minus 5 degrees. The choice between a forced circulation system and a solar water heater is determined by the number of people. If the number is over 25, forced circulation is used. System choice is also determined by the cost of applying these systems

and by building design.

4.Solar Energy Simulation Program

The simulation program for hot water supply systems(SOLASD) and the simulation program for heating(SOLASH) are used to examine performance and simulate systems. The flow chart using these programs at the design stage is shown in Fig.1. The total amount of solar radiation, the useful solar energy, the heat loss from strage tank, collectors and pipe, and the calories needed for an auxilirary heater and hot water are obtained as SOLASD outputs. The simulation sequences are shown in Fig.2. Four packaged programs make up SOLASD. One program contains weather data.(AIRCON-2) which is the air-conditioning computation program. This program is contained in the public data communication system DEMOS-E (DEnden kosha Multi-access Online System) serviced by NTT. The index to evaluate the hot water supply system is shown Table 5 and is calculated from SOLASD outputs. The cost saving from reducing fuel consumption, the figure of merit, pay back period and annual expenses are used as the index to examine performance. The best hot water supply system design results from using this index.

5.Problems Of Current Systems

Table 6 shows systems NTT has in practical use. Investigating these systems, the problems are as follows.

*They are difficult use and maintain.

It is difficult for users to use and maintain such solar systems because piping and the systems themselves are

complicated. The more they can be simplified, the more usable they will become.

*Freezing

As water is the main heat transfer fluid used, freeze protection is necessary. However, freezing is still a problem which results in damage to solar systems and solar collectors. So, there must be reliable freeze protection.

*The amount of water used for systems in practical use is less than that used for systems in the design stage.

In rural areas, this rate of use at telephone and telegraph offices has been decreasing in recent years. Therefore it is necessary for solar systems for urban and rural use to have different water-use ratio. Also, the water-use ratio at each design stage is important.

*There is much energy loss from pipes as well as wasted water.

As pipe length increases, energy loss and water waste increases. Therefore, pipe length has to be shortened by appropriate installation. This has the additional benefit of simplifying the system.

*Many systems leak too much water.

Water leakage is mainly caused by construction mistake, and also by freezing. As much pipe is used, it is difficult to check mistake.

6.An Investigation Of Flat Plate Solar Collectors

An investigation of flat plate solar collectors which had been in operation for 5 years was carried out. We studied the solar collectors performance, rust on the solar collectors and pipes, and the deterioration of solar collector parts.

These collectors were installed at telephone exchange. A photograph of the telephone exchange is shown in Fig.3. The solar energy system shown in Fig.4 was adopted in this telephone exchange.

This telephone exchange has 324 square meters telecommunications equipment room and 120 square meters of office space. This system was designed to utilize solar energy for 78% of the annual cooling load and 59% of the annual heating load.

There are 160 solar collector units on the roof. The solar collectors are mounted at a 25 angle to horizontal to make the most efficient use of the summer sun. These solar collectors supply hot water having a temperature of 90C in the summer and 55C in the winter.

Result Of Investigation

*Solar Collector Efficiency

The efficiency of the experimental solar collector is shown in Fig.5. This figure also compares the test sample with products presently on the market. There was little difference between the efficiency of this test sample which had been used for 5 years, and new units. The performance of the solar collector did not deteriorate appreciably.

*Selective Surface

The measured values for absorptance (=0.903-0.911) and emitance (=0.084-0.097) for our test sample fall within the efficency range published by present solar collector makers. The selective surface showed that deterioration was negligible.

*Glass Cover

The decrease in light transmission through the glass due to dirt or degradation resulted in only a 4.5% drop in collector efficiency, which is even less than the expected design loss of 5%.

*Absorber Plate

In 5 years. the absorber plate was coated with grime. However, when this coating was wiped away, the plate had close to its original luster. Therefore, this grime was not a result of corrosion.

*Solar Collector Pipe

Pipe thickness was measured and found to range from 3.0 to 3.4 millimeters. which was only slighty below the original range of 3.3 to 3.8 millimeters. Thus. these pipes can be used for many more years.

*Inside the Absorber Plate

An analysis of the composition of the material clogging the pipe shown in Table 8. Most of the component parts are made of zinc and steel. The material did not contain chrome, molybdenum and niobium. Therefore. the inside of the absorber plate did not corrode.

*Storage Tank And Water Quality

The porcelain enamel finish on the inside surface of storage tank is wasted away and the surface of the steel plate is expose. However, the thickness of the plate was 6 millimeters. Thus. storage tank can be used for many more years.

The water in the storage tank was analyzed three times. The

change in water quality is shown in Table 9. The water quality changed little after 4 months.

This investigation has shown that solar collector performance deterriorated little in 5 years. NTT is next going to investigate solar energy systems which have been in operation for 10 years.

Table 1 Climate conditions for solar energy utilization

Division	Quantity of solar radiation (cal/cm²·day)	※Days with snowfall
Very effective place	Over 300(yearly average) and over 200(January average)	Under 5 days
Effective place	From over 260 to under 300 (yearly average) and under 200(January average)	From over 5 days to under 30 days
Not effective place	Under 260(yearly average)	Over 30 days

※ Note The days when the level of snowfall is over 50 cm.

Table 2 Hot water volume (60 ℃)

Name of apparatus	Building	Use	Volume (liters)
Basin	T. and T. office A. office L. center B. hall	To wash hands and face	5(per person)
Kitchen sink	C.R. housing T. and T. office A. office L. center	Cooking	15(per use)
		Except dish washing	10(per use)
		Dish washing	60(per use)
Bath	All types of building	Filling the bath	10(per person)
		After bath	20(per person)
		Western-style bathtub/shower	50(per person)

Note T. and T. office : Telephone and telegraph office
B. hall : Bachelor hall
A. office : Administrative office
L. center : Lineman center
C.R. housing : Corporation residential housing

Table 3 Frequency per day

Name of apparatus	Place		Frequency
Basin	T. and T. office lavatory A. office lavatory		2
	L. center lavatory		3
	B. hall lavatory		2
	Bath room		2
Kitchen sink or Sink for cleaning	L. center lavatory		3
	B. hall		8
	C.R. housing		3
	T. and T. office A. office L. center	Except kitchen	1
		Kitchen	2

Note T. and T. office : Telephone and telegraph office
B. hall : Bachelor hall
A. office : Administrative office
L. center : Lineman center
C.R. housing : Corporation residential housing

Table 4 Utilization ratio of bath

Use	Building	Number of people	Ratio (%)
Bath	T. and T. office A. office	M.N. staying overnight	40 (also shower)
	L. center	M.N. working in field	40 (also shower)
	B. hall	Fixed number	60
	C.R. housing	Based on house plan	100

Note T. and T. office : Telephone and telegraph office
B. hall : Bachelor hall
A. office : Administrative office
L. center : Lineman center
C.R. housing : Corporation residential housing
M.N. : Maxmum number

Table 5 Solar energy system evaluating index

Index	Definition	Case
Efficency of energy reducing	$\delta = 1 - \frac{Q_a}{Q_b}$	Decision to utilize solar energy or not
Efficency of energy saving	$\varepsilon = \frac{Q_b - Q_a}{J}$	
Coefficient of perfomance	$C_{.o.p} = \frac{Q}{Q_a + Q_b}$	Evaluation of system
Solar percent	$\sigma = \frac{Q_s}{Q}$	
Solar utilize rate	$\eta = \frac{Q_s}{J}$	Evaluation of each part of system

Note J : Total amount of solar radiation
Q : Annual calories needed for hot water
Q_s : Utilized annual solar energy
Q_a : Annual energy consumption of solar energy utilizing system
Q_b : Annual energy consumption of solar energy not utilizing system

Table 6 NTT's solar energy system

Table 6 NTT's solar energy system

Name of building	Kibougaoka denpoudenwakyoku	Tanabe denpoudenwakyoku	Yuutenji syataku	Kitami syokuin club	Kohakura dokushinryou
Type of building	Lineman center	Lineman center	Corporate residetial housing	Rest house	Bachelor hall
Location	Yokohama City Kanagawa Prefecture	Tanabe City Wakayama Prefecture	Meguro Ward Tokyo	Kitami City Hokkaido	Naha City Okinawa Prefecture
Year of construction	1983	1979	1983	1983	1983
Solar system	Forced circulation system	Forced circulation system	Solar water heater	Forced circulation system	Forced circulation system
Angle from the horizon	45°	30°	45°	45°	30°
Use	Heating, Hot water supply	Hot water supply	Hot water supply	Hot water supply	Hot water supply
Solar unit	52 units	40 units	1 unit	18 units	18 units
Solar percent (%)	33 (yearly average)	73 (yearly average)	89 (summer average)	61 (summer average)* 32 (winter average)	100 (summer average)* 74 (winter average)

Note * Design Stage

Table 7 Solar Collector

	Model	Sample
Absorber plate	Type	Flat plate with selective surface
	Construction	Tube-in-sheet
	Material	Ultra low carbon ferritic stainless steel
	Effective area (m^2)	1.91
Selective surface	Absorptance (α)	0.92
	Emittance (ε)	0.11
Glass cover	Number	1
	Type	Tempered glass, clear
	Thickness (mm)	3.2
	Transmittance	Over 0.875
Insulation	Type	Fiber glass, clear
	Back thickness (mm)	50
	Side thickness (mm)	15
Piping	Connection (inch)	
Housing	L×W×D (mm)	2002×1002×95
	Material	Galvanized steel
	Finish	Electro deposition & acrylic electrostatic paint

Table 8 Corrossion ingredient ratio at inside of absorbed plate

Ingredient	Ratio (%)	Ingredient	Ratio (%)	Ingredient	Ratio (%)
Zn	32.08	Ca	0.80	Cr	0.04
Fe	31.79	Mg	0.29	Ni	0.03
Si	1.91	Cu	0.25	Ti	0.01

Table 9 Water Quality

	At the beginning	After 2 months	After 4 months	(reference) After 1 year
Turbidity (degree)	0	6	1	16
Color (degree)	1	8	12	56
Transparency (degree)	over 100	100	100	400
PH	7.3(22℃)	8.9(23℃)	8.6(19℃)	9.1(31℃)
Alkalinity ($mgCaCo_3/\ell$)	43	25	35	37
Hardness ($mgCaCo_3/\ell$)	82	39	60	20
Sulfate ion Concentration (mg/ℓ)	25	20	22	16
Chlorine Concentration in Chloride (mg/ℓ)	18	17	17	9.8
Silica gel ($mgSiO_2/\ell$)	9.3	9.6	9.5	13
Iron (mg/ℓ)	under 0.05	0.44	0.38	2.2
Copper (mg/ℓ)	under 0.02	0.03	0.02	0.05

