

I. Construction Innovation Forum • NOVA Award Nomination**Instructions****Step 1** Enter a Descriptive Name for the Process/Method/Technique you are nominating on line A of this page.**Step 2** Complete this page,
"I. Construction Innovation Forum • NOVA Award Nomination"

- a. Be sure to provide original signatures in Section B and E on this page. Your nomination cannot be reviewed without them.
 b. If you need additional space for names and addresses you may attach additional pages for names and address information.
 You may attach extra pages only for sheet I.

Step 3 "II - Innovation Description" — attach one (one only) 8-1/2" X 11" page that gives a succinct written description of the innovation. Put the name of the innovation at top of page. Tell us what you think is innovative about this. You should include:

- What the innovation is
- Why it is innovative
- What it changed or replaced
- Where and when it originated, has been used, and is expected to be used in the future
- If the nomination is for an innovative project, specifically identify its innovations.

Please type, with 1" margins, 10 characters per inch, 6 lines per inch.

Step 4 "III - Innovation Illustration" — attach one (one only) 8 1/2" X 11" page that contains one or more photographs, drawings, tables, graphs, clauses, etc., that visually describe the innovation. Do not submit more than one page of visuals. The jurors will see only one sheet for review. Put the name of the innovation at top of page.**Other** You must submit 12 (twelve) sets of sheets I, II and III (a total of 36 pages)

Nominations are due September 15 mailed or delivered to:

The Construction Innovation Forum, 1000 Campus Drive, Suite 100, Ann Arbor, MI, USA 48104-6792, Phone: 313-995-1855, Fax: 313-975-5002

A. Name of Innovation: _____**B. Person(s) and/or Organization(s) Primarily Responsible for the Innovation (Those to whom NOVA Award should be presented.)**

Name: _____ Yasuyoshi Miyatake

Title: _____ Executive Vice President

Affiliation: _____ Shimizu Corporation

Address: _____ No.2-3, Shibaura 1-Chome,
Minato-ku, Tokyo, Japan

Phone: _____ 03-5441-1111

Signature: _____ *Yasuyoshi Miyatake*

(Signature(s) indicate acceptance of the nomination and consent to have CIF research and make presentations on the innovation for the purpose of jurying and publicizing awards.)

C. Other Primary Sources of Information on the Innovation: (in addition to the persons nominated above.)

Name: _____ Keiji Murahashi

Title: _____ Deputy Division Head

Affiliation: _____ Technology Division

Shimizu Corporation

Address: _____ No.2-3, Shibaura 1-Chome,
Minato-ku, Tokyo, Japan

Phone: _____ 03-5441-1111

Name: _____ Takeji Matsumoto

Title: _____ Deputy General Manager

Affiliation: _____ Mitsubishi Heavy Industries, Ltd.

Hiroshima Machinery Works

Address: _____ 6-22, 4-Chome, Kanonshinmachi,
Nishi-ku, Hiroshima 733, Japan

Phone: _____ 082-292-3121

Name: _____ Roozbeh Kangari

Title: _____ Professor

Affiliation: _____ Georgia Institute of Technology

School of Civil Engineering

Address: _____ Atlanta, Georgia 30332, USA

Phone: _____ 404-894-2278

D. Independent Reference(s) familiar with the use of the Innovation

Name: _____ Akira Kikuchi

Title: _____ Project Manager

Title: _____ The Juroku Bank Nagoya Project

Affiliation: _____ Nagoya Branch, Construction Division

Address: _____ Shimizu Corporation

3-1-5, Nishiki, Naka-ku, Nagoya

Phone: _____ Aichi 460, Japan

052-961-5430

E. Person(s) making nomination.

Name: _____ Yasuyoshi Miyatake

Title: _____ Executive Vice President

Affiliation: _____ Shimizu Corporation

Address: _____ No.2-3, Shibaura 1-Chome,

Minato-ku, Tokyo, Japan

Phone: _____ 03-5441-1111

Signature: _____ *Yasuyoshi Miyatake*

(Signature(s) indicate familiarity with the innovation and signify that information contained in the nomination is correct to the best of one's knowledge.)

SMART system

SMART is a self-elevating, automated assembly system which provides an integrated building construction environment. When the assembly of one story is completed, the system moves up one level and begins assembly of the next story. The process is repeated until the building has been completed. Prefabricated building components are transported to the construction site in "J.I.T.", and are conveyed directly to the installation position by an automated vertical lift and overhead cranes. The transportation systems and the robots are fully programmable, making the construction system automated. The system consists of an automated transportation system, a lifting mechanism raising the assembly platform, and a dedicated computer system to control the operation.

It is now recognized that single-task oriented construction robots which work in an isolated environment are not having a major impact on overall construction productivity improvement. The major reason for this is that robots have not been utilized in an integrated fashion to realize constructed facilities.

The major part of construction labor cost is related to materials handling. The SMART system provides a flexible construction material transfer in a global concept that integrates all critical materials-related processes. It consists of: Computer aided planning; Transporting and controlling materials in order to optimize resources. This in turn resulted in a major construction cost reduction.

SMART consists of: Automated Conveying System; Lift-up System; Automatic Welding System; Real-time Monitoring System; Production Information Management System; Communication Network. It realizes (1) Automated transportation of prefabricated components(beams, columns, floor panels, window panels, etc.); (2) Automatic placement and adjustment of the prefabricated components in place; and (3) Automatic welding by welding robots with a laser guided positioning.

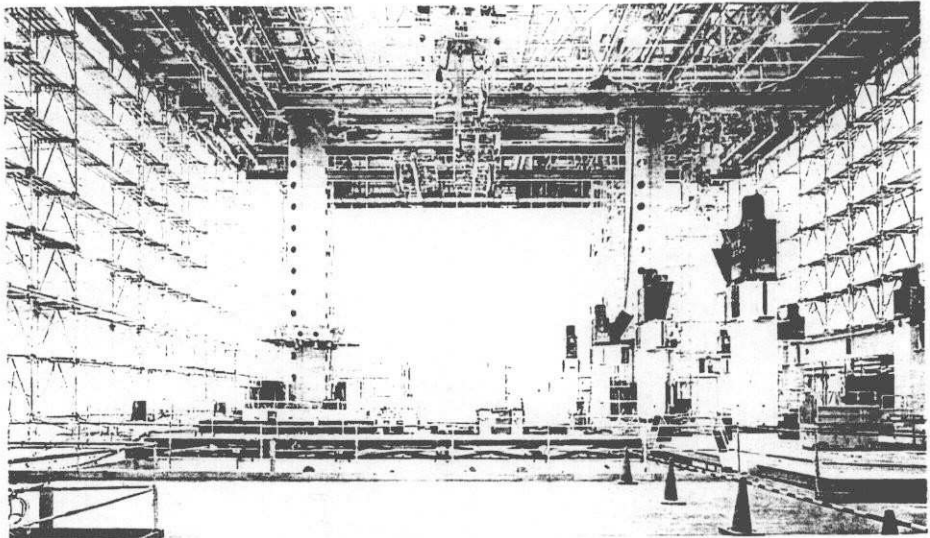
The system is currently used for construction of the Nagoya Juroku Bank building in Nagoya, Japan. The project was started in October 1991, and the SMART operation completes in July, 1993. The building will stand 88 meters tall upon completion in February, 1994 with 20 stories above ground and 2 stories underground. The total floor space will measure 20,000 square meters.

The SMART system at Nagoya has resulted in the development of: (1) Innovative design of structural steel connections (beam to beam, and beam to column); (2) New automatic welding system with a laser guided positioning; (3) New automated flexible construction material-handling system; (4) Enhanced safety specifications; and (5) Improvement of work comfort by all-weather protection. There are a number of advantages gained due to computerized control and robotics, and prefabrication and modulations: (a) Reduction in labor man-hour requirements by approximately 30%; (b) Reduction on site management personnel workload; and (c) Approximately 70% reduction in construction wastes. These new SMART system ideas have provided a major change in the basic way in which building structures are constructed.

SMART SYSTEM



General View



Internal View of the System like Automated Factory
Safe, Bright, All-Weather, and FA-like Construction Environment



Welding Robot

A welding robot travels along the rail welds the joints of steel columns including corners. The robot is also able to check p to be welded with a laser sensor



Control Room

All Weather Working Environment

Construction site is covered by sheets to protect from the affects of the weather.

Control Room

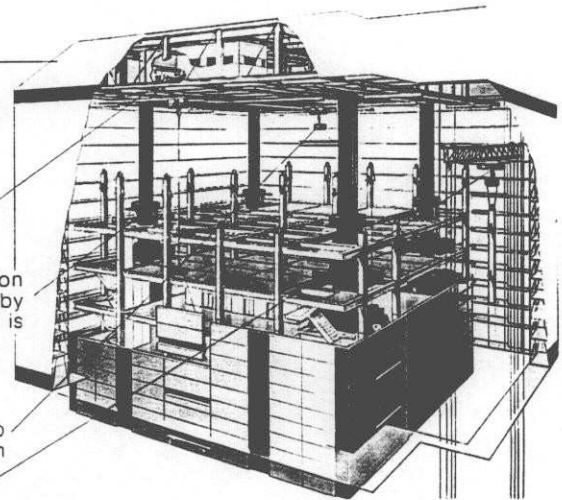
All equipments such as Material Transportation System and Lift-up System are controlled by computer. The motion of each equipment is displayed in real-time on monitor screens.

Lift-up System

When one floor is completed, the Lift-up System lifts up the entire operating platform smoothly. (about 90 min./one floor)

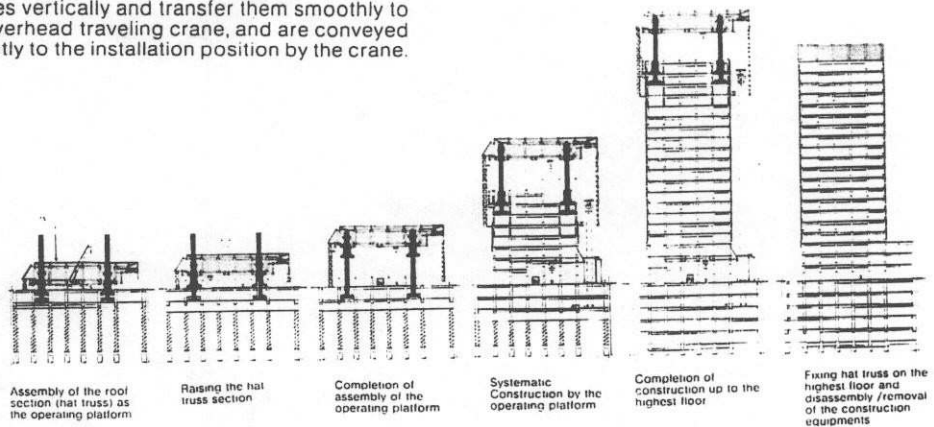
Material Transportation System

Materials are hung from the hoists, which then moves vertically and transfer them smoothly to an overhead traveling crane, and are conveyed directly to the installation position by the crane.



Steel Column Erection

Columns are normally designed for easy and



Construction Procedure by the SMART SYSTEM

AWARD MANAGER'S SUMMARY

AWARD MANAGER'S SUMMARY
Nomination 9402

THE SMART SYSTEM

The Innovation

The SMART system is a self-elevating assembly factory for the construction of highrise buildings. The system provides an enclosed construction environment and uses sophisticated, automated subsystems that form an integrated whole.

