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Environmentally Conscious Activities and Products Edition

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Environmentally Conscious Activities and Products Edition

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Our cover for this special issue on environmentally conscious activities and products shows the symbol mark chosen to represent the Mitsubishi Electric group's commitment to earth and the environment, and specifically its environmental protection activities, with a combination of a stylized globe and a young plant. Here it is shown against a background of flowers.

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Foreword

Ecology: A Catalyst for Success in the New Economy

*by Takashi Kitaoka**

In only three years we will enter the 21st century. Sometimes I wonder if others see, as I do, the signs of the dawn of an entirely new era, an era when all Mitsubishi Electric's business units will undergo dramatic change. To succeed in the business environment at that time, speed and creativity are the two most important factors. That is why, in my New Year's message just a few months ago, I said that the future of Mitsubishi Electric depends on the ability to create an "agile company" comprised of "creative individuals" and spirited teams.

How does one foster agility, creativity and spirit on a company-wide basis? One way is to focus that company's attention on the environment. With today's unrestricted flow of information across borders, people have become more aware of the environmental crisis now threatening the planet. And as growing populations and technologies place ever-increasing demands on Earth's resources, we will more frequently come face-to-face with ecological limits. That is why it is vital to develop a means of sustainable growth; i.e., providing products and services that dramatically reduce negative impact on the Earth. Mitsubishi Electric's ability to do this is a test of its agility and responsiveness. Every environmental need is a market waiting to be developed. I want Mitsubishi Electric to identify, respond to and prosper by meeting environmental needs better and faster than any of its competitors.

As a part of the plan Vision 21, a new business group was established in line with the company's promise to make significant contributions toward global environmental protection. The early results of efforts to develop cutting-edge environmental technologies are promising, including the introduction of a fully automated recycling plant for electric products and a chemical-free water purification plant that utilizes ozone storage technology.

Internally, the philosophy is "Everything begins from consideration of the environment," and the corporate environmental policy is based on the principles of industrial ecology. These fit perfectly the organizational need to be agile and creative. Industrial ecology treats businesses like nature rather than machinery. Nature is agile and creative. It responds to change quickly, and grows more efficient over time. In nature, constant change maintains the vitality of the system and breathes new life into it. Through industrial ecology, Mitsubishi Electric is establishing educational and communication systems that bring the vitality and life required to operate effectively and respond in a timely manner to reduce environmental costs early on, before the expense becomes too great. In this way, the company is changing gradually so that drastic changes can be avoided later.

Only a company staffed by creative individuals, motivated by the spirit to overcome challenges and serve public needs, can expect to survive into the 21st century. The danger in a large company is that people assume that the future is guaranteed, and therefore lose the spirit to meet new challenges. The employees of Mitsubishi Electric have made great strides to overcome many challenges in the past and continue to do so now. Through Vision 21, the company is now showing its willingness to break with the past and boldly step into the new businesses required to make a safer, more comfortable world for future generations.

The desire to be recognized as a company known for its excellence in environmental matters is an equally important force for change. Contributing to the preservation of the planet is a challenge that is bringing forth the agility, creativity, spirit and drive required for Mitsubishi Electric to succeed in the new economy of the 21st century. ❑

**Takashi Kitaoka is the president of Mitsubishi Electric Corporation.*

Overview: Work for Environmental Protection and Quality Improvement

*by Takashi Mitsuhashi, Haruo Ishizu, Takashi Yoshida, Yoshinobu Narita, Mutsuko Fukui and Ikuyuki Hirata**

To promote a sustainable society, both enterprises and the public share responsibility in preserving the global environment. One factor in industry being affected by current environmental circumstances is the conception of "quality" sought after by manufacturers and consumers. This important factor in production requires consideration from a wider perspective; one which gives sufficient weight to protecting the earth and its natural resources.

Private enterprise has been working to address environmental problems through creating autonomous management organizations that incorporate environmental conservation. It is the opinion of Mitsubishi Electric that this approach is leading to better handling of environmental issues than approaches based on piecemeal regulations or abstract ethical principles: it suits the characteristics of the free-market society, is effective and responsible, and represents the shortest path towards the concerted goal of a cyclical self-sustaining society. In line with this approach, Mitsubishi Electric views management and environmental planning as interdependent parts of a single whole. And showing a commitment to support this ideology, in May 1996 we drafted a new environmental plan that acknowledges corporate responsibilities with respect to conservation and initiates actions to uphold them.

This special article introduces environmental and quality management issues, both past successes and present endeavors implemented by Mitsubishi Electric. Also discussed is the creation of new business in the field of environmental preservation.

Environment-Related Activities

The corporation has long worked to prevent pollution due to industrial accidents: in December 1991, an environmental protection department was established and an environmental officer designated; and in 1993 the corporation's 1st Environmental Plan was publicly announced. The plan set numerical targets and prescribed activities in four areas: protection of the ozone layer through elimination of chlorofluorocarbons (CFCs), prevention of global warming through reduction of energy consumption, reduction of industrial wastes, and resource savings and recycling in electrical appliances. Table 1 lists these areas and the results achieved.

In May 1993, environment management rules (Corporate Rules, Article 8600) were adopted based on the plan to create environmental management systems (EMSs) that conform to ISO 14000 series standards, and the implementation of EMSs at all Mitsubishi Electric facilities began in earnest. The corporation also began conducting in-house seminars on ISO 14000 series concepts and environmental auditing techniques, and increased environmental auditing. As a result of these efforts, Germany-based Mitsubishi Semiconductor Europe received certification from the European Eco-Management Audit scheme in November 1995, becoming the world's first semiconductor manufacturer to do so.

After revising its environmental plan to reflect recent developments, the corporation introduced the 2nd Environmental Plan in May 1996.

Table 1 Environmental Objectives (Defined in March 1993)

Tasks & Achievements
Protection of ozone layer (phasing out of CFCs) - Eliminate all listed CFCs by the end of June 1995 - Eliminate all trichloroethane cleaning applications by the end of 1995 - Eliminate all carbon tetrachloride applications by the end of 1993 *All Mitsubishi Electric plants, subsidiaries and affiliates have met these targets.*
Energy-saving to prevent global warming - Reduce annual energy use to 25% of the FY 1990 energy use by FY 2000 (adjusted for sales increases) *Energy use 3% below the FY 1990 level was achieved in FY 1995.*
Waste reduction - Reduce annual waste production to 30% of the FY 1991 level by FY 1995 (adjusted for sales increases)
Waste output 44% below the FY 1991 level was achieved in FY 1995 (target achieved).
Promotion of home appliance recycling and resource conservation - Increase the ratio of recyclable components in FY 1995 by 30% of the FY 1992 level - Reduce the use of expanded polystyrene packing material to 30% below the FY 1990 level by FY 1995 *The ratio of recyclable components in home appliances was increased 50% (target achieved).* *The use of expanded polystyrene packing material was reduced by 35% (target achieved).*

**Takashi Mitsuhashi is with Corporate Total Productivity Management & Environmental Programs, Haruo Ishizu, Takashi Yoshida, Yoshinobu Narita and Mutsuko Fukui are with the Environmental Systems & Quality Management Department and Ikuyuki Hirata is with the Environmental Business Development Center.*

Quality-Related Activities

Mitsubishi Electric has evolved a company-wide system for maintaining quality that includes technical committees, technical working groups and small-group quality-assurance activities. In May 1993, we established a Quality Management Department and instituted a three-year program to build ISO 9000 conformant quality management systems. Currently some 27 sites worldwide have been certified ISO 9000 compliant. The corporation is also working to ensure product safety through compliance with the EU's CE marking regulations and conforming to local product liability laws in all nations where it does business.

Towards a Comprehensive Management Philosophy Incorporating Environment and Quality Issues

We believe that to protect the global environment we need to broaden current concepts of product quality and environmental impact and that they should constitute an integral part of corporate management. We also believe that product quality considerations should be extended past a product's useful life and include the impact of the product's disposal. Such environmental impact considerations should be extended to all business activities.

In March 1996, Mitsubishi Electric established the Environmental Protection and Quality Management Department to address the implementing of these principles. Programs to ensure product quality at each of our production facilities are being expanded to include protecting the global environment as well.

The 2nd Environmental Plan incorporates incremental steps toward numerically targeted environmental goals for the year 2000. This new plan introduces an extraordinary opportunity for the corporation to extend its technologies and knowhow. Basically, the plan promotes a framework to maintain global environmental quality by reducing the negative environmental impact of business activities by the start of the 21st century. The policy is supported by three pillars. The first is a core environmental philosophy and an action policy (Table 2). These set out basic attitudes toward environmental issues at all Mitsubishi Electric group companies, both domestic and overseas. Within, it is stated that managers should recognize their responsibility to reduce the environmental impact of their business operations and take active, voluntary measures to protect the environment and contribute to its development. The second pillar is emplacing EMSs capable of reducing the environmental impact of business activities and products. The third pillar is establishing concrete numerical targets for reductions in negative environmental impact.

Table 2 Core Environmental Philosophy and Action Policy

Core Environmental Philosophy	
	Under the principle of "sustainable development," the Mitsubishi Electric group is committed to protecting and improving the global environment through all business activities, utilizing its accumulated knowledge and the technologies it will develop in the future.
Action Policy	
1.	We will strive to reduce any negative environmental impact resulting from our products and activities. We will develop technologies and processes that are compatible with the environment. Products will be fully assessed over their entire life cycle, and our facilities will promote resource efficiency, conservation and recycling.
2.	We will commit ourselves to improving our understanding of environmental problems and contributing to a universal awareness of the need for businesses to integrate their activities with the natural cycles of nature.
3.	We will establish environmental management systems at all our business sites and operate them according to accepted standards. At the same time, we will continually improve environmental controls through environmental audits and similar methods.
4.	We will educate, train and motivate employees to be good environmental stewards in their own right, as well as support employees and their families when they engage in activities that promote environmental protection.
5.	We will foster active communication and cooperation regarding environmental protection worldwide.

CORE ENVIRONMENTAL PHILOSOPHY. The revised core environmental philosophy reaffirms the corporation's responsibility to reduce the negative environmental impact of business activities; for active, autonomous management; and to contribute to environmental protection through business activities. The core philosophy calls upon all group companies and affiliates to work together to reduce environmental problems on a global scale. It stipulates that we will reevaluate environmental issues in existing plants as well as consider them in new projects, and its scope extends to all business activities and the work of all our employees. The core philosophy expresses the importance of all employees to have general awareness of the environment in their daily life so that they can contribute to reductions in global environmental problems not only through their work activities but also through their consumption patterns.

One approach to reducing environmental problems is utilization of technological advances. We believe utilization of existing environmental protection technologies should be supplemented by new technologies that reflect current environmental priorities. The core philosophy declares that as a manufacturer, we are responsible to use these technologies for the benefit of society in the form of business operations and products that will protect and contribute to the global environment.

ACTION POLICY. This policy (also listed in Table 2) specifies five commitments adopted by Mitsubishi Electric group companies: 1) to evaluate the impact of activities and products and improve those areas that have negative environmental impact; 2) to actively resolve environmental problems through business activities; 3) to establish EMSs; 4) to institute educational activities to boost environmental awareness among employees when performing their work; and 5) to enter dialogue with parties interested in worldwide environmental protection. The policy also states the corporation's support of environmental activities outside the scope of business including volunteer activities and non-governmental and nonprofit organizations.

We hope to gain the understanding of others by providing information on the corporation's environmental plan and activities. Through such communication, our aim is to help increase the environmental awareness of society as a whole.

ESTABLISHMENT OF ENVIRONMENTAL MANAGEMENT SYSTEMS. EMSs are frameworks for autonomous management that take environmental quality into consideration. Mitsubishi Electric plans to implement EMSs that target manufacturing activities as well as products.

In December 1995, the Board of Directors decided to organize corporate operations to meet the ISO 14001 certification requirements listed in Table 3, and planned for 80% of Mitsubishi Electric sites in Japan to be ISO 14001 certified by the end of fiscal '97.

Japanese enterprise is implementing ISO 14000 series standards more rapidly than it introduced the ISO 9000 series, with companies in a range of industries working actively to bring their operations into compliance. While this quick response is certainly due to the immediacy of environmental problems, it is also possible because the basic concepts and principles are shared with the ISO 9000 requirements previously implemented. For example, both sets of standards share the plan-do-check-action (PDCA) cycle and its associated requirements that a company clearly define authorities and responsibilities within its organization, conduct system audits, and emplace recordkeeping and documentation practices.

The ISO is initiating discussion of generic management systems that would integrate key aspects of corporate operations including product quality, environmental protection, occupational health and safety, finance and accounting. We view this as a sign that enterprise is moving toward the integration of environment management and quality management as we enter the next century.

In the field of quality control, we are seeing a transition from total quality control to total quality *management* where the focus is on the quality of the entire process or company function. In the field of environment, reuse and recycling of products at the end of their useful lives is extremely important; thus product quality evaluations should include environmental impact at the end of product life. Mitsubishi Electric plans to expand the range of products that receive environmental assessment from household electrical appliances to all of its products, and to incorporate the concept of "design for environment (DFE)" in all product design and development operations (Table 4).

ENVIRONMENTAL OBJECTIVES. Table 5 lists numerical targets Mitsubishi Electric has established for prevention of global warming; resource conservation, recycling and waste reduction; and chemical substances management for the entire Mitsubishi Electric group. Table 6 lists the practical measures being undertaken to achieve these targets.

Prevention of Global Warming: In March 1993, the corporation established global-warming related targets for the year 2000, recently supplemented with additional product-related targets. Although these targets are high, we expect to achieve them by combining traditional attention

Table 3 Environment Management Systems

In order to achieve our goal of reducing the negative environmental impact of our activities, we will implement an environmental management system conforming to ISO 14001.
Targets
- All production sites in Japan will achieve third-party certification within three years starting from FY 1996.
- All affiliated companies in Japan and abroad will achieve third-party certification within five years starting from FY 1996.

Table 4 Product Assessment

The promotion of assessment activities to reduce negative environmental impacts is of paramount importance with respect to both manufacturing activities and products over their entire life cycle from development to disposal.
Target: Conduct assessments of all products by the end of FY 1997.

