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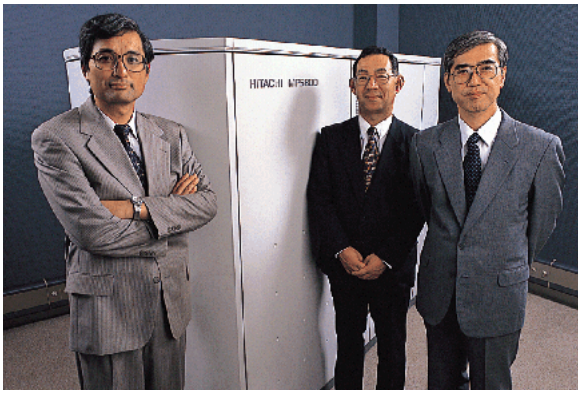
Backbone Servers for the Era of Network Computing —the MP5800E and MP5600E Series—

Network computing systems that enable companies to exploit the vast data assets stored on their mainframes through global access to their databases via the Internet and corporate intranets and strategic use of core data through data warehousing are drawing increased attention. This has led Hitachi to strengthen its lineup of M Parallel Series MP5800E and MP5600E model backbone servers and enhance its VOS3/FS operating system.



Akira Yamaoka (left) and Masaya Watanabe (middle) of the Enterprise Server Division and Kazuo Imai (right) of the Software Division were instrumental in developing the MP5800E and MP5600E models.

Seamless Integration with Open Systems

—Objectives in bolstering the M Parallel Series

Against the backdrop of deregulation and the financial industry's "Big Bang," we've entered an era in which the ability of businesses to rapidly respond to market needs and provide value-added customer services is more important than ever before. This has led companies to reassess the value of mainframes that are clearly superior in terms of overall cost (deployment, operations management, and maintenance), but that also ensure high-speed reliable management of large-scale on-line database processing, large-scale batch processing, and backbone networking. It is inevitable that in the environment now emerging in which various open systems are distributed in a confused and complex way, mainframes will come to assume an increasingly important role as backbone servers. Our intent, therefore, is to provide state-of-the-art processors and architecture that will serve as the nucleus of a network computing system while building on traditional strengths and accommodating the latest technologies and leading-edge open-application environment.

Supports Java and Distributed Object Technology

—Features of the new MP5800E and MP5600E models

Compared to the MP5800 that uses ACE technology to provide the world's fastest uniprocessor performance, the MP5800E models offer 1.3-fold improvement in processing performance, a 15% improvement in price-performance ratio, and support one- to eight-way processor configurations. The MP5800E models also provide built-in LAN adapters and enhanced network connectivity.

Similarly, compared to the MP5600 that set new records for compact implementation and cost-performance by adopting cutting-edge CMOS technology throughout and enhanced parallel processing technology, the E model version achieved a 2-fold improvement in processing performance and a 15% improvement in price-performance ratio. The result is a range of scalability representing a 100-fold increase in power across the same group. This provides a broad array from which to select and expandability that enables a company's mainframe to grow as its business expands.

—Evolution of the VOS3/FS operating system

Even while strengthening the operating system's most basic capabilities of supporting continuous parallel processing of database, batch, and transaction processing 24 hours a day 365 days a year, it has also been significantly enhanced in other ways. The new VOS3/FS is designed to provide support for Java, WWW, distributed objects, data warehousing, and other open application technologies, as well as better connectivity with open networks. This not only supports seamless interworking between new and legacy applications, it also provides a total management approach, and enhances the mainframe's functionality, reliability, and operability as a backbone server.

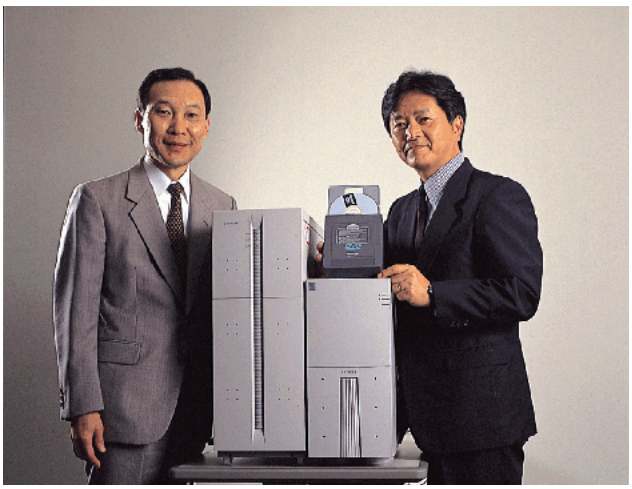
—Future development

Going into the 21st century, Hitachi plans to redouble its mainframe development efforts in order to support the global competitiveness demanded by businesses. While we are currently focusing most of our efforts on developing a next-generation M parallel series model to succeed the ACE technology-based MP5800, we also plan to commercialize a new addition to the MP5600 line that fully exploits a range of state-of-the-art technologies.

Java is a trademark or a registered trademark of Sun Microsystems, Inc. in the U.S. and other countries.
ACE is an acronym for Advanced CMOS-ECL, a Hitachi proprietary technology in which a CMOS (Complementary Metal-Oxide Semiconductor) and a bipolar ECL (Emitter Coupled Logic) element are monolithically integrated on the same chip.

MP5600E Model

DVD Library System for Implementing a Massive Storage Network Warehouse at Low Cost



Masahito Sumitomo (left) and Masao Nakamura (right) of the Digital Media Systems Division were instrumental in developing the DVD library system for long-term storage of massive data.

As the market for electronic data services and contents providers using digital satellite broadcasting and the Internet has continued to expand, this has fueled an increasing demand for systems that can accommodate massive amounts of video, audio, and other multimedia data. At the same time, we are seeing an increasing number of data warehousing deployments and the sheer volume of data handled by ordinary businesses is exploding. Under these circumstances, conventional optical and tape devices are giving out as they reach their natural limits in terms of capacity, long-term storage retention, and operability. It was these considerations which led us to develop a DVD library system that is implemented with DVD-RAM (Digital Versatile Disc Random Access Memory), the new technology that is attracting widespread attention as the next-generation large-capacity universal storage media.

