COMPETITIVE POSITION OF U.S. PRODUCERS OF ROBOTICS IN DOMESTIC AND WORLD MARKETS

Report on Investigation No. 332-155, Under Section 332(b) of the Tariff Act of 1930

USITC PUBLICATION 1475

DECEMBER 1983

United States International Trade Commission / Washington, D.C. 20436

UNITED STATES INTERNATIONAL TRADE COMMISSION

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Preface

On February 23, 1983, on its own motion under section 332(b) of the Tariff Act of 1930 (19 U.S.C. 1332(b)), the U.S. International Trade Commission instituted investigation No. 332-155 to assess the competitive position of U.S. producers of robotics in domestic and foreign markets. The study was to assess the impact of growing competition in the industry and explore the related developments most likely to affect the future market position of the U.S. industry. Notice of the investigation was given by posting copies of the notice of investigation at the Office of the Secretary, U.S. International Trade Commission, Washington, D.C., and by publication of the notice in the Federal Register (48 F.R. 9971, Mar. 9, 1983) (app. A).

The study limits the coverage of robots to industrial devices excluding manual manipulators and fixed-sequence machines, which are classified as robots in Japan and certain other countries, but not in the United States. The report covers the period 1979-83, with producers, purchasers, and importers providing estimates of their operations for July-December 1983.

In the course of this investigation, the Commission collected data from questionnaires sent to 30 producers, 15 importers, and 80 purchasers of robotics. Responses were received from 21 producers, 13 importers, and 51 purchasers. Responses received from the 21 producers represent more than 90 percent of the value of U.S. shipments, and those received from the 13 importers account for virtually all U.S. imports. Responses received from the 51 purchasers account for a large cross section of user industries, including 78 divisions of the largest U.S. automotive producer. Information was also collected in testimony presented at the public hearing on September 7, 1983, and from public and private sources, and in interviews with corporate executives representing purchasers, producers, and importers (app. B). Information on major foreign industries was supplied by the U.S. Department of State.

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Executive Summary

Robotics, along with other forms of automation, are being applied in manufacturing industries worldwide. The application of robotics reduces the labor content of products produced and increases the relative productivity of the countries employing them. The rate at which robots are being produced and installed, however, varies considerably from country to country. At present, Japan leads all countries in the application of robotics, including the United States, where the technology was developed. In 1982, about 50,000 robots were in operation worldwide excluding those in operation in Communist countries. Of these robots, 64 percent were in operation in Japan, compared with 14 percent in the United States and 7 percent in West Germany. The major findings of this study are summarized below.

1. Structure of the domestic and foreign industries.

   o <u>About 50 firms produce robots in the United States</u>.

In 1982, robots were produced by about 50 U.S. firms, with 6 firms together accounting for about 80 percent of U.S. shipments. Of these six firms, three are divisions of large, end-product producers, one is a joint venture of the largest U.S. automotive producer, and one is a subsidiary of a foreign electrical-equipment producer. The remaining firm is an independent producer of robots.

   o <u>U.S. producers' shipments increased during 1979-83 although shipments to domestic markets accounted for a decreasing share</u>.

U.S. producers' shipments of robots increased from $28 million in 1979 to $143 million in 1982, and are expected to reach $169 million in 1983. 1/ Shipments to domestic markets were valued at $19 million in 1979, increasing to $123 million in 1982. In 1983, shipments to domestic markets are expected to reach $135 million, and account for 80 percent of total shipments. Shipments to the domestic market accounted for 86 percent of total shipments in 1982.

The reduced growth of domestic shipments was caused largely by economic consequences of the recent U.S. recession. Heavy losses in the automotive industry and low capacity utilization rates in manufacturing industries, the major users of robotics, resulted in severe curtailment of funds available for capital equipment. The curtailment of funds is reflected by a 42-percent decline since 1981 in shipments of spot-welding robots, used largely in the automotive industry.

1/ Estimates of producers' shipments for July-December 1983 were provided by U.S. producers.

o <u>Employment increased in the industry during 1979-83</u>.

Employment in the robotics industry increased from 716 persons in 1979 to 1,934 persons in 1982, and is expected to reach 2,251 persons in 1983. Engineers, administrators, and other professional personnel together accounted for the majority of workers employed during the period, increasing from 47 percent of total employment in 1979 to 57 percent in 1983.

o <u>Industry production capacity increased during 1979-83, but was underutilized</u>.

The capacity of U.S. producers' plants increased from 1,264 robots in 1979 to 6,827 robots in 1983. During the period, capacity utilization of these plants peaked at 55 percent of maximum effective capacity in 1981, and declined to 48 percent in 1983. Producers' capacity was expanded during the period in anticipation of a large increase in demand which never materialized. New producers entered the industry in 1983 with added capacity, exacerbating this condition.

o <u>The robotics industry is research intensive, reflecting the importance of technology to U.S. producers</u>.

Expenditures by U.S. producers for research and development (R. & D.) are expected to reach $30 million in 1983, compared with $6 million in 1979. During the period, R. & D. expenditures as a share of producers' shipments increased steadily, reaching 19 percent of shipments in 1983. Funds to support R. & D. were largely provided by the robot producers, although a few producers reported that funds for R. & D. were received from venture capitalists. Funds provided directly by the U.S. Government to robot producers for R. & D. were largely nonexistent. Indirectly, the industry benefits from R. & D. funded by the Department of Defense (DOD) covering projects such as sensor technology and artificial intelligence. In 1982, about $27 million was provided by the DOD to support such projects, and about $44 million is expected to be provided in 1983.

o <u>Large losses were incurred in the robotics industry during 1979-83</u>.

U.S. producers reported that the median return in the industry decreased from 23 percent of net sales in 1979 to a loss of 9 percent in 1981, and then increased to a loss of 42 percent in 1982. Losses are expected to reach 49 percent of sales in 1983. The accelerated losses in 1982 and 1983 are related to a crowding effect caused by new entrants coming into the market and by increased R. & D. expenditures by robot producers. The new firms entering the market are often producers with low sales volumes and high product development costs. Losses were not limited to small producers, but were spread across the industry to include established producers as well.

o The majority of world producers of robots, including most U.S. producers, are linked through various agreements.

The majority of U.S. producers of robots, including all major producers, are connected with the major foreign robot firms through various agreements covering joint ventures, marketing, distribution, and technology transfer. An increasing number of such agreements cover manufacturing or resale arrangements with U.S. end-product producers attempting to establish a market presence. Through these agreements, the dispersion of technology between producing countries has been accelerated, and the need for research and development by new firms entering the industry has been reduced. Numerous foreign firms are also connected through similar agreements with each other. Most of these firms are located in Japan, West Germany, Norway and Sweden. Royalties received by U.S. producers from foreign sources during 1979-83 far exceeded royalties paid.

o More robots are installed in Japan than in all other countries combined.

About 31,900 robots were installed in Japan through 1982, representing an increase of 22,000 robots installed since 1978. The number of robots installed in Japan accounts for about 64 percent of the robots installed worldwide and is more than four times that installed in the United States and 7 times that of West Germany. The spread of robotics in Japan is related to an increasing demand within manufacturing firms, coupled with alleged Government assistance to producers and users of robots. The major type of Government assistance was the organization of a leasing company which provides Japanese producers with a ready market for robots and encourages the use of robots. Interest-free loans are also provided to members of the robot association to test market robots, engage in market research, and translate foreign documents. Users are also provided with accelerated depreciation allowances to encourage the purchase of robots. About 250 firms produce robots in Japan, many of which are large users.

2. The current U.S. market.

o Apparent U.S. consumption of robots increased during 1979-83.

Apparent U.S. consumption of robots increased from $23 million in 1979 to $138 million in 1982. Apparent consumption is expected to reach $164 million in 1983, representing the smallest increase in consumption since 1979, and reflecting the current recessionary effects on user industries. U.S. imports decreased from 16 percent of apparent consumption in 1979 to 11 percent in 1982, but are expected to increase to 18 percent in 1983.

o The largest users of robotics are the automotive industry and industries producing appliances, electrical machinery, and aircraft.

