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FUJI-DRAVO DENITE SYSTEM

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I. INTRODUCTION

In recnet year, "pollution-abatement technology" has appeared to aid in the cleaning up of the deteriorating environment, and Fuji Electric occupies a special participation in the field of this technology related to such processes as the freezing-thawing dewatering and ozone treatment, as well as other contributions from the electrical machinery and instrumentation departments. Under the present environmental clean-up conditions, regulations related to the environment have become more severe and competition in equipment development has been increasing rapidly. The contaminents removed are of two types: suspended solids (SS) and organic compounds (BOD) and because of tertiary contaminents which have been overlooked, water pollution, especially in lakes and the inland sea, is continuing.

These tertiary pollution components are called "nutrient" and are mainly nitrogen and phosphorus compounds. While techniques to remove this nutrient has been established from the standpoints of environment purification and conservation, regulations are being implemented to stop the spread of pollution. Naturally, these regulations should be applied from two standpoints: a reconsideration of the pollution generation process and treatment of the unabated pollution. Fuji Electric has introduced technology from the American Dravo Corporation* concerning a process for the treatment of pollution including tertiary pollutants. With the addition Fuji Electric's own technology, the Fuji-Dravo denite system has been developed and is introduced here.

The wide application range of the Fuji-Dravo denite system includes the treatment of domestic sewage such as that from large apartment complexes, treatment of night soil, treatment of industrial effluents and the treatment of municipal sewage. Together with the other environment-related techniques in this paper, we ask that our customers investigate this system and we hope that it will serve as one link in the purification of the Japanese environment.

*The Dravo Corporation is a large construction company with headquarters in Pittsburge, Pennsylvania and one of its departments deals with wastewater treatment. The microorganism treatment methods developed by this department have been the basis for sewage treatment methods in common use and the deep-bed filter method. The company is one of the best in the USA with respect to the stability and reliability of its technology. It should dominate the wastewater treatment field in the USA in the future.

II. NECESSITY OF ADVANCED WASTEWATER TREATMENT

Historically, sewage treatment started with the settling method in which the sewage was let stand and suspended solids settled out. This treatment was aimed mainly at the removal of large solids, and soluble pollutants or minute suspended solids could not be removed. The next step was to consider the removal of these two types of pollutants. A wastewater treating system was developed by which the cleaning by microorganisms, just as in nature, is controlled industrially. In this process, the substances to be removed are devoured as an energy source for the microorganisms and the water becomes the supernatant. This is known as the activated sludge method. In this system, this method is used for the removal of organic compounds for which ingestion by the microorganisms proceeds easily. Minute suspended materials are removed by adsorption on groups of microorganisms since the microorganisms used also have flocculation characteristics. Therefore, this systems achieves its goals. The activated sludge method which removes soluble organic material and minute suspended solids is differentiated from the previously mentioned process to remove large solids and they are called secondary and primary treatment respectively.

Materials which have not been removed by the level of secondary treatment are mainly soluble salts (such as table salt), nitrogen compounds (such as ammonium salts), and phosphorus compounds (such as orthophosphates and tripolyphosphates). In times when the population was not too dense and chemical industrial development not too great, the concentrations of these unremoved pollutants were also low and no serious problems occurred, as some sort of treatment, so called "the cleaning of the natural environment", was effective. However, today when the concentration of these pollutants has become so high as to exceed the natural cleaning ability, this pollution can no longer be overlooked. Technically, the nitrogen and phosphorus compounds among these pollutants are known as nutrient** and are considered to be the main pollutants to be removed by tertiary treatment following secondary treatment.

The harm caused by the release of nutrient into the stream is mainly as follows:

1) That which occurs because of the nutrient

(1) Harm for fish be ammonia poisoning

(2) Damage to crops by nitrogen compounds; poor crop of rice

(3) Harm to humans if mixed in drinking water; especially in the case of release into upstream riverwater when the downstream water is used as a source of drinking water. These salts are mixed into ground water for drinking via the ground water veins.

(4) As soluble salts, they increase the electrical conductivity of the water and this causes corrosion of metals.

2) That which is due indirectly to nutrient

(1) Eutrophication in lakes and bays leads to propagation of algae and plankton and this causes increased consumption of the oxygen in the water and death of fish. This results in red tide and large amount of algae.

(2) The attractive appearance of rivers, lakes and bays is destroyed by the algae, etc. which propagate due to the euttrophication in the water.

