TECHNOLOGY TRANSFER AND COOPERATIVE RESEARCH IN JAPAN

Thomas W. Eagar

INTRODUCTION

There is much being written about Japanese businesses and their current success; a number of reasons have been proposed to explain this phenomenon. One of the most admired aspects in manufacturing is the Japanese ability to assimilate and apply new technology from around the world. In addition, Westerners are often impressed with Japanese preparation and knowledge concerning seemingly minor details. One American engineer tells the story of a meeting he had with a Japanese company in Tokyo one afternoon. He asked a rather specific question but received a rather general answer. The next morning, feeling unsatisfied with the response, he phoned another member of the company who was stationed at an office 600 miles away and asked the same question. His friend answered by saying that he thought that the question had been answered by his colleagues in Tokyo the previous afternoon! The Japanese company certainly had excellent communications both about what was said and about what was allowed to be said to this engineer.

Another claim which is often heard is that Japan is a unified economy tied together in some sinister way labeled "Japan, Inc." To those westerners who have spent much time in Japan yet another common characteristic of the Japanese is their apparently endless series of meetings. In this paper, I will attempt to explain some of the specific ways in which the Japanese achieve such rapid assimilation of new technology, and such excellent communications, why they hold so many meetings, and whether they are unified in their research. This is presented primarily through a description of the organization and the administration of two Japanese professional societies with which I am familiar: *viz.* the Japan Welding Society (JWS) and the Japan Welding Engineering Society (JWES); however, the general organizational format is very similar to most other Japanese engineering societies. It will be seen that these societies take a much more active role than most of their counterparts in the United States. It is believed that this active role of the professional societies is the glue which holds Japanese universities, national laboratories, and industries together and contributes not only to excellent communication of new technology but also to considerable cooperative research.

Before starting a discussion of the JWS and the JWES it may be useful to describe a few facts concerning the role of engineering and, specifically, the welding profession in Japan. In the United States, the most respected profession is a physician followed in second or third place by a scientist. The engineering profession generally ranks in the lower of the top ten professions. In Japan, the situation is reversed. Engineering is the most highly respected profession with science ranking within the top ten, but considerably lower than engineering. This difference between the United States and Japan is easily seen in the number of science and engineering graduates (Table I). There are roughly seven times as many scientists educated in the United States as in Japan, but equal numbers of engineers. On a per capita basis this means that Japan has twice as many engineers as the United States. As a result of this dominance of engineering professionals in Japan, the more practical or applied disciplines receive much more attention (and financial support) than in the United States. This is especially true for welding, which in the U.S. is considered to be on the low end of the technical scale. In Japan, welding is a much more respectable profession because the Japanese recognize that it permeates all types of manufacturing even if it is not very scientific; welding has tremendous practical importance. This importance is illustrated by the inclusion of welding as one of the 59 national committees of the Science Council of Japan (JSC). The JSC is the statutory advisor to the Japanese government on science and the National Committee of Welding ranks equally in the JSC with National Committees of Physics, of Mathematics, of Chemistry and of Space Research. Whether one agrees with such a ranking or not, this example demonstrates the importance of the practical engineering disciplines as perceived by the Japanese.

THE JWS--A PROFESSIONAL SOCIETY FOR INDIVIDUALS

As a professional society dedicated to individual members, the Japan Welding Society is similar to an engineering professional society in the United States. It holds two annual meetings, issues publications, holds training courses and the like. There are also nine technical research committees (listed in Table II); however, what is unusual is the activity of these technical committees. Each committee meets for one or two days, four to six times each year with 50 to 100 people in attendance. With only 25% of the 4000 JWS members as active committee participants, this represents five man days of technical committee work each year per active committee member. While this alone might not seem excessive, one has to combine this with the six days of semiannual technical meetings and the activities of the JWES which will be described subsequently.

These technical research committee meetings are not short administrative groups held in conjunction with other professional society business as is often done in the United States; they are full day stand-alone meetings. As an example, in November 1984 a day-long-meeting was held by the Welding Processes Committee to discuss narrow gap welding. In the morning, five persons from industry discussed the status and future potential of this process in the pressure vessel, heavy machinery, construction, shipbuilding, and hydroelectric industries. This was followed in the afternoon with five hours of discussion concerning narrow gap welding among experts from industry, national laboratories, and universities. Such an extensive discussion on such a limited topic must have provided each of the experts with a comprehensive knowledge of the state-of-the-art of narrow gap welding in Japan, its major problems, and its future industrial potential. In essence, this was a specialized seminar, given by experts for other experts in the same field. Although very labor intensive, such a meeting is very effective in transferring technology among laboratories, and industry.