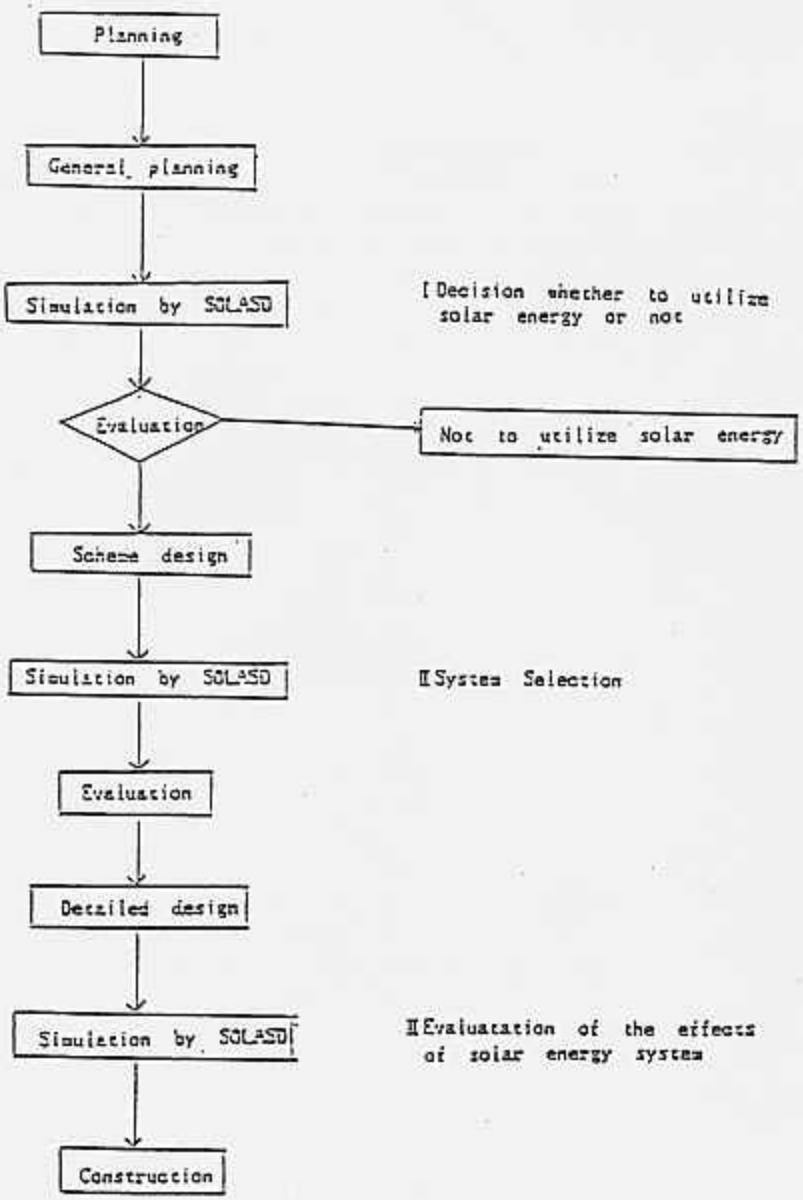
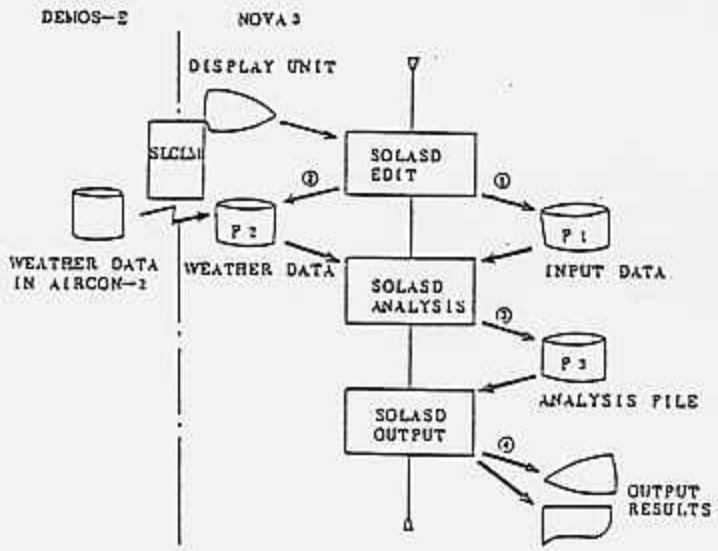


Fig.1 Flow chart



SLCLM : SoLar CLiMate

Fig.2 Seqence of SOLASD

Fig 3 Telephone exchange

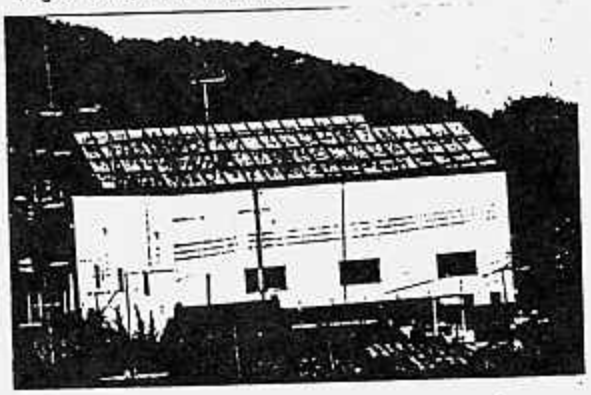


Fig 4 Telephone exchange solar energy system

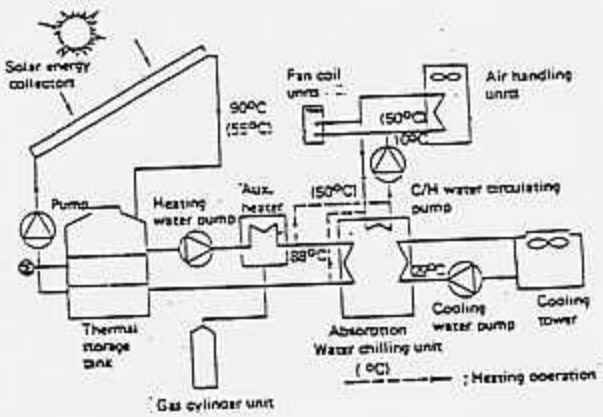
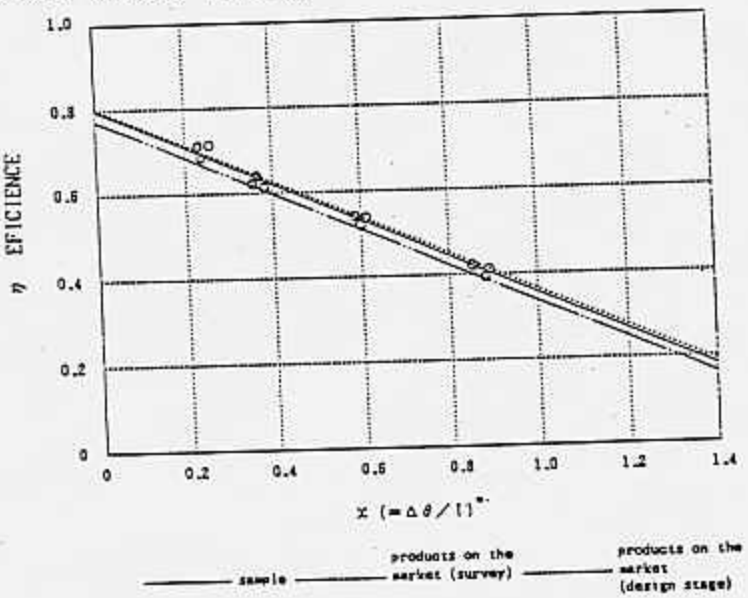


Fig 5 Solar Collector Efficiency

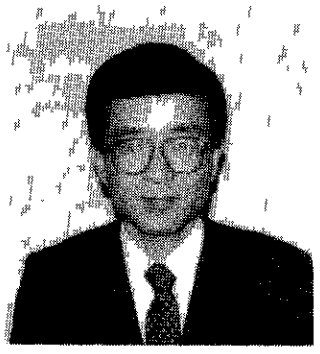


Note * $\Delta\theta = (\theta_{wi} - \theta_{wo})/2$

θ_{wi} :Collector inlet water temperature

θ_{wo} :Collector outlet water temperature

I :Solar radiation



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PRESENT STATUS OF HOME WATER HEATERS IN JAPAN

12th CIB-W62 SYMPOSIUM — TOKYO—
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9,10, 1985 : KENCHIKU KAIKAN

Summary

This report introduces the present status of home water heaters in Japan. First of all, energy and residential situations in Japan are described as a prior condition for home water heaters. Then, difference in the bathing manners between Japanese and Westerners is explained since the hot water consumption for bathing occupies a large share in the domestic hot water supply load of Japan, and the items to be observed when considering the hot water supply facility for residential use in Japan are clarified. In the next place, this report points out that many kinds of home water heaters are used in Japan in which an instantaneous gas water heater ranks at the top. And the development of the instantaneous gas water heater is shown from various aspects such as the stability of hot water temperature and energy saving characteristics. Lastly, the concept of efficiency measurement by mode operation proposed recently and the measurement result obtained by the above method are outlined. In addition, the recent topics relating to water heaters are described.

Résumé

Ce rapport présente l'état actuel des chauffe-eau domestiques au Japon. Tout d'abord, les conditions énergétiques et d'habitation au Japon, conditions préalables aux chauffe-eau domestiques, sont décrites. Puis, les différences dans la manière de prendre un bain des Japonais et des occidentaux sont expliquées, vu le fait que la consommation en eau chaude destinée au bain occupe une part importante de l'approvisionnement en eau chaude domestique du Japon. Suit alors une clarification des points à observer lorsque l'on envisage la mise en place d'installations d'approvisionnement en eau chaude à usage résidentiel au Japon. Ensuite, ce rapport souligne que de nombreux types de chauffe-eau domestiques sont utilisés au Japon; le plus répandu étant le chauffe-eau instantané à gaz. Le développement de ce chauffe-eau instantané à gaz est montré sous différents aspects, tels que la stabilité de la température de l'eau chaude et les propriétés d'économie d'énergie. Finalement, des explications sont données à propos du concept proposé récemment de mesures de rendement en fonction du mode d'exploitation et à propos des résultats des mesures obtenues selon cette méthode. En plus, une description est faite sur les découvertes récentes en rapport avec les chauffe-eau.

Zusammenfassung

In diesem Bericht wird die heutige Situation auf dem Gebiet der Heim-Wassererhitzer in Japan beschrieben. Zunächst wird die energiemäßige und wohnungsmäßige Situation in Japan als Rahmenbedingung der Installation von Wassererhitzern in Japan beschrieben. Dann werden die Unterschiede in den Badesitten zwischen Japan und der westlichen Welt beschrieben. Der Warmwasserverbrauch im Bad stellt einen großen Anteil des häuslichen Warmwasserverbrauchs in Japan dar, und die bei der Untersuchung der Warmwasserbereitungsanlagen für häusliche Verwendung in Japan zu berücksichtigenden Punkte werden erläutert. Anschließend wird in diesem Bericht aufgezeigt, daß viele Arten von Haus-Warmwassererhitzern in Japan verwendet werden, unter denen Gas-Durchlauferhitzer an an erster Stelle liegen. Die Entwicklung des Gas-Durchlauferhitzers wird unter verschiedenen Aspekten, wie Stabilität der Warmwassertemperatur und Eigenschaften der Energieersparnis, beleuchtet. Zum Schluß wird das Konzept der Effizienz-Messung durch Modus-Betrieb, das kürzlich vorgestellt wurde, und die mit dieser Methode erhaltenen Messungen beschrieben. Außerdem werden neue Themen, die sich auf Wassererhitzer beziehen, beschrieben.

概要

本報は、日本の家庭用給湯器の現状を紹介することを目的としている。 そこで、日本の家庭用給湯器を考える際の前提条件として、日本のエネルギー事情と住宅事情についてまず述べ、次いで入浴での湯の使用が、日本の家庭での給湯負荷に大きな比重を占めることから、日本人と欧米人との入浴習慣の違いについて述べ、日本での住宅用給湯設備を考える際に留意すべき点につき整理した。 その後、日本で使用されている家庭用給湯器の種類が多いこと、その中ではガス瞬間式給湯器が最も多く用いられていることを示し、 このガス瞬間式給湯器の進歩につき 湯温の安定性、省エネ性等の各種側面から述べた。 最後に、最近提案されたモード運転による効率測定の考え方とその方法による測定結果の概要を示すとともに、給湯器に関する最近の話題について述べた。

1. Energy and residential situations in Japan

The energy and residential situations in Japan, which forms a prior condition to consider home hot water supply facility, are outlined here.

a. Energy situation in Japan

Japan are short of underground resources, and 83.3% of the primary energy supply amount, 380,741 x 10^{10}kcal, was imported in 1983 which counts a high 45% or more in the total import amount of the same year, US$129,351 x 10^{6}. The energy consumption for residential use counts only some fifteen percent, however, it tends to increase year by year. The energy consumption by application for one home in one year is shown in Fig.2. As seen from the figure, the consumption ratio of heating application is decreasing due to progress of insulation and airtight construction for residences, while that of hot water supply application is increasing. Regarding the kinds of energy used, over 98% of the total consumption is covered by kerosene, gas fuels (LPG plus city gas) and electricity, in which the ratio of gas fuels and electricity tends to increase while that of kerosene to decrease.

b. Residential situation in Japan

Because of the destruction of residences by fire due to the air attack during the World War II counting 2300 thousand residences inside Japan (equivalent to 17% of the total residences at the opening of the War, 14000 thousand), and the repatriation from overseas areas counting 6500 thousand, the number of shortage for residences was assumed to be 4200 thousand. Therefore, it is not too much to say that the post war period of Japan started from the absolute shortage number of residences.

