AIIM

Centimeter

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 mm

1 2 3 4 5

Inches

1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5 2.8 3.2 3.6 4.0 4.5 5.0 5.6 6.3

1 of 2

ORNL-6766

Japanese Suppliers in Transition from Domestic Nuclear Reactor Vendors to International Suppliers

C. W. Forsberg
W. J. Reich
W. J. Rowan

June 27, 1994

Prepared for the
U.S. Department of Energy
OFFICE OF FOREIGN INTELLIGENCE
Washington, D.C. 20585

prepared by
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6495
managed by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
under contract DE-AC05-84OR21400

CONTENTS

LIST OF FIGURES vii
LIST OF TABLES ix
ACRONYMS xi
ABSTRACT S-1
EXECUTIVE SUMMARY S-1
1. INTRODUCTION AND SCOPE 1-1
1.1 REPORT OBJECTIVES 1-1
1.2 REASONS FOR IMPORTANCE 1-1
1.3 CAVEATS 1-3
1.4 REPORT ORGANIZATION 1-3
2. THE VENDORS AND THE *KEIRETSU* 2-1
2.1 OVERVIEW 2-1
2.2 *KEIRETSU* 2-1
2.2.1 Definition and Importance of *Keiretsus* 2-1
2.2.2 The Evolution of Japanese Business Culture 2-2
2.2.3 Ties That Bind *Keiretsu* Groups Together 2-2
2.3 IMPLICATIONS OF GROUP ORGANIZATION 2-10
2.3.1 Shareholder Interest 2-10
2.3.2 Management-Owner Relationships 2-10
2.3.3 Risk Spreading 2-10
2.4 LIFETIME EMPLOYMENT 2-12
2.4.1 Practices 2-12
2.4.2 Implications 2-13
2.5 TECHNOLOGICAL LEADERSHIP 2-14
2.6 MODULAR POWER PLANT CONSTRUCTION 2-15
2.7 IMPLICATIONS 2-17
3. MITSUBISHI GROUP AND MHI 3-1
3.1 STRUCTURE OF THE MITSUBISHI *KEIRETSU* 3-1

CONTENTS
(continued)

3.1.1 History and Evolution of Mitsubishi 3-1
3.1.2 Ownership of Mitsubishi Nuclear Organizations 3-1
3.1.3 Project Management of Nuclear Programs 3-4
3.2 TECHNOLOGY 3-6
3.2.1 The History of Mitsubishi as a Nuclear Power Plant Supplier 3-6
3.2.2 Current and Future Reactor Products 3-7
4. THE VENDORS AND THE UTILITIES 4-1
4.1 OVERVIEW 4-1
4.2 JAPANESE ELECTRIC UTILITIES 4-1
4.3 UTILITY ECONOMICS 4-8
4.4 STRUCTURE OF VENDOR-UTILITY RELATIONSHIPS 4-8
4.5 ROLE OF UTILITIES IN THE DEVELOPMENT OF COMMERCIAL REACTORS 4-9
4.6 PURCHASE OF POWER PLANTS: ONLY ONE SUPPLIER 4-11
4.7 PLANT OPERATIONS AND MAINTENANCE: UTILITY-VENDOR DIVISION OF RESPONSIBILITY 4-11
4.8 REACTOR PERFORMANCE 4-12
5. THE VENDORS AND THE JAPANESE GOVERNMENT 5-1
5.1 POLITICAL SUPPORT 5-1
5.2 SUPPORT OF COMMERCIAL LWR TECHNOLOGY 5-2
5.3 LONG-TERM RESEARCH 5-2
6. COMPARATIVE STRENGTHS AND POTENTIAL WEAKNESSES OF JAPAN'S REACTOR VENDORS ON THE INTERNATIONAL MARKET ... 6-1
6.1 ADVANTAGES IN EXPORT MARKET 6-1
6.1.1 Industrial Base 6-1
6.1.2 Current and Planned Reactor Products 6-1

CONTENTS
(continued)

6.1.3 Nuclear Plant Financing 6-1
6.1.4 Modular Shipyard Construction 6-2
6.1.5 Legal Constraints 6-2
6.2 DISADVANTAGES IN EXPORT MARKET 6-2
6.2.1 Japanese Utilities 6-2
6.2.2 Japanese History 6-3
6.2.3 Fuel Cycle Support 6-3
6.2.4 Nonproliferation 6-3
6.2.5 Economics and Currency Fluctuations 6-3
6.3 IMPLICATIONS FOR EXPORT 6-3
6.4 OTHER JAPANESE VENDORS 6-4
7. CONCLUSIONS 7-1
8. REFERENCES 8-1
APPENDIX A. MEMBERSHIP IN THE SIX MAIN INTERMARKET *KEIRETSUS* A-1
APPENDIX B. EVOLUTION OF JAPANESE BUSINESS CULTURE AND THE MITSUBISHI *KEIRETSU* B-1
APPENDIX C. NUCLEAR POWER PLANT VENDORS C-1
APPENDIX D. DATA SHEETS ON SELECTED MITSUBISHI *KEIRETSU* COMPANIES D-1
APPENDIX E. SUMMARY OF MAJOR STOCKHOLDINGS IN MITSUBISHI *KEIRETSU* COMPANIES E-1
APPENDIX F. DATA SHEETS ON MAJOR JAPANESE UTILITIES F-1
APPENDIX G. SUMMARY OF MAJOR STOCKHOLDINGS IN MAJOR JAPANESE UTILITIES G-1
APPENDIX H. MITSUBISHI *KEIRETSU* AND WESTINGHOUSE ELECTRIC COMPANY CONNECTIONS H-1

LIST OF TABLES

Table 1.1	Nuclear power plant vendors and domestic nuclear power plant markets	1-2
Table 2.1	*Keiretsu* fraction of Japanese firms listed on the first section of the Tokyo Stock Exchange	2-3
Table 2.2	Size of major Mitsubishi companies listed on the first sector of the Tokyo, Osaka, and Nagoy Stock Exchanges who are involved with the nuclear industry	2-4
Table 2.3	Cross-ownership of *keiretsu* financial and industrial companies in other members of same group and other groups, %	2-5
Table 2.4	Source of borrowed capital, %	2-6
Table 2.5	MHI Board of Directors	2-8
Table 2.6	Percentage of trade (sales and purchases) of individual Mitsubishi companies handled by Mitsubishi Corporation	2-9
Table 2.7	Required corporate rates of return for R&D projects with a 10-year lag in payoff for different countries	2-15
Table 3.1.	Nuclear segment of the Mitsubishi *keiretsu* with an indication of the level of management's control	3-2
Table 3.2.	Cross stockholdings of the major players in the Mitsubishi nuclear *keiretsu*	3-3
Table 3.3.	Nuclear power project roles of Mitsubishi companies	3-5
Table 3.4	Principal design parameters of Mitsubishi PWR nuclear power plants	3-8
Table 4.1	Summary of Japanese electric utilities	4-2
Table 4.2	Japanese nuclear plants by electric utility	4-4
Table 4.3	Nuclear power development roles of government, utility, and industry in Japan	4-10
Table 4.4	Measures of power reactor performance by country	4-12
Table A.1	Membership in the six main intermarket *keiretsu*	A-3

LIST OF TABLES
(continued)

Table C.1	Nuclear power plant vendors	C-3
Table D.1	Mitsubishi keiretsu organizations in the nuclear business	D-4
Table E.1	Summary of major holdings and foreign holdings of 21 of the Mitsubishi group companies (Percentage of outstanding stock)	E-3
Table E.2	Major insurance company stock holdings of 21 Mitsubishi companies (Insurance company holdings in percent by *keiretsu* percentage of outstanding stock)	E-5
Table E.3	Bank holdings of 21 Mitsubishi companies (Bank holdings in percent of outstanding stock)	E-7
Table E.4	Trust company holdings of 21 Mitsubishi companies (Trust company holdings in percent of outstanding stock)	E-9
Table E.5	Japanese industrial, materials, or manufacturing company holdings of twenty-one Mitsubishi companies	E-11
Table E.6	Japanese chemical, gas, and petroleum company holdings of 21 Mitsubishi companies	E-13
Table E.7	Other notable significant holdings of 21 Mitsubishi companies	E-15
Table G.1	Principal stockholdings of major Japanese utilities	G-4
Table G.2	Major institutional holdings in Japanese utilities with PWRs (%)	G-5
Table G.3	Major institutional holdings in Japanese utilities with BWRs (%)	G-6
Table G.4	Major institutional holdings of two selected Japanese utilities	G-7

ACRONYMS

ABB	Asea Brown Boveri
ABWR	Advanced boiling-water reactor
APWR	Advanced pressurized-water reactor
ATR	Advanced thermal reactor
BWR	Boiling-water reactor
CRIEPI	Central Research Institute of Electric Power Industry (Japan)
DOE	U.S. Department of Energy
EPRI	Electric Power Research Institute (U. S.)
FBR	Fast-breeder reactor
FSU	Former Soviet Union
GCR	Gas-cooled reactor
GE	General Electric Co. (U.S.)
GEC	General Electric Co. (UK)
HGET	Hitachi, General Electric, and Toshiba
HWLWR	Heavy-water/light-water reactor
JAERI	Japanese Atomic Energy Research Institute
JAPC	Japanese Atomic Power Company (Japan)
KSEW	Kobe Shipyards and Engine Works
LMFBR	Liquid-Metal Fast-Breeder Reactor
LOCA	Loss-of-Coolant Accident
LWR	Light-water Reactor
MAPI	Mitsubishi Atomic Power Industries (Japan)
MELCO	Mitsubishi Electric Company (Japan)
MHI	Mitsubishi Heavy Industries, Ltd. (Japan)
MITI	Ministry of International Trade and Industry (Japan)
MM	Mitsubishi Materials (Japan)
MNFC	Mitsubishi Nuclear Fuel Company (Japan)
MPTE	Mitsubishi Power Training Center (Japan)
NNC	National Nuclear Corporation (UK)
NPI	Nuclear Power Incorporated (France and Germany)
NPTC	Nuclear Power Training Center (Japan)
NUPEC	Nuclear Power Engineering Corporation (Japan)
NUSEC	Nuclear Plant Engineering Services
PCV	Primary Containment Vessel
PNC	Power Reactor and Nuclear Fuel Development Corporation (Japan)
PWR	Pressurized-water reactor
R&D	Research and Development
SHI	Sumitomo Heavy Industries, Ltd. (Japan)
STA	Service and Technology Agency (Japan)
TBD	To be determined
TEPCO	Tokyo Electric Power Company (Japan)
TMW	Takasago Machinery Works (Japan)

ACRONYMS
(continued)

TVA	Tennessee Valley Authority (U.S.)
W/NNC	Westinghouse/NNC

JAPANESE SUPPLIERS IN TRANSITION FROM DOMESTIC NUCLEAR POWER VENDORS TO INTERNATIONAL SUPPLIERS

C. W. Forsberg, W. J. Reich, W. J. Rowan
Oak Ridge National Laboratory

ABSTRACT

Japan is emerging as a major leader and exporter of nuclear power technology. In the 1990s, Japan has the largest and strongest nuclear power supply industry worldwide as a result of the largest domestic nuclear power plant construction program. The Japanese nuclear power supply industry has moved from dependence on foreign technology to developing, designing, building, and operating its own power plants. This report describes the Japanese nuclear power supply industry and examines one supplier—the Mitsubishi group—to develop an understanding of the supply industry and its relationship to the utilities, government, and other organizations.

EXECUTIVE SUMMARY

Japan is emerging as a major leader in commercial nuclear power technology based on the strengths of its domestic nuclear power industry and changing relationships with historic (U.S.) commercial partners. In the 1990s, Japan has the largest and most active nuclear power research, development, engineering, supply, and construction industries in the world. In the 1980s, the largest nuclear power construction programs were in the former Soviet Union (FSU), Japan, and France. Political and economic changes limit the domestic demand for added nuclear power plants in the FSU, while expansion of nuclear power in France is limited by the market. Nuclear power supplies ~80% of the electricity in France. The large Japanese domestic demand ensures a large domestic supply industry. Japan has the third largest installed nuclear capacity [33.2 GW(e)] worldwide behind the United States [98.2 GW(e)] and France [56.5 GW(e)], and it is rapidly expanding its nuclear power capacity. Nuclear power currently provides 27% of Japan's total electricity. There is continued growth in electricity demand and no significant domestic energy resources.

Each of Japan's two reactor vendor groups—Mitsubishi Heavy Industries (MHI) and Hitachi-General Electric (U.S.)-Toshiba (HGET)—operates in a domestic environment that is dominated by its interactions with three entities: its *keiretsu* affiliation, its utility customers, and the national government. The first relationship—that with the vendor's *keiretsu*, a long-term alliance among multiple Japanese companies—is unique in many ways to Japan; the second two kinds of ties are common to all reactor vendors worldwide, although in Japan they assume new characteristics. According to the study, the three combined exert a unique influence on how these vendors do business and determine the competitive characteristics of MHI and HGET vis-à-vis other vendors in international reactor markets.

Reactor Vendors and the Government

The Japanese government actively supports the nuclear industry in Japan. Perhaps most importantly, it has made the expansion of nuclear power a centerpiece of its energy strategy, consequently encouraging rapid expansion of domestic nuclear generating capacity and thus the development of a strong Japanese reactor industry. Even after members of the antinuclear Socialist Party attained cabinet posts following national elections earlier this year, Tokyo's nuclear power policies remained unchanged. In Japan, utilities are regulated by the government; thus, the most important support is via regulation of utility rates and agreement on appropriate utility activities. The government also provides assistance to Japan's nuclear industry in the form of substantial research funding: Nuclear Power Engineering Corporation (NUPEC), which is subordinate to the Ministry of International Trade and Industry (MITI), tests

equipment for safety and reliability, while the Science and Technology Agency (STA) underwrites long-term, large-scale nuclear research. Indeed, the line between government and vendor interests frequently blurs in Japan: MITI, for example, is responsible for both promoting and regulating Japan's nuclear industry. Government agencies also staff many positions with personnel obtained from Japanese industry, including the nuclear sector.

Japan's activism in promoting its nuclear industry domestically has given reactor vendors a strong base that is an essential prerequisite to moving into international sales. More importantly from an international perspective, Tokyo's partisanship is unlikely to stop at Japan's borders. On the other hand, the government's close involvement in the industry introduces other, more conservative considerations to potential export contracts. The government's concern over the potential for serious repercussions for its domestic nuclear generating program should an accident occur at a Japanese-built plant overseas undoubtedly restricts the available export field.

Reactor Vendors and the Utilities

Japan's utilities—small in number, very large in size—work far more closely with their reactor suppliers than do their U.S. counterparts. These utilities strongly support nuclear power on the basis of economics and energy security. Utility-vendor relationships are long-term partnerships in which the utilities play an unusually large role in guiding and funding new product development and the vendors assume a sense of "ownership" for nuclear power plants. This "ownership" role includes providing operator training and most of the plant maintenance.

The internal structure of the Japanese utility industry further increases the influence of the utilities on the vendors and the government. The Japanese utility system consists of nine, politically powerful, large, private utilities with three very large utilities and six mid-size utilities. There is no significant government owned electric generating sector. Tokyo Electric Power Company is the largest private utility in the world; it operates over half of the boiling water reactors in Japan, the power reactor product of the HGET group. Kansai Electric Power Company, the next largest utility in Japan, operates over half of the pressurized water reactors (PWRs) in Japan, the power reactor product of the Mitsubishi group. The existence of single customers that dominate the market increases their influence over the vendors. The close, long-term relationship between utilities and their reactor vendors is likely to affect vendors' competitiveness in a number of other ways. The stability of the vendors' relationships with their customers, like government backing, provides them with a stable domestic base from which to begin exploiting overseas markets. Utility financial and technical support for technologies near commercialization will further broaden the resources available to the vendors. Again, on the negative side, utilities are far more cautious than vendors would be about reactor sales opportunities in countries with little reactor operating experience, given the potential effect on Japan's nuclear program should an accident occur at a Japanese-built plant overseas. In such a case, utility views would weigh in very heavily.

Reactor Vendors and the *Keiretsu*

The *keiretsu* system, with its network of companies sharing financial, technical, and managerial resources, is very advantageous to capital-intensive industries such as nuclear power, and both MHI and HGET are *keiretsu* members. Their groups are very large. For example, the Mitsubishi *keiretsu* group includes hundreds of companies with total sales exceeding 300 billion dollars per year. Given the key importance of financing in securing commercial reactor sales, access to financial services through fellow *keiretsu* members is likely to prove a major asset to Japanese vendors seeking overseas contracts. The *keiretsu* system also encourages development of improved designs and new products, because risk is effectively spread over a larger group, technical expertise is available from a larger pool, and members are willing to accept lower rates of return on their investment in order to expand market share. An example of this "forward-leaning" bias in reactor exports is Mitsubishi's work in designing a 600-MW(e) reactor that is too small for most Japanese utilities but is appropriate for export.

International Activities

The Japanese nuclear power program historically lagged behind the U.S. nuclear power program,

which peaked in the early 1970s and the European nuclear power programs, which peaked in the early 1980s. The potential for Japanese nuclear power exports was restricted by limited industrial capacity that was committed to an expanding domestic nuclear power industry and earlier technology licensing agreements to Japanese vendors until the late 1980s. Japanese nuclear history (war and peace), utility influence on vendors, and governmental uncertainties on nuclear power exports all act as further brakes on exports. The balance has begun to shift because of excess manufacturing capabilities, a clear lead in many nuclear power technologies, and higher levels of confidence.

Japanese vendors, like most power reactor vendors worldwide, are members of international consortia with partners in different countries. Sales in a particular country will be through the group member best able to make such sales. Business from such sales will be shared by consortium partners. Japanese vendors will receive a major portion of any such business because these vendors are world leaders in nuclear power technology, finance, and manufacturing. The constraints on Japanese vendors (historical animosities with Pacific-rim countries, Japanese utility concerns, and the rising value of the Japanese yen) are much reduced when operating as part of an international consortium with another vendor in the "public lead" role.

The two vendor groups have different characteristics. The HGET group has jointly developed, marketed, and sold nuclear power plants. It involves companies that have had close connections in other fields since the 1920s. The nuclear power agreements can be viewed as one part of a larger business alliance. It has the largest market share in Japan; partly because utilities associated with HGET have had more recent success in siting nuclear power plants. This success strengthens utility influence on the vendor.

The Mitsubishi group originally licensed nuclear power technology from Westinghouse Electric Company (U.S.). These agreements have changed to cross-licensing agreements between the two companies with an agreement to work together in some third-country markets (e.g., Indonesia, Taiwan, and the United Kingdom). MHI, the vendor, has historically been a major exporter of heavy industrial equipment.

In the last 3 years, the Mitsubishi group has bid on and won major sales for nuclear subsystems (steam generators, pressure vessels, etc.) in various parts of the world. It has not yet won a contract to supply an entire power plant. However, this is a fundamental shift in direction. For example, in FY 1991, Mitsubishi for the first time bid independently on providing a two-unit nuclear power plant to the Czech Republic. Japan has begun to enter the world market.

1. INTRODUCTION AND SCOPE

1.1 REPORT OBJECTIVES

The objectives of this report are to describe the emerging Japanese nuclear power supply industry and how its changes may affect international competitiveness, and nuclear power directions worldwide. The report describes the industry and examines the largest Japanese vendor—Mitsubishi—to develop an understanding of the system with a real example.

1.2 REASONS FOR IMPORTANCE

The Japanese nuclear power industry is in a state of transition. Japan has a large and growing domestic nuclear power industry. Japan currently has the largest nuclear power plant construction program in the world. Through the mid-1980s, that industry exported small components for nuclear power plants. In the last 5 years, it has begun to export the major components of a nuclear power station, such as reactor vessels and steam generators (MacLachlan 1992). Its industries are fully capable of exporting entire nuclear power plants and are bidding on such contracts worldwide (Dizard III 1992).

The scale of the Japanese nuclear power industry compared to other countries is shown in Table 1.1. Since 1980, the three countries with the largest nuclear power construction programs and, hence, the largest nuclear supply industries have been Russia, Japan, and France. The collapse of the former Soviet Union (FSU) along with the resultant economic difficulties have slowed the FSU nuclear power program to a near stop. In France, the success of the nuclear power program has resulted in 79.2% of its electricity in 1992 being generated by nuclear power (*Nucleonics Week 1993*). With almost all its electricity generated by nuclear power, there is little demand for added nuclear power stations. In contrast, Japan has a large nuclear power construction program. Nuclear power supplies only 27% of the Japanese electrical demand, and the other sources of energy are more expensive and/or have associated political risks (e.g., with supply).

Japanese industry has a number of major advantages that are likely to make it a world-class exporter of nuclear power plant technology. Its reactor designs are among the most advanced, and it has a recent history of very high nuclear power plant reliability. It has specialized in the design of large modules built in shipyards; these modules are then assembled at the sites into power plants. This is the preferred technology to minimize on-site requirements for skilled labor—an important consideration in developing countries. Last, it has the financial organizations and depth to finance building of new power plants.

1.3 CAVEATS

This report uses data from numerous sources, but not all of the data are consistent. This is particularly evident with the financial data. Inconsistencies reflect partly the different times in which particular studies were undertaken, different assumptions by various authors, and different assumed currency conversion rates. Information sources are referenced herein, as are assumptions of previous studies, when known.

Table 1.1. Nuclear power plant vendors and domestic nuclear power plant markets

Country	Vendor	Vendor group[a]	Vendor nuclear power plant construction starts since 1980		No. of domestic nuclear power plants		Domestic generating capacity (TWh)[c]	
			Domestic[b]	Foreign	Under construction	Operating	Nuclear	Total
Canada	Atomic Energy of Canada		4	3	0	22	80	459
China	China National Nuclear Corporation		3	0	1	2	2.6	582
France	Framatome	NPI	16	5	6	56	304	380
Germany	Siemens	NPI	4	2	0	20	160	484
Great Britain	National Nuclear Corporation		1	0	1	37	60	292
India	Department of Atomic Energy		6	0	6	11	7.4	245
Japan								
	Hitachi	HGET	5	0	2	10		
	Mitsubishi		11	0	4	19		
	Toshiba	HGET	7	0	4	14		
	Totals		23	0	10	43	182	705
Russia	Minatom		43	0	15	25	213	1,649
Sweden	ABB-Atom	ABB	2	0	0	12	66	136
U.S.								
	ABB Combustion	ABB	0	0	0	15		
	GE	HGET	0	5	1	37		
	Westinghouse	W/NNC	0	1	3	51		
	Others		0	0	2	9	—	—
	Totals		0	6	6	112	528	2,781

[a]NPI is Nuclear Power Incorporated; HGET is Hitachi, GE and Toshiba; ABB is Asea Brown Boveri; W/NNC is the joint venture between Westinghouse and NNC to build the Sizewell B nuclear reactor.

[b]With breakup of the FSU, republics, except Russia, are considered foreign countries.

Source: United Nations 1991 (see Sect. 8, "References").

The approach of this report is to better understand the Japanese reactor industry by examining one major set of players—the Mitsubishi group. Detailed information on the other vendors is not supplied.

1.4 REPORT ORGANIZATION

The report is structured as follows: The "Executive Summary" (see front matter) provides an overview of the report. The body of the report provides a more narrative and detailed description of the structure of the Japanese nuclear power industry. The appendixes contain detailed information that provides the basis for conclusions and increased understanding.

The strengths and weaknesses of the Japanese nuclear power industry reflect both industry-specific factors and the broader structure of Japanese business. Because the Japanese business structure is substantially different from that of other countries, an overview of this structure is provided (Sect. 2). This structure is a major strength of the Japanese nuclear power industry.

The largest Japanese nuclear power vendor is Mitsubishi. Its structure and organization are described (Sect. 3) as is the structure of the Japanese utility industry (Sect. 4). An important defining characteristic of the Japanese nuclear power industry is the long-term relationship between the vendor and utility. The utilities are partners with the vendors and will strongly influence vendor actions. Strong interactions also occur between vendor and government (Sect. 5).

A brief discussion of the technology and the Japanese-specific characteristics that will strongly influence Japan's potential to export nuclear power plants is provided (Sect. 6). Japan has two other nuclear power plant vendors that are members of a single consortium. Their activities are briefly described (Sect. 6.4).

2. THE VENDORS AND THE *KEIRETSU*

2.1 OVERVIEW

The business structure of the Japanese nuclear power industry and the vendors within that industry reflect the broader structure of Japanese industry and culture. Because that structure is substantially different from that of the United States, an understanding of this structure is required to understand Japanese nuclear power suppliers. Japan, Europe, and the United States have market economies as the basic economic organizing principle. Their internal structures are very different, and the largest difference is between the United States and Japan. Therefore, these two will be compared to aid us to understand what is happening.

In the United States there are two major levels of economic organization: the company—including large multidivision corporations—and the national economy. Japan, because of a variety of historical factors, has a third level of economic organization—long-term alliances among businesses. Different terms have been used to describe this phenomena, including alliance capitalism (Gerlach 1993) and communitarian capitalism (Thurow 1993). Most of the large industrial organizations in Japan—including all of the nuclear power vendors—are members of business alliances called "*keiretsus*." An understanding of the *keiretsu* is required to understand the strengths and weaknesses of the nuclear power supplier. The Japanese utilities are not members of *keiretsus*, however, they are closely allied with their suppliers. Finally, much of the Japanese work force has lifetime employment. This tradition also alters how business is conducted and significantly impacts how products are developed.

The largest Japanese nuclear power vendor is Mitsubishi Heavy Industries (MHI), Ltd., which is part of the Mitsubishi *keiretsu*. For this reason, Mitsubishi is used as an example of Japanese business organization.

2.2 *KEIRETSU*

2.2.1 Definition and Importance of *Keiretsus*

A *keiretsu* is a type of long-term intercorporate alliance among banks, trust companies, insurance companies, general trading companies, and manufacturing companies. Each company is a specialist in a particular industry (Gerlach 1992) with its own core competencies (Prahalad 1990) and its own markets. The members of the *keiretsu* work together on products or service that require multiple types of expertise. The companies have permanent partners. There has never been a major Japanese corporation that, once it has become a senior member (Presidents council, see below) of a *keiretsu*, has left it—except by merger or other types of group reorganizations. Inside a *keiretsu* is a network of cooperation and controlled competition supporting intense competition outside the *keiretsu*.

In a *keiretsu*, corporate members are major stockholders in other companies that are part of the same group and are connected by a variety of other mechanisms. If a member of the group has financial or management difficulties, the group as a whole can provide financial support or force change in management of a specific

corporation. *Keiretsus* have been developed as a mechanism to (1) allow the creation of very large groups that share business risks while avoiding the difficulties of organizational rigidity and (2) reduce the cost of transactions between and among corporations working together in particular areas. This mechanism has major implications for nuclear power vendors and vendors of other high-capital-cost complex technologies. Each member of a *keiretsu* can partly call on the resources of family members. Each member also has access to engineering information from other members of the family. This connectiveness requires an understanding of the *keiretsu* to understand the reactor vendor.