The automotive industry is the largest U.S. user of robotics, accounting for 50 to 60 percent of the robots installed domestically. Principal applications in the automotive industry are in welding, painting, and material handling. Principal applications in appliance, aircraft, and other user industries are for loading/unloading machines, measuring, coating, and injection molding.

o U.S. imports increased during 1979-83.

U.S. imports of robots increased from $3.8 million in 1979 to $15.1 million in 1982 and are expected to reach $28.9 million in 1983. The largest foreign supplier during the period was Japan, which accounted for 56 percent of imported value, followed by Sweden with 13 percent and Norway with 11 percent. The significant increase in 1983 is related to an increased demand for foreign robots in the domestic market and resale agreements in effect between U.S. and foreign producers.

o A diversified marketing strategy is emerging among U.S. producers to serve small- and mid-size firms.

Large end-product firms were the initial users of robots which were sold largely through negotiated contracts. Although this approach is still used with large firms, according to industry sources, a different approach is required to sell to small- and mid-size firms. The most promising producers' strategy is a systems approach whereby the robot is integrated into a flexible manufacturing system with machine tools, inspection equipment, and other devices which simulate a factory setting. The robot is demonstrated and sold as a part of the system. Unlike with machine tools, distributors are seldom used in the marketing of robots. Imported robots are sold through resale agreements, joint ventures, and U.S. end-product firms.

3. Factors of competition.

o U.S. demand for robots is affected by competing processes and the cost of installation.

The demand for robots has been adversely affected by other forms of automation (dedicated) and the high cost of robot installation. At present, over 90 percent of the robots being installed in the United States are integrated with equipment which is 10 to 20 years old. The cost of installation can vary between 175 and 500 percent of the initial cost of the robot. In a recent survey of industrial engineers whose firms had installed both automated equipment and robotics, automated equipment was rated as a more effective means to increase productivity than robotics. Industrial engineers are the individuals in user firms who usually provide justification for capital equipment purchases.

o Competitive factors affecting the sale of U.S. and foreign produced robots include prices, performance features, availability, supplier relationships, servicing/training, and marketing and distribution. When these factors are considered in the aggregate, it appears that U.S. firms producing robots have an overall competitive advantage in the domestic market vis-a-vis foreign producers based on response received from U.S. purchasers and producers.

U.S. products were found to have superior performance features in at least two robot categories; in all other categories performance features are not considered to be significantly different for domestic and foreign robots. Robot availability was not a significant factor overall in the current market except in the area of spare parts where domestic producers hold an advantage in making spare parts available on a timely basis. U.S. producers have stronger supplier relationships than foreign producers based on more extensive previous robot installations and through existing corporate agreements. U.S. producers hold a decided advantage over foreign producers in servicing U.S. robot installations and providing training to domestic production personnel, as foreign producers are hampered by a general lack of U.S. service and marketing networks and inadequate inventories of parts. Although domestic and foreign robots are marketed in much the same fashion, the foreign producers are at a disadvantage as foreign products are rarely sold directly by the producers as are the domestic products. Instead the foreign producer must rely on a U.S. partner or sales agent over whom control is limited. The competitive factors in which the U.S. producer does not appear to have a competitive advantage are price and maintenance costs. Foreign robots were found to be priced lower than U.S. robots in five of the eight broad categories examined based on weighted average unit values paid by U.S. purchasers during 1979-1983.

- Cost reductions and product improvements were instituted by U.S. producers to become more competitive.

U.S. producers reported that cost reduction and product improvement programs were instituted by them in response to increased competition from foreign producers. U.S. producers also reported that they shifted to more advanced product lines. Certain producers reported they reduced production capacity and began to import robots. No producer reported leaving the industry because of import competition.

- The value of U.S. exports increased during 1979-83.

U.S. exports of robots increased from $8.9 million in 1979 to $20.3 million in 1982 and are expected to reach $33.7 million in 1983. With the increased level of exports, U.S. producers became more dependent on foreign markets in 1983 with exports accounting for 20 percent of shipments.

- Western Europe provides the largest foreign market for U.S.-produced robots.

Countries in Western Europe provide the largest foreign market for U.S. exports. The level of exports to Western Europe is related to the advanced robots produced by U.S. firms and the stage of development of robotics in most European countries. User industries in these countries are dependent on foreign-produced robots, since they are not locally available. A loss of export markets in Western Europe could adversely affect U.S. producers, since export markets for U.S.-produced robots in Japan and elsewhere are limited. Currently, Japan has not been a large factor in the European market, although Japanese producers have developed an extensive marketing network there.

o <u>A positive U.S. balance of trade was maintained during 1979-83</u>.

The U.S. positive balance of trade in robotics increased from $5.2 million in 1979 to $12.7 million in 1981, and then decreased to $5.2 million in 1982. In 1983, the trade balance is expected to decrease to $4.8 million.

4. Future markets in the United States and foreign countries.

o <u>Markets for domestically produced robots are expected to show significant growth during 1984-88</u>.

U.S. producers are optimistic about future foreign and domestic markets, projecting that U.S. production will reach 22,000 robots in 1988, increasing from the expected production of 3,400 units in 1984. Although these projections include an increasing number of low-cost educational robots, the expected growth rate is much higher than that currently experienced in the industry. Future growth markets for robots will most likely come in new types of devices for component and end-product assembly. Markets for spot welders and coaters are likely to decline as the installation of these devices in the automotive and other major manufacturing industries engaged in mass production reaches saturation levels. The expected growth in assembly robots will depend on the development of improved grippers, sensors, and improved machine repeatability, which is the capability of the robot to perform a task to exact specifications time after time. Competition with foreign suppliers will remain intense, particularly with the Japanese who have directed production to relatively less expensive machines, which can be easily diffused through industries.

Description and Uses

A robot is a computerized device described as "a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks." 1/ The programming capability of the robot permits the device to operate independently of human operators and provides flexibility for adapting to various operations.

A robot consists of a gripper (hand) attached to an arm, which is supported on a base and controlled by a computer or central processing unit. The gripper is most often of mechanical, vacuum, or magnetic design, depending on the application for which the robot was intended. The movements of the arm and the gripper are effected by various prime movers, usually compressed air, hydraulic fluid, or electric motors. The prime mover chosen has a significant bearing both on the mechanical strength of the device and its price.

Robots using compressed air as a prime mover are usually light in weight, low in price, and capable of relatively fast movements. These devices, however, are limited by their lack of strength and are best suited for pick-and-place operations; robots driven by hydraulic fluids are similar to those driven by air, but are stronger and more expensive to construct. Hydraulic devices have two major deficiencies, in that they are prone to fluid leaks and are subject to losing their accuracy and repeatability with changes in the temperature of the hydraulic fluid. Despite these drawbacks and the need for pumps and fluid storage tanks, hydraulic-driven robots are the most popular devices in use. Robots driven by electric motors possess the greatest strength, but are also the most expensive to produce.

All robot manipulators have largely evolved around four different arm configurations: (1) cartesian (or rectangular) (2) cylindrical, (3) polar or spherical, and (4) articulated or jointed spherical, (fig. 1). Articulated manipulators resemble human arms, which are capable of bending and flexing at their wrists, elbows and shoulders, and are especially suited to reach small and difficult locations. This type of arm is more difficult to control than other types and is usually not capable of handling heavy work loads. A cylindrical manipulator is characterized by a center-mounting post with an extended arm which is capable of a perpendicular movement toward and away from the post, and of being rotated and moved up and down. A polar manipulator is similar to the cylindrical manipulator, having an extended arm mounted on a center post capable of being rotated. The extended arm of the polar device is designed, however, to provide a tilt movement above and below its mounting level. The cartesian manipulator is, in effect, a device constructed on three different tracks--one to control the height, one to control the depth, and the other to control the width. This type of manipulator provides a high degree of accuracy and repeatability, but is relatively slow in operation.