In 1955, Japan Housing Corporation (present Housing-Urban Development Corporation) was established to construct apartment houses with fireproof structure mainly in the major urban districts. As a result, the signs of improvement for residential situation began to appear from

1965. However, the number of residences exceeded that of homes all over Japan only in 1973. As you know, the first oil crisis was commenced in the year of 1973. Namely, we entered into energy saving period just at the stage when the lowest living standard providing one residence to one home was satisfied and many remaining problems relating to residences were initiated to be improved. According to the house data of EC Committee, Japan were sharply criticized as "Westerners feel that Japanese works too much while living poor residence like a rabbit hutch.", however, it may be said that the residences of Japan are improving graduately thereafter.

2. Japanese and bathing

It is said that Japanese like bathing. According to the mean value of a certain questionnaire, they take a bath everyday in summer somewhat caused by the high temperature and humidity, 5.3 times a week even in comparatively dry winter and the intermediate numbers in other seasons.

In the period after the World War II, Sento (public bath) was most popularly used. Installing a bath in each residence as a general knowledge was triggered by the apartment houses built by Japan Housing Corporation. Thereafter, a bath was installed in each home rapidly, and approximately 85% of residences have been individual bath at present. Without the bath, therefore, we can not talk about the hot water supply facility of Japan, however, we have to observe the points below.

- The kinds of bathtub include Japanese, Western and Japanese-Western combined styles. The Japanese and Japanese-Western types have deep bathtub containing much hot water, and have no overflow outlet requiring waterproof bathroom generally.
- With the bathing manner of Japanese, the body is warmed inside bathtub, and washed outside bathtub. Therefore, the hot water inside the bathtub is not replaced for each person generally.

• Under the circumstance, additional heating or high temperature hot water supply is desired to prevent the cooling of water until all family members finish their bathing. Further, remaining water inside bathtub is reheated sometimes.

• Requirement for shower in addition to bathtub has been increased especially by younger people. The using frequency of shower tends to be high in summer.

As explained, additional heating of bath or supplying of high temperature hot water, and comfortable use of shower are important factors when the hot water supply facility in Japan is considered.

3. Kinds of water heaters being used

The energy source of home water heaters being used in Japan mainly depends on gas, kerosene and electricity. (Although solar water heaters are considerably used, they are excluded from this report.) The number of shipment of gas, kerosene and electricity water heaters after 1975 are shown in Table-1. (In Japan, a bath furnace to heat water inside bathtub only is classified in the water heaters generally. This report follows to this classification.) Almost electricity types utilize so called night discount rate. From this table, it is clarified that the shipment of gas water heaters, especially instantaneous type, are remarkable. These water heaters are classified by not only fuel to be used or structure such as instantaneous/storage types but also function such as that exclusive for hot water supply or combined use for hot water supply and heating, installation position and supply exhaust system resulting in numerous numbers in the kind.

The hot water supply facility around 1955 to 1965 was usually a bath furnace and a small gas instantaneous water heater Class-4 * or so installed at kitchen sink. Such situation was improved gradually, however, so called individual central hot water supply system by a large water heater was em-

ployed by apartment houses on a full scale only after 1975. Due to the above partly, all water heaters in numerous kinds are still manufactured today.

(* Class-1 has capacity to heat 1 ℓ /min of water by 25°C, namely, equivalent to output of 1,500kcal/h.)

4. Development of gas water heaters

As explained before, gas type instantaneous hot water heaters are most frequently used in Japan. Consequently, the heaters of this kind showed remarkable development. Here describe this point mainly.

a. Ignition system/Air supply exhaust system

Many Japanese residences were open and the airtightness was inferior. Along with the popularization of aluminum sash and the increase of residences having high airtightness due to the increase of concrete apartment houses, troubles caused by the incomplete combustion of gas water heaters and bath furnaces were increased. Backed by such situation, Balanced Flue(BF) type Class-11 water heaters were put in market in 1962 taking the literatures of foreign countries including W.Germany as references. In 1965, BF type bath furnaces were put in market, and in 1968, BF type bath furnaces combined with Class-6 to 7 shower were in market. Since the mounting measurement of the supply/exhaust holes of both furnaces were same enabling indoor installation work, these furnaces were popularized especially for apartment houses. However, since BF type equipment should be installed closed to external wall, Forced Flue(FF) type hot water heater was developed in 1972. After around 1978, outdoor installation type water heaters are increasing. For the ingnition of gas, match was used firstly. In 1957, heater ignition system using dry battery, in 1964, piezoelectric ignition system taking the hint from the piezoelectric device used in single cylinder engines, in 1971, high voltage continuous spark ignition system in which

100V AC power source is raised to 10,000V approximately through transformer and is sparked continuously at electrode for ignition, were developed. The high voltage continuous spark ignition system is adapted to appliances using electricity such as FF type instrument, while the piezoelectric ignition system is to BF type and other instruments.

b. Stability of hot water temperature

As the most faulty point of instantaneous water heater, the hot water temperature changes depending on the hot water volume to be used as shown in Fig.4(a). In 1971, the heater of which gas combustion volume can be selected manually as shown in the same figure (b) was developed, however, it can not solve the above problem completely. In 1979, a heater enabling to maintain hot water temperature constant by changing gas combustion volume to match the hot water supply volume as shown in the same figure (c) was appeared. This improves the using convenience significantly. Even in this case, however, the hot water temperature drops when the hot water supply volume exceeding the capacity is required. The water heaters completed during 1981 to 1982 were provided with a mechanism to minimize water volume when the supply volume over the capacity is required as shown in the same figure (d). This enables to provide hot water with constant temperature. In Fig.4(c) and (d), examples allowing to set hot water temperature as desired are indicated, however, fixed temperature type heaters like a storage heater are also available. Regarding the control system, feed back and the combination of feed back and feed forward are available.

The Better Living Housing Component approved by the Minister of Construction (called BL component. The evaluation is made by Center for Better Living.) requires considerably severe conditions that 3 or more stages selection are needed for the capacity manual selection type (Fig. 4(b)) principally, that the hot water temperature of shower without

thermostat should be within ±1.5°C of the set hot water temperature with another water plug opened for the automatic selection types (Fig.4(c), (d)), and that all Lo-capacity should be minimized to that of Class-4.

c. Energy saving characteristics

Almost all conventional water heaters are provided with a pilot burner being ignited for all the time. Therefore, with instantaneous types, gas of 100～200kcal/h is burned in waste. In the field of recent large water heaters, that permitting the combustion of the pilot burner only during the combustion of the main burner, that permitting pilot burner combustion several minutes after main burner fire extinguishing and automatic extinguishing afterwards for intermittent use, and that permitting direct ignition to main burner without having pilot burner are main stream. With instantaneous water heaters, the efficiency lowers at the low combustion due to excessive air. To solve this problem, a type to control air volume to match the combustion volume is increasing in number for water heaters using fan for supply/exhaust. In addition, so called waste heat recovery type water heaters installing a heat exchanger for the preheating of water in addition to the ordinary heat exchanger have appeared.

d. Small size

The greatest merit of the instantaneous water heaters is smaller in size than that of storage type heaters, and the former is widely employed in Japan due to the above among other reasons. Especially for lotting-out apartment houses, small size heaters are strongly required. To match such requirement to the maximum, so called compact type water heaters have been popularized rapidly which can be mounted even on the access door of pipe shaft in apartment houses. This type was completed in 1981. The Class-13 with $W_{480} \times H_{530} \times D_{190mm}$ has a solid capacity in one third of the conventional models approximately. In 1982, compact

type water heaters equipped with forced additional heating device were put on market, of which width is 480mm as same with the above while the height and depth are larger in the shape.

e. Additional heating of bath

As described before, requirement for additional heating of bath is strong in Japan. For the unified equipment of bath furnace and water heater, that progressed from BF type bath furnace was firstly developed, and several kinds of models were developed. However, since these models have natural circulation system in their additional heating mechanism, they should be installed inside or near bath room providing strict limitation on installation condition. To suppress this condition, so called water heaters with forced circulation bath furnace by mounting a circulation pump to the heat exchanger were developed.

This type includes indirect system by which hot water inside bath is heated additionally through a heater, and direct system by which hot water inside bath is circulated directly. Recently, fully automatic bath furnaces are developed which include that heats water to the set temperature automatically after supplying proper hot water with somewhat lower temperature, and that keeps the set temperature constantly thereafter.

f. Others

The conventional instantaneous water heaters do not operate if the inlet water pressure is lower than 0.4kg/cm^2 approximately. However, the heaters operating with lower pressure and that allowing no combustion with entering water to the heater at temperature higher than a certain temperature in addition, which is designed to combine with solar water heater, have appeared. Further, an ultrasmall water heater with additional heating function is marketed enabling to mount on the external wall utilizing the hole of top of BF type model in order to install a larger bathtub in the bathroom which used BF type bath furnace before. The heater

is shown in Fig.6.

5. Efficiency measurement by mode operation of water heaters

The BL type water heater (all gas type presently) introduced before satisfies the standard of heat efficiency indicated in Table-2. However, the measurement of the heat efficiency is for that under stationary hot water supply condition. Contrary to the above, the Committee installed in the Institute of Building Energy Conservation proposes to measure the efficiency by the operation mode shown in Fig.7 based on the understanding that hot water supply is made intermittently. In the figure, L mode, M mode, S mode represent a home consuming a large hot water volume, standard volume and small volume of which annual hot water supply heat amount is counted 4.3, 3.3 and 1.7×10^6kcal respectively. The hot water heaters are to be operated at the part marked "o" in the figure. And the air and hot water supply temperature are set to 15 ± 5°C based on the understanding that hot water supply is made throughout a year. The hot water supply model A is for washing stand and kitchen, B for bathtub and C for shower. The model D is for the additional heating of bathtub which can be made by either hot water supply over 60°C or the raising of hot water of 180ℓ at 39.5°C inside bathtub to 45°C. The measurement of heat efficiency of various water heaters conducted through this method resulted in the following items and so on.

- On the whole, the water heaters rank within a range of 60～80%.
- The heat efficiency usually measured under stationary state has positive relation with that measured by this method. Especially, with instantaneous type, the value appears approximately 92% of that under stationary state.
- Storage heaters show better efficiency as the consumption of hot water increases, while instantaneous heaters show constant value regardless of hot water consumption.

6. Recent topics relating to water heaters

The home water heaters in Japan have been improved steadly. Here, the recent topics relating to water heaters are shown in items.

(1) With storage type heaters, heat loss increases as the hot water temperature inside the storage tank is higher. With electric water heaters utilizing night discount rate which can only be heated during nighttime, it is difficult to heat water to satisfy hot water use in the next day. For this reason, electric water heaters equipped with a device to decide an appropriate hot water temperature by detecting entering water temperature, or a device enabling to set weekly program by considering the bathing days of which hot water consumption occupies a large share in Japan, have appeared.

(2) With storage electric heaters utilizing night discount rate (powering from 11:00PM to 07:00AM), hot water temperature is desired to reach that suitable to use near 07:00 in the morning when hot water consumption starts. For this reason, heaters enabling to shift the powering time frame to 07:00 in the morning have been developed. A special discount rate is applied to these models.

- In addition to the conventional night discount rate for 8 hours, new night discount rate for 5 hours powering from 01:00AM to 06:00AM has been established. In accordance with this new system, electric water heaters to match the system have been put on market.
- Electric heat pump chiller water heaters utilizing waste heat at cooling, and surplus heat at heating, and that utilizing night discount rate have been appeared.
- A pulse combustion type water heater which succeed to obtain a heat efficiency of 95% due to the high load combustion and increased heat trnasfer coefficient through explosive combustion like automotive engines, and for which a supply/exhaust pipe around 5m (double tube with 45mm O.D. approxi-

mately) can be mounted, has been mostly completed. In addition, a gas engine heating/cooling and water heater of which large size model has already put in practical use, is mostly developed for residential application.

● The improvement of kerosene water heaters has been promoted for higher equipment efficiency and smaller size.