An All-in-One System Integrating Software and Hardware

—Features of the DVD library system

Implemented using 100-by-150 DVD-RAM discs each having a memory capacity of 2.6 gigabytes per side and featuring a built-in high-speed autochanger, the system provides a massive memory storage capacity of 260 by 390 gigabytes. Since DVD-RAM discs support read/write capabilities and of course can be randomly accessed, files can be flexibly updated or deleted. The system has excellent long-term memory retention, and considering its compact implementation and lower cost per bit compared with conventional optical media, this offers the ideal solution for long-term storage of massive amounts of data.

Most significantly, the system provides an all-in-one intelligent storage solution. It comes as an integrated system package with a full range of application-specific software, so there is no need to purchase additional hardware or software to deploy and run the system. The system can also be brought on line very easily by simply plugging it in as is to your existing network, because it supports the open architecture industry standard TCP/IP protocol and Windows NT.

An Extensive Lineup Ranging from Home to Office Use

—Management and maintenance

The DVD library system can be installed anywhere there is a network environment, and thus does not have to be installed near the system operator's terminal as in the past. What is more, the system operator can set up and run the system using a web browser on Windows 95 or NT. A special system operator terminal is therefore not required, and the status of the system can be easily monitored from a remote location. The system is implemented very compactly, and introducing and maintaining the system is facilitated by the fact that it comes in an air-tight case and doesn't require a keyboard, mouse, or display.

—Who are potential users?

The system would be ideal for such media-oriented enterprises as electronic art museums, natural history museums, and electronic libraries, but would also serve the needs of businesses by providing massive capacity storage for documents, records, CAD drawings, and so on. Especially with the recent revision of the tax code that allows national tax records to be held in digital form, the DVD library system offers an excellent way to keep corporate tax records beginning with the first of the year 1999, and to maintain those records for long periods of time at low cost.

—Outlook

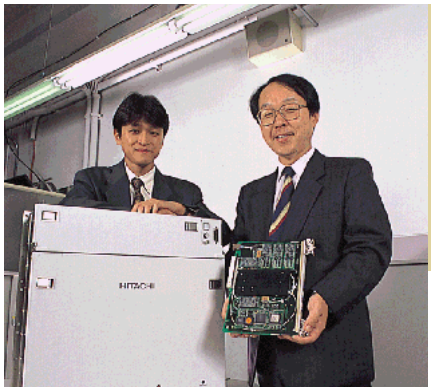
Accepted as an international standard, DVD-RAM offers a high degree of flexibility and will provide even greater capacity at lower cost in the years to come. Hitachi plans to offer an extensive lineup of DVD library systems, not only to serve the needs of the corporate marketplace, but also tailored to the needs of the home market for storing digital satellite broadcasts, images captured with MPEG cameras, and other storage needs.

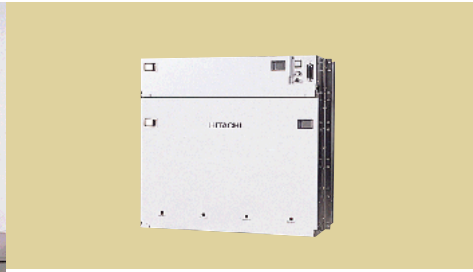
Japan's tax laws were revised in July 1998 to allow tax-related records created by a computer to be maintained in digital form.

DVD Library System

Optical Wavelength-division Multiplexing Transmission System Capable of 320-Gbit/s Transmission

Demand is increasing at an accelerating pace for larger capacity trunk communication lines that can accommodate faster throughputs between Internet terminals and that will support video and other broadband multimedia services. Hitachi is a key player in this emerging worldwide market as exemplified by the popular acceptance of its 10-Gbit/s optical transmission equipment that was rolled out in 1997. Yet demand for increased capacity is relentless. It is projected that demand will increase 20 fold requiring a throughput capacity of 200 Gbit/s by the turn of the century. This motivated Hitachi's Telecommunications System Group in 1998 to develop an optical wavelength multiplexing transmission system capable of combining up to 32 separate wavelengths, each carrying 10 Gbit/s. The device is now being aggressively marketed around the globe along with the 10-Gbit/s optical transmission equipment.





Hiroyuki Nakano (right) and Kazutaka Sakai (left) of the Telecommunications System Group were instrumental in developing the optical wavelength-division multiplexing transmission system.

Combining up to 32 Different Wavelengths, Each Carrying a 10-Gbit/s Optical Signal

—Principle of optical wavelength-division multiplexing

Hitachi is proud of its achievement in developing a rugged practical optical transmission equipment that supports the fastest throughput that is currently available, 10 Gbit/s. Even though this is equivalent to 120,000 voice channels through a single fiber, it is still far short of the capacity needed to support the needs of next-generation multimedia communications. This is why optical wavelength division multiplexing technology is employed, for it allows multiple lightwave signals to be carried on separate channels or wavelengths, over a single fiber at the same time. To illustrate how this works, imagine that data is transmitted by turning a signal on and off using red light. Now, with optical wavelength-division multiplexing, separate signals can be carried over the same fiber using green and yellow in addition to red to turn their respective signals on and off.

—Features of Hitachi's optical wavelength-division multiplexing system

The system is configured using two types of devices: End Terminals (ETs) connected to multiple 10-Gbit/s optical transmission equipment that sorts and routes the lightwave signals carried on separate wavelengths, and line amplifiers (LAs) that amplify and stabilize the signals while they are in route between ETs. Recently, we have succeeded in increasing the number of wavelengths from 16 to 32, for a total capacity of 320 Gbit/s over a single filament of optical fiber, by developing a very stable laser light source that effectively suppresses fluctuations in laser wavelength and a more precise demultiplexer.

Over linear or ring topologies alike, the system permits users to increase the number of optical wavelengths carried in accordance with their needs. This provides a way of flexibly increasing throughput capacity at modest cost without altering the fiber-optic lines that are already in place. The Line Amplifiers are ideal for implementing direct city-to-city infrastructure facilities, because they support relatively long-hop relay intervals up to 400 km thanks to their noise reduction and high level of output.