As shown in Table 2.1, *keiretsu*-related companies are a major fraction of Japanese economic output and a continuing feature of the economy. This particular analysis (Kyōkai 1990; Gerlach 1992)[a] is based on firms listed on the first section of the Tokyo Stock Exchange, where membership in a *keiretsu* is based on capital affiliation.

Six major intermarket *keiretsus* exist in Japan. Appendix A identifies the *keiretsus* and lists the major members of each group. Each is headed by a major bank or trust company. Each member company is in a different line of business. Each of the companies listed by itself is a very large multibillion-dollar company. An example is the Mitsubishi group, and the Mitsubishi companies associated with nuclear power are shown in Table 2.2. Competition is primarily between that *keiretsu* and other *keiretsus*, not among members of a particular *keiretsu*. *Keiretsu* members that are directly involved in nuclear power are listed in italics in Table 2.2.

2.2.2 The Evolution of Japanese Business Culture

Most major Japanese companies are members of large organizational groups that have histories that go back to the 1800s. Initially these groups were business families, or *zaibatsu*, that developed large and strong organizations. Today's version of these organizations are more loosely connected business groups known as *keiretsu*. The evolution of these corporate families, *zaibatsu*, *keiretsu*, or groups has played a major role in the evolution of the Japan's economic system and political structure. The continued existence of these groups over such long periods of time indicate that they are deeply embedded within Japanese culture. Appendix B provides some history of these groups.

2.2.3 Ties That Bind *Keiretsu* Groups Together

Keiretsus are bound together by a variety of financial and nonfinancial ties. The degree of coupling depends upon the individual corporation and varies from multiple tight connections between specific corporations to relatively loose connections. A company can join a *keiretsu* group by its actions over a period of one or two decades. It is a constantly changing and evolving structure.

Long-Term Investor Base with Cross-Ownership

The ownership of large Japanese companies that are members of *keiretsus* are significantly different from that of large companies in the United States or Europe. In the United States, typically 95%+ of the corporate stock is owned by market investors (institutions and individuals)

Table 2.1 *Keiretsu* fraction of Japanese firms listed on the first section of the Tokyo Stock Exchange

	1970	1980	1990
Percent of sales	71.2	78.5	75.9
Percent of assets	65.8	75.7	68.8
Number of companies	371.0	536.0	577.0

whose incentive for ownership is the dividend that the corporation pays its stockholders and stock value appreciation. Stock ownership is a method for control of corporate resources. In a typical large Japanese company, 20–30% of the stock is owned by market investors. Stable investors—primarily of affiliated companies including, but not limited to, *keiretsu* members—own 70–75% of the stock. Share ownership is acquired for business-influence purposes, not as a market investment solely to acquire return in the form of dividends. These stable investors are normally suppliers and customers of the corporation and have ownership proportional to business that is transacted. The cross-ownership of stock within the six major groups is shown in Table 2.3. In older groups, there is more cross-ownership.

Capital Markets

Members of a group preferentially borrow capital (loans, bonds, etc.) from the financial organizations within their own group (Table 2.4). On the average, it is 15 times more likely that a group member will borrow funds from organizations in its own group than it will borrow from a financial organization that is a member of a different *keiretsu*.

Board of Directors

In the United States and Europe, a traditional mechanism for controlling and coordinating multiple companies has been the use of interlocking boards of directors. The same directors are on the boards of related companies. The board of directors has as its central responsibility the monitoring of management performance, setting policy, and when appropriate, the power to replace management.

In Japan, the typical board of directors consists primarily of senior managers of the company. The board of directors has a similar legal status as in the United States, but it does not serve the same function. It is not a major mechanism for control.

Studies (Ballon et al. 1976; Bacon and Bacon, 1973) indicate that over 90% of the board members of large companies are full-time managers in those companies. For example, Table 2.5 lists the board of directors of MHI and the affiliations of its board members. All except two are MHI managers.

Table 2.2 Size of major Mitsubishi companies listed on the first sector of the Tokyo, Osaka, and Nagoy stock exchanges which are involved with the nuclear industry

Company	Industry	No. of Employees	Gross income ¥ (billion)[a]	Gross income $ (billion)[a]	Type of Income
Mitsubishi Bank	Banking	15,985	3,500	35	Revenues
Mitsubishi Corporation	Trading company	10,002	18,000	180	Sales
Mitsubishi Electric Company	Electric machinery (turbine generator)	51,331	3,200	32	Sales
Mitsubishi Heavy Industries	Heavy machinery (reactor vendor)	45,775	2,800	28	Sales
Mitsubishi Materials Corporation	Metals and ceramics (fuel fabricator)	10,161	1,500	15	Sales
Mitsubishi Trust and Banking	Trust Bank	7,112	1,250	12.5	Revenues
Totals		140,336	30,250	302.5	

[a]Assume 100¥ per U.S. dollar.

Table 2.3. Cross-ownership by *keiretsu* financial and industrial companies in other members of same group and other groups, %[a]

Affiliation of company holding shares (number of group companies)	Affiliation of company issuing shares (number of group companies)					
	Mitsubishi (15)	Mitsui (15)	Sumitomo (13)	Fuji (17)	Sanwa (19)	Dai-Ichi Kangyo Bank (22)
Mitsubishi (16)	63.4	1.6	0.9	4.0	4.7	4.4
Mitsui (15)	2.3	51.4	2.1	0.7	4.4	5.3
Sumitomo (13)	2.2	1.6	63.9	3.7	3.9	2.8
Fuji (17)	1.5	0.0	2.2	38.1	4.8	4.4
Sanwa (19)	8.8	10.1	9.1	11.1	28.0	10.2
Dai-Ichi Kangyo Bank (22)	3.1	1.3	0.9	10.4	12.8	31.6
Other Cos. (137)	19.0	33.7	21.0	34.7	42.4	42.0

Source: Gerlach 1992 (see Sect. 8, "References").

[a]Table based on examination of top ten shareholders in each company (e.g., 16 Mitsubishi companies in total own 63.4% of the outstanding shares of 15 Mitsubishi companies).

Table 2.4. Source of borrowed capital, %[a]

Affiliation of lending institution (number of group financial companies)	Affiliation of industrial borrower (number of group companies)					
	Mitsubishi (12)	Mitsui (12)	Sumitomo (10)	Fuji (13)	Sanwa (17)	Dai-Ichi Kangyo Bank (20)
Mitsubishi (3)	42.8	1.0	2.9	4.3	4.8	4.5
Mitsu (3)	1.9	39.5	1.0	1.8	2.5	7.1
Sumitomo (3)	3.5	3.0	42.4	5.3	1.6	4.2
Fuji (4)	0.7	0.5	0.0	26.6	8.9	3.2
Sanwa (2)	0.5	1.0	0.0	3.0	32.2	6.8
Dai-Ichi Kangyo Bank (2)	4.0	5.8	0.0	8.1	4.9	23.3
Other banks (29)	46.5	49.2	53.8	51.0	45.0	50.9

Source: Gerlach 1993 (see Sect. 8, "References").
[a]Analysis considers only top 10 lenders.

Table 2.5. MHI Board of Directors

Individual	Title	Responsibility
Yotaro Iida	Chairman	Chairman of the Board of Directors
Kentaro Aikawa	President	President
Hajime Sakuma	Executive Vice President	General Manager of Industrial Machinery Headquarters
Takahisa Niwa	Executive Vice President	General Manager of Power Systems Headquarters
Yoshitake Makise	Executive Vice President	General Manager of Air-Conditioning and Refrigeration Systems Headquarters
Hideo Hirotsu	Executive Vice President	General Manager of Presidential Administration Office and Project Development and Construction Headquarters
Akira Miyazaki	Managing Director	General Manager of Shipbuilding and Ocean Development Headquarters
Takeshi Matsuoka	Managing Director	
Michiaki Kono	Managing Director	General Manager of Technical Headquarters
Yoshihisa Akita	Managing Director	
Hiroshi Akita	Managing Director	General Manager of General Machinery and Components Headquarters
Kiyokazu Kawai	Managing Director	General Manager of Steel Structures and Construction Headquarters
Yutaka Hineno	Managing Director	General Manager of Aircraft and Special Vehicle Headquarters
Nobuyuki Masuda	Managing Director	General Manager of Machinery Headquarters
Tsuneo Uebayashi	Managing Director	General Manager of Nuclear Energy Systems Headquarters

Personnel Transfers

Personnel transfers between companies of the same *keiretsu* do occur—both to provide special knowledge in a specific area and to provide assistance if a particular company is in significant financial difficulty. It is particularly common for companies in trouble to receive managers from group financial companies. Although such transfers are permanent, it is expected that persons in management will maintain contact with their original company, although they are not employed by that company.

A particular type of transfer is that of a dispatched director who joins the board of a company and becomes a senior manager in that company at the same time. An analysis of dispatched directors showed that more came from other companies within the particular group. This varies by group—from a high of 60% of the dispatched directors from Mitsubishi companies coming from other Mitsubishi groups to a low of 25% for the younger Fuji group.

Presidents Council and Other Intercorporate Executive Councils

Each of the six *keiretsus* has a Presidents Council. The presidents from each major company in the *keiretsu* (Appendix A) meet together in this council once a month. The regular business of each council includes common business of the *keiretsu*, such as trademarks and public relations activities. The councils are the public manifestation of the *keiretsus*. The organization of the councils varies by group; the Mitsubishi group has the most centralized council.

Observers of these activities (e.g., Gerlach 1992) believe that the most important function is symbolic. By attending these meetings, a company president sends the message to his own organization that it is a member of a larger group and that when other factors are approximately equal, preference should be clearly given to doing business with the members of the same *keiretsu*. It is the symbol of group unity.

The Presidents Council also provides a regular mechanism for informal, high-level discussions of the conditions of business; how to assist a group member in economic trouble; or whether some new joint venture should be initiated. Because such a meeting is always scheduled at the same time each month, it provides a natural mechanism for consultation without loss of face or undue attention.

In addition to the Presidents Council, each group has a variety of interconnected executive councils at different levels in a variety of organizations. These lower-level councils address more specific issues.

Trading Companies

A specialized form of interconnection within the Japanese *keiretsu* is the trading company. These are very large companies that both own shares in their group's industrial companies and, in turn, are partly owned by the industrial companies. Trading companies sell products, arrange financing, arrange currency transactions, provide shipping, and handle other middleman services. Their specialty is to enable sales or purchases that might not otherwise occur because of financial or other limitations. Trade is made possible by complex multiparty trades and financial

packages which provide a mechanism to bring together *keiretsu* companies to participate in large projects.

The trade connections of Mitsubishi Corporation—the Mitsubishi trade company—with other members of the Mitsubishi group are shown in Table 2.6. The large fraction of purchases and sales are handled by the trade companies for the large industrial companies within the group is noteworthy. In this specific case, MHI is the largest Japanese reactor vendor. Understanding the full capabilities of MHI requires one to understand the Mitsubishi Corporation, for clearly the trading company is part of the resources available to MHI.

2.3 IMPLICATIONS OF GROUP ORGANIZATION

2.3.1 Shareholder Interest

The Japanese shareholder structure alters the strategic goals of the corporation. The primary shareholders are the long-term business partners whose interests extend beyond the dividend check. The bank that owns shares in a corporation will profit if that company expands because of the need for additional bank loans and other financial services. Because the financial institutions also own parts of the suppliers and customers, they also gain through increased business by these organizations. The suppliers gain if their customers are prosperous and acquire more goods. In effect, the major shareholders of a particular corporation receive their "income" in terms of dividends, stock appreciation, and added business. This business structure contributes to two well-known characteristics of Japanese corporate performance:

- **Market Share: First Priority.** Surveys of Japanese corporate management indicate corporate growth is the first priority, whereas surveys of U.S. managers show return on investment is the primary corporate priority. The willingness of Japanese corporations to accept lower return on investment is a major competitive strength.

- **High Japanese Stock Market Prices.** The price: earning ratio of a typical Japanese stock is higher than the corresponding ratio in the United States or Europe. From the perspective of a market investor, this makes Japanese stock unattractive. The high price reflects, among other things, the greater value of the stock to business partners who will derive increased influence and/or business for other corporations they own or control.

2.3.2 Management-Owner Relationships

The cross-ownership of stock within the *keiretsu* alters the relationship between management and owners. With stock primarily held by long-term business partners, a corporate takeover of companies that are in trouble—such as might occur in the United States or Europe—is impossible.

There are, however, other mechanisms to replace management if there is management malfeasance or incompetence. The stockholders are few in number, but typically they have held stock for decades and are *keiretsu* financial organizations, major customers, or suppliers. They have an interest

Table 2.6. Percentage of trade (sales and purchases) of individual Mitsubishi companies handled by Mitsubishi Corporation

	Sales	Purchases
Industrial companies		
MHI	55	27
Mitsubishi Oil	25	35
Mitsubishi Metals	22	38
Mitsubishi Chemicals	26	41
Mitsubishi Aluminum	75	100
Component-assembly and consumer companies		
Mitsubishi Electric	20	15
Nippon Kogakuy (Nikon cameras)	7	11

Source: Okumura 1983 (see Sect. 8, "References").

in the corporation's future through both their investments and their interactions as business partners. These multiple positions provide them with continuous inside information. In this context, upper management of a Japanese corporation may be more carefully scrutinized than it is in companies in other parts of the world.

2.3.3 Risk Spreading

The cross-ownership provides a mechanism to spread business risk. No major *keiretsu* company has ever gone into bankruptcy. This reflects both (1) the business incentive to avoid losing investments and customers/suppliers and (2) a cultural perspective that failure of any member of a *keiretsu* would reflect poorly on the skills, honor, and trustworthiness of other *keiretsu* members. The *keiretsu* becomes an insurance mechanism. The ability to spread economic risk is considered by many Japanese companies to be the primary benefit to being a member of a *keiretsu*. It involves both gains and obligations.

Japan has suffered two major economic shocks within 30 years. The first was the rapid increase of oil prices in the 1970s. This increase made much of the economic industrial structure uneconomical because of resulting high energy costs. Many industrial facilities had to be replaced. The second was the rapid increase (doubling) in value of the Japanese yen. The perspective in Japan is that the *keiretsu* provided a mechanism to adjust to these shocks. Multiple mechanisms are used to assist *keiretsu* companies that are in trouble because of broad economic changes, for example, the following:

- Discount loans from *keiretsu* banks and finance companies.

- Temporary reductions in costs of materials from suppliers.

- Priority by trading companies and customers to sell additional products from the company in trouble.

- Long-term loan and/or transfer of lifetime employees from troubled company to other *keiretsu* companies (last resort).

The risk-spreading characteristics also apply to reducing the risk under good economic conditions for new product development. This is particularly important in capital-intensive industries such as nuclear power, electronics, and aviation. Development of a new, complex product and market usually requires expertise in multiple fields and multiple development efforts on multiple components. If a single company is to develop a new product, some parts will be developed in-house. Other parts must be developed by other organizations with the appropriate skill. In a market economy system such as the United States, the company pays other companies to develop these components. The company that finances the development of the product must usually accept the total risk. In a *keiretsu* where there are long-term relations, other companies of the *keiretsu* may develop specific components needed for a particular product at their own financial risk with the implicit contract that if the product is successful, they will provide those components at a profit.

There is a second characteristic of this system—one usually has the same business partners. There is no need to develop new contractual relationships for each new product or sale. This alliance reduces transaction costs with the following benefits.

- Development time is reduced, no new organizational relationships must be developed, and the learning curve for organizations is avoided. A comparison between U.S. and Japanese nuclear power plant design and construction practices is illustrative. In the United States, utilities have historically ordered different power plant components (nuclear steam supply system, turbine-generator, and architect engineering) from different suppliers. These different suppliers must work together so that the various systems function in a plant. In Japan, the same companies participate each time. A new organization need not be built with each plant.

- Product integration is improved because the different suppliers have long-term relationships and begin to understand the needs of their customers.

Risk spreading between corporations requires acceptance of significant obligations when a particular corporation develops a business relationship with another corporation. A company may accept some risk in development of components for a new product of a fellow *keiretsu* company although it might not normally choose to enter the particular line of business. The choice of business partners is limited by earlier decisions. One cannot readily switch to different suppliers. Assistance may be required by a company in deep financial trouble. These

obligations result in several characteristics of Japanese business:

- Business relationships develop over years or decades. Quick agreement with new suppliers or customers would not be expected because those entering such relationships recognize the implicit obligations.

- Companies have a very strong interest in good management of related *keiretsu* companies because of the high cost to themselves if a customer or supplier is in trouble.

2.4 LIFETIME EMPLOYMENT

2.4.1 Practices

The employment philosophies of the United States, Europe, and Japan are substantially different although the practical differences are not as great as implied by theoretical economic models. Japanese employment practices are based on lifetime employment, whereas U.S. employment practices are based on free labor markets. Policies in both countries are a result of cultural, economic, and political beliefs.

In the United States, employment is at the will of the employer. The economic rationale is that corporations must be able to change employment levels and relative skills to adjust to changing market conditions. The market provides the highest awards to those with the appropriate skills and a mechanism for companies to avoid the costs of nonperforming employees.

In Japan, lifetime employment has been considered preferable to ensure employee loyalty, create company team spirit (member of a group), and thus allow the corporation to adjust to changing market conditions. The perspective is that if the employee has a lifetime commitment to the organization, the employee will support changes in how business is conducted to ensure success of the business. Change does not threaten employment; hence, change is accepted. An important corollary to lifetime employment is that a significant fraction of an employee's income is in the form of bonuses that depend on how well the company is doing. The bonuses are both incentives to the employees to ensure business success and a mechanism to lower labor costs in poor economic times.

The practical differences between Japanese and U.S. employment practices are somewhat less. Many U.S. corporations have very stable employment with commitments to long-term employment. Many Japanese corporations have permanent employees and contract employees. The contract employees do not have lifetime employment rights.

2.4.2 Implications

These differences in employment policies have major impacts on how business is conducted. Several characteristics of Japanese corporations are reinforced by the obligations created by lifetime employment.

- Lifetime employment creates additional incentives for corporations to be members of *keiretsus* as a method to reduce business risk and avoid large fluctuations in their need for manpower as driven by the business cycle.

- Lifetime employment further reinforces a major priority of Japanese management—increased market share. Loss of market share with a fixed workforce is very expensive.

Lifetime employment changes the emphasis on the preferred mechanism for technology transfer among national laboratories, cooperative industrial research efforts, and individual corporations. Japan, like the United States and Europe, has national laboratories for many industries, including nuclear power. There are also various industrial cooperative organizations such as the Central Research Institute of Electric Power Industry (CRIEPI)—the Japanese version of the U.S. Electric Power Research Institute (EPRI). A characteristic of such organizations is that many of the staff are on temporary loan from major corporations. The people are the mechanism for technology transfer. Such methods are less common in the United States and Europe in part because the corporation has no assurance that key individuals will return to the parent corporation with the knowledge that was gained. If the employee accepts work elsewhere, the corporation loses both expertise to competitors and the financial loss from supporting that individual with no realization of long-term gain.

Last, lifetime employment encourages development of a more highly skilled, cross-trained workforce. This alters how business is done. If employees cannot be laid off, the corporation has a strong incentive for cross-training individuals. This added flexibility allows the transfer of people from areas in which less work is available to areas where additional help is needed. Cross-training to improve productivity can be emphasized because the corporation has confidence that the individual will remain with the company and that the company will get a full return on the investment. This approach has several other impacts on business.

- Management requirements are reduced. Management must match the right people to the right job. With a highly skilled, cross-trained workforce, more people are available to meet particular short-term needs.

- Cross-training allows faster response by the corporation to unexpected events. A trained and diverse manpower pool is available.

An example of the effects of lifetime employment and a different management philosophy is the operational philosophy for maintenance of Japanese nuclear power plants. In the United States, maintenance is traditionally organized by craft: plumbers, pipefitters, electricians, etc. A particular craftsman is assigned to whatever must be repaired that day. The assignment structure requires significant management input to match skills to the jobs. A major complication is that the ratio of electricians to pipefitters to any other craft varies among jobs. Japanese power plant maintenance staffs are organized by functional area (reactor, turbine hall, etc.). This has two major benefits: (1) responsibility and ownership for a section of a plant is clearly assigned—it is their part of the plant and (2) management difficulties in balancing relative numbers of particular crafts are reduced—hence, the management loads are reduced. The cost is providing the needed cross-training.

2.5 TECHNOLOGICAL LEADERSHIP

Japan is a technological leader in many areas of design and commercial nuclear power plants. The term *commercial* herein implies reactor designs that can be built without requiring a prototype reactor to prove economic or technical feasibility. Japan is stronger in this area than in fuel cycles or advanced reactor concepts such as liquid metal reactors. Some examples can clarify these Japanese strengths, that in part, reflect structural characteristics of Japanese industry and government.

Japan leads in automated inspection equipment for nuclear power plants. This is a result of Japanese regulatory and operating philosophies. The Japanese regulator, Ministry of International Trade and Industry (MITI), compared to other regulatory agencies in other countries, requires a very detailed inspection of all nuclear power plants once a year. Furthermore, Japanese utilities have emphasized maximizing reliability by a once-a-year overhaul of each plant with detailed inspections. It is expected that there will be few or no significant equipment failures between inspections. These requirements have created the need for rapid, by operating automated inspection equipment to minimize downtime for inspection and overhaul.

Japanese vendors have demonstrated more willingness than other vendors to incorporate improvements in reactor design where there are clear long-term economic or technical advantages despite high development costs and lengthy development times. An example is the development of horizontal steam generators for the MS-600 reactor rather than continued use of conventional vertical steam generators. A steam generator is a heat exchanger where hot reactor water is used to boil water to steam that is then sent to the turbine to produce electricity. It has been recognized that horizontal steam generators, compared to vertical steam generators, have safety advantages, improved plant reliability, and possibly lower costs (Hibbs, July 1993; Forsberg et al., 1989). The drawback is that steam generators are the largest components in a power plant and that changing their orientation necessitates redesign of much of the power plant and some risk of "teething" problems in the first such plant.

The willingness of Japanese vendors to make these kinds of improvements in part reflects: (a) their ability to spread development risks (see Sect. 2); (b) their goal of increasing market share; and (c) their willingness to accept a lower rate of return on research and development (R&D) investments. Table 2.7 shows a recent study (Thurow 1992; Financial Times 1990) of acceptable return on investments for R&D in different countries. A willingness to accept lower returns on investments implies a willingness to develop technologies that will require a significant time lapse to obtain a return on an investment.

The Japanese vendors have begun to develop and incorporate totally new technologies into their plants, such as fluidic accumulators designed for the MS-600. This activity is an indicator of the Japanese belief that they have incorporated the useful foreign technology and must now generate their own advanced technology. The historic perspective is that Japanese industry copies and then incrementally improves the technology. In nuclear power, they have moved clearly

beyond this stage and are becoming a leader in innovation (Hansen 1992). Recent surveys (Bonsignore 1993) of patents granted in 1992 by the U.S. Patent Office reflect a similar perspective. Of the top five companies that received patents, four were Japanese and one was American [General Electric Co. (GE)]. The four Japanese companies included the three Japanese reactor vendors: Mitsubishi, Hitachi, and Toshiba.

2.6 MODULAR POWER PLANT CONSTRUCTION

A significant competitive advantage of the Japanese nuclear power industry is its ability to build nuclear power plants from large modules constructed in shipyards. Modular construction of nuclear power plants is considered today (Johnson and Orr 1988) to be the best method to minimize cost, minimize construction time, and maximize quality. Modular construction consists of building large sections of a nuclear power plant in shipyards, transporting the sections to the power plant site, and assembling the sections to build the power plant. The benefits are obtained by manufacturing large plant sections (up to 2000 tons each) indoors with permanent skilled staff and automated equipment. This approach minimizes field construction where temporary facilities must be built and temporary employees trained for short-duration construction jobs.

Japan is the world's leader with most of the world's experience in modular shipyard construction of nuclear power plant components as a result of a combination of historical events.

- All Japanese nuclear power plant sites are located on the ocean and have easy transport of modules from shipyard to power plant site.

- Because of high population densities and high cost of land, power plant sites are very small by U.S. standards. Shipyard construction minimizes the space required at the construction site for construction activities.

- The Japanese vendors own shipyards; thus, they have ready access to shipyard facilities. By historical accident, none of the other vendors worldwide were heavily involved in shipbuilding. Because these companies started as shipping and shipbuilding companies, there was, and is, an inclination to use shipyards for construction where feasible. The vendors understood both the strengths and weaknesses of shipyard fabrication.

- Last, in the late 1970s there was a sharp decline in shipbuilding at the same time both nuclear power and offshore energy activities grew rapidly. At this time, Japan was the world's dominant shipbuilder. With lifetime employment, heavy shipyard investments, and excess capacity, the shipyards needed new business (Parkinson and Orsi 1982). The nuclear vendors used their shipyards for construction of nuclear plant modules to reduce shipyard loses, but discovered major cost and schedule savings.

An example of this technique was the construction of the Kashiwazaki Kariwa Unit 4. Here the completed control room—the most complex part of the

Table 2.7. Required corporate rates of return for R&D projects with a 10-year lag in payoff for different countries

Country	Rate of return (%)
Germany	14.8
Japan	8.7
United Kingdom	23.7
United States	20.3

plant—was delivered in two modules with a savings of 4 months in its construction schedule. The larger module weighed 438 tons (*Atoms* November 1991) with dimensions of 15.8 m (52 ft.) by 26.0 m (85 ft.) by 11.65 m (38 ft.)

The use of large-scale modular construction fundamentally changes how engineering is done. In traditional engineering design from houses to nuclear power plants the facility is designed by system. There are sets of structural, electrical, and mechanical blueprints. For efficient shipyard fabrication these designs must be converted into construction blueprints for fabrication of modules. Module design must be optimized for efficient fabrication within the constraints of normal shipyard practice. This is a very specialized form of engineering.

The use of modular construction techniques changes the optimum design of the power plant. If large modules are to be shipped to the site, they must have the structural integrity to survive the stresses of shipping. These may or may not be the same as the power plant might receive during normal or accident conditions. Economically optimized designs ensure that steel required for strength during shipping has a useful function within the plant. The optimum design for field construction, truck-shippable modules, and shipyard modules are different. Japanese designs are optimized for shipyard fabrication of modules. This is optimum for coastal sites, such as exist in Japan.