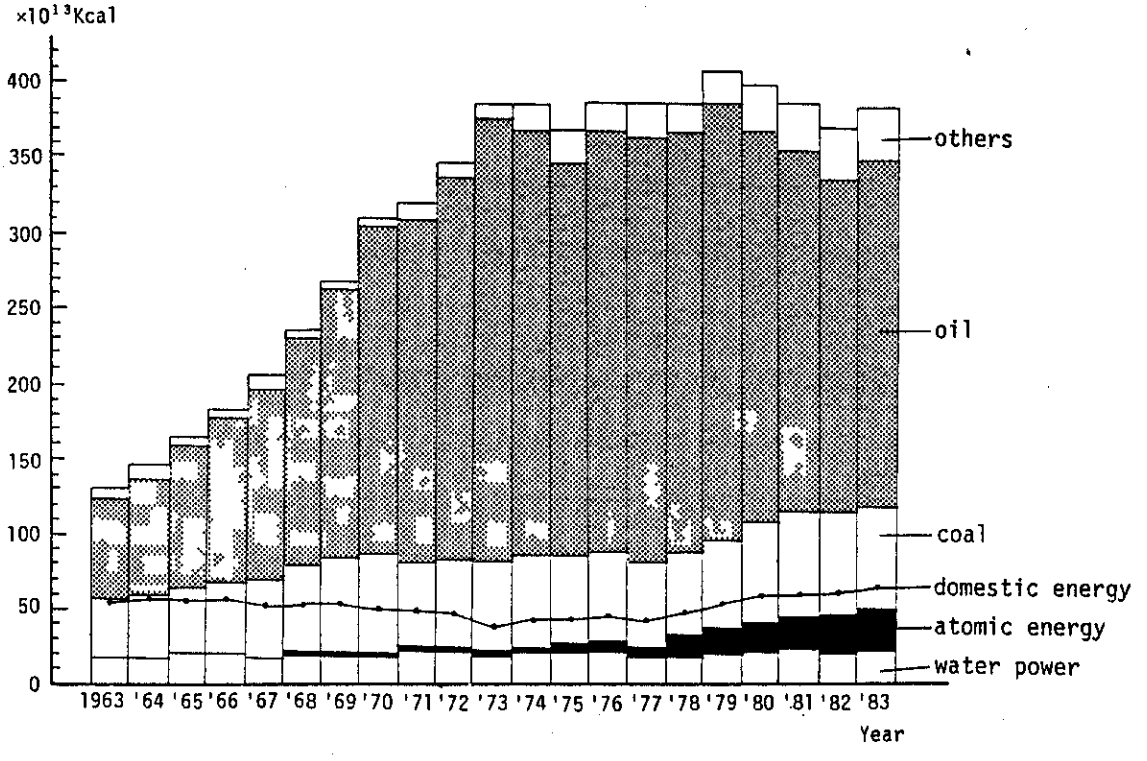


Fig.1 Change of energy supply in Japan.

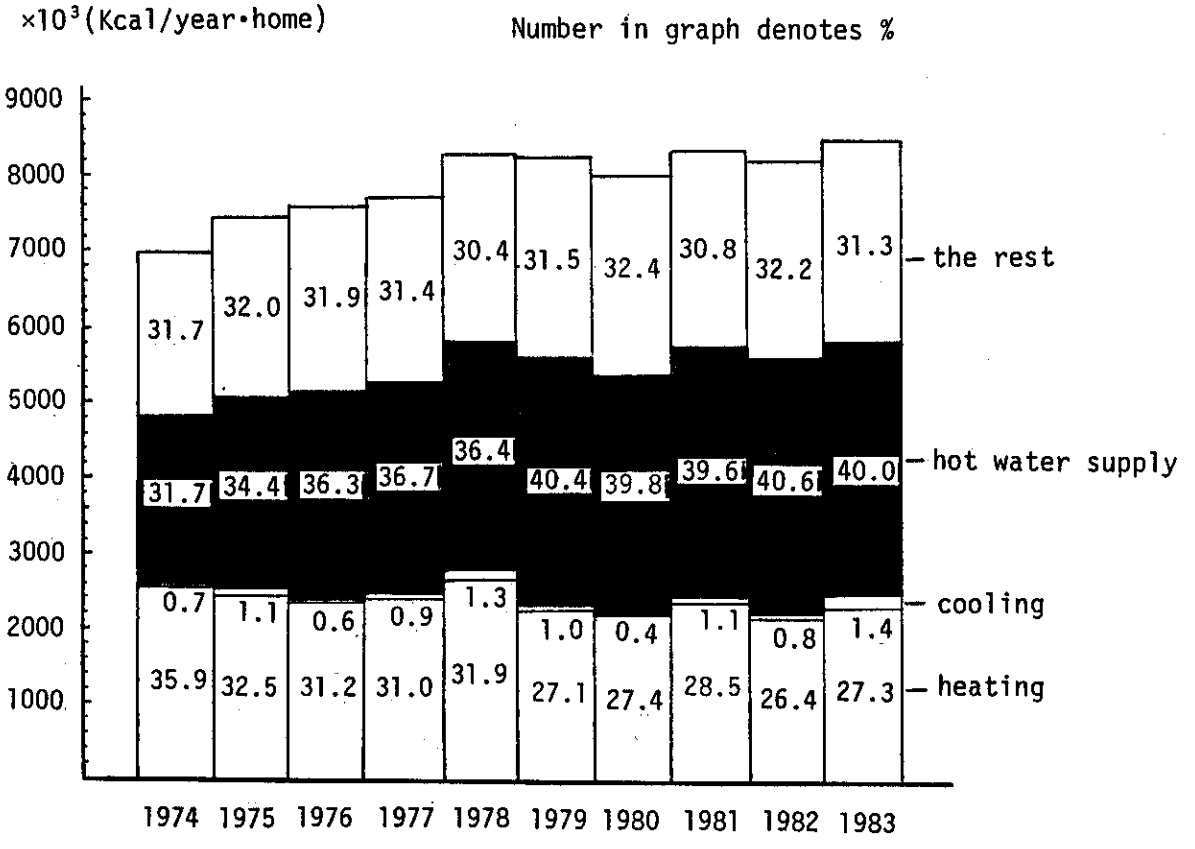
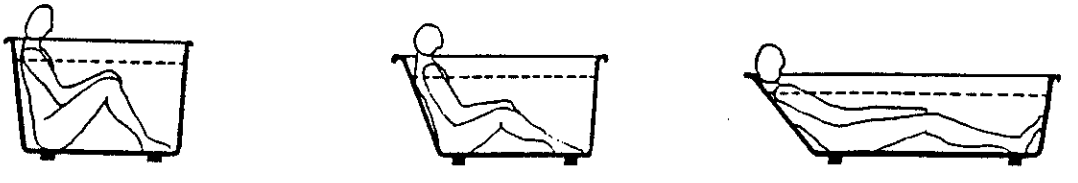
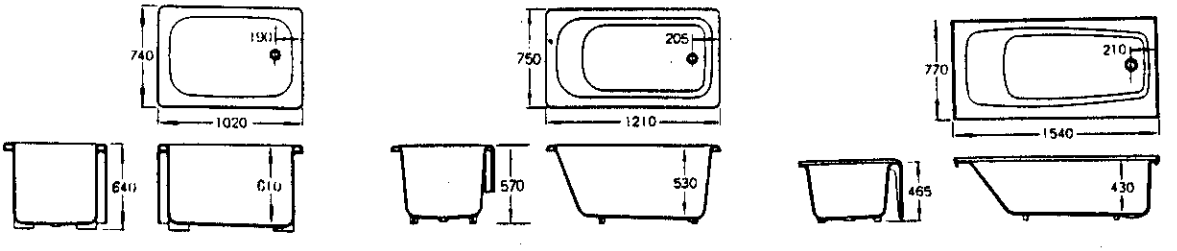


Fig.2 Change of energy consumption in Japanese home.



An example of each type bathtub's dimension is showed below.



Japanese style

Japanese-Western combined style

Western style

Fig.3 Kinds of bathtub being used in Japan.

Table-1 Number of shipment of water heaters.

	kerosene water heater			gas water heater				electric water heater (storage type)	the sum total
	water heater	bath furnace	total	instan-taneous type	storage type	bath furnace	total		
1974	*43×10³		*43×10³	2151×10³	58×10³	*1394×10³	*3603×10³	356×10³	4002×10³
1975	*92	*37×10³	*129	2183	47	1461	3691	334	4154
1976	*184	*92	*276	2429	52	1635	4116	323	4715
1977	*255	*153	*408	2396	62	1581	4039	260	4702
1978	*370	*259	*629	2419	90	1571	4080	235	4944
1979	269	166	435	2449	152	1733	4334	293	5062
1980	226	173	399	2228	144	1670	4042	240	4681
1982	240	182	422	2414	140	1585	4139	172	4733
1983	243	147	390	2356	124	1650	4130	137	4657
1984	245	151	396	2629	73	1559	4261	128	4785

*the estimated number

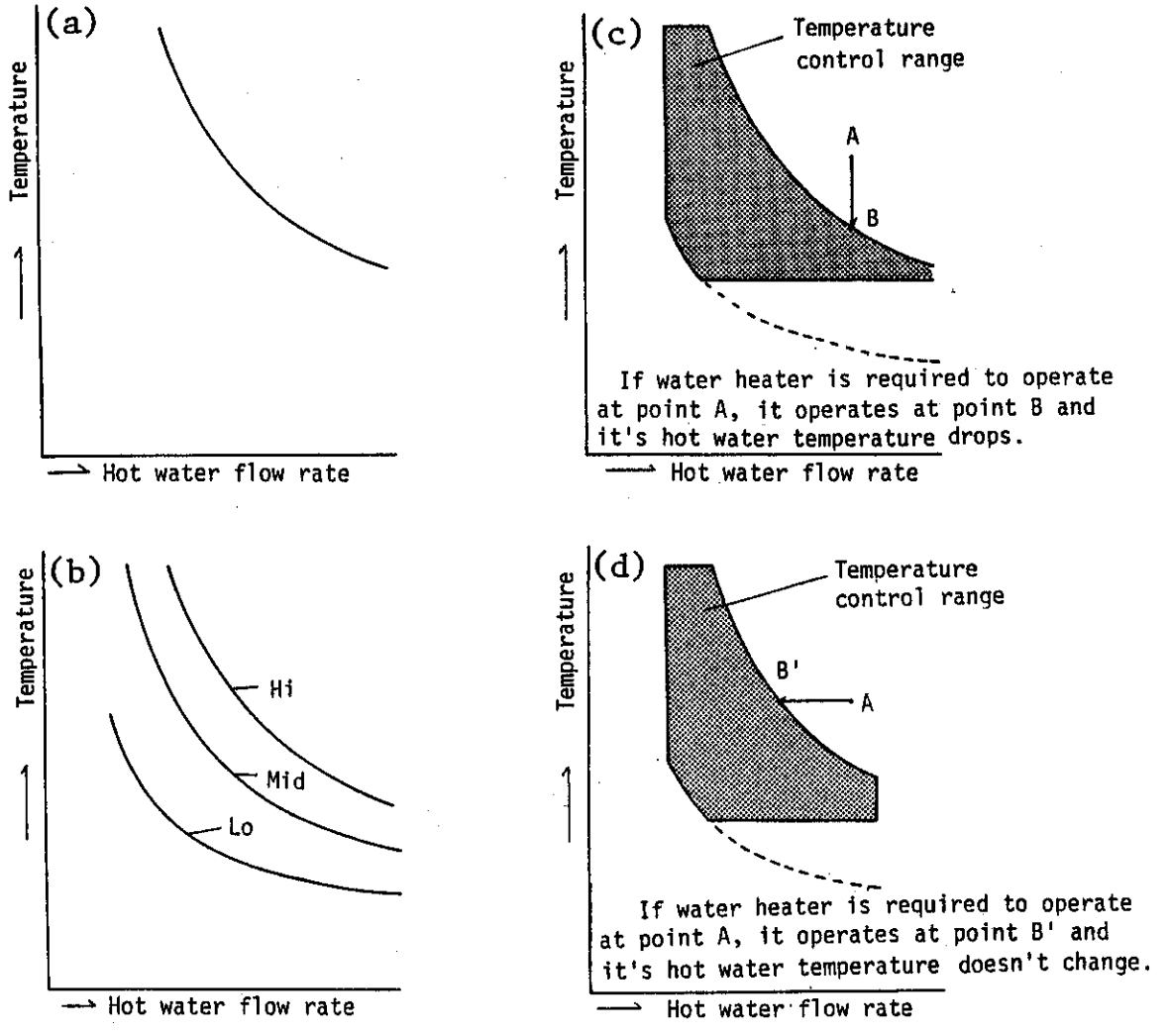
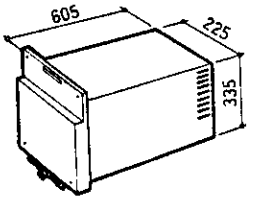


Fig.4 Improvement of hot water temperature control method.