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As another example of these open, yet closed, meetings, this author was invited by a Japanese colleague to attend another society's technical meeting. This was the Iron and Steel Institute of Japan meeting in Hiroshima in October 1984. The meeting was in Japanese, but there was a special two-day seminar of particular interest on accelerated cooling of steel plates, a new technology in which Japan clearly leads the world. Upon arriving with an interpreter, we were told that foreigners could not attend the seminar. After explaining that we were invited by a Japanese friend, apologies were made and we were permitted to enter. The surprising aspect of the seminar was that most papers dealt with the design and construction details of the processing equipment and how to avoid technical pitfalls. After the meeting, I commented that this was certainly unusual by U.S. seminar standards and my Japanese colleague responded that this is the Japanese way of "normalizing" their knowledge among the entire industry. It is not a practice that is illegal in Japan and it certainly is an effective means of intraindustry technology transfer.

Each technical research committee defines the scope of its interests. For example, the Strength of Welded Structures Committee lists the following four points of interest:

- weld cracking and residual stresses,
- fracture-safe design,
- time dependent fracture, e.g., fatigue, creep and stress corrosion cracking, and
- fabrication problems--sharing of experiences.

The chairman has four subchairmen, each of whom is a university professor, who are responsible for extracting one or two papers in each area, usually from industry, for presentation at the committee meetings. In this way, several dozen papers on weld strength are discussed in detail each year.

Another example of technical committee organization and activities comes from the Committee on Solid Phase Welding and Brazing. The JWS recognized in 1983 that more use will be made of dissimilar materials in the future and the conventional fusion welding processes are not appropriate. As a result, they formed this newest committee which held its first meeting in 1984. Starting a committee requires a strong and influential chairman. He must invite companies, universities, and national laboratories to participate. Each company pays a small annual fee ($100 to $200) to support the administrative expenses of the committee. After one year, the Solid Phase Welding and Brazing Committee now has 45 industrial members and about a dozen more from universities and national laboratories. After defining their scope, which in this case includes both metal-to-metal and metal-to-ceramic bonding, they divided up responsibilities for a worldwide literature survey of the state-of-the-art. At the next meeting, different laboratories agreed, at their own expense, to repeat some of the better studies which were found. This allows the Japanese laboratories to build up their expertise to world-class standards. In future meetings, the results of these studies will be presented and new research will be suggested. Each company can volunteer to perform some part of the study and share the results with other committee members. By such cooperative research, the Japanese can quickly develop world-class capabilities in this new area and can pool their resources to advance the state-of-the-art. While some of the early reviews of the current state-of-the-art may be published in English at the International Institute of Welding, most of the new research results will remain in Japanese with distribution limited to committee members.

Although professional societies for individuals in the United States have active technical committees, their activities cannot usually compare with the effort and the scope of the technical research committees of the JWS. Most professional society technical committees in the United States deal with topics such as public meetings, continuing education, or development of new standards. In Japan, the technical research committees function much more toward a "normalization" of research knowledge between universities, national laboratories, and industry. This is certainly one method by which the Japanese achieve rapid technology transfer from the laboratory to the production facility on an industry-wide basis. Although Japanese industry usually competes fiercely in sales and marketing of products, there is much truth to the idea that research studies are unified and coordinated and the results of this research are widely shared within Japan. In former times of rapid market growth, this sharing was very open but in the more competitive market of today's economy sharing is becoming more limited. Even so, this sharing of research knowledge is still much greater in Japan than in the United States.

THE JWES--A PROFESSIONAL SOCIETY FOR CORPORATIONS

Although the JWS is a professional society made up of individuals, the Japan Welding Engineering Society consists primarily of 160 corporate members and 300 invited personal members. The corporate membership dues are $1000 to $3500 per year and there is no fee for personal members. Although the JWES coordinates its work closely with the JWS (their headquarters are located in the same building), the JWES is primarily organized along industrial lines and their primary duties include cooperative research, qualification of engineers and welders, and the development of industrial standards.

Table III lists the technical divisions and research committees of the JWES. Each technical division has a division chairman, usually selected from an industrial company, but many also have a technical chairman, who is a university professor. The technical chairman of both the divisions and the research committees have several long-range projects. For example, The Welding Data System Research committee is trying to establish a welding data base which will be computerized. Approximately 20 companies and several universities are contributing information which can be used by everyone. It has been said that such cooperation was very generous a decade ago when the Japanese shipbuilding and steel industries were very busy, but in today's recession, it is more difficult to convince companies to share all of their knowledge. The Japanese claim that it is much more competitive now and it is only through the leadership of influential committee technical chairmen that companies can be encouraged to participate. As noted above, most of the committee technical chairmen are senior professors from the universities. Their old ties with former students make it possible to extract information which a company might otherwise avoid discussing in public.