There are disadvantages of modular shipyard construction. Additional engineering is required to be sure the modules can withstand the stresses of shipping (wave actions, etc.). Furthermore, most of the engineering must be completed before the start of construction to be sure modules will fit together in the field. There is a significant engineering and field construction learning curve (costs) for the first several jobs. In Japan, this learning curve was paid for, in part, by the need to minimize shipyard losses. Partly by happenstance, a technique originally designed to minimize shipyard losses could prove to be a major advance in power plant construction.

The modular construction combined with a variety of other factors (Hansen 1990; Hinman and Lowinger 1986) have made Japanese construction of nuclear power

plants highly efficient. An evaluation of on-site labor requirements to build nuclear power plants indicated 17,400 person-hours/MW of power plant capacity were needed in Japan vs 26,400 person-hours/MW of power plant capacity in the United States. Similarly, construction times in Japan for a nuclear power plant are ~48 months—the shortest construction times in the world with many countries having construction times twice as long.

2.7 IMPLICATIONS

The structural characteristics of the Japanese industrial system assist the development of capital intensive, technologically intensive industries such as nuclear power. The system does require informal consensus between many groups to start projects, but once such a consensus is reached, rapid progress results with no financial and few technical limitations.

In the specific case of nuclear power, one other structural characteristic has greatly strengthened the industry: the vendors started as shipbuilders. This reflects industrial history where shipbuilding (rather than railroads) was the centerpiece of industrialization. The use of modular shipyard construction techniques substantially improves nuclear power economics and gives nuclear power a major economic advantage in Japan.

3. MITSUBISHI GROUP AND MHI

3.1 STRUCTURE OF THE MITSUBISHI *KEIRETSU*

3.1.1 History and Evolution of Mitsubishi

The Mitsubishi group is one of the oldest corporate groups in Japan. It was started by Yataro Iwasaki in the mid 1800s as a family owned group of companies. The structure of the group has changed with time. The group was broken up after WWII but reformed as a *keiretsu* in the 1960s.

Mitsubishi has historically been a shipbuilding company with growth into other industrial products as a result of its basic shipbuilding operations. This orientation, as discussed later, has had a significant impact on its nuclear power activities and the unique Japanese emphasis on construction of nuclear power plants from large modules built in shipyards. Appendix B provides a more detailed history.

3.1.2 Ownership of Mitsubishi Nuclear Organizations

The nuclear capability of the Mitsubishi *keiretsu* is concentrated in three major companies: MHI, Mitsubishi Electric Company (MELCO), and Mitsubishi Materials (MM). MHI is the lead organization. It also designs the power plant and the nuclear reactor. MELCO provides electrical generators and control systems. MM provides nuclear fuel. Mitsubishi *keiretsu* is financed by the Mitsubishi Bank, Mitsubishi Trust Company, Mitsubishi Corporation (trading company), and Meiji Insurance Company. These companies, their affiliates, major divisions, and numerous equipment suppliers in the *keiretsu* represent a massive financial business power. The Mitsubishi *keiretsu* includes over 700 companies and affiliates and subsidiaries, with over $300 billion in annual revenue.

The major Mitsubishi nuclear companies are shown in Table 3.1 with the Mitsubishi companies that are their major stockholders, (subsidiaries, affiliates, and/or divisions) and that perform the work associated with Mitsubishi's nuclear business.

The major stockholders of the Mitsubishi financial, trading, and industrial companies in the nuclear business are shown in Table 3.2. This does not include other financial connections between these companies and other Mitsubishi companies not involved with nuclear power. Details are provided in Appendix E. All the financial companies have major holdings in the industrial companies, and the industrial companies have significant holdings in the financial companies. The estimates are that "most large Japanese firms have well over half of their total equity controlled by stable shareholders with a variety of business interests in the company; and in the case of some firms, such as commercial banks and other financial institutions, this figure is over 90%" (Gerlach 1991). Mitsubishi bank has an unusually large fraction of its stock owned by other Mitsubishi companies, but the large number of Mitsubishi companies limit how much each can own.

The financial link between industrial and financial companies ensures that financing will be available to the industrial companies when needed. This is a key requirement

Table 3.1. Nuclear Segment of the Mitsubishi *Keiretsu* With an Indication of the level of management's control.

FINANCIAL and TRADING COMPANIES (Financing)	
Meiji Insurance Company[a]	
Mitsubishi Bank[a]	
Mitsubishi Trust Company[a]	
Mitsubishi Corporation (Trading)[a]	
INDUSTRIAL COMPANIES (Manufacturing)	
MHI[a]	MHI
Mitsubishi Atomic Power[b]	MAPI
Mitsubishi Power Training Center[b]	MPTC
Takasago R&D Center	TR&DC
Kobe Shipyard and Engine Works[c]	KSEW
Nuclear Plant Service Engineering Company[c]	NUSEC
Takasago Machinery Works[c]	TMW
Mitsubishi Materials[a]	MM
Mitsubishi Nuclear Fuel Company[c]	MNFC
Mitsubishi Electric Company[a]	MELCO
MELCO Equipment Division[c]	

[a] Major Mitsubishi *keiretsu* companies in the nuclear industry — they are publicly owned companies.

[b] Major Subsidiaries and/or Joint Ventures that are primarily controlled by MHI but their control is shared with others

[c] Major Divisions or Companies that are totally controlled by one *keiretsu* Company.

Table 3.2 Cross-stockholdings (%) of the major players in the Mitsubishi nuclear *keiretsu*[a]

Keiretsu organizations		Major stock holders[a]						
		Financial			Trading	Industrial		
Type	Company	MEIJI Insur	MIT Bank	MIT Trust	MIT Trading[d]	MHI[b]	MELCO	MM[e]
Financial	MEIJI	X[c]	--[d]	--	--	--	--	--
	MITBank	5.8	X	1.8	1.7	3.0	X	X
	MITTrust	4.8	3.1	X	X	2.7	1.8	X
Trading	MIT[c] Trading	6.0	4.9	5.3	X	3.1	X	X
Industrial	MHI	3.2	3.6	6.1	1.5	X	X	X
	MELCO	4.1	3.4	3.8	X	X	X	X
	MM	6.4	4.2	5.6	X	X	X	X

[a] These data only include the major stockholders directly or indirectly associated with nuclear power—there are numerous other significant cross stockholdings in the *keiretsu*.

[b] MHI owns a significant part of the financial and trading companies.

[c] The *keiretsu* trading companies' major stockholders include all the *keiretsu* financial organizations and MHI.

[d] The *keiretsu* trading company owns a major stockholding in the *keiretsu* bank and MHI.

[e] MM, the *keiretsu* nonferrous materials company does not have major holdings of any of the nuclear *keiretsu* financial or industrial organizations included in the Table. However, it owns 100% of MNFC, which supplies all the fuel for Mitsubishi nuclear plants.

for success in capital-intensive businesses, such as nuclear power, where financing is a major consideration in sales.

There are also financial links between MHI and Mitsubishi Corporation—the world's largest trading company. This is important in terms of exports. The business of trading companies is to connect buyers with sellers and provide the middlemen services, including transportation, currency trading, insurance, and other services. This includes arrangement of multicountry swaps of goods, multinational financing, and other three-or-more party agreements. For Table 3.1 large facilities such as power plants, the ability to arrange such services often determines whether a sale is possible.

A number of related industrial companies do not have major holdings in each other. The *keiretsus'* influence on these companies is from mutual respect, long personal relationships, and through the *keiretsu* financial organizations with major stockholdings.

The financial size of these organizations is much larger than nuclear power groups in other countries. Appendix C shows sales of the parent companies of various reactor vendors worldwide to give some perspective on relative financial strengths.

3.1.3 Project Management of Nuclear Programs

Table 3.3 shows how nuclear project work is divided among Mitsubishi's three major nuclear companies. The project management is done by MHI. Component design and manufacturing are with MHI, MNFC, MELCO, and smaller *keiretsu* companies. In addition, MHI teams up with the utilities to accomplish the construction and civil work, using a hybrid management system that combines features of the French Framatome/EdF operations and the U.S. architect engineering/constructor/reactor manufacturer's relationships.

MHI has two organizations focused exclusively on direct service to nuclear customers: The Nuclear Power System Engineering Company (NPSEC) and the Nuclear Power Training Center. These organizations perform maintenance inspection and/or training tasks that a utility might need. They know the plants and the customers, and they are the direct links to the Mitsubishi organizations who design, build, and conduct research on future systems and components.

The overall coordination of Mitsubishi nuclear research and development (R&D) is accomplished by MHI Takasago R&D center with inputs and requests from all the Mitsubishi nuclear organizations, all the utilities with pressurized-water reactors (PWRs), Japanese government organizations (primarily MITI), and numerous foreign R&D programs that the Japanese either fund, partially fund, or participate in through personal transfers.

3.2 TECHNOLOGY

3.2.1 History of Mitsubishi as a Nuclear Power Plant Supplier

The strategy used by Mitsubishi in developing its capability in the nuclear industry is direct and simple: when entering an industry, it obtains a good understanding of what has been accomplished in the past. In the case of

Table 3.3. Nuclear power project roles of Mitsubishi companies.

Functions, systems, and/or hardware	Organizations controlling and performing tasks
Prime contractor function	MHI
System design	
Reactor	
Primary system	MAPI
Secondary system	MHI and MAPI
Fuel	MNFC
Turbine	Takasago facility of MHI
Electrical	MAPI and MELCO
Buildings	MHI and MAPI
Site work	MHI and MAPI
Manufacturing	
Reactor	
Primary system	MHI
Secondary system	MHI
Fuel	NFC
Turbine	MHI at Kobe
Electrical	MELCO at numerous MELCO facilities
Construction/civil	Utilities and MHI
Buildings	
Site work	
Operations	Utilities with support from · Nuclear Plant Engineering Services NUSEC (owned by MHI) · Nuclear Power Training Center (NPTC) (jointly owned by Utilities and MHI)
R&D	R&D is managed and coordinated by MHI through the Takasago R&D center

nuclear power, this includes understanding what was built by the leaders, what is being built by others, and what is being explored in the various R&D programs around the world. Their strategy is: Build your capability with the help of those who have existing capability, develop an independent capability with your own source of technical information, and pursue a path of independence based on excellence in engineering and management while producing quality hardware. This strategy is not new at Mitsubishi; it started with shipbuilding a hundred years ago and continued with the building of electrical equipment in the 1920s, airplanes in the 1930s, general heavy industry in the 1950s, automobiles in the 1960s, electronics in the 1970s, and computers in the 1980s. Typically, these products are developed over a 30-year period with a methodical process of laboratory testing and market development. In the case of nuclear power, Mitsubishi's capability has evolved over the past 40 years and through 5 generations of plant development.

Mitsubishi companies started working in the field of nuclear power when the 1945 business restrictions were rescinded in the early 1950s.

In the same time period, there was an internal Japanese debate on whether to develop indigenous nuclear power technology or obtain licenses for the technology from U.S. vendors. The utilities strongly preferred the latter option, which was ultimately accepted. Mitsubishi had earlier technical agreements with Westinghouse and signed new nuclear power licensing agreements with Westinghouse. Nine plants were designed and built as a part of the first generation of plants; these designs and much of the hardware were from the Westinghouse corporation. The sizes were varied, but they fell into three power ranges: 340 to 566, 826, and 1175 MW(e).

By 1958 the *keiretsu* decided to establish a company completely committed to nuclear power and founded Mitsubishi Atomic Power Industries, Inc. (MAPI). Even though Mitsubishi worked on this first generation of plants started in the early 1950s, the initial plants were considered to be Westinghouse plants. The first MAPI designed plants did not go into commercial service until the 1970s. The components were progressively changed to Japanese domestic products through this period.

In the 1960s, the second generation of Japanese Mitsubishi PWR plants were designed and placed in service in the 1980s. These plants were in essentially the same power ranges: ~560, ~880, and ~1160 MW(e). However, the Japanese consider these plants to be based on Mitsubishi technology, Japanese R&D, and the experience gained from the construction and operation of their first-generation plants. Major components were essentially of Japanese designs and were manufactured in Japan.

In the 1970s, the third generation of PWRs in Japan were designed, and seven plants were built: three at <600-MW(e), one at 890 MW(e), and three at 1180 MW(e). This is essentially the generation of the 1990s. It includes an advanced steam generator design (Model 52F), a digital control system, and a 52-in. low-pressure turbine-blade design. MAPI's objectives are improved operability, reliability, safety, and economy. Three of these plants are currently in commercial operation, and the

other four are scheduled to start operations by 1997.

The fourth generation of PWR plants to be built in Japan will be the advanced pressurized-water reactor (APWR) plants expected to start commercial operation in the early 2000s. The APWR is a coproduct of five Japanese utilities, Westinghouse, and MHI. Because Mitsubishi *keiretsu* companies took part in the development, they consider the APWR a product of the Mitsubishi *keiretsu*. The technical role and the financial role of the Japanese utilities in the development of the APWR are very significant. They include participation in the development of performance goals; the establishment of verification procedures; and review and comment on the results of design, analysis, tests, and evaluations conducted by Westinghouse and MHI. The development of the APWR is considered complete; therefore, it is ready for construction.

MHI is currently developing the MS-600 and MS-1200 as candidate designs for what could be called its fifth generation of PWRs. It is not clear what joint-venture design, construction, or marketing approaches will be used, or explored, with this generation of reactors. This work is being done independently of Westinghouse and any other foreign suppliers.

The APWR is an evolutionary-type reactor, based on conventional PWR technology. The MS 600- and 1200-MW(e) reactors are hybrid designs combining passive and active technologies. Mitsubishi plans to offer both designs to satisfy the customers' preference and the market needs.

3.2.2 Current and Future Reactor Products

Current Japanese nuclear reactor products are considered third-generation designs (as described earlier in this section). More advanced and evolutionary reactor products are considered fourth- and fifth-generation designs with modular shipyard construction being used to decrease construction times and on-site construction requirements. This section will focus on all three design generations. First- and second-generation reactors are only of historical interest because there is no current market for sales.

The third generation of Mitsubishi PWR designs are currently in use: Three units are in operation, and four units are under construction. These current PWR reactors were developed as improved designs of Mitsubishi's second-generation reactors. They represent the latest commercially available PWR reactor technology in Japan—with three basic models designated for export to other countries. The principal design parameters of these three third-generation export models are given in Table 3.4. Similar reactor core and coolant system designs are used in all three reactors with improvements in steam-generator design and with control systems and turbine designs being incorporated into the larger four-loop reactor.

Advanced Pressurized Water Reactor

The fourth generation of Mitsubishi PWRs consists of the APWR, which was developed as a part of Japan's MITI's Standardization Program for light-water reactors (LWRs). The APWR was developed through an international cooperative program that includes MHI,

Westinghouse Co., and five Japanese electric power companies (Kansai Electric Co., Kyushu Electric Co., Shikoku Electric Co., Hokkaido Electric Co., and Japan Atomic Power Co.). The APWR development program was started in 1982 and completed in 1987.

The APWR is a 1,350-MW(e) nuclear power plant designed to be used in the next decade. The design and development of the APWR is considered complete, and commercial operation of the first units are expected to begin around the year 2000. The objectives of the APWR include design simplification, enhanced availability, improved economics, enhanced safety, and simplification of reactor operations and maintenance.

The overall building volume has been reduced by using a more effective plant layout and advanced structural designs. Fuel costs have been reduced over 20% by decreasing the core power density, installing a radial neutron reflector around the core, and applying more effective moderator control to generate and subsequently burn more plutonium in the fuel. A larger fuel assembly grid reduces power density and allows for a high-burnup fuel design and improved reliability. Further simplifications in core internals and control rod drive mechanisms improve operational reliability.

Redesigned reactor vessel components prevent uncovering of the core during a loss of coolant accident (LOCA) with increased water inventory in the upper core area to enhance core cooling under such accident conditions. Increased redundancy and independence in the emergency core cooling system improve reactor safety substantially. Finally, the APWR has adopted a digital control and protection system throughout the plant with application of human factors technology to improve the man-machine interfaces.

MS Reactor - The Fifth Generation Plant for the Next Century

The fifth generation of Mitsubishi PWRs involve major design changes in contrast to the evolutionary changes among the first four generations of power plants (Table 3.4). This is the first generation of Mitsubishi power reactors without historical foreign partners and, hence, reflects Japanese design philosophies. Conceptual designs have been completed for the Mitsubishi Simplified Pressurized Water Reactor (MS-PWR) in both a 300-MW(e) (MS-300) and a 600-MW(e) (MS-600) size. Conceptual design of a 1200-MW(e) reactor is being initiated.

Recent design work, already advancing beyond the conceptual stage, has focused primarily on the MS-600 design. MHI has begun a more detailed design and testing phase that will continue through 1996. The design objectives are to develop a plant that has improved safety, better economy, and higher reliability. To meet these objectives, the MS-600 design uses horizontal steam generators, a low-power density core, top-mounted in-core instrumentation, passively cooled drive mechanisms for the control rods, and a hybrid safety system.

The MS series uses a new hybrid reactor safety system that reflects Japanese design philosophies for high levels of safety and very high plant lifetime reliability. All current power reactors use active safety systems that include diesel generators, pumps, motors, and control systems to

Table 3.1 Principal design parameters of Mitsubishi PWR nuclear power plants

Design parameters	Current PWR designs (3rd generation)			Advanced PWR design (APWR) (4th generation)	Evolutionary technology PWR designs (MS series) (5th generation)	
Electrical power [MW(e)]	700	1,000	1,250	1,350	300	630
Thermal power [MW(t)]	1,994	2,910	3,582	3,839	854	1,825
No. of coolant loops	2	3	4	4	2	2
Fuel assembly type	17 by 17	17 by 17	17 by 17	19 by 19	14 by 14	15 by 15
No. of fuel assemblies	109	157	193	193	121	157
Accumulator type	Conventional			Conv.	Fluidic design[b]	
Steam-generator type	Vertical-60F	Vertical-60F	Vertical-52F	Vertical-65F-1	Horizontal, U-Tube type[b]	
No. of steam generators	2	3	4	4	2	2
Steam-turbine type	TC4F-44	TC4F-44	TC6F-52	TC6F52	TC2F40	TC4F40
Safety-system design	Active	Active	Active	Active	Active & passive	
Containment vessel descriptions	Cylindrical prestressed concrete containment with hemispherical dome and carbon-steel liner. Four-loop design has option for hybrid high-tensile steel containment.			Cylindrical prestressed concrete containment with hemispherical dome and carbon-steel liner	Steel primary containment with concrete-filled, steel secondary containment.[a]	

[a]Containment design optimized for fabrication of major subsections in shipyard.

[b]The fluidic accumulators and horizontal steam generators represent innovative design aspects that are significant improvements over conventional Western PWR designs.

ensure safety. In an emergency, these systems must start up and continue operation for an extended period of time. Evolutionary technology reactors under development, such as the Mitsubishi MS series, the Westinghouse Advanced Passive-600, and the General Electric Co. simplified boiling-water reactors (BWRs) have semipassive safety systems. All of these semipassive systems follow from a series of inventions and development work by ABB in the early 1980s. These systems must be started up (open valve etc.) in an emergency, but they are passive in operation. They do not require operation of active equipment such as motors and pumps and, hence, should be more reliable with better safety and lower costs than earlier plants.

The MS series is unique in that it contains a small, active safety system and a large semipassive safety system. The large semipassive safety system can handle all accidents and is conceptually similar to advanced designs by other reactor vendors. The small active safety system is designed to handle small incidents and accidents that can be realistically expected to occur over the lifetime of a number of power plants. An example of such an accident is a single tube failure in the steam generator. The rationale for the small active safety system is that it allows a measured response that simultaneously ensures safety while minimizing auxiliary damage. If the active safety system fails or the accident is too large, the large semipassive safety system takes over. It is similar to the concept of the fire department's fighting small fires with a fire extinguisher, while the fire truck with high-pressure water hoses is standing ready to assist. The firemen using the fire truck can put out the fire, but the auxiliary water damage would be significant and would delay the opening of the facility.

The MS series are the first PWRs outside the FSU designed with horizontal steam generators. Vertical steam generators have historically been the least reliable, most troublesome component in nuclear power plants and responsible for more reactor downtime than any other cause. Changing the orientation of the steam generators from vertical to horizontal eliminates many, but not all, problems. Horizontal steam generators, when compared to the more common vertical designs, offer a number of advantages such as the elimination of sludge buildup on the tube plates, increased resistance to seismic events, and significantly enhanced natural circulation cooling under accident conditions. The enhanced natural circulation is a result of the horizontal arrangement of the steam generators that prevents gas bubbles from forming in the U-tubes and blocking the flow.

The MS series of designs with no foreign partners is fully optimized for shipyard construction. This and other characteristics makes it much more suitable for export than earlier reactor designs.

4. THE VENDORS AND THE UTILITIES

4.1 OVERVIEW

The Japanese electric utility industry consists of nine privately owned electric utility companies, a number of smaller public utilities owned by local autonomies, and three special-purpose utility systems. At the end of 1992, Japan had 42 nuclear power plants in operation and producing a net electrical output of 32,044 MW(e) and another 12 units under construction or on order which would increase the nuclear-generated electrical output to 43,716 MW(e) [American Nuclear Society (ANS) 1993].

Total electricity production in Japan was over 152 GW(e) in 1992. Nuclear power contributed about 21.4% of the total; and hydroelectric, 13.4% of the total; the remainder coming from thermal production (coal, natural gas, and oil).

The utility structure of Japan reflects common features of Japanese business culture, but in a somewhat different form because of the constraint of being a utility. These constraints apply to electric, telephone, and railroad utilities. The constraints include the following:

- Corporate size and location are defined by geography. Utilities, by definition, serve a specific area, whereas other companies can build their facilities anywhere in the country. A utility's customers are predetermined. It is not a matter of choice to whom it sells its product.
- Utilities worldwide are considered monopolies and, thus, are regulated by the government at different levels. Utilities have a regional emphasis.

There is an important characteristic to Japanese utilities that does impact nuclear power. Historically, each Japanese utility has bought nuclear and other types of power plants from the same vendor over a period of decades. The Japanese utilities are partners with their chosen vendors.

4.2 JAPANESE ELECTRIC UTILITIES

The Electric Utility Law of 1964 governs Japan's electric power utilities and their activities. The law effectively permits the country's nine regional electric power companies to monopolize the retail sale of electric power in their respective service areas, but it also regulates the electric power rates to ensure equitable pricing.

A summary of the Japanese electric utilities is given in Table 4.1, which shows the total electric capacity in MW(e) by fuel type and the percent of nuclear electric capacity for each utility. The first nine utilities are privately owned and sell electricity at retail; the last three are special-purpose utilities and sell electricity at wholesale to the private utilities.

The nine privately owned utilities produce over 91% of Japan's total electricity. A listing of all the Japanese nuclear plants by electric utility is shown in Table 4.2. The Japanese utilities are among the largest in the world. The three largest Japanese utility companies—Tokyo Electric, Kansai Electric, and Chuba Electric—produce 42.3, 29.4, and 21.0 GW(e)/year, respectively. This accounts for 61% of Japan's total

Table 4.1 Summary of Japanese electric utilities

Utility name	Total electric capacity [MW(e)]	Nuclear electric capacity (%)	Electric capacity by fuel type [MW(e)]			
			Nuclear	Coal	Gas/oil	Hydroelectric
Utilities with BWRs						
Chuba Electric Power Co.	20,969	11.83	2,480	0	15,274	1,961
Chugoku Electric Power Co.	8,897	14.39	1,280	1,000	3,125	1,523
Hokuriku Electric Power Co.	3,954	0.00	0	0	2,162	502
Tohoku Electric Power Co.	10,058	5.21	524	2,850	5,890	460
Tokyo Electric Power Co.	42,335	26.68	11,296	0	26,686	3,938
Utilities with PWRs						
Hokkaido Electric Power Co.	4,415	26.23	1,158	950	0	300
Kansai Electric Power Co.	29,426	29.19	8,588	422	17,369	3,943
Kyushu Electric Power Co.	13,299	21.79	2,898	1,012	7,427	1,280
Shikoku Electric Power Co.	5,401	20.96	1,132	0	2,624	600
Other organizations						
Electric Power Development Co.	10,251	0.00	0	3,300	0	5,925
Japan Atomic Power Co.	2,783	100.00	2,783	0	0	0
Power Reactor & Nuclear Fuel Development Corp.	428	100.00	428	0	0	0

Table 4.2 Japanese nuclear plants by electric utility (reactors under construction in italics)

Utility name	Plant name	Net electrical capacity [MW(e)]	Plant type	Reactor vendor	Commercial operation
Chuba Electric Power Co.	Hamaoka 1	515	BWR	Toshiba	3/76
	Hamaoka 2	806	BWR	Toshiba	11/78
	Hamaoka 3	1056	BWR	Toshiba	8/87
	Hamaoka 4	1092	BWR	Toshiba	9/93
Chugoku Electric Power Co.	Shimane 1	439	BWR	Hitachi	3/74
	Shimane 2	790	BWR	Hitachi	2/89
Hokkaido Electric Power Co.	Tomari 1	550	PWR	MHI	6/89
	Tomari 2	550	PWR	MHI	4/91
Hokuriku Electric Power Co.	Shika 1	513	BWR	Hitachi	7/93
Japan Atomic Power Co.	Tokai 1	129	GCR	GEC	7/66
	Tokai 2	1056	BWR	GE	11/78
	Tsuruga 1	340	BWR	GE	3/70
	Tsuruga 2	1115	PWR	MHI	2/87
Kansai Electric Power Co.	Mihama 1	320	PWR	Westinghouse	11/70
	Mihama 2	470	PWR	MHI	7/72
	Mihama 3	780	PWR	MHI	12/76
	Takahama 1	780	PWR	Westinghouse	11/74
	Takahama 2	780	PWR	MHI	11/75
	Takahama 3	830	PWR	MHI	1/85

Table 4.2 Japanese nuclear plants by electric utility (reactors under construction in italics) (continued)

Utility name	Plant name	Net electrical capacity [MW(e)]	Plant type	Reactor vendor	Commercial operation
	Takahama 4	830	PWR	MHI	6/85
	Ohi 1	1120	PWR	Westinghouse	3/79
	Ohi 2	1120	PWR	Westinghouse	12/79
	Ohi 3	1127	PWR	MHI	12/91
	Ohi 4	1127	PWR	MHI	2/93
Kyushu Electric Power Co.	Genkai 1	529	PWR	MHI	10/75
	Genkai 2	529	PWR	MHI	3/81
	Genkai 3	*1127*	*PWR*	*MHI*	*3/94*
	Genkai 4	*1127*	*PWR*	*MHI*	*7/97*
	Sendai 1	846	PWR	MHI	7/84
	Sendai 2	846	PWR	MHI	11/85
Power Reactor & Nuclear Fuel Development Corp.	Fugen, ATR	148	HWLWR	Hitachi/MHI/ SHI/Fuji	3/79
	Monju	*280*	*LMFBR*	*Toshiba/Hitachi/MHI/Fuji*	*?/93*
Shikoku Electric Power Co.	Ikata 1	538	PWR	MHI	9/77
	Ikata 2	538	PWR	MHI	3/82
	Ikata 3	*846*	*PWR*	*MHI*	*3/95*
Tohoku Electric Power Co.	Onagawa 1	497	BWR	Toshiba	6/84

Table 4.2 Japanese nuclear plants by electric utility (reactors under construction in italics) (continued)

Utility name	Plant name	Net electrical capacity [MW(e)]	Plant type	Reactor vendor	Commercial operation
	Onagawa 2	*796*	*BWR*	*Toshiba*	*7/95*
	Maki 1	796	BWR	TBD	3/2002
Tokyo Electric Power Co.	Fukushima Daiichi 1	439	BWR	GE	3/71
	Fukushima Daiichi 2	760	BWR	GE	7/74
	Fukushima Daiichi 3	760	BWR	Toshiba	3/76
	Fukushima Daiichi 4	760	BWR	Hitachi	10/78
	Fukushima Daiichi 5	760	BWR	Toshiba	4/78
	Fukushima Daiichi 6	1067	BWR	GE	10/79
	Fukushima Daini 1	1067	BWR	Toshiba	4/82
	Fukushima Daini 2	1067	BWR	Hitachi	2/84
	Fukushima Daini 3	1067	BWR	Toshiba	6/85
	Fukushima Daini 4	1067	BWR	Hitachi	8/87
	Kashiwazaki Kariwa 1	1067	BWR	Toshiba	9/85
	Kashiwazaki Kariwa 2	1067	BWR	Toshiba	9/90
	Kashiwazaki Kariwa 3	1067	BWR	Toshiba	7/93
	Kashiwazaki Kariwa 4	*1067*	*BWR*	*Hitachi*	*7/94*
	Kashiwazaki Kariwa 5	1067	BWR	Hitachi	4/90
	Kashiwazaki Kariwa 6	*1315*	*BWR*	*GE/Toshiba*	*7/96*
	Kashiwazaki Kariwa 7	*1315*	*BWR*	*GE/Hitachi*	*7/97*

electricity. Their production of electricity from nuclear power plants is 11.3, 8.6, and 2.5 GW(e)/year, respectively. For comparison, in the United States, there are many smaller private and public utilities. There are 47 U.S. nuclear utilities large enough to be listed by the ANS in its biannual listing of nuclear reactors (ANS March 1993). The three largest U.S. electric utilities—Tennessee Valley Authority (TVA), Commonwealth Edison Co., and Texas Utilities Electric Co.—produce 30.8, 25.4, and 21.1 GW(e)/year, respectively. Note that the largest U.S. electric utility, the government-owned TVA, is about a third smaller than the largest Japanese utility, Tokyo Electric. Only the 4 largest U.S. electric utilities produce over 20 GW(e)/year, and most individual U.S. electric utilities produce between 5 to 15 GW(e)/year.