(3) A bad odor results from the rotting of deal algae, etc. resulting from eutrophication and the water becomes unsuitable as a source of drinking water.

In the United States, there already legal regulations related to the removal of part of the nitrogen. In Japan, there is also a movement being started by residents, water users, etc. to require equipment to prevent this type of pollution from the standpoint of environmental conservation.

The Fuji-Dravo denite system has its distinctive features not only in secondary treatment mainly for organic compounds but also in stable and reliable tertiary treatment mainly for the removal of nutrient.

III. PRINCIPLE OF ADVANCED WASTEWATER TREATMENT

Advanced wastewater treatment is the stage behind the common secondary treatment level and high-order treatment which assures high level treatment by utilizing the common methods of secondary treatment followed by new

** Nitrogen and phosphorus compounds are indispensible for living beings. Normally when microorganisms propagate, they use organic compounds as energy sources but types of algae with autotrophic characteristics use carbon dioxide and sunlight as energy sources. Therefore, the propagation of such autotrophic does not depend on the presence of organic compounds but does depend on the presence of nutrient salts of nitrogen, phosphorus, etc. In the case of the secondary treatment which deals mainly with organic compounds, the propagation of this type of microorganism can not be prevented.
One bad point is that the nutrient ingested into the bodies of these mitcorganisms are released after their death and these are again used in reproduction using carbon dioxide and sunlight as energy sources. Therefore, when the nutrient which have entered accumulate, a fixed continuing CO_2 cycle occurs and the pollution in the water rapidly increases. This phenomenon is known as the eutrophication.

Table 2 Unit processes used in the secondary treatment of wastewater

Unit process	Function
Racks and screens	Removal of coarse solids.
Grit chamber	Removal of grit, sand and gravel.
Primary sedimentation tank	Removal of settleable solids and floating material.
Aeration tank (suspended growth)	Organic materials are removed by action of microorganisms. Organic nitrogen compounds and ammoniacal nitrogen compounds are oxidized to form nitrate.
Fixed bed tank or bio-disk (fixed growth)	Function is the same as suspended growth. This is suitable for low load, nitrification and variable load.
Settling tank	Separation of activated sludge and effluent.
Chlorine contact tank	Disinfection with chlorine.

Table 1 Processes used in the advanced wastewater treatment

	Treatment		Level	Process	Principle	Items to be removed	Analysis compounds	Removal level
Fuji-Dravo denite system	Advanced treatment	Conventional treatment	Primary treatment	Racks and screen	Interception	Coarse sewage solids		
				Grit chamber	Settling	Grit, sand and gravel		
				Sedimentation tank	Settling	Settleable solids		
			Secondary treatment	Biological treatment	Predation by microorganism	Soluble organic materials	BOD	20 mg/ℓ >
					Adsorption by microorganism	Suspended solids	SS	40 mg/ℓ >
		Advanced treatment	Tertiary treatment	Fine filtration	Filtration	Minute suspended solids	BOD, SS	10 mg/ℓ >
				Activated carbon	Adsorption	Soluble substances	BOD, COD	5 mg/ℓ >
				Nitrogen removal	Decomposition by microorganism	Nitrogen compounds	N	3 mg/ℓ >
				Phosphorus removal	Chemical precipitation	Phosphorus compounds	P	1 mg/ℓ >
				Ozone treatment	Chemical oxidation	Color, odor and bacteria		
				Desalination	Reverse osmosis, ion exchange, electrodialysis	Soluble salts		50 mg/ℓ >

processes. The Fuji-Dravo denite system is the above mentioned advanced wastewater treatment, which is able to form a stable process resulting from techniques already completed by the level of secondary treatment. *Table 1* gives an outline of advanced wastewater treatment processes. The Fuji-Dravo denite system has the features of the tertiary treatment processes as can be seen from the *Table.* The following sections will describe the tertiary treatment of this system based on the principles of advanced treatment (refer to *Table 2* for the functions up to the secondary treatment).

1. Denite Filter

The denite filter is the heart of this system and has been developed on the basis of gravity type deep bed filtration equipment which is highly stable. The gravity type filter tank uses sand as the filter media and was developed in the 1930's mainly for the treatment of wastewater from steel works. In the process of widening the range of application of this filter and especially when it was used to filter wastewater including nitrogen in the form of nitrate, it was observed that the filter clogged rapidly and this was found to be caused by the action of microorganisms growing in the sand layer. Therefore, techniques were established to cope with this phenomenon and thereafter, with demands for the removal of nitrogen as environmental pollution worsened, the denite filter was developed utilizing the microorganisms propagating in the filter which had been considered as harmful to filter action (this type of filter has been in actual operation since 1967). Therefore, a stable process is possible both with respect to hardware reliability and software history.