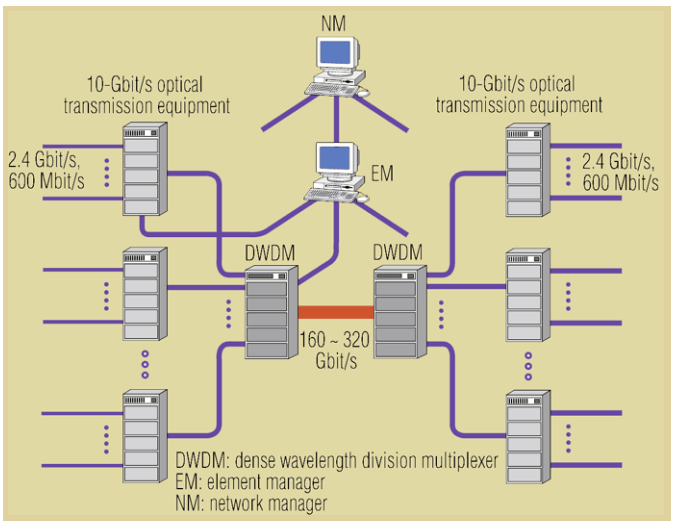
Development of an End-to-End Network Management System

—System reliability and maintenance

A network management system can be easily implemented in the optical wavelength-division multiplexing transmission system by installing an optical interface called Optical Supervisory Channel (OSC) between an ET and an LA for monitoring. We are already equipping the 10-Gbit/s optical transmission equipment with Hitachi's proprietary network monitoring control system called Network Manager (NM), that is fully compliant with the latest TMN (Telecommunication Management Network) international standard. But by implementing both the OSC and NM in combination, this gives Hitachi the ability to support throughput upgrading of trunk transmission links end to end.

—Future development

We now have an Optical Add/Drop Multiplexing System under development that will permit signals at the wavelength level to be split off or combined at intermediate points along trunk networks. By integrating this system with the optical wavelength-division multiplexing transmission system, we can rapidly deploy lightwave communications networks that are flexibly tailored to the needs of customers in much the same way that smaller arterials branch off from highways and highways are interconnected with other highways.



Schematic of the 10-Gbit/s X 32 Dense Wavelength Division Multiplexing System

M-700 Series Microwave Plasma Etching System for Handling Large-diameter 300-mm Wafers

Working out of the Kasado Adminisrative Division, Ken Yoshioka (left) and Yoshiaki Satou (right) were the primaries in developing the M-700 Series microwave plasma etching system.

Etching equipment to cope with shrinking design rules as VLSI technology evolves toward smaller features and new levels of density must not only provide superior processing performance, but must also yield cost merits in terms of return on investment. In addition, there are many obstacles that must be overcome as the industry shifts over beginning in 1999 to larger diameter 300-mm wafer fab lines: automating wafer handling, reducing the footprint of major equipment, and lowering costs. Hitachi has considerable expertise in developing plasma etching equipment that is capable of processing deep submicrometer range features at lower operating pressures. Anticipating the need for even smaller design rules of 0.18-µm and faster throughput, Hitachi developed the Model M-700 Series microwave plasma etching system that already complies with next-generation line standards before it is mandated.

Reconciling Larger Diameter Wafers with 0.18-µm Design Rules

—Technologies to accommodate larger wafers

While most semiconductor devices today are fabricated on 200-mm wafers, this is now changing. In line with the need for new levels of density and greater efficiency, we are now embarking on a new era of more stringent 0.18-µm design rule processing on larger 300-mm wafers. To meet these requirements, the M-700 Series etching system adopts a multi chamber approach with two chambers each for etching and for ashing, and an enhanced version of the microwave plasma source used on the M-600 Series system for processing 200-mm wafers. By optimizing the design of the microwave plasma source for 300-mm wafers, the plasma uniformity reached the level of 6%.

It was a daunting task to reconcile larger diameter wafers with 0.18-µm features. We met the challenge by developing an Advanced-ECR (Electron Cyclotron Resonance) plasma source that effectively controls the overall plasma uniformity, and by further refining the robust processing technology of the current M-600 Series system that is already capable of mass producing devices with 0.18-µm scale features.

Compact footprint and Compliance with SEMI High Throughput

We applied a double-arm high-speed vacuum transfer robot that effectively doubles the arm extension speed of the previous system, and this cut the time in half from 20 seconds to 10 seconds to remove a finished wafer and mount a new wafer for processing. The processing speed has also been reduced by introducing a new type of electrostatic chuck that only requires one plasma discharge. The current production system requires two plasma discharges: one when the wafer is attached to the chuck and the other when the piece is removed from the chuck. In addition, a new system has been adopted for coupling high-frequency power to the ashing chamber, the processing speed has been increased three-fold, 10% uniformity is achieved, and various other design enhancements that improve throughput have been implemented.

—Application to next-generation lines

The space taken up by major equipment in cleanrooms-which are exorbitantly expensive to maintain-is reflected in production costs. The M-700 Series system was implemented very compactly by optimizing the layout, so the system's footprint is only 10% larger than the M-600 Series system. We also incorporated a number of functions and maintenance enhancements that will be required on next-generation lines in compliance with the US-based SEMI (Semiconductor Equipment and Materials Institute), the de facto international standard. These include an air-tight cassette interface, low particle levels, and long-wait cycles.

—Future development

The quest for improved process performance and smaller features sizes, as well as the R&D to sustain these developments is never ended. As the market for larger diameter 300-mm wafers heats up, we plan to further upgrade and refine the performance and reliability of the M-700 Series microwave plasma etching system.

View of the M-700 Series Microwave Plasma Etching System

The World's Largest Helical Fusion Experimental Device, Completed by the Ministry of Education's NIFS



Three persons who have been working on the development of LHD for the past eight years. From left, Yoshikatsu Yasue of the Nuclear Fusion & Accelerator Project Division, Katsuhiko Asano of Nuclear Systems Division, and Sei Inomata of the Chubu Area Operation.