There are three special electric generating organizations that have different functions. The Electric Power Development Company promotes the development of large-scale hydroelectric and coal-fired thermal plants. The Japan Atomic Power Company (JAPC) was chartered to promote the safe use of nuclear power in Japan. It demonstrates new commercial nuclear power technologies. It was originally created by the government but is now jointly owned by the 9 private utilities and the nuclear supply industry (see below). JAPC owned the first commercial nuclear reactor in Japan. That reactor started up in 1966. Power Reactor and Nuclear Fuel Development Corporation (PNC) is a government corporation that is responsible for experimental power reactors. It operates the 100-MW(t) experimental Joyo fast breeder reactor (FBR), which began operation in 1978; the 148 MW(e) Fugen prototype advanced thermal reactor (ATR), which is a heavy-water moderated/light-water cooled, pressure-tube-type reactor; and the 280-MW(e) Monju prototype liquid-metal fast-breeder company (LMFBR), which is scheduled to start operation in 1994. These three organizations produce <9% of the total Japanese electricity capacity.

The utility regulatory structures of Japan and the United States are different. In the United States, there are state-level public utility commissions that provide rate regulation of nuclear and other power plants operated by investor-owned utilities. U.S. government-owned utilities and rural electric co-operatives are nonprofit enterprises that are self-regulated. However, in Japan, there is no state, (or prefecture) regulation. Electricity rates in Japan are governed at the national level by the MITI.

According to MITI, the official projection for Japan's nuclear power growth is an increase to 72,500 MW(e) by 2010; this amounts to an average yearly growth of 2,000 MW(e) from the current nuclear production. Other groups have postulated less optimistic projections for nuclear growth—ranging from a low of 55,000 MW(e) to MITI's high of 72,500 MW(e) by 2010 [American Nuclear Society (ANS) February 1993].

4.3 UTILITY ECONOMICS

Japanese utilities have historically supported the use of nuclear power. Estimates are that nuclear power is currently (*Atoms* September 1993) the most economic source of electricity in Japan and

will remain (*Atoms* March 1991) as the most economic source of electric power.

4.4 STRUCTURE OF VENDOR-UTILITY RELATIONSHIPS

The structure of Japanese industry encourages partnership relationships between vendors and utilities. A comparison of the structure of the U.S. and Japanese utility-vendor relationship can clarify this.

The U.S. industrial structure encourages independent utility-vendor relationships. The United States has hundreds of utilities with 47 utilities owning nuclear power stations. There are no dominant utilities. In part, this reflects the regulation of utilities by state governments that complicate operation of multistate utilities. In addition, this reflects traditional American political concerns about concentration of economic power and utility trusts. For a reactor vendor, this structure encourages the vendor to first develop a product and then sell it to multiple utilities. The utilities are individually relatively small. This, in turn, limits the technical and financial influence of a utility on the vendor.

In Japan, the business structure encourages vendor-utility partnerships. There are nine large utilities, regulated at the national level. Three of these utilities are megautilities—Tokyo Electric Power Company (TEPCO), Chubu Power Company, and Kansai Power Company. Each is sufficiently large such that it could buy or create its own vendor. With the size come high levels of technical expertise and financial power. The three Japanese vendors have three big customers and six smaller customers among them. For any vendor, most of its business will be carried out with one or two very knowledgeable utilities. Under such circumstances, the vendor does not develop a product and then see if it can find a customer. Instead, the vendor forms a partnership with the utility. Similarly, the big utilities recognize that they dominate the vendor business and will, in the end, pay most of the development costs of any new product. There is no set of 20 utilities buying reactors with development costs spread over a large number of utilities. The megautility recognizes it is forming a partnership with the vendor.

Partnership relationships between vendors and customers is not unique to the Japanese nuclear power industry. Partnership relationships are common in industries with (1) few customers and few vendors and (2) high product development costs. In the United States, the commercial aircraft manufacturing industry (e.g., Boeing and McDonald Douglas) has had similar relationships with major airlines when developing new types of commercial aircraft.

4.5 ROLE OF UTILITIES IN THE DEVELOPMENT OF COMMERCIAL REACTORS

Japanese utilities are partners with Japanese vendors in development of new commercial power reactors. This partnership (Hansen 1990) includes both vendor and government (Table 4.3), each of which has particular responsibilities. A noteworthy characteristic of this partnership is the heavy utility involvement in both planning and financing of R&D.

Table 4.3 Nuclear power development roles of government, utility, and industry in Japan

Division of work	Government	Utility	Industry
R&D	· Safety research · Reliability verification test · Large-scale R&D · Financial support	· Planning of R&D · Review and application · Financial support	· R&D implementation
Construction of nuclear power plant	· Authorization of electrical power development · Regulatory administrations · Establishment of codes, standards and regulations	· Planning · License · Contract · Construction management · Purchase of fuel material and enrichment	· Engineering · Licensing support · Design, manufacturing and installation of equipment · Fuel fabrication · Startup test · Operator training
Operation of nuclear power station		· Operation · Periodical inspection and maintenance · Core management	· Inspection work · Maintenance and repair work · Supply of reload fuel

In recent years, the Japanese utilities have provided (1) ~$200 million per year for development of near-term commercial LWR technology; (2) ~$100 million per year for development of longer term future nuclear power options (high-temperature gas cooled reactors, ATRs, and FBRs); and (3) $200 million per year for support of fuel cycles. During the development of the APWR led by MHI, the five utilities using PWR technology and led by Kansai Power Company paid for one-third of the development costs. In the development of the advanced BWR (ABWR), four consortium partners are officially listed: Hitachi, GE, Toshiba, and TEPCO. TEPCO played a major technical role in its development in addition to its financial support. These are very large numbers compared to funds provided by utilities elsewhere in the world to support their vendors.

This utility support for nuclear power R&D is only one component of a larger utility effort to develop advanced technologies for the utility industry. In FY 1993, total R&D spending by Japanese utilities (*Atoms* 1993e) was ~2 billion dollars (218.2×10^9 yen) with about 0.7 billion dollars (77.6×10^9 yen) for nuclear power. These numbers exclude government and industrial R&D.

Many economists argue the benefits of strong vendor-customer partnerships in development of new industrial technologies (Kaijser 1992). The vendor in the partnership has the technical design and construction experience. The customer provides (1) financial stability, (2) the detailed operating knowledge of design requirements—what is important—and (3) an industrial structure in which the first-of-a-kind facility can operate in an industrial environment while the inevitable teething problems are resolved.

The utilities have also developed an institutional structure to build large-scale nuclear power demonstration plants or first-of-a-kind commercial power plants. In 1957, the Japanese Atomic Power Company (JAPCO) was established to build Japan's first nuclear power station—a 160-MW(e) gas-cooled reactor (GCR), which is based on British technology at the Tokai site. Since then, the utilities have used JAPCO to build first-of-a-kind commercial power plants (JAPCO 1993). The ownership of JAPCO is 90.42% utilities, 7.52% nuclear power suppliers, and 2.06% other companies. This mechanism remains in place for utilities to work with vendors to demonstrate on a commercial scale new nuclear power technologies. It is expected that the first next-generation Mitsubishi APWR will be built by JAPCO.

4.6 PURCHASE OF POWER PLANTS: ONLY ONE SUPPLIER

Historically, each Japanese utility has bought only from its chosen vendor or vendors (Table 4.2). This applies to both nuclear and conventional power plants. When new technology is involved, foreign supplies will be used, but the utility's vendor will be involved in the project and normally obtain a license for the technology.

Several Japanese utilities work with multiple vendors. For example, TEPCO buys nuclear power plants from Hitachi and Toshiba. It is noteworthy that TEPCO's recent purchase of two ABWRs (Kashiwazaki 6 and Kashiwazaki 7)

involved one purchase from each of its vendors but that both plants are identical.

This multidecade relationship changes how the utility and vendor interact. The vendor begins to view the operating plants as his plants because he recognizes that he must support plant operations for the life of the plant. He becomes part of the *operating* utility team. If a plant goes down, the first priorities are to repair the plant and then to put it back on line. The hands-off contractual issues (cost etc.) can be addressed after the immediate problem has been resolved. The utility expects such rapid response in return for being a loyal customer of the vendor. This type of relationship occurs in many small business relationships worldwide, but in Japan it has been extended to involve very large activities.

4.7 PLANT OPERATIONS AND MAINTENANCE: UTILITY-VENDOR DIVISION OF RESPONSIBILITY

The Mitsubishi Nuclear Power Training Center, Ltd. (NPTC) is responsible for operator training for PWRs. This is in contrast to training operations in the United States and many other countries where operator training is primarily a utility responsibility. The different mix of utility-vendor responsibility requires as an initial condition long-term utility-vendor relationships. This company, NPTC, is jointly owned by MHI and Japanese utilities. However, each utility company has its own simulators and other related facilities for operator training on its nuclear power plant sites. The programs at these facilities are closely coordinated by the Mitsubishi training center, NPTC. The NPTC is an integral part of the infrastructure MHI has developed to ensure that there is a continual flow of information to the R&D, design, and manufacturing people by the operating people of the utility staffs. The joint ownership of NPTC enhances the rotation of MHI, MAPI, and utility people to and from this organization, thus ensuring the development of personal relationships between people in Mitsubishi's design and development sections with operating people at the utility sites.

In most Japanese power plants, the vendor is also the prime maintenance contractor (Lester and Crockey 1987; Hinman and Lowinger 1987). Up to 70% of the maintenance work is done by the vendor.

4.8 REACTOR PERFORMANCE

The performance of a nuclear power reactor depends upon the utilities and their suppliers. Recent multinational comparisons (Hansen et al. 1990) indicate very high performance for Japanese nuclear power plants (Table 4.4) compared to those in most of the rest of the world.

There is one unique characteristic of how Japan operates nuclear power plants. All Japanese nuclear power plants are shut down periodically for detailed maintenance and detailed inspection. The detailed inspections are one of the requirements of the Japanese regulatory authority (*Atoms* January 1993; Horns 1993f). The requirements of inspection and maintenance exceed those of other countries. This results in the plants being offline for ~25% of each year. Simultaneously, the down time of Japanese reactors due to equipment failures is very low (1-2%) by world standards. The

Japanese philosophy is to strongly emphasize maintenance to assure that the power plant operates with very high reliability.

Table 4.4. Measures of power reactor performance by country[a]

Category	Japan	United States
Unscheduled shutdowns per reactor year	0.1–0.2	2.1
Average capacity factors, %	75%	65%
Premature fuel assemblies discharged per reactor year[b]	0.15	1.6–3.8
Maximum ^{131}I activity in coolant, $\mu Ci/cm^{3}$[b]	10^{-5}	5×10^{-3}
Personnel radiation dose, man-rem/reactor year[b]	30	350–500

[a]Based on 1987–1988 data. Note: U.S. performance has begun to improve in recent years.

[b]These accomplishments reflect the very high fuel quality and the lowest fuel failure rates in the world.

5. THE VENDORS AND THE JAPANESE GOVERNMENT

The Japanese government supports the reactor vendors directly and indirectly through a variety of mechanisms. These mechanisms strengthen vendor capabilities.

5.1 POLITICAL SUPPORT

The most important support to the nuclear power supply industry is the Japanese government's policy to increase the fraction of electricity generated using nuclear power. The current plans include adding 2000 MW(e) of nuclear electric generating capacity per year through 2010. With this commitment, there is assurance of utility orders for nuclear power plants. With markets assured, the vendors have the confidence that the products that they develop will be bought by utilities. As a practical matter, assured domestic markets are far more important than are all other types of assistance together, and by themselves assure strong vendors.

The Japanese government support for nuclear power is based on multiple considerations: (1) favorable economics of nuclear power; (2) a lack of domestic energy resources (no oil, gas, coal, and limited hydroelectric); and (3) a history of energy shortages. Strategic concerns about energy availability and the high cost of earlier energy shortages have significantly influenced policy. Domestic energy shortages were a contributor to Japanese expansion in the 1930s and 1940s that led to Japanese entry into World War II. The early postwar environment saw severe energy shortages. The 1973 oil embargo resulted in large-scale economic dislocations.

This support is through several mechanisms:

- In Japan, the national government provides economic regulation of the utilities. This provides assurance to the utilities of a return on investment in nuclear power plants. The regulatory structure also defines allowable expenses for R&D, and other purposes. This is in contrast to the United States, where state governments regulate utilities. With state- government utility regulation, national government energy policies can not be easily supported via the utility regulatory structure.

- The Japanese government provides financial and other forms of assistance to local communities where power plants are sited. Such assistance is for selected hydroelectric, fossil, and nuclear power plants (*Atoms* August 1993; *Atoms* September 1993).

There is one other characteristic of the Japanese system that provides financial continuity of government support. There is a three-fourths of 1% tax on electricity for the special account for Power Resource Development. This type of "trust fund" ensures the long-term availability of government financing.

5.2 SUPPORT OF COMMERCIAL LWR TECHNOLOGY

Following the oil embargo of 1973, the Japanese government initiated a series of industrial cooperative programs to further

nuclear power. These were organized by the MITI, which is responsible for research with the goal of commercialization. These activities were implemented by the NUPEC—a government-sponsored organization reporting to the Agency of Natural Resources and Energy, which in turn, reports to the MITI and, hence, to the Japanese cabinet. NUPEC's stated objectives are to

- "Help improve and develop nuclear power technology through test and development for research, improving on and confirming safety and reliability of nuclear power generations equipment."

- "Help set up of consensus among the public concerning use of nuclear power as an energy source through public relations activities in order to help develop a sound Japanese economy and help stabilize and improve the living standards of Japanese people."

NUPEC has built and now operates very large-scale test facilities to test the reliability and safety of nuclear power equipment. It also conducts generic large-scale tests. Such activities clearly assist both evaluation of safety (regulation) and vendor development of new technologies. The current budget is approaching 25 billion yen/year ($250 million/year).

5.3 LONG-TERM RESEARCH

The Japanese government supports large-scale, longer-term energy R&D programs. This includes support for breeder reactors and fusion. Such research provides long-term assistance to industry, but not short-term commercial assistance. This support is through the Science and Technology Agency (STA). Within the STA are the Japanese Atomic Energy Research Institute (JAERI) and the PNC. While MITI and STA objectives are separated by time-scale (short-term vs longer term), in fact, STA does significant work that assists near-term LWR development.

6. COMPARATIVE STRENGTHS AND POTENTIAL WEAKNESSES OF JAPAN'S REACTOR VENDORS ON THE INTERNATIONAL MARKET

The Japanese nuclear power industry has both unique advantages and disadvantages (Lester 1993) for export of nuclear power technology.

6.1 ADVANTAGES IN EXPORT MARKET

6.1.1 Industrial Base

Japan has the largest nuclear power research, development, engineering, and construction industries in the world with a worldwide industrial reputation for excellence. They are world leaders in commercial nuclear power technology. There are no questions about competence and capabilities.

6.1.2 Current and Planned Reactor Products

The Japanese utilities have historically preferred large nuclear power plants to minimize costs and siting difficulties. The vendors have programs to develop smaller reactors (Sect. 3.2.2). These have limited applicability in Japan. The development of power reactors of different sizes will allow Japanese vendors to compete in different markets worldwide, with different requirements for nuclear reactors.

6.1.3 Nuclear Plant Financing

The financing of nuclear power plants is a major issue in all parts of the world because new plants require multibillion dollar commitments. These are major expenditures in any economy. In France and Canada, the government-owned utilities, combined with strong government involvement with vendors, minimize these problems. In the United States, small utility sizes often put the issue in the category of "betting the company" on the success of the project because net worth and/or annual budgets of many utilities are not large compared to the multibillion dollar cost of a new plant. In Japan, the individual utility sizes are quite large; so, a new plant commitment is a significant issue, but not a "bet" the company would risk.

In smaller and less developed countries, the cost of a power plant can be a major item in their national budgets. It is for these reasons that the financing of a new power plant is not only a major issue but also possibly a totally dominating political and economic issue. The technical factors associated with a power plant design selection are sometimes relegated simply to accepting the designs of previously built plants that have respectable performance. Therefore, the power plant supplier's ability to support and/or totally manage the financing of a new plant project is a major factor in obtaining new business. Financing is a dominant prerequisite for both companies and countries that are considering the construction of a nuclear plant. This is true for most foreign power plant markets.

In Japan's *keiretsu* system, the banks, insurance companies, and trust companies play a major role in the control, management, and financing of the *keiretsu* companies. The structure/system required to develop the financial plans for utilities and countries is in place and operating in organizations, such as the Mitsubishi

Group. The cost of a nuclear plant ($2, 3, or 4 billion) is not large compared with the $300-billion yearly revenues of the Mitsubishi group. There are a limited number of countries besides utilities, construction companies, or reactor suppliers who can provide the sufficient financial depth necessary to compete with this strength.

6.1.4 Modular Shipyard Construction

Japan, for historical reasons (see Sect. 2.6), has led the world in construction of nuclear power plants using modules built in shipyards. The system has been optimized for building reactors on ocean coasts in Japan. These are the same conditions that would apply for most future reactor sites around the Pacific rim.

For power reactor exports to newly industrialized countries, modular shipyard construction has the usual benefits found in industrialized countries, plus minimization of skilled field labor and minimization of a local infrastructure to support construction. The experience base in these design and construction techniques provides the Japanese nuclear power industry a competitive advantage. The actual shipyard modules could be built in shipyards in countries with lower costs (South Korea etc.). The competitive skill is how to design and field-assemble shipyard modules into power stations.

6.1.5 Legal Constraints

Japanese vendors are not legally constrained in the export of nuclear power technologies. The Japanese vendors were originally licensees of U.S. vendors. In the early 1990's these licensing agreements were renegotiated with most restrictions on export eliminated. The vendors are legally independent of industrial licensing restrictions.

6.2 DISADVANTAGES IN EXPORT MARKET

6.2.1 Japanese Utilities

The single largest export constraint are the Japanese utilities. In Japan, the utilities and vendors are permanent partners, with the utilities supplying much of the research and development funding to the vendors. Obligations go both ways. The utility concern is, "what happens if a Japanese nuclear power plant is exported and has an accident?" This could reflect on the design of Japanese power plants with increased domestic opposition to nuclear power. The utilities have both a large investment in nuclear power and believe that it is the lowest-cost energy source to generate electricity.

6.2.2 Japanese History

The dominant market for nuclear power plants in the 1990s is the Pacific Rim (South Korea, Taiwan, China, Indonesia, etc.). There are very strong historical animosities between most of these countries and Japan. Japan today is the dominant trade partner in the Pacific Rim because of its advanced technology and economy. Business self-interest has usually overcome history. It is, however, still a constraint—particularly for potentially controversial, high- visibility technologies.

6.2.3 Fuel Cycle Support

Historically, fuel cycle services have been sold with power reactors. Japan has a

large capability to fabricate power reactor fuel and is starting up enrichment facilities to produce enriched uranium for power reactors. Twenty years ago, this was a decisive competitive export advantage. It is less of an advantage today because of the excess capabilities of nuclear fuel cycle facilities worldwide. With the end of the cold war and conversion of Russian, U.S., and British military fuel cycle facilities to commercial application, it is becoming a minor disadvantage not to be able to offer all fuel cycle services.

6.2.4 Nonproliferation

The Japanese government has historically been concerned with nonproliferation because of its own unique history. This places some constraints on exports.

6.2.5 Economics and Currency Fluctuations

The value of the Japanese currency has steadily increased in the past decade, thus making Japanese products more expensive and less competitive. Simultaneously, continued trade imbalances with other countries are a major source of economic and political conflict. Economic competitiveness can be partly addressed in export markets by offshore fabrication of many nuclear plant components with engineering and high technology components produced in Japan.

The political dimension of economic competiveness raises different constraints. The Japanese government has negotiated various economic agreements with different countries. Such agreements involve trade-offs—which Japanese exports should be encouraged: electronics, cars, nuclear power equipment, etc. The risks of nuclear power exports make it a less desirable export than many other products.

6.3 IMPLICATIONS FOR EXPORT

The large size of the Japanese research, development, engineering and construction nuclear power programs implies major influence in three areas: components supply, engineering, and complete plants. The Japanese suppliers are rapidly becoming major component suppliers worldwide. It is likely that within a decade the situation will be similar to the electronics industry. It is difficult to find electronic equipment worldwide that doesn't have some Japanese parts. The same is true of the nuclear power industry.

In plant design, the Japanese are becoming the dominant influence. Because most of the commercial nuclear power market for new facilities is in Japan, Japanese organizations lead in these areas. For example, the ABWR is a joint effort of GE (U.S.), Hitachi (Japan), and Toshiba (Japan). The development of the APWR was a joint effort between Mitsubishi and Westinghouse (U.S.). Because most of the market is in Japan, most of the engineering is in Japan. The reactor designers emphasize those design features desired by Japanese utilities. The ABWR will probably be built in multiple countries by different vendors, but much of the basic design will be done by or reflect Japanese design philosophy.

Japan will likely export entire nuclear power plants. Japanese vendors have begun to bid on providing full nuclear power stations. This is a very recent development (within the last 3 years). There are, however, internal Japanese

constraints that will limit when the Japanese vendors will lead an international consortium to build a foreign nuclear power plant.

It is important to note that most nuclear power plants that are exported are sold by international consortia of multiple suppliers. This allows a supplier to be a major supplier without the lead role—the prime contractor. The prime contractor does not necessarily have most of the business associated with a foreign sale. For many countries, Japanese vendors will become the major suppliers, but not the lead vendor.

6.4 OTHER JAPANESE VENDORS

Japan has two vendor groups. As previously discussed (Sect. 6), the Mitsubishi group is led by MHI. The group sells PWRs with the technology originally licensed from Westinghouse (U.S.), but now being developed independently. The second group consists of three vendors: Hitachi (Japan), GE (U.S.), and Toshiba (Japan)—HGET. These vendors sell BWRs with the technology originally licensed from GE.

The HGET alliance involves long-term relationships among the three companies in many areas of industrial technology beyond nuclear power (Kano October 1993). The General Electric–Toshiba partnership started in the 1920s; thus, the nuclear power agreements must be considered as only part of a larger partnership (Schlender 1993). In Japan, Hitachi and Toshiba are considered separate vendors, but it is noteworthy that many products in the nuclear area are identical. In 1992 the three companies agreed to extend their 25-year technical cooperation agreements in nuclear energy by another 10 years (Nuclear Plant Journal). The agreement included the Japan Nuclear Fuel Company—a jointly owned company of the three parent companies.

In recent years, the HGET group has been developing the ABWR. This effort has included the fourth major partner—TEPCO, which is the world's largest privately owned utility. The ABWR was clearly developed to meet the requirements and needs of TEPCO, which has ordered and is currently constructing two ABWRs. In the United States, GE is in the process of having this reactor licensed by the U.S. Nuclear Regulatory Commission for use in the United States. It is noteworthy that the reactor has many components designed to Japanese standards.

The ABWR is also being offered for foreign non-U.S. and non-Japanese sales. The decision as to which partner will bid on a particular foreign bid is determined by which HGET partner has the greatest potential for winning the bid. This advantage depends upon a variety of technical, political, and financial factors that are country-dependent. The strong involvement of TEPCO will strongly influence these decisions.

The Japanese HGET partners are members of *keiretsus* and have many of the same characteristics of the Mitsubishi *keiretsu*. The major differences between the Mitsubishi group and HGET is that because of historical factors, HGET has a foreign partner (GE), which provides an alternative approach for foreign sales.

7. CONCLUSIONS

Japan has the largest nuclear power plant construction program of any nation in the world, and Japan has the largest private utilities in the world. These utilities have the financial, technical, and managerial resources to support the largest nuclear power construction program. Japan is totally dependent on foreign-energy sources; with only a fifth of its electricity currently being generated by nuclear power. It has major incentives to build more nuclear power plants to minimize energy costs and to have higher assurances of energy supplies. Japan has an excellent nuclear power operating record and has maintained low-cost nuclear power.