Fig.5 Compact type water heaters.



dimension (mm)

Water heater:
Class-8.2

Capacity of additional heating:
10000Kcal/h

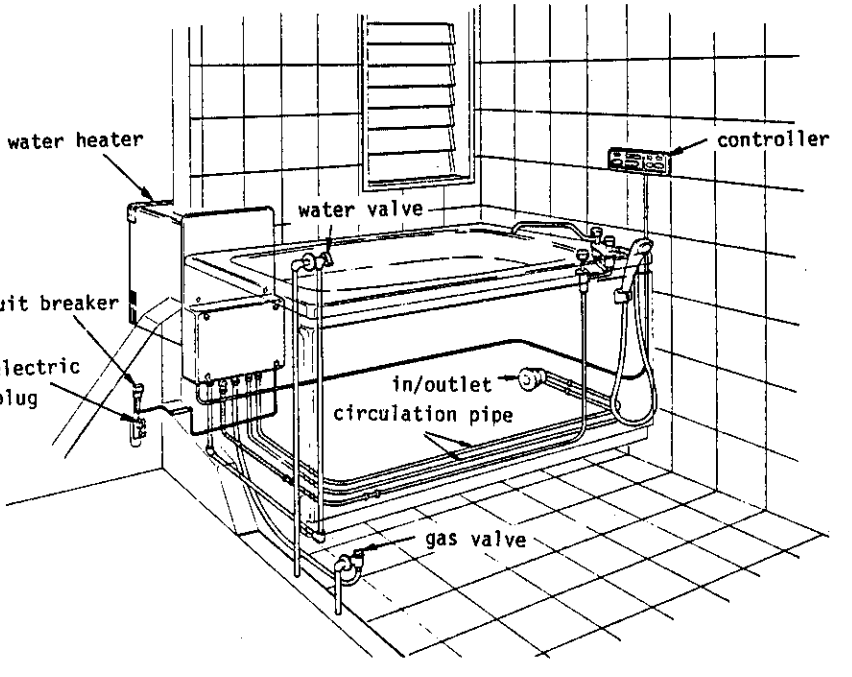
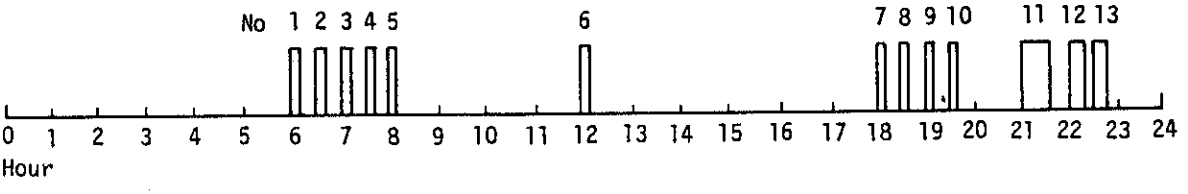


Fig.6 Ultrasmall water heaters with additional heating function.

Table-2 BL standard of heat efficiency for gas water heaters.

Hot water supply	Hi	Instantaneous type	≧78% *1
		Storage type	≧70% *2
	Lo	All type	≧70% *3
Additional heating			≧70%

*1) ≧ 80% (Central system for many homes)
*2) ≧ 78% (Constant water flow test method)
*3) ≧ 75% (Central system for many homes)
Heat loss of storage water heater should be less than 120 Kcal/h.



No	Temperature hot water	Temperature water at inlet	Flow rate	Running time	Volume of hot water	Heat quantity	Supply model	L mode	M mode	S mode
1	42°C	15°C	6 ℓ/min	2.65min	15.9 ℓ	430Kcal	A	○	○	○
2	〃	〃	〃	〃	〃	〃	〃	○	○	○
3	〃	〃	〃	〃	〃	〃	〃	○	○	—
4	〃	〃	〃	〃	〃	〃	〃	○	—	—
5	〃	〃	〃	〃	〃	〃	〃	○	—	—
6	〃	〃	〃	〃	〃	〃	〃	○	—	—
7	〃	〃	〃	〃	〃	〃	〃	○	○	○
8	〃	〃	〃	〃	〃	〃	〃	○	○	○
9	〃	〃	〃	〃	〃	〃	〃	○	○	○
10	〃	〃	〃	〃	〃	〃	〃	○	—	—
11	45	〃	—	—	180	5400	B	○	○	○1/2
12	42	〃	8	5	40	1080	C	○	○	—
13	—	〃	—	—	—	1000	D	○	—	—

Fig.7 Operation mode for the efficiency measurement of home water heaters.

CIB

CIB-W62 SYMPOSIUM

Domestic Water Heating by Solar Energy

I. Silberstein

April 9,~10, 1985

TOKYO, JAPAN



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The Standards Institution of Israel

DOMESTIC WATER HEATING BY SOLAR ENERGY

12th CIB-W62 SYMPOSIUM - TOKYO -
WATER SUPPLY AND DRAINAGE FOR BUILDINGS
APRIL 9, 10, - 1985: KENCHIKU KAIKAN

Summary

Technical and energetic aspects of the use of solar energy for domestic water heating in Israel are reviewed.

Israeli experience with problems related to the compatibility of solar water heating systems with the rest of the plumbing in residential buildings is discussed.

Résumé

Aspects techniques et énergétiques de l'utilisation de l'énergie solaire pour le chauffage de l'eau en Isarël.

Expérience en Israël des problèmes de compatibilité des systèmes solaires de chauffage de l'eau avec le reste de la plomberie dans des immeubles d'habitations.

Zusammenfassung

Technische und energetische Aspekte der Verwendung von Solarenergie bei der Haushaltswassererwärmung in Israel werden besprochen.

Die israelische Erfahrung mit Problemen der Kompatibilität von Solarwasserheizsystemen mit den übrigen Installationen in Israel wird diskutiert.

概　要

イスラエルにおける太陽熱を利用した住宅用給湯の技術的，効果的な方向性を述べた。

太陽熱利用の給湯システムと集合住宅における他の給排水配管との両立性に関連して，イスラエルの技術的な問題について論じた。

Domestic Water Heating by Solar Energy

I. Silberstein, The Standards Institution of Israel.

1.0 Introduction

One of the functions of residential plumbing systems is to supply hot water for domestic use. Various sources of energy may be employed for heating water. Many countries - including Israel - have made extensive progress in using solar energy for the heating of water for residential applications.

When discussing solar energy systems for water heating, the following aspects must be taken into consideration:

a. - The energetic aspect - to what extent can the solar energy system replace other energy sources, and what features and conditions can optimize the thermal efficiency of the solar energy system.

b. - The functional aspect - to what extent can the solar energy system ensure hot water supply to suit domestic requirements, and how can we ensure reliable and maintenance-free prolonged operation of the system.

c. - The aspect of integration in domestic plumbing systems - to what extent can the solar water heating (SWH) system be integrated in the existing plumbing system without running into difficulties.

d. - The economic aspect - in what manner can the solar water heating (SWH) system be adopted economically. Because of the frequent changes in energy costs, repeated examination of the economic feasibility is required.

Research work performed in recent years was primarily concerned with the energetic, functional and economic aspects, and only to a slight degree with the integration of solar systems in existing plumbing systems.

The objective of this paper is to discuss the use of solar energy in Israel, and to present the features that were troublesome and that led to the initiation of special studies. The main problems are related to integration in the domestic plumbing system, and are therefore presented herewith in the framework of CIB-W 62.

2.0 Solar energy for water heating in Israel

2.1 General

Until twenty years ago, it was common practice in Israel to heat water for domestic purposes by means of electric water heaters. Such means fitted in well with the method used for measuring water consumption in individual apartments. In the sixties, central water heating by means of diesel oil was introduced in new buildings as a separate system or in conjunction with the general domestic heating system. The use of diesel oil increased until 1973, at which time the energy crisis occurred.

It should be noted that in the late forties thermosiphonic solar systems were first introduced into Israel. Solar systems became especially popular among people of lower income, by reason of their belief that they are getting hot water at practically no cost. In the early seventies, however, the installation of SWH systems was almost completely stopped due to architectural difficulties. Over the years, various solutions were found to circumvent these problems by changing the configuration of the SWH systems. These solutions were implemented by standards and regulations that were obligatory on architects and builders. In 1973 it was estimated that every fifth family in Israel was equipped with a SWH system. Due to the energy crisis, which drastically raised fuel and electricity costs, the adoption of SWH systems began to expand significantly. With the increased demand, manufacturers hastened to produce solar collectors, storage tanks and various ancillary equipment used in SWH systems. Concomittantly, relevant standards were prepared and published (see list of standards at end of paper) to ensure satisfactory quality of the SWH systems and their components.

Regulations issued in 1980 by the Ministry of Interior, made it mandatory to install SWH systems in all new residential buildings. At present about 40% of all apartment units in Israel are equipped with SWH systems, and about 70,000 new units are being installed each year.

The advantages of thermosiphonic solar systems include simplicity of construction and low cost relatively high caloric output, and integration in individual water metering systems for each apartment. The drawbacks of residential thermosiphonic solar systems include reduced effectiveness with

increasing number of stories under the roof of the building, necessity of open roof area, impairment of architectural appearance, and limitation of hot water storage to 200 liters per apartment.

The compulsory introduction of central SWH systems greatly diminished these drawbacks. Roof installations were restricted to solar collectors only, while storage facilities, circulating pumps and other auxiliaries were installed within the building or partly even in the apartment. The design and installation of central solar heating systems were prescribed technical specifications of the Ministry of Energy and the Standards Institution of Israel (Spec. 97).

2.2 Distribution of residential energy requirements

According to data published by the Ministry of Energy in 1980, domestic energy requirements in Israel were filled by the following types of energy:

Electric energy	65%
Gas	10%
Kerosene, diesel oil	14%
Refined crude oil	3%
Solar energy (*)	8%
Total	100%

Distribution of the domestic energy consumption in 1980 was:

Cooking, refrigeration, laundry, TV	46%
Air conditioning (heating and cooling)	24%
Heating of water	25%
Lighting	5%
Total	100%

The table indicates that air conditioning and water heating are dominant consumers of energy in residential applications, which explains the efforts being made to find cost-effective solutions to solar energy utilization for these two applications. As things stand today, economically justifiable solutions have been found for solar water heating, but no satisfactory solutions have been found as yet for air conditioning.

(*) Note: In recent years, residential solar energy consumption has risen from 8% to about 10%.

Based on the data presented above, 25% of the residential energy consumption is absorbed by water heating. It seems therefore that in the most favorable case, 16% - 18% of the total energy required for domestic consumption may be supplied by solar energy. The difference between 16% and 25% is intended to serve as back-up energy, which must be supplied by other than solar energy sources.

We may note that the current consumption of solar energy in Israel is about 2.3% of its total yearly energy consumption. This percentage is expected to rise by reason of new regulations, and because of the increased use of concentrating solar energy collectors for industrial applications, which require water at temperatures higher than 60°C.

2.3 Climatic, radiation-related and other factors

The yearly average value of incident cumulative radiation on horizontal surface varies in Israel from 4600 to 5000 Kcal per square meter per day. If this amount of radiation energy is theoretically sufficient to fill energy demands during most months of the year, cloudiness in winter prevents full utilization and necessitates the drawing of supplementary energy from the back-up. Long-term follow-up indicates that supplementary energy is required on 60 - 80 days per year in thermosiphonic systems and for longer periods of time in central heating systems.

For calculating the flat collector areas when designing solar systems, the Israel Standard specifies an incident radiation of 4060 Kcal per square meter per day (equal to 17,000 J per square meter per day), although for long periods during the year, the radiation is much higher. The Standard also specifies - for the heating of water - an energy supply of about 40 Kcal per liter per day for open circuit SWH systems, and about 46 Kcal per liter per day for closed circuit SWH systems.

2.4 Description of SWH systems and their components

Following are brief descriptions of the main characteristics of SWH systems installed in Israel and their principal components.

2.4.1 Collectors

Collectors are the chief component of the solar energy system, the proper operation and efficiency of which determine the amount of energy transmitted to the water.

Residential SWH systems contain flat collectors that comply with Israel Standard SI 579, Part 1. Some features of widely used collectors are given in the following table.