Data on the robotics industry are usually collected on the basis of the principal end uses of robots, rather than by their power sources or the types

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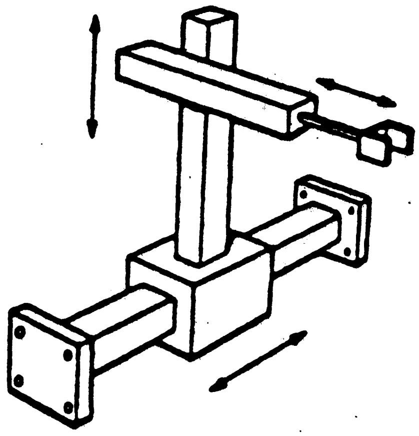
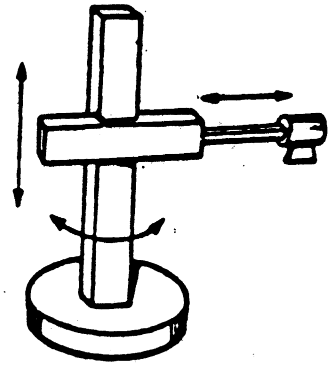
1/ "Robotics Today," RIA News, Spring 1980, p. 7. This definition excludes mechanical and electrical devices such as manual and fixed-sequence manipulators.

Figure 1

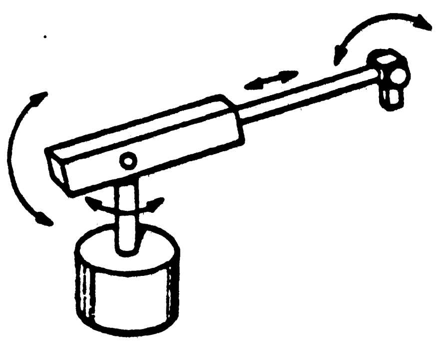
Basic Manipulator Geometries



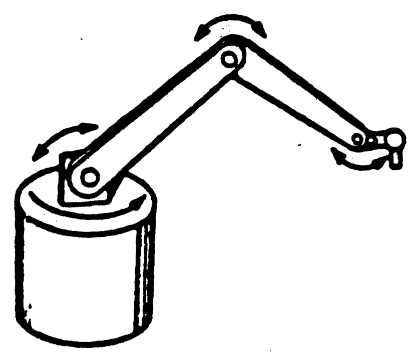
1.
Rectangular
(Cartesian coordinates)



2.
Cylindrical coordinates



3.
Spherical
(Polar coordinates)



4.
Articulated or Jointed Spherical
(Revolute coordinates)

Source: U.S. Department of Commerce, National Bureau of Standards, An Overview of Artificial Intelligence and Robotics, Vol. II, Robotics, March 1982, p. 11.

of manipulators they employ. Separation by end use reflects the current practice used by the industry and eliminates confusion associated with various manipulator movements. Seven end-use provisions largely cover all types of robots in use or in production, along with an additional provision to cover special types of devices, which are described as follows:

1. Spot welders.--Spot welders are resistance devices which are capable of joining articles of metal through the use of a low-voltage, high-current power source developed across a set of electrodes.

2. Arc welders.--Arc welders are devices which are capable of joining articles of metal through the use of a consumable or nonconsumable electrode in the presence of an inert gas.

3. Coaters.--Coaters are spraying devices which are able to apply paint, lacquer, or other liquids to articles requiring surface treatment.

4. Assemblers.--Assemblers are devices which are utilized to fit or join together manufactured articles to make a subassembly or completed products. These operations are usually accomplished through the use of screws and nuts, rivets, pins, or similar fasteners.

5. Material handlers.--Material handlers are devices used to move and store materials and parts during various stages of production.

6. Metalworking apparatus.--Metalworking apparatus are limited to the various metal-removing devices, such as lathes, mills, boring machines, punch presses, and drill presses. Welding machinery is not included.

7. Loaders/unloaders.--Loaders/unloaders are devices used to supply and remove parts or material from other machines (metalworking machines, molding apparatus, and so forth) which perform the manufacturing operation.

8. Other.--"Other" includes devices fitting the definition for robots, but not described in types (or categories) 1 through 7 above. Such other devices may be combinations of the above devices in types 1 through 7 or other types of robots, e.g., measuring, inspection, and testing robots.

The largest user of industrial robots in the United States is the automotive industry. The sheetmetal assembly and surface preparation of vehicle components are readily adapted to robotics, especially spot welders and coaters. These devices also account for a large share of the robots in use in other manufacturing industries. See robotics illustrations in figures C-1 through C-11, app. C. Following the automotive industry, industries producing electrical machinery, fabricated metals, electronics, home appliances, aircraft, and heavy machinery are large users of robotics. Applications of robots in some of the major U.S. industries are discussed below.

Automobile assembly

Robots are currently being used in the automotive industry in a full range of applications. However, the large-scale and still-predominant automotive application for robots is in spot welding. The spot-welding robot has, in fact, become a permanent fixture on automotive assembly lines. Coating or spray-painting robots have also found widespread use in the automotive industry, as have machine-loading and machine-unloading, and material-handling devices. Robots for assembly, arc welding, and other specialized applications are not as prevalent, with manufacturers experiencing some difficulty integrating them into their production operations. More sophisticated visual and tactile acuity and increased repeatable accuracy will be needed to expand the universe of these applications.

Aircraft manufacture

The principal applications in which robots are being applied in the aircraft industry are machine loading and unloading, material handling, and spray painting or coating. Spot-welding and arc-welding uses are virtually nonexistent owing to the extensive use of fasteners, especially rivets, in production. Assembly robots have also found limited use in the industry due in part to the newness of the technology (producers are just now seriously evaluating assembly systems) and to the high level of hard (or dedicated) automation already in place in aerospace facilities. Many of the current robots in use have displaced workers in hazardous or monotonous production operations (e.g., spraying chromate paints and transferring parts from one bin to another). Among the specific functions to which robots have been and are expected to be dedicated in the aerospace industry are routing, chamfering, drilling, and deburring of metal parts; ultrasonic inspection of engine cowlings (covers); insertion of connectors into electronic test equipment panels; and assembling circuit boards for aircraft radar.

Home appliance production

The operations to which robots are dedicated in the production of home appliances are predominantly assembly, spray painting, machine loading and unloading, and material handling. Many of these operations are tedious, monotonous, and/or hazardous and as such are readily adaptable to robotic techniques. Robots are being used in the coating of refrigerator doors and the assembly of small electric motors, among other things. One-quarter of appliance manufacturers surveyed in 1980 reported using robots; another one-quarter indicated the expected future use of such equipment. 1/

Tariff Treatment

U.S. tariff treatment

Industrial robots were not separately provided for in the Tariff Schedules of the United States Annotated (TSUSA) until January 1981.

1/ Dale Chaney and Norman Remich, "Robots Gain Acceptance in U.S. Industry," Appliance Manufacturer, December 1980, p. 56.

At that time, statistical annotations were implemented covering materials-handling robots under TSUSA item 664.1005 and welding robots under TSUSA item 683.9005. On January 1, 1983, two additional annotations were implemented covering miscellaneous industrial robots under item 678.5086 and parts of miscellaneous industrial robots under item 678.5087. Excerpts from the TSUSA (1983) which pertain to robots and show actual tariff language are provided in app. D.