Nuclear fusion research aims to reproduce on earth the hydrogen burning process that serves as the energy source of our sun and other fixed stars, i.e. to establish "a second sun on the earth's surface". Research on this potentially ideal energy source for humanity is advancing in countries throughout the world. As one of the experimental devices developed in the course of this research, this newly-completed Large Helical Device (LHD) is being hailed as a further step toward achieving controlled nuclear fusion.

Putting Japan's Unique Helical Device to Use

—What is NIFS?

The National Institute for Fusion Science (NIFS), an organization established in Toki City, Gifu Prefecture, Japan, in May 1989. Scientists from a number of universities around the country jointly participate in it, with the aim of conducting research on the nuclear fusion plasma principle and its applications. Nagoya University, Kyoto University and Hiroshima University are among the participants. It took eight years to build LHD, the core research equipment there. Plasma was first ignited there in March 1998, and it is now being put to very good use.

—How does LHD differ from other types of nuclear fusion experimental devices?

Many plasma confinement methods are being studied. Like the tokamak device, the method used in LHD is to confine plasma in a doughnut-shaped magnetic field. But unlike the tokamak device, it generates the magnetic field with helical coils and that's where the name comes from. Two coils wrap helically around the outside of a vacuum chamber, and a confining magnetic field called a heliotron magnetic field is formed by running current through the coils in the same direction. This method, developed at Kyoto University, is unique to Japan.

—Advantages of using a helical device

With the tokamak device, a strong driving current is running through the plasma. This has to do with the magnetic field configuration and because of it, the plasma can only be preserved for a very short period of time. With the helical device, however, the plasma rotates as if it were entwined in the line of magnetic force, and thus there is no need for a driving current and you get continuous stable operation as a result.

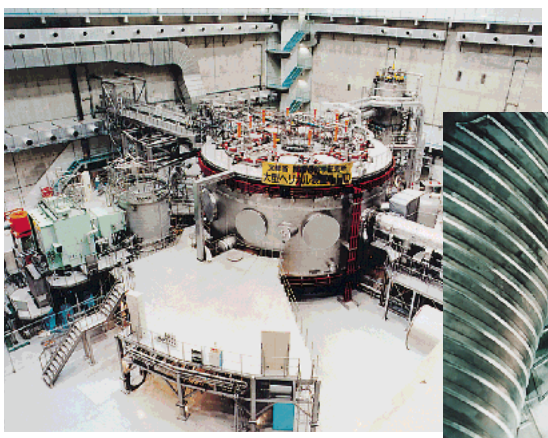
40 Years of History, Still Striving for Higher Technology

—What things did you have to pay particular attention to or put a lot of effort into during the construction of LHD?

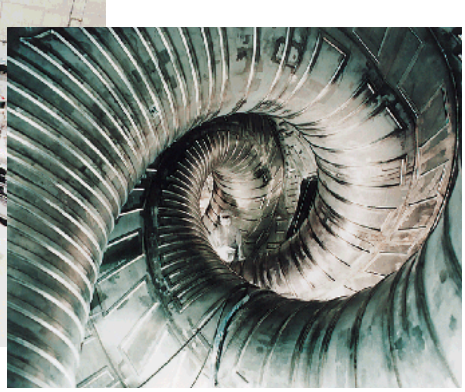
In a big project like this one, it's pretty tough to follow the original development schedule that was laid out. A lot of changes had to be made in the course of the project, changes in development factors and so on, and so we were constantly discussing many different things with NIFS during the research, development, and production steps. We paid a lot of attention to 3D design and production technologies, how to get high precision, accuracy and reliability, high-volume superconducting technologies and so on, and a lot of effort was expended on technologies that none of us has had any experience with before. Then, too, the scale of the device was about two degrees of magnitude bigger than anything preceding it, so inevitably it became an on-site construction project. At the height of the production period there were over 200 employees working on the project, and so we had to pay a lot of attention to personnel management, too.

—Hitachi's involvement in the nuclear fusion field

We are the only manufacturer in the country that has a nuclear fusion experimental device, and we have participated in the design, development and construction of such devices for 40 years. Of course we are very proud of this, but to really make the dream of controlled nuclear fusion a reality, we will have to not only apply the technologies we have developed to date, but also strive to achieve an even higher level of technology. We will have to make even more of an effort in the years to come. While receiving assistance and cooperation from other nuclear fusion research organizations, we will have to make even more of an effort in the years to come.



The NIFS Large Helical Device, with which plasma ignition was first successfully achieved on March 31, 1998. Outer diameter: 13.5m; weight: approx. 1,500 tons; plasma diameter: 8m; magnetic field strength: 3T.



Interior of Vacuum Chamber That Confines the High Temperature (as high as 100 million°C) Plasma. Two superconducting helical coils wrap around the vacuum chamber, giving the chamber the complicated appearance seen in the photograph.

Renewal of the Central Load Dispatching Center at the Kansai Electric Power Co., Inc. for the 21st Century

The renewal project of Central Load Dispatching Center at the Kansai Electric Power Co., Inc. is completed. The central dispatching center is the mainstay of controlling all the generators based on the results of load forecasting. We have developed various functions for this system combining the best technology of distributed systems and optimization methods. And it contributes to realize the advanced operating environment such as reduction of fuel cost for generation, maintaining security control index and supply control index. This system is expected to be the new standard of central dispatching center for the 21st century.

Mr. Shigeru Tamura (left) of the Omika Administrative Division, and Mr. Chihiro Fukui (right) of the Hitachi Research Laboratory took part in the renewal project of Central Load Dispatching Center at the Kansai Electric Power Co., Inc.

Advanced ELD (Economic Load Dispatching) System Considering Dynamic Relation Between the Fuel Cost and the Generation

— When did the project begin?

Every ten or fifteen year that the central load dispatching center is renewed. This is a very big project. We had set about the research and development for the project since 1989. First, we renewed the basic function of monitoring power network such as power flow of transmission lines and output of generators, and then, we developed and installed full system from 1995 to 1997. It was such a big and complicated system with the high expectation of customer that we had made a lot of joint studies with customer. In the process of the joint studies, we developed new algorithms (the procedure to solve the problem or the series of solution) and made effort to implement the new system in cooperation with the research laboratory and the works.

— What is the characteristic point of the new system?