Type of collector	Description	Value of efficiency (*) at reference point
Regular	Steel pipes, steel absorber plate painted black	52%
Improved	Steel or copper pipes, steel absorber plate with black chrome plating	53 - 62%
Honeycomb	Copper pipes, aluminium fins as collector plate	60 - 62%

(*) According to Israel Standard SI 579, the efficiency is measured and calculated by the NBS method, which is based on the average temperature of the water in the collector. The collector efficiency η by this method is shown on a graph as a function of X, where

$$X = \frac{\frac{t_1 + t_2}{2} - t_a}{I}$$

η = collector instantaneous efficiency (%)

t_1 = water temperature at collector inlet (°C)

t_2 = water temperature at collector outlet (°C)

t_a = ambient temperature

I = insolation (w/m^2)

The collector instantaneous efficiency η is calculated from the curve η = f (χ), at the reference point

$$X = \frac{1}{40} \left[\frac{m^2 \cdot K}{w}\right]$$

Most of the solar collectors produced in Israel have an aperture area of 1.4 m^2 or 2.0 m^2, which is adequate for heating the volume of water in the storage tanks.

2.4.2 Storage tanks

Storage tanks comprise the main auxiliary component of the SWH system. Residential SWH systems generally include storage tanks of 120 or 150 liter capacity, and in rare cases a maximum of 200 liter capacity. The storage tanks are corrosion-protected by means of magnesium anodes (complying with Israel Standard SI 579). For additional protection it is customary to coat the inner surface of the collector with enamel, epoxy or portland cement.

Each storage tank is equipped with electrical back-up of 1500-2000 W capacity, protected by means of an adjustable thermostat and a temperature limiting switch set to 105°C.

2.4.3 Residential thermosiphonic SWH systems

As mentioned earlier, most of the installed solar energy systems are residential thermosiphonic systems. A schematic lay-out of a typical residential thermosiphonic system is given in Fig. 1.

In Israel, open thermosiphonic SWH systems are used, due primarily to the low danger of frost conditions.

The daily thermal efficiency of the thermosiphonic SWH system is 40% - 45%, and since in most months the incident cumulative radiation on the aperture area of the collector in Israel is higher than 5000 Kcal per square meter per day when the sky is clear, the temperature of the water for consumption may reach 55°C - 60°C.

2.4.4 Central SWH systems

There are many types of central SWH systems, classified primarily by type of storage (central or individual apartment) and by type of back-up (electri-

cal or fuel). This is not the place to go into detail regarding the construction of different systems, however, note should be taken of certain basic, general data.

The design and installation of the central solar systems are based on the requirements of Israel Specification 97.

Specification 97 specifies the storage capacity according to 40 liter of water per person per day, and this is the basis on which the collector thermal outputs and their areas are calculated. The daily thermal output of the collector area of the system is adapted to the storage volume based on the standard requirements of 41 - 46 kcal per liter of stored water per 24 hour day.

A follow-up of the operation of the systems has shown that the actual demand of hot water is greater than the calculated stored volume by 73% on the average. The additional water consumption was caused by the following factors:

a. - Since the hot water consumption of each apartment is not measured separately, the demand of hot water increases by about 10%.

b. - The consumption of hot water depends on the disposable income of the population, which is the total net income less the average expenses of the population. The residents of high-rise buildings equipped with central SWH systems, are generally on a higher economic level.

In 90% of the central SWH systems in Israel, back-up energy is produced by diesel oil.

Checks of central SWH systems have shown that their thermal output is clearly dependent on the satisfactory operation of the system and its maintenance.

From among the various types of central SWH systems, priority was given to the central SWH systems with the hot water storage facilities in each apartment, which permits separate measurement of hot water consumption by each apartment.

2.5 Anticipated energy savings by use of SWH systems

Investigations have shown that the average yearly savings obtained from residential thermosiphonic solar systems designed for the heating of sanitary water is about 900 Kwatt hour per apartment per year. These savings are about 78% of the average consumption of electricity required for heating water by means of a residential electric water heater.

A study made in 1983 showed that a central SWH system designed and installed according to relevant technical specifications, saves about 32% to 84% of energy. The average yearly savings are about 63% when the back-up is by means of diesel oil. The studies showed that these central systems are economically advantageous and the period of capital return is on the average about five years. These data show that the savings in central solar systems with diesel oil back-up are smaller than in those with electrical back-up. This difference in savings is due to combustion losses in the water heater, when using diesel oil back-up.

The wide percentage range of energy savings (32% up to 84%) noted in central SWH systems is a direct result of the consumption regime of the hot water, which is completely different in central SWH systems from SWH systems for individual apartments. It should be noted that these great differences in energy savings are not contingent on the technical characteristics of the central solar systems.

3.0 Integration of SWH systems in residential plumbing systems

Some of the SWH systems installed in Israel were in existing buildings, where the solar system replaced the electric water heaters in the apartments. In these cases, it is necessary to ensure the compatibility of the new appliance with the existing plumbing system, as noted in the guidelines given in the installation specifications.

Other SWH systems have been installed in new buildings, where the SWH system could be designed as part of the plumbing system. Under such conditions it was easier to solve most of the problems relating to the two systems.

The experience gathered during many years of SWH systems installation and the follow-ups of their performance, was of great help in solving problems and questions that arose. The following pages include a brief description of the steps taken to supply answers. Part of these answers have found their way into standards and specifications relating to the installation of SWH systems. These standards and specifications undergo frequent revisions.

3.1 Influence of copper pipes in solar systems on the corrosion of residential piping

In Israel, the conventional residential water supply piping is of galvanized steel. However, corrosion damage in this piping is rather high, and the question arose to what extent the increased damages are caused by combining the different materials used in SWH systems in the plumbing system. In an effort to answer this question, the Ministry of Housing initiated in 1981 an investigation, which was conducted by the Israel Centre of Waterworks Appliances (ICWA).

The general opinion of most professional agencies that work in the field of copper as well as of zinc, is that the presence of copper in the water accelerates corrosion. Based on this opinion, many public and private bodies in Israel fear that solar collectors constructed of copper pipe may cause heavy damage in residential water supply systems using galvanized steel piping. On the one hand, there were some (including interested parties) who demanded a ban on solar collectors using copper. On the other hand, the manufacturers of solar collectors claimed that many copper solar collectors that have been installed in Israel are operating satisfactorily for prolonged periods of time without causing damage to the residential steel piping.

The objectives of the ICWA study were to investigate the effect of copper solar collectors on the residential galvanized steel piping connected to SWH systems and to pinpoint the cases where corrosion appeared after installation of the collectors.

A summary of the conclusions reached by the ICWA study reveals the following:

a. - In general, the findings of the study do not warrant anxiety as to installation of copper solar collectors in galvanized steel residential water supply systems, provided that the collectors were installed according to pertinent specifications. It should be noted that this conclusion is based on relatively short-term

data, and that longer observation periods are required for proper follow-up.

b. - the claim of some technical publications that new galvanized piping is more susceptible to corrosion than old piping has not been found valid. This claim is probably based on the fact that frequently layers of mineral deposits form on old pipes, which prevent contact of copper ions with the galvanized surface.

c. - The study revealed several typical failures:

- Increased corrosion in storage tanks whose inner faces were not properly protected against corrosion.

- Corrosion of steel connecting pipes. To prevent this type of failure, it is recommended that copper connecting pipes be used whenever copper solar collectors are to be connected to a steel piping system.

d. - One of the means recommended for the prevention of copper ion contact with the galvanized surface is the installation of a filter element composed of aluminium chips, which by means of ion exchange action prevent the copper ions from reaching the galvanized pipe.

3.2 Effect of SWH systems on residential plastics water supply piping

As presented in a paper submitted to Seminar No. 11 of CIB-W 62 in Tel-Aviv, in October 1983, installation of plastics piping for residential cold and hot water supply has increased significantly in Israel. The pipes are produced of CPVC, cross-linked polyethylene or of polybutylene. The specification sets the maximum allowable temperature at 82°C for operation of the pipes at the water pressure in the supply network.

In electric water heaters, the water temperature may be regulated by means of a thermostat, so that at satisfactory operation of the system the temperature of the water will not exceed 82° C.

A different situation exists in residential thermosiphonic SWH systems, where the water temperature in continuous hot water use generally does not exceed 82°C. In the summertime, water temperature is about 50°C. When, however, for various reasons, hot water consumption stops for a prolonged period of time (e.g. several days),

the water temperature in the storage tank may reach stagnation temperature, which has been measured as 96°C in extreme cases. The question arises therefore whether the life-span of the plastics piping would not be seriously impaired when the SWH system is reconnected.

To answer this question, it will be necessary to initiate an investigation to determine whether possible failures in the plastics piping may be caused by excessively high temperatures produced by the SWH system.

Another approach would be to install a thermostatic mixer at the outlet of the solar collector, to mix the hot water with cold water and thus maintain the maximum temperature of the hot water at a level that cannot damage the plastics piping.

In central SWH systems, a prolonged cessation of hot water use is not to be expected and therefore a dangerous rise in water temperature is unlikely.

3.3 Effect of SWH systems on pressure losses in residential piping

Most residential buildings in Israel are condominium buildings, three and more stories high. The residential SWH system, which is installed on the roof of the building, is connected to the apartment piping by means of inlet and outlet pipes (see Fig.1) . These two pipes may increase considerably the length of the hot water supply piping, and consequently the pressure losses of the piping.

The length of the inlet and outlet varies with the distance of the apartment from the roof and from the storage tank on the roof. The length of these two pipes varies from 10 to 30 meters, and sometimes even more.

In buildings where the SWH system replaced an electric water heater, the inlet and outlet pipes are generally ½" (12 mm) copper pipes. In new buildings these pipes are generally of the same size as the apartment piping, which is usually greater than the 12 mm copper piping.

Experience has shown that an increase in the length of the apartment piping does not create problems of pressure insufficiency at various demand points

in the apartment, except that longer time spans are required for filling the bath. It should be noted that during filling of the bath, practically no hot water is delivered by other taps.

Calculations of pressure losses have shown:

a. - Assuming a flow rate of 10 l/min (about 2.5 gpm) for showering, the flow velocity in a copper pipe of 12 mm outside diameter is 1 m/s. The pressure drop at this velocity per unit length of pipe is 1.3 KPa/m (0.13 m/m), which is not significant.

b. - For filling a bath, we can make the following assumptions:

- Quantity of water required to fill bath is 100 liter.
- When the temperature of the hot water is 55°C, and of the cold water 24°C, the quantity of hot water is about 50 liter to fill the bath with 100 liter of water.

- The time required to fill the bath is 4 minutes. The flow velocity of hot water for this time span is 2.3 m/s. At this velocity, the pressure drop per unit length of pipe is 5.7 KPa/m (0.57 m/m), which is significant and must be taken into account. Lately, tests are being conducted to determine the possibility of replacing the copper inlet and outlet pipes with plastics pipe suitable for hot water. In such cases, the inside diameter of the pipe increases from 12 mm (copper pipes) to 16 mm (plastics pipes), which will reduce pressure losses.

3.4 Cold water losses caused by lengthening the hot water piping

Whenever we open the hot water tap, a certain amount of water is lost, due to the time water is wasted until it reaches the desired temperature. The further the point of demand from the hot water supply, the greater the water loss. When residential thermosiphonic SWH systems are used, the length of the supply line increases and the cold water losses increase proportionately.

In addition to wasting water for unproductive purposes, the lost water reduces the availability of hot water. For each opening of the hot water tap, approxi-

mate losses are given in the following table:

Case No.	Length of pipe section		Volume of water in pipe section		
	Galv. steel pipe ½"	Copper pipe 12 mm Ø	Galv. steel pipe ½"	Copper pipe 12 mm Ø	Total
1	5 m	15 m	0.88 l	1.30 l	2.18 l
2	10 m	15 m	1.77 l	1.30 l	3.07 l
3	10 m	30 m	1.77 l	2.00 l	4.37 l

The water losses are relatively insignificant when related to baths and showers. They become relatively significant, however, when related to brief periods of hot water use and long intervals between uses.

The daily water losses caused by the features described above depend on demand factors, and wherever steps are taken to improve the use of water, thought should be given to possible water losses.

In the event that the 12 mm copper pipes will be replaced by 16 mm plastics pipes, the cold water losses will increase.

In central SWH systems with separate storage facilities for each apartment, cold water losses decrease and approximate the cold water losses when using individual electric water heaters.