The most-favored-nation (MFN) rates of duty (col. 1) applicable to imports of robots currently range from 3 percent ad valorem for industrial welding robots to 4.4 percent ad valorem for miscellaneous industrial robots and parts thereof (table 1). Under an agreement reached in the Tokyo round of the Multilateral Trade Negotiations (MTN), the rates will undergo additional annual staged reductions through January 1, 1987. On that date, the most favored nation duty rates will range from 2 to 3.7 percent ad valorem; these final staged reductions are currently applicable to imports from certain least developed developing countries (LDDC's). The column 2 rate of duty applicable to imports of all types of robots from designated Communist countries is 35 percent ad valorem. In addition, robots have been designated for duty-free treatment when imported under the Generalized System of Preferences (GSP) from certain beneficiary developing countries, subject to the "competitive need limitations" covered under title V of the Trade Act of 1974. 1/ On April 1, 1983, Hong Kong, the Republic of Korea, and Taiwan were declared ineligible to export industrial robots and parts duty free to the United States, having exceeded these limitations under Tariff Schedules of the United States (TSUS) item 678.50.

Statistical reporting provisions in the TSUSA were slow to appear for a number of reasons, which included the low level of import trade in robotics and the general lack of an international agreement on a robot definition. Robots also presented tariff classification (and statistical reporting) problems since imported articles are often entered without their dedicated systems attached (e.g., a welding system), which would provide distinguishing-type characteristics. Finally, robot parts and components such as electric motors are often imported under TSUSA items other than those for robots.

Foreign tariff treatment

At this time, robots are not separately provided for in the Customs Cooperation Council Nomenclature (CCCN). Owing to the lack of a standard international definition, no serious effort is currently under consideration to enumerate these devices. In the absence of specific provisions, imports of robots into countries using the CCCN are classified by the function to which a particular device is dedicated. The three provisions in the CCCN which would apply to the majority of imported robots are 84.21D (spraying guns and the

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1/ Duty-free imports entered under a TSUS item from a beneficiary developing country are limited to a percentage of the U.S. gross national product and to 50 percent of the appraised value of imports. Eligibility also requires at least 35 percent of the appraised value of the TSUS item eligible under the GSP be added in the beneficiary developing countries.

Table 1.--Robots and parts: U.S. rates of duty, present and negotiated, and GSP and LDDC status

(Percent ad valorem)

TSUSA item 1/	Description	Present col. 1 rate of duty 2/	Negotiated col. 1 rate of duty 3/	Present col. 2 rate of duty 4/	LDDC 5/
664.1005A	Material-handling robots (lifting, handling, loading, unloading, and similar functions).	3.5%	2.0%	35.0%	2.0%.
678.5086A* and 678.5087A*	Miscellaneous industrial robots and parts thereof.	4.4%	3.7%	35.0%	3.7%.
683.9005A	Industrial electric welding robots.	3.0%	2.0%	35.0%	2.0%.

1/ The designation "A" or "A*" indicates that the item is currently designated as an eligible article for duty-free treatment under the U.S. Generalized System of Preferences (GSP). "A" indicates that all beneficiary developing countries are eligible for GSP. "A*" indicates that certain of these countries, specified in general headnote 3(c) of the Tariff Schedules of the United States Annotated, are not eligible. The GSP, under title V of the Trade Act of 1974, provides duty-free treatment of specified eligible articles imported directly from designated beneficiary developing countries. The GSP, implemented by Executive Order No. 11888 of Nov. 24, 1975, applies to merchandise imported on or after Jan. 1, 1976, and is scheduled to remain in effect under Jan. 4, 1985.

2/ Rate in effect on Jan. 1, 1983. The rates of duty in col. 1 are most-favored-nation (MFN) rates, and are applicable to imported products from all countries except those Communist countries and areas enumerated in general headnote 3(f) of the TSUSA. However, such rates would not apply to products of developing countries which are granted preferential tariff treatment under the GSP or under the "LDDC" rate of duty column.

3/ Final rate negotiated under the Tokyo round of the Multilateral Trade Negotiations to be achieved through 8 annual staged duty reductions effective Jan. 1, 1987.

4/ The rates of duty in col. 2 apply to imported products from those Communist countries and areas enumerated in general headnote 3(f) of the TSUSA.

5/ The rates of duty in the rate of duty column "LDDC" are preferential rates (reflecting the full U.S. most-favored-nation (MFN) concessions rate for a particular item without staging) and are applicable to products of the least developed developing countries designated in general headnote 3(d) of the TSUSA which are not granted duty-free treatment under the GSP.

Source: Federal Register, Presidential Proclamation 4707, Dec. 13, 1979, and Tariff Schedules of the United States Annotated (1983).

like), 84.22 (lifting, handling, loading, or unloading machinery, and so forth), and 85.11 (. . . electric or laser operated welding, brazing, soldering, or cutting machines and apparatus). Imports of robots into the European Community under CCCN 84.21 are currently dutiable at 5.2 percent ad valorem; those entered under CCCN 84.22 and 85.11 are dutiable at 4.8 and 6.3 percent ad valorem, respectively, as shown in table 2. Imports of robots into Japan under the comparable Japanese customs provisions are currently dutiable at 4.9, 5.3, and 4.9 percent ad valorem, respectively.

Imports into Canada are classified under item 42700-1, machines not otherwise provided for, and under item 44621-1, welding apparatus and parts. Imports under these provisions are dutiable at 12.1 percent ad valorem.

World Consumption of Robotics

The number of robots in operation worldwide (excluding Communist countries) increased from 16,000 in 1978 to 50,000 in 1982. During the period, Japan accounted for a large share of robots in operation, with the number installed in Japan increasing from more than 10,000 to almost 32,000. The number of operational robots in Japan does not include manual manipulators and fixed-sequence devices, which are not considered robots using the U.S. definition. Compared with installations in Japan, the number in the United States lags far behind; less than 2,900 robots were installed in 1978 and less than 7,300 were installed in 1982. West Germany lags even further behind, with an installed base of 3,500 robots in 1982, having increased from 450 in 1978, as shown in table 3.

The number of robots installed in Japan is related largely to the structure of the industry and the country's extensive facilities for the production of motor vehicles. The major robot producers in Japan are the large electrical and electronic equipment firms which produced robots for installation in their manufacturing operations. Since 1980, the electrical and electronic industries have provided the largest market for robots, accounting for 30 percent of the robots in operation in 1982. 1/ When combined with the automotive industry, together they accounted for 57 percent of the robots in operation. 2/

The growth of robotics in Japan has also been encouraged by the Japanese Government. The encouragement has allegedly come through the establishment of a Japanese company which provides preferential leasing rates to user firms, through funds provided for research and development, and allowances provided for accelerated depreciation. 3/ These encouragements are discussed further in the "Foreign Industries" section of this report.

Table 2.--Robotics: Selected rates of duty, present and negotiated, in principal foreign markets for U.S. exports

(Percent ad valorem)

Market	Description of commodity and foreign tariff item No.	Present rate of duty 1/	Negotiated rate of duty 2/
Canada	Machines, n.o.p., and accessories, attachments, control equipment, and tools for use therewith; parts of the foregoing; other (42700-1).	12.1%	9.2%.
	Electric apparatus designed for welding, n.o.p., and parts thereof, not including motors (44621-1).	12.1%	9.2%.
European Community.	Mechanical appliances (whether or not hand operated) for projecting, dispersing, or spraying liquids or powders; and so forth (84.21D).	5.2%	4.4%.
	Lifting, handling, loading, or unloading machinery, and so forth. . ., other (84.22D).	4.8%	4.1%.
	Machines and mechanical appliances, having individual functions, not falling within any other heading of ch. 84 (84.59E).	5.2%	4.4%.
	Industrial and laboratory electric furnaces, ovens and induction and dielectric heating equipment; electric or laser-operated welding, brazing, soldering or cutting machines, and apparatus (85.11B).	6.3%	5.1%.
Japan	Mechanical appliances (whether or not hand operated) for projecting, dispersing, or spraying liquids or powders; and so forth (84.21-031).	4.9%	4.9%.
	Lifting, handling, loading, or unloading machinery, and so forth, other (84.22-260).	5.3%	5.3%.
	Machines and mechanical appliances, having individual functions, not falling within any other heading of ch. 84 (84.59-729).	5.3%	5.3%.
	Industrial and laboratory electric furnaces, ovens, and induction and dielectric heating equipment; electric or laser-operated welding, brazing, soldering or cutting machines and apparatus (85.11-219).	4.9%	4.9%.