Table 5 New Environmental Objectives

Activities
Prevention of global warming Control CO_2 emissions by reducing energy consumption of business activities. Target: Reduce annual energy use to 25% below the FY 1990 level by FY 2000 (adjusted for sales increases).
Products
Reduce product energy use and develop new low-energy and alternative-energy products Target: Set specific targets for product energy consumption reductions by the end of FY 1996.
Activities
Promotion of resource conservation, recycling and industrial waste reduction Reduce generation of both industrial and general waste through resource conservation, waste reduction and recycling. Target: Reduce the amount of waste disposed of by waste haulers to 30% under the FY 1995 level by the end of FY 2000.
Products
Promote conservation and recycling of materials used for both products and packaging Targets: - Conduct assessments of all products by the end of FY 1997. - Establish targets to reduce disassembly times and component counts.
- Increase use of recycled materials (excluding metal) by 30% above the FY 1995 level by the end of FY 2000.
- Reduce packaging materials by 20% under FY 1995 level by the end of FY 2000.
Activities
Control of chemical substances Reduce chemical waste emissions from manufacturing processes through use of control equipment or alternative production processes. Targets: - Identify amounts of chemical substances used in production processes by the end of FY 1997 and set reduction targets. - Eliminate the use of chlorinated solvents in open systems by the end of FY 2000. - Reduce the use of volatile organic solvents in open systems and promote their recovery and reuse.
Products
Identify chemical substances used in products and reduce amounts used. Targets: - Identify and quantify chemical usage in products by the end of FY 1997 and set targets for reduction or elimination. - Phase out HCFC refrigerant applications by the year 2010. - Phase out HCFC foaming agent applications by the year 2004.

to economy with new energy-efficient solutions in the areas of process technology, alternative energy technology, unutilized energy resources and systems thinking.

Promotion of Resource Conservation, Recycling and Reduction of Industrial Waste: In the past, resource conservation and recycling have been treated separately from waste reduction, however, the first effect of promoting recycling is a reduction in the waste stream. Further, promoting

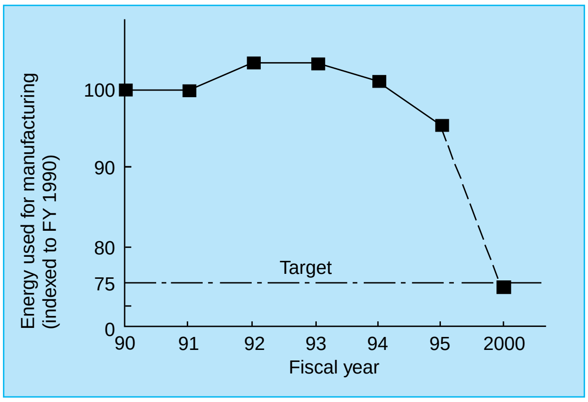

Fig. 1 Global warming reduction targets and achievements.

effective use of resources requires precise knowledge of absolute waste levels. We therefore combined these activities and have established numerical targets for reduction in absolute levels (Fig. 1).

Control of Chemical Substances: The advance of technology has led to the use of an extremely wide variety of chemical substances, which need to be managed to prevent environmental pollution over the period from material selection to final disposal. Rules for managing and handling chemical substances have been implemented for substances dangerous to human health, but the wide variety of substances and their uses make this approach cumbersome. Last year, government, industry associations and member companies drafted a proposal (shown in Fig. 2) that would grant industry greater autonomy in handling listed substances. The proposal uses the PDCA cycle of ISO 14000 series standards and ongoing development is expected.

Handling of specified substances in the manufacturing industry involves clarifying the chemical composition of all materials used in products and industrial processes, and reducing use, finding substitutes and developing safe handling procedures for substances that present risks to people or the environment. Mitsubishi Electric uses an extremely diverse array of chemicals in the journey from raw materials to product, and the variety of distribution and processing paths can make it difficult to identify the chemical composition of each substance. However, we are seeking to establish an information system that can report on the materials balance of our manufacturing processes through a process of in-house investigations and collation of a chemical substances database.

PLAN IMPLEMENTATION AND INFORMATION INFRASTRUCTURE. Mitsubishi Electric makes an ex-

Table 6 Examples of Specific Measures for Implementing the Environment Plan

Specific Measures for Business Activities	Specific Measures for Products
Prevention of global warming.	
- Energy savings: Installation of multiple small boilers, introduction of highly efficient air-conditioning equipment, improvement of air-conditioner control systems, use of inverter-based appliances, control of the number of compressors in operation, introduction of high-efficiency lighting equipment - New energy systems: Photovoltaic power generation systems, fuel cells - Use of underutilized energy resources: Introduction of cogeneration systems, power generation from industrial waste incinerators, district heating and cooling, use of waste-heat storage and ice thermal storage systems - Improvement of production processes: Improvement of production technologies including processes and equipment, improvement of quality control for better yields and lower rejection ratios, improvement of testing procedures through review of test standards and reductions in test time - Comprehensive measures: Establishment of committees and projects to address common problems, use of TPM, VA and small-group activities, analysis and evaluation of energy control data, energy-savings audits	- Energy-saving solutions to offset the growing size and complexity of household electrical products and information equipment, including solutions for lowering power consumption during equipment operation and standby - A range of activities for achieving standards of the International Energy-Star Program and the requirements for product listed under the Japanese Energy Conservation Law, including advanced technologies such as heat exchangers, high-efficiency fans, high-efficiency motors, and high-performance insulation with better sealing - Promotion and active introduction of practical energy-saving technologies including photovoltaic power generation, generation from industrial waste incinerators, and fuel cell technologies. Active participation in field tests by NEDO, NEF and other institutions
Promotion of resource conservation, recycling and reduced output of industrial waste	
- Enhanced recycling and reuse processes: Waste separation and recycling, including complete waste paper collection, collection of waste oil and separation of water from waste oil. Developing relationships with recycling specialists - Resource flow management and other measures to eliminate waste generation: Waste source control, including identification of waste sources, studies of preventive measures, and implementation - Reduction of packaging material consumption through use of delivery boxes, returnable packages, and reduced-mass packaging - Improvement of production processes: Improvements in plating, painting and machining processes leading to reduced input of auxiliary materials; enhanced quality control for reductions in rejection ratios and yield improvements; improved testing procedures through review of test standards and shortening of test times - Enhancement of in-house intermediate waste processing: Installation of new incinerators and replacement of existing units. Improvement of the ratio of water removal from sludge/Better oil-water separation; improvement of systems for wastewater disposal, including coagulant studies	- Product assessment: Systemization, establishment of rules, horizontal communications, technical improvements - Studies on Design-for-Environment methods: Development toward life-cycle assessment technology - Horizontal communications on use of recycled materials - Use of recycled paper for instruction manuals; increased reuse of expanded polystyrene - Reduced use of packaging materials - Review of packing design: Design optimization, review of packaging-standards, promotion of returnable packaging
Control of chemical substances	
- Identify amounts of chemical substances used and materials balance Procedures at materials receiving to determine purchase quantities and materials balance (amount of chemical substance retained in product and discharged to soil, water and atmosphere); analysis of environmental conditions to determine substances contained in excessive amounts in products or excessively discharged - Reduction in quantity and number of chemical substances used through optimized design, use of safer chemicals and processes, increased collection and reuse.	
- Total ban on the use of chlorinated solvents in open systems, voluntary efforts to eliminate their use in closed systems, reduction in use of organic solvents in open systems High priority on developing cleaning-free processes that eliminate chlorinated solvent cleaning requirements; substitution of water-based cleaning systems, reduced cleaning through more selective use of cleaning operations; adoption of closed cleaning systems where solvent can be more fully recovered	- Total elimination of HCFCs in both refrigerant and foaming applications, development of alternative refrigerants and foaming agents

tremely wide variety of products ranging from space and satellite systems to household appliances. We therefore utilize a system of autonomous divisions to ensure that operations associated with each product category are managed in an accountable and responsible fashion. Each product division incorporates the corporate environment plan into its own operations and takes independent steps with respect to products and operations. The latest information technology is being deployed to support the efficacy of these activities.

The corporation published a model document of its ISO 14001-based environment standards manual in the second half of fiscal 1995 over a corporate intranet, making it available at all plants and offices. Computer-based tools that support efficient development and maintenance of EMSs

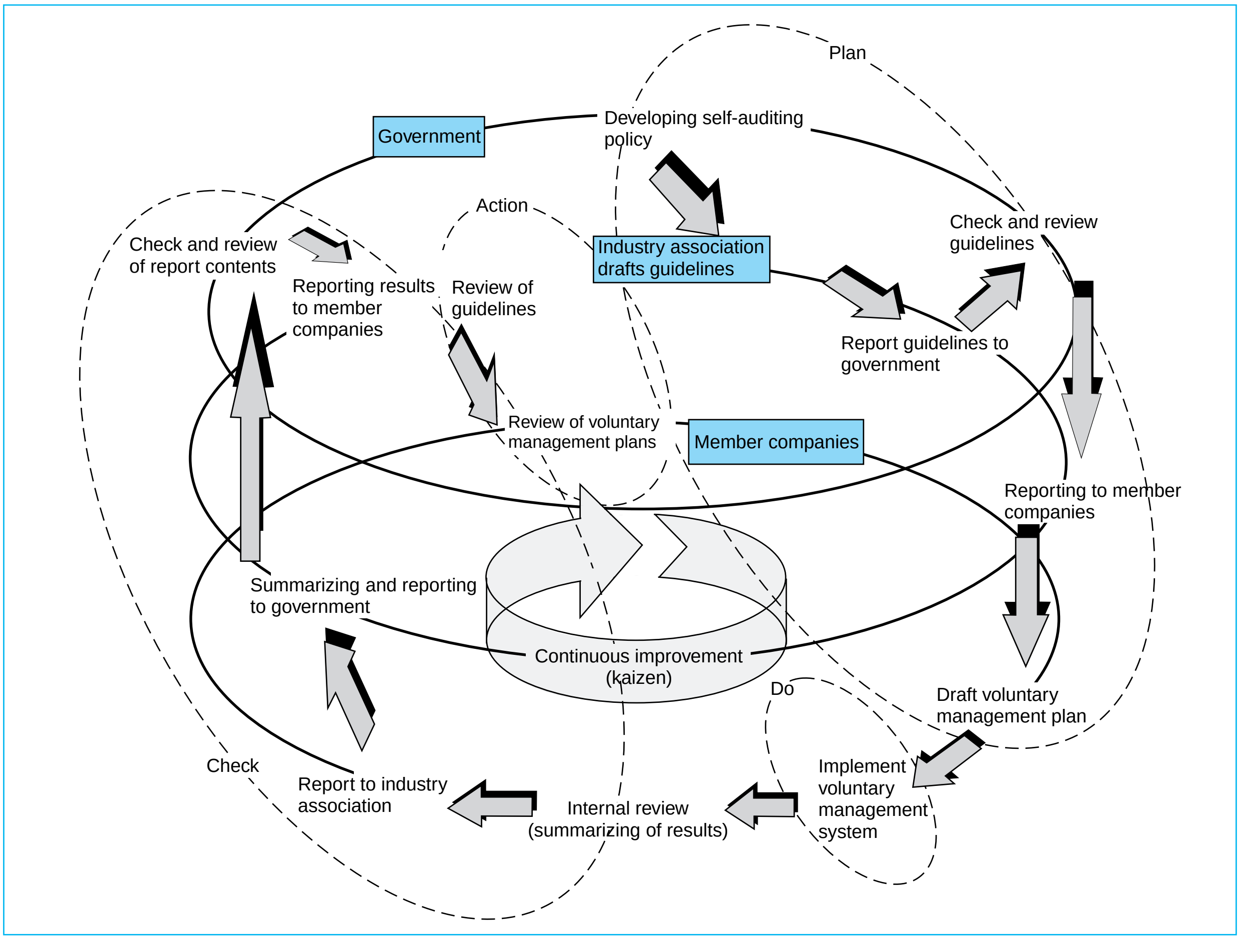

Fig. 2 A voluntary management system for reducing pollutants.

have also been introduced.

In the area of DFE-based product design and development, the corporation is developing an environmental CAE tool that integrates DFE concepts with 3D CAD capabilities, and a "Commerce at Light Speed" (CALS) compatible information system that supports product life cycle management from raw-materials procurement to post-use recycling and disposal.

Towards Construction of a Cyclical Society

ENVIRONMENT-RELATED BUSINESS. Simply complying with environmental regulations and sponsoring socially valuable activities does not constitute sufficient concern for the environment. A company must work for the good of the environment and contribute to establishment of cyclic social systems through the design of its routine business operations and the pursuit of environment-related business operations within the context of a free market economy.

When the Global Environmental Panel of MITI's Industry Structure Council published its "Environmental Vision for Industry" in July 1994, it sought to redefine the environment industry as "developing environmental solutions through industrial activities," replacing the previous image of the environment industry as the manufacture of pollution-control equipment. The publication defined the scope of the environment industry as the range of industrial activities with the potential to contribute to positive rather than negative environmental impact while creating new business opportunities. Fig. 3 lists six major sectors of the environment industry.

MITSUBISHI ELECTRIC'S ENVIRONMENT-RELATED BUSINESS ACTIVITIES. As a corporation, we believe that efforts to overcome environmental hurdles will lead to market growth as systems thinking and other new concepts are applied to the effective use of energy and resources. Mitsubishi Electric has a history of environment-related R&D covering a broad range of fields including alternative energy resources, safer technologies for nuclear power generation and thermonuclear fusion systems, residential air-conditioning and lighting systems, ozone generators and storage equipment for water treatment, photovoltaic power generation systems, environment monitoring equipment, and electronic control technology for low-pollution direct-injection gasoline engines, electric cars and hybrids.