Another example of cooperative industrial research sponsored through these technical committees, is research on a project entitled, Metal Working by High Power Lasers. In March 1980, a technical committee of the JWES was formed to evaluate high power lasers as metal working tools. The project is led by Professor K. Masubuchi of Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, who uses the 15 kW CO_2 laser at AVCO Everett (now Combustion Engineering) and Professor I. Masumoto of Nagoya UNiversity who has a 2 kW CO_2 laser. The experimental program, listed in Table IV, was financed by the 15 member companies. Each company can propose a specific portion of the research provided they are willing to provide the research funds. The advantage of this system is that not only can each company have its own specific research needs addressed, but can share in the overall results of the entire study. This is very effective cooperative research.

Of the JWES divisions, each carries out an average of three cooperative research projects per year. In most cases, companies do not directly finance the study through JWES as with the high power laser study at AVCO, but rather, they agree on which companies will perform which research and they share their research results. Any member company can request a cooperative research program by suggesting a topic in one of the division's committee meetings.

In addition to these industrially-sponsored cooperative welding research projects, the JWES often acts as a contractor for the Japanese government in administering research programs. There are currently 18 government-sponsored projects. Those sponsored by the Power Reactor and Nuclear Fuel Development Corporation (PRC), the Japan Atomic Energy Research Institute (JAERI), and the Japan Defense Agency are listed in Table V. The Ministry of International Trade and Industry (MITI) also provides monies for development of industrial standards, although the amount of money provided is very small.

When a government research contract is received by the JWES, a strong chairman is assigned who can encourage companies to participate. This is necessary because industry will receive only 10 to 30% of the total research costs while participating national laboratories and universities will receive 50 to 80% of the costs if they agree to participate. In any case, the government can have a large cooperative research program, administered by an eminently qualified expert in the field using highly-leveraged research funds.

It should be mentioned that although companies feel very pressured to participate in such projects when invited by influential chairmen, industrial participation is not guaranteed. When MITI began one of its nine large-scale industrial projects on a flexible manufacturing system complex provided with a laser, Hitachi, Toshiba, and Mitsubishi Electric were invited to participate in designing a high power CO_2 laser. Even though this was a $60 million eight-year project, Hitachi felt that they were well ahead of their competitors in laser development and they chose not to participate even under extreme pressure. Hitachi felt that they had more to lose than to gain. Today, at the end of the project, Hitachi, Toshiba and Mitsubishi Electric each have comparable CO_2 laser technology. Toshiba and Mitsubishi Electric shared their development costs with the government and shared the results with each other. Hitachi paid all of its costs itself and did not share directly in the results of Toshiba and Mitsubishi Electric.

It should be noted that for a project of this magnitude, a new professional society was formed entitled, "Engineering Research Association of Flexible Manufacturing System Complex with Laser." This association includes 20 companies and some 200 engineers from industry and 40 from national laboratories. It is clear that this society is a private administrative agency of MITI, based on the fact that questions referred to the Association two months after the project completion were referred back to MITI for response.

SUMMARY

If one asks how the Japanese achieve such effective technology transfer between laboratory and production, certainly one answer is that they hold many meetings on an industry-wide basis. There is not just technology transfer within a company, in Japan, but between companies and between companies and universities through the many meetings of the individual professional societies. The topics discussed at many of these meetings include much more technical content and detail than is common in the United States. In addition, all research laboratories become familiar with the efforts at other laboratories resulting in rapid dissemination of new results and less duplication of effort. The meetings also permit the Japanese to communicate knowledge of works outside of Japan very effectively. The Japanese are often frustrated by multiple groups of Americans coming to learn what has already been explained to previous visitors. There is not a system in the United States which disseminates information on international research activities as effectively as the Japanese system.

There are a number of reasons why the Japanese meeting system works. One is the strong leadership of the university professors who serve as committee chairmen. There are strong ties between these professors and their former students that do not exist in the United States. Japanese industry does not have any higher regard for the research done at Japanese universities than American industry has for research at American universities, but there is a much greater respect for old acquaintances in Japanese society as compared with American society. Another factor is the community spirit of the Japanese rather than the individualistic spirit of Americans that makes the Japanese more willing to share their successful ideas with one another rather than keeping them to themselves for private advantage. Still another factor is the greater patience of the Japanese. Few senior American scientists would tolerate spending 10 to 20% of their time in outside professional meetings in addition to the internal meetings within their organizations. Finally, a very important factor contributing to successful technical meetings in Japan is the Shinkansen, the "Bullet" Train. In many ways the small size of Japan is a curse, but insofar as holding meetings, it is a blessing. With the Shinkansen, most people can attend a one-day meeting at relatively small expense and only consume one day of their time including travel.

These differences suggest that the Japanese method of technology transfer cannot be transferred directly to the United States with equal effectiveness. Scientists in the U.S. should consider which aspects of the Japanese system of technology transfer can be used and should then try to implement such changes. One thing is certain, the impression that the Japanese have more effective technology transfer is true, and there is probably much that the United States can learn from the Japanese in this regard.