1/ Rate currently applicable to imports from the United States.
2/ Final rate negotiated under the Multilateral Trade Negotiations (Tokyo round).

Table 3.--World robot population, 1978-82 1/

(In Units)

Country	1978	1979	1980	1981	1982
Japan	10,095	11,533	14,246	21,684	31,900
United States	2,831	3,340	3,849	4,700	7,232
West Germany	450	2/	823	2,301	3,500
Sweden	800	2/	1,133	1,700	2/
France	2/	2/	200	620	993
United Kingdom	125	2/	371	713	977
Belgium	2/	2/	2/	44	305
Canada	2/	2/	2/	214	273
Italy	2/	2/	400	450	600
Finland	2/	2/	40	2/	75
Austria	2/	2/	2/	2/	70
Norway	2/	2/	2/	2/	20
Switzerland	2/	2/	2/	2/	200
Taiwan	2/	2/	2/	2/	11
All other	2/	2/	2/	2/	3/ 2,000
Total 2/	16,000	19,000	24,000	35,000	50,000

1/ Excluding Communist countries.
2/ Information or estimates are not available.
3/ Estimated by the staff of the U.S. International Trade Commission.

Source: Japan Industrial Robot Association, responses from questionnaires of the U.S. International Trade Commission, and Paul H. Aron, The Robot Scene in Japan: An Update, Sept. 7, 1983.

U.S. Industry

U.S. producers

In 1982, robots were produced by about 50 firms in the United States, with 6 firms together accounting for 80 percent of U.S. producers' shipments. The majority of the firms, including all major producers, operate under agreements with robot firms in Canada, Western Europe, and Japan. These agreements cover joint ventures, marketing, distribution, manufacturing rights, and technology transfer. Many of the foreign producers also operate under agreements with each other.

1/ Paul Aron, op. cit., p. 42.
2/ Ibid.
3/ Ibid, pp. 23-27.

The oldest of the six largest firms produced the first known servo-controlled robot 1/ in the early 1960's, which is recognized as a milestone in the development of robotics. The firm also licensed its technology to a Japanese firm in the 1960's. As a result of this technology transfer, the Japanese producer became the largest robot producer in that country and remained in that position for many years. Another of the six firms was awarded two patents in 1975, one for a general-purpose coordinate system and the other for a method for controlling a machine along a predetermined path. The robot developed from these patents was based on the extensive experience gained through the production of numerically controlled machine tools. Like robots, numerically controlled machine tools are capable of being reprogrammed. The firm also has an agreement with a Japanese firm which currently is the seventh largest producer of robots in the country.

Two of the largest firms are 50 percent or more beneficially owned by foreign producers. One is a subsidiary of Sweden's largest producer of electrical equipment which is recognized for superior technology in the production of welding and coating robots. The other is a joint venture formed between the largest U.S. producer of automobiles and a major Japanese producer of robots. The joint venture was reportedly created to supply the automotive producer with its robotics needs but, in effect, reduces the domestic market for other U.S. robot producers. 2/ It is believed by the industry that the joint venture may become the leading producer of robots, since the automotive producer represents a large share of the U.S. robotics market. 3/ In addition, a third firm of the big six is recognized as a strong competitor in the production of painting robots with technology obtained under a license agreement with a leading producer in Norway. Under the agreement, the firm has obtained exclusive marketing rights for North America and has improved and upgraded the robots to U.S. electrical standards. The firm is operated as a separate division of a U.S. spark plug producer. The last of the six largest firms is noted as a producer of heavy-duty loading/unloading robots. The firm recently purchased the patents of a former producer which first introduced robots into Japan in the 1960's.

Firms have entered the domestic robotics industry, usually concentrating on limited product lines. These firms, including producers of computers, semiconductors, and electrical equipment, entered the industry with plans to be well established when the market begins to show significant growth. 4/ Easy entry has been provided through agreements with foreign firms to purchase generic robots which are later equipped with domestic end effectors (e.g., grippers) and controllers. License and manufacturing agreements arranged with foreign firms reduced the need for research and development and provide for low-cost production. It should be noted that these agreements are often

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1/ A servo-controlled robot is controlled by a servomechanism or device which monitors an operation as it proceeds and makes necessary adjustments to keep the operation under control. This is accomplished by a closed-loop system in which the error or deviation from a desired or preset norm is reduced to zero.

2/ "An Enigma Becomes a Venture," Detroit Automotive News Extra, Apr. 25, 1983, p. D-18.

3/ Ibid.

4/ "The Robots are Coming," Barron's, Apr. 11, 1983, p. 8.

dynamic and can change over time. A list of the principal agreements is shown below.

Agreements Existing Between U.S. and Foreign Robotics Producers

From	Type of Agreement	To
DEA (Italy)	License and marketing.	General Electric Co.
Volkswagen (West Germany)	License and marketing.	General Electric Co.
Hitachi Ltd. (Japan)	License and marketing.	General Electric Co.
Fujitsu Fanuc (Japan) 1/	Joint venture	General Motors Corp.
Unimation	License	Kawasaki Heavy Industries (Japan).
Unimation	License	Nokia (Finland).
Prab Robots, Inc	Manufacturing	Fabrique Nationale (Belgium).
Prab Robots, Inc	Manufacturing	Murata Machinery (Japan).
Prab Robots, Inc	Manufacturing	Canadian English Co. (Canada).
Trallfa (Norway)	License	DeVilbiss Co.
Renault (France) 1/	Joint venture	Ransburg.
Yaskawa Electric (Japan)	Marketing	Hobart Brothers.
Yaskawa Electric (Japan) 1/	Technology exchange.	Machine Intelligence Corp.
Sankyo Seiki (Japan)	Purchase	IBM.
Komatsu (Japan)	License and marketing.	Westinghouse Electric.
Mitsubishi Electric (Japan).	License and marketing.	Westinghouse Electric.
Olivetti (Italy)	License and marketing.	Westinghouse Electric.
Basfer (Italy)	License	Nordson.
Dainichi Kiko (Japan)	Marketing	GCA.
Hitachi Ltd. (Japan)	Marketing	Automatix.
Nachi Fujikoshi (Japan)	License	Advanced Robotics Corp.
Nimak (West Germany)	License	United Technologies.
Asea (Sweden)	Subsidiary	Asea, Inc.
Cincinnati Milacron	Manufacturing	Dainichi Kiko (Japan).

1/ Information and technology flow in both directions.

Source: Compiled from various sources by the staff of the U.S. International Trade Commission.

U.S. production

Robot production reported by 21 U.S. producers in Commission questionnaires increased from 614 units in 1979 to 2,585 units in 1982. On the basis of their output for January-June 1983, U.S. producers estimated that production would reach 3,234 units for the entire year, as shown in the tabulation below:

Year	Quantity (units)	Annual increase (percent)
1979	614	-
1980	1,118	82.1
1981	1,993	78.3
1982	2,585	29.7
1983 1/	3,234	25.1

1/ Data are based on projections provided by 21 U.S. robot producers.
Although production volume increased by 2,620 units during the period, the production growth rate declined each year, from 82 percent in 1980 to an expected 25 percent in 1983.

U.S. production of robots has been influenced since 1980 by a significant increase in instructional or educational devices used to acquaint students, teachers, and users with robotics. 1/ These devices are relatively simple in design and are often sold in the open market for under $3,500. When these devices are removed from the data, robot production increased about 16 percent in 1982, and it is expected to increase 22 percent in 1983. Robots are generally produced as universal devices whose types are determined only after an order is received and their controls are attached.