Major subsystems included in the SMART system are an automated conveying system, a lift-up (or raising) system, an automatic welding system, a real-time video monitoring system, a production management information system, and a communications network.

These integrated systems make it possible to:

- (1) Automate the transportation of prefabricated components. (beams, columns, floor panels, window panels, etc.)
- (2) Automate the placement and adjustment of the prefabricated components.
- (3) Automate the welding of the components by using welding robots and laser guided positioning.

Using a "just in time" philosophy, prefabricated building components are transported to the construction site and are conveyed directly to their installation positions. A vertical lift system, that resembles a conventional bridge crane hoisted by cables at the ends of the bridge, is used to lift the components to the assembly floor. This system has sensors that detect the swinging movement of the load and automatically stop the lift if the movement is beyond normal. When the load reaches the assembly platform, it is automatically transferred to other bridge type cranes and moved into its final position. Once the load is self supporting, the hook of the crane is automatically released. The entire movement of the load from truck to position is automatically controlled by computers and observed by the video system.

Building frame components must be fabricated with special shapes and end connections. Columns have hollow square cross sections. The lower column segment has a cross shaped stud projecting from its top. This engages the bottom of the upper column and serves as temporary support until the two segments are welded. Column to column connections are made by computer controlled automatic welding robots that make multiple pass welds around the square column. The columns are made plumb by use of a laser set at the base of the column.

At the start of the SMART operation, the roof and top floor of the building is constructed. The cranes are installed beneath

the top floor and the main control room is built on the floor. These units are then raised to the top of four lifting towers that resemble the tower legs of an off-shore drilling platform. The exterior is covered with a weatherproof net that protects workers and materials so that the space becomes a covered factory-like work environment.

It is within this enclosure that the assembly of the building floors takes place. The building frame of columns and beams is erected, and prefabricated floor and wall panels are installed to complete one story. When the assembly of one story is completed, the enclosure is jacked up one level and begins the assembly of the next story. The process is repeated until the building has been completed.

The base of each of the four lifting towers has six legs that rotate into place and rest on the girders in the building. Two floors up from the base is another fixed support that provides stability and has lifting jacks. The raising of the towers begins by retracting the legs on the base and then the jacks pull the tower base upward one floor. The base legs are then extended to bear on building girders. The jacking ring is then repositioned. All the lifting jacks are controlled by computer so that all four lifting towers are raised at the same time.

The computerized management control system has specially design computer software. The software for controlling the movement of the components and other material uses the latest techniques for optimizing transportation costs based on queuing and optimization theory. The transportation system uses a real-time CAD display. Sensors throughout the system cause animated pictures to appear on a computer screen thereby allowing the system's operators to track the position of each component as it moves into position. Ten video cameras feeding into five monitors in the control booth at the top of the building also show operations taking place on the floor. This video system is used for fine control of material movement, for the enhancement of safety, and for a backup to the sensor system.

There is two-way communication between the ground floor where the components enter the system and the factory assembly floor. There is an auxiliary control room on the second floor that focuses on the reception of the units and interacts with the

Background of Innovation

The Shimizu company has been a leader in the development of construction robots. However they have now recognized that construction robots oriented toward a single task or which work in an isolated environment are not having a major impact on overall construction productivity improvement.

Shimizu also recognized that a major part of construction labor cost is related to material handling. These two factors

lay behind the development of the SMART system. The SMART system integrates some construction robots and automates the material handling operations that occur during the construction of a highrise building. The result is that labor costs are lowered, labor quantities are reduced, and the speed of erection is increased.

The Taisei Corporation has developed a system called T-UP. T-UP is similar in terms of jacking up the building, but it uses the building frame directly instead of the four jacking columns of SMART. T-UP uses some automatic welding and has a simple control system, but does not appear to have reached the level of integration displayed in SMART.

Application

The system has most recently been used for construction of the Nagoya Juroku Bank building in Nagoya, Japan. The project was started in October 1991, and the SMART operation was completed in October, 1993. The building will stand 88 meters tall upon completion in February, 1994, with 20 stories above ground and 2 stories underground. The total floor space will measure 20,000 square meters. The internal finishing of the building is now being done and the project is on schedule.

The Nagoya building is actually the second building built using SMART, but it is the first commercial building. The first building constructed using the system was a demonstration building on the Shimizu site.

The system is flexible and can be adapted to other buildings. Seventy to eighty percent of the system can be used again, but it appears that probably twenty percent or so is not salvageable.

Shimizu is planning to apply the system to two new projects; a 29 story building and a 57 story building, both in Tokyo.

Notes on Nominated Persons

Mr. Yasuyoshi Miyatake is the Executive Vice President of Shimizu Corporation. He was the top person in charge of the development of the SMART system.

Opinions of Outside Persons

Professor C. William Ibbs

Professor Ibbs is one of the leaders in construction robotics technology. He is from the University of California at Berkeley. Professor Ibbs visited the SMART system in Nagoya last summer. His visit was on the last day of use of the lift system, so the use of the system was nearing completion. Professor Ibbs talked

to the Shimizu principles who were there to observe the dismantling of the lift system. Professor Ibbs did not visit any site other than Shimizu.

Professor Ibbs says that the SMART system is really an integration of nine subsystems. He said that he was impressed with integration of these systems, the size of the operation, and the spotlessly clean working area. He said he was, in fact, overwhelmed.

Professor Ibbs says that Nagoya is a city with lots of industrial fabrication facilities. It is the center of the Japanese auto industry. Because of this, the SMART system is amply supported. Nagoya is not as congested as Tokyo or Yokohama. There appears to be a trade off between fabrication and congestion which could make a difference as to the future use of the system.

Dr. Roozbeh Kangari

Dr. Kangari is Professor of Civil Engineering at the Georgia Institute of Technology. He has been a researcher of construction robotics for a number of years. He spent his last sabbatical in Japan working on robotics projects with the Shimizu Corporation. Professor Kangari visited the SMART system in Japan in March, 1993. He spent three days at the site. At the time of his visit they were erecting the tenth floor of the Nagoya Bank building

Professor Kangari says that the SMART system is designed for earthquakes. It is designed to not damage the building under construction.

Professor Kangari says that Shimizu America is Shimizu Corporation's subsidiary in the United States and that they have offices in Los Angeles and New York. Professor Kangari says that these offices act as project managers for Shimizu and other Japanese companies working in the US. He doesn't think they are very familiar with the SMART system.

Mr. Keiji Murahashi

Mr. Murahashi is Division Head of the Technology Development Division of the Shimizu Corporation. He does not speak English well, so Mr. Okubo, Deputy Division Head served as interpreter during the interview with Mr. Murahashi.

Mr. Murahashi was asked if other Japanese companies were doing similar things. He said that other companies are investigating methods for the erection of highrise buildings, but the Shimizu SMART system is the only one with such a high level of integration of the subsystems. The others are more primitive when compared to the very advanced SMART system.

Mr. Murahashi said that the SMART system function on the Nagoya building was completed in October, 1993, and it has been dismantled. The internal finishing of the building is now being done and the project is on schedule.

Award Managers' Comments

The SMART system seems to be an advance in the construction of highrise buildings. It is an integration of systems into a total configuration that has a number of implications for these types of structures. Labor has a clean, secure environment in which to work, and even though the final structure is very tall, all construction tasks are being carried on at low levels.

Both Mr. Murahashi and Mr. Okubo of the Shimizu Corporation seemed excited about being on the short list for the award. They were very cooperative.

SELECTED INTERVIEW SUMMARIES

Phone Interviewer: Harris
Date: 11/23/93

#9402
No. 1

Name: Dr. Roozbeh Kangari
Title: Professor
Affiliation: Georgia Institute of Technology
School of Civil Engineering
Atlanta, GA 30332

1. Professor Kangari visited the SMART system in Japan and spent three days at the site. One of the innovative things in the system is the material handling system. It uses nontraditional cranes that open up new horizons. They move in an enclosed environment. The vertical transportation system has a sensor system that will stop the lift if the movement is beyond normal. It stops the load from swinging.
2. Another innovative thing is the connection between beams and columns and from column to column. These connections are made with a welding robot. The use of the robot requires different end shapes for the beams and columns.
3. The welding is innovative. The welding is by robot that circles the column and makes three passes. The columns have self aligning guides to permit this method.
4. The columns are made plumb by the use of a laser at the base of the column and a target at the column top.
5. There are also computer software issues that are innovative. The software for controlling the movement of material uses the latest techniques on queueing theory and optimization. The optimization is based on optimizing transportation costs.
6. The SMART system uses a real-time CAD system to show the position of the material. Sensors cause animated pictures to appear on the computer screen. Video cameras show the operations on the floor and are used for finer controls and for safety. They also monitor material movement and serve as a backup to the sensor system.
7. The SMART part of the building being built at Nagoya is complete. The Nagoya building is actually the second building built using SMART. The first was a demonstration building on the Shimizu site. Nagoya is the first commercial building being built with the SMART system. The system is flexible and can be adapted to other buildings. A third project is under study that will be taller and bigger. Dr. Kangari believes this building will be near Tokyo. The company needs to convince the client of SMART's feasibility. Seventy to eighty percent of the system can be used again. Probably twenty percent or so is not salvageable.
8. Professor Kangari says that the SMART system is designed for

earthquakes. It is designed to not damage the building under construction.

9. When Professor Kangari was there in March of 1993, they were erecting the tenth floor.

10. Roozbeh refers us to Bill Ibbs at University of California at Berkeley and to the ENR fellow that prepared the article in that magazine.

11. As to others on the nomination sheet:

Mr. Miyatake is the top person in charge.

Mr. Murahashi is very knowledgeable but he doesn't speak English.

Mr. Matsumoto is unknown to Dr. Kangari.

Mr Kiuchi is not fluent in English.

12. Shimizu America is the company's office in the US. They have offices in Los Angeles and New York. Professor Kangari says that these offices act as project managers for other Japanese companies working in the US. He doesn't think they are familiar with the SMART system.

Phone Interviewer: Harris
Date: 11/26/93

#9402
No. 2

Name: Dr. Roozbeh Kangari
Title: Professor
Affiliation: Georgia Institute of Technology
School of Civil Engineering
Atlanta, GA 30332

1. Professor Kangari has arranged for Mr. Murahashi to call me on the evening of November 30. This is a day later than previously planned.
2. Mr. Murahashi doesn't speak enough English so a translator will be used.
3. Mr Murahashi is more knowledgeable about SMART than is Mr. Miyatake.

Phone Interviewer: Harris
Date: 11/30/93

#9402
No. 3

Name: Keiji Murahashi and Mr. Okubo
Title: Division Head Deputy Division Head

Affiliation: Technology Development Division
Shimizu Corporation
No.2-3, Shibaura 1-Chome
Minato-ku, Tokyo, Japan

Mr. Murahashi does not speak very good English. Mr. Okubo served as translator.

1. Mr. Okubo said that they would send additional and more complete information, but that the main characteristics of the SMART system are:

(a) An automated transportation and conveying system. When a prefabricated unit of the structure arrives by truck, it is picked up with the lifting system and then transferred to other cranes at the top. It is then moved into final position. This process is all computer controlled. It might be called a robot.