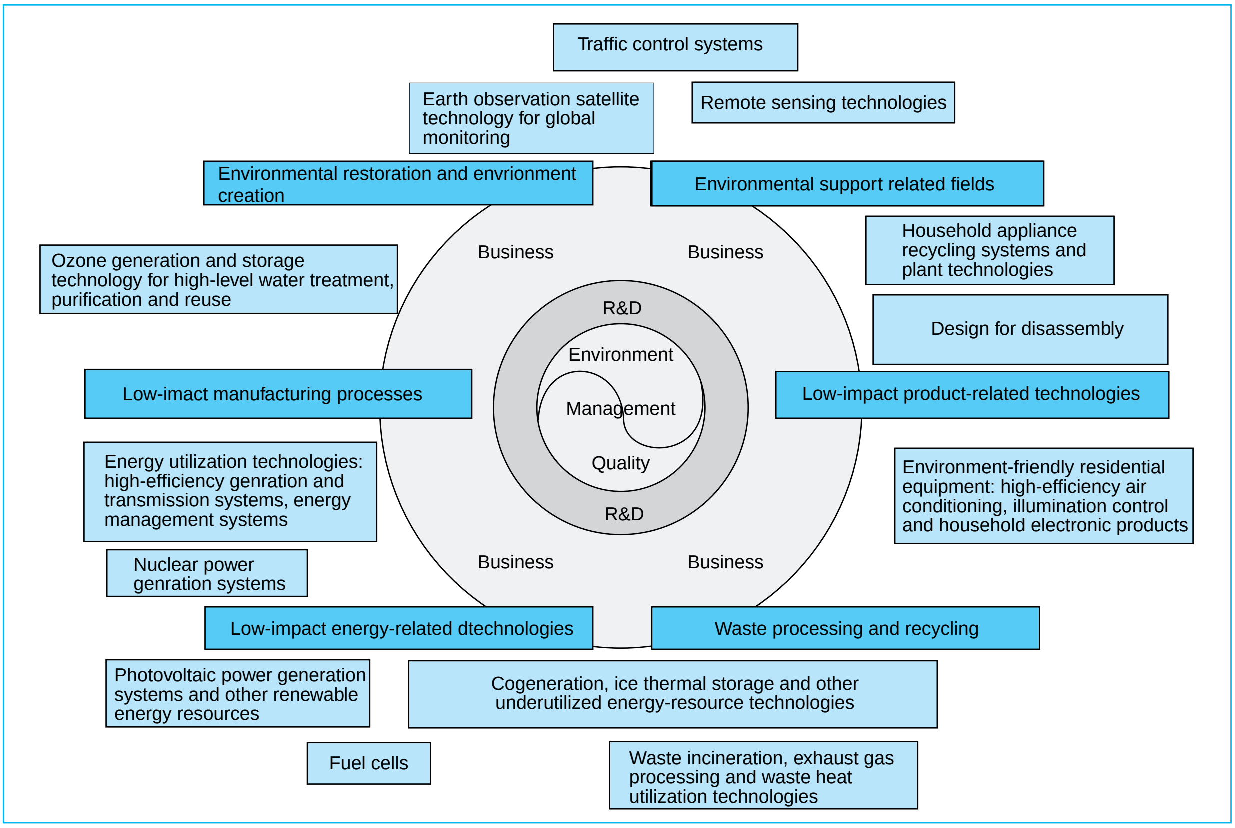

Fig. 3 This diagram shows how a sample of Mitsubishi Electric's practical environment-related products and technologies relates to six major fields specified by MITI as "environmental industries."

Based on Mitsubishi Electric's perspective of society in the year 2010, "Vision 21," a plan to give the corporation new direction, was published in July 1994. Under this plan, six business domains have been targeted for the development of new business. Environment, one of the six domains, includes the development of technologies and systems for electrical appliance recycling plants, incinerator exhaust-gas processing and waste-heat utilization.

As shown above, we believe that efforts to overcome environmental hurdles will lead to market growth as systems thinking and other new concepts are applied to the effective use of energy and resources. Active partnerships with other industries as well, will surely further contribute to solving environmental problems and expand environment-related business activities.

RELATION BETWEEN ENVIRONMENTAL MANAGEMENT AND ENVIRONMENT BUSINESS OPERATIONS. The synergy between environmental management and environment-related business will be the determining factor in corporate success in adapting to 21st century corporate models. In the future, we expect that transnational corporations will be required to restructure their operations to minimize negative environmental impact, and this restructuring promises new business opportunities. Mitsubishi Electric stands to benefit since it is now gaining valuable know-how and experience from establishing environmentally friendly manufacturing operations of its own.

Humanity now faces the challenge of realizing a cyclical society that utilizes limited resources in a closed-loop system. These changes will dramatically alter flows of resources, money and information. Companies that can adapt to these changes and utilize them as business opportunities will thrive in the coming century. Mitsubishi Electric believes that productivity of resources will be the key to success in the manufacturing industry and is committed to progressing in this direction. While the Japanese economy has shown dramatic growth through improvements in labor productivity, we believe that improved resource productivity is required to keep Japan at the forefront of the world economy in the 21st century.❑

A Hybrid Photovoltaic-Diesel Power Generation System for Miyako Island

*by Masahisa Asaoka and Sueo Sakata**

Mitsubishi Electric has developed a hybrid photovoltaic-diesel power generation system for Miyako Island under the Ministry of International Trade and Industry's New Sunshine Project. The primary power source is a 750kW photovoltaic array supplemented by a 300kW diesel generator. The system has supplied electricity to private households for two and a half years with an average output of 95kW.

Background

Remote islands in the Japanese archipelago rely primarily on diesel generators for electric power. Diesel generators suffer from a number of drawbacks, specifically, high cost and uncertain fuel supply. Environmental considerations make the introduction of clean photovoltaic power generation desirable. Mitsubishi Electric conducted technology development for such a system under contract to the New Energy and Industrial Technology Development Organization.

In addition to the advantages conferred by using nonpolluting and inexhaustible photovoltaic power generation, the hybrid photovoltaic-diesel power generation system has developed the following features: The utilization rate of photovoltaic generation is high, the system minimizes the capacity requirements for photovoltaic arrays and storage batteries, and the system provides a reliable power supply despite variations in solar irradiation.

Fig. 1 An aerial view of the pilot plant.

Configuration

Fig. 1 shows an aerial view of the system, Fig. 2 illustrates its configuration and Table 1 lists the main specifications. A stand-alone system

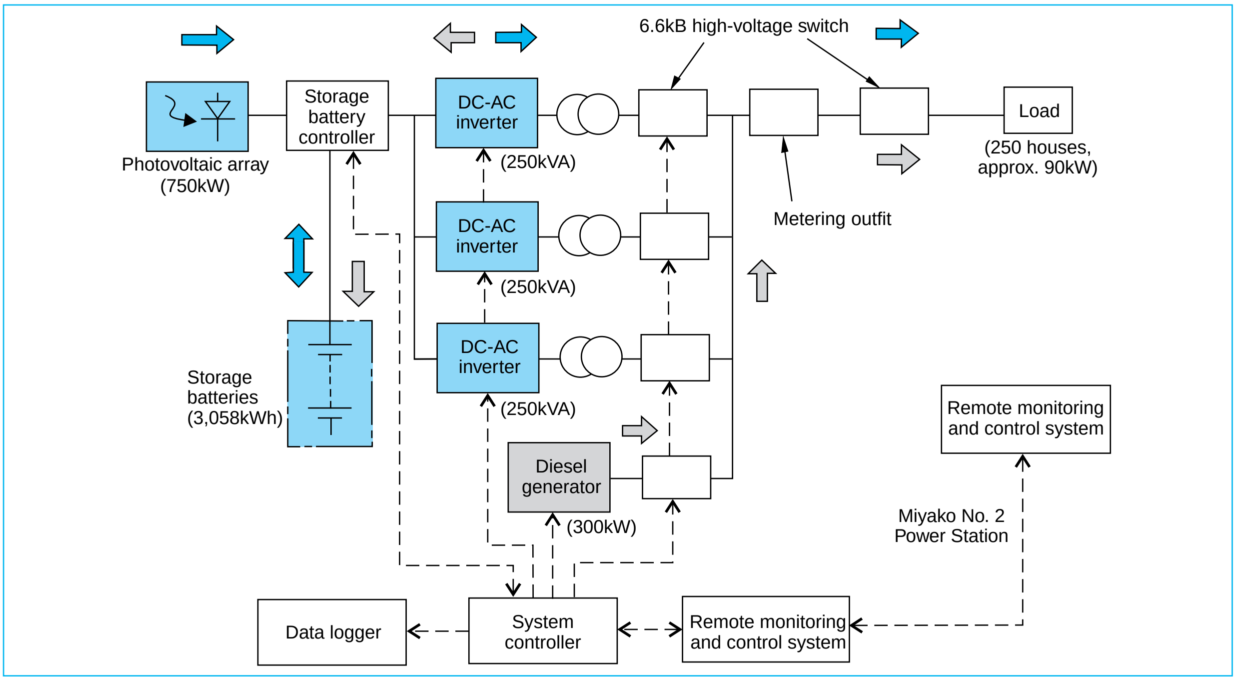

Fig. 2 System configuration.

*Masahisa Asaoka and Sueo Sakata are with the Transmission & Distribution, Transportation Systems Center.

Table 1 Major Specifications

Photovoltaic array capacity	750kW
Site area	Approx. 16,000m^2
Array area	Approx. 10,300m^2
Planned annual energy output Photovoltaic Diesel generator	807,600kWh (92.2kW average) 671,200kWh (76.6kW average) 136,400kWh (15.6kW average)
Nominal AC output	6.6kV, 60Hz, three phase
DC input voltage	350~600V (430V nominal)
Power conditioner	3 x 250kVA inverters with transistor PWM control; 94% rated energy efficiency; 92% effective energy efficiency at 40% load
Harmonic distortion factor	5% or less in voltage terms
Control method	Constant-voltage constant-frequency control
Storage battery capacity	3,058kWh (4 x 1,950Ah 10HR)
Diesel generator capacity	300kW

that uses photovoltaic cells with storage batteries to supplement photovoltaic output at night and on rainy or overcast days requires a large investment in battery capacity. In contrast, the hybrid system uses a diesel generator that gives the system a high capacity factor, allowing a smaller solar array and a 75~80% reduction in storage battery capacity.

The system, which is not connected to a commercial power grid, provides an average of 95kW to some 250 residences, making this the largest photovoltaic power generation system in Japan. Excess power generated by the photovoltaic array during the day is used to charge the storage batteries for future use. The diesel generator automatically starts when photovoltaic power generation drops and the storage batteries are unable to meet the power demand. A unique charging control system was developed in which the diesel generator output goes through an inverter and charges the batteries. This configuration boosts the fuel efficiency (liters of fuel consumed per kWh generated) by improving the loading ratio of the diesel generator.

Table 2 lists the diesel generator's fuel consumption characteristics. Fuel efficiency is highest at 100% load and lowest with a light load. The diesel generator output was boosted by 19% to cover losses in the inverter and storage batteries, while fuel consumption was reduced by 20% through a control system that increases the diesel operating load from 30% (which is sufficient to drive a 95kW load) to 100% of the rated output.

Table 2 Fuel Consumption Characteristics of the Diesel Generator

Load rate (%)	25	30	50	75	100
Fuel consumption rate relative to 100% load	1.57	1.45	1.19	1.06	1.00
Fuel consumption rate (L/kWh)	0.456	0.421	0.346	0.307	0.290

We determined the capacities of the photovoltaic array and storage batteries by conducting simulations and an economic analysis of the system with respect to the planned load. An excessively large array raises system cost, reduces the supplementary energy provided by the diesel generator and causes poor utilization of the photovoltaic power. Too small an array is insufficient to charge the storage batteries, increasing the need for supplementary energy and raising diesel generator operating costs and fuel usage. We selected the inverter capacity to drive about three times the average load, using three units of 250kVA (200kW), two for routine use and one in reserve against component malfunction. A 300kW auxiliary diesel generator is used.

Components

The photovoltaic modules have an average maximum output of 62.0W and an average maximum operating voltage of 20.3V with an efficiency of 12% under standard test conditions of 1kW/m^2, 25°C and air mass of 1.5. The solar array consists of 24 photovoltaic modules connected in series and configured with 503 parallel circuits.

The storage batteries are 1,950Ah (10HR) long-life tubular-type lead-acid batteries designed for repeated charge/discharge cycles. These are connected together in four parallel groups each consisting of 192 batteries in series with an output voltage of 392V.

The storage battery charge, measured in ampere hours, is monitored by integrating the current flows in and out of the batteries over time. The charge is maintained at 20~100% of capacity. By limiting discharge to 80% of the storage capacity, the battery lifetime has been extended to an estimated 1,700 discharge cycles.

Stand-alone photovoltaic power generation systems, where irregular charging and discharging occurs, are particularly vulnerable to variations in electrolyte concentration that shorten battery life. We eliminated this problem by using an air pump to agitate the battery electrolyte at 30-minute intervals.

The inverter employs insulated-gate bipolar transistor (IGBT) power modules. The power demand of private residences is generally characterized by light loads that continue for long periods. The load factor and system efficiency have been boosted by using multiple inverters and selecting the number in service to match the load. The system capacity factor is improved by connecting the entire array to the same DC busbar.

The inverter uses a constant-voltage constant-frequency control system when it operates independently, and uses phase and voltage control to match the diesel generator output when the generator operates, controlling the effective and reactive power.

The diesel generator cost is reduced by eliminating a synchronized closing/load-sharing controller and implementing synchronous load-sharing operation entirely through inverter control.

Operation Results

Fig. 3 shows the power generation activity of the system over the two-year test period from April 1995 to March 1997. The photovoltaic output was inadequate over the winter months from December to February, resulting in extensive operation of the diesel generator over that period. The photovoltaic array generated excess power over the months from June to September. Seen cumulatively, the photovoltaic panels generated a respectable 80% of the total power produced over the two years, with the diesel generator responsible for the remaining 20%.

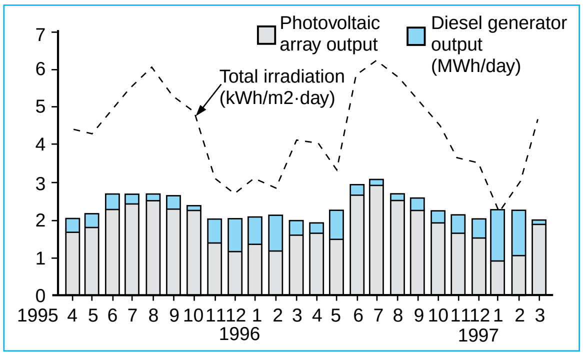

Fig. 3 Operation results.

Hybrid photovoltaic systems offer a clean alternative to diesel power generation for islands and mountainous regions isolated from the commercial power grid. Further efficiency and cost improvements will be needed for these systems to enter wide use. ❑

A Residential Photovoltaic Power System

by *Yoshihiko Kishizoe**

Concerns about global environmental problems have stimulated consumer interest in photovoltaic power systems, which offer a clean, renewable energy source. With photovoltaic power entering wider use in private residences, Mitsubishi Electric has developed a residential photovoltaic power system for commercial production. The system provides high conversion efficiency while offering the simple handling and high reliability needed for general market use.

Overview

Fig. 1 shows the appearance and Table 1 the specifications of Mitsubishi Electric's 3.1kW photovoltaic power system. The 3.1kW rating corresponds to the system output under standard conditions of 1,000W/m^2 irradiance and 25°C.

Table 1 Specifications of the 3.1kW System

Module	
Model	PV-MR001
Dimensions	1,200 x 802 x 46mm (W x D x H)
Weight	12.5kg
No. of modules	24
Photovoltaic power generating area	24.0m^2
Nominal output	3.10kW
Power conditioner	
Model	PV-PN04B
Rated input voltage	210VDC
Rated output voltage	202VAC, 50/60Hz
Rated output	3.3kW
Power conversion efficiency	More than 95%
Harmonic energy	Less than 5%
Inverter type	Voltage controlled
Switching method	Sinewave PWM
Insulation system	Transformerless
Electrical system	Two-wire single-phase suitable for connecting to a three-wire single-phase residential power supply
Protection functions	Overvoltage, undervoltage, over frequency, under frequency
Islanding operation detection functions	Active and passive types
Dimensions	430 x 140 x 240mm (W x D x H)
Weight	14kg

Fig. 1 The residential photovoltaic power generation system.