2. Denite Filter Construction

The construction of the denite filter is shown in *Fig. 1* and the principle in *Fig. 2.* The basic construction is as follows:

1) Contaiment vessels
   Large-capacity: made of concrete
   Small-capacity: made of steel plates
2) No. of tanks
   At least two tanks in principle.
3) Media (filter layers)
   diameter of 2–6mm, silica sand, 1,200–2,000mm thick
4) Bottom construction
   Concrete tank : concrete M or D bottom
   Steel tank : steel channels C bottom
5) Back-wash operation

Table 3 Denitrification reaction

Stage 1	
	$NO_3^- + 1/3CH_3OH = NO_2^- + 1/3CO_2\uparrow + 2/3H_2O$
Stage 2	
	$NO_2^- + 1/2CH_3OH = 1/2N_2\uparrow + 1/2CO_2\uparrow + 1/2H_2O + OH^-$
Whole unit	
	$NO_3^- + 5/6CH_3OH = 1/2N_2\uparrow + 5/6CO_2\uparrow + 7/6H_2O + OH^-$

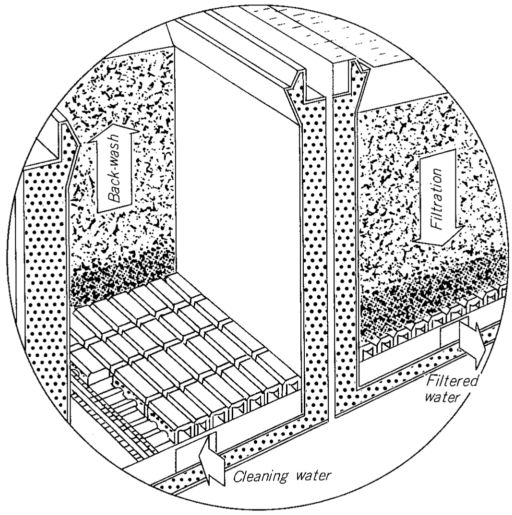

Fig. 1 Shematic construction of Fuji-Dravo denite filter

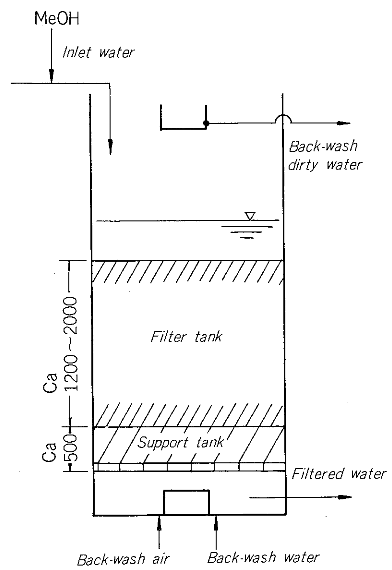

Fig. 2 Principle of denite filter

In principle, automatic by pneumatically operated valve. Back-washing uses both air and water.

3. Filter Operation

The following points should be noted concerning filter

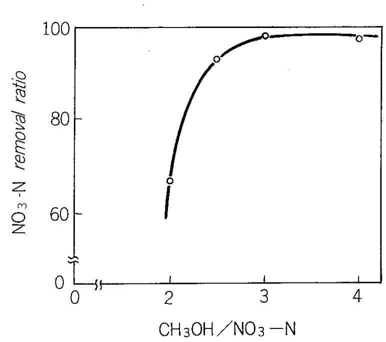

Fig. 3 NO_3-N removal ratio vs. methanol injection ratio

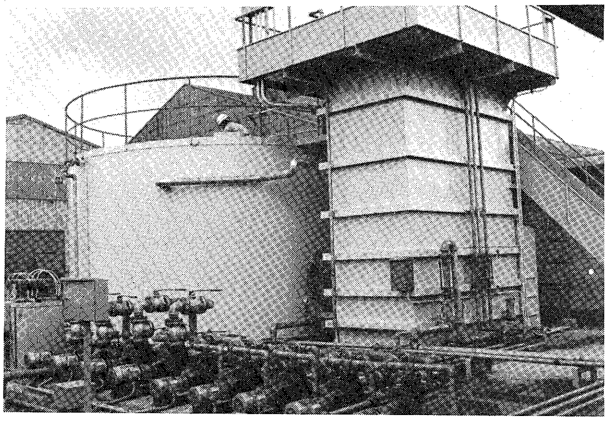

Fig. 4 Denite filter (220 m³/d)

operation:

1) Addition of methanol

To promote the reaction shown in *Table 3* in the filter, it is necessary to add methanol, etc. as an organic nutrient source. The denitrification reaction in the filter occurs in accordance with the amount of methanol added as shown in *Fig. 3*.