The Japanese methods of coordinating and cooperating in research could probably be used effectively in the United States if they were not illegal under U.S. statutes. There is much duplication of research effort in the United States. One thing which we can learn from Japan is that cooperation in research does not mean a lack of competition in the marketplace. Japanese businesses compete actively, while also cooperating in research. In contrast, American industry is hampered by laws and regulations which were made 75 years ago in a very different world economy. While the concept of a "Japan, Inc." in the world marketplace is not very accurate, there is a form of "Japan, Inc." in the research community. As one Japanese leader stated, "In order to avoid the useless duplication of research work and to push forward the development and application of research efficiently [to] needs in industry, it is preferable to establish a study system for joint research [by] industrial and academic circles."[1] Japanese research money is spent more efficiently because of this strong cooperative research effort.

[1] "Welding Research in the Far Eastern Countries," in *Proceedings for International Congress on Welding Research,* T. Kobayashi. Welding Research Council, New York, 1984.

TABLE I

SCIENCE AND ENGINEERING GRADUATES
IN THE UNITED STATES AND IN JAPAN

	United States	Japan	Ratio
Physical Sciences			
Bachelor	83,859	11,803	7.1
Master's	15,318	1,710	9.0
Doctoral	7,374	822	9.0
Engineering			
Bachelor	71,094	75,188	0.9
Master's	18,550	6,975	2.7
Doctoral	2,742	1,186	2.3

TABLE II

NINE STANDING TECHNICAL RESEARCH COMMITTEES
IN THE JAPAN WELDING SOCIETY

Technical Committee on Strength of Welded Structures
Chaired by Professor K. Satoh (Osaka University)

Technical Committee on Welding Arc Physics
Chaired by Professor H. Maruo (Osaka University)

Technical Committee on Welding Processes
Chaired by Professor I. Masumoto (Nagoya University)

Technical Committee on Welding Metallurgy
Chaired by Professor F. Matsuda (Osaka University)

Technical Committee on Fatigue Strength of Welded Joints
Chaired by Professor K. Iida (University of Tokyo)

Technical Committee on Electron Beam Welding
Chaired by Y. Arata (Osaka University)

Technical Committee on Resistance Welding
Chaired by Professor S. Nakada (Osaka University)

Technical Committee on Microjoining
Chaired by Professor S. Nakada (Osaka University)

Technical Committee on Solid Phase Welding and Brazing
Chaired by Dr. H. Nakamura (National Research Institute for Metals)

TABLE III

JAPAN WELDING ENGINEERING SOCIETY
TECHNICAL DIVISIONS AND RESEARCH COMMITTEES

Technical Division

- Welding Filler Metal
- Electric Welding Machine
- Gas Cutting
- Shipbuilding and Marine Structure
- Aircraft
- Machinery
- Rolling Stock
- Automotive
- Civil Engineering
- Patent
- Iron and Steel
- Precious Metal Brazing

Research Committees

- Special Materials Welding
- Chemical Plant Welding
- Nuclear Engineering
- Plastic Design
- Robots Promotion
- Welding Data System Research Committee

Committees for Contract Research

(Currently about 18 in total)

TABLE IV

SUMMARY OF RESEARCH PROGRAM CARRIED OUT BY HPL COMMITTEE OF JWES [a]

Theme	Mark of Experiment		Titles of Experiments	Members	Time* Schedule	Remarks
on beam characteristics	A		The relation between beam power and beam profile	K.H.I.	Step 1	AVCO
	B	B-1	On TEM mode	O.T.C.	Step 1	AVCO
		B-2	Beam profile	O.T.C.	Step 1	
	C		Influence of slope-up and slope-down to weld penetration	Toshiba	Step 1	AVCO
	D		Slope bead on plate test	K.H.I.	Step 1	AVCO
on welding	E	E-1	The relation between welding conditions and penetration and/or weld defects	M.H.I.	Step 2	AVCO
		E-2		I.H.I.		
		E-3		O.T.C.		
	F		Bead on plate test of aluminum alloy	Nissan	Step 2	AVCO
	G		Mechanical properties of HPL welded joints	S.H.I. Kobe St. Hitachi	Step 3	AVCO
	H	H-1	Fillet welding of aluminum alloy	Mitsui	Step 3	AVCO
		H-2	Fillet welding of steel plate	N.K.K.		
on heat treatment	I		Fundamental study on beam pattern	Toshiba	Step 1	AVCO
	J-1		Hardenability of materials	Nippon St. S.H.I. Hitachi S. M.H.I.	Step 2	AVCO
on cutting	K-1		Thick plate cutting	O.T.C.	Step 1	AVCO
	K-2		High speed cutting of thin steel	Hitachi	Step 2	UTRC
	K-3		Cutting of heated steel plate	Kawasaki S.	Step 3	AVCO
on practical applications	N		Irradiation test for sintered silicon compound	Nissan .	Step 3	Nagoya Uni.
	O		Study of precise bending by laser line heating	N.K.K.	Step 2	AVCO
	P		Lining welding of stainless steel	Mitsui	Step 3	AVCO
	Q		Joining of ceramics to metals	Daido	Step 3	Nagoya Uni.
	R		Surface alloying	Hitachi	Step 3	AVCO
	S		High speed welding of thin stainless steel	Hitachi	Step 3	AVCO