The system is designed to operate either in stand-alone mode or utility-connected mode. In the latter case, power is automatically sold to the power utility when generation exceeds demand and purchased when demand exceeds generation. The system automatically disconnects itself from the commercial power supply during power outages, which facilitates the subsequent recovery of electric utility services.

A power conditioner controls the entire system automatically with manual control required only in the stand-alone mode.

Photovoltaic Modules

Each photovoltaic module consists of an array of solar cells mounted on a surface, connected together, and covered with a sheet of glass and clear plastic. This configuration gives the module a useful life of more than 20 years of normal use.

For this system, we used high-efficiency single-crystal 125x125mm solar cells with an efficiency

**Yoshihiko Kishizoe is with the Nakatsugawa Works.*

of 16%. Each panel houses 54 cells and has a rated output of 129W with an efficiency of 13.4%. The complete system employs 24 modules organized as three parallel strings of eight series-connected modules for a total rated capacity of 3.1kW.

Mitsubishi Electric currently manufactures single crystalline silicon cells, while polycrystalline and thin-film cells are currently under development. The corporation will introduce these technologies once acceptable tradeoffs can be made between performance and mass production requirements.

Power Conditioner

We developed a compact highly efficient transformerless power conditioner for commercial production. High-performance trench-type insulated-gate bipolar transistors (IGBTs) serve as switching elements for the converter and inverter functions, trimming power losses by 30% compared to previous technology. In addition, the gate drive circuit has been optimized to provide more than 95% efficiency at the rated output. The power conditioner occupies a volume of 14 liters, which is extremely compact for its capacity.

Pulse-width modulation (PWM) control for converter and inverter sections is implemented using a digital signal processor (DSP) and digital logic ICs. The DSP controls pulse-width signals to create a sinewave current that is phase-synchronous to the utility power supply. Fig. 2 shows the output waveforms.

A grid fault detection function tracks the line frequency and voltage, and detects system islanding caused by a commercial power outage. A local fault detection function shuts down the system immediately on detecting overvoltage, overcurrent or overheating.

The output of the photovoltaic modules varies dramatically with temperature and solar irradiance level, and the operating current and voltage must be constantly controlled to maximize output. This is accomplished by a maximum power-point tracking function in the power conditioner.

Careful component placement and use of noise filters limit noise generated in the transformerless circuitry to within VCCI-2 compliance requirements.

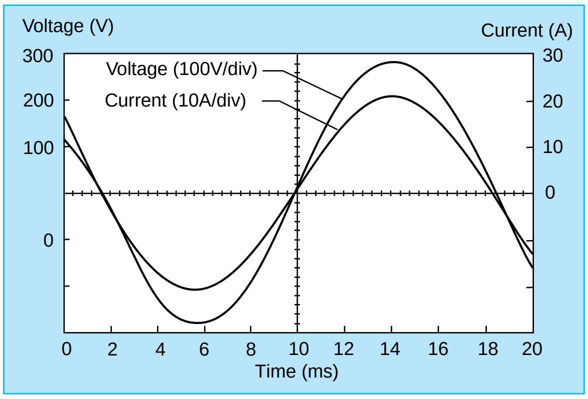

Fig. 2 Voltage and current output waveforms for integration with commercial electrical service.

Connection Box

The connection box makes electrical connections between the photovoltaic modules, while the power conditioner absorbs surges from the modules and further provides the function to isolate individual strings of modules for testing purposes.

The connection box is usually installed outdoors, where it unites the cables from the photovoltaic module strings into a single power output cable which enters the house and connects to the power conditioner.

Module Installation

The 3.1kW power system employs 24 modules with a total area of 24m^2. The modules are usually installed flat on the house roof since the loss associated with non-optimum roof angle is generally just a few percent.

The mounting system accommodates a variety of roof configurations and metal, synthetic and ceramic roofing materials. Diagrams and instructions for mounting panels on stands are provided. Fig. 3 shows a typical installation.

Energy Payback

Fig. 4 shows measurements of solar irradiance and power output over the course of a clear spring day. Power generation starts at about 6am and increases to a peak at about noon. Power output falls as afternoon progresses, reaching zero in the evening. Cumulative output for the day is 16kWh.

The 3.1kW system will generate approximately

Fig. 3 A typical installation.

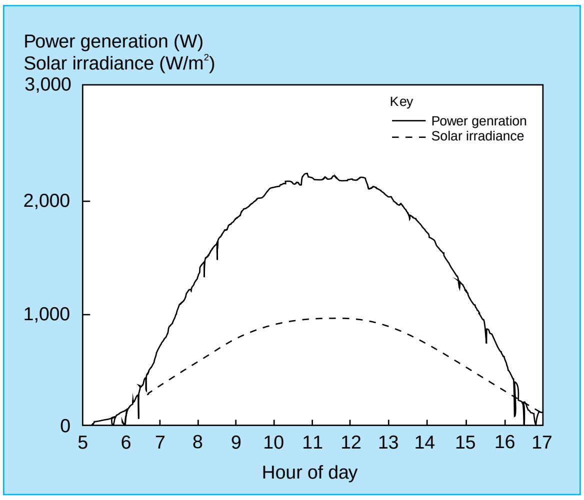

Fig. 4 Solar irradiance and power output over a day.

3,100kWh in one year, which corresponds to the consumption of about 730 liters of crude oil in a thermal power plant. Three to four years of operation generates the energy required to manufacture the system.

Photovoltaic power is a environment-friendly energy source. The corporation is committed to its future development and wider use.❑

MELSAVE: An Advanced Lighting System for Energy Conservation

*by Kazuho Uemura and Kazuo Ban**

Mitsubishi Electric has developed MELSAVE, an advanced lighting system that reduces power consumption to about 50% of conventional lighting. The system uses a sensor that measures the brightness of a room, and saves energy with a continuous dimmer function that eliminates excessive illumination when sunlight is available through windows or when new lamps have been installed.

Background

Energy conservation issues have taken on increased urgency as humanity faces the possibility of climate change, ecological disturbances and other dangers of global warming. Studies are underway worldwide on methods to reduce energy consumption and the associated carbon dioxide emissions that contribute to greenhouse-effect warming.

The corporation has been investigating energy-saving lighting systems since the Japanese government enacted the Energy Conservation Law in March 1993. Fifteen percent of of Japan's electricity use, about 100 billion kWh per year, is for lighting and some 70~80% of this energy is used to operate fluorescent lights. Energy savings in fluorescent fixtures is therefore vital, and has been targeted for improvement under the Energy Conservation Law.

System Description

MELSAVE is one such system developed under the corporation's research program. This system (Fig. 1) consists of highly efficient, continuous-dimming high-frequency (Hf) lighting fixtures (91.8 lumen/W) and light intensity sensors and controllers that control the automatic dimmer function. Each controller uses one sensor and can operate up to 50 lighting fixtures. The MELSAVE lighting fixtures are the world's first to have an inverter-controller dimmer using high-voltage ICs. This design realizes stable dimming performance from 5 to 100%, and has been tested at ambient temperatures as low as 5°C, demonstrating a versatility comparable to conventional fixtures.

Operation

The system implements a control loop comprised of a light intensity sensor input device, a controller, which serves as the information processor, and Hf continuous-dimming lighting fixtures, which serve as the output devices. The light intensity sensor measures the brightness of the room; the controller compares the room brightness with a preset brightness level to generate a dimmer control signal; and the light fixtures dim their output accordingly to maintain the appropriate room illumination. This basic

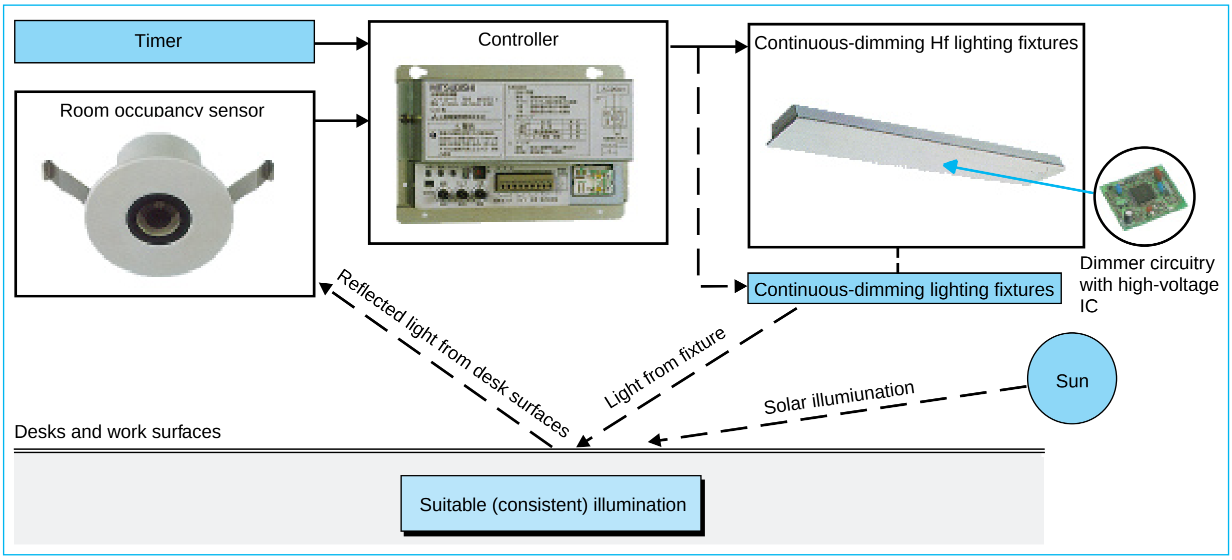

Fig. 1 The control loop of the MELSAVE system.

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functionality can be supplemented by timers and room occupancy sensors that lower lights when the room is not in use.

Energy-Saving Features

Several factors account for the remarkable energy savings of this system.

HIGHLY EFFICIENT LAMPS. The Hf fluorescent lamps and electronic ballast combined use 24% less energy while yielding the same output as rapid-start 40W fluorescent fixtures.

SOLAR ILLUMINATION. The controller will save energy by dimming the lights when sufficient solar illumination is available through windows and skylights. The extent of the energy savings will vary dramatically with the particular room setting, but we estimate solar illumination will allow MELSAVE system users to save 25% on their lighting energy costs (Fig. 2).

LAMP-EFFICIENCY COMPENSATION. A third area of power savings lies in compensating for changes in lamp efficiency over the life of the lamp. The efficiency of a fluorescent lamp changes with use; initially high and then decreasing gradually over the lamp's service life. When lighting is designed, the output of the lighting fixtures is derated by 30% in calculations to ensure that adequate light is provided even toward the end of a lamp's service life.

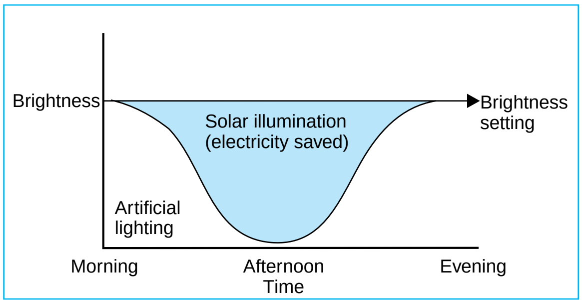

Fig. 2 Use of solar illumination.

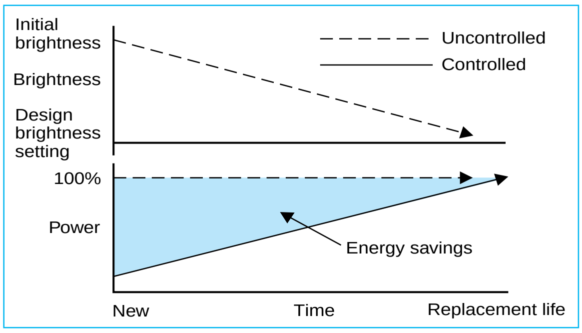

Fig. 3 Energy savings during new lamp period.

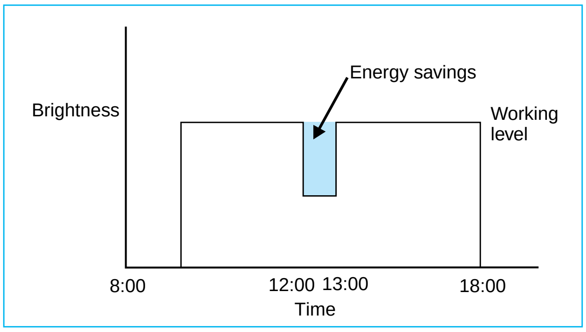

Fig. 4 Timer control function.

This means that the lighting is often brighter than actually necessary. The MELSAVE system reduces the lamp output when it senses the brighter illumination of newly changed lamps so that lighting is never brighter than the intended level. This yields power savings on average of 12.5% over the service life of the lamps (Fig. 3).

TIMER OPERATION. Energy can be saved by dimming room lights during meal times and other times when a room is not being used. For example, if the lights are dimmed 50% one-hour during a ten-hour day, the energy savings will be 5% (Fig. 4).

When all these savings are taken into account, the MELSAVE system achieves an astonishing 50% reduction in energy use over conventional lighting.

Total energy savings is:
100% – 76% x 75% x 87.5% x 45% = 50%

A secondary benefit of the energy saved by the system is lower air-conditioning costs, since the lighting fixtures dissipate only about half as much heat. A final benefit of the system is that it tends to reduce peak power demand on electric power utilities since lights are dimmed in response to solar illumination when the electrical demand is the greatest.

MELSAVE, which has been commercially available since June 1996, received the Resources and Energy Agency Chairman's Prize at the 1996 Energy Savings Vanguard 21 event sponsored by the Energy Conservation Foundation. Mitsubishi Electric plans to refine this technology still further by shifting system designs from stand-alone control to balanced group control, from fixed level control to variable level control, from zone control to individual fixture control, and from illumination control to interior environment control. ❑

Energy-Saving Air-Conditioning and Lighting Systems for Offices and Factories

*by Masaki Komatsu and Hiroyuki Kobayakawa**

Energy conservation activities are needed to stem growing electricity use and to reduce the CO_2 emissions associated with global warming. This article introduces energy-saving technologies for air-conditioning and lighting systems for office and factory applications, which account for a large proportion of energy consumption.