The Japanese vendors are members of the world's largest industrial groups—the Japanese *keiretsus*. The vendors, by themselves, are among the world's largest corporations. The utilities and the government financially support the vendors in the development of nuclear power technology. The Japanese vendors together have more recent experience in building nuclear power plants than has any other country. They are leaders in nuclear power plant technology.

The Japanese reactor vendors have recently begun to enter the world market. Given the extraordinary domestic strength of the Japanese vendors, it is reasonable to conclude that they will become one of the dominant suppliers in the export market unless they are limited by political factors. The major limitation is the concern by Japanese utilities of the domestic political consequences of a nuclear power reactor accident at Japanese designed power plant outside Japan. The extraordinarily strong linkages between vendors and utilities, that is a major factor in the success of the domestic nuclear power program, is simultaneously the largest constraint on exports of entire power plants. This constraint is not as significant of a barrier for supply of component parts, technology transfer, or joint partnerships where the "lead" partner is not a Japanese company.

There are two reactor consortiums: HGET and Mitsubishi. The HGET consortium has the largest market share in Japan. This is partly because the utilities associated with HGET have been more successful recently at siting nuclear power stations. Mitsubishi is the largest single reactor vendor in Japan and historically has been a major exporter of heavy industrial equipment. Difficulties in power reactor sitings have limited sales. It has become the leading Japanese reactor vendor in terms of exports.

8. REFERENCES

American Nuclear Society 1993. *World Directory of Nuclear Utility Management*, 6th ed., American Nuclear Society, pp. 54–72, 1992.

Atoms November 1991. "Control Room Modules Installed at Kashiwazaki Kariwa Unit 4," *Atoms in Japan* 35(11),29.

Atoms March 1991. "Nuclear Power Generating Costs Will Be Cheapest by the Year 2010, IEE Reports, *Atoms in Japan* 35(3),4.

Atoms September 1993. "IEE Estimates: Nuclear Is the Cheapest Power Source," *Atoms in Japan* 37(9),20.

Atoms August 1993. "Mitsubishi Heavy Industries To Merge with MAOI in October 1994," *Atoms in Japan* 37(8),23.

Atoms July 1993. "Government Designates Suzu Nuclear and Others as Siting Assistance Units" *Atoms in Japan* 37(7),21.

Atoms September 1993. "Nuclear Budget Request for Fiscal 1994 Reaches 458 Billion Yen, Up 1.7%," *Atoms in Japan* 37(9),4.

Atoms May 1993. "Japan's Utility Industry To Spend 79.6 Billion Yen on Nuclear Technology Development in FY 1993," *Atoms in Japan* 37(5),4.

Atoms January 1993. "Japan's Nuclear Plants Achieve 73.6% of Average Capacity Factor for 1992," *Atoms in Japan* 37(1),30.

Atoms April 1993. "Japan Reaches 74.2% Nuclear Capacity Factor in FY 1992, Tenth Straight Year Above 70%," *Atoms in Japan* 37(4),34.

Bacon, J. and Brown, J. K. 1978. *The Board of Directors: Perspectives and Practices in Nine Countries*, Conference Board, New York.

Ballon, R. J., et al. 1976. "Financial Reporting in Japan," *Cadence International*, Tokyo.

Besker, A. 1991. *The Pacific Rim Almanac*, Harper Perennial

Bonsignore, M. R. Fall 1993. "Global Leadership in a Technological World," *Items*, University of Minnesota.

Chugoku Inc., 1993. *Chugoku Electric Power Company, Inc., Annual Report 1993*, Hiroshima, Japan.

Derdak, T. *International Directory of Company Histories*, St. James Press, Chicago.

Dizard III, W. March 26, 1992, "Royalties Built-In New Westinghouse Mitsubishi Licensing Agreement," *Nucleonics Week.*

Elliott, T. C., editor 1991. *International Directory of Electric Utilities*, Third edition, McGraw-Hill, Inc.,

Financial Times June 1, 1990. p. 3.

Forsberg, C. W., et al. October 1989. *Proposed and Existing Passive and Inherent Safety-Related Structures, Systems, and Components (Building Blocks) for Advanced Light-Water Reactors*, ORNL-6554, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory.

Fukasaki, Y. 1992, *Technology and Industrial Development in Prewar Japan*, Routtedge Press, London.

Gerlach, M. L. 1992. *Alliance Capitalism: The Social Organization of Japanese Business*, University of California Press, Berkeley, California.

Gerlach, M. L., March 1992, "The Japanese Corporate Network: A Blockmodel Analysis," *Administrative Science Quarterly*, 37(n1),105

Goedertur, J. M., *A Dictionary of Japanese History*, Walker-Weatherhill, New York

Hansen, K. F. et al., October 1990. *Nuclear Power in Japan* (Japanese Technology Evaluation).

Hibbs, M. July 1993. "Russia's RBMKs and VVER-440s Are Still Outperforming Newer PWRs," *Nucleonics Week.*

Hinman, G. W. and Lowinger, T. C., July 1987. "A Comparative Study of Japan and U.S. Nuclear Enterprise: Industry Structure Regulation and Construction Experience," Energy Systems and Policy, vol. 2, p. 205, Taylor and Francis.

Hokuriku Inc. 1993, *Hokuriku Electric Power Company Annual Report 1993*, Toyama City, Japan.

Japco 1993, *The Japan Atomic Power Company*, Tokyo, Japan.

Johnson, F. T. and Orr, R. S., Oct. 30–Nov. 4, 1988. "Modular Construction Approach for Advanced Nuclear Plants," *Tran. Am. Nuc. Soc.* 57, 191.

Kaijser, A. 1992. "Redirecting Power: Swedish Nuclear Power Policies in Historical Perspective," *Ann. Rev. Energy Env.* 17, 437.

Kansai 1993, "Kanai Electric Power Company, Inc.: Current Information 1993," Osaka, Japan.

Kano, C. Oct. 4, 1993, "How Toshiba Makes Alliances Work," *Fortune* 128(8), 116.

Kearns, R. L. 1992. *Zarbatsu America, How Japanese Firms Are Colonizing Vital U.S. Industries*, The Free Press, a Division of Macmillan, Inc., New York.

Kyôkai, K. C., 1990. *Keiretsu* no Kenkyū (Research on Industrial Groups), Tokyo.

Kyushu, Inc. 1992. *Kyushu Electric Power Company, Incorporated, Annual Report.*

Lester, R. K. and Crockey, M. B. August 1987, The Economic Organization of Nuclear Plant Projects: Some Cross-National Comparisons, MIT-EL87-009WP, Massachusetts Institute of Technology, Cambridge, Massachusetts

Lester, R. K. Fall 1983, "Structural Change in the Nuclear Power Plant industry in the Pacific Basin Region," *The Columbia Journal of World Business*, Columbia University.

MacLachlan, A. April 9, 1992, "Siemans-Framatome and MHI Chosen To Supply Spanish, Belgian SGs," *Nucleonics Week*, 33(15),1.

Matsuoka, T., Tabuchi, K., Sugizaki, T., and Okabe, K. April-June 1992, "Safety Features of the Simplified Mitsubishi Pressurized-Water Reactor, *Nuclear Safety*, 33(2),196.

Matsuoka, T. June 1993. "A Simplified Japanese PWR," *Nuclear Engineering International.*

Mitsubishi Electric Company 1992, *Annual Report*, Tokyo, Japan.

Mitsubishi Heavy Industries 1993. *Annual Report 1992.*

"1992 IAEA Figures Say France Has Highest Ratio of Nuclear Power," *Nucleonics Week*, August 19, 1993.

Nuclear Plant Journal Jan.-Feb., 1993, "Technical Agreements: G. E. Nuclear Energy."

Papinot, E., *Historical and Geological Directory of Japan*, Frederick Ungar Publishing Co., New York.

Parkinson, G., Short, J., and Ushio, S. Nov. 15, 1982. "For More Projects the Word Is: Go Modular," *Chem Eng.*, p. 67.

Perkins, D., *Encyclopedia of Japan*, Roundtable Press, New York.

Porter, M. E., 1990. *The Competitive Advantage of Nations*, The Free Press, a Division of Macmillan, Inc., New York.

Schlender, B. R., October 4, 1993, "How Toshiba Make Alliances Work," *Fortune* 128(8):116

Schroeder, M., March 8, 1993, "The Decline and Fall of Westinghouse Paul Lego," *Business Week*, p. 68.

Schroeder, M., May 11, 1992, "Does Everything Add Up At Westinghouse Credit," *Business Week*, p. 80.

Seubert, T. W., May 1988 *Modular Shipbuilding and Its Relevance To Construction of Nuclear Power Plants*, (Thesis) Massachusetts Institute of Technology, Cambridge, Massachusetts.

Shikoku, 1993, "Shikoku Electric Power Company, Inc., Annual Report 1993, Takamastsu, Japan.

Stafford, D. C. and Purkins, R. H. A., 1989. *Directory of Multinationals, 1989*

TEPCO, 1993, Tokyo Electric Power Company, "Tokyo Electric Power Company: An Overview," Tokyo, Japan.

Thurow, L., 1992. *Head to Head: The Coming Economic Battle Among Japan, Europe, and America*, Warner Books, New York.

Tohoku, 1993, *Tohoku Electric Power Company, Inc., Annual Report 1993*, Sendai, Japan.

United Nations, 1991. Energy Statistics Yearbook, 1989, New York, New York.

Wray, W. D., 1984. *Mitsubishi and the NYK, 1870-1914: Business Strategy in the Japanese Shipping Industry*, Harvard University Press, Cambridge, MA.

APPENDIX A. MEMBERSHIP IN THE SIX MAIN INTERMARKET *KEIRETSU*

Table A.1 Membership in the six main intermarket *keiretsu*

Industry	Mitsubishi (29 Cos.)	Mitsui (24 Cos.)	Sumitomo (20 Cos.)	Fuyō (29 Cos.)	Sanwa (44 Cos.)	Dai-Ichi Kangyo (47 Cos.)	Total market share by all *keiretsus* (%)
City bank	Mitsubishi Bank	Mitsui Bank	Sumitomo Bank	Fuji Bank	Sanwa Bank	Dai-Ichi Kangyo Bank	40.5
Trust bank	Mitsubishi Trust	Mitsui Trust	Sumitomo Trust	Yasuda Trust	Toyo Trust		
Life insurance	Meiji Life	Misui Life	Sumitomo Life	Yasuda Life	Nippon Life	Asahi Life Fukoku Life	52.8
Casualty insurance	Tokio F&M	Taisho F&M	Sumitomo F&M	Yasuda F&M		Taisei F&M Nissan F&M	52.8
Trade & commerce	Mitsubishi Corp.	Mitsui Mitsukoshi	Sumitomo Corp.	Marubeni	Nissho Iwai Nichimen Iwatani Takashimaya	C. Itoh Nissho Iwai Kanematsu-Gosho Kawasho Seibu Dept. St.	66.7
Construction	Mitsubishi Constr.	Mitsui Constr. Sanki Engnr.	Sumitom Constr.	Taisei	Ohbayashi Toyo Constr. Sekisui House Zenitaka	Shimizu Constr.	66.7
Real estate	Mitsubishi Estates	Mitsui Real Estate	Sumitomo Realty	Tokyo Tatemono			55.1
Fibers & textiles	Mitsubishi Rayon	Toray		Toho Rayon Nisshin Spinning	Unitica Teijin	Asahi Chemical	40.3

Table A.1 Membership in the six main intermarket *keiretsu*

Industry	Mitsubishi (29 Cos.)	Mitsui (24 Cos.)	Sumitomo (20 Cos.)	Fuyō (29 Cos.)	Sanwa (44 Cos.)	Dai-Ichi Kangyo (47 Cos.)	Total market share by all *keiretsus* (%)
Chemicals	Mitsubishi Kasei Mitsubishi Petro. Mitsubishi Monsanto Mitsubishi Gas Chem. Mitsubishi Plastics	Mitsui Toatsu Mitsui Petro-chemical	Sumitomo Chemical Sumitomo Bakelite	Showa Denko Nippon O&F Kurha Chem.	Sekisui Chemical Ube Industries Hitachi Chemical Fujisawa Kansai Paint Tokuyama Soda Tanabe Seiyaku	Denki Kagaku Nippon Zeon Sankyo Shiseido Lion Asahi Denka Kyowa Hakko	43.3
Oil & coal	Mitsubishi Oil	Mitsui Mining Hokkaido Coll.	Sumitomo Coal Mining	Tonen	Cosmo Oil	Showa Shell	45.0
Glass & cement	Asahi Glass M. Mining and Cement	Onoda Cement	Nippon Sheet Glass Sumitomo Cement	Nihon Cement	Osaka Cement	Chichibu Cement	48.8
Paper	Mitsubishi Paper	Oji Paper		Sanyo-Kokusaku		Honshu Paper	37.7
Steel	Mitsubishi Steel	Japan Steel Works	Sumitomo Metal Ind.	NKK	Kobe Steel Nakayama St. Hitachi Metals Nisshin Steel	Kawasaki Steel Kobe Steel Japan M&C	52.7
Nonferrous metals	Mitsubishi Metal Mitsubishi Aluminum Mitsubishi Cable	Mitsui M&S	Sumitomo M&M Sumitomo Electric Sumitomo Light Metal		Hitachi Cable	Nippon Light Metal Furukawa Co. Furukawa Electric	56.0

Table A.1 Membership in the six main intermarket *keiretsu*

Industry	Mitsubishi (29 Cos.)	Mitsui (24 Cos.)	Sumitomo (20 Cos.)	Fuyō (29 Cos.)	Sanwa (44 Cos.)	Dai-Ichi Kangyo (47 Cos.)	Total market share by all *keiretsus* (%)
General and transportation machinery	**Mitsubishi Heavy Ind.** Mitsubishi Kakoki Mitsubishi Motors	Toyota Motors Mitsui Eng. & Ship.	Sumitomo Heavy Ind.	Kubota Nippon P.M. Nissan Motors	NTN Toyo B. Hitachi Zosen Shin Meiwa Daihatsu	Niigata Engnr. Kawasaki Heavy Ind. IHI Heavy Ind. Isuzu Motors Iseki & Co. Ebara Corp.	45.5
Electrical & precision machinery	**Mitsubishi Electric** Nikon	**Toshiba**	NEC	**Hitachi Co.** Oki Electric Yokogawa Elec. Cannon	**Hitachi Co.** Iwatsu Electric Sharp Nitto Electric Kyocera Hoya	**Hitachi Co.** Fujitsu Fuji Electric Yasakawa Electric Nippon Columbia Asahi Optical	39.3
Shipping	Nippon Yusen	Mitsui-OSK Lines		Showa Denko	Yamashita-SII	Kawasaki Kisen	58.7
Warehousing	Mitsubishi W.	Mitsui W.	Sumitomo W.			Shibusawa W.	33.9
Other industries (N.A.)	Kirin Brewery	Nippon Flour	Sumitomo Forestry	Nisshin Flour Milling Sapporo Breweries Nichirei Tobu Railway Keihin Railway	Ito Ham Toyo Tire Nippon Express Hankyu Suntory Orix	Yokohama Rubber Korakuan Stadium Nippon Express Nippon K.K. Securities Orient	

Source: Gerlach 1992.

APPENDIX B. EVOLUTION OF JAPANESE BUSINESS CULTURE AND THE MITSUBISHI *KEIRETSU*

B.1 THE EVOLUTION OF JAPANESE BUSINESS CULTURE

Most major Japanese companies are members of large organizational groups that have histories that go back to the 1800's. Initially, these groups were business families, or *zaibatsu*, that developed large and strong organizations. Today's version of these organizations are more loosely connected business groups known as *keiretsu*. The evolution of these corporate families, *zaibatsu, keiretsu*, or groups has played a major role in the evolution of the Japan's economic system and political structure. The continued existence of these groups over such long periods of time indicate that they are deeply embedded within Japanese culture. This Appendix provides some history of these groups.

Japan's government changed from a feudal system to a centralized government in the middle of the nineteenth century. The trend to centralize the Japanese government started in the 1830s and ultimately led to a palace coup in January 1868 when a group of anti-Tokugawa court nobles, led by Iwakura Tomomi, overthrew the existing government. This group of revolutionaries declared the shogunates abolished, confiscated the land, and supported the emperor as the formal leader of the country. The strength of the new emperor Meiji was established and consolidated by a brief civil war (The Boshin War). The new emperor was only nominally in control by 1868; by 1870 work was started on the development of a constitution. A final draft of the "Meiji Constitution" was available in 1888 and by 1890 the government was generally operating under the new constitution. Political leaders of the period implemented a broad modernization program using slogans with broad appeal such as, "civilization enlightenment" and "rich country and strong army." Even the name chosen by the emperor reflected the climate of the times: *Meiji* means "enlightened rule."

The prime movers calling for the changes were businessmen, merchants, and traders who recognized the isolation policies of the Tokugawa regime as having a smothering influence on the growth of Japan's industry and trade. Local laws restricting travel, shipping, and the construction of ocean-going vessels existed until 1853. Therefore, there was no infrastructure to support shipbuilding, shipping, or the manufacturing of industrial equipment. This also meant that there were virtually no people with industrial experience or the capability for managing complex projects.

During this period, it was clear that if the required modernization were to occur quickly, technology had to be imported. Such a step required foreign currency from the export of large quantities of domestic products (primarily tea, spices, silk, textiles, and saki). It was also evident that the foreign trading companies and shipping companies were in the key positions that controlled the flow of exports and the profits for Japanese merchants.

In the 1850s, a Russian frigate sunk off the coast of Japan and was rebuilt by Japanese bakufu (local government) workers who were supported with funding and technical guidance from Russia. The bakufu immediately proceeded to build ten more ships of the same type. In 1857, a small steamer was built in the Nagasaki Yard with the help of Dutch engineers. With this experience and the help of French engineers, a steam gunboat, the *Chiyada*,

was then built in a shipyard at Yokosuka. This series of projects provided the base for developing Japan's manufacturing capability as well as its shipbuilding industry.

When the Meiji government took over, it confiscated han and bakufu facilities at Nagasaki, Hyogo, Yokosuka, and Ishikawajima. It was during this period that the business and merchant families acquired major facilities through government transactions. The families of Mitsui, Iwasaki (Mitsubishi), and Sumitomo gained their strength by expanding from basically traders to managers of multiple industrial companies that expanded in all directions and were tied together as *zaibatsus*.

During the periods around 1894, 1904, 1918, and 1940, the *zaibatsus* grew stronger by supporting Japan with a flow of military equipment for the Sino-Japanese War, Russo-Japanese War, World War I, and World War II. Between the wars, they reduced staffs and closed facilities, but continued to develop and maintain a stable growth of core companies and the people who were members of the *zaibatsu*. A tradition of developing suppliers and customers, ensuring their financial support, and demanding performance from companies of the *zaibatsu* was nurtured and maintained.

Similarly, the traditions of supporting long-term employment, education of employees, and the development of strong personal relationships between government and business associates was developed. The logic of maintaining contacts with government leaders, reliable suppliers, major customers, and maintaining lifetime employees began at the time the *zaibatsu* were formed. This started when the Meiji government was installed and continued until the *zaibatsu* were disbanded by General MacArthur in 1945. At that time, all the large *zaibatsu*, including Mitsui, Mitsubishi, and Sumitomo, were disbanded.

In 1950, many of the restrictions on business in Japan were lifted, and organizations developed along lines of the old *zaibatsu*. These new groups were called, and still are called, *keiretsus*. They operate with most of the traditional approaches; however, because they are publicly owned, many of the constraints that the *zaibatsu* family domination imposed on the older organization no longer apply.

The *keiretsu* system has served the Japanese business community effectively over the past 40 years. Japan is now undergoing new political changes. Given the previous history of >100 years, it is reasonable to project that the *keiretsu* will change as Japan changes, but remain as a unique Japanese economic organizational approach.

B.2 HISTORY AND EVOLUTION OF MITSUBISHI *KEIRETSU*

In 1868 the new Meiji government established a series of corporations as a part of its industrial modernization program. Most of these newly established companies were subsequently purchased at attractive prices by powerful Japanese families: Mitsui, Sumitomo, and Yasuda. Mitsubishi's founder, Yataro Iwasaki, in 1870, acquired Tsukumo Shokai, the official Tosa shipping company, and in a few years changed its name to Mitsubishi. Shortly thereafter, Mitsubishi was selected by the government to provide the ships for

an expedition to Formosa and subsequently received government funding to ensure a competitive position in world shipping for Japan.

By 1880, Mitsubishi was expanding at a rapid rate, it had moved into the warehouse business, developed a maritime insurance company, acquired the Takashima coal mine (guaranteeing its shipping fleet's fuel source), leased and later purchased the Nagasaki Shipyard from the government, and purchased the majority of its major competitor's stock, Nikon Yuseu Kaishu. The companies were soon merged to form Nikon Yuseu Kaishu (NYK), the large Japan shipping company.

Although Mitsubishi was theoretically a public corporation, Yataro Iwasaki operated the company as a family business. His brother, Yanosuke, later assumed the leadership of Mitsubishi Skokai and NYK in 1886 after Yataro's death. The Japanese production of "black ships" was dominated by Mitsubishi's building of steel ships and boilers. The Japanese then expanded their shipping routes to include Europe, North America, Australia, India, China, and Formosa. At the start of the 20th Century, the Sino-Japanese War accelerated the growth of NYK. Yanosuke Iwasaki then diversified the company by acquiring gold and silver mines and real estate in the Tokyo area. The development of design and manufacturing capability, including all the equipment and power systems, associated with shipbuilding, was a by-product of the basic shipyard operations. In 1916, Koyata Iwasaki restructured the Mitsubishi Company with divisions for banking, mining, real estate, shipbuilding, and trading.

The *zaibatsu* structure significantly contributed to the strengthening of Japan and its ability to demonstrate world-class business and industrial capability. As one of the victors of World War I, Japan gained additional world status. Mitsubishi was one of the largest *zaibatsu* participating in Japan's development as a major player in post-World War I world trade. In 1918, Mitsubishi was incorporated; its stock was totally owned by the Iwasaki family. Mitsubishi Shoji Kaisha (Trading Company) and other divisions were made independent public companies to attract additional capital (Mitsubishi Heavy Industry, 1917; Mitsubishi Bank, 1919; and Mitsubishi Electric, 1921). In the 1930s, all the *zaibatsus* constrained their operations to avoid drawing terrorist attacks by the militarists who had gained strength in Japan. Mitsubishi provided shipping, shipbuilding, mining, heavy manufacturing, electrical generation equipment, aircraft, warehousing, and trading as a part of this expansion and growth.

Mitsubishi's strength and size increased as it became a major contributor to Japan's World War II effort; but its capabilities were significantly damaged in the bombings of 1945. The U.S. plan for Japan's reconstruction, implemented by MacArthur, outlawed the *zaibatsu* as monopolistic, divided Mitsubishi into 139 independent companies, and precluded integrated business strategies and cross-ownership of stock. Many of these restrictions were lifted in the early 1950s because of media criticism of the policy and, to some extent, the need for Japan's industrial power in the Korean War. Several of the Mitsubishi *zaibatsu* companies were quickly revived at this time. The Mitsubishi Shoji Kaisha name and the three diamond symbol were

revived, and many of the companies were reorganized.

The MITI coordinated the redevelopment of *zaibatsu*-like organizations (Mitsui, Mitsubishi, Sumitomo, Fuji, Sanwa, and Dai-Ichi Kanyo) as *keiretsus*. In 1971, the executives of 19 independent Mitsubishi companies began monthly meetings of a group called the Kinyo-Kai (Second Friday Conference); through this process they maintained their independence while they coordinated business strategies. Executives from the six major *keiretsus* in Japan (Mitsui, Mitsubishi, Sumitomo, Fuyo, Sanwa, and Dai-Ichi Kangin) also met once a month providing high-level coordinated strategies.

APPENDIX C. NUCLEAR POWER PLANT VENDORS

Table C.1 Nuclear power plant vendors

Country Company *Vendor*	Power reactor construction starts since 1980[a]	Approximate total corporate sales ($ billion/y)	Comments
Canada			
Atomic Energy of Canada	10	Government[c]	Sole international supplier of heavy-water reactors', technical agreements with South Korea
China			
China National Nuclear Corporation	1	Government[c]	Planned rapid expansion in 1990s, currently somewhat limited capabilities
France			
Commissariat a L'Energie Atomic (CEA) *Framatome (France)* *Babcock & Wilcox (U.S.)*	20	Government[c]	Part owner with Siemens of joint venture: NPI
Germany			
Siemens *Kraftwerk Union (Germany)* *Skoda (Czechoslovakia)*[d]	9	41/Mixed	Part owner with Framatome of joint venture: NPI
Great Britain			
National Nuclear Corporation (NNC)	4	Mixed	Multiple agreements with Westinghouse: joint venture to build the first British PWR, agreement for joint bids on foreign plants
India			
Department of Atomic Energy	8	Government[c]	Local vendor: no significant international activities, relatively small power reactors

Table C.1 Nuclear power plant vendors

Country Company *Vendor*	Power reactor construction starts since 1980[a]	Approximate total corporate sales ($ billion/y)	Comments
Japan			
Hitachi	6	55	Part of larger Dia-ichi Kangyo Bank Group with 688 member companies, member of HGET[c] joint product development consortium
(MHI) and Mitsubishi Electric Co. (MELCO)	11	20 (MHI) 25 (MELCO)	Part of larger Mitsubishi Group with sales of $300 × 10^9/year; agreements with Westinghouse
Toshiba	7	36	Part of the larger Mitsui Group with 489 member companies; member of HGET joint product development consortium
Russia			
Minatom	43	Gov[c]	Uncertain future; only major vendor not part of larger international consortium, many reactor construction projects shut down or canceled
South Korea Korea Heavy Industries and Construction Co.		Mixed	Building Korean reactors with ABB; Korean content ~90%, approaching independent vendor status
Sweden/Switzerland			
ABB *ABB Atom (Sweden)* *ABB Combustion (U.S.)*	5	27	Largest industrial and utility equipment manufacturing company in world; technical agreements with South Korea

Table C.1 Nuclear power plant vendors

Country Company *Vendor*	Power reactor construction starts since 1980[a]	Approximate total corporate sales ($ billion/y)	Comments
United States			
GE	1	50	Member of HGET joint product development consortium
Westinghouse	3	9	New agreement on future reactors with Mitsubishi, technical agreement with NNC and others

[a]Power reactors sold with start of construction after 1980. There have been major changes in market share among vendors over the last several decades. A power reactor requires 4 to 12 years to build. Listing reactors with start of construction since 1980 provides an estimate of recent vendor sales and capabilities. Construction starts rather than reactor sales provides the best measure of vendor business since some sales fail and some sales are, in fact, options for purchase.

[b]HGET = Hitachi/General Electric/Toshiba.