2) Bumping (gas removal)

In the operation to remove nitrogen gas arising in the filter bed as a result of denitrification, the gas is removed by means of bumping with only water. Normally, the process is set for once every 4 – 6 hours. Because of the small amount of water used at this time, only a small amount of filtered water is returned and there is no dirty back-wash water.

3) Back-washing

This is an operation intended to remove the fine suspended solids caught in the media of the filter by means of water inflow. Both air and water are used for back-washing.

4. Correlation of the Denite Filter with Secondary Treatment

Because of the denitrification reaction with the denite filter as shown in *Table 3*, all of the nitrogen compounds in the wastewater up to the denite filter must be oxidized to form nitrate (or nitrite) type nitrogen (*Fig. 5*). Since this oxidation, namely nitrification, is not included in ordinary secondary treatment, it is necessary to remember that this nitrification must be performed in the secondary treatment when the denite filter is used for tertiary treatment. The methods in this case differ in accordance with the mode of

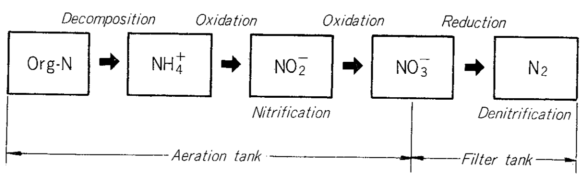

Fig. 5 Biological oxidation/reduction of nitrogen compounds

secondary treatment as follows:

1) Case of extended aeration as secondary treatment

It is possible to complete the nitrification just by considering the alkalinity of influent, the concentration of the nitrogen compounds and the sludge age.

2) Case of conventional activated sludge method of secondary treatment

A nitrification tank must be added. The fixed growth type, fixed bed, bio-disk, etc. are suitable.

In the Fuji-Dravo denite system, the optimum process is achieved by selection of the method in accordance with each case.

5. Removal of phosphorus compounds

The removal of phosphorus compounds is achieved by reacting the phosphorus compounds with metallic salts of iron, aluminium, calcium, etc. to form insoluble metallic phosphates which are precipitated out. Normally, a special chemical flocculation tank is used for this chemical reaction but in the Fuji-Dravo Defos system (phosphorus removal system), such a special tank is not always needed and phosphorus removal is performed during the secondary treatment, i.e. this chemical reaction is performed in the secondary activated sludge tank. In this case, since secondary treatment, i.e. removal of organic compounds is performed in the same tank in the presence of microorganisms, it is necessary that phosphorus removal be performed under conditions which are good for the microorganisms. When phosphorus removal is performed in one tank, metallic phosphates will naturally become mixed into the excess sludge and if this is undesirable such as in cases where excess sludge is used as fertilizer for the restoration of agricultural land, phosphorus removal must be performed using a special phosphorus removal tank or settling basin.

IV. FIELDS OF APPLICATION OF ADVANCED WASTEWATER TREATMENT

The level of advanced treatment demanded at present is highly diverse, including various types of substances to be removed. To meet these demands, the Fuji-Dravo denite system is sufficiently flexible. The following are some typical examples of applications of the system.

1. SS Fine Removal (Community Plants, etc.)

In the most primitive tertiary treatment requirements, there must be high level treatment of SS in the ordinary secondary treatment effluent. In such cases, this can be handled by the design of a system, using the functions of the denite filter, i.e. SS removal capacity.

The denite filter can sufficiently cope with this level of requirement. A typical flow chart is shown in *Fig. 6*. In this case, the addition of methanol is not necessary.