U.S. domestic shipments

Domestic shipments of U.S.-produced robots increased from 443 units in 1979 to 2,107 units in 1982 and are expected to reach 2,666 units in 1983 (table 4). 2/ The increase in unit shipments during 1979-83 represents a high growth rate, although the rate slowed in 1982 and declined further in 1983. Domestic shipments are expected to increase about 26 percent in 1983, compared with those in 1982, representing a significant decrease from the annual growth rates attained in previous years. Captive (intracompany) shipments accounted for less than 6 percent of total domestic shipments during the period.

Shipments of arc-welding, material-handling, educational, and assembly robots have experienced the most rapid growth in recent years. Advances in sensor technology have accelerated the introduction of arc-welding robots into

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1/ Instructional robots simulate full-scale industrial robots and are used to acquaint engineers, educators, and hobbyists with using robots. See Robotics Today, February 1983, p. 9.

2/ Data received from 21 responses to Commission questionnaires represent more than 90 percent of industry shipments.

the shipbuilding and other industries. Material-handling robots have also made significant inroads into a number of industries largely because of the

Table 4.--Robots: U.S. producers' domestic shipments, by types, 1979-83

Type	1979	1980	1981	1982	1983 1/
	Quantity (units)				
Spot welders	155	344	644	434	372
Arc welders	28	52	57	91	196
Coaters	0	0	26	156	153
Assemblers and material handlers 2/	114	153	259	550	1,025
Metalworking apparatus	4	7	10	16	15
Loaders/unloaders	79	111	167	163	188
Other 3/	63	141	344	697	717
Total	443	808	1,507	2,107	2,666
	Value (1,000 dollars)				
Total 4/	19,168	43,293	90,076	122,523	134,916
	Unit value				
Average	$43,267	$53,580	$59,772	$58,150	$50,606

1/ Data for 1983 are based on projections provided by U.S. producers.
2/ Data are combined to prevent disclosure.
3/ Includes small, instructional and educational devices.
4/ Data by types are not available.

Source: Compiled from data submitted in response to questionnaires of the U.S. International Trade Commission.

need for quick and reliable movement of materials. Material-handling robots are second only to educational robots in quantity of annual shipments.

Shipments of spot-welding robots, on the other hand, with their limited range of applications (primarily in the automotive industry), are declining, leading some industry observers to conclude that the U.S. market for these devices has peaked. Responses from domestic producers largely support this conclusion, since U.S. shipments of spot welders increased from 155 units in 1979 to 644 units in 1981, and then declined to 434 units in 1982. Producers of spot welders anticipate further erosion in shipments to 372 units in 1983. Future demand for spot welders will depend increasingly on the need to replace existing robots due to physical wear and tear and from technological obsolescence.

The value of domestic shipments (excluding export shipments) increased from $19 million in 1979 to $123 million in 1982 and is expected to reach $135 million in 1983. The value of shipments in 1982 was inflated by a number of relatively expensive robots which accounted for a large share of the increase in the total value of domestic shipments from 1981 to 1982. The large quantity of expensive robots shipped in 1982 contributed to a high per unit value for 1982 domestic shipments. The volume of shipments accounted for by small robots relatively low in price and classified in the "other" category, increased significantly in 1983. As a result, it is estimated that the per unit value of total domestic shipments of robots in 1983 compared with that in 1982 will decline by about 15 percent.

U.S. exports

U.S. exports by reporting firms are expected to reach $33.7 million in 1983, representing an increase of $13.4 million compared with those in 1982, and $10.4 million compared with those in 1981. In 1979, exports were valued at $8.9 million. In terms of quantity, exports increased annually during 1979-82, from 173 units to 428 units, and are expected to reach 631 units, in 1983, as shown in the following tabulation:

Year	Quantity (units)	Value (1,000 dollars)	Average unit value (1,000 dollars)
1979--------------	173	8,909	51.5
1980--------------	340	20,766	61.1
1981--------------	413	23,309	56.4
1982--------------	428	20,322	47.5
1983 1/-----------	631	33,738	53.5

1/ Estimated by U.S. robot producer respondents.

In response to Commission questionnaires, U.S. producers were largely unable to identify the dedicated end use of the devices which they exported. The end use can only be determined after the foreign purchaser equips the devices with controls and sensors. Despite the lack of knowledge concerning intended end use, it is believed that exports during the period represent a changing product mix, since the average unit value of the devices fluctuated between $48,000 and $61,000 during 1979-83. According to industry sources, about 95 percent of the robots exported during the period were destined for markets in Western Europe; since their robotics industries are small, many European countries are dependent on imported robots for their user industries. Japan has not been a large factor to date in the European market, although networks have been established in West Germany, France, and the United Kingdom.

Export markets have become even more important to U.S. robot producers than in previous years. Compared with an expected 10-percent increase in robotic shipments to the domestic market in 1983, shipments to export markets are expected to increase by 66 percent. As a share of the value of total U.S. producers' shipments, exports are expected to account for 20 percent in 1983, compared with 14 percent in 1982. With the significant rise in exports, a continued U.S. positive balance in trade in robots in 1983 is expected.

Capacity

In response to Commission questionnaires, U.S. producers reported annual production capacity of 1,264 robots in 1979 and capacity of 5,126 robots in 1982, as shown in the tabulation below:

Year	Quantity (units)
1979	1,264
1980	2,296
1981	3,496
1982	5,126
1983 1/	6,827

1/ Data are based on projections provided by U.S. producers.

Capacity expanded by an average of 1,391 robots each year during the period, or at an average annual rate of about 52 percent. Reporting firms expect production capacity to reach 6,827 robots in 1983, representing an increase of 33 percent compared with that in 1982.

Excess capacity existed in U.S. robot-manufacturing facilities during 1979-83; most producers reported that less than 50 percent of their production capacity was utilized during the period. As shown in the following tabulation, annual production of robots as a percentage of capacity (capacity utilization rate) peaked at 55 percent in 1981 before declining to an estimated 48 percent in 1983, its lowest level in the 5-year period:

Year	Capacity utilization (percent)
1979	48
1980	50
1981	55
1982	49
1983 1/	48

1/ Data are based on projections provided by U.S. producers.

The rapid growth in shipments of robots during 1979-81 and producers' expectations of continued growth triggered an industrywide buildup of capacity which has exceeded the growth in robot production since 1981. Although U.S. production capacity increased by 47 percent from 1981 to 1982, U.S. production (in units) increased by 30 percent. On the basis of producers' questionnaire responses, most of the increase in capacity during 1981-83 can be attributed to the market entry of a large number of new producers.

Research and development

Research and development (R. & D.) expenditures reported by U.S. producers increased rapidly during 1979-83, from $5.6 million to an estimated $30.4 million, as shown in the following tabulation:

Year	Research and development expenditures (1,000 dollars)
1979	5,646
1980	9,488
1981	15,355
1982	26,468
1983 1/	30,422

1/ Data are based on projections provided by U.S. producers.

The most rapid growth occurred during 1979-82, when expenditures on R. & D. increased at an average annual rate of 66 percent. Unlike capital spending, expenditures on R. & D. continued to increase in 1983 (at about a 15 percent annual rate), providing evidence of the importance that U.S. producers place on robot technology and design in increasing their competitive position in the robotics industry.

Expenditures on R. & D. amounted to 19 percent of U.S. producers' shipments in 1982, and are expected to remain at that level in 1983. In 1981, R. & D. expenditures represented only 14 percent of shipments. A combination of startup R. & D. expenditures and low-volume shipments by a large number of new producers attempting to a establish a position in the market accounts for the relatively high ratio of R. & D. to the value of shipments. In most U.S. manufacturing industries, R. & D. expenditures range between 5 and 7 percent of sales.

The vast majority of R. & D. funds originate from within the firms; only a few of the producers surveyed reported any other sources of funds. A few producers received R. & D. funds from other U.S. firms, primarily venture capitalists. The only other supplier of R. & D. funds mentioned in producers' responses to questionnaires was the U.S. Government. In 1982, the National Science Foundation awarded a leading manufacturer of educational robots a modest grant for research and development. The grant accounted for only a small portion of the firm's R. & D. expenditures that year.