[c]Gov = government agency.

[d]Siemens has an agreement with Skoda to buy a controlling share of the Skoda division responsible for commercial nuclear power equipment.

APPENDIX D. DATA SHEETS ON SELECTED MITSUBISHI *KEIRETSU* COMPANIES

This appendix provides information about selected Mitsubishi companies and/or divisions associated with the nuclear business. These data are interpretations of data from technical, financial, and other business documents. The composite of this information is considered to provide a representative picture of these Mitsubishi companies.

- Not all Japanese stockholdings are included in the ownership sections of these data; only those Japanese stockholdings that are part of the companies' ten largest stockholdings (major holdings) are included.

- Table D.1 shows MHI as the leader of the *keiretsu* nuclear work with seven large organizations supporting this work. Three other *keiretsus* are also shown because they provide significant financial support and long-term strategic business guidance to all the nuclear organizations.

Table D.1. Mitsubishi *Keiretsu* Organizations in the Nuclear Business

Parent Organization	Subsidiary	Activity	Acronym
MHI	Mitsubishi Atomic Power Industries, Inc.	Basic design of nuclear steam supply system. Balance of plant and nuclear fuel	MAPI
	MHI Kobe Shipyard and Engine Works	Detailed design, manufacture, and construction of NSSS	
	Nuclear Plant Services Engineering Co., Ltd.	Plant maintenance	PSEC
	MHI Takasago Machinery Works	Design, manufacture, and construction of turbine plant	
	MHI Takasago R&D Center	Research	TR&DC
	Nuclear Power Training Center	Operator training	PTC
Mitsubishi (MITCOR)		Trading company	
Mitsubishi Bank (MITBK)		Banking	
Mitsubishi Materials (MM)	Mitsubishi Nuclear Fuel Co., Ltd.	Fabrication of nuclear fuel	NFC
Mitsubishi Electric Corporation (MELCO)		Design, manufacture, and construction of electrical equipment	

MITSUBISHI *KEIRETSU* DATA

NAME Mitsubishi Heavy Industries (MHI)
2-5-1 Marunouchi, Chiyoda
Tokyo 100
Japan

OWNERSHIP[1]

Major Stockholders[2]		Mitsubishi *Keiretsu* Holdings
Japanese Insurance Companies	— 9.8%	3.2%
Japanese Banks	— 3.6%	3.6%
Japanese Trust Companies	— 9.5%	6.1%
Japanese Manufacturing Cos.	— 1.5%	1.5%
Foreign Holdings	— 13.3%	

BUSINESS[1]

- First in Japanese shipbuilding, nuclear industry, aerospace, other heavy machines, and air conditioning.
- Fills major orders for Defense Agency.
- Exports 27% of sales.

SIZE[1]

- Number of employees — 45,775
- Sales — ¥2,800,000 million — March 1993
- R&D Expenditures — ¥117,000 million — March 1993

NUCLEAR RESPONSIBILITY[3]

- MHI is the official reactor vendor for the Mitsubishi Nuclear business. It is the main contractor (Prime Contractor) which jointly designs, manufactures, and constructs with MAPI, MELCO, and other *keiretsu* companies.
- Primary and secondary system equipment manufacturing and R&D.
- Following basic system design, detailed hardware design is completed at MHI Kobe Shipyard and Engine Works. Some manufacturing of nuclear island components is also performed at MHI Kobe.
- Design, manufacture, and construction of the turbine plants for Mitsubishi power plants is performed at MHI Takasago Machinery Works.

[1] Japanese Company Handbook — Spring 1993.
[2] Additional information on these holdings is provided in the tables in Appendix B.
[3] Mitsubishi organization charts and literature.

MITSUBISHI *KEIRETSU* DATA

NAME — Mitsubishi Atomic Power Industries, Inc. (MAPI)

OWNERSHIP — MAPI is now a fully-owned subsidiary of MHI with announced plans to merge with MHI on October 1, 1994[3].

BUSINESS[1] — In April 1958, the Mitsubishi *keiretsu* decided to establish a company solely devoted to nuclear energy and MAPI, Inc., was founded. MAPI was the first of this kind of company and was originally owned by 25 Mitsubishi companies.

SIZE

- Number of employees 900
- Sales NA
- R&D Expenditures NA
- Capitalization 4.5×10^9 ¥

NUCLEAR RESPONSIBILITY[2]

- MAPI performs the basic design of NSSS, BOP, and Nuclear Fuel in coop. with MHI.
- MAPI has concentrated on developing the uses of nuclear energy for commercial electrical power generation, ship propulsion reactors, research reactors, nuclear fuel, and radio isotope equipment.
- MAPI is involved in R&D in all areas of nuclear energy including the engineering of FBRs, ATRs, and fuel cycle facilities. MAPI participated in the JOYO and MONJU FBR plants as well as the "FUGEN" HWR prototype ATR and fusion projects.
- MAPI's Nuclear Development Center has two technical institutes:
  - Omiya Technical Institute — reactor chemistry, fuel cycle technology, fusion reactor technology, and radiation safety management.
  - Tokai Technical Institute — study of fuel materials and fuel assembly testing.
- PWR Development — An [APWR 1300-MW(e)] design has been completed in cooperation with Westinghouse, MHI, and Japanese PWR utilities.
  - Small PWRs with passive safety features are under development with outputs of 300 and 600 MW(e).
  - Ship propulsion 100-MW(e) reactors.
- MAPI played a major role in the design of "MONJU" prototype, which is being built for PNC by a group of four companies — Mitsubishi, Toshiba, Hitachi, and Fuji.

[1] Correspondence from Mitsubishi - H. Mukai, 1993.
[2] Mitsubishi Atomic Power Industry, Inc., Profile Publication.
[3] *Atoms*, 1993(b).

MITSUBISHI *KEIRETSU* DATA

NAME

Mitsubishi Nuclear Fuel Company Ltd. (MNF)
5-2 Ohtemachi 1-chome
Chiyoda-ku 100
Tokyo, Japan

OWNERSHIP

Original ownership was 49% by Mitsubishi metals corporation (MMC), 17% by MHI, and 34% by Westinghouse. In 1990, Westinghouse sold its 34% to MMC.

BUSINESS

Design, development, and manufacture of nuclear fuels

SIZE

- Number of employees NA
- Sales NA
- R&D Expenditures NA

NUCLEAR RESPONSIBILITY[1]

- Fabrication of nuclear fuel.
- Design of fuel assemblies, pins, and pellets.
- R&D on fuel materials and related hardware.

[1] Mitsubishi organization charts and literature.

MITSUBISHI *KEIRETSU* DATA

NAME

Kobe Shipyard & General Machinery (KSEW)
1-8, Nishide-Machi 1-Chome
Hyogo-ku 652
Japan

OWNERSHIP

KSEW is a subsidiary of MHI

BUSINESS

- Pumps and pumping equipment.
- Air compressors and blowers.
- Steel shipbuilding and repair (history dating back to the 1880s).
- Large equipment design and fabrication.

SIZE

- Number of employees N/A
- Sales N/A
- R&D Expenditures N/A

NUCLEAR RESPONSIBILITY

- Detailed design, manufacturer, and construction of NSSS systems and buildings.
- Design of major nuclear plant components.

MITSUBISHI *KEIRETSU* DATA

NAME

Nuclear Plant Services (NUSEC)
Engineering Co., Ltd.
1-1, 1 Chome Wadasaki-cho,
Hyogo-KU, Kobe
Japan

OWNERSHIP

100% owned by MHI
NUSEC does not issue an annual report.

BUSINESS[1]

Established in 1978 to provide the service functions for Mitsubishi Nuclear contracts as a nuclear service company separated from the service departments of Kobe and Takasago divisions of MHI.

The president has a General Affairs Department and three divisions [Engineering, Nuclear Service, and Takasgo (secondary systems and pump service)].

SIZE

- Number of Employees — ~500 (mostly dispatched from MHI)
- Sales — N/A
- R&D Expenditures — N/A

NUCLEAR RESPONSIBILITY[1]

- NUSEC performs service activities on all Japanese operating PWR plants supplied by MHI.
- NUSEC performs other main refueling activities:
  - Reactor coolant pump maintenance.
  - Steam generator sludge lancing.
- NUSEC also performs the planning, scheduling, supervising, consulting, development of special tools, and numerous other tasks as a part of the service functions.

[1] Correspondence with NUSEC.

D-10

MITSUBISHI *KEIRETSU* DATA

NAME Takasago R&D Center (TR&DC)
1-1 Shinhama 2-Chome
Arai-Cho, Takasago
Hyogo Pref., Japan

OWNERSHIP Takasago R&D Center is a Division of MHI

BUSINESS Conduct R&D programs for the Mitsubishi nuclear organizations.

Maintain contacts with numerous R&D organizations and manufacturing organizations.

SIZE

- Two experimental sections.
- Eleven technical research laboratories.

PROGRAMS/RESPONSIBILITY

- Perform Nuclear Systems' R&D programs for, and with, Mitsubishi organizations.
- Utility and government organizations interface with MHI; appears that MHI has its organizations work with TR&DC, but MHI also acts as the filter for contacts with organizations out of the *keiretsu*.
- Reliability programs for PWRs.
  - Failure-experience studies.
  - R&D on PWR safety.
- Development and improvement of MHI technology.
  - Steam generators.
  - Core internals.
  - Main coolant pumps.
  - Reactor vessel.
  - Turbine and plant equipment.
- Repair technology.
- Predictive and preventative maintenance studies.
- Evaluation of material degradation and management of component aging.

[1] Correspondence with TR&DC.

MITSUBISHI *KEIRETSU* DATA

NAME Mitsubishi Electric Company (MELCO)
2-2-3 Marunouchi, Chiyoda - Ku,
Tokyo 100
Japan

OWNERSHIP[1]

Major Stockholding		Mitsubishi Holdings
Japanese Insurance Companies	— 12.5%	4.1%
Japanese Banks	— 3.4%	3.4%
Japanese Trust Companies	— 9.3%	3.8%
Japanese Manufacturing Cos.	— 0.0%	
Foreign Holdings	— 0.0%	

BUSINESS[1]

- Ranks third among comprehensive electric machinery makers.
- Top in defense electronics.
- Bolstering semiconductors to catchup in field of electronics.
- Exports 22% of Sales.
- Joint ventures in Southeast Asia, Latin America, North America, and Europe in 1960s[4].

SIZE[1]

- Number of employees — 51,331 — March 1993
- Sales — ¥ 3,200,000 million —March 1993
- R&D Expenditures — ¥ 270,000 million — March 1993

NUCLEAR RESPONSIBILITY

- Electrical equipment manufacturing[1].
- Has a tie-up with Westinghouse (U.S.) in nuclear power[1].
- Expanded to accommodate demand for household and industrial appliances in the 1950s and 1960s.

[1] Japan Company Handbook, Spring 1993.

MITSUBISHI *KEIRETSU* DATA

NAME Nuclear Power Training Center., Ltd. (NPTC)

OWNERSHIP[1] Jointly owned by MHI and Japanese utilities.
(Each utility has its own simulators and other training facilities on their own site.)

BUSINESS Ensure that all operator training functions (at any level) needed for Mitsubishi Nuclear Plants are provided efficiently at the appropriate location.

NUCLEAR RESPONSIBILITY[1]

- Provide the operator training services for Japanese PWR plants.
- Coordinate the training of utility and other associated organization's personnel at the various corporate, utility, and national facilities.

[1] Mitsubishi organization charts and literature.

MITSUBISHI *KEIRETSU* DATA

NAME Mitsubishi Corporation (MITCOR)
2-6-3, Marunouchi
Chiyoda-KU,
Tokyo 100
Japan

OWNERSHIP[1]

Major Stockholding[2]		Mitsubishi Holdings
Japanese Insurance Companies	— 17.9%	6.0%
Japanese Banks	— 8.3%	4.9%
Japanese Trust Companies	— 10.10%	5.3%
Japanese Manufacturing Cos.	— 3.1%	3.1%
Foreign Holdings	— 5.8%	

BUSINESS[1]

- Nucleus of the Mitsubishi Group.
- Japan's largest trading company.
- Outstanding in oil and other energy-sources transactions.
- Boast great resources development capability.
- Strong in heavy industrial products.
- Moving into satellite communication through JV.
- Active in overseas investment.
- Listed on London and Paris stock exchanges.
- Exports 56% of Sales.
- Sales Breakdown (September 1992)

Construction Machinery	— 17%
Energy	— 17%
Plastics	— 18%
Steel products & Machinery	— 12%
Electric Machinery	— 20%
Paper & Pulp	— 6%
Other	— 18%

SIZE[1]

- Number of employees — 10,002
- Sales — ¥18,000,000 million — March 1993
- R&D Expenditures — ¥270,000 million — March 1993

NUCLEAR RESPONSIBILITY

- Only as *keiretsu* overview and for strategic planning.

[1] Japan Company Handbook, Spring 1993.
[2] More detailed information on these holdings is provided in the tables of Appendix B.

MITSUBISHI *KEIRETSU* DATA

NAME Mitsubishi Bank (MITBK)
2-7-1 Marunouchi
Chiyoda-KU
Tokyo 100
Japan

OWNERSHIP[1]	Major Stockholding[2]		Mitsubishi Holdings
	Japanese Insurance Companies	— 15.3%	5.8%
	Japanese Banks	— None	None
	Japanese Trust Companies	— 1.8%	1.8%
	Japanese Manufacturing Cos.	— 6.3%	4.7%
	Foreign Holdings	— 1.3%	

BUSINESS[1]

- Bank of the Mitsubishi *keiretsu*.
- Fifth ranking city bank in Japan.
- Currently developing internationally.
- Building strongholds in South East Asia and Oceania now that it is established in the U.S. and Europe.
- First Japanese bank to be listed on the New York Stock Exchange.

SIZE

- Number of employees — 15,985
- Income — ¥3,500,000 million
- R&D expenditures — N/A

NUCLEAR RESPONSIBILITY

- Only as *keiretsu* overview and for strategic planning.

[1] Japan Company Handbook, Spring 1993.
[2] More detailed information on these holdings is provided in the tables in Appendix B.

MITSUBISHI *KEIRETSU* DATA

NAME Mitsubishi Materials (MM)
1-5-1 Ohtemachi
Chiyoda-Ku
Tokyo 100
Japan

OWNERSHIP[1]

Major Stockholding[2]		Mitsubishi Holdings
Japanese Insurance Companies	— 9.1%	6.4%
Japanese Banks	— 5.6%	4.2%
Japanese Trust Companies	— 13.9%	1.8%
Foreign Holdings	— 4.6%	

BUSINESS[1]

- Leading Japanese metal and ceramic firm.
- Leader in superhard tools.
- Leader in production of aluminum cans.
- Strength in nuclear fuel processing.
- Formally Mitsubishi Metals, but changed name after merger with Mitsubishi Mining and Cement in 1990.

SIZE[1]

- Number of employees — 10,161
- Sales — ¥1,500,000 million
- R&D Expenditures — ¥18,000 million

NUCLEAR RESPONSIBILITY

- Owns Mitsubishi Nuclear Fuel Company.

[1] Japan Company Handbook, Spring 1993.
[2] More detailed information on these holdings is provided in the tables of Appendix B.

APPENDIX E. SUMMARY OF WHO OWNS THE MITSUBISHI *KEIRETSU* COMPANIES

Appendix E provides major stockholdings data of many of the Mitsubishi Group companies (those listed on the first sections of the Tokyo, Osada, and Nahoya stock exchanges).

Japanese insurance companies, banks, and trust companies own the bulk of the major stock holdings in these companies; the insurance companies own the largest part of this stock. A summary of these holdings is provided in Table E.1. The companies are listed in the order of insurance company holdings.

On an average, 38% of these Mitsubishi companies are owned by other Mitsubishi Japanese companies, and the individual holdings are as high as 65%, as in the case of Mitsubishi Petroleum Company.

On an average, about 5% of these companies are owned by foreign organizations, the maximum foreign holding is about 20% of Mitsubishi Petroleum Chemical.

Tables E.2 through E.7 provide the details of the organizations/companies which have the holdings that are summarized in the Insurance, Bank, Trust, Manufacturing, and Gas/Chemical columns in Table E.1. The Mitsubishi *Keiretsu* holdings are italicized in these tables. Companies belonging to one of the other five major *keiretsus* of Japan are signified with a "K" in the column.

Table E.1 Summary of major holdings and foreign stock holdings in 21 of the Mitsubishi group companies
(Percentage of outstanding stock)

Mitsubishi		Types of companies owning stock in Mitsubishi companies							
Company	Business	Insurance companies	Banks	Trust	Manufacturing	Gas, chemical, and petroleum	Total major Japanese holdings	Foreign holdings	Others[a]
Mitsubishi Kasei	Chemicals	25.3	10.50	4.50	0.00	0.00	40.30	3.1	0.00
Mitsubishi	Commerce	17.9	8.30	10.10	3.10	0.00	39.40	5.8	0.00
Mitsubishi Bank	Banking	15.3	0.00	1.80	6.30	0.00	23.40	1.3	0.00
Mitsubishi Gas and Chemical	Chemicals	14.4	12.90	7.70	0.00	0.00	35.00	5.0	0.00
Mitsubishi Warehouse and Transportation	Warehouse	13.6	4.80	20.60	10.30	0.00	49.30	7.4	2.20
Melco	Heavy electric, machinery	12.5	3.40	9.30	0.00	0.00	25.20		3.20
Mitsubishi Paper Mills	Paper and pulp	12.2	9.20	9.50	2.60	2.20	35.70	6.6	0.00
Mitsubishi Steel	Ferro alloys	11.3	4.90	10.30	10.70	0.00	37.20	5.6	0.00
Mitsubishi Kakoki	Industrial machinery	9.9	4.90	12.40	11.80	0.00	39.00	9.0	0.00
MHI	Ship building, etc.	9.8	3.60	9.50	1.50	0.00	24.40	13.3	0.00
Mitsubishi Petro Chemical	Chemical	9.6	4.00	3.90	4.90	26.80	49.20	19.8	0.00
Mitsubishi Material	Nonferrous material	9.1	5.60	13.9	0.00	0.00	28.60	4.6	0.00
Mitsubishi Estate	Real estate	7.5	4.50	8.5	10.40	0.00	30.90	6.7	0.00
Mitsubishi Trust and Bank	Banking	5.7	3.10	1.3	8.60	0.00	18.70	2.8	0.00
Mitsubishi Shindoh	Nonferrous material	5.5	8.30	4.80	39.00	0.00	57.60	0.6	0.00
Mitsubishi Pencil	Miscellaneous manufacturing	5.4	15.80	7.10	0.00	0.00	28.30	0.7	0.00
Mitsubishi Motors	Motor vehicles	5.5	4.90	4.20	34.70	0.00	49.30	9.1	7.00
Mitsubishi Belting	Rubber	4.6	9.70	9.10	12.40	0.00	35.80	1.1	0.00
Mitsubishi Oil	Petroleum	3.0	7.00	15.60	17.30	0.00	42.90	6.0	0.00

Table E.1 Summary of major holdings and foreign stock holdings in 21 of the Mitsubishi group companies
(Percentage of outstanding stock)

Mitsubishi		Types of companies owning stock in Mitsubishi companies							
Company	Business	Insurance companies	Banks	Trust	Manufacturing	Gas, chemical, and petroleum	Total major Japanese holdings	Foreign holdings	Others[a]
Mitsubishi Cable	Wire and cable	2.6	7.60	9.20	34.00	0.00	53.40	2.0	0.00
Mitsubishi Plastics, Inc.	Chemicals	2.1	4.90	6.60	0.00	51.60	65.20	2.8	2.20
Spread	Maximum	25.3	11.1	20.6	43.0	51.6	65.20	19.8	NA
	Average/mean	9.4/10.0	6.7/=6.0	5.6/=9	10.5/=5.0	NA	38.5/=36	5.4/=5	
	Minimum	2.1	3.1	1.3	0.00	0.00	18.7	0.00	

[a]These items may also be included in foreign holdings.

Table E-2. Major insurance company stock holdings in 21 Mitsubishi companies
(Insurance company holdings in percent by *kabutsu* percentage of outstanding stock)

Mitsubishi		Insurance companies owning stock in Mitsubishi companies								
Company	Business	Total	*Meiji MK*	Nippon	Sumitomo	Dai-ichi	TokyoM&F	Taiyo L.I	Dowa	Daido
Mitsubishi Kasei	Chemicals	25.3	*7.5*	6.4	3.0	4.0	2.6	2.8		
Mitsubishi	Commerce	17.9	*6.0*	3.1		2.7	6.1			
Mitsubishi Bank	Banking	15.3	*5.8*	3.1		3.5	4.3	1.7		
Mitsubishi Gas and Chemical	Chemicals	14.4	*5.0*	7.5	1.9					
Mitsubishi Warehouse and Transportation	Warehouse	13.6	*7.7*				5.9			
Melco	Heavy electrical machinery	12.5	*4.1*	3.8	1.8	1.7				
Mitsubishi Paper Mills	Paper and pulp	12.2	*7.8*				4.4			
Mitsubishi Steel	Ferro alloys	11.3	*5.8*				3.1	3.4		
Mitsubishi Kakoki	Industrial machinery	9.9	*7.4*				2.5			
MHI	Shipbuilding	9.8	*3.2*	2.0	1.3		2.0	1.3		
Mitsubishi Petro Chemical	Chemical	9.6	*5.0*				4.6			
Mitsubishi Material	Nonferrous material	9.1	*6.4*	1.4				1.3		
Mitsubishi Estate	Miscellaneous manufacturing	7.5	*4.5*					3.0		
Mitsubishi Trust and Bank	Motor vehicles	5.7	*4.8*				1.9			
Mitsubishi Shindoh	Rubber	5.5	*4.2*				1.3			
Mitsubishi Pencil	Petroleum	5.4			2.7				2.7	
Mitsubishi Motors	Wire and cable	5.0	*3.1*				1.9			

2 of 2

Table E-2. Major insurance company stock holdings in 21 Mitsubishi companies
(Insurance company holdings in percent by *keiretsu* percentage of outstanding stock)

Mitsubishi		Insurance companies owning stock in Mitsubishi companies								
Company	Business	Total	*Meiji MK*	Nippon	Sumitomo	Dai-ichi	TokyoM&F	Taiyo L.I	Dowa	Daido
Mitsubishi Belting	Chemicals	4.6		2.0						2.6
Mitsubishi Oil		3.0	*3.0*							
Mitsubishi Cable		2.6					2.6			
Mitsubishi Plastics, Inc.		2.1	*2.1*							

Note: MK and italic indicate that the organization is a member of the Mitsubishi *keiretsu*. "K" indicates that the organization is a member of a major *keiretsu*.

Table E-3. Bank stock holdings in 21 Mitsubishi companies
(Bank holdings in percent of outstanding stock)

Mitsubishi		Banks owning stock in Mitsubishi companies									
Company	Business	*Mitsubishi MK*	Yokohama	Norinchukin	Sumitomo K	DKB K	Sanwa K	Sakura	LTCB	I B J	Total
Mitsubishi Kasei	Chemicals	*4.7*		2.9						2.9	10.50
Mitsubishi	Commerce	*4.9*				3.4					8.30
Mitsubishi Bank	Banking										0.00
Mitsubishi Gas and Chemical	Chemicals	*4.4*	2.7	2.8						3	12.90
Mitsubishi Warehouse and Transportation	Warehouse	*4.8*									4.80
Melco	Heavy electrical machinery	*3.4*									3.40
Mitsubishi Paper Mills	Paper and pulp	*4.7*		4.5							9.20
Mitsubishi Steel	Ferro alloys	*4.9*									4.90
Mitsubishi Kakoki	Industrial machinery	*4.9*									4.90
MHI	Shipbuilding	*3.6*									3.60
Mitsubishi Petro Chemical	Chemical	*4.0*									4.00
Mitsubishi Material	Nonferrous material	*4.2*		1.4							5.60
Mitsubishi Estate	Real estate	*4.5*									4.50
Mitsubishi Trust and Bank	Banking	*3.1*									3.10

Table E-3. Bank stock holdings in 21 Mitsubishi companies
(Bank holdings in percent of outstanding stock)

Mitsubishi		Banks owning stock in Mitsubishi companies									
Company	Business	*Mitsubishi MK*	Yokohama	Norinchukin	Sumitomo K	DKB K	Sanwa K	Sakura	LTCB	I B J	Total
Mitsubishi Shindoh	Nonferrous material	*4.3*								4	8.30
Mitsubishi Pencil	Miscellaneous manufacturing	*3.2*	4.7		3.2					4.7	15.80
Mitsubishi Motors	Motor vehicles	*4.9*									4.90
Mitsubishi Belting	Rubber						4.9	4.8			9.70
Mitsubishi Oil	Petroleum	*4.9*			2.1						7.00
Mitsubishi Cable	Wire and cable	*4.5*							3.1		7.60
Mitsubishi Plastics, Inc.	Chemicals	*3.0*		1.9							4.90

Note: MK and italic indicate that the organization is a member of the Mitsubishi *keiretsu*. "K" indicates that the organization is a member of a major *keiretsu*.

Table E.4. Trust company stock holdings in 21 Mitsubishi companies
(Trust company holdings in percent of outstanding stock)

Mitsubishi		Trust companies owning stock in Mitsubishi companies							
Company	Business	*Mitsubishi MK*	Sumitomo K	Mitsubishi K	Tokyo	BOT	Chao	Yasuda K	Total
Mitsubishi Kasei	Chemicals	*4.5*							4.50
Mitsubishi	Commerce	*5.3*				4.8			10.10
Mitsubishi Bank	Banking	*1.8*							1.80
Mitsubishi Gas Chem	Chemicals	*5.6*			2.1				7.70
Mitsubishi Warehouse and Transport	Warehouse	*6.5*	3.9	3.9	2.6			3.7	20.60
Melco	Heavy electrical machinery	*3.8*	2.8	2.7					9.30
Mitsubishi Paper Mills	Paper and pulp	*5.2*	2.1	2.2					9.50
Mitsubishi Steel	Ferro alloys	*5.0*			2.5			2.8	10.30
Mitsubishi Kakoki	Industrial machinery	*5.9*	2.5					4.0	12.40
MHI	Shipbuilding	*6.1*	1.9		1.5				9.50
Mitsubishi Petro Chemical	Chemical	*3.9*							3.90
Mitsubishi Material	Nonferrous material	*5.9*	2.3	2.0	2.2			1.5	13.90
Mitsubishi Estate	Real estate	*8.5*							8.50
Mitsubishi Trust and Bank	Banking					1.3			1.30

Table E.4. Trust company stock holdings in 21 Mitsubishi companies
(Trust company holdings in percent of outstanding stock)

Mitsubishi		Trust companies owning stock in Mitsubishi companies							
Company	Business	*Mitsubishi MK*	Sumitomo K	Mitsubishi K	Tokyo	BOT	Chao	Yasuda K	Total
Mitsubishi Shindoh	Nonferrous material	*3.0*	1.8						4.80
Mitsubishi Pencil	Miscellaneous manufacturing		3.0				4.1		7.10
Mitsubishi Motors	Motor vehicles	*4.2*							4.20
Mitsubishi Belting	Rubber	*1.6*	2.4		5.1				9.10
Mitsubishi Oil	Petroleum	*7.0*	2.2	1.9		2.4		2.1	15.60
Mitsubishi Cable	Wire and cable	*5.6*	1.9	1.7					9.20
Mitsubishi Plastics, Inc.	Chemicals	*3.9*	1.3		1.4				6.60

Note: MK and italic indicate that the organization is a member of the Mitsubishi *keiretsu*. "K" indicates that the organization is a member of a major *keiretsu*.