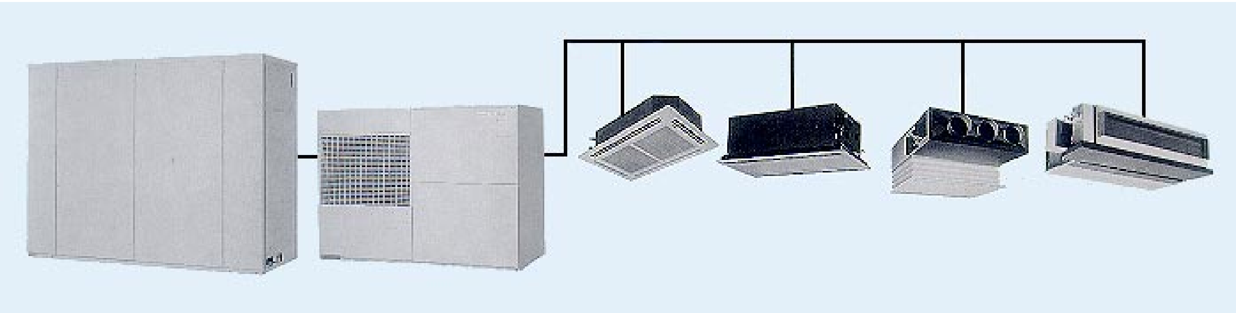

Fig. 1 Air-conditioning system with a thermal storage tank.

An Air-Conditioning System with a Thermal Storage Tank

Fig. 1 shows a photograph of a multi-unit air conditioner with a thermal storage tank that reduces daytime electricity use. During the summer months, the system produces ice at night to reduce the electricity requirements of daytime air conditioning. During the cold season, the system heats water at night to reduce the electricity requirements of daytime heating.

The nighttime thermal storage function takes advantage of low nighttime electricity rates. The system also serves to level power usage so that substation capacity can be reduced. The tank is relatively compact since 70% of the holding capacity can be filled with ice, a figure referred to as the "ice packing factor."

The MELSAVE Energy-Saving Illumination System

This system has an automatic dimmer function that maintains appropriate workplace illumination levels while lowering power consumption by 50~70%. Fig. 2 shows the basic configuration. The system consists of a sensor that monitors the illumination level of a particular area, a controller that adjusts the lighting level based on the sensor input, and lighting fixtures equipped with Model Hf 32W fluorescent tubes and a continuous-dimming function. The Hf lamps use 24% less energy than conventional rapid-start tubes.

The system adjusts lamp illumination to the optimum level following the installation of new fixtures, fixture cleaning or lamp replacement,

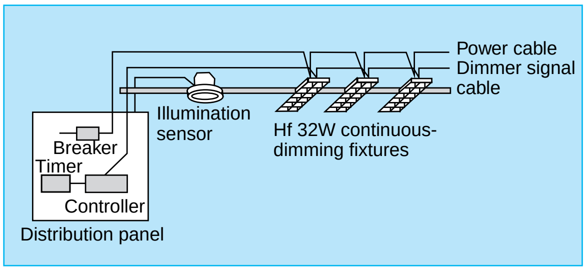

Fig. 2 Configuration of the MELSAVE lighting-control system.

Table 1 Cost Comparison of Conventional and Energy-Saving Technologies (Units: 1,000 yen)

	Initial cost	Running cost per year	
		Electricity	Maintenance
Conventional air-conditioning	17,322	2,109	150
Conventional illumination	2,585		
Total	19,907	2,259	
Air conditioning with thermal storage	18,081	1,357	220
MELSAVE illumination system	3,469		
Total	21,550	1,577	

*Masaki Komatsu and Hiroyuki Kobayakawa are with the Living Environment Systems Engineering Center.

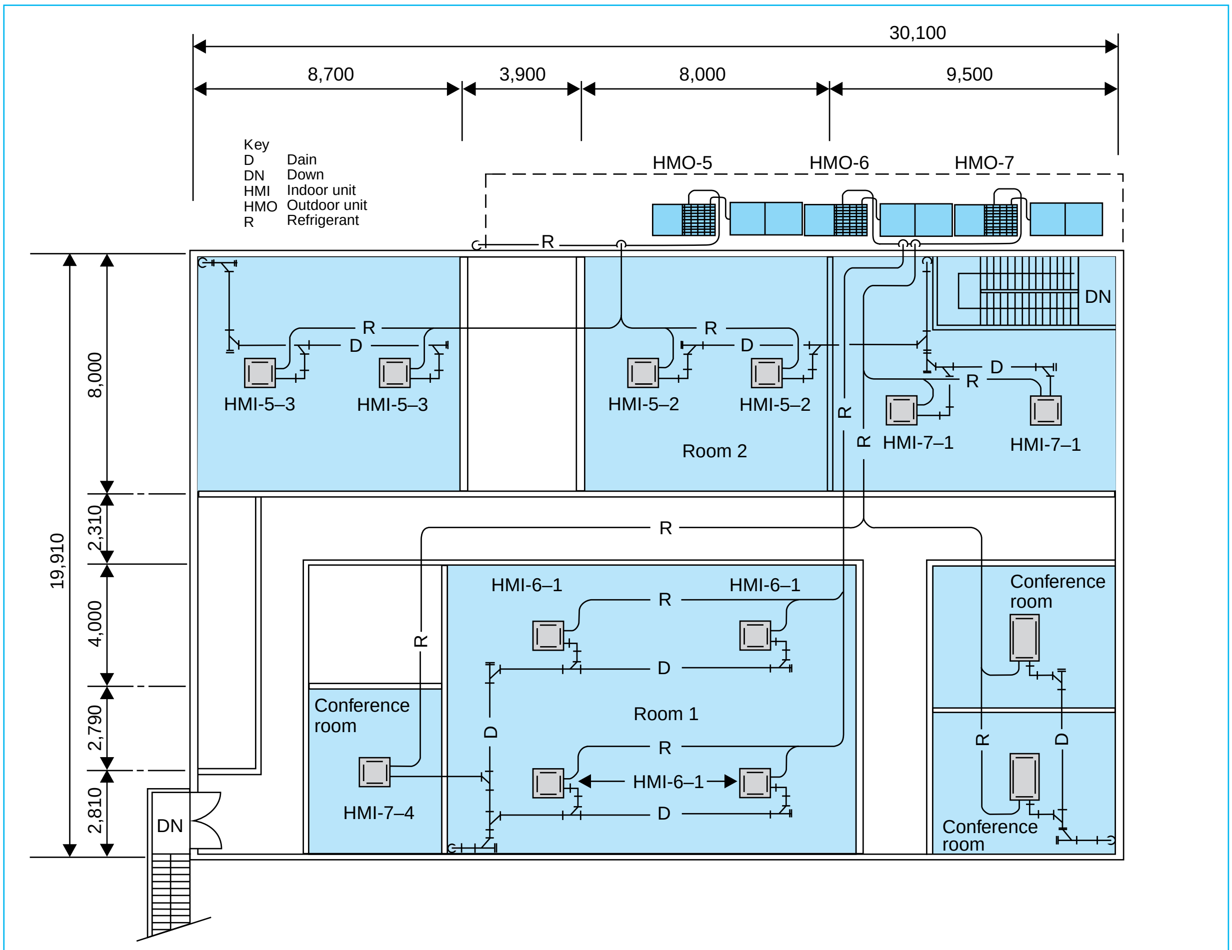

Fig. 3 Air conditioner layout in second floor office space.

which yields an energy savings of approximately 12.5%. The system also responds to daylight solar illumination by reducing lamp output, which lowers energy consumption by some 25%.

Application Example

Both of the above systems were fitted to a two-story building at the Air-Conditioning Refrigeration Systems Works. The first floor consists of a storage area and boiler room comprising a total area of 900m². The second floor consists of 600m² of office space.

Multi-unit thermal-storage air-conditioning systems were fitted to the first floor storage area and the second floor office. Fig. 3 shows the office installation. Room 1 has four indoor units linked to a 16 horsepower outdoor unit. The number of indoor units in the other rooms is matched to the heating and cooling loads, and the units in each room are connected to a separate 16 horsepower outdoor unit.

The illumination control system was installed only on the second floor. The office has windows on all four walls and receives excellent natural illumination. Fig. 4 shows five zones in the office that benefit almost equally from outside light. Each zone is fitted with an illumination sensor, a controller and multiple lighting fixtures, each with two Hf 32W lamps and a dimmer control function. The system generates an annual energy savings of 43%, which

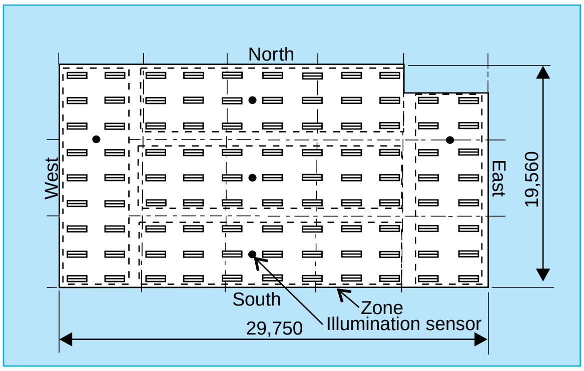

Fig. 4 Zoning.

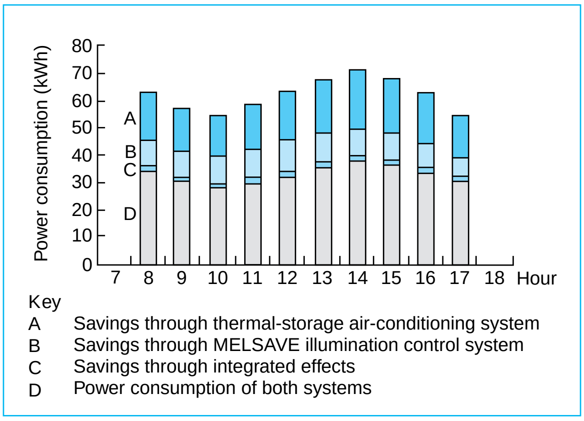

Fig. 5 Electricity use for cooling and illumination on a typical August day in Wakayama, Japan. The total height of the bars indicates power consumption using conventional cooling and lighting technology.

corresponds to a 43% reduction in greenhouse gas emissions as well as a 43% reduction in running costs, which amounts to 227,000 yen per year. At this rate of saving, the initial higher cost for equipment and installation (884,000 yen) can be recovered in about four years.

Cooling requirements are further reduced when the two systems operate together because less energy used for lighting translates into a lower load on the air-conditioning system. The total initial cost is 1,643,000 yen higher than for conventional cooling and lighting systems, but with an annual running cost that is 682,000 yen lower, the difference is amortized over 2.4 years.

Fig. 5 compares power consumption for air conditioning and lighting on a typical August day for conventional and energy-saving systems. Overall, the energy-saving system uses 45% less power. The technology further lowers the cost to electricity consumers since substation equipment can be smaller and a lower basic rate can be negotiated with the power utility. Finally, since these technologies lower the peak power demand, wider use will enable electric power utilities to meet peak demand without constructing additional generation facilities.

The thermal-storage air-conditioning system and MELSAVE illumination control system offer individual and substantial integrated effects that lower annual power use, energy costs and CO_2 emissions. The systems also serve to lower peak power demand, reduce the basic electricity rate and reduce the size of substation equipment. New facility construction and remodeling of existing facilities both offer excellent opportunities to introduce this important environmental technology. ❑

Remote Sensing Satellites for Global Environmental Surveillance

by Tsutomu Iwahashi and Nobuyoshi Imura*

Humanity is observing environmental changes on a global scale that include ozone depletion and loss of tropical rainforest areas. Remote sensing satellites support the ongoing, global observation needed to elucidate the mechanisms behind these changes. This report surveys present technology and future directions in remote-sensing earth observation satellites.

Global Environmental Observation by Remote Sensing Saellites

A remote-sensing earth observation satellite is typically placed in a low earth orbit of 500 to 800km that allows it to scan the planet's entire surface over a period ranging from several days to several weeks. Fig. 1 illustrates the overall concept and configuration of remote-sensing satellite systems.

Following several years of independent programs, Japan, France and the United States have teamed up in planning a series of earth observation satellites for resource surveys and marine and terrestrial observation. The National Space Development Agency (NASDA) of Japan launched the first Advanced Earth Observing Satellite (ADEOS) in August 1996, and ADEOS-II is scheduled for launch in August 1999.

ADEOS is collecting data on meteorological abnormalities and slow-changing environmental phenomena such as global warming, ozone depletion and loss of tropical rainforest lands.

ADEOS II will continue the earth observation mission and will also carry an advanced microwave scanning radiometer (AMSR) that can observe water-related phenomena including water vapor and precipitation levels, ocean surface temperature, marine winds and marine ice. The AMSR is capable of making observations day and night and can see through cloud cover. America's National Aeronautics and Space Administration (NASA) is planning to launch a similar sensor, called AMSR-E, aboard EOS-PM1, which is part of NASA's planned EOS series of earth observation satellites.

Mitsubishi Electric is playing an active role in these projects, serving as system integrator

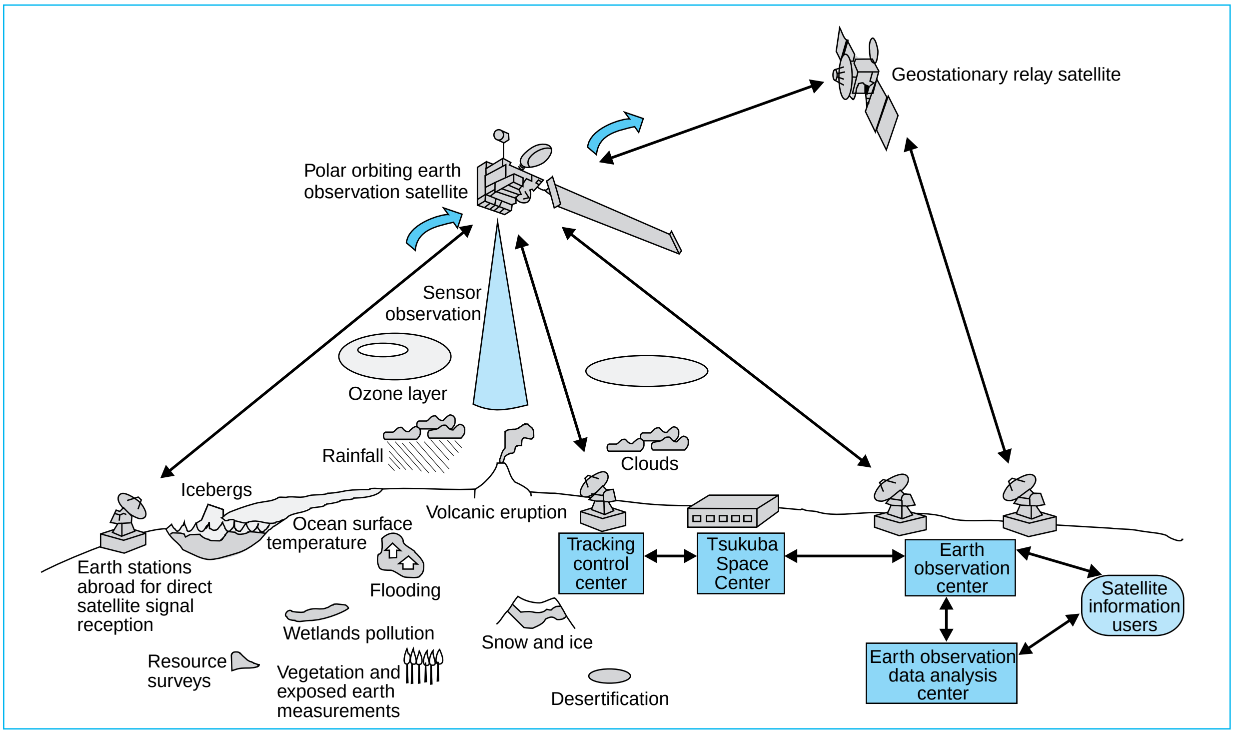

Fig. 1 Concepts and basic configuration of a remote sensing satellite system.