2. BOD Fine Removal (Community Plants, etc.)

This is the case of BOD reduction from 20 mg/ℓ to

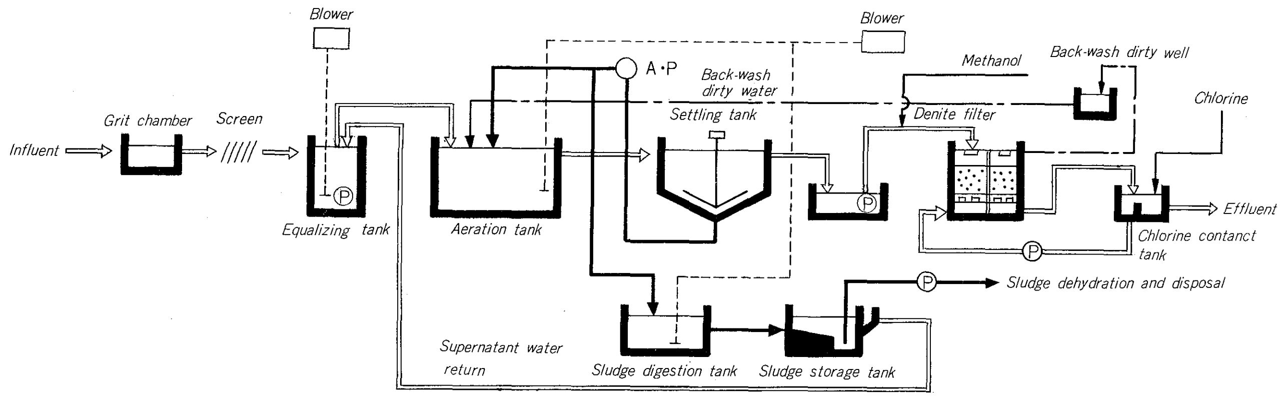

Fig. 6 Typical flow chart of denite system

10 mg/ℓ or less in conventionary treated effluent. The method used is the same as in the preceding section. Since over 50% of the BOD in the secondary treatment water is in the form of suspended BOD, it is possible to achieve a BOD of 10 mg/ℓ by removing this suspended BOD. The capacity to remove dissolved BOD by the action of microorganisms inside the denite filter also plays a role. In both this application and that in the preceding section, the economy and stability of the denite filter are manifested.

When the BOD must be 5 mg/ℓ or less, it is necessary that carbon adsorption is used together with the denite filter as a prefilter.

3. Removal of Nitrogen Compounds (Community Plants, etc.)

The flow chart in *Fig. 6* is used.

4. Application to Night Soil Treatment

This is basically the same as **1**, **2** and **3** but in the case of night soil, the concentration of nitrogen compounds is higher than in normal sewage and special consideration must be given to nitrification and denitrification.

5. Applications to Industrial Wastewater

This system can be applied to industrial wastewater containing domestic sewage and wastewater with high BOD and nitrogen compound contents from food processing, etc. However, in this case, it is necessary to design the system very carefully with measurements and analysis of water quality and flow in each case.

6. Application to Wastewater Recycling

Recently, cases of limitations on water supply in urban buildings and factories using large amouns of water, etc. have been increasing and there is an increasing necessity to use wastewater recycling. This is because water supplies can not cope with increased concentration of demand and it is necessary to plan wastewater recycling on the user's side. In this case, since wastewater recycling is used mainly for miscellaneous purposes, there is now no standard opinion on to what degree it is necessary to treat the sewage and results are being accumulated by actual recycling water

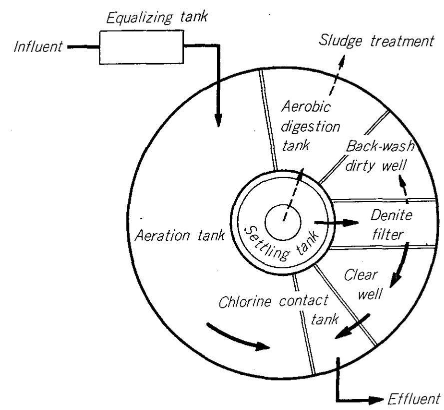

Fig. 7 Fuji-Dravo super aeropack

treated at various levels. The minimum requirement is advancedly treated water with the removal of SS, BOD, etc. and the Fuji-Dravo denite system can meet these conditions. In addition, water with nutrient removed is also suitable for wastewater recycling from the standpoints of slime formation, algae growth, etc. and one concept is based on maximum reutilization with advancedly treated water to save on water resources.

7. Application to Municipal Sewage

Municipal sewage is present in large amounts and the water quality has great influence on the water quality environment. To treat large amounts of water, denite filters with concrete contaiment vessels are ideal both structurally and with respect to stability. When tertiary treatment is added to remove nitrogen compounds, consideration being not given at present to nitrification in large scale sewage treatment plants, so the addition of a nitrification tank and a denite filter is needed.