Table E-5. Japanese industrial, materials, or manufacturing company stock holdings in twenty-one Mitsubishi companies

Mitsubishi		Other Japanese companies owning stock in Mitsubishi companies																
Company	Business	*MHI* *MK*	*MCorp* *MK*	Nip'n Steel K	MM K	Furukawa Elec	Taisei Corp K	Shimizu Corp K	Obayashi Corp	Takenaka Komuten	*Asahi Glass* *MK*	*Mitsubishi Chiknd* *MK*	*Maico* *MK*	Mitsubishi Estate K	Nissan Motor K	Toyota K	Kinzo	Total
Mitsubishi Kasei	Chemical														0.00			0.00
Mitsubishi	Commerce	*3.1*																3.10
Mitsubishi Bank	Banking	*3*	*1.7*	1.6														6.30
Mitsubishi Gas Chemical	Chem'l																	0.00
Mitsubishi Wrh/Trn	Warehouse	*6.5*												3.8				10.30
Maico	HvElMh																	0.00
Mitsubishi Paper Mill	Paper and pulp		*2.6*															2.60
Mitsubishi Steel	FerroAl	*6.9*	*3.8*															10.70
Mitsubishi Kakoki	IndsMac	*6.1*	*5.7*															11.80
MHI	Shipbuilding		*1.5*															1.50
Mitsubishi PetChem	Chem'l										4.90							4.90
Mitsubishi Material	Nonfer's																	0.00
Mitsubishi Estate	RealEst						3.6	2.5	2.2	2.1								10.40
Mitsubishi Trust and Bank	Banking	*2.7*									*2.3*		*1.8*	1.8				8.60
Mitsubishi Shindoh	Nonfer's				33.9							*5.1*						39.00
Mitsubishi Pencil	MiscMfg																	0.00

Table B-5. Japanese industrial, materials, or manufacturing company stock holdings in twenty-one Mitsubishi companies

Mitsubishi		Other Japanese companies owning stock in Mitsubishi companies																
Company	Business	*MHI* *MK*	*MCorp* *MK*	Nip'n Steel K	MM K	Furukawa Elec	Taisei Corp K	Shimizu Corp K	Obayashi Corp	Takenaka Komuten	*Asahi Glass MK*	*Mitsubishi Chlind MK*	*Maico MK*	Mitsubishi Estate K	Nissan Motor K	Toyota K	Kinno	Total
Mitsubishi Motors	MotVeh	*25.7*	*9*															34.70
Mitsubishi Belting	Rubber														5.2	4.6	2.6	12.40
Mitsubishi Oil	Petro'm		*17.3*															17.30
Mitsubishi Cable	Wir/Cb				29.7	4.3												34.00
Mitsubishi Pasticinc	Chem'l																	0.00

Table E.6. Japanese chemical, gas, and petroleum company stock holdings in 21 Mitsubishi companies

Mitsubishi		Chemical, gas, and petroleum companies owning stock in Mitsubishi companies						
Company	Business	*Mitsubishi Gas and Chemical MK*	Shell Petroleum K	Shell Japan K	Mitsubishi KOSEI K	Showa Shell Sekiju K	Mitsubishi Kasei Vinyl K	Total
Mitsubishi Kasei	Chemicals							0.00
Mitsubishi	Commerce							0.00
Mitsubishi Bank	Banking							0.00
Mitsubishi Gas and Chemical	Chemicals							0.00
Mitsubishi Warehouse and Transport	Warehouse							0.00
Melco	Heavy electric machinery							0.00
Mitsubishi Paper Mills	Paper and pulp	2.2						2.20
Mitsubishi Steel	Ferroalloys							0.00
Mitsubishi Kakoki	Industrial machinery							0.00
MHI	Shipbuilding							0.00
Mitsubishi Petro Chemical	Chemical		12.6	5.7	4.7	3.8		26.80
Mitsubishi Material	Nonferrous material							0.00
Mitsubishi Estate	Real estate							0.00
Mitsubishi Trust and Bank	Banking							0.00

Table E.6. Japanese chemical, gas, and petroleum company stock holdings in 21 Mitsubishi companies

Mitsubishi		Chemical, gas, and petroleum companies owning stock in Mitsubishi companies						
Company	Business	*Mitsubishi Gas and Chemical MK*	Shell Petroleum K	Shell Japan K	Mitsubishi KOSEI K	Showa Shell Sekiju K	Mitsubishi Kasei Vinyl K	Total
Mitsubishi Shindoh	Nonferrous material							0.00
Mitsubishi Pencil	Miscellaneous manufacturing							0.00
Mitsubishi Motors	Motor vehicles							0.00
Mitsubishi Belting	Rubber							0.00
Mitsubishi Oil	Petroleum							0.00
Mitsubishi Cable	Wire and cable							0.00
Mitsubishi Plastics, Inc.	Chemicals				47.7		3.9	51.60

Note: MK and italic indicate that the organization is a member of the Mitsubishi *keiretsu*. "K" indicates that the organization is a member of a major *keiretsu*.

Table E.7. Other notable significant stock holdings in 21 Mitsubishi companies

Mitsubishi		Other groups owning stock in Mitsubishi companies				
Company	Business	Employee sharehold	Chrysler Corporation	Cosmo Securities	Kiri Brewery	Total
Mitsubishi Kasei	Chemicals					0.00
Mitsubishi	Commerce					0.00
Mitsubishi Bank	Banking					0.00
Mitsubishi Gas Chemical	Chemicals					0.00
Mitsubishi Warehouse and Transportation	Warehouse				2.2	2.20
Melco	Heavy electric machinery	3.2				3.20
Mitsubishi Paper Mills	Paper and pulp					0.00
Mitsubishi Steel	Ferroalloys					0.00
Mitsubishi Kakoki	Industrial machinery					0.00
MHI	Shipbuilding					0.00
Mitsubishi Petro Chemical	Chemical					0.00
Mitsubishi Material	Nonferrous material					0.00
Mitsubishi Estate	Real estate					0.00
Mitsubishi Trust and Bank	Banking					0.00
Mitsubishi Shindoh	Nonferrous material					0.00
Mitsubishi Pencil	Miscellaneous manufacturing					0.00
Mitsubishi Motors	Motor vehicles	1.9	5.1			7.00

Table E.7. Other notable significant stock holdings in 21 Mitsubishi companies

Mitsubishi		Other groups owning stock in Mitsubishi companies				
Company	Business	Employee sharehold	Chrysler Corporation	Cosmo Securities	Kiri Brewery	Total
Mitsubishi Belting	Rubber					0.00
Mitsubishi Oil	Petroleum					0.00
Mitsubishi Cable	Wire and cable					0.00
Mitsubishi Plastics, Inc.	Chemicals			2.2		2.20

APPENDIX F. DATA SHEETS ON MAJOR JAPANESE UTILITIES

Appendix F provides information about the Japanese utilities. All PWRs made in Japan are produced by the Mitsubishi *keiretsu* companies. The initial Japanese PWRs were built by Westinghouse.

There are nine major Japanese utilities: four use PWRs, four use BWRs, and one does not use nuclear plants (however, it is considering the use of nuclear power). Electricity is also generated by the JAPCO, which demonstrates the merits of various types of nuclear power. It has one PWR, BWR, LWR, and HTGR. JAPCO is not a publicly owned company in the same sense as the other utilities. It is a joint utility- and vendor-owned operation for the demonstration of new technology.

It is interesting to note that most of the utilities indicate strong growth in the household use of electric power and sluggish growth in industrial use of electric power. This could be indicative of the saturation among industrial users in Japan. The domestic section is showing a strong growth, possibly as a result of a trend toward improvement in the overall standard of living in Japan.

JAPANESE UTILITY COMPANY DATA

NAME Shikoku Electric Power Company
2-5 Marunounchi
Takamatsu City 760-91
Kagawa Prefectare
Japan

OWNERSHIP[1]

Major Stockholding[2]		Mitsubishi Holdings
Japanese Insurance Companies	— 12.0%	3.3%
Japanese Banks	— 6.4%	0.0%
Japanese Trust Companies	— —	0.0%
Japanese Manufacturing Cos.	— 4.7%	0.0%
Foreign Holdings	— 3.1%	

BUSINESS[1]

- Power supplier to Shikoku.
- Nuclear energy largest fraction of production of the nine domestic private power companies.
- Shikoku has its own route to procure nuclear fuel.
- Demand growing 0.3%/year, helped by steady growing household demand.

SIZE[1]

- Total electric capacity — 5.94 GW(e)
- Nuclear electric capacity — 1.1 GW(e)
- Nuclear capacity under construction — 0.8 Gw(e)
- Number of employees — 5,834
- Sales — ¥505,500 million — March 1993
- R&D Expenditures — ¥8,031 million — March 1993

NUCLEAR RESPONSIBILITY[1]

- PWR user.
- Nuclear power is the largest percent of total power produced by any of the large nine Japanese Utilities.
- Construction of Ikata № 3 nuclear power plant proceeding with a March 1995 target startup.

[1] Japan Company Handbook, Spring 1993.
[2] Shikoku 1993.

JAPANESE UTILITY COMPANY DATA

NAME Kyushu Electric Power Company, Inc.
1-82 Watanabe - Dori
2 Chome, Chuo - Ku
Fukuoka 810
Japan

OWNERSHIP[1]

Major Stockholding[2]		Mitsubishi Holdings
Japanese Insurance Companies	— 21.3%	6.6%
Japanese Banks	— 6.7%	0.0%
Japanese Trust Companies	— 1.5%	0.0%
Japanese Manufacturing Cos.	— —	0.0%
Foreign Holdings	— 3.4%	

BUSINESS[1]

- Medium-scale electric power company serving Kyushu.
- Diversifying power resources into nuclear energy, LNG, coal, and geothermal energy.
- Offices in U.S. and Europe to attract foreign enterprises to Kyushu.
- Demand rising at rate of 2%/year, backed by steady household demand.

SIZE[1]

- Total electric capacity — GW(e)
- Nuclear electric capacity — 2.8 GW(e)
- Nuclear capacity under construction — 2.3 GW(e)
- Number of employees — 13,985
- Sales — ¥665,000 million — March 1993
- R&D Expenditures — ¥13,340 million — March 1993

NUCLEAR SCOPE [1]

- PWR user.
- Investment growing in both nuclear and coal plants.

[1] Japan Company Handbook, Spring 1993.
[2] Kyushu 1992.

JAPANESE UTILITY COMPANY DATA

NAME Kansai Electric Power Company
3-3-22 Nakanoshima
Kita-Ku
Osaka 530-70
Japan

OWNERSHIP[1]

Major Stockholding[2]		Mitsubishi Holdings
Japanese Insurance Companies	— 9.5%	0.0%
Japanese Banks	— 9.5%	0.0%
Japanese Trust Companies	— 1.7%	0.0%
Japanese Manufacturing Cos.	— 11.2%	0.0%
Foreign Holdings	— 3.2%	

BUSINESS[1]

- Second largest power company in Japan.
- Received Deming prize for quality movement in power industry.
- Commercial and industrial use 63% of revenues — residential use 33%; other 3%.
- KWh sales volume peaking at only 0.2% growth because of sluggish industrial demand despite steady household demand.

SIZE[1]

- Total electric capacity — 34.7 GW(e)
- Nuclear electric capacity — 9.8 GW(e)
- Nuclear capacity under construction — 0.0 GW(e)
- Number of employees — 25,581
- Sales — ¥2,450,000 million — March 1993

NUCLEAR RESPONSIBILITY[1]

- PWR user.
- Pioneer in nuclear and LNG power generation.
- Kansai needs to regain public confidence due to an accident at Mihama nuclear power plant.
- Fuel costs falling thanks to increased utilization of nuclear plants and strong Yen.
- Oi № 4 nuclear plant starting in '93.

[1] Japan Company Handbook, Spring 1993.
[2] Kansai 1993.

JAPANESE UTILITY COMPANY DATA

NAME Hokkaido
1-2 Ohdori - Higashi
Chuo - Ku Sapporo 060-91
Japan

OWNERSHIP[1]

Major Stockholding		Mitsubishi Holdings
Japanese Insurance Companies	— 20.4%	0.0%
Japanese Banks	— 1.6%	0.0%
Japanese Trust Companies	— 7.7%	3.2%
Japanese Manufacturing Cos.	— 7.6%	0.0%
Foreign Holdings	— 1.9%	

BUSINESS[1]

- Heavily dependent on thermal power generation using local high-cost coal.
- Fuel cost declining because of abundant water supply and strong yen.
- Commercial and industrial use 57% of rev. — residential use 41% and other 2%.
- KWh sales volume rising 2.6%, thanks to growth in household demand.

SIZE[1]

- Total electric capacity — ___ GW(e)
- Nuclear electric capacity — 1.1 GW(e)
- Nuclear capacity under construction — 0.0 GW(e)
- Number of employees — 6,550
- Sales — ¥520,000 million — March 1993
- R&D Expenditures — ¥4,000 million — March 1993

NUCLEAR RESPONSIBILITY[1]

- PWR user.
- Enthusiastic about using imported coal and nuclear power.
- Repair cost swelling due to regular repairs of Tomari № 1 & № 2 nuclear power plants.

[1] Japan Company Handbook, Spring 1993.

JAPANESE UTILITY COMPANY DATA

NAME Chubu
1 Higashi - Shincho
Higashi - Ku, Nagoya 461-91
Japan

OWNERSHIP[1]

Major Stockholding		Mitsubishi Holdings
Japanese Insurance Companies	— 15.7%	5.4%
Japanese Banks	— 10.8%	0.0%
Japanese Trust Companies	— 0.0%	0.0%
Japanese Manufacturing Cos.	— 2.4%	0.0%
Foreign Holdings	— 2.8%	

BUSINESS[1]

- Service area is Chuba region.
- Third-ranked electric power company (power sales).
- Active in LNG-fueled power generation.
- Current profits declining because of increased depreciation, repair expense, and increasing interest rates.
- Developing new equipment with Science and Technology Agency and Fuji Electric.
- Commercial and Industrial, 70% of rev. — residential use, 27% — other, 3%.

SIZE[1]

• Total electric capacity	—	___ GW(e)	
• Nuclear electric capacity	—	2.4 GW(e)	
• Nuclear capacity under construction	—	1.1 GW(e)	
• Number of employees	—	20,622	
• Sales	—	¥1,960,000 million	— March 1993
• R&D Expenditures	—	¥24,419 million	— March 1993

NUCLEAR RESPONSIBILITY[1]

- BWR user.
- Placing emphasis on expansion of nuclear power generation for cost reduction.

[1] Japan Company Handbook, Spring 1993.

JAPANESE UTILITY COMPANY DATA

NAME Tokyo Electric Power
1-1-3 Uchi - Saiwaicho
Chiyada - Ku, Tokyo 100
Japan

OWNERSHIP[1]

Major Stockholding[2]		Mitsubishi Holdings
Japanese Insurance Companies	— 11.5%	0.0%
Japanese Banks	— 6.2%	0.0%
Japanese Trust Companies	— 2.0%	2.0%
Japanese Manufacturing Cos.	— 3.1%	0.0%
Foreign Holdings	— 4.0%	

BUSINESS[1]

- Serves Kanto area, including Tokyo.
- The world's largest private electric power company.
- Making an effort in communications business.
- Commercial and industrial use, 63% of rev. — residential use, 34% — other, 3%.
- Industrial demand reducing, but consumer demand is steady.

SIZE[1]

- Total electric capacity — 48.3 GW(e)
- Nuclear electric capacity — 12.4 GW(e)
- Nuclear capacity under construction — 4.8 GW(e)
- Number of employees — 40,789
- Sales — ¥4,720,000 million — March 1993
- R&D Expenditures — ¥68,369 million — March 1993

NUCLEAR RESPONSIBILITY[1]

- BWR user.
- After oil crises, TEPCO made a large switch to nuclear power, coal, and LNG.
- TEPCO has close ties with General Electric in nuclear power.
- Joint nuclear power plant with Tohoku Electric Power in Aomori Pref. reaching agreement with local fishermen's association for first time in 27 years.

[1] Japan Company Handbook, Spring 1993.
[2] Tepco 1993.

JAPANESE UTILITY COMPANY DATA

NAME Tohoku Electric Power Company
3-7-1 Ichiban-cho
Aoba-Ku, Sendai 980
Japan

OWNERSHIP[1]	Major Stockholding[2]	Mitsubishi Holdings
Japanese Insurance Companies	— 14.5%	0.0%
Japanese Banks	— 8.0%	0.0%
Japanese Trust Companies	— —	0.0%
Japanese Manufacturing Cos.	— 1.7%	0.0%
Foreign Holdings	— 4.7%	

BUSINESS[1]

- Electricity supplier to Tohoku and Nūgata areas.
- Pooling power supply with TEPCO.
- Started demonstration test of fuel cells and solar power generation.
- Commercial and industrial use 59% of rev. — residential use 59%, — other, 8%.
- Household growth about three times the industrial growth.

SIZE[1]

• Total electric capacity	—	___ GW(e)	
• Nuclear electric capacity	—	0.5 GW(e)	
• Nuclear capacity under construction	—	0.8 GW(e)	
• Number of employees	—	13,864	
• Sales	—	¥1,280,000 million ($11 billion)	— March 1993
• R&D Expenditures	—	¥14,520 million	— March 1993

NUCLEAR RESPONSIBILITY[1]

- BWR user.
- Pushing diversification of sources to nuclear, LNG, and coal.
- Reaching agreement with local fishermen's association for Totsu Nº 1 nuclear plant (joint with TEPCO).

[1] Japan Company Handbook, Spring 1993.
[2] Tohoku 1993.

JAPANESE UTILITY COMPANY DATA

NAME Hokuriku Electric Power Company
15-1 Ushejima-cho
Toyama City 930
Japan

OWNERSHIP[1]	Major Stockholding		Mitsubishi Holdings
	Japanese Insurance Companies	— 9.2%	0.0%
	Japanese Banks	— 13.8%	0.0%
	Japanese Trust Companies	— 1.7%	0.0%
	Japanese Manufacturing Cos.	— 7.3%	0.0%
	Foreign Holdings	— 2.0%	

BUSINESS[1]

- Provides electricity to three prefectures in Hokuriku area.
- Large hydroelectric power generation percentage of total output.
- Power rates lowest of the nine power companies.
- Commercial and industrial use 65% of rev. — residential use, 25% — other, 10%.
- Housing demand growing, industrial demand sluggish, total 2.3% increase.

SIZE[1]

• Total electric capacity	—	___ GW(e)	
• Nuclear electric capacity	—	0.6 GW(e)	
• Nuclear capacity under construction	—	0.5 GW(e)	
• Number of employees	—	5,472	
• Sales	—	¥450,000 million ($38 billion)	— March 1993
• R&D Expenditures	—	¥3,709 million	— March 1993

NUCLEAR RESPONSIBILITY[1]

- BWR user.
- Major efforts underway to increase efficiency and install nuclear plants.
- Shiga plant, the company's first nuclear plant started 25 years after the project was announced.

[1] Japan Company Handbook, Spring 1993.
[2] Hokuriku 1993.

JAPANESE UTILITY COMPANY DATA

NAME Chugoku Electric Power Company

OWNERSHIP[1]

Major Stockholding[2]	Mitsubishi Holdings
Japanese Insurance Companies	
Japanese Banks	
Japanese Trust Companies	
Japanese Manufacturing Cos.	
Foreign Holdings — 0.0%	

BUSINESS[1]

SIZE[1]

• Total electric capacity	— 7.7 GW(e)		
• Nuclear electric capacity	— 1.3 GW(e)		
• Nuclear capacity under construction	— 0.0 GW(e)		
• Number of employees	— 0000		
• Sales	— ¥979,718 million ($8.5 billion)	—	March 1993
• R&D Expenditures	— ¥000,000 million	—	March 1993

NUCLEAR RESPONSIBILITY[1]

[1] Japan Company Handbook, Spring 1993.
[2] Chugoku.

APPENDIX G. SUMMARY OF MAJOR STOCKHOLDINGS IN MAJOR JAPANESE UTILITIES

Appendix G provides the major stockholdings data (including foreign stockholding as a separate entry) of the major Japanese utilities.

There are nine major privately owned utilities in Japan: Four own and operate PWRs; four own and operate BWRs; and one does not currently have any nuclear reactors, but is considering nuclear energy as a future source. JAPCO is a utility in Japan that uses first-of-a-kind (for Japan) power plants. They have one PWR, one BWR, an LMR expected to be operational in 1993, an HTGR planned as well as plans for other advanced nuclear power plants.

TABLES G.1 and G.2

The tables of Appendix G identify the companies that have major stockholdings in Japanese Utilities. It is interesting to note that:

- The major holdings represent about 25% of these utilities;
- insurance companies own almost half of these major holdings;
- the other half is distributed among banks, trust companies, and the cities served by the utilities;
- most of the insurance companies, banks, and trust companies are owned by the six major *keiretsus*;
- the Mitsubishi *keiretsu* owns a noticeable amount of the major stockholdings of utilities. There is not a large difference in their major holdings of PWR users vs BWR users; and
- the local communities, cities, or prefects are major shareholders of utility stock.

Table G.1. Principal stockholdings of major Japanese utilities

Electric power companies	Japanese insurance companies	Japanese Banks	Japanese Trust	Other Japanese companies	Total principal Japanese holdings	Foreign
			Utilities with PWRs			
Shikoku	12.0	6.4	--	4.7	23.10	3.1
Kyushu	21.3	6.7	1.5	--	29.50	3.4
Kansai	9.5	9.5	1.7	11.2	31.90	3.2
Hokkaido	20.4	1.6	7.7	7.6	37.30	1.9
Maximum	21.3	9.5	NA	NA	37.3	3.4
Average	13.5	6.0	NA	NA	21.6	NA
Minimum	9.5	1.6	NA	NA	23.1	1.9
			Utilities with BWRs			
Chubu	15.7	10.8	--	2.4	28.9	2.8
Tepco	11.5	6.2	2.0	3.1	22.8	4.0
Tohoku	14.5	8.9	--	1.7	25.1	4.7
Hokuriku	9.2	13.8	1.7	7.3	32.0	2.0
Maximum	15.7	13.8	2.0	7.3	32.0	4.7
Average	12.7	9.9	NA	NA	27.2	NA
Minimum	*9.2*	*6.2*	*1.7*	*1.7*	*22.8*	*2.0*
			Major utility without nuclear power			
Chugoku	12.3	8.3	4.2	13.3	38.1	1.2
			A utility with PWR, BWR, LMR & HTGCR			
Japco	--	--	--	--	--	

Table G.2. Major institutional holdings in Japanese utilities with PWRs (%)

Companies with major holdings in power companies		Electric power companies with PWRs			
		Shikoko	Kyushu	Kansi	Okkaido
Insurance companies					
Nipon Life	K	3.7	4.8	4.9	6.3
Meiji Life	*MK*	*3.3*	*6.6*	--	--
Dai-Ichi Life	K	2.3	2.4	--	4.3
Sumitomo	K	--	2.4	2.0	2.4
Asaki		--	2.3	--	--
Totals		12.00	21.30	9.50	16.30
Banks					
Sumitomo	K	--	2.3	2.6	--
Sanwa	K	--	--	2.6	--
Daiwa			--	2.6	--
I B J		2.7	2.8	2.6	3.3
L T C D		--	--	--	1.6
D K B	K		2.6	--	--
Sakura		1.4	--	1.7	--
Hyakujushi		2.7	--	--	--
Fukuoka		--	1.8	--	--
I Y O		2.3			
Totals		6.40	6.70	9.50	1.60
Trust companies					
Sumitomo	K	--	1.5	1.7	1.7
Mitsubishi	*MK*				*3.2*
Yasuda	K				2.8
Totals		0.00	1.50	1.70	7.70
Other					
Sumitomo	K	2.5	--	--	--
Kochi Pref.		2.2	--	--	--
Kobe City		--	--	2.7	--
Opaka City		--	--	8.5	--
Takugin					4.2
Zenkyoren					3.4
Totals		4.70	0.00	11.20	7.60

Table G.3. Major institutional holdings in Japanese utilities with BWRs (%)

INSTITUTIONS	Electric power companies with BWR's				
	CHUBU	TEPCO	TOHOKU	HOKURIKU	JAPCO
Insurance Co's					
Meiji Life MK	5.4				
Nippon Life K	4.6	3.9	4.3	3.8	
Dai-ichi Life K	3.2	4.4	1.5		
Chiyoda Life			2.3		
Sumitomo Life K	2.5	1.7	2.1	2.3	
Taiyo Life			1.2		
Asahi Life K		1.5	3.1	3.1	
Totals	15.70	11.50	14.50	9.20	0.00
BANKS					
SAKWA	3.1	2.4			
TOKAI	2.9	2.3			
I B J	2.9		4.2	3.5	
L T C B	1.9		3.1	2.8	
D K B K		1.5	1.6		
HOKURIKU				4.7	
HOKKOKU				2.8	
Totals	10.80	6.20	8.90	13.80	0.00
TRUST					
MITSUBISHI MK		2.0			
SUMITOMO K				1.7	
Totals		2.0		1.7	
OTHER					
Kondo Spinning	2.4				
Tokyo Met. Gov't		3.1			
SOGO TAXI			1.7	2.2	
TOYAMA Pref.				5.1	
Totals	2.40	3.10	1.70	7.30	0.00

Table G.4. Major institutional holdings of two selected Japanese utilities

Institutions with major holdings in electric power company		Chugoku Electric Power Co.	Japan Atomic Power Company (JAPCO)
Insurance company			
Nipon Life	K	6.9	
Dai-Ichi Life	K	4.4	
Asahi Life	K	1.0	
Totals		12.30	
Banks			
I B J		4.1	
L T C B		2.9	
Hiroshima		1.3	
Totals		8.30	
Trust Company			
Sumitomo	K	2.8	
Mitsubishi	K	1.4	
Totals		4.20	
Other			
Yamaguchi Pref.		13.3	
Shinko Zaidan			
Totals		13.30	

APPENDIX H. MITSUBISHI *KEIRETSU* AND WESTINGHOUSE ELECTRIC COMPANY CONNECTIONS

Appendix H provides information on the various relationships that have existed between Mitsubishi companies and Westinghouse Electric Corporation.