4. Concluding remarks

This paper reviews various aspects of the use of solar energy for water heating in Israel, and problems arising in integrating SWH systems in residential plumbing.

The picture is of course incomplete, and aspects such as ageing of the solar collectors and its effect on the efficient functioning of the system must be considered (*).

More experiencemust be gained on the compatibility of materials used in the system, and a basis for effective quality assurance must be established.

We hope to present our findings and thoughts on the matter in a future paper.

(*) A study of solar collector ageing has been recently conducted by the Standards Institution of Israel (see Reference 7).

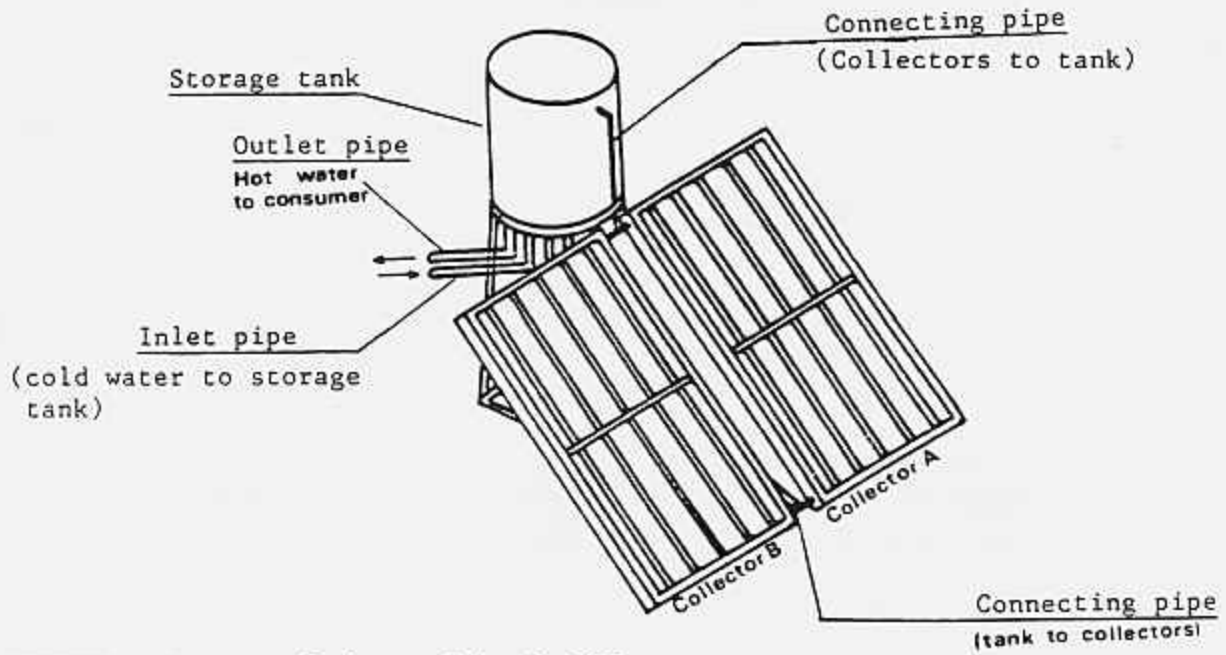


FIGURE 1. Layout of thermosiphonic SWG system.

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The Hydraulic Stability of Hot Water Heating System

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Summary

The hydraulic stability of a hot water heating system means that, the internal network in a heat consumer or the external distributing network of the whole system having been circuit balanced and commissioning regulated, then the flow rates properly distributed between the heat consumers, what degree of ability to maintain the original flow rates would be ensured.

The quality of the hydraulic stability can be measured by the proportion of the pressure loss of the internal network to that of the whole system. In a system with good hydraulic stability, when any consumer changes its flow rate, all other consumers would change their flow rates with smaller amplitude, i.e. the imbalance is lighter. It is the same the other way round.

For the internal network in a consumer, the method such as connecting the heating appliances in series, using the regulating valves with larger pressure loss before the heating appliances, and so on, to increase the pressure loss ratio of the appliance to the system, and then the degree of hydraulic stability of the system increased, is worth adopting.

But, for the external network as to increase the hydraulic stability, adding extra regulating devices to the farthest consumer in the index circuit to get the pressure loss ratio of the external network to the consumer system H_w/H_y=3:1--2:1 orless, would cause the pressure head and the consumption of electricity of the circulating pump

considerably. So that, this method could not be adopted rashly, as the cost is too high and the loss outweighs the gain.

Résumé

La stabilité hydraulique du systeme de chauffage est la capacité de maintien invariable après avoir défini la distribution des débits de consommateurs par la régulation primaire ou de fonctionnement suivant le calcul équilibre des reseux intérieur et extérieur.

La qualité de la stabilité hydraulique peut être évaluée par une proportion des pertes de pression entre le réseau intérieur et tout le systeme de réseaux. Dans un systeme de bonne stabilité hydraulique, lorsque le débit d'un consommateur a été modifié, ceux des autres ne change que dans un amplitude très limitée et le balancement hydraulique est aussi très léger . Si c'est dans un cas contraire , son résultat serait inverse.

Dans un réseau intérieur de consommateur, on utilise la méthode de connexion en serie des installations de chauffage pour agrandir la valeur proportionnelle des pertes de pression entre les installations de consommation et on prend la valve de grande résistance ainsi que d'autres mesures, afin d'améliorer la stabilité hydraulique du systeme. En effet, cette métode est très bien applicable dans ce domaine.

Au contraire , cette méthode n'est pas applicable dans le réseau extérieur: bien que la stabilité hydraulique soit améliorée, cela augmenterait une résistance exceptionnelle

pour les consommateurs les plus loins. Et la valeur propotionnelle des pertes présente Hw/Hy ≤3:1~2:1 entre le réseau intérieur et le réseau extérieur; la course de la pompe de circulation sera élevée et la consommation d'électricité augmenterait considérablement. Par conséquence , il faut avoir de prudence pour adopter cette méthode.

Zusammenfassung

Als hydraulische Stabilitaet einer Warmwasserheizungsanlage ist die Faehigkeit gemeint, die Durchflusswassermengen einzelner Verbraucher jeweils konstant zu halten, die auf der Grundlage der Rohrnetzberechnung des Gebaeudenetzes oder der ganzen Anlage und nach der Abnahme- und Probebetriebseinregulierung festgelegt sind.

Die Qaulitaet der hydraulischen Stabilitaet kann durch das Verhaeltniss des Druckverlustes des Gebaeudenetzes zu dem der ganzen Anlage beurteilt werden. Bei Anlagen mit guter hydraulischen Stabilitaet aendern sich die Durchflusswassermengen der uebrigen Verbraucher nur einigermassen, wenn irgendein Verbraucher seine Durchflusswassermenge aendert, d.h.die hydraulische Unausgeglicheheit ist klein. Dasselbe gilt auch fuer den umgekehrten Fall.

Fuer das Gebaeudenetz lohnt es sich, Massnahmen wie Hintereinanderschalten mehrerer Waermeverbraucher und Einbauen von Regelventilen mit grossem Druckverlust vor den Waermeverbrauchern usw. zu treffen, um das Verhaeltniss des Druckverlustes des Waermeverbrauchers zu dem des Gebaeudenetzes zu vergroessern und damit die hydraulische Stabilitaet im Gebaeudenetz zu verbessern.

Fuer das Verteilungsnetz bedeutet aber ein zusaetzlicher Druckverlust beim entfernsten Verbraucher, der erforderlich ist, um das Verhaeltniss des Druckverlustes des Verteilungsnetzes zu dem des Gebaeudenetzes von $H_w / H_y \leqq 3:1 \ldots 2:1$ zu erreichen und somit die hydraulische Stabilitaet zu verbessern, eine wesentliche Erhoehung des Foerderdrucks der Umwaelzpumpe und des Elektrizitaetsverbrauchs. Diese Methode ist deshalb allzu aufwendig, und zwar Verlust groesser als Gewinn, und darf nicht ohne weiteres angewandt werden.

THE HYDRAULIC STABILITY OF HOT WATER HEATING SYSTEM

1. The meaning of hydraulic stability

In "HEATING" by Kobiev, USSR, there is a definition for hydraulic stability:"In a heating system, having been commissioning or operating regulated and then the flow rate distribution between the heat consumers also determined, the hydraulic stability is the ability to maintain the original flow rates." This definition is very perfect, I think.

The problem of hydraulic stability is mainly dealt with the district heating systems, not space heating systems. The reason may be that the kinds of the heat consumers in district heating are more complicated than that in space heating, such as process heating, domestic hot water supply, space heating, and so on. So that there usually be some consumers changing their flow rates by shut down or regulation, and then causing the other consumers to alter their flow rates to some extent, i.e. causing the hydraulic imbalance. It is the phenomenon of "Pull one hair and the whole body is affected."

If the amplitude of flow rate flucluation is large, it means the system is with bad hydraulic stability; on the contrary, if the amplitude is small, its called with good hydraulic stability.

2. The calculating method and measuring index for hydraulic stability.

The basic formulae for calculating the flow rate change in the consumers or pipe lines are conventional, as follows:

flow rate $G = a\sqrt{H}$ (m^3/hr) (1)

pressure loss $H = SG^2$ $(m\ aq)$ (2)

in which a = flowability coefficient $(m^3/hr\ m^{1/2})$

$S = 1/a^2$ = hydraulic character value.

The overall hydraulic character value of the circuits connected in series S, can be calculated from that the flow in every circuit is equal, the total resistance is equal to the sum of all the circuits in series.

$$S = S_1 + S_2 + S_3 + \cdots\cdots \quad (3)$$

in which S_1, S_2, S_3 and so on are the hydraulic character values of the various sections in series.

The overall hydraulic character value of the circuits connected in parallel S, can be calculated from that the pressure at the common joint is the same, the total flow rate is equal to the sum of all the circuits in parallel.

$$\frac{1}{S} = \frac{1}{\sqrt{S_1}} + \frac{1}{\sqrt{S_2}} + \frac{1}{\sqrt{S_3}} + \cdots\cdots \quad (4)$$

The flow rate distributing between the circuits connected in parallel is:

$$G_1 : G_2 : G_3 : \cdots\cdots = \frac{1}{\sqrt{S_1}} : \frac{1}{\sqrt{S_2}} : \frac{1}{\sqrt{S_3}} : \cdots\cdots \quad (5)$$

in which S_1, S_2, S_3 $\cdots\cdots$, and G_1, G_2, G_3 $\cdots\cdots$, are the hydraulic character values and flow rates of the various sections or circuits in parallel.

With the equations above, from far to near, calculating the hydraulic character values of every section and every joint, step by step, the flow rates of various sections and consumers can be calculated. (At first, supposing the pump head unchanged).

The definition of hydraulic imbalance X:

$$X = G'/G = \sqrt{H'_y / H_y} \tag{6}$$

The definition of limit hydraulic imbalance X_{lim}:

$$X_{lim} = G_{max}/G = \sqrt{H_r/H_y} \tag{7}$$

in which G' = actual flow rate of the consumer.

G = the design or specified flow rate of the consumer.

H'_y = the actual pressure head at the inlet of the consumer.

H_y = the design pressure head at the inlet of the consumer.

H_r = the total design pressure head at the heating plant.

Obviously, the larger the H_r/H_y, the more serious the imbalance. Hydraulic stability denoted by Y, possesses the contrary nature to hydraulic imbalance.

$$Y = G/G_{max} = \sqrt{\frac{H_y}{H_r}} = \sqrt{\frac{H_y}{H_y+H_w}} = \sqrt{\frac{1}{1+H_w/H_y}} \tag{8}$$

in which H_w = the pressure loss of the exterior network in regular condition.

From eq(8), it is supposed that there are two limits for Y: the one is Y=1, when H_w=0. That means the diameters of the external network were infinitely large. The hydraulic stability would reach the best limit, any consumer changes its flow rate in operation, the other consumers will be kept steady. The other one is Y=0, when $H_w=\infty$. That means the diameters of the external network were infinitly small. The hydraulic stability would

reach the worst limit, any consumer changes its flow rate in operation, the whole of this flow changing will be shifted on to the other consumers.

Obviously, the above two limits are not practical, any network possesses its hydraulic stability Y, some value between 0—1.