	Planned period	Actual period
*Step 1:	from Oct. 1980 to April, 1981 !	from Nov. 1980 to June 1981
Step 2:	from March 1981 to Aug., 1981	from Oct. 1981 to Sept. 1982
Step 3:	from July 1981 to Jan., 1982	from Jan. 1982 to Dec. 1982

[a] Reference for Table IV taken from *Technical Report on Research on Metal Working by High Power Laser* by Massachusetts Institute of Technology to the High Power Laser Committee of the Japan Welding Engineering Society, September 26, 1983.

TABLE V

JWES-ADMINISTERED GOVERNMENT RESEARCH

- Sponsored by the Power Reactor and Nuclear Fuel Development Corporation

  Acoustic Emission Signal Analysis for the Purpose of Structural Integrity of Piping Components for Fast Breeder Reactors (FBR)

  Establishment of Welding Procedures for FBR Structural Components

  Creep-Fatigue Crack Propagation Behavior of Structural Materials for Liquid Metal FBR

  Nondestructive techniques for FBR Structural Welds

  Structural Design of FBR

- Sponsored by the Japan Atomic Energy Research Institute

  Fatigue Strength of Light Water Reactor (LWR) Components

  Fracture Mechanics Evaluation of LWR Primary System

- Sponsored by the Japan Defense Agency

  Welding Code for Ni-Cr-Mo-Nb Ship Steel

  NDE of Steel Weldments--Development of Standards

  High Deposition Rate SMAW for Submarine Steels

  Standards for Fabrication of Submarine Hulls

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The chairman has four subchairmen, each of whom is a university professor, who are responsible for extracting one or two papers in each area, usually from industry, for presentation at the committee meetings. In this way, several dozen papers on weld strength are discussed in detail each year.

Another example of technical committee organization and activities comes from the Committee on Solid Phase Welding and Brazing. The JWS recognized in 1983 that more use will be made of dissimilar materials in the future and the conventional fusion welding processes are not appropriate. As a result, they formed this newest committee which held its first meeting in 1984. Starting a committee requires a strong and influential chairman. He must invite companies, universities, and national laboratories to participate. Each company pays a small annual fee ($100 to $200) to support the administrative expenses of the committee. After one year, the Solid Phase Welding and Brazing Committee now has 45 industrial members and about a dozen more from universities and national laboratories. After defining their scope, which in this case includes both metal-to-metal and metal-to-ceramic bonding, they divided up responsibilities for a worldwide literature survey of the state-of-the-art. At the next meeting, different laboratories agreed, at their own expense, to repeat some of the better studies which were found. This allows the Japanese laboratories to build up their expertise to world-class standards. In future meetings, the results of these studies will be presented and new research will be suggested. Each company can volunteer to perform some part of the study and share the results with other committee members. By such cooperative research, the Japanese can quickly develop world-class capabilities in this new area and can pool their resources to advance the state-of-the-art. While some of the early reviews of the current state-of-the-art may be published in English at the International Institute of Welding, most of the new research results will remain in Japanese with distribution limited to committee members.

Although professional societies for individuals in the United States have active technical committees, their activities cannot usually compare with the effort and the scope of the technical research committees of the JWS. Most professional society technical committees in the United States deal with topics such as public meetings, continuing education, or development of new standards. In Japan, the technical research committees function much more toward a "normalization" of research knowledge between universities, national laboratories, and industry. This is certainly one method by which the Japanese achieve rapid technology transfer from the laboratory to the production facility on an industry-wide basis. Although Japanese industry usually competes fiercely in sales and marketing of products, there is much truth to the idea that research studies are unified and coordinated and the results of this research are widely shared within Japan. In former times of rapid market growth, this sharing was very open but in the more competitive market of today's economy sharing is becoming more limited. Even so, this sharing of research knowledge is still much greater in Japan than in the United States.

THE JWES--A PROFESSIONAL SOCIETY FOR CORPORATIONS

Although the JWS is a professional society made up of individuals, the Japan Welding Engineering Society consists primarily of 160 corporate members and 300 invited personal members. The corporate membership dues are $1000 to $3500 per year and there is no fee for personal members. Although the JWES coordinates its work closely with the JWS (their headquarters are located in the same building), the JWES is primarily organized along industrial lines and their primary duties include cooperative research, qualification of engineers and welders, and the development of industrial standards.