*Tsutomu Iwahashi and Nobuyoshi Imura are with the Kamakura Works.

for ADEOS and ADEOS-II. The company is supplying key instruments for the satellites including AMSR, AMSR-E, and an advanced visible and near-infrared radiometer (AVNIR). It has also been contracted to develop terrestrial data processing facilities for the AMSR data.

Ozone Layer Observations

In 1974, first reports on ozone layer destruction by CFCs attracted the interest of scientists and the general public. In 1985, an American observation satellite detected the Antarctic ozone hole, igniting worldwide concern. Fig. 2 shows an image of the ozone distribution taken in September 1996 by the ADEOS total ozone mapping spectrometer (TOMS). Ozone depletion has also been observed over the North Pole and development of an Arctic ozone hole is thought possible.

Terrestrial Observation

A satellite of the National Oceanic and Atmospheric Administration (NOAA) became the focus of widespread public attention when images from its advanced very high-resolution radiometer (AVHRR) provided the first visual documentation of rainforest shrinkage and desertification happening on a global scale. Fig. 3 shows a 1988 image taken by NOAA's AVHRR. Although designed primarily for ocean surface temperature and cloud measurements, two of the instrument's five wavelength ranges, the visible and near-infrared bands, are suitable for studying terrestrial vegetation.

Fig. 4 shows a mosaic of images of the Amazon basin taken by a synthetic aperture radar (SAR) on NASDA's Japan Earth Resources Satellite 1 (JERS-1). The instrument, developed by Mitsubishi Electric, generates clear terrestrial images that are unaffected by clouds, precipitation and solar illumination, making it useful for resource surveys and monitoring changes in rainforests and other terrestrial ecological systems.

Ocean Surface Observation

Increasing carbon dioxide emissions are a principal factor in the progression of global warming.

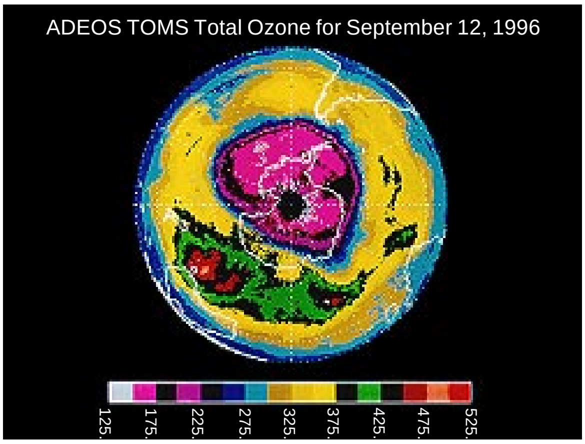

Fig. 2 Ozone distribution above the South Pole taken by ADEOS TOMS (courtesy of NASDA).

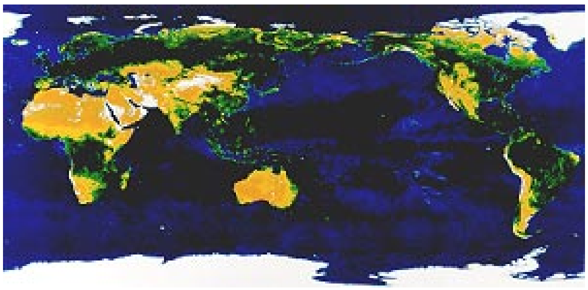

Fig. 3 Global vegetation imaged by NOAA's AVHRR (courtesy of NASDA).

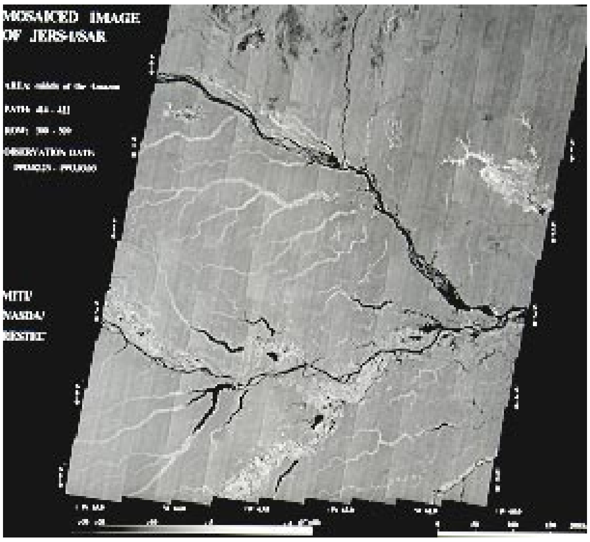

Fig. 4 The Amazon basin seen by the JERS-1 SAR (courtesy of NASDA).

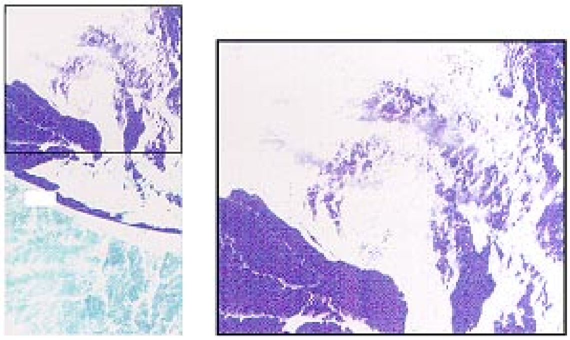

Fig. 5 Ice floes off Mombetsu City imaged by SPOT's HRV.

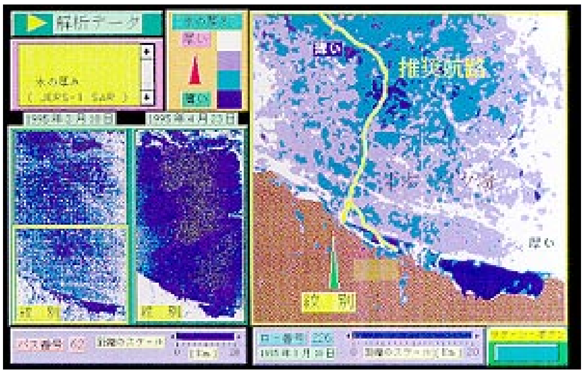

Fig. 6 Ice thickness information from the JERS-1 SAR.

Table 1 Future Directions in Remote Sensing Satellite Technology

Sensing
- Wider spectrometer bands
- Spectrometers tailored to specific applications
- Deployment of all-weather sensors.
- Improved space resolution
Observation Patterns
- Increased observation frequency
- Realtime observation through use of multiple satellites
- Establish long-term monitoring programs
- Establish forecasting capabilities for local or short-lived phenomena
- Detect and monitor marine pollutants including petroleum and suspended solids
- Combine data from multiple sensors in innovative ways
Data Utilization
- Frequent or realtime data delivery
- Provide data for regional planning
- Establish monitoring stations for state and local governments
- Link data directly to the satellite network for regular monitoring
- Regular telecast of atmospheric, moisture and forest information

Global warming is a serious concern because even a small increase in atmospheric temperature will cause melting of the Arctic and Antarctic ice packs, leading to a dangerous rise in ocean levels. Remote sensing satellites provide early warning of such changes by monitoring the state of the ocean surface, earth surface and atmosphere. A C-band SAR aboard Canada's RADARSAT took some of the first satellite images of oil slicks from the Russian tanker *Nakhodka* that wrecked off the northern coast of Honshu this year.

Figs. 5 and 6 show enhanced images of offshore ice floes near Mombetsu City in Hokkaido. Fig. 5 shows ice floes observed in February 1994 by a high-resolution visual imaging instrument (HRV) aboard France's SPOT satellite. These images cover a large area, clearly showing movement of ice down from the Sea of Okhotsk. Fig. 6 is a processed image from the JERS-1 SAR that shows the ice thickness. These images aid marine navigation by helping ships find the shortest ice-free route to their destination.

Future Directions in Remote Sensing Technology

Table 1 lists future directions in remote sensing technology in the areas of sensors, observation patterns and data utilization.

All of humanity shares the obligation to preserve the environment and natural beauty of the planet. Remote-sensing earth observation satellites are uniquely capable of observing long-term environmental and climatic changes associated with global environmental problems. Mitsubishi Electric plans to continue developing its remote sensing satellite technologies and applying them in the service of environmental protection. ❑

An Integrated Recycling Process for Electric Home Appliances

*by Yoshikazu Kotera and Shin'ya Sato**

Under contract with the Japan Association for Electric Home Appliances, Mitsubishi Electric has developed an automated disassembly process to be incorporated in integrated recycling plants for electric home appliances. The process automates disassembly operations, assists workers and contributes to higher recycling efficiency.

Background

Social demand for waste recycling is stronger than ever. Large streams of waste are creating serious problems for urban areas due to the limited space remaining in landfill sites and the potential for environmental pollution in adjoining areas. Further, the development of landfill sites consumes large amounts of energy, especially in the case of discarded electrical appliances, which may be disposed of only in a controlled landfill area under Japanese regulations.

Recycling of Used Appliances

Japan has enacted laws promoting the use of recycled resources that target televisions, refrigerators, air-conditioners and washing machines for recycling. Table 1 lists the compositions of these major appliances. Air-conditioners and refrigerators contain large amounts of pure steel, copper and aluminum, and televisions contain mostly high-quality glass by weight. Recycling recovers these resources, saves energy that would otherwise be spent in processing raw materials, and helps conserve supplies of rare-earth materials and scarce metals. Recycling is also preferable to disposal because old appliances often contain lead, CFCs and other substances that have a negative impact on the environment.

Disassembly Processes

Used appliances collected by local governments or retail stores are carried by conveyer into the plant. The appliances are identified by product type, and each type is handled by a customized process.

In previous automated recycling, a "shredder" reduced the entire appliance to small pieces, which were then separated by magnetic and gravity methods to extract glass and metal. For this project, we introduced a primary disassembly process with some manual procedures that precede the shredding process. While this innovation increases resource recovery efficiency and contributes to lower pollution levels, it requires that the facility environment be engineered to enable human and mechanical processing to take place in unison.

Some processes inevitably involve noise, dust and odor. Dust problems have been minimized by proper design of exhaust and ventilation equipment. Noisy equipment is surrounded with acoustic barriers, and odors are handled by use of special measuring instruments and deodorizing equipment.

Table 1 Materials Composition of Refrigerators and Televisions

Product	Refrigerator*1		Television*2	
Substances used	Weight (kg)	% of product weight	Weight (kg)	% of product weight
Steel	28.50	49.78	3.93	10.70
Copper	2.32	4.05	1.06	2.88
Aluminum	0.54	0.94	0.16	0.44
Phosphor bronze	—	—	0.09	0.24
Stainless steel	—	—	0.01	0.03
Ferrite	—	—	0.39	1.06
Polyurethane foam	6.36	11.11	—	—
Rubber	0.77	1.34	—	—
Other plastics	17.48	30.53	8.15	22.19
Paper	0.10	0.17	0.10	0.27
Glass	0.04	0.07	18.18	49.48
CFCs and refrigerant oil	0.30	0.52	—	—
PCBs*3	0.16	0.28	1.95	5.31
Condenser*3	0.03	0.05	—	—
Electron gun*3	—	—	0.06	0.16
Transformers*3	—	—	0.93	2.53
Loss during disassembly	0.65	1.14	1.73	4.71
Total	57.25	100.00	36.74	100.00

Note 1: A company's 320-liter 1987 model
Note 2: B company's 25-inch 1989 model
Note 3: Not reduced to raw materials

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The manual disassembly operations also required engineering analysis to develop procedures for handling large and heavy items that help to increase worker safety.

Automation Technology for Disassembly

The automated conveyer system used inside the plant must be able to handle products of varying size and weight. We developed a measurement and image processing unit that determines a product's dimensions, type and manufacturer so that appliances can be automatically routed into the appropriate processes.

We also conducted investigations on how to maintain a nearly constant throughput despite supply variations—seasonal variations due to consumer behavior, and daily and weekly variations that result from collection and transport scheduling. Fig. 1 shows an example of a simulation study on the relationship between input variations and plant transport and processing capabilities. We experimented with creating buffer zones of different sizes in the plant to soak up supply variations. We also investigated how load variations can be handled at the plant management level.

Primary Disassembly Process

In the interest of efficiency, the disassembly process is not a strict reversal of the assembly process. In some cases it involves complicated and demanding operations. We therefore developed automated equipment and measuring instruments to facilitate disassembly operations.

The materials and structures of future appliances are expected to change dramatically; therefore we designed the automatic equipment to be as simple and versatile as possible. We used general-purpose processing robots with software control and automatic tool selection for maximum performance. Fig. 2 shows the appearance of the recycling plant.

The processing plant is designed to handle refrigerators, air-conditioners, washing machines and televisions. Table 2 lists components and materials removed in the primary disassembly process.

We developed procedures for recovering CFC gas and lubricating oil from the coolant circuits of air-conditioners and refrigerators, for removing compressors and motors, and for removing CRTs from television cabinets.

A special pallet for holding the television set was developed to facilitate removal of the rear cover. The television is held by a vacuum pad while a general-purpose robot cuts the rear cover away. We also developed a teaching system for the robot that determines the cutting path automatically after measuring the rear cover shape.