Most remarkable point of this system is the introduction of distributed system and optimization technique. First, in regard to the distribution system, it was constructed from independent sub-systems that include several computers for each function, and the customers can add new functions as sub-systems according to their design preference at any time. Comparing with the former systems that controls whole power network with centralized large host computers, new system provides the highly dependability for running whole system continuously in case of emergency. Second, as for the optimization technique, we give an example of generating power at power plant. It is the problem that should control many thermal generators for reducing fuel cost according to the load fluctuation. For this problem, we had been applying traditional method considering only static fuel cost curve to operate generators efficiently. But to meet the demands of the cost reduction, we developed the technique of advanced ELD, which considers future load fluctuations and can reduce the total fuel cost in a day. From the viewpoint of reducing further the thermal generation cost, we applied the technique of considering dynamical characteristics between fuel cost and generation power in this ELD function. This is the first system in the world that applied this advanced ELD technique.

Main Operation Control Is Thermal and Hydro-pumped Generations

— How the load should be forecasted?

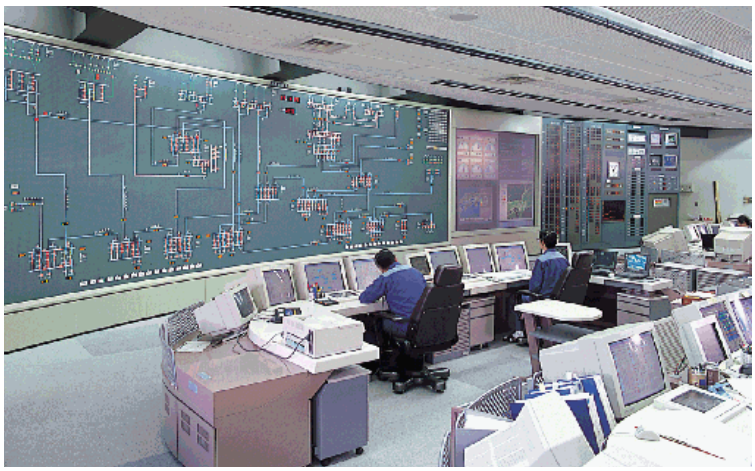
The forecasting result can be revised according to the forecasting target interval, yearly, monthly, weekly, daily forecasting. As the total demand of power depends on the weather and temperature, first, we calculate the weekly rough result of load forecasting, and then, calculate successively the daily result of load forecasting in detail according to the exact data. If we forecast daily load much higher than actual need, it will cost much more than usual, because the available number of generators would be increased. On the contrary, if we forecast daily load much less than actual need, it will also cost much more than usual, because the deficient power should be supplied from the generator or other power company with high cost. Therefore, correct load forecasting is the most important work in the power company.

— What is the target of operation control?

The output power of nuclear generators is almost constant. It is called as base load. Target of ELD detailed above is thermal and hydro-pumped generators. As for the thermal generators, it is important to decide which generators should be stopped in the night, and in regard to the hydro-pumped generators, it is important to decide how much water should be pumped up in the night.

— What is the future trend?

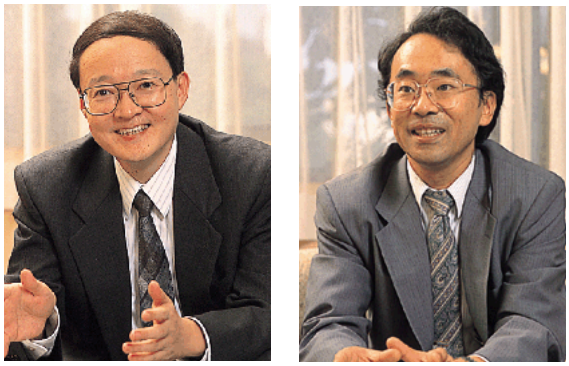
With the progress of time, more and more information-oriented or automation-oriented system will be developed in the future.



Monitoring and Instruction Room at the Central Load Dispatching Center which realize the human friendly interface for operators with large display. Information on the monitoring board is transmitted from the computers made by Hitachi.

An Environmental Management Support System to Help Users Gain ISO 14001 Certification

Environmental management is becoming increasingly vital with the ongoing spread of internationalization and broadening concern for the earth's environment. In this climate, acquiring ISO 14001 (the internationally recognized environmental management standard) certification has been called the "passport" for firms supporting the era of internationalization. The Environmental Management Support System for ISO 14001 certification, developed by Hitachi's Omika Administrative Division, is a tool that meets the needs of such firms. It has earned high praise from users and affiliates of users. For its development Omika Administrative Division in May 1998 received the 25th Environmental Award supported by the Environmental Agency, jointly sponsored by the Environment Investigation Center and The Nikkan Kogyo Shimbun, Ltd.



Co-coordinators of the Environmental Management Support System development program, Yoshiaki Ichikawa (left) of the Omika Administrative Division and Industrial Systems Division, and Seiten Takahashi (right) of the Power & Industrial Systems R&D Laboratory.

Development Planned Incorporating Advanced Know-how

—What is ISO 14001 and what is its objective?

It's an international common standard to help companies and organizations do what they can to solve the problems involved in preserving the earth's environment. Taking environmental protection measures is one of the major management issues in companies, and this standard aims to help them systemize and improve the way measures are taken.

—When was the standard established?

The ISO (International Standards Organization) standardized it in September 1996, and the month after that JIS (Japan Industrial Standard) 14001 was determined. Actually, there was an almost identical standard already in existence in the U.K. at that time, British Standard 7750, and some firms had already been certified under that standard. Our Data Storage & Retrieval Systems Division was the third establishment in Japan to gain BS7750 certification.

—What was the motive in developing the Support System

Our Omika Administrative Division was simultaneously awarded ISO and JIS certification in October 1996, the eighth establishment within Hitachi to be so awarded. But it was pretty hard going for the people in charge of obtaining the certification since all of the work was paper-based. This inspired us to convert know-how accumulated up to then into digital data, not only to lighten our own load but also to create a product for use by others outside the company.

Monthly Updates of Regulation Data via the Internet

—What is it that's particularly hard about getting certified?