Table III lists the technical divisions and research committees of the JWES. Each technical division has a division chairman, usually selected from an industrial company, but many also have a technical chairman, who is a university professor. The technical chairman of both the divisions and the research committees have several long-range projects. For example, The Welding Data System Research committee is trying to establish a welding data base which will be computerized. Approximately 20 companies and several universities are contributing information which can be used by everyone. It has been said that such cooperation was very generous a decade ago when the Japanese shipbuilding and steel industries were very busy, but in today's recession, it is more difficult to convince companies to share all of their knowledge. The Japanese claim that it is much more competitive now and it is only through the leadership of influential committee technical chairmen that companies can be encouraged to participate. As noted above, most of the committee technical chairmen are senior professors from the universities. Their old ties with former students make it possible to extract information which a company might otherwise avoid discussing in public.

Another example of cooperative industrial research sponsored through these technical committees, is research on a project entitled, Metal Working by High Power Lasers. In March 1980, a technical committee of the JWES was formed to evaluate high power lasers as metal working tools. The project is led by Professor K. Masubuchi of Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, who uses the 15 kW CO_2 laser at AVCO Everett (now Combustion Engineering) and Professor I. Masumoto of Nagoya UNiversity who has a 2 kW CO_2 laser. The experimental program, listed in Table IV, was financed by the 15 member companies. Each company can propose a specific portion of the research provided they are willing to provide the research funds. The advantage of this system is that not only can each company have its own specific research needs addressed, but can share in the overall results of the entire study. This is very effective cooperative research.

Of the JWES divisions, each carries out an average of three cooperative research projects per year. In most cases, companies do not directly finance the study through JWES as with the high power laser study at AVCO, but rather, they agree on which companies will perform which research and they share their research results. Any member company can request a cooperative research program by suggesting a topic in one of the division's committee meetings.

In addition to these industrially-sponsored cooperative welding research projects, the JWES often acts as a contractor for the Japanese government in administering research programs. There are currently 18 government-sponsored projects. Those sponsored by the Power Reactor and Nuclear Fuel Development Corporation (PRC), the Japan Atomic Energy Research Institute (JAERI), and the Japan Defense Agency are listed in Table V. The Ministry of International Trade and Industry (MITI) also provides monies for development of industrial standards, although the amount of money provided is very small.

When a government research contract is received by the JWES, a strong chairman is assigned who can encourage companies to participate. This is necessary because industry will receive only 10 to 30% of the total research costs while participating national laboratories and universities will receive 50 to 80% of the costs if they agree to participate. In any case, the government can have a large cooperative research program, administered by an eminently qualified expert in the field using highly-leveraged research funds.

It should be mentioned that although companies feel very pressured to participate in such projects when invited by influential chairmen, industrial participation is not guaranteed. When MITI began one of its nine large-scale industrial projects on a flexible manufacturing system complex provided with a laser, Hitachi, Toshiba, and Mitsubishi Electric were invited to participate in designing a high power CO_2 laser. Even though this was a $60 million eight-year project, Hitachi felt that they were well ahead of their competitors in laser development and they chose not to participate even under extreme pressure. Hitachi felt that they had more to lose than to gain. Today, at the end of the project, Hitachi, Toshiba and Mitsubishi Electric each have comparable CO_2 laser technology. Toshiba and Mitsubishi Electric shared their development costs with the government and shared the results with each other. Hitachi paid all of its costs itself and did not share directly in the results of Toshiba and Mitsubishi Electric.

It should be noted that for a project of this magnitude, a new professional society was formed entitled, "Engineering Research Association of Flexible Manufacturing System Complex with Laser." This association includes 20 companies and some 200 engineers from industry and 40 from national laboratories. It is clear that this society is a private administrative agency of MITI, based on the fact that questions referred to the Association two months after the project completion were referred back to MITI for response.

SUMMARY

If one asks how the Japanese achieve such effective technology transfer between laboratory and production, certainly one answer is that they hold many meetings on an industry-wide basis. There is not just technology transfer within a company, in Japan, but between companies and between companies and universities through the many meetings of the individual professional societies. The topics discussed at many of these meetings include much more technical content and detail than is common in the United States. In addition, all research laboratories become familiar with the efforts at other laboratories resulting in rapid dissemination of new results and less duplication of effort. The meetings also permit the Japanese to communicate knowledge of works outside of Japan very effectively. The Japanese are often frustrated by multiple groups of Americans coming to learn what has already been explained to previous visitors. There is not a system in the United States which disseminates information on international research activities as effectively as the Japanese system.