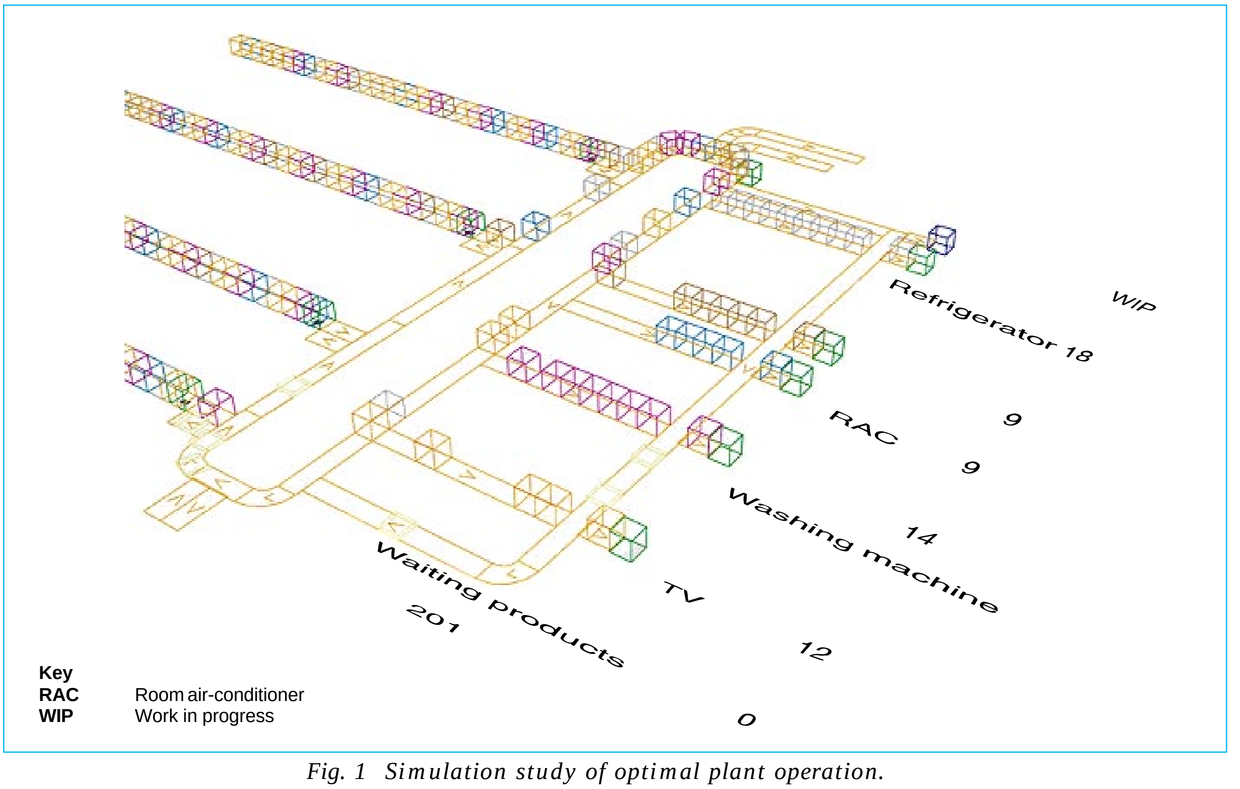

Fig. 1 Simulation study of optimal plant operation.

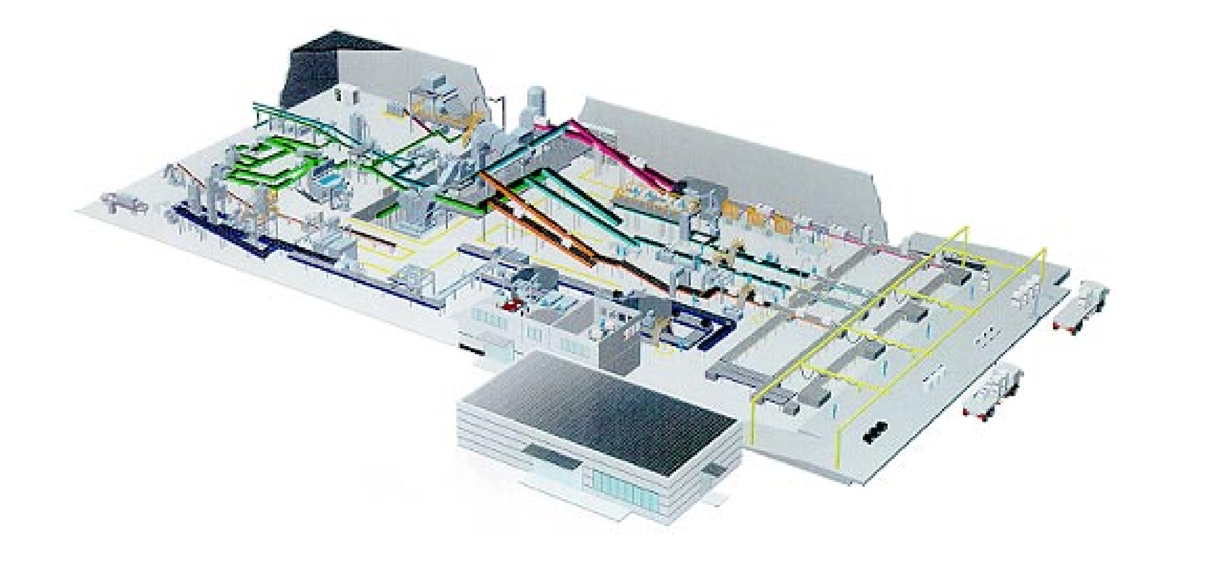

Fig. 2 Illustration of the integrated recycling facility.

We developed equipment that facilitates CRT removal by recognizing the position of and unscrewing the fixing nuts. We also developed a compression crushing device that relieves the CRT vacuum and helps remove the electron gun. This equipment eliminates the need for workers to perform potentially risky manual procedures on heavy CRTs.

Table 2 Materials and Components Removed at Primary Disassembly

Product	Component	Recoverable material
Refrigerator		
Valuable	Chassis	Steel
	Heat exchanger	Copper, aluminum
Compressor		Steel, copper
EIS[1]	CFC gas, refrigerant oil	
Air-conditioner (outdoor unit)		
Valuable	Chassis	Steel
	Heat exchanger	Copper, aluminum
	Compressor	Steel, copper
EIS	CFC gas, refrigerant oil	
Air-conditioner (indoor unit)		
Valuable	Heat exchanger	Copper, aluminum
	Body	
EIS	PCBs	Solder
Washing machine		
Valuable	Motor	Steel, copper
	Body	
EIS	Balancer	Salt water
Television		
Valuable	CRT	P/F glass
	D yoke	Copper
	Electron gun	Rare-earth metals
EIS	PCBs	Solder

Note: [1] Environmental impact substance

We developed a labor-saving robot cutter that removes the compressor from the refrigerator after the refrigerant has been recovered. We also developed a similar robot to cut free the compressor in air-conditioner outdoor units.

The indoor units of consumer air-conditioners consist of a heat exchanger, motor, fan and power supply. A process was developed to recycle the heat exchanger, which consists of high-purity aluminum and copper. The motor has casting that will shorten the life of the shredder blade. It is removed and sent to a cryogenic shredding unit or other specialized processing.

Plant Management and Control Functions

Plant control computer applications have been developed to ascertain efficient plant operation.

One of the key developments is a material-balance control system. The plant output is measured to ensure that the maximum value is extracted from incoming appliances. The amount of resources to be expected from a particular appliance is estimated when the appliance is loaded on the line and identified. This information can then be compared with measured resource recovery data to evaluate recycling efficiency, and thus provide information for adjusting the plant's operations. We are investigating the use of AI technology for this purpose.

Manual operation is assisted by a display at each work station that indicates the disassembly procedure, the tools required, the name and location of parts to be removed, and the num-

Table 3 Scheduling Functions

Facility load used	Introduce products to line based on facility availability
Workload balancing	Introduce products to line based on labor availability
Preferential processing	Introduce products already warehoused
Energy minimization	Introduce products to minimize energy usage

ber of manual operations required. When an appliance enters the line, a database of registered appliances is searched and data is displayed at stations along the line before the appliance arrives. This approach has the potential to enhance operation efficiency while contributing to worker safety.

Product identification also makes it possible to estimate disassembly time and the number of operations involved for each product, so entry to the line can be timed to suit current plant performance. This serves to smooth overall line operation, preventing jams and idle time.

Table 3 lists strategies for optimizing plant efficiency with respect to several different objectives.

Environment-Friendly Manufacturing

Appliance manufacturers are well placed to make major contributions to the development of disassembly processes. Disassembly technologies and processes are an extension of the manufacturing process, and require much of the same knowledge and experience needed for production. There is now a demand for manufacturers to consider not only the manufacturing process, but also the economic and environmental impact of products over the entire life cycle.

New products should be developed to facilitate end-of-life recycling, and Mitsubishi Electric is working towards this goal. Information that the manufacturer holds about the product is indispensable for optimum recycling. We believe that manufacturers should take an active interest in products over their entire life cycle, voluntarily assist recycling efforts, and work towards product designs that are both user and environment friendly. The authors would like to express thanks to all of their collaborators and to the Japan Association for Electric Home Appliances for funding this project. ❑

An Electricity Distribution Monitoring System

by Fumiaki Sakai and Masayoshi Kawaguchi*

The Framework Convention on Climate Change is an international agreement aimed at reducing emissions of carbon dioxide, one of the greenhouse gases implicated in global warming. One of its recommendations is that manufacturers reduce their energy use. This article reports on a system for monitoring that can contribute to energy conservation and meets ISO 14001 requirements for continuous monitoring.

Overview of Energy Management

The essence of energy management is to monitor and control energy use—whether electricity, gas or heat—to facilitate efficient use of energy and better maintenance of the equipment that supplies it. Measures aimed at energy conservation generally involve the following steps:

- Reducing overall energy use;
- Reducing maximum demand, so that demand can be met within the capacity limit of the current contract; and
- Improving the power factor, so that less reactive power is involved.

The remainder of this article reports on the B/NET electricity distribution monitoring system and compact B/NET-based load monitoring system.

The B/NET Electricity Distribution Monitoring System

The B/NET system acquires data from substation equipment and other heavy electrical equipment in buildings and factories, provides realtime monitoring, and generates daily and monthly reports. The system handles analog data, pulse-encoded digital data and contact point data. We will describe an energy-saving installation at an assembly factory using an extremely high substation voltage of 66kV.

Power is monitored not only at the primary feed, but also at the high and low-voltage feeders at 22 secondary transformer installations throughout the facility. Fig. 1 shows the system configuration. Monitoring terminals are placed in the power control center and in the security office, with transmission terminals located in each of the secondary transformer cubicles. Multiplex information is transmitted over twisted-pair cables. Fig. 2 shows the B-MRU1 transmission terminal built into a substation cubicle. The unit has the same dimensions as an electronic power meter, and fits into the same space as a mechanical meter. Use of digital processing allows power feeder metering that used to require five meters, four transducers and one power meter to fit into the form factor of a single meter.

When a central installation is used to monitor multiple transformers, an interface to the B/NET

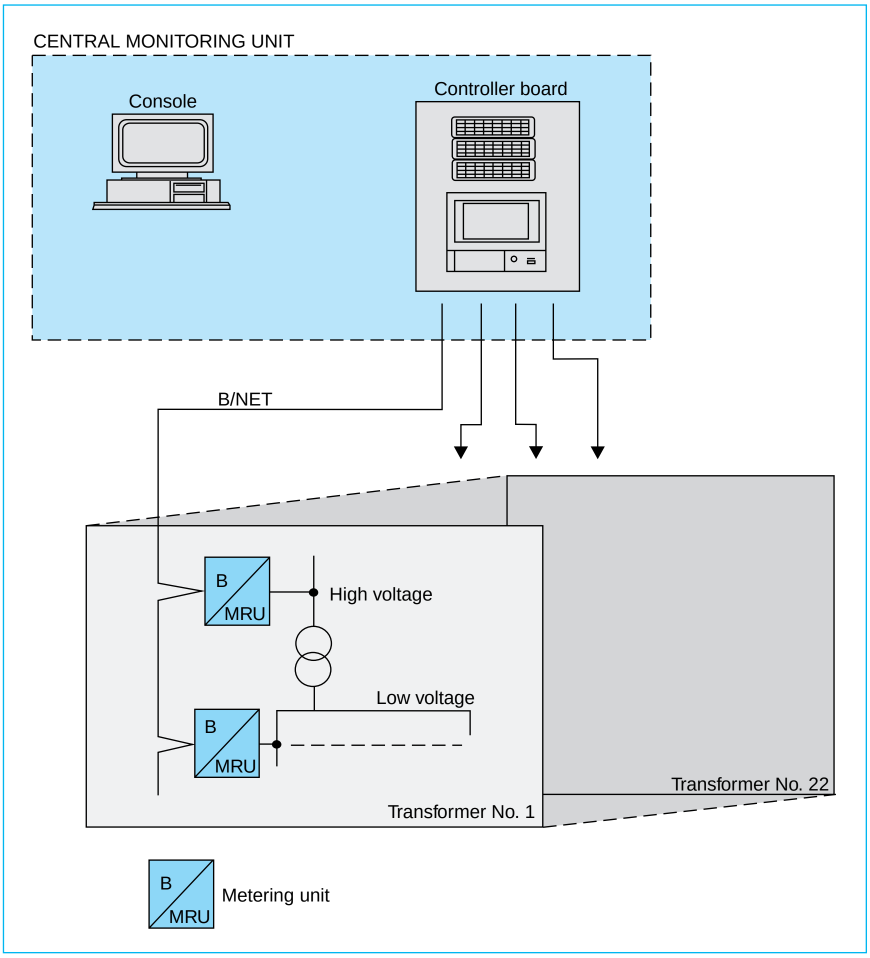

Fig. 1 An application of the B/NET electricity distribution monitoring system.

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(a) Substation cubicle *(b) Transmission terminal*

Fig. 2 B/MRU1 transmission terminal built into a substation cubicle.

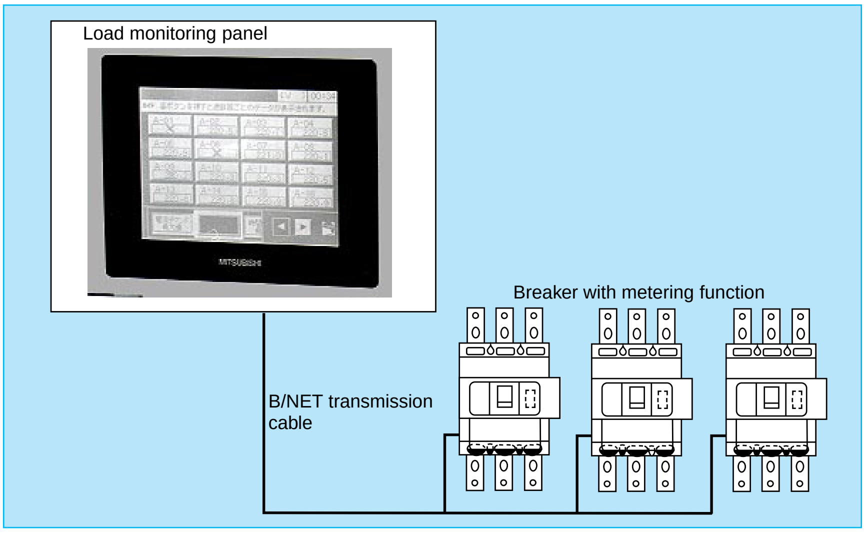

Fig. 3 Load monitoring system.

transmission network supports connectivity to a host computer.