Two things, mainly. First, related regulations are modified or updated very frequently, and it's hard to keep up with the changes. Second, we don't know what method will be used to assess environmental impact in the certification process. Also, even if you do become certified, there is an annual check called 'surveillance' you have to pass, and it is necessary to be re-certified after three years. So documents, records and so forth have to be carefully managed. This means that it is essential to have specialized knowledge of laws and regulations, the environmental effects of chemicals and so on. In our case, we started the certification process by compiling an environmental database, using information obtained from Hitachi research labs. We also got a lot of help and cooperation from the CHUO HOKI Publishing Co., Ltd., with their specialized knowledge of environment-related legislation.

—What advantages does the Support System provide to users?

It provides them with impact assessment, regulation checking, document handling, training & education management, and measurement recording functions, and allows them, via the Internet, to get monthly updates of data on environment-related laws and regulations. The Support System is not merely a software package; users can freely use our know-how to make it easier to make preparations for gaining ISO 14001 certification. Some users have been able to get certification in only four months. Preparations for inspections after the second year can also be made smoothly since the process is not a paper-based one. Finally, we also conduct seminars to assist those who want to be certified but do not have much experience in PC usage or Internet accessing.

Window of Access Environmental Impact

Design of the West Japan Railway Company's Series 500 Shinkansen Train—Winner of the 1998 JIII's Inventions Award—

Recipients of National Commendation for Invention (The Prize of the Minister of Ministry of International Trade and Industry) for their creation. From left, Morishige Hattori of the Transportation Systems Division, and Hirofumi Tanaka of the Design Center.

At the National Commendation for Inventions Awards Ceremony sponsored by the Japan Institute of Invention and Innovation in June 1998, the West Japan Railway Company (JR West) and Hitachi, Ltd. received the prestigious International Trade and Industry Minister's Inventions Award for the creation of its Series 500 "Nozomi" Shinkansen, the super-sleek bullet train that links Tokyo with Hakata. At the same ceremony JR West and Hitachi, Ltd. were jointly presented with the Meritorious Invention Award for their development of the train. Highly praised for its combination of design and technology, with a top speed of 300 km/h that ranks among the world's fastest, the train features a unique blend of ideas combined into a forum that goes beyond anything preceding it.

Main Development Objective: Minimize Hard Pressure Waves and Sound in Tunnels

—When and how did the idea for your invention come about?

In November 1991, our Design Center and the Transportation Systems Division jointly sponsored a 'Transportation Vehicle Fair' to showcase Hitachi's railway vehicle technology. This was a first-time experiment for the industry, and one of the models we had on display caught the eye of JR West, which was then looking to achieve higher speed in its trains. It was that model that eventually led to the development of the 500 Series.

—When did the development actually begin?

JR West began doing aerodynamic field tests on the WIN350, a prototype train for the 500 Series, in 1992. In these tests they measured and analyzed factors such as hard pressure waves and sound in tunnels. We also participated in the tests. Actual development started in June of 1993 and we got an order for full-scale production in December 1994.

—What do you mean by "hard pressure waves in tunnels"?

Well, when a high-speed train goes into a tunnel, the air in the tunnel compresses, and when the energy from some of the pressure waves is forced out of the exit at the other end of the tunnel it makes a loud noise. Same principle as a popgun. Now, there are 142 tunnels on the Sanyo Shinkansen track, and they cover almost half the length of the entire track. So the main point in developing the new cars is to reduce the noise as much as possible by further streamlining of the head of the lead car and the cross sections of all the cars.

—So what sort of car shape came out after the development stage?

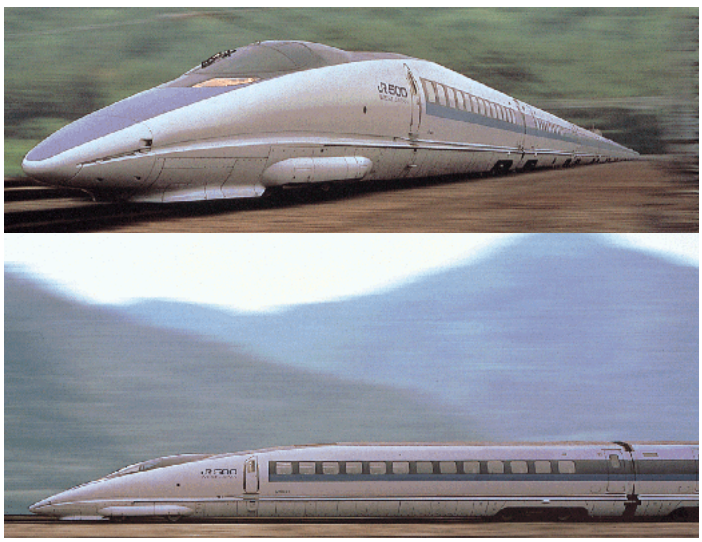
We conducted tests jointly with the Railway Technical Research Institute, and on the basis of the results obtained held discussions with users, planners and designers to determine the kind of shape we would use. In the end we decided to go with a 15-meter nose length for the front car and a cylindrical cross section for the cars. To ensure both lightness and rigidity we decided on an aluminum honeycomb structure, and to reduce air resistance we went for curved-glass windows and plug doors (doors whose surfaces are flush with the surfaces bordering them). And we tried to achieve a uniquely beautiful shape so that the cars would have long-term appeal.

—What results did you get in combining design and technology?

Even at 300 kilometers per hour, we were able to achieve a lower track noise level and fewer hard pressure waves in tunnels than had been achieved previously at 270 kilos per hour with the 300 Series introduced in 1992. Compared with the 300 Series, we reduced running resistance by 30 percent and energy consumption by 15 percent. Finally, we were able to reduce the vibration generated when trains pass each other or run through a tunnel, which makes the ride more comfortable.

—How do you evaluate the speed results you achieved?

First, the 300 kilometers per hour reached on the Sanyo Line is the highest ever for a train. Also—and not many know this—the train set two other records that made the 1997 Guiness Book, an average speed of 242.5 kilos per hour from starting station to terminal station, and an average speed from one station to the next of 261.8 kilos per hour. So the speed records of the 500 Series are there for all the world to see.