There are a number of reasons why the Japanese meeting system works. One is the strong leadership of the university professors who serve as committee chairmen. There are strong ties between these professors and their former students that do not exist in the United States. Japanese industry does not have any higher regard for the research done at Japanese universities than American industry has for research at American universities, but there is a much greater respect for old acquaintances in Japanese society as compared with American society. Another factor is the community spirit of the Japanese rather than the individualistic spirit of Americans that makes the Japanese more willing to share their successful ideas with one another rather than keeping them to themselves for private advantage. Still another factor is the greater patience of the Japanese. Few senior American scientists would tolerate spending 10 to 20% of their time in outside professional meetings in addition to the internal meetings within their organizations. Finally, a very important factor contributing to successful technical meetings in Japan is the Shinkansen, the "Bullet" Train. In many ways the small size of Japan is a curse, but insofar as holding meetings, it is a blessing. With the Shinkansen, most people can attend a one-day meeting at relatively small expense and only consume one day of their time including travel.

These differences suggest that the Japanese method of technology transfer cannot be transferred directly to the United States with equal effectiveness. Scientists in the U.S. should consider which aspects of the Japanese system of technology transfer can be used and should then try to implement such changes. One thing is certain, the impression that the Japanese have more effective technology transfer is true, and there is probably much that the United States can learn from the Japanese in this regard.

The Japanese methods of coordinating and cooperating in research could probably be used effectively in the United States if they were not illegal under U.S. statutes. There is much duplication of research effort in the United States. One thing which we can learn from Japan is that cooperation in research does not mean a lack of competition in the marketplace. Japanese businesses compete actively, while also cooperating in research. In contrast, American industry is hampered by laws and regulations which were made 75 years ago in a very different world economy. While the concept of a "Japan, Inc." in the world marketplace is not very accurate, there is a form of "Japan, Inc." in the research community. As one Japanese leader stated, "In order to avoid the useless duplication of research work and to push forward the development and application of research efficiently [to] needs in industry, it is preferable to establish a study system for joint research [by] industrial and academic circles."[1] Japanese research money is spent more efficiently because of this strong cooperative research effort.

[1] "Welding Research in the Far Eastern Countries," in *Proceedings for International Congress on Welding Research*, T. Kobayashi. Welding Research Council, New York, 1984.

TABLE I

SCIENCE AND ENGINEERING GRADUATES IN THE UNITED STATES AND IN JAPAN

	United States	Japan	Ratio
Physical Sciences			
Bachelor	83,859	11,803	7.1
Master's	15,318	1,710	9.0
Doctoral	7,374	822	9.0
Engineering			
Bachelor	71,094	75,188	0.9
Master's	18,550	6,975	2.7
Doctoral	2,742	1,186	2.3

TABLE II

NINE STANDING TECHNICAL RESEARCH COMMITTEES IN THE JAPAN WELDING SOCIETY

Technical Committee on Strength of Welded Structures
Chaired by Professor K. Satoh (Osaka University)

Technical Committee on Welding Arc Physics
Chaired by Professor H. Maruo (Osaka University)

Technical Committee on Welding Processes
Chaired by Professor I. Masumoto (Nagoya University)

Technical Committee on Welding Metallurgy
Chaired by Professor F. Matsuda (Osaka University)

Technical Committee on Fatigue Strength of Welded Joints
Chaired by Professor K. Iida (University of Tokyo)

Technical Committee on Electron Beam Welding
Chaired by Y. Arata (Osaka University)

Technical Committee on Resistance Welding
Chaired by Professor S. Nakada (Osaka University)

Technical Committee on Microjoining
Chaired by Professor S. Nakada (Osaka University)

Technical Committee on Solid Phase Welding and Brazing
Chaired by Dr. H. Nakamura (National Research Institute for Metals)

TABLE III

JAPAN WELDING ENGINEERING SOCIETY
TECHNICAL DIVISIONS AND RESEARCH COMMITTEES

Technical Division

- Welding Filler Metal
- Electric Welding Machine
- Gas Cutting
- Shipbuilding and Marine Structure
- Aircraft
- Machinery
- Rolling Stock
- Automotive
- Civil Engineering
- Patent
- Iron and Steel
- Precious Metal Brazing

Research Committees

- Special Materials Welding
- Chemical Plant Welding
- Nuclear Engineering
- Plastic Design
- Robots Promotion
- Welding Data System Research Committee

Committees for Contract Research

(Currently about 18 in total)

TABLE IV

SUMMARY OF RESEARCH PROGRAM CARRIED OUT BY HPL COMMITTEE OF JWES [a]