The U.S. robotics industry benefits indirectly, however, from Government support of science and industrial base applications. For more than two decades, the Department of Defense has supported the advancement of artificial intelligence, and the Office of Naval Research has been instrumental in establishing robotics centers at Carnegie Mellon University and at Massachusetts Institute of Technology. 1/ The U.S. Navy recently dedicated a robot center to study the application of robots on ships,

1/ Dr. Edith Martin, Deputy Under Secretary of Defense For Research and Advanced Technology, from the transcript of the hearings before the Committee on Science and Technology, U.S. House of Representatives, June 2, 23, 1983, pp. 360 and 361.

including fire fighting and munitions handling. 1/ In 1982, about $26.7 million was provided by the DOD to users and research institutions to advance robot technology, including $4.0 million provided by the U.S. Air Force to support aircraft inspection and repair, machining systems, and plasma spray coating. 2/ In 1983, funding to support this research was increased by the DOD to $44.0 million. 3/

Royalty payments and receipts

During 1979-83, royalties received by U.S. producers from foreign sources far exceeded the royalties paid, with one U.S. producer accounting for virtually all of the royalties received. As recent license agreements have proliferated, however, foreign producers have substantially reduced the gap with U.S. producers in the international flow of royalty payments. Annual royalties paid to foreign firms by U.S. producers increased from the equivalent of 14 percent of royalties received from foreign sources in 1981 to 51 percent in 1982. Most of the increase is attributed to firms which have shifted from importation of robots to the production of robots using foreign technology. Reporting firms estimated that total royalties paid to foreign producers in 1983 would decline to the equivalent of about 40 percent of the royalties received from foreign producers. Total 1983 royalty payments made by reporting firms both to other domestic producers and foreign producers are expected to amount to less than 4 percent of their R. & D. expenditures, indicating the emphasis that U.S. producers as a whole place upon internally developed technology.

Capital investment

During 1979-82, a total of $33 million was invested in capital equipment and facilities by U.S. producers for the production and marketing of robots. About 64 percent of this amount was directed toward acquisition of new machinery and equipment, and approximately 34 percent was directed toward buildings and leasehold improvements. Only a small share, about 2 percent of total expenditures, was used for land acquisition and improvements (table 5). Producers responding to Commission questionnaires projected that expenditures on buildings and leasehold improvements in 1983 will decline to about 21 percent of total capital investment, with expenditures on machinery, equipment, and fixtures largely accounting for the remainder.

On an annual basis, capital expenditures by reporting firms more than tripled during 1979-81. Capital investment reached an alltime high of $12.4 million in 1982, up 18 percent from that in 1981, before decreasing by 41 percent to an estimated $7.2 million in 1983. Capital spending by the six largest U.S. producers (those with over $5 million in sales in 1982) experienced the most rapid decline. Large producers sharply reduced capital

1/ "Navy Plans Robots To Do Boring Jobs," Washington Post, Oct. 22, 1983, p. B5.
2/ Dr. Edith Martin, op. cit., p. 370.
3/ Ibid.

spending in 1982, but expenditures by new producers building up production capacity were sufficient to raise the overall level of capital spending in 1982 to 18 percent above the level that prevailed in 1981. The ratio of capital expenditures accounted for by these large producers to total capital expenditures is expected to be reduced by one-half in 1983.

Table 5.--Robots: Capital investments of U.S. producers, 1979-83

(In thousands of dollars)

Year	Land or land improvements	Building or leasehold improvements	Machinery, equipment, and fixtures	Total
1979	155	1,449	1,916	3,520
1980	-	1,766	4,486	6,252
1981	-	3,504	6,934	10,438
1982	450	4,512	7,390	12,352
1983 1/	10	1,520	5,716	7,246

1/ Data are based on projections provided by U.S. producers.

Source: Compiled from data submitted in response to questionnaires of the U.S. International Trade Commission.

U.S. robot producers undertook little capital investment in foreign countries over the last 5 years. During 1979-82, overseas capital spending accounted for less than 1 percent of U.S. producers' total capital investment. On an annual basis, overseas capital spending peaked at about 2 percent of U.S. producers' total capital spending in 1981, but remained below 1 percent in all other years.

The growth in U.S. producers' annual capital expenditures from 1979 to 1982 lagged behind the growth in their annual shipments. As a result, capital investment declined from approximately 13 percent of shipments in 1979 to about 9 percent of shipments in 1982, and is expected to decline further in 1983, to about 4 percent of shipments, which is representative of most U.S. manufacturing industries.

Profits

The U.S. robotics industry experienced losses during 1979-82. Total losses of reporting firms exceeded (and are expected to exceed in 1983) total reported profits before taxes in each of the past 5 years. Furthermore, the number of producers reporting net losses exceeded the number of producers reporting net profits in every year.

Losses experienced by producers as a share of sales lessened during 1979-81, as shown in the following tabulation:

Year	Median loss 1/ as a share of net sales (percent)
1979	23
1980	18
1981	9
1982	42
1983 2/	49

1/ Profit data were not reported by a large producer, although the firm indicated losses were incurred.
2/ Data are based on projections provided by U.S. producers.

U.S. producers' median return went from a loss of 23 percent of sales in 1979 to a loss of 9 percent of sales in 1981. In 1982, the median return reported by U.S. producers dropped to a loss of 42 percent of sales. The median loss of reporting firms, according to their own estimates of profitability, is expected to increase further in 1983, to an estimated 49 percent of net sales for the year. These firms anticipate total losses on sales of robots in 1983 of more than $53 million.

Small producers experienced the largest losses as a share of sales during this period. Many of these producers encountered substantial startup expenses as the growth in sales of U.S.-produced robots slowed dramatically from the growth rates of 1979-81. According to questionnaire responses, the large established producers, although faring somewhat better than average over this period, experienced significant erosion in market share, due mainly to increased competition from other U.S. producers, along with the general stagnation in the demand for robots which affected the industry in 1982 and 1983.

In addition, increased imports of foreign-produced robots have exerted downward price pressure on virtually all robots sold in the United States, making net profits even more difficult to obtain. 1/ According to U.S. producers, they face greatly intensified competition in the still relatively small market for robots, which must expand considerably beyond its present size if the large number of U.S. firms now producing robots are to become profitable.

Employment

In 1983, total employment in the U.S. robotics industry by reporting firms is estimated at 2,251 employees, which includes 969 production and related workers and 1,282 employees involved in engineering, sales,

1/ Transcript of the hearing, Sept. 7, 1983, pp. 56 and 57.

administration, and general office work (table 5). In 1979, there were 716 persons employed by these firms, including 376 production and related workers, supported by a combined total of 340 engineers, salesmen, and administrators. Employment increased by an average of 384 workers per year during 1979-83, or at an average annual rate of about 34 percent. Employment in the U.S. robotics industry, however, remains at a relatively low level (by comparison, it amounts to less than 5 percent of employment in the U.S. machine tool industry).

Employment of production and related workers more than doubled during 1979-81 but remained flat during 1982, when the growth in total shipments of U.S.-produced robots slowed to an annual rate of 26 percent, down from a 77-percent annual rate in 1981. In contrast, employment of professional workers increased in 1982 and overall experienced more rapid growth during 1979-82. The rapid expansion of producers' R. & D. projects accounted for a large share of the increase. In addition, R. & D. projects helped to stabilize the growth in employment of professional workers, since expenditures on R. & D. continued to increase in 1982 while employment of production workers remained largely unchanged.