(b) The use of a robot welding machines for column to column connections. These machines are controlled by computer with instructions in a database. The alignment of the columns is laser guided. The robot works on square columns.

(c) A simplified installation. The factory-like assembly of the building floors.

(d) The management control system. This is a computer management system that uses ten video cameras the feed into five monitors in a control booth at the top of the structure,

(e) The covered factory-like work space. The exterior is covered by a weatherproof net that protects workers and materials from the weather so that the space becomes siimilar to an industrial shop.

2. Each base of the four lifting towers has six legs that rotate into place and rest on three girders in the building. These legs are retracted during jumping the towers from floor to floor. Two floors up from the legs is another fixed point to provide stability. All the lifting is controlled by computer. All four lifting towers are raised at the same time.

3. There is two-way communication between the ground floor where the material enters the system and the factory floor where the pieces are being assembled. There is an auxillary control room on the second floor that focuses on the reception of the units and interacts with the control room at the top of the building.

4. During column erection, the crane hook is automatically released as soon as the top column is seated.

5. Mr. Murahashi was asked if other Japanese companies were doing similar things. He said that other companies are investigating methods for the erection of highrise buildings, but the Shimizu SMART system is the only one with such a high level of integration of the subsystems. The others are more primitive when compared to the very advanced SMART system.

6. The SMART system function on the Nagoya building was completed in October 1993 and it has been dismantled. The internal finishing of the building is now being done and the project is on schedule.

7. Shimizu is planning to apply the system to two new projects; a 29 story building and a 57 story building, both in Tokyo.

8. Shimizu will send additional information.

NOTE:

Both Mr. Murahashi and Mr. Okubo seemed excited about the prospects. They were very cooperative.

Phone Interviewer: Harris
Date: 12/21/93

#9402
No. 4

Name: C. William Ibbs
Title: Professor
Affiliation: Department of Civil Engineering
215-A McLaughlin Hall
University of California - Berkeley
Berkeley, CA 94720

1. Professor Ibbs visited the SMART system in Nagoya last summer. It was on the last day that they were using the lift system, so the use of the system was nearing completion. Professor Ibbs talked to the Shimizu principles who were there to observe the dismantling of the lift system. Professor Ibbs did not visit any site other than Shimizu.
2. Professor Ibbs says that the SMART system is really an integration of nine subsystems. He said that he was impressed. He was overwhelmed.
3. The cables seen in the pictures of the lift system are the lifting cables. They lift the bridge of the crane at the ends of the bridge,,
4. Taisei Corporation has a system called T-UP. T-UP is similar in terms of jacking up the building, but it uses the building frame directly instead of the four jacking columns of SMART. T-UP also has automatic welding and a control system. Professor Ibbs understands that there is not as much integration of systems in T-UP.
5. Professor Ibbs was impressed with the spotless clean working area. He was able to collect a lot of data while on the site.
6. Nagoya is a city with lots of industrial fabrication facilities. It is the center of the Japanese auto industry. Because of this, the SMART system is amply supported. Nagoya is not as congested as Tokyo or Yokahama. There appears to be a trade off between fabrication and congestion which could make a difference as to the future use of the system.
7. The use of the SMART system has influences on the prefabrication processes being used. It changes the way that steel is fabricated in both shape and size.
8. The system operators, the controllers, are Shimizu employees. Most of the other employees are subcontracted. Fabrication and Erection are both subcontracts.

CONTACTS MADE

Contacts Made

Name: C. William Ibbs
Title: Professor
Affiliation: Department of Civil Engineering
215-A McLaughlin Hall
University of California - Berkeley
Berkeley, CA 94720

Name: Dr. Roozbeh Kangari
Title: Professor
Affiliation: Georgia Institute of Technology
School of Civil Engineering
Atlanta, GA 30332

Name: Mr. Keiji Murahashi and Mr. Okubo
Title: Division Head Deputy Division Head
Affiliation: Technology Development Division
Shimizu Corporation
No.2-3, Shibaura 1-Chome
Minato-ku, Tokyo, Japan

Components of the SMART System

Operating Room

The SMART system is controlled by one operator

Hat-Truss

Monorail hoists are set by structure, and will eventually top of the building

Weather Protection Cover

The entire construction site is covered by sheet to avoid any affect of the adverse weather.

Jacking Tower

Automated Building Construction Plant is supported by four Jacking Towers

Steel Column Joint

Joints of steel-frames are specially designed for easy assembly.

Welding Robot

Steel-column and beams are welded automatically by Welding Robots

Automated Exterior Panel Installation

Window panels and air conditioning units are pre-installed in the curtain



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y be the

Monorail Hoist (Horizontal Transportation)

Trolley hoists carrying construction materials run along a ceiling rail transporting materials automatically.

Vertical Lifting Crane

Hoists with the structural frames are lifted to the construction plant

Lifting Mechanism

The construction plant is lifted floor by floor by hydraulic jacks

Pre-cast Concrete Floor Planks

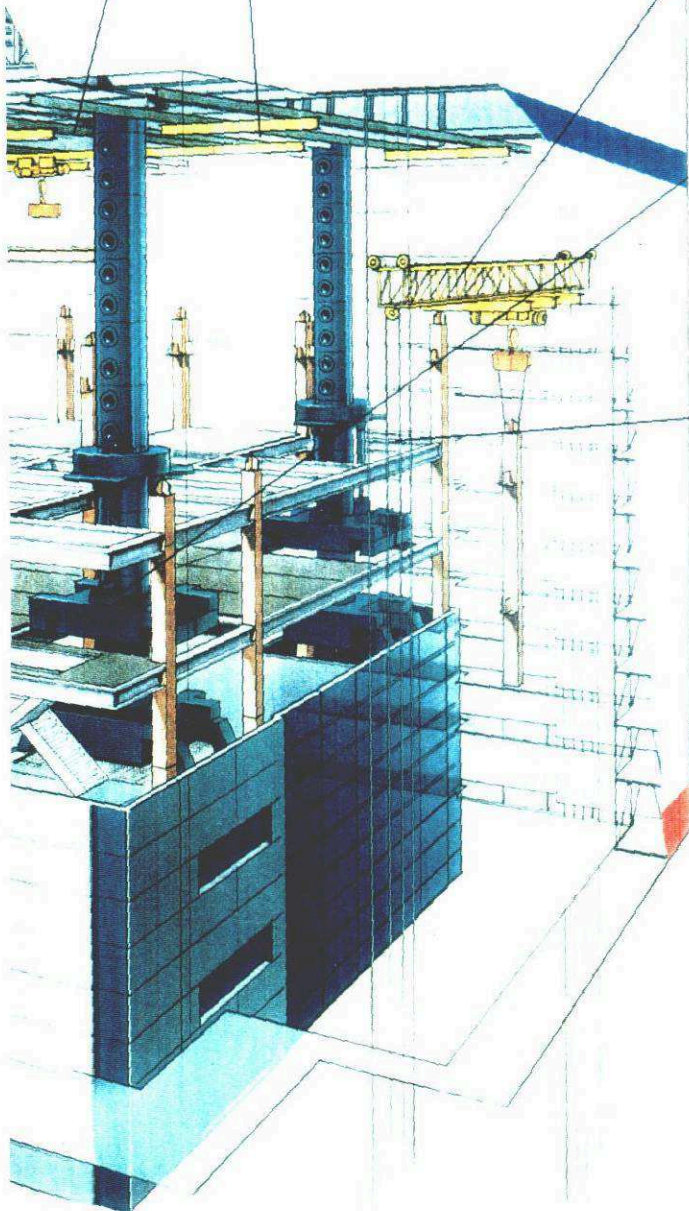
Pre-cast concrete floor planks are transported and set on the beam by conveyor system.

Pre-fabricated Units

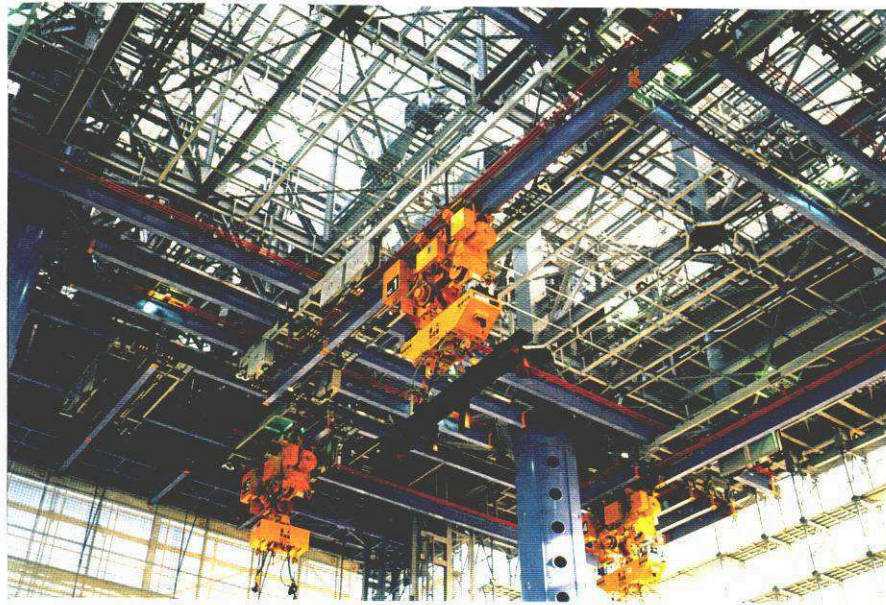
Pre-fabricated units of pipes, pipe shafts and toilets are used