3. The hydraulic stability requirement of the internal and external network

1) In the book "HEATING" by Kobiev, a clear and strict requirement has been put forward: "In many cases, in order to increase the hydraulic stability of the heating system, some more pressure head has to be used, at the same time, a throttling orifice should be installed even at the farthest consumer in the index circuit. When the hydraulic stability having been increased, as there is a lot of energy saved in distributing the heating medium, there would be more benefit than the pressure head used". "Not only the heat distributing system but also the local system should get its hydraulic stability increased. This can be carried out by properly choosing the regulating valve or throttling orifice before the heating appliance, connecting the heating appliances in series, changing the structure of the appliance, or decreasing the pressure loss of the distributing network in the local system, and so on. The resistance of the distributing network in the local system should be able to compare each other with that of the heating appliance. For example, when the hydraulic resistance of the whole

heating system in a consumer is 1,000mm aq., it is expected that the hydraulic resistance of the heating appliance with open cock or globe valve, will be about 200—300mm aq. When the pressure loss of the whole heating system in a workshop is 10—15m aq., the hydraulic resistance of the hot air heater will be 3—5m aq.."

In above idea, a specific expectation has been put forward for the local system, but for the external network there is not any specific requirement.

2) In our country, there is an idea which has put forward a specific requirement: "As for increasing the hydraulic stability of the external network, the ratio of the pressure loss of the external network to that of the internal network Hw/Hy must be decreased to 3:1—2:1 or less. So that, the pressure loss of the consumer system including the farthest one in the index circuit must be increased. On this basis, the hydraulic circuit balancing will be carried out forward section by section. And then, the regulating orifice or small diameter regulating valve need be installed to use up the surplus pressure head of every consumer."

The ground of the above requirement is that if only the pressure loss ratio of the external to the internal network decreased to 3:1—2:1 or less, the actual flow rate of the farthest consumer would not be less than 60% of the design flow rate even without circuit balancing. Moreover, it says: "Operating practice has shown that if the actual flow rate of the consumer is not less than 60%

of the design flow rate, there will be no serious hydraulic and thermal imbalance in the consumer."

The above idea is not actual and the reason is clear, I think.

The indoor temperature could not be maintained if the actual flow rate were only 60% of the design value. For example, in Harbin, Shen-yang, Beijing, and Ji-nan, for the heating system with the supply and return hot water temperatures of 130—70, 120—80, and 95—70°C, the indoor temperature would be only 9.9—15.2°C, although the design temperature is 18°C. It is not permissible anyway.

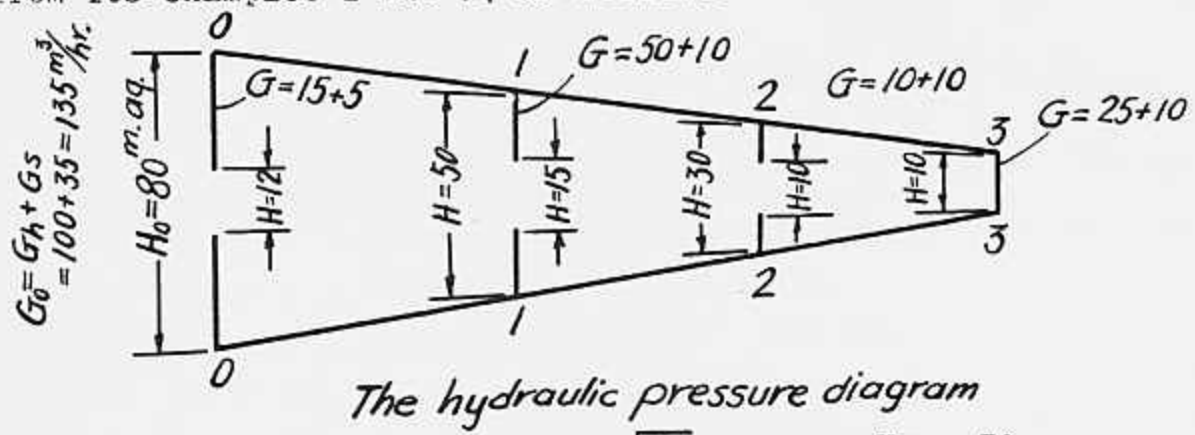
4. Measures to increase the hydraulic stability and the gain and loss in energy consumption.

In any heating system, increasing the pressure loss of the consumer, in fact, increasing the ratio of pressure loss of the consumer to the external network, the hydraulic stability is increased, and then the hydraulic imbalance in operation would be lightened. This quantitative conception is beyond doubt. The problem is that installing extra regulating devices at the farthest consumer and getting Hw/Hy = 3:1—2:1 or less, whether it is worth in energy consumption.

1) Examples from "HEATING" by Kobiev:

In this book, although the idea of installing extra regulating orifice at the farthest consumer to increase the hydraulic stability has been put forword, it is not adopted. As for contrast, extracting the main results

from its examples 2 and 3, as follows.



The hydraulic pressure diagram

The hydraulic stability is: $Y = \sqrt{\frac{10}{80}} = 0.354$, $\frac{Hw}{Hy} = \frac{70}{10} = 7:1$.

When the calorifiers of hot water supply, GS = 35m^3/hr. being wholely shut down, in example 2, the hydraulic imbalance of the consumers has been calculated. In example 3 when the hot water supply with indirect calorifiers is changed to directly drawing off in the consumers, and then the flow through the return pipe is only that of the space heating system, the degree of hydraulic imbalance is also calculated.

As for contrast, the pressure loss of the farthest consumer is increased to H = 30m aq. to increase the hydraulic stability. Now, $Y = \sqrt{\frac{30}{100}} = 0.55$, $\frac{Hw}{Hy} = \frac{70}{30} = 2.33:1$. Then the degree of hydraulic imbalance is also calculated. All the results are put in the following table.

When the pressure head at the farthest consumer increased from H = 10 to H = 30m aq., the redistributed flow is decreased from 28 to 19.4m^3/hr. When the hot water supply is drawn off directly, the redistributed flow is the least, i.e. 10m^3/hr.

Flow rate $m^3/hr.$		Consumers				The whole system
		0	1	2	3	
regular value	hot water supply	5	10	10	10	35
	space herting	15	50	10	25	100
hot water supply wholely shut down	the farthest consumer H=10m	19	59	15.8	34.2	128
	the farthest consumer H=30m	17.8	57.1	13.3	31.2	119.4
hot water supply being drawn off, the flow rates of heating system		16.5	53.5	11.8	28.2	110

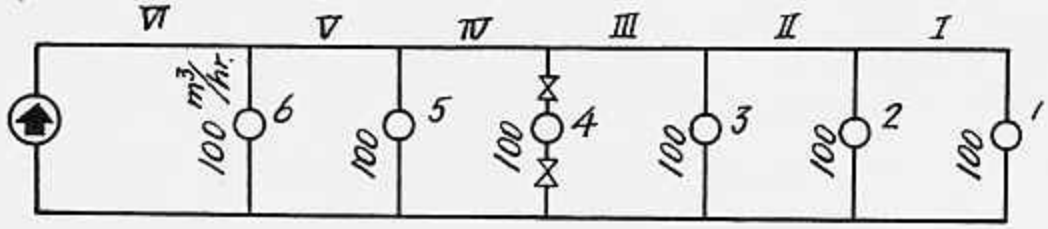
Now, the energy benefit is analysed as follows: Roughly speaking, for the circulating pumps, 1% capacity reduced, 0.73% the pressure head increased, and 0.38 the electric power decreased.

In the above example, due to the pressure head increased by 20m aq., supposing that the total capacity and pump efficiency unchanged, the electric power will be increased by (100-80)/80 = 25%in regular operation. At the same time, the degree of hydraulic imbalance is lightened by (128-119.4)/128 = 7%, the electric power will be dreased by 0.07 x 0.37 = 2.66% $\approx$ 3% only.

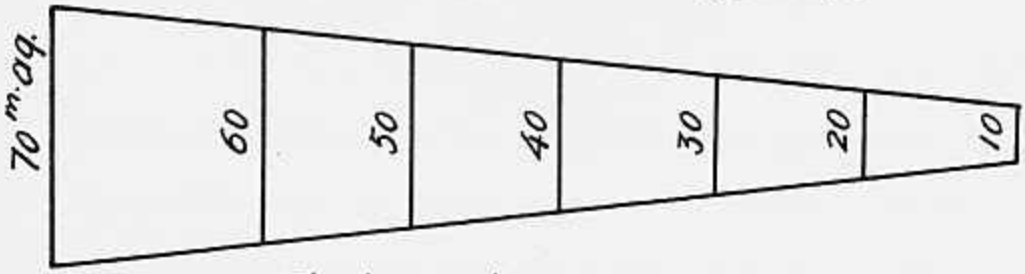
2) In our country, an idea of increasing the pressure head at the farthest consumer to increase the hydraulic stability, should be thought over. Its main points are as the following example:

When consumer "4" being shut down, calculate the flow rates and the hydraulic imbalance of the other consumers. The hydraulic stability of the above system is $Y = \sqrt{\frac{10}{70}} = 0.38$

Hw/Hy = 60/10 = 6:1.



Plan of the external network



The hydraulic pressure diagram

As for contrast, increase the pressure head at the farthest consumer, No. 1, from Hy = 10 to Hy = 30m aq. The results are all put in the following table:

$$\text{Now, } Y = \sqrt[N]{\frac{30}{90}} = 0.58; \quad Hw/Hy = 60/30 = 2:1.$$

heat consumers	1	2	3	4	5	6	the whole system
flow rates in regular condition $m^3/hr.$	100	100	100	100	100	100	600
flow rates after condition changed(consumer No. 1, Hy=10m aq.)$m^3/hr.$	109.3	109.3	109.3	0	104.5	101.5	533.9
hydraulic imbalance (X)	1.093	1.093	1.093	0	1.045	1.045	0.89
flow rates after condition changed(consumer No. 1, Hy=30m aq.)$m^3/hr.$	107.8	107.8	107.8	0	101.5	101	525
hydraulic imbalance (X)	1.078	1.078	1.078	0	1.015	1.01	0.875

In the above table, an extra pressure loss of 20m aq. due to the regulating device installed in the farthest consumer,

resulting in increasing the regular electric consumption by 20/70 = 29% roughly. At the sametime, the quantity of hydraulic imbalance of the consumers decrease from 0.89 to 0.875, the difference is quite small really. The electric consumption, due to improving the hydraulic stability, decreases by (533.9-525)/533.9 x 0.38 = 0.76%≈1% only.

5. Concluding remarks.

In any hot water heating system, the internal and external networks possess their definite degree of hydraulic stability. The index of hydraulic stability is ordinarily measured by the ratio of the pressure loss of the internal network to that of the whole system. The hydraulic stability can show the degree of flow fluctuation of the other consumers when any consumer changes its flow through shut down or regulation. By increasing the pressure loss of the heat consumer, the hydraulic stability of the distributing network can be increased simultaneously, and then the hydraulic imbalance lightened.

For the internal network of a consumer, the method such as connecting the heating appliances in series, increasing the pressure loss of the heating appliances, is good for increasing the degree of hydraulic stability, and worth adopting. Yet it must be noticed, first of all, it's good for hydraulic circuit balancing. At this point, there is community, or consistancy between the hydraulic circuit balancing and the hydraulic stability.

In designing and installing stage of a heating system, if the circuit balancing is not properly carried out, there

would be some hydraulic imbalance accordingly. Generally, it is the inconsistent imbalance, i.e. some consumers obtain more than their design flow rates, and some consumers less than their design flow rates. This kind of imbalance possesses the character innate and basic, and influences the whole life of the system. So that, the hydraulic circuit balancing should be highly thought of, and the commissioning regulation of the system should be conscientiously carried out.

Even in a well ballanced system, there would be some degree of hydraulic imbalance during operation caused by the flow changes of some consumers. Generally, it is consistent imbalance with equal ratio or unequal ratio. That means, some consumers obtain the larger quantities, and some the smaller quantities relative to their design flow rates. This kind of imbalance possesses the character postnatal, usually temporary, and depending on conditions. From the point of causing imbalance, there is community or similarity between the hydraulic circuit balancing and the hydraulic stability. But, the difference between them should be noticed.

Except for very small systems, it is not easy to get Hw/Hy = 3:1—2:1 or less. In ordinary systems the extra consumption of electricity would usually be 20—30%, while the saving of electricity due to improving the hydraulic imbalance is only 1—5%. This method could not be adopted rashly, because the cost is too high and the loss outweighs the gain.