<table>
<tr><th>Theme</th><th colspan="2">Mark of Experiment</th><th>Titles of Experiments</th><th>Members</th><th>Time* Schedule</th><th>Remarks</th></tr>
<tr><td rowspan="5">on beam characteristics</td><td colspan="2">A</td><td>The relation between beam power and beam profile</td><td>K.H.I.</td><td>Step 1</td><td>AVCO</td></tr>
<tr><td rowspan="2">B</td><td>B-1</td><td>On TEM mode</td><td>O.T.C.</td><td>Step 1</td><td>AVCO</td></tr>
<tr><td>B-2</td><td>Beam profile</td><td>O.T.C.</td><td>Step 1</td><td></td></tr>
<tr><td colspan="2">C</td><td>Influence of slope-up and slope-down to weld penetration</td><td>Toshiba</td><td>Step 1</td><td>AVCO</td></tr>
<tr><td colspan="2">D</td><td>Slope bead on plate test</td><td>K.H.I.</td><td>Step 1</td><td>AVCO</td></tr>
<tr><td rowspan="5">on welding</td><td>E</td><td>E-1
E-2
E-3</td><td>The relation between welding conditions and penetration and/or weld defects</td><td>M.H.I.
I.H.I.
O.T.C.</td><td>Step 2</td><td>AVCO</td></tr>
<tr><td colspan="2">F</td><td>Bead on plate test of aluminum alloy</td><td>Nissan</td><td>Step 2</td><td>AVCO</td></tr>
<tr><td colspan="2">G</td><td>Mechanical properties of HPL welded joints</td><td>S.H.I.
Kobe St.
Hitachi</td><td>Step 3</td><td>AVCO</td></tr>
<tr><td rowspan="2">H</td><td>H-1</td><td>Fillet welding of aluminum alloy</td><td>Mitsui</td><td rowspan="2">Step 3</td><td rowspan="2">AVCO</td></tr>
<tr><td>H-2</td><td>Fillet welding of steel plate</td><td>N.K.K.</td></tr>
<tr><td rowspan="2">on heat treatment</td><td colspan="2">I</td><td>Fundamental study on beam pattern</td><td>Toshiba</td><td>Step 1</td><td>AVCO</td></tr>
<tr><td colspan="2">J-1</td><td>Hardenability of materials</td><td>Nippon St.
S.H.I.
Hitachi S.
M.H.I.</td><td>Step 2</td><td>AVCO</td></tr>
<tr><td rowspan="3">on cutting</td><td colspan="2">K-1</td><td>Thick plate cutting</td><td>O.T.C.</td><td>Step 1</td><td>AVCO</td></tr>
<tr><td colspan="2">K-2</td><td>High speed cutting of thin steel</td><td>Hitachi</td><td>Step 2</td><td>UTRC</td></tr>
<tr><td colspan="2">K-3</td><td>Cutting of heated steel plate</td><td>Kawasaki S.</td><td>Step 3</td><td>AVCO</td></tr>
<tr><td rowspan="6">on practical applications</td><td colspan="2">N</td><td>Irradiation test for sintered silicon compound</td><td>Nissan</td><td>Step 3</td><td>Nagoya Uni.</td></tr>
<tr><td colspan="2">O</td><td>Study of precise bending by laser line heating</td><td>N.K.K.</td><td>Step 2</td><td>AVCO</td></tr>
<tr><td colspan="2">P</td><td>Lining welding of stainless steel</td><td>Mitsui</td><td>Step 3</td><td>AVCO</td></tr>
<tr><td colspan="2">Q</td><td>Joining of ceramics to metals</td><td>Daido</td><td>Step 3</td><td>Nagoya Uni.</td></tr>
<tr><td colspan="2">R</td><td>Surface alloying</td><td>Hitachi</td><td>Step 3</td><td>AVCO</td></tr>
<tr><td colspan="2">S</td><td>High speed welding of thin stainless steel</td><td>Hitachi</td><td>Step 3</td><td>AVCO</td></tr>
</table>

	Planned period	Actual period
*Step 1:	from Oct. 1980 to April, 1981	from Nov. 1980 to June 1981
Step 2:	from March 1981 to Aug., 1981	from Oct. 1981 to Sept. 1982
Step 3:	from July 1981 to Jan., 1982	from Jan. 1982 to Dec. 1982

[a] Reference for Table IV taken from *Technical Report on Research on Metal Working by High Power Laser* by Massachusetts Institute of Technology to the High Power Laser Committee of the Japan Welding Engineering Society, September 26, 1983.

TABLE V

JWES-ADMINISTERED GOVERNMENT RESEARCH

- Sponsored by the Power Reactor and Nuclear Fuel Development Corporation

  Acoustic Emission Signal Analysis for the Purpose of Structural Integrity of Piping Components for Fast Breeder Reactors (FBR)

  Establishment of Welding Procedures for FBR Structural Components

  Creep-Fatigue Crack Propagation Behavior of Structural Materials for Liquid Metal FBR

  Nondestructive techniques for FBR Structural Welds

  Structural Design of FBR

- Sponsored by the Japan Atomic Energy Research Institute

  Fatigue Strength of Light Water Reactor (LWR) Components

  Fracture Mechanics Evaluation of LWR Primary System

- Sponsored by the Japan Defense Agency

  Welding Code for Ni-Cr-Mo-Nb Ship Steel

  NDE of Steel Weldments--Development of Standards

  High Deposition Rate SMAW for Submarine Steels

  Standards for Fabrication of Submarine Hulls