Construction Waste Reduction

Building materials are pre-cut, pre-fabricated to reduce construction waste



1. Automated Transportation System



Overhead Cranes and Monorail Hoists



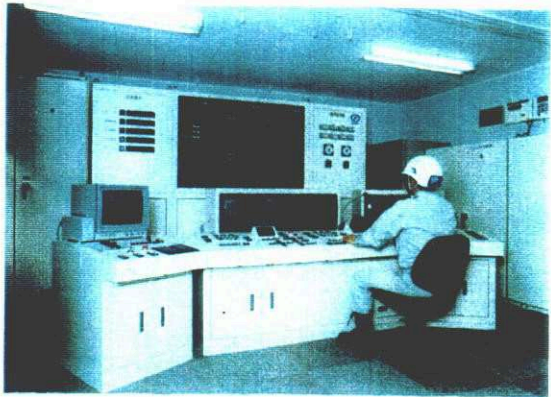
Vertical Lifting Crane



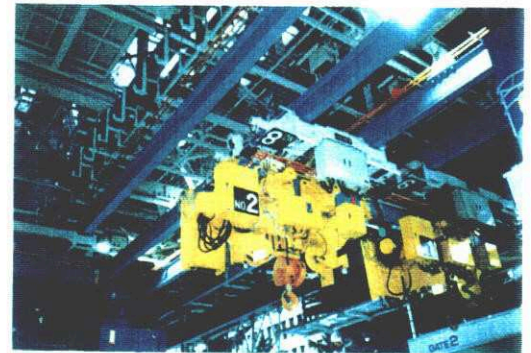
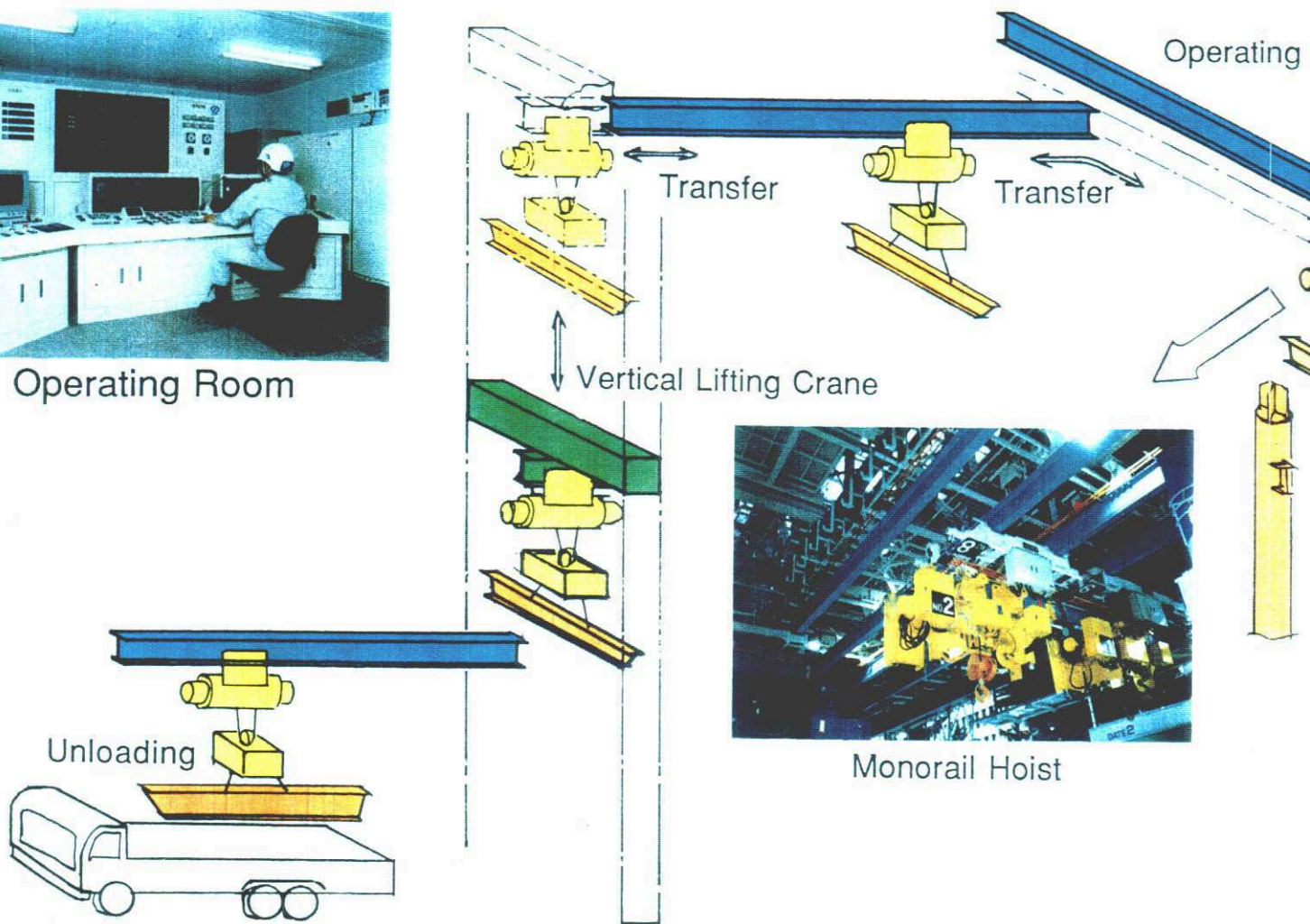
Automated Transportation
System

Material conveying System

《 Conveying and Positioning Work - Outline 》

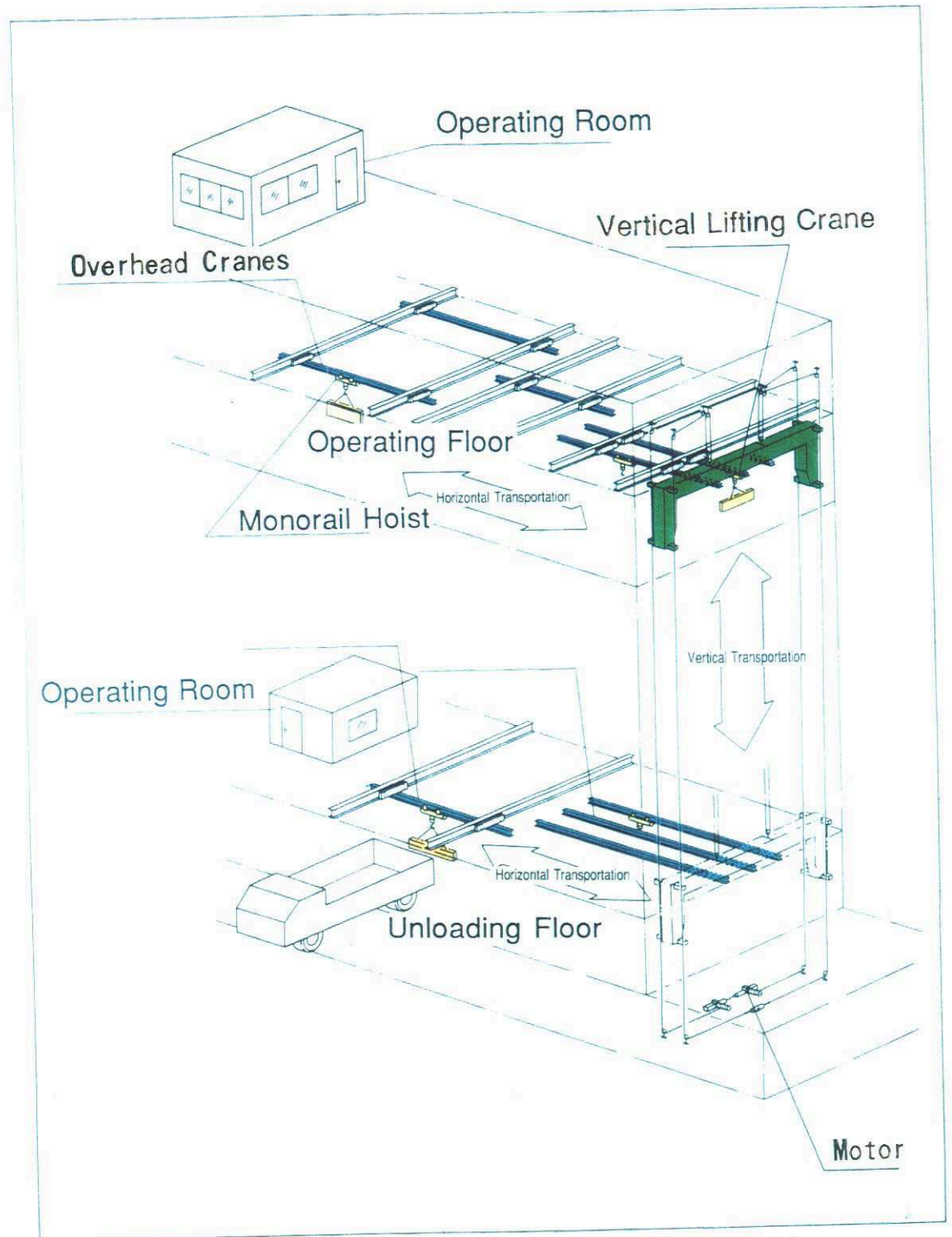
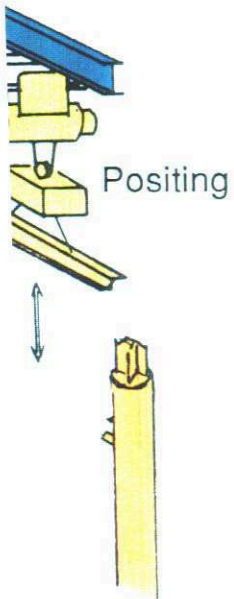