V. PLANT CONSTRUCTION TECHNOLOGY

The general construction of sewage treatment facilities is the provision of various process tanks with concrete vessels. However, since this requires large scale civil engineering and construction work. The pre-engineered package types are being prepared using vessels in the form of a single unit of steel plate construction for small and medium facilities which require simple equipment. The package with the entire unit in the form of a cylinder is known as the Fuji-Dravo super aeropack. The package is arranged around a settling tank in the center with the various tanks in the form of sectors. This is a rational layout with the water transport all to adjacent tanks (refer to *Fig. 7*).

VI. CONCLUSION

This article has introduced the Fuji-Dravo denite system which has been planned to handle general treatment by itself but such a comprehensive system can not be fully outlined in such a small space. However, please feel free to inquire since all necessary information can be supplied. Development of new processes based on future trends and accumulation of results using actual equipment and test plants are now underway and the results will be introduced in later articles.

We are also now looking for future trends in advanced treatment systems and there is considerable evolution of systems to meet the times. Therefore, more guidance from customers is requested.

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MICRO-CONTROLLER SYSTEM FOR WATER AND SEWAGE WORKS

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I. INTRODUCTION

The instrumentation for water and sewage works have made great progress in the last several years. Because of the higher levels and greater diversity operation and the higher levels maintenance of water and sewage works, the role of instrumentation has been rapidly increasing.

Recent water supply and sewage treatment facilities have faced such new problems as wider ranges managements, power savings and conservation of natural resources. Together with these trends, the scope of instrumentation for recent water supply and sewage works has been greatly expanded from mere measurement and automatic control for equipments to the management of working.

Therefore, the instrumentation for water and sewage works has come to the level which centralized control systems with the introduction of computers systems are being used and the importance of instrumentation has increased.

The progress in electronics is still remarkable and the appearance of microcontrollers has had great influence in various fields. In the field of instrumentation, microcontrollers have brought about a revolution in instrumentation system and new instrumentation system using microcontrollers have been advocated and have gone into use. In that place, we also had developed the microcontrollers systems (the FUJI MICREX-P) in 1975.

In the case of water and sewage works instrumentation, it has become necessary to consider new instrumentation system according to the appearance of these new techniques because of the increased importance of instrumentation and demands for higher reliability. Therefore, there must be instrumentation system which are well adapted to the characteristics of water and sewage works. It has been necessary to investigate not only hardware but also the software of water and sewage works. We have developed the FUJI MICREX-W (W: water and waste water) system, a new instrumentation system for water and sewage works employing microcontrollers, by bringing together water and sewage works control technology gained from long years of experience and technology in the fields of instrumentation system, computer control system and telemeter and telecontrol system to meet these needs. This system is shown here.

II. BASIC CONCEPTS OF THE FUJI MICREX-W

Water and sewage works instrumentation has reached the stage where computers are used and this has resulted in not only larger scales and higher levels but has also given rise to many problems. The basis of this is digitalization, greater complexity because of the very high level of centralization and handling of accidents. This new instrumentation system must be able to solve these problems and this indicates the concepts on which the instrumentation should be based.

The FUJI MICREX-W has been developed from this standpoint. The following are the basic concepts:

1) Improved reliability by decentralized control

A centralized control system using one computer has wide ranging effects when the main computer breaks down and according to circumstances, gives entire facilities the serious damages. The FUJI MICREX-W has decentralized functions because of the use of many microcontrollers and the system reliability has been greatly improved by functional and risk decentralization so that the entire facilities are not affected during a controller breakdown.

2) Improved expansionability by decentralized control

By the decentralized control system, expandability of both the software and hardware has been improved. In centralized control system, the software for control system and management system are lorded in the common computer and when the some section of software is improved, it is necessary to stop all operation of computer control system until the renovation is completed. In the decentralized control system, when the software for management is improved, it is not necessary to stop control system by microcontrollers and when the software for control system is improved, it is necessary to stop only the microcomputer concerned. When the management and control system is expanded in conformity with expanded facilities, it is necessary to stop the existing system for long periods while the new system is connected with the existing system in the case of centralized control systems but when the control system is decentralized, the new microcomputers can be inserted in the existing data way by means of connectors.

3) Improved processing speed by means of decentralized control

Centralized control system have software for both