Series 500 Shinkansen Train

A High-throughput, Nanometer-level Ultrathin-film Evaluator

In the field of research on next-generation devices and new device materials, and in the device fabrication process, there is a growing need for accurate controlling of the multilayer structure characteristics of nanometer-level ultrathin films. To meet this need, Hitachi has developed the new HD-2000 Ultrathin-film Evaluator, which employs a new electron optics system to observe, analyze, and measure electron-level structures with high resolution and high contrast.

Shigeto Isakozawa (left) and Osamu Tanaka (right), both members of the Instruments, are co-developers of the HD-2000 Ultrathin-film Evaluator.

A New System Combining the Advantages of SEM and TEM

—Objective in developing the HD-2000 evaluator

Year by year semiconductor-based electronic devices are becoming both thinner and more multilayered. So it has become important to achieve film structure and composition where the electron level is on the order of a few nanometers (a nanometer is one-millionth of a millimeter). It is essential to obtain high-resolution images of these thin films so that they can be observed and evaluated. This will be necessary for the development of new semiconductor materials and improve the yield of the semiconductor device fabrication process. But it was becoming difficult to do this with conventional electron microscopes.

For example, users can operate a SEM (scanning electron microscope) while watching the monitor even in a brightly lit room. But the maximum resolution of SEMs is only 1.5 nanometers. With a TEM (transmission electron microscope), on the other hand, resolution is as high as 0.2 nanometers, but TEMs are quite bulky and considerable expertise is required to operate them. Furthermore, obtaining results with them is a time-consuming process because images have to be printed out on paper.

The objective, then, was to develop a tool that combined the advantages of SEMs and TEMs, one that would enable users to observe very thin films with high resolution even in brightly-lit spaces, produce results quickly, and do highly sensitive analysis of the films. This will be a requirement for next-generation devices. This was the rationale behind the development of this unique Hitachi concept, the HD-2000 Ultrathin-film Evaluator.

—Main features of the HD-2000

A newly designed objective lens and X-ray detecting element, which raises analysis sensitivity to about 2.5 times that of a conventional TEM. This makes nanometer-order element analysis possible. Moreover, all operations—from setting test object samples to observing, analyzing and measuring them—can be done in brightly-lit spaces with high resolution of 0.2 nanometers. And images can be easily observed on the GUI (graphical user interface) of a Windows 95 operating system. Of course, as with TEMs no film is necessary. And since all images can be saved as digital data, analysis results can be quickly processed and sent to factories and research laboratories linked by a computer network.

Fast, Pinpoint Sample Production by Linking HD-2000 With FIB

—I hear you were also able to achieve improved throughput in sample production.

In making samples, one must be able to accurately cut parts to be observed, and grind them down to micrometer-order thin films. In the past one had to rely on highly skilled technicians to do this work, and even so it might take as long as 25 hours to complete the job. And pinpoint gate technology could only be applied in limited cases. We then developed a FIB (focused ion beam) device which could automatically cut samples with ions and make samples in about two hours, and succeeded in linking it to HD-2000 with the use of a joint folder. After getting clear images of a sample's inner structure with the HD-2000, we used highly accelerated voltage secondary electron images to obtain the regions to be analyzed with 0.1-μm accuracy, then again used FIB to make high-precision thin films. In this way we were able to fabricate samples more easily and more quickly, in fact with processing speed more than 20 times greater than that of the conventional method.

—What's the next step in your work?

The X-ray mapping of HD-2000 makes it possible to clearly observe nanometer-level element distribution. Here, too, it provides heretofore unattainable precision in analysis. But we would like to go further, to achieve even higher resolution so that element distribution could be shown as more realistic images.

Ultrathin-film Evaluator "HD-2000"

"PAM Refrigerator" Series: The World's First Refrigerators with PAM Control Mode

Kazuhisa Ichimoto (left) and Akinobu Takemoto (right), both members of the Refrigeration & Air Conditioning Division, are co-developers of the PAM Refrigerator.

In October 1998, Hitachi unveiled its "PAM Refrigerator" series, nine refrigerator models employing PAM (Pulse-Amplitude Modulation) control, the first-ever refrigerators with this feature. Following on the heels of the world-standard "Vegetable-centered Refrigerators" (vegetable compartment in the middle) introduced in January 1996, they represent a wholly new concept in home refrigerators. PAM control simultaneously enables both energy saving and high power, earning high praise from industry analysts. In February1999 Hitachi received the International Trade and Industry Minister's Energy Conservation Award from the Energy Conservation Center for the development of the series.

PAM Control Provides Both Energy Saving and High Power

—What is PAM control?

'PAM' is an acronym for Pulse-Amplitude Modulation. PAM control is the technique of controlling the compressor's DC motor to maintain operational efficiency throughout the entire revolutions area, from low speed to high speed. This is the first time this technique has been applied to refrigerators. It was necessary to develop a number of new technologies in order to do this, and so we ended up applying for 18 separate patents during the development period. The idea behind developing PAM refrigerators was to combine energy conservation with the refrigerator's ability to preserve the texture and flavor of the foodstuffs it stores. The PAM refrigerator's "fast-freezing" function, which reduces the freezing time of conventional refrigerators by some 40 percent, also helps to preserve food flavor.

—How were you able to keep the refrigerator's noise level down?

A PAM refrigerator's compressor runs at between 2,000 and 4,300 revolutions per minute, and we tried to obtain energy-saving operation at the lowest possible revolutions area. Furthermore, mechanical resonance is avoided by using a six-step compressor, whose revolutions mode varies with the steps. In this way we can keep noise to a minimum.

Simple Operation: Two Buttons on the Door

—How do PAM refrigerators differ from conventional inverter refrigerators?

With inverter control, the input voltage to the compressor motor is fixed at 250 volts, but with PAM control it is 170 volts for low motor speed and 280 volts at high motor speed. Because of this, the revolutions area is about double that for a conventional refrigerator, and high-efficiency operation can be obtained throughout the entire revolutions area. Also, with PAM refrigerators it is easy to switch between energy-saving operation (with the lowest power consumption in the industry) and high-power operation (with the shortest freezing time in the industry, 25 minutes); all one has to do is push the two buttons on the door.