Operating Room



Monorail Hoist

loor



Automated Continuous Transportation System

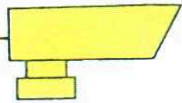
Operating Control System of SMART

Control Room at the Operating Platform



Insulated Trolley for Control Signal

Monitor Camera



Display of Material Code

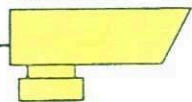


Computer Utilized for Production Control



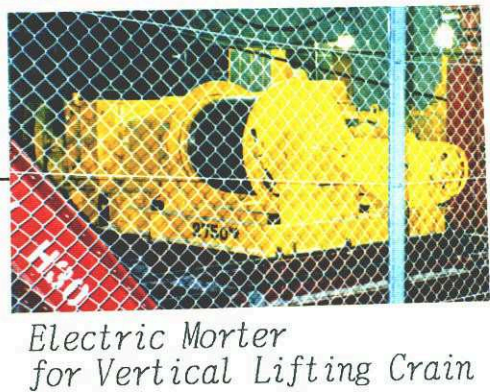
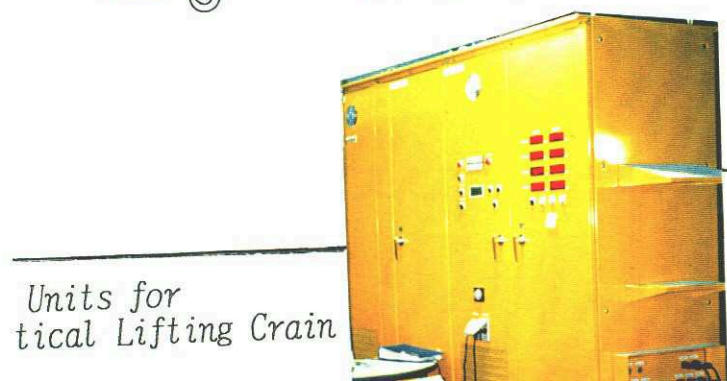
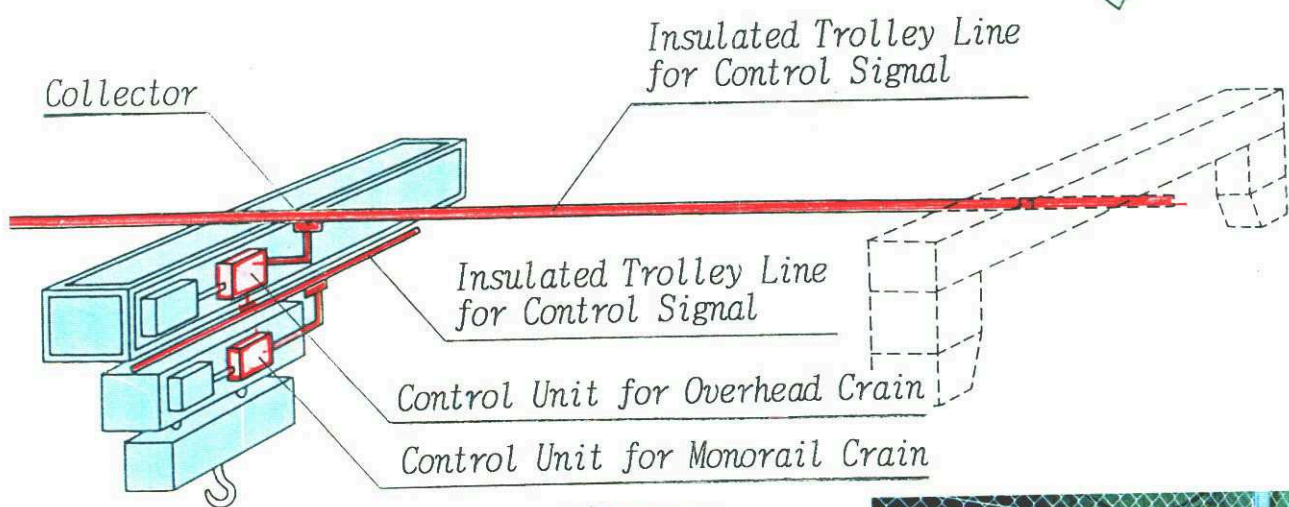
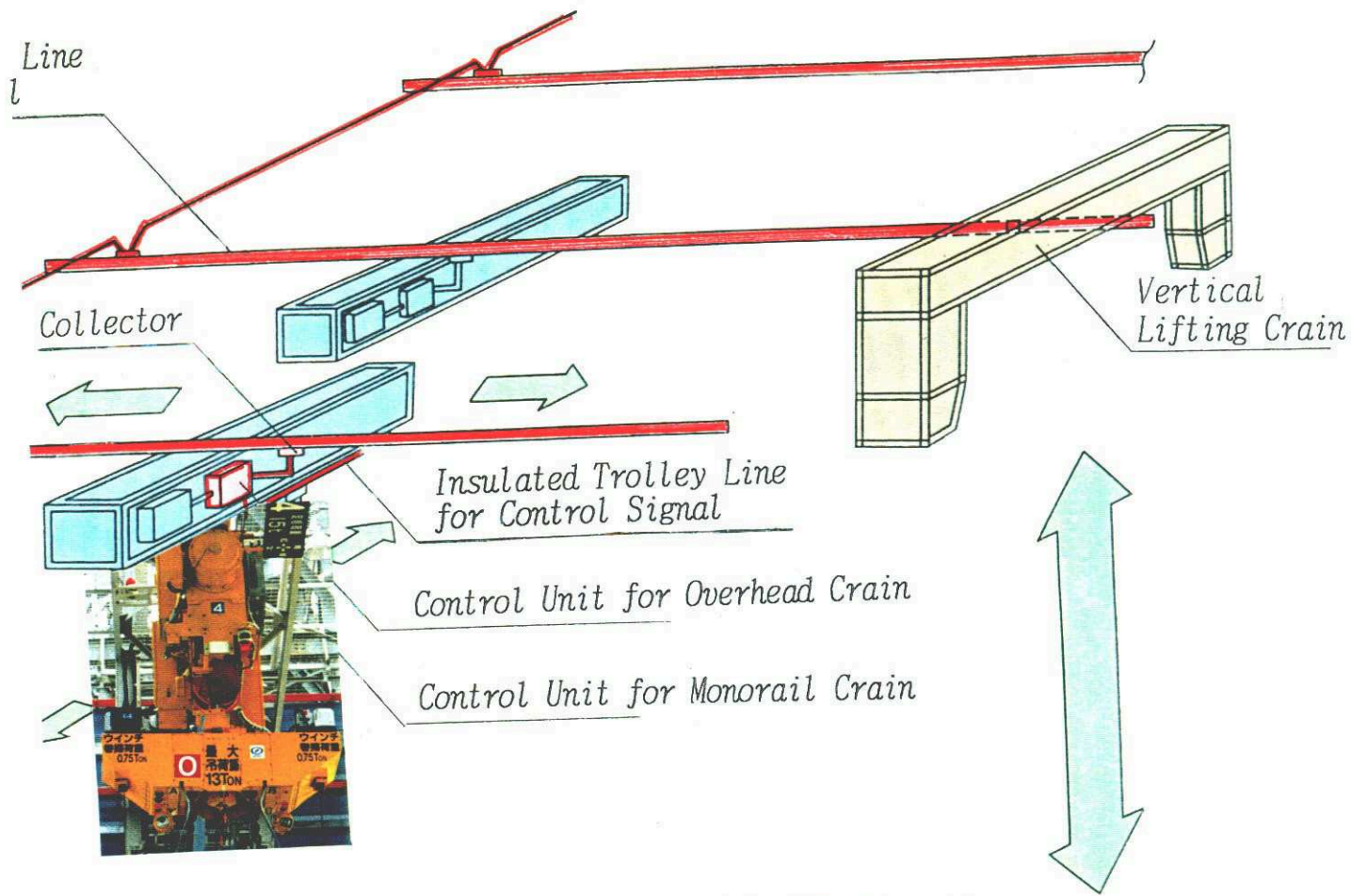
Control Room at Ground Floor

Monitor Camera

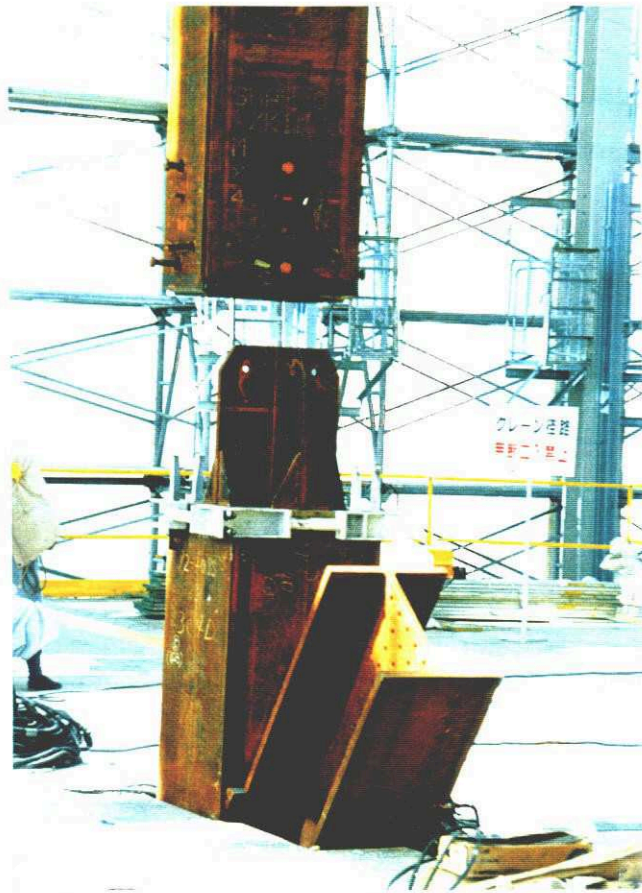


Display of Material Code





2. Steel Assembling System



Column-to-column Joint suited for automated Assembly

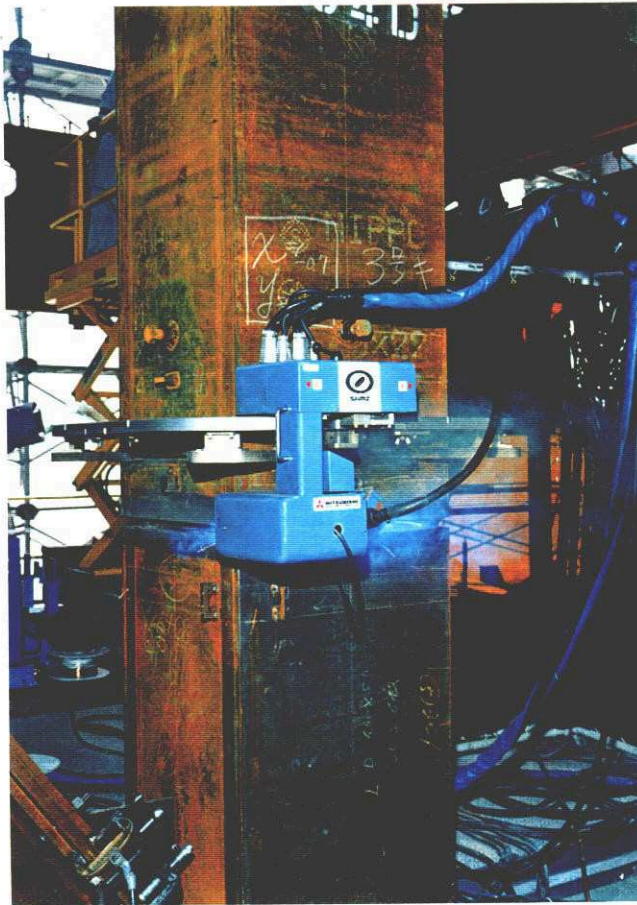


Automated Measuring and Adjustment system of Columns

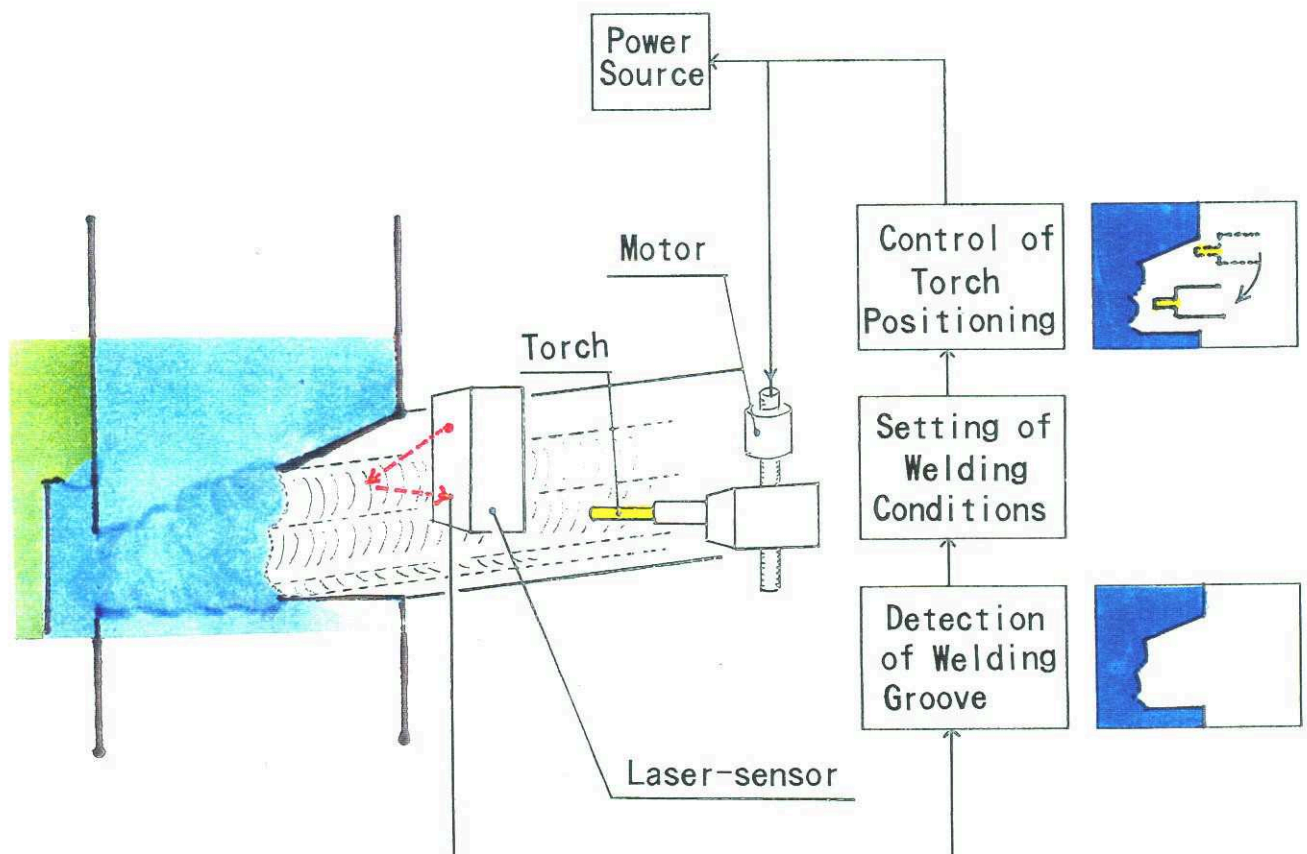


Remote Control of Crane Releasing

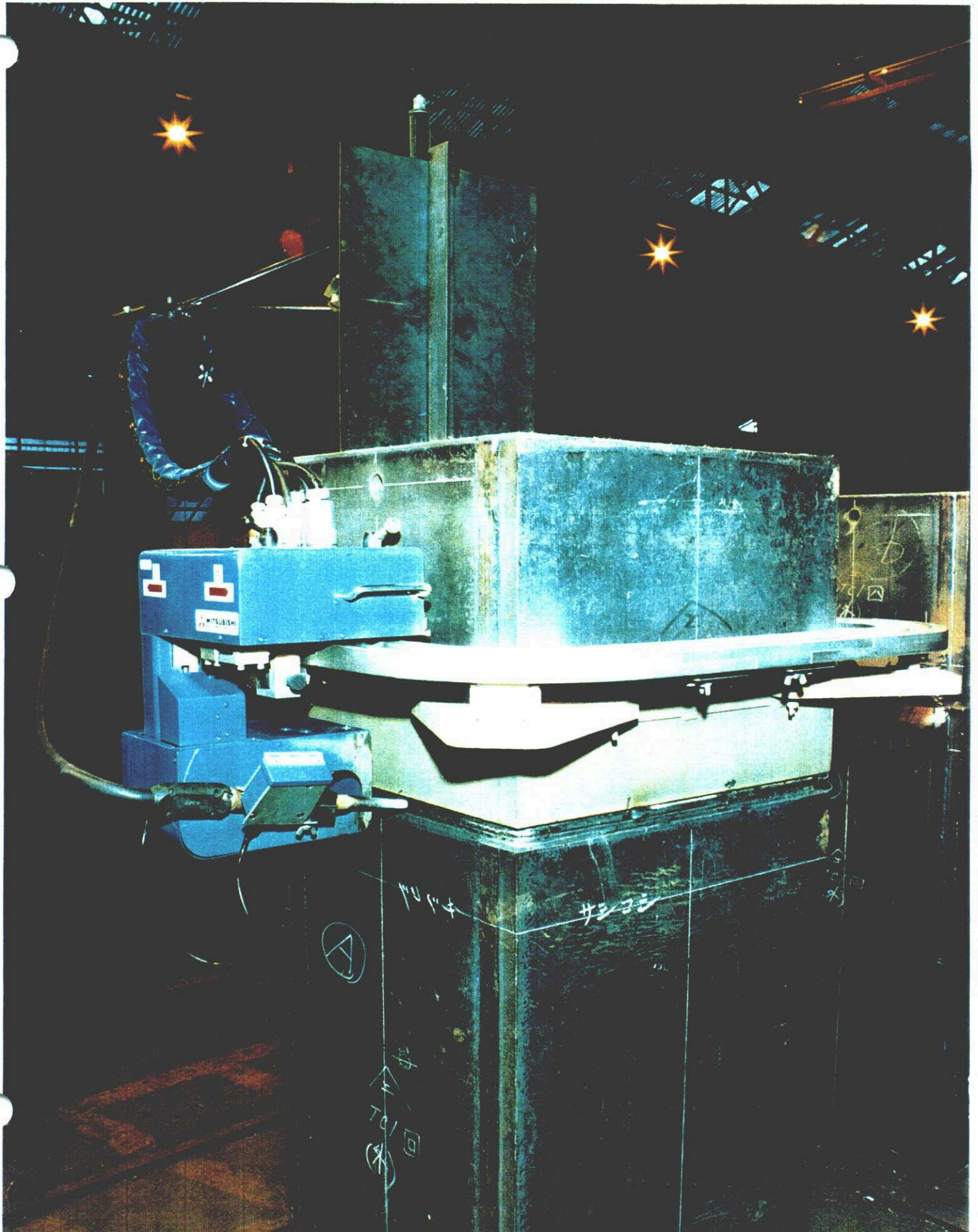
3. Automated Welding System



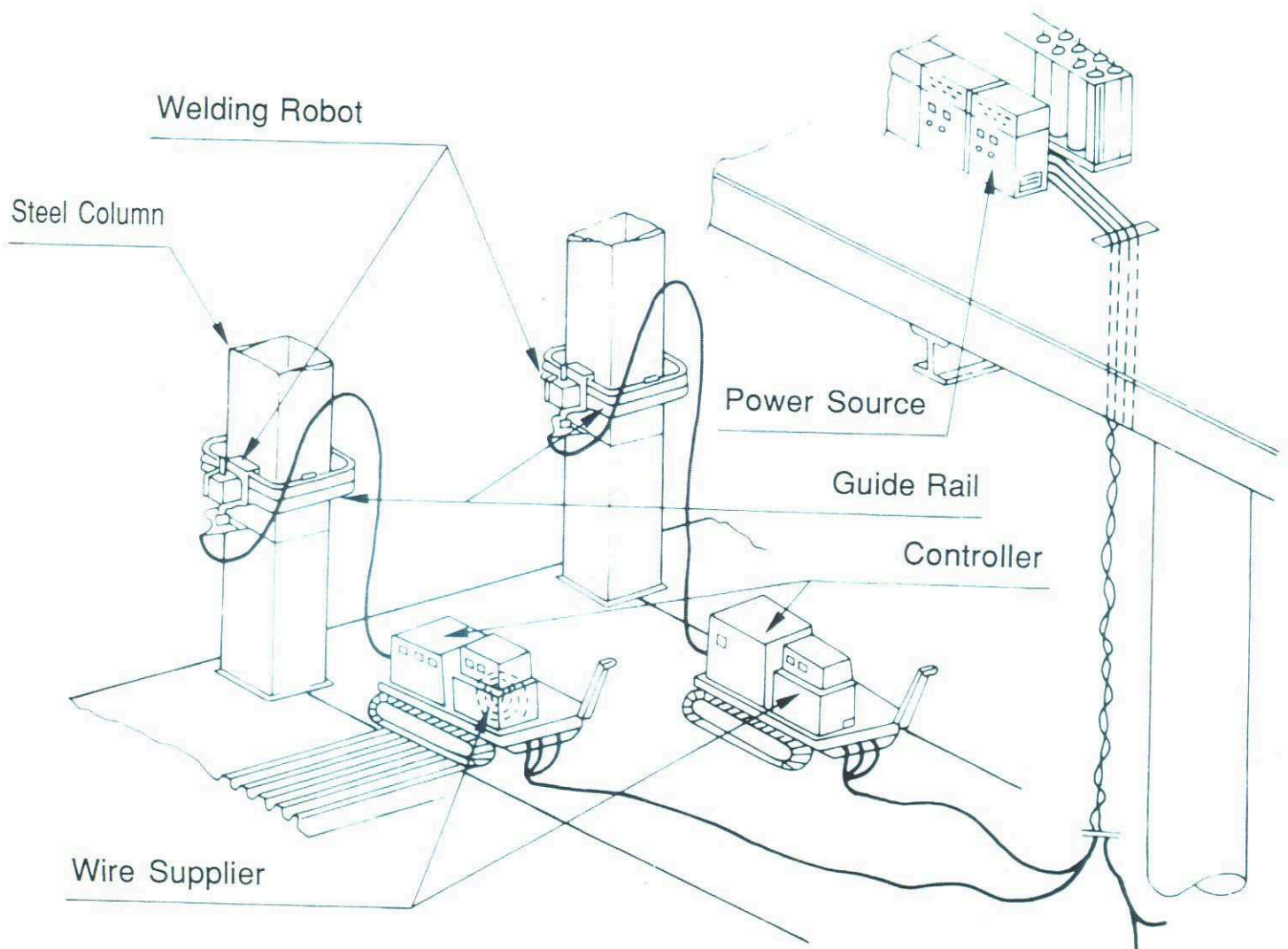
Welding Robot for Columns



Welding Robot "Yosetsu-kun"



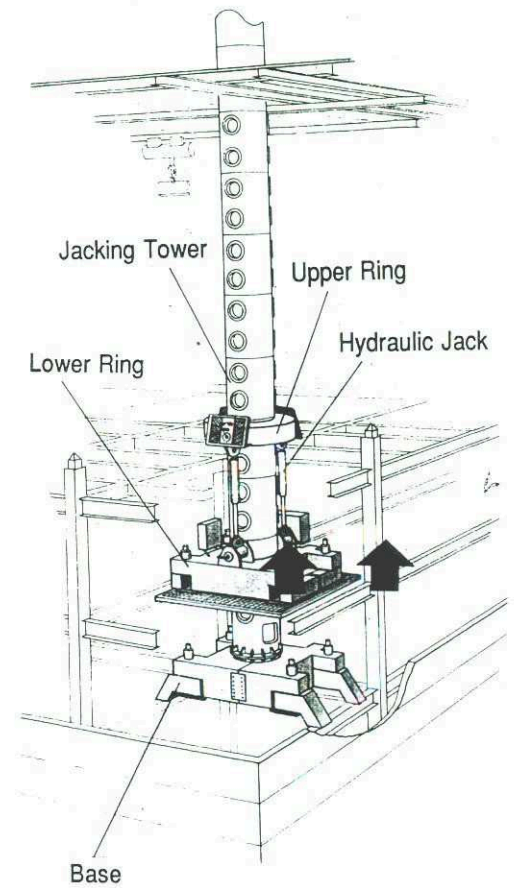
System-Outline



4. Lift-up System



Upper/Lower Ring

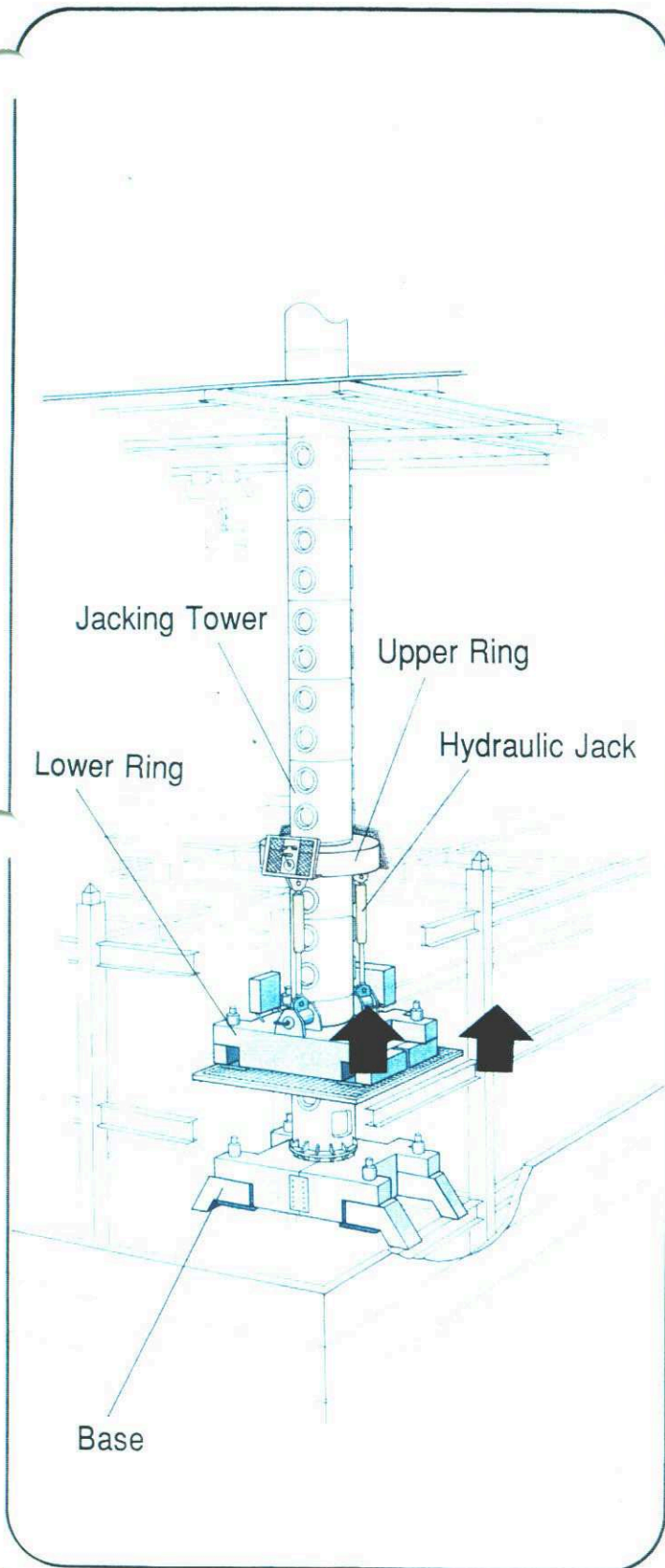


Lift-up Mechanism

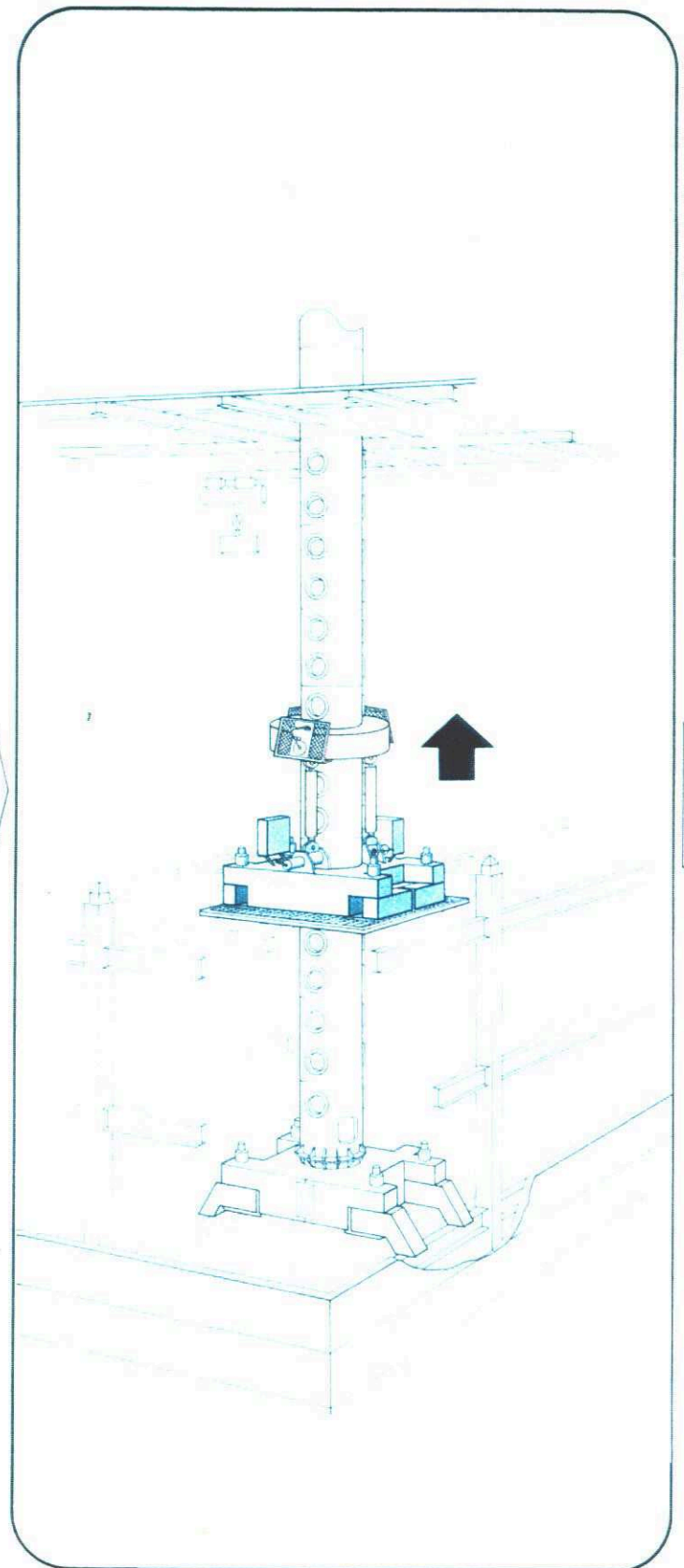


Base

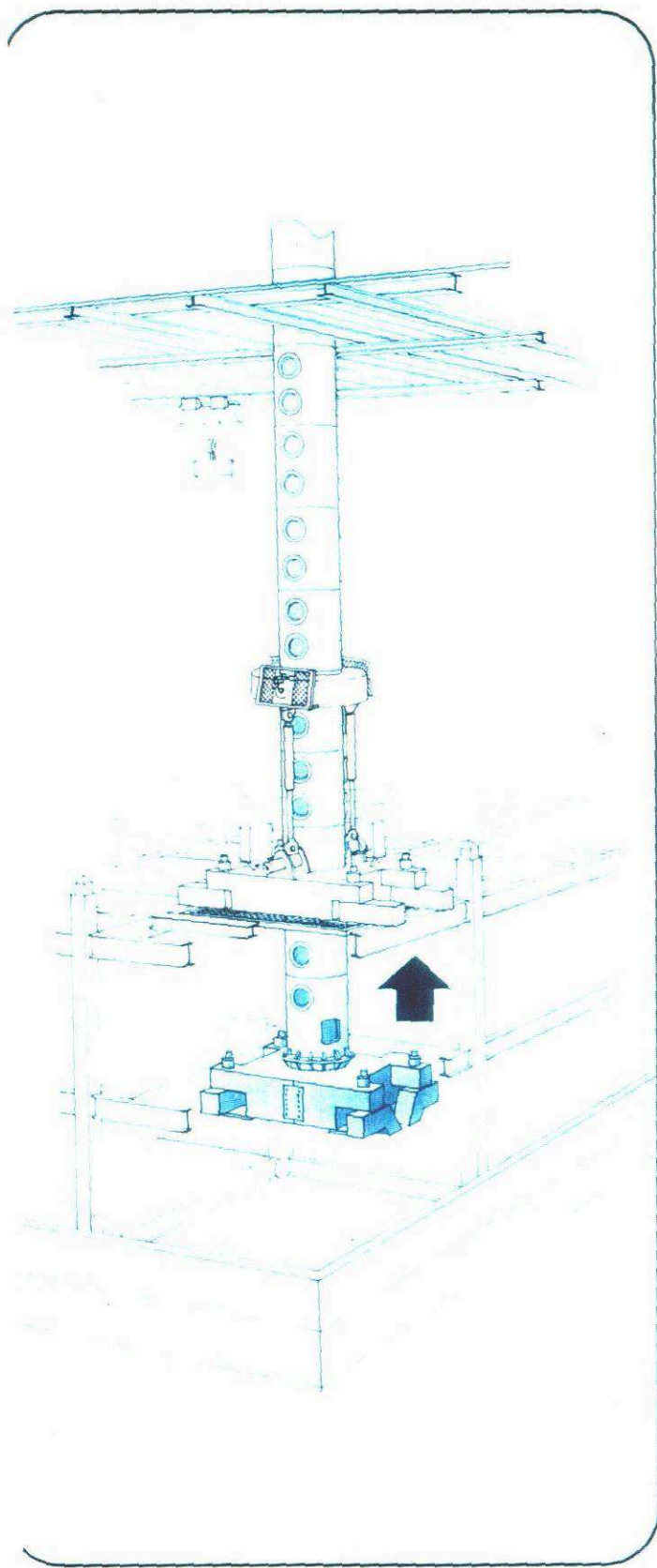
Lift-up procedure of the lifting me



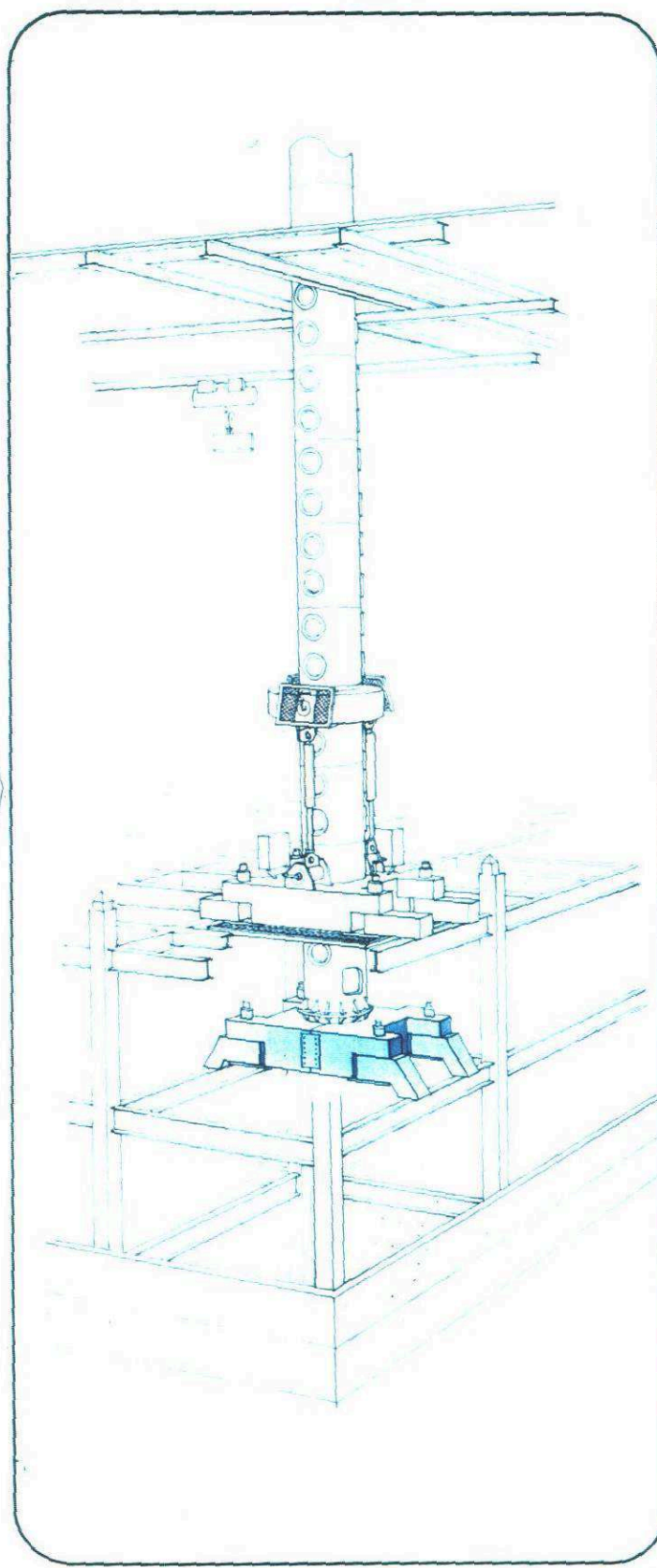
Climbing of Upper and Lower Rings



Fixing the lower ring to the beam



Climbing of Jacking tower and base



Fixing the base to the beam
(Completion of lift-up)

SECONDARY EXHIBITS

The McGraw-Hill Construction Weekly March 1, 1993 \$5

ENR

Engineering News-Record

Forget the robots Japan advances automated construction



Building-by-numbers in Japan

A mechanized systems approach spurs productivity and slices erection time on a 20-story bank building.



Forget robots. Japan's construction industry is trying a new approach to mechanization and claiming dramatic gains in speed and productivity.

The recent economic downturn has dampened the effects of a chronic shortage of skilled laborers in Japan, but the nation is still looking for ways to get its work done without admitting foreign workers. Instead of automating individual tasks, the new approach aims to turn jobsites into factories for the assembly of prefabricated components. Typically, a staging platform comprising the top floor of the building or a temporary structure is erected atop the foundation. The platform supports a crane system, provides weather protection and is jacked up as the rest of the building is constructed from the ground up, underneath the platform.

Rather than push the envelope on sensors and robots, developers want to optimize the mix of computer control,

automation, mechanical innovations and plain old-fashioned hand labor.

The claims are impressive. Tokyo-based Shimizu Corp. says its Smart System will cut by 30% the number of man-hours required to complete a 20-story, 223,000-sq-ft office building now under construction in Nagoya. Taisei Corp., Tokyo, expects its T-Up system to cut the construction time of a 33-story, 1.2 million-sq-ft office tower it is building in Yokohama from 30 to 24 months.

"It's a new era in construction," boasts Yasuyoshi Miyatake, who led the development of Shimizu's system.

Systems race. Shimizu claims to be the first to have its system up and running, but it is no more than half a stride ahead of a half-dozen competitors. The systems are all variations on a common theme. But Shimizu seems to have gone as far as anyone to integrate computer control and automation.

System setup took about a month and a half. After completing the foun-

dation, Shimizu erected the building's top floor and roof atop four jacking towers. Each tower has three 132-ton jacks. As the building rises, the jacking towers push up the 1,323-ton top floor assembly and lift their own tower bases from floor to floor in a 2.5-hour process.

A network of nine 15-ton rail cranes is connected to the underside of the structure. Several 13-ton trolley hoists can travel from rail to rail to deliver material to any point on the floor below. The hoists also travel on a vertical lift erected alongside the building to bring material from ground level. The movement of all these hoists and cranes is controlled by a computer housed on the top floor.

The computer-run crane system can erect building components automatically. In actual practice, however, a spotter on the working level and an operator in the control room both monitor the hoists as they position their loads. The

One-touch joints (far right) consist of steel-plate cross-assembly atop column base. Beveled edges help center segments lowered in place by crane. Worker fine-tunes the fitting with torque wrench and laser-guided gauge.

control room operator views the operation through video cameras mounted on each hoist and at other strategic locations. But while the lone operator is watching one hoist placing steel, the computer is moving the hoist carrying the next member into position.

Rather than rely on sensors or robotic manipulators for precise positioning, Shimizu has developed what it calls one-touch joints. For example, a cross-shaped assembly of steel plates protrudes from the top of each square tube column section. This cross fits into the bottom of the upper column section. The top outside corners of the plates are beveled so as to catch the column as it is lowered into position. The plate assembly is also tall and snug enough to hold the columns in place after the hoist hook lets go, which is done automatically once the weight of the member is supported by the lower column.

This one-touch concept has been applied to the connections for beams and girders, precast deck sections, exterior curtain wall panels and interior shaft wall panels. All of these components and assemblies of plumbing risers will be erected using the lifting system. Before erecting the deck on each floor, the system is used to move to the floor below additional materials such as gypsum board for column fireproofing.

Attaboy, Sparky. The closest thing to a robot in the system is a welding machine used on the column splices. An operator sets the welding machine on a track mounted on the columns. The machine then welds automatically using a laser sensor to follow the joint and programmed instructions on weld thickness. Shimizu figures one operator can tend two welding machines.

Shimizu was able to cut the erection crew from 20 to 13. This and additional prefabrication have reduced the number of man-hours for the project 30%. Miyatake says Shimizu is aiming for an eventual 50% reduction.

Scaffolding hangs from the top floor and the framework is wrapped with a vinyl-coated polyester fine-mesh fabric, providing weather protection on the working level. What emerges from the bottom of the shroud looks from the outside like a finished building. Inside, finish work proceeds much as on a typical building.

Shimizu developed the



jacking towers and related assemblies in cooperation with Mitsubishi Heavy Industries Ltd., Tokyo. Shimizu estimates it has spent roughly \$16 million since 1988 developing the system. The system itself cost about \$8 million.

Other systems vary to reflect their developer's particular objectives. A scheme developed by Osaka-based Ohbayashi Corp. will crawl up the building columns, eliminating jacking towers. Taisei's system relies on a staging platform that surrounds and hangs from the steel core. Two jib cranes mounted atop the platform erect the

core steel while two cranes suspended beneath the platform erect the surrounding steel.

"It's very unusual to be able to safely operate four cranes on one job site at the same time," says Takanobu Kumano, a Taisei technology development manager. The four-crane arrangement helps shorten the construction schedule, he adds.

Both Shimizu



Operator in control room oversees activity on jobsite with video monitors and computer.



and Taisei say the use of these systems did not lower contract prices for owners. Shimizu's client is Nagoya-based Juroku Bank Ltd. The contract amount was not released. The building using Taisei's system is for Mitsubishi Heavy Industries, which also developed the hardware for the system. Taisei leads a 15-company joint venture constructing the building for \$400 million, excluding mechanical equipment.

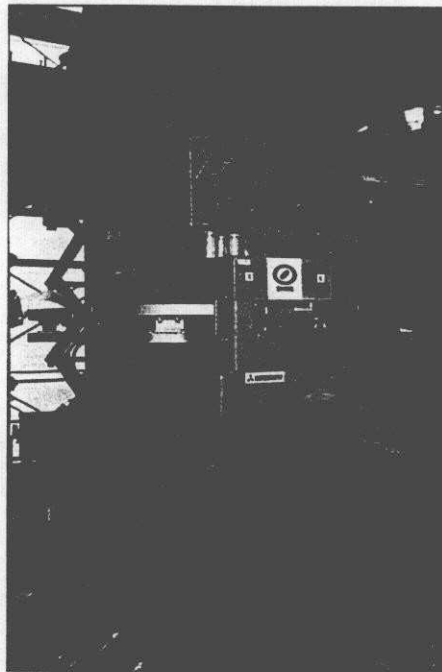
"Eventually, cost savings will flow from manpower and time reductions," says Shimizu's Miyatake.

One key will be to spread development investment over several projects. Miyatake believes the system is fairly flexible. Most hardware is reusable, though crane rail lengths will have to be tailored to each project. And computer programming can be modified by inputting new building geometric data.

Social priorities. But cost savings are not the highest priority. "The biggest problem the industry faces is the labor shortage," Miyatake says.

With the country's determination to protect its cultural homogeneity, there is little chance of using foreign workers on a large scale. The industry believes it has to automate, even if costs are not significantly reduced.

The industry's first attempt at automation, however, has not proven suc-



Automatic welder is programmed to splice column segments to specified thickness.

Hasegawa says it was always clear that automating on-site handling of precast concrete was going to be easier than automating on-site casting and finishing. Ten years ago, he says, contractors



Overhead rail crane system delivers material to entire building interior as erection proceeds.

cessful. "The industry has developed over 100 types of robots," says Yukio Hasegawa, head of Waseda University's construction robot research program. "But very few are actually used."

considered systems they are now adopting impractical.

The effort was not a waste. "They've got 10 years of experience with mechanization," Hasegawa says. Bits and

pieces of robotic technology are showing up in the new systems. Shimizu's autorelease clamps were originally developed in the mid-1980s for an earlier steel erection scheme.

While the industry expects the systems will prove more useful than the robots, there are still questions as to how much of an overall impact they will have. The gains from the increased productivity and speed have to offset the time and effort required to set the systems in place. Taisei's Kumano says the lower limit for their system is probably around 30 stories. "We probably only have seven or eight projects each year that could use this system," he says.

Takayoshi Sato, a general manager for Tokyo-based Futaba Quantity Surveying Co., suggests that greater gains could come from more prefabrication. In 1990, Futaba and Hanscomb Associates Inc., an Atlanta-based cost consultant, compared Japanese and American construction labor productivity. U.S. workers, with wages roughly double those of their Japanese counterparts, were found to be more productive in seven of nine labor categories. Sato says that greater efficiency largely stems from more widespread use of standardized and prefabricated components.

"Japan's construction sites are still very labor intensive," he says.

Sticker shock. This difference in productivity is one factor making Japan by far the most expensive industrialized country in which to build. According to surveys done jointly by Futaba and Hanscomb, comparable buildings are from two to three times more expensive in Japan than in the U.S.

Despite high initial costs, Roozbeh Kangari, associate professor of civil engineering at Georgia Institute of Technology, believes Japan's mechanization efforts will pay off. Kangari spent a year in Japan studying Shimizu's system under a National Science Foundation grant. He notes that the Juroku Bank building is only the system's second large-scale test, after an earlier test run at Shimizu's research center.

"Within five to 10 years, the Japanese will be able to come up with very economical systems," he predicts.

Miyatake says they aim to extend the Smart System concept to low-rise offices and other types of buildings. And they are already working to improve performance. After erecting a couple floors of steel, they modified the control software, cutting from 400 seconds to 200 seconds the time it takes for a hoist to traverse the rail crane network.

"It's not really going to be a smart system at least until the end of this project," he says.

By Dennis Normile in Nagoya