As shown in table 6, employment of both production and professional workers should experience moderate growth during 1983. According to producers' estimates, average employment of production workers in 1983 is

Table 6.--Average number of employees in U.S. establishments producing robots, 1979-83

Item	1979	1980	1981	1982	1983 1/
Average number employed in the reporting establishments producing all products:					
All persons 2/	9,667	8,974	10,380	9,413	9,021
Production and related related workers 2/	5,452	4,968	5,473	4,307	4,510
Average number employed in the reporting establishments producing robots:					
All persons	716	1,032	1,672	1,934	2,251
Production and related workers	376	507	816	820	969

1/ Data are based on projections provided by U.S. producers.
2/ Employment data on all products were not included for 1 firm to prevent disclosure.

Source: Compiled from data submitted in response to questionnaires of the U.S. International Trade Commission.

projected to be about 18 percent higher than that in 1982. Average employment of professional workers is expected to be about 16 percent higher. The growth in employment is not expected to exceed the growth in total shipments (in dollars) of U.S.-produced robots, largely because certain producers contributing to the increase in employment are expected to purchase more robot assemblies in lieu of in-house fabrication.

Average employment in reporting establishments during 1979-83 became more dependent on production of robots relative to the production of other products. Most new producers entering the market deal exclusively in robots. In addition, employment in other product lines (e.g., machine tools) of established producers has declined substantially in recent years. As a result, all persons involved in the production of robots as a share of all persons involved in the production of all products in reporting establishments has increased significantly, from about 7 percent of all employees in 1979 to about 21 percent of all employees in 1982. In 1983, all workers involved in the production of robots are expected to account for nearly 25 percent of all workers in reporting firms.

Foreign Industries

The principal foreign producers of robots (other than Communist countries) are Japan, West Germany, and Sweden. Each of these countries has large motor-vehicle production facilities in which robots are installed. France, the United Kingdom, and Italy, with extensive motor-vehicle facilities, are also sizable robot producers. Other countries, except Norway, are small producers of robots or are in the process of developing robots. Norway is noted for its technology in a specific line of robots. A discussion of the principal foreign producers follows.

Japan

On the basis of the broad Japanese definition, the number of robot producers in Japan is estimated at 250 firms, with 80 firms producing robots only for internal consumption. Many of these firms are small enterprises with capital of less than $500,000. The number of firms which produce industrial robots is not known; however, data indicate that the Japanese industry is composed of small firms producing conventional robots (manual manipulators and fixed-sequence devices) and large firms producing sophisticated industrial robots. 1/ An indication of the major robot producers is the membership of the robot association in Japan which lists 55 firms as members.

In 1982, the largest robot producer in Japan was the country's leading producer of consumer electronic products, with estimated sales of $54 million, and accounted for about 9 percent of total Japanese shipments. The 10 largest producers had combined shipments of $254 million and accounted for 42 percent of the Japanese sales. It is believed that, unlike in previous years, up to

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1/ U.S. Department of State telegram, Aug. 5, 1983, p. 3.

80 percent of Japanese robot shipments in 1982 shown in the tabulation below were devices classified as robots in the United States: 1/

Producer	Shipments 1/ Value (1,000 dollars)	Percent of total
Matsushita Electric-----------	54,167	9.0
Hitachi-----------------------	33,333	5.6
Kawasaki Heavy Industries-----	31,250	5.2
Yaskawa Electric--------------	27,917	4.7
Fanuc-------------------------	25,000	4.2
Mitsubishi Electric-----------	23,983	4.0
Dainichi Kiko-----------------	19,167	3.2
Komatsu-----------------------	16,667	2.8
Star Seiki--------------------	13,333	2.2
Kobe Steel--------------------	9,583	1.5
All other---------------------	345,058	57.6
Total---------------------	599,458	100.0

1/ Exchange rate of 240 yen per dollar.

Robots found their way into Japan reportedly as the result of licensee agreements, joint ventures, and, in the beginning, technology transfer by a U.S. firm. The U.S. firm introduced the first industrial robot into Japan in 1967, and later that year, the robot was installed in a Toyota Automobile Group plant. 2/ In 1967, Japanese firms also approached the leading U.S. producer of robotics with proposals for a joint venture whereby the U.S. firm's technical know-how would be shared with these Japanese firms. Ultimately, Japan's third largest producer was selected from the group, and the U.S. producer entered into an agreement with that firm. 3/ Through the agreement, the Japanese producer was able to obtain the rights to the U.S. firm's patents and processes. A renewal of this original agreement is still in effect. 4/ In 1973, the 10th largest producer in Japan entered into an agreement with a producer in Norway for paint-spraying technology, and a Japanese trading company reached an agreement with a U.S. producer of appliances. Robot technology was also imported into Japan from two firms in Sweden. Today, numerous agreements exist between Japanese and foreign robot producers, although the technology is now beginning to originate in Japan.

Robots were largely developed and utilized in Japan within the robot-producing firms. By installing the robot within the firm, the producer not only gained valuable knowledge in the operation of the robot, but also was in a position to demonstrate to a potential customer how the robot performed

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1/ Paul H. Aron, The Robot Scene in Japan: An Update, Sept. 7, 1983, p. 49-52.

2/ Dr. Robert U. Ayres, Leonard Lynn, and Steve Miller, "Technology Transfer in Robotics between the U.S. & Japan," U.S. Japan Technological Exchange Symposium, October 1981, p. 92.

3/ Ibid.

4/ Ibid.

in an actual working environment. 1/ This apparently proved to be a valuable marketing tool for Japanese robot producers, which became totally familiar with how robots behave and what their deficiences were. Confidence, which was built up over time, permitted Japanese firms to be more competitive in foreign markets once their own requirements were satisfied.

The Japanese Government has been active in developing and supporting robotics since the first U.S.-produced robot was introduced. 2/ The support is related to the close cooperation between members of the robot association, the Japan Robot Leasing Co. (JAROL), and the coordination of the research and development conducted by leading research institutes (along with research conducted within producer firms). All of this has come about with the encouragement of the Ministry of International Trade and Industry (MITI). 3/

In 1978, the Japanese Government designated robots as products for experimental promotion and rationalization; shortly thereafter, robots were clearly defined under Japanese Industrial Standards. Following these decisions, the Government of Japan undertook a number of steps to increase the development of robotics and to promote the diffusion of these devices throughout Japanese industries. The major undertaking by the Government was the organization of JAROL, which was established in 1980, reportedly under the guidance of the MITI. 4/ JAROL was organized as a joint venture between 24 Japanese producers of robots, 10 insurance companies, and 7 firms engaged in general leasing. About 60 percent of JAROL's operational funds were provided at preferential rates by the Japanese Development Bank. The remainder of the funds were provided by the Long-Term Credit Bank, city banks, and the Industrial Bank of Japan. The creation of JAROL provided Japanese producers with a ready market for their robots, thus relieving them of the costs associated with inventory and marketing and accelerating the return of their manufacturing capital. JAROL, in turn, encouraged the use of robots by leasing them to user firms at preferential leasing rates. In 1981, JAROL entered into user leases for 435 devices, valued at $14 million, and in 1982, into leases on an estimated 790 devices, valued at $26 million.

In addition to leasing, the MITI has provided for accelerated depreciation allowances on robots purchased by Japanese users, allowing an additional 13 percent of the purchase price to be written off the first year during 1980-82 and 10 percent during 1983-85. 5/ The liberal definition applied to robots in Japan permits users to qualify for accelerated depreciation on a wide range of mechanical devices called "robots." The robot association, in close cooperation with the MITI, provides interest-free loans to member producers to test market robots. The Japanese Government also provides subsidies to Japanese producers to enable them to develop new robot applications. The Japanese Government provides subsidies to the association

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1/ Hearings Before the Subcommittee on Investigations and Oversight of the Committee on Science and Technology, U.S. House of Representatives, June 2, 23, 1983, p. 5.

2/ Ibid.

3/ Paul Aron, Robotics in Japan: Past, Present, Future, Mar. 2, 1982, p. 13.

4/ Ibid.

5/ U.S. Department of State airgram, Aug. 5, 1983, p. 8.

to cover the costs of translating