—What are the main features of the R-S50PAM, the top model in the series?

It's inner capacity is 495L even though it has the same external dimensions as a conventional 450L refrigerator. It consumes less electrical power than any refrigerator in its class. Also, besides the central vegetable compartment and freezer, it has a "variable temperature freezer" in which the temperature can be switched from sub-zero chilled (about -1°C) to full freeze (about -18°C). Finally, it has a separate icebox that makes virtually odor-free ice in only 55 minutes, the fastest in the industry.

—Are PAM refrigerators what you would call 'environmentally friendly'?

Yes. In inverter-controlled refrigerators, the power factor (a measure of how effectively electric power is used) is only about 75%. We have improved that to 95%, which greatly reduces the load on the unit's electrical equipment. The R-S50PAM also uses a more environmentally-friendly packing material than the usual vinyl chloride.

PAM Refrigerator "R-S50PAM"

A 128-Mbit Single-electron Memory: The First-ever Super-highly Integrated Memory Operable at Room Temperature

A single-electron memory is one in which the movement of individual electrons can be controlled, thus allowing one bit of information to be stored by only a few electrons. At the beginning of the 1990's, the possibility of achieving such a memory was but a distant dream, but by 1993, Hitachi had achieved the first-ever single-electron memory that could be operated at room temperature. In 1995 its capacity was increased to 64 bits, and 1998 saw the first-ever development of a 128-megabit single-electron memory suitable for application in today's memory semiconductor devices.

Overcoming Memory Semiconductor Device Limitations

—Could you explain the background to the development of single-electron memory devices?

Today's semiconductor memory devices, such as DRAMs (dynamic random access memory) and flash memories, are basically achieved by combining a capacitor and a switch. Here, the capacitor stores and discharges some 100,000 electrons at a time to record 'o' or '1' binary data. Devices using this system, however, cannot increase memory capacity without limitation, and devices cannot be made smaller than a certain fixed size. Thinking, therefore, how great it would be to have memory that could record with only a few electrons, we came up with the idea of single-electron memory.

Actually, the first proposals for single-electron memory devices were made more than 10 years ago. But these devices could only operate at extremely low temperature of -273°C. It was Hitachi that in 1993 first developed a device that could operate at room temperature. In 1996 an IC (integrated circuit) level device was developed. And then we succeeded in making a big jump in 1998 to the LSI (large-scale integration) level with the 128 megabit device. The capacity of this device is two million times greater than the one that preceded it.

Amassing Electrons in Naturally Formed Minute Pores

—What are the technologies with which the impossible can be made possible?

By making memory scale on the order of 10 nanometers. This is an extremely small scale since it takes 100,000 nanometers to make one millimeter. But since the minimum scale with available processing technology was only 100 nanometers, we then thought of the possibility of applying a natural structure. We fabricated a very thin silicon film, and used the minute pores that formed naturally in it as memory electrodes. By chance the first film formed had a thickness of 3 nanometers, and by good fortune the pores that formed at that thickness turned out to be most suitable for amassing and controlling the movement of electrons at room temperature. And through our unique process for controlling film thickness we achieved operability at room temperature. Then we improved the procedure in two ways by adding 0.25-μm processing technology to it. First, we obtained perpendicular current flow instead of the conventional parallel flow in the memory elements on the wafer surface. Second, we obtained a two-level, top-and-bottom structure. Finally, by applying CMOS (complementary metal-oxide semiconductor) technology for reading and writing, we could construct circuits that automatically controlled writing time in response to memory element variability. It was these technologies that enabled the development of the 128 megabit device.

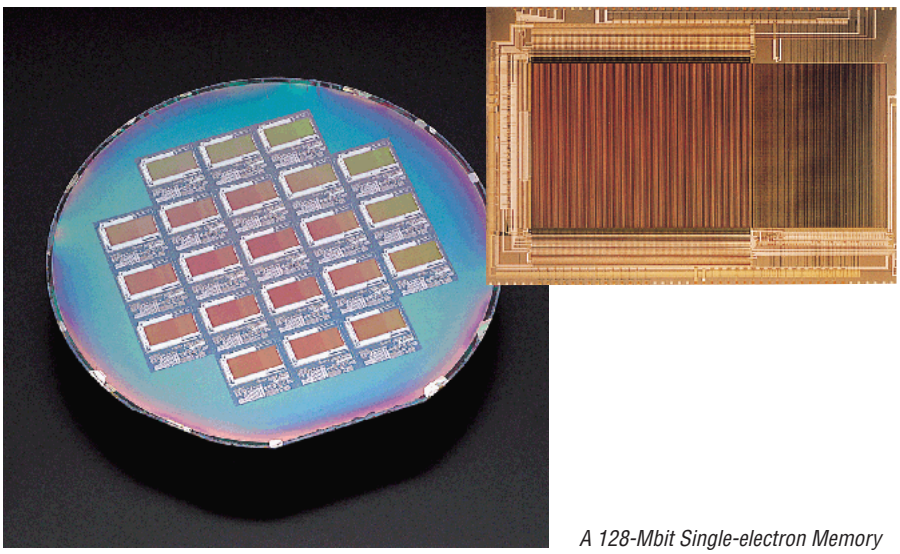
Kazuo Yano (left) and Tomoyuki Ishii (right), both researchers at the Central Research Laboratory, are co-developers of the 128-megabit single-electron memory.

—Advantages of single-electron memory devices

First, because of their simple structure, they are only one-fourth the size of DRAMs with equivalent capacity. Second, if we can get memory structure down to 10 nanometers, we should be able to get memory capacity as high as one trillion bits, instead of the 10 billion with current semiconductor technology. This would be the same as getting all the digital data from 20 full-length feature films onto the tip of your finger.

—What will be the next step in your work?

To make an actual product out of the device, there are a number of choices we will have to make regarding the chip specifications. We will have to decide whether to aim at high access speed, or to put emphasis on production cost, or to maximize memory capacity. At the same time we will have to achieve high reliability in the device and improve it so that it can be suitably mass-produced. We are aiming at putting the device to practical use by the year 2005.



A 128-Mbit Single-electron Memory