Energy-Saving Measures

Information from the B/NET system supports a variety of energy-saving measures. In this application, we used daily and monthly reports to track monitor transformer demand and schedule a shutdown of excess transformer capacity, which eliminated power dissipation in unloaded transformers. We also monitored power usage trends to identify waste, and rescheduled loads to reduce peak power consumption. Finally, we transferred data to a personal computer via floppy disk for spreadsheet analysis, which we used to lower power expenditures for air conditioning. Use of B/NET in this application reduced power consumption by 2% per year, while providing the continuous monitoring required to comply with ISO 14001 recommendations.

Load Monitoring System

We also developed a B/NET-based load monitoring system for use at secondary transformers (Fig. 3). A circuit breaker with a metering function is installed at the transformer's low-voltage bus and transmits data to a load monitoring panel. Table 1 lists the measurement capabilities.

The system also provides data for preventive maintenance or energy-conservation programs. Placing a metered breaker on each feeder circuit enables monitoring of feeder

Table 1 B/NET Monitoring Capabilities

Current	
Present level	Averaged over 0~15 minute intervals
Maximum value	Since reset
Date and time of maximum	Measured since reset
Voltage	
Present level	Averaged over 0~15 minute intervals
Maximum value	Since reset
Date and time of maximum	Measured since reset
Power	
Cumulative to present	Measured since reset by host computer
Harmonic current	
Maximum time power value	Since reset
Date and time of maximum	Measured since reset
Overall system	
Breaker alarm	Any alarm condition is communicated to host computer if AL, AX and ECA are included
Mode setting for leakage alarm/breaker function	Available when leakage alarm includes ATU

capacity utilization as well as leakage monitoring, which helps lower the chance of damage to circuits and equipment.

Each metering breaker can monitor load voltage, current, power and harmonic energy. Improvements in breaker technology have reduced the size of the breaker mechanism, providing space in the standard form factor to include voltage and current transformers for metering. The metering circuitry was placed in the breaker while maintaining the same outline, improving space efficiency. Data transmission is accomplished using the B/NET network for power distribution control equipment.

The load monitoring panel permits monitoring of all the low-voltage-side main breakers, with detailed monitoring of individual breakers easily available.

These applications of the B/NET electricity distribution and load monitoring system illustrate how the simple addition of monitoring capability for circuits and equipment can lead to substantial energy savings. ❑

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Advances in Waste-Processing Technologies for Bulky and Burnable Wastes

*by Minoru Kokaji and Shin'ichi Hattori**

Humanity faces a pressing need to reduce the environmental impact associated with solid wastes and harmful emissions of carbon dioxide, nitrogen oxides and CFCs. Successful handling of solid waste will be a key factor in realizing the cyclical resource flows that conserve limited natural resources.

Solid wastes derive from consumer and industrial sources. Consumer wastes in Japan are sorted into bulky, burnable and non-burnable wastes. This report addresses the handling of bulky and burnable waste.

Background

Mitsubishi Electric has delivered electrical equipment to Japan's largest center for processing bulky waste, and has established methods for efficient and stable facility operation. In the area of burnable waste processing, the corporation has introduced a feed-forward incinerator control system that uses a realtime analysing apparatus to reduce emissions of dioxins and other harmful substances during the transitions at incinerator startup and shutdown as well as during continuous operation. The corporation has also implemented an environment for three-dimensional simulation of incinerator combustion dynamics for optimizing incinerator design.

BULKY WASTE PROCESSING TECHNOLOGY. THE growing volume of bulky waste collected for disposal has necessitated the construction of processing facilities to handle them. Mitsubishi Electric has supplied electrical equipment to Japan's largest facility for processing bulky waste. In this section, we introduce this equipment and related technologies.

The facility has two processing lines that can handle 200 metric tons in 5 hours, for a combined capacity of 400 tons per day. The incoming waste is cut and crushed into pieces as needed and sorted into five categories: non-burnable, plastic, burnable, iron and steel, and aluminum. Non-burnable and plastic items are disposed of in landfills, burnable items are incinerated, and iron, steel and aluminum items are recycled.

Fig. 1 shows a flowchart of the processing sequence. Handling bulky waste requires a large-scale facility. For such a facility to operate reliably it must be durable and well managed.

We addressed the durability issue through motor design. The crusher must reduce bulky waste to small pieces of about 15cm which are fed to a subsequent sorting operation, and it must handle a variety of materials. For this application we

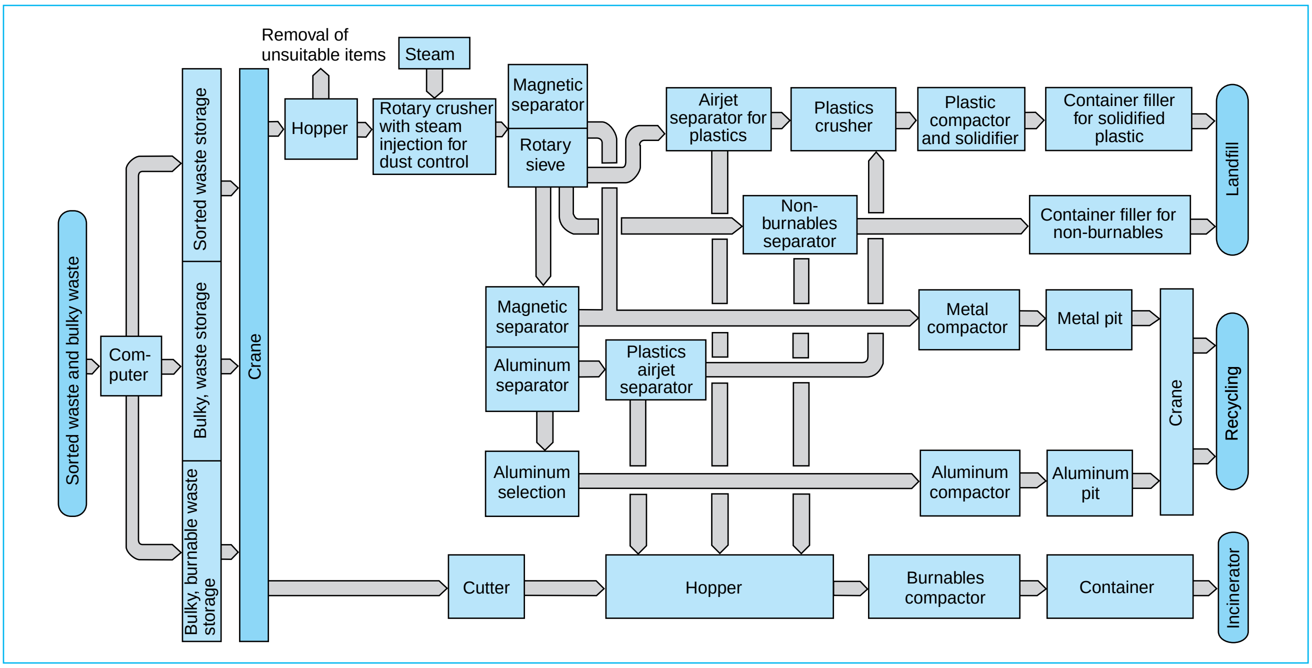

Fig. 1 Process flow at a facility for bulky and burnable wastes.

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manufactured a 1,000kW 10-pole wound-rotor induction motor that operates on a 6,600V, 60Hz supply (Fig. 2). The motor handles high loads of up to GD^2 38,000kg·m^2, resists vibration up to 6G and has a high starting torque of 250%.

CENTRALIZED MONITORING AND CONTROL. We addressed operation management issues by engineering the equipment for both efficient operation and improved maintenance. Efficient fault recovery and maintenance become increasingly important with growing facility size and complexity.

We implemented a distributed control system that allows the facility to be monitored and managed using CRTs instead of a conventional graphic monitoring board based on programmable controllers. Fig. 3 shows the system configuration.

Demands on the operating staff have been lowered, establishing a single startup and shutdown procedure in place of the separate procedures for each of the five sorting lines and by creating an operating environment that simplifies monitoring and control tasks. High-resolution 1,472 × 1,152-dot CRTs for system monitoring display four main monitoring screens simultaneously. Monitoring and control for overall facility lines and each equipment block are handled by several layers of displays and several levels of windows. Fig. 4 shows the operation desk.

PREVENTIVE MAINTENANCE SUPPORT. We took several steps to reduce downtime associated with facility maintenance, mainly involving timely replacement of worn

Fig. 2 Large electric motor for crusher.

parts and management of replacement parts. The operating hours of crushing hammers, reducers and conveyer belts are logged and data archives are maintained for three years so that the operating life of these components can be predicted and future replacement scheduled.

Incineration Technology

Incineration reduces the waste

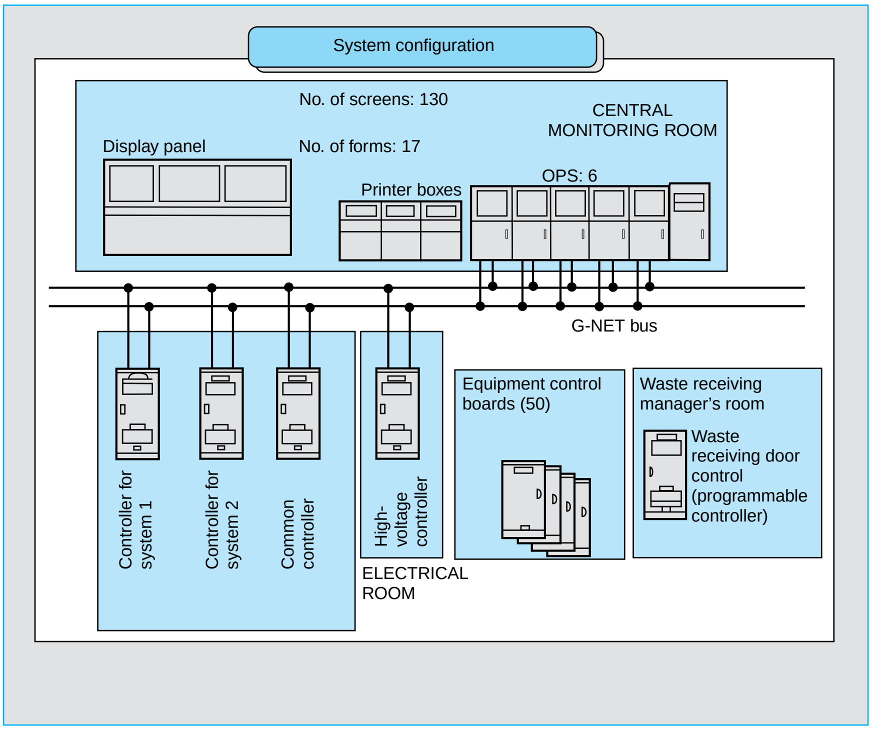

Fig. 3 Monitoring and control system.

Fig. 4 Operator's station in the central control room.

volume and renders many wastes harmless. We developed technologies for monitoring the combustion process and adjusting the incineration process to minimize harmful emissions, especially difficult to reduce dioxin.

COMBUSTION CONTROL. The key to minimizing dioxin emissions is to ensure complete combustion

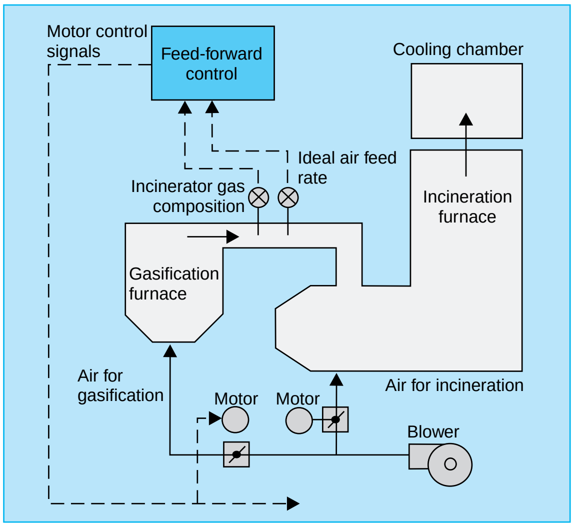

Fig. 5 Construction of the test incinerator.

Fig. 6 Test incinerator.

during the three stages of incinerator startup, continuous operation and shutdown. Concerns over batch and partial duty incinerators are especially high since complete combustion is most difficult to achieve during incinerator startup and shutdown. The corporation has been investigating technologies that can ensure nearly complete combustion during these periods.

Conventional incinerator control systems employ a feedback control loop that monitors parameters such as temperature and pressure in the incineration furnace, boiler evaporation value and oxygen density in the flue gas and adjusts furnace controls to maintain the desired parameter values. This approach cannot achieve optimal combustion control due to the time lag between detection of incomplete combustion and adjustment of the air supply to restore complete combustion. We therefore have been developing a more sophisticated feed-forward system that precomputes air and waste feed rates. The system conducts realtime analysis of gases produced by thermal cracking in the waste preheating and gasification stage, and uses this information to determine appropriate airflow and other incinerator operating parameters. We are currently evaluating this technology in a test incinerator. Fig. 5 shows the configuration of this test system and Fig. 6 a photograph.

INCINERATOR DESIGN OPTIMIZATION. Guidelines for control of dioxin emissions specify incineration temperature, incineration time and gas turbulence. While control over air and waste feed rates is essential to achieving these targets, consideration must also extend to incinerator design, including the shape of the incineration chamber and the position and number of air supply ports. The corporation has established simulation tools for evaluating incinerator designs. This technology analyzes thermal convection flows to determine the flow patterns set up by hot combustion gases and the temperature distribution in the furnace, making it possible to analyze the combustion process and optimize incinerator design.

Technology development directed toward environmental issues promises to contribute much to protecting the global environment. Reduced incinerator emissions through better combustion control and product design for disassembly and recycling are two areas where technology can effect positive change. Mitsubishi Electric is applying comprehensive technical capabilities including combustion control, energy management and simulation to address these important environmental needs. ❑

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