1923 Mitsubishi Electric Company (MELCO) developed a close association with Westinghouse Electric Corporation (W), thereby provided MELCO with the Japanese marketing and licensing rights to sell and produce W design products (D. C. Stafford and R. H. A. Purkis). As a result, MELCO successfully built a large 2300-kVA vertical-axis-type hydraulic generator.

1950s The first generation of PWRs built in Japan were Westinghouse plants and in the 1970s, Mitsubishi supplied plants based on Westinghouse technology. These plants were designed and developed in the 1950s and 1960s. They were constructed and operated in the 1960s and 1970s. They included:

—	1970	Mihama	— 1
—	1972	Mihama	— 2
—	1974	Takahama	— 1
—	1975	Genkai	— 1
—	1976	Takahama	— 2
—	1977	Mihama	— 3
—	1977	Ikata	— 1
—	1979	Ohi	— 1
—	1979	Ohi	— 2

These 9 plants have a total capacity of about 6 GW(e).

1966 MELCO began to sell technology to W, revised its technical exchange agreement, and achieved a significant change in its technical status.

1980s The second generation of PWRs were based on Mitsubishi technology acquired through R&D and experience of construction and operation of the first generation. The second generation included the following reactors:

—	1981	Genkai	— 2
—	1982	Ikata	— 2
—	1984	Sendai	— 1
—	1985	Takahama	— 3
—	1985	Takahama	— 4
—	1985	Sendai	— 2
—	1987	Tsuruga	— 2

These 7 plants have a total capacity of 6 GW(e).

1990s The third generation of PWRs are designed to provide improved operability, reliability, safety, and economy. The following third generation plants are either operating or scheduled for operation in the 90s.

—	1989	Tomari	— 1
—	1991	Tomari	— 2
—	1991	Ohi	— 3
—	1993	Ohi	— 4
—	1994	Genkai	— 3
—	1995	Ikata	— 3
—	1997	Genkai	— 4

These 7 plants have a total capacity of 6 GW(e).

MHI and Westinghouse — March 23, 1992 (News Release Information, *Atoms* 1992a)

In the early 1990's, Westinghouse had severe financial setbacks in its credit and real estate divisions (Schroeder 1992, Schroeder 1993). This required the selling of assets to cover bank debts. The business press reported that Westinghouse considered selling the corporation to MHI. Westinghouse denies that discussions were held with MHI. A major restructuring of Westinghouse followed where the corporation was downsized by about a third. This financial crisis altered relationships between Westinghouse and MHI.

Westinghouse Electric Corporation and MHI, Ltd. signed a new 10-year agreement. The agreement altered the relationship between Westinghouse and MHI from a Westinghouse licensing agreement to MHI to an agreement between equal partners who will cooperate where mutually benefitted. The agreement covers:

- Cooperation on the development of commercial nuclear power technology; however, R&D on the detailed designs of advanced PWRs and medium sized advanced passive plants will be conducted independently for the time being.
- Combination of their future efforts to market in third world markets.
- Continuation of combination of efforts to benefit both companies and the customers.
- Joint marketing (Dizard III, 1992) efforts in third countries: Indonesia, Taiwan, United Kingdom, and China.
- Mitsubishi has been a licensee of Westinghouse on nuclear technology since 1958.
- Both companies to have access to new nuclear steam supply system technology development by the other.
- Marketing operations to include turn-key plants, nuclear islands, and nuclear technology.
- Mitsubishi and Westinghouse have worked together on development of APWR and to market the design in Taiwan and United Kingdom.
- Previous licensing agreements on fuel design and nuclear services to be continued.

MELCO and Westinghouse — April 15, 1992 (News Release Information)

Westinghouse Electric Corporation and MELCO signed a new 10-year agreement. This agreement covers:

- The two companies to investigate advanced generator technologies and materials for commercial applications.
- The two companies to work to establish sources for low-cost materials and components for existing products and products in development.
- W & MELCO spent a significant part of this century working together on power generation.
- Companies to exchange with each other technologies and techniques for

reducing electrical generators service time.

Westinghouse Power Generation business unit HQ are in Orlando, Florida, with manufacturing in Charlotte, North Carolina; Pensacola, Florida; and Fort Payne, Alabama.

MELCO HQ are in Tokyo with manufacturing in Kobe and Nagasaki.

MHI, Fiat Avio and Westinghouse — May 31, 1992 (News Release Information)

Westinghouse Electric Corporation, Fiat Avio, and MHI signed a new 10-year agreement.

- Three companies to cooperate in the development, manufacture, and marketing of combined turbine technology.
- Three companies to share existing technology, flexible manufacturing arrangements, and cooperative sourcing for parts and materials.
- Agreement to be basis for a new generation of highly competitive combustion turbine products.
- Three companies to continue development work on a 200-MW class, advanced 50-Hz, high-efficiency combustion turbine.
- The three companies to pursue major projects world-wide.
- Westinghouse has cooperated with Fiat Avio in this field since 1954.
- Westinghouse has cooperated with MHI in this field since 1961.

INTERNAL DISTRIBUTION

1. P. A. Abate
2. J. J. Bedell
3. J. M. Begovich
4. J. T. Bell
5. B. L. Bush
6. J. B. Cannon
7. S. A. Carnes
8. E. D. Copenhaver
9. A. G. Croff
10. S. R. Damewood
11. P. D. Fairchild
12. T. D. Ferguson
13. S. B. Floyd
14-18. C. W. Forsberg
19. W. Fulkerson
20. R. K. Genung
21. S. W. Hadley
22. L. J. Hill
23. F. J. Homan
24. C. R. Hudson, Jr.
25. H. Jones
26. J. E. Jones, Jr.
27. C. R. Kerley
28. T. S. Kress
29. M. A. Kuliasha
30. R. Lee
31. S. B. Ludwig
32. G. E. Michaels
33. B. W. McConnell
34. H. A. McLain
35. L. E. McNeese
36. E. Newman
37. J. P. Nichols
38. R. E. Norman
39. E. Peelle
40-44. W. J. Reich
45. J. W. Roddy
46-50. W. J. Rowan
51. J. H. Saling
52. M. J. Saltmarsh
53. J. L. Scott
54. R. B. Shelton
55. R. K. Tallent
56. D. B. Trauger
57. R. E. Uhrig
58. R. E. Upchurch
59. J. D. White
60. T. J. Wilbanks
61. R. G. Wymer
62. A. Zucker
63-64. Central Research Library
65-66. Laboratory Records
67. Laboratory Records-RC
68. ORNL Y-12 Technical Library
69. Document Reference Section
70. ORNL Patent Section

EXTERNAL DISTRIBUTION

71. Said I. Abdel-Khalik, Georgia Institute of Technology, Nuclear Engineering and Health Physics Programs, Atlanta, GA 30332

72. Vic Alessi, U.S. Department of Energy, NN-40, 1000 Independence Avenue SW, Washington, DC 20585

73. Junko Angel, DCI Nonproliferation Center, Central Intelligence Agency, FGIS/TAD, Washington, DC 20505

74. Mark Assur, Department of Energy, NN-30, 1000 Independence Avenue, Washington, DC 20585

75. K. Bailey, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94550

76. Ken Baker, U.S. Department of Energy, HQ, NN-2, 1000 Independence Avenue, Washington, DC 20585

77. W. Barrows, Central Intelligence Agency, NIO/AF, Washington, DC 20505

78. Karin Barry, U.S. Department of Energy, HQ, PO-70, 1000 Independence Avenue, Washington, DC 20585

79. R. Batzel, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94550

80. Doug Bauer, ORNL Washington D.C. Office, Suite 306W, 600 Maryland Avenue Southwest, Washington, D.C. 20024

81. Wallace B. Behnke, P.E., 323 Glen Eagle, Kiawah Island, SC 29455

82. Phil Berman, Defense Intelligence Agency, DIA/DT-1A, Washington, DC 20340-6161

83. John Bickel, Idaho National Engineering Laboratory, P.O. Box 1625, Idaho Falls, ID 83415

84. D. Blink, CIA/NESA/IA/I, Washington, DC 20505

85. Robert C. Block, Rensselaer Polytechnic Institute, Department of Nuclear Engineering & Engineering Physics, Troy, NY 12180-3590

86. Beth Bloomfield, DCI Nonproliferation Center, Central Intelligence Agency, Washington, DC 20505

87. Al Boni, Environmental Technology Division, Savannah River National Laboratory, P.O. Box 130, New Ellenton, SC 29809

88. Albert E. Bolon, Department of Nuclear Engineering, University of Missouri-Rolla, 102 Fulton Hall, Rolla, MO 65401-0249

89. Joan Boudreau, Los Alamos National Laboratory, IT-1, P.O. Box 1663, Los Alamos, NM 87545

90. Don Bradley, Pacific Northwest Laboratory, Battelle Boulevard, P.O. Box 999, Richland, WA 99352

91. E. C. Brolin, U.S. Department of Energy, HQ, NE-1, 1000 Independence Avenue, Washington, DC 20585

92. H. J. Bruschi, Westinghouse Electric Corp., P.O. Box 355, Pittsburgh, PA 15230-0355

93. Kevin Burke, U.S. Nuclear Regulatory Commission, International Programs, Washington, DC 20555

94. Max W. Carbon, University of Wisconsin-Madison, Department of Nuclear Engineering and Engineering Physics, 151 Engineering Research Building, Madison, WI 53706

95. Sal Ceja, U.S. Department of Energy, NN-40, 1000 Independence Avenue, Washington, DC 20585

96. Varada Charyulu, Idaho State University, College of Engineering, Lillibridge Engineering Laboratory, P.O. Box 8060, Pocatello, ID 83209

97. David D. Clark, Cornell University, Ward Laboratory of Nuclear Engineering, Ithaca, NY 14853-7701

98. M. Clark, DCI Nonproliferation Center, Central Intelligence Agency, Washington, DC 20505

99. Stuart Cohen, DCI Nonproliferation Center, Central Intelligence Agency, Washington, DC 20505

100. Collins, AFTAC/TD, TNP, 1030 S. Highway A1A, Patrick Air Force Base, Florida 32925-3002

101. Al Conner, Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545

102. Peter Cover, U.S. Department of Energy, HQ, FE-4, 1000 Independence Avenue, Washington, DC 20585

103. Steven C. Crow, University of Arizona, Department of Nuclear and Energy Engineering, Tucson, AZ 85721

104. Richard A. Danofsky, Iowa State University, Nuclear Engineering Program, Department of Mechanical Engineering, Ames, IA 50011

105. MaryBeth Davis, U.S. Department of Energy, HQ, NN-30, 1000 Independence Avenue, Washington, DC 20585

106. Jim Dewar, U.S. Department of Energy, HQ, NN-30, 1000 Independence Avenue, Washington, DC 20585

107. A. Duckworth, c/o C. W. Forsberg, Oak Ridge National Laboratory, P.O. Box 2008, 105 Mitchell Rd., Oak Ridge, TN 37831-6495

108. Donald J. Dudzaik, North Carolina State University, Department of Nuclear Engineering, 1110 Burlington Laboratories, Raleigh, NC 27695-7909

109. Roy Eckart, University of Cincinnati, Department of Mechanical, Industrial, and Nuclear Engineering, Mail Location 72, Cincinnati, OH 45221

110. N. Dean Eckhoff, Kansas State University, Department of Nuclear Engineering, Ward Hall, Manhattan, KS 66506-2503

111. Steve Ecton, Department of State, EAP/Japanese Affairs, Washington, DC 20585

112. Ed Fei, U.S. Department of Energy, HQ, NN-40, 1000 Independence Avenue, Washington, DC 20585

113. Thomas Fingar, Department of State, INR/East Asia and Pacific, 2201 C Street NW, Washington, DC 20505

114. W. Fitzgerald, CIA/OSWR/NED, Washington, DC 20505

115. M. Fitzgibbon, Department of Defense, OASD/ISA/NPP, Room 2D453, Pentagon, Washington, DC 20301-2400

116. James Ford, U.S. Department of Energy, NN-30, 1000 Independence Avenue, Washington, DC 20585

117. D. Fortney, DCI Nonproliferation Center, Central Intelligence Agency, Washington, DC 20505

118. T. Kenneth Fowler, University of California, Department of Nuclear Engineering, Berkeley, CA 94720

119. Peretz Friedmann, University of California, Mechanical, Aerospace, and Nuclear Engineering Department, School of Engineering and Applied Science, 46-147N Eng IV, 405 Hilgrad Avenue, Los Angeles, CA 90024-1597

120. Torrey Froscher, CIA/OSWR/NED, Washington, DC 20505

121. Robert Gallagher, U.S. Department of Commerce (Office of Intelligence Liaison), Room 6854, 14th and Constitution Ave. NW, Washington, D.C. 20230

122. Bob Gallucci, Department of State, Room 7325A, 2201 C Street NW, Washington, DC 20520

123. Kermit L. Garlid, University of Washington, 303 Benson Hall, BF-20, Department of Nuclear Engineering, Seattle, WA 98195

124. D. C. Gibbs, ETEC - Rockwell International, P.O. Box 1449, Canoga Park, CA 91304

125. Mark Gielecki, U.S. Department of Energy, Energy Information Agency, Washington, DC 20585

126. Jessica Glicken, Sandia National Laboratory, P.O. Box 5800, Albuquerque, NM 87185

127. S. Golan, Bechtel Corporation, P.O. Box 193965, San Francisco, CA 94119-3965

128. B. Gordon, Department of State, ACDA/NWC, Room 4936, 2201 C Street NW, Washington, DC 20520

129. J. A. Gordon, National Security Council, Old Executive Office Building, Room 386, Washington, DC 20500

130. Kent Hanson, Massachusetts Institute of Technology, Department of Nuclear Engineering, 77 Massachusetts Avenue, Bldg. 24-102, Cambridge, MA 02139

131. A. Harris, AFTAC/TD, IN, 1030 S. Highway A1A, Patrick AFB, Florida 32925-3002

132. Jessie Harris, U.S. Department of Energy, HQ, PO-4, 1000 Independence Avenue, Washington, DC 20585

133. Terry Hawkins, Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545

134. Bill Henoch, Argonne National Laboratory, 9700 S. Cass Avenue, Argonne, IL 60439

135. Thomas Hubbard, Department of State, EAP, 2201 C Street NW, Washington, DC 20520

136. W. M. Jacobi, 119 Mount Vernon Drive, Monroeville, PA 15146

137. Harold Jaffee, U.S. Department of Energy, HQ, PO-70, 1000 Independence Avenue, Washington, DC 20585

138. Wynne James, U.S. Department of Energy, NN-30, 1000 Independence Avenue, Washington, DC 20585

139. Doug Jenkins, DCI Nonproliferation Center, Central Intelligence Agency, Washington, DC 20505

140. George John, Air Force Institute of Technology, School of Engineering, Department of Engineering Physics, Mail Code AFIT/ENP, Wright-Patterson AFB, Ohio 45433-6583

141. M. Johnson, CIA/NPIC/IEG/IID, Washington, DC 20505

142. Barclay G. Jones, University of Illinois, 103 S. Goodwin Avenue, Department of Nuclear Engineering, Urbana, IL 61801

143. Mujid S. Kazimi, Massachusetts Institute of Technology, Department of Nuclear Engineering, 77 Massachusetts Avenue, Bldg. 24-102, Cambridge, MA 02139

1144. John G. Keliher, U.S. Department of Energy, HQ, NN-1, 1000 Independence Avenue, Washington, DC 20036

145. Thomas W. Kerlin, University of Tennessee-Knoxville, Nuclear Engineering Department, 315 Pasqua Building, Knoxville, TN 37996-2300

146. Edward H. Klevans, The Pennsylvania State University, Nuclear Engineering Department, 231 Sackett Building, University Park, PA 16802

147. John Kriese, Central Intelligence Agency, JAEIC Chairman, Washington, DC 20505

148. Jay F. Kunze, University of Missouri-Columbia, Nuclear Engineering Program, 333 Electrical Engineering Building, Columbia, MO 65211

149. Edward N. Lambremont, Louisiana State University, Nuclear Science Center, Baton Rouge, LA 70803-5820

150. Stephen Lanes, U.S. Department of Energy, HQ, NE-50, 1000 Independence Avenue, Washington, DC 20585

151. L. Gary Leal, University of California, Department of Chemical and Nuclear Engineering, Santa Barbara, CA 93106

152. E. Clark Lemmon, University of Idaho, Program of Nuclear Engineering, Department of Mechanical Engineering, Moscow, ID 83843

153. Professor Richard Lester, Department of Nuclear Engineering, Massachusetts Institute of Technology, Building 24-102, Cambridge, MA 02139

154. Samuel W. Lewis, Department of State, Policy Planning Staff, 2201 C Street, Washington, DC 20520

155. Leon Lidofsky, Columbia University, Department of Applied Physics, New York, NY 10027

156. Winston Lord, Department of State, EAP, 2201 C Street, Washington, DC 20520

157. Andy Luksic, Pacific Northwest Laboratories, Battelle Boulevard, P.O. Box 999, Richland, WA 99352

158. Arvid Lundy, Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545

159. William R. Martin, University of Michigan, 108 Cooley Lab, North Campus, Department of Nuclear Engineering, Ann Arbor, MI 48109-2104

160. T. Marton, Electric Power Research Institute, P.O. Box 10412, Palo Alto, CA 94303

161. C. McDonald, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94550

162. D. J. McGoff, U.S. Department of Energy, NE-40, 1000 Independence Avenue, Washington, DC 20585

163. Fred McGoldrick, Department of State, PM/N, 2201 C Street, Washington, DC 20520

164. John W. McKlveen, Arizona State University, College of Engineering and Applied Sciences, Nuclear Engineering Science Program, Tempe, AZ 85287-5706

165. Steve Mercado, DCI Nonproliferation Center, Central Intelligence Agency, Washington, DC 20505

166. Don W. Miller, The Ohio State University, Nuclear Engineering Program, 206 West 18th Avenue, Columbus, OH 43210

167. S. Miller, CIA/OIR/DSD/DP, Washington, DC 20505

168. Brian Mohler, Department of State, EAP/Japanese Affairs, 2201 C Street, Washington, DC 20520

169. Asako Moore, CIA/FBIS/Asia, Washington, DC 20505

170. Garry Moore, Defense Intelligence Agency, PAG-1A, Washington, DC 20340-6161

171. Jim Mosquera, U.S. Department of Energy, HQ, NE-50, 1000 Independence Avenue, Washington, DC 20585

172. Sallie Mullen, U.S. Department of Energy, NN-30, 1000 Independence Avenue, Washington, DC 20585

173. Frank J. Munno, University of Maryland, Department of Materials and Nuclear Engineering, Nuclear Engineering Program, College Park, MD 20742-2115

174. John Nuckolls, Director, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94550

175. Gordon Oehler, DCI Nonproliferation Center, Central Intelligence Agency, Washington, DC 20505

176. G. Patton, Sandia National Laboratory, P.O. Box 5800, Albuquerque, NM 87185

177. James P. Phelps, University of Lowell, Program in Nuclear Engineering and Energy Engineering, Department of Chemical and Nuclear Engineering, One University Avenue, Lowell, MA 01854

178. Dan Poneman, National Security Council, Room 389, Old Executive Office Building, Washington, DC 20500

179. John W. Poston, Texas A&M University, Department of Nuclear Engineering, 129 Zachry Engineering Center, College Station, TX 77843

180. Rich Pound, DCI Nonproliferation Center, Central Intelligence Agency, Washington, DC 20505

181. Jim Powers, U.S. Department of Energy, NN-30, 1000 Independence Avenue, Washington, DC 20585

182. Martin Prochnik, Department of State, Office of Cooperative S&T Programs, 2201 C Street, Washington, DC 20520

183. Don Quinn, DCI Nonproliferation Center, Central Intelligence Agency, Washington, DC 20505

184. Victor H. Ransom, Purdue University, School of Nuclear Engineering, West Lafayette, IN 47907

185. B. Ressman, CIA/OIA/IID, Washington, DC 20505

186. Albert B. Reynolds, University of Virginia, Department of Nuclear Engineering and Engineering Physics, Charlottesville, VA 22903-2442

187. Joanne Reynolds, DCI Nonproliferation Center, Central Intelligence Agency, LDA, Washington, DC 20505

188. Alan H. Robinson, Oregon State University, Department of Nuclear Engineering, Radiation Center C116, Corvallis, OR 97331-5902

189. Bernard Rock, U.S. Department of Energy, Nuclear Import-Export Office, Room F-403, Washington, DC 20585

190. E. Rodwell, EPRI, 3412 Hillview Avenue, P.O. Box 10412, Palo Alto, CA 94303

191. John Rooney, U.S. Department of Energy, NN-40, 1000 Independence Avenue, Washington, DC 20585

192. M. Rosenthal, Department of State, Room 4678, 2201 C Street, ACDA/NWC/INA, Washington, DC 20520

193. Professor Geoffrey Rothwell, Department of Economics, Stanford University, Stanford, CA 94305-6072

194. Lt. Colonel C. Rowe, Defense Intelligence Agency, DIA/DT-1B, Washington, DC 20340-6161

195. Joe Santiucci, Electric Power Research Institute, P.O. Box 10412, Palo Alto, CA 94303

196. Gary M. Sandquist, University of Utah, Nuclear Engineering Program, Salt Lake City, UT 84112

197. J. Scarborough, MS-1643, U.S. Nuclear Regulatory Commission, Washington, DC 20555

198. Jim Shea, Nuclear Regulatory Commission, Washington, DC 20555

199. Jack Siegal, U.S. Department of Energy, HQ, FE-1, 1000 Independence Avenue, Washington, DC 20585

200. Marvin Singer, U.S. Department of Energy, HQ, FE-2, 1000 Independence Avenue, Washington, DC 20585

201. W. Singlevich, AFTAC/TD, TD, 1030 S. Highway A1A, Patrick AFB, Florida 32925-3002

202. Diane Soran, Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545

203. Dave Spetrino, Office of the U.S. Trade Representative, 600 17th Street NW, Washington, D.C. 20506

204. Ralph Stajdohar, Argonne National Laboratory, 9700 S. Cass Avenue, Argonne, IL 60439

205. Andrea Starks, DCI Nonproliferation Center, Central Intelligence Agency, CIA/NPIC/IEG/IID, Washington, DC 20505

206. W. Glenn Steele, Mississippi State University, Department of Mechanical and Nuclear Engineering, P.O. Drawer NE, Mississippi State, MS 39762

207. Danny Stillman, Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545

208. Laura Stone, Department of State, INR/EAP/Japan, 2201 C Street, Washington, DC 20520

209. Richard J. K. Stratford, Department of State, PM/N, 2201 C Street, Washington, DC 20520

210. Mark Sultan, DIA/DT-1, Defence Intelligence Agency, Washington, DC 20340-6161

211. J. Swanson, Department of Defense, DTSA, 400 Army Navy Drive, Suite 300, Arlington, VA 22202

212. J. J. Taylor, EPRI, 3412 Hillview Avenue, P.O. Box 10412, Palo Alto, CA 94303

213. George Tenet, Special Assistant to the President and Senior Director for Intelligence Programs, National Security Council, Room 300, Old Executive Office Building, 17th and Pennsylvania Ave. NW, Washington, D.C. 20506

214. John Tidd, DCI Nonproliferation Center, Central Intelligence Agency, Washington, DC 20505

215. Sue Tierney, U.S. Department of Energy, HQ, PO-1, 1000 Independence Avenue, Washington, DC 20585

216. Garry Tittemore, DCI Nonproliferation Center, Central Intelligence Agency, Washington, DC 20505

217. N. E. Todreas, Massachusetts Institute of Technology, Department of Nuclear Engineering, 77 Massachusetts Avenue, Bldg. 24-102, Cambridge, MA 02139

218. Notre Trulock, U.S. Department of Energy, HQ, NN-30, 1000 Independence Avenue, Washington, DC 20585

219. James S. Tulenko, University of Florida, Department of Nuclear Engineering Sciences, Room 202, Nuclear Science Center, Gainesville, FL 32611

220. Elizabeth Vaden, U.S. Department of Energy, NN-30, 1000 Independence Avenue, Washington, DC 20585

221. Peter Velz, U.S. Department of Energy, HQ, NN-30, 1000 Independence Avenue, Washington, DC 20585

222. K. C. Wade, U.S. Department of Energy, Energy Information Agency, Washington, DC 20585

223. Bernard W. Wehring, The University of Texas At Austin, Nuclear Engineering Program, Department of Mechanical Engineering, Austin, TX 78712

224. M. Weidemann, Sr. Dir., Asian Affairs, National Security Council, Room 365, Old Executive Office Building, 17th and Pennsylvania Ave. NW, Washington, D.C. 20506

225. A. Weinberg, Oak Ridge Associated Universities, Room E17, Vance Road, Oak Ridge, TN 37830

226. C. Wild, CIA/EUR/RR, Washington, DC 20505

227. Frank L. Williams, University of New Mexico, Department of Chemical and Nuclear Engineering, Farris Engineering Center, Room 209, Albuquerque, NM 87131

228. Rhys Williams, U.S. Department of Energy, HQ, NN-30, 1000 Independence Avenue, Washington, DC 20585

229. Ed Wonder, Ogden Environment and Energy Service Co., 3211 Germantown Rd., P.O. Box 10130, Fairfax, VA 22030

230. Tom Wright, Sandia National Laboratory, P.O. Box 5800, Albuquerque, NM 71858

231. Rick Yanuzzi, DCI Nonproliferation Center, Central Intelligence Agency, Washington, DC 20505

232. Mason York, DCI Nonproliferation Center, Central Intelligence Agency, OEA/J, Washington, DC 20505

233. DCI Nonproliferation Center, CIA/DO/NR/ Reports, Washington, DC 20505

234. DCI Nonproliferation Center, Central Intelligence Agency, DO/EA/J, Washington, DC 20505

235. DCI Nonproliferation Center, CIA/NRD, Washington, DC 20505

236. Department of State, INR, 2201 C Street, Washington, DC 20520

237. National Security Agency, B7, 9800 Savage Rd., Fort Meade, MD 20755-6000

238. National Security Agency, B72, 9800 Savage Rd., Fort Meade, MD 20755-6000

239. National Security Agency, /B7, 9800 Savage Rd., Fort Meade, MD 20755-6000

240. Office of Assistant Manager of Energy Research and Development, P.O. Box 2008, DOE-ORO, Oak Ridge, TN 37831-6269.

241-242. Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831.

DATE
FILMED
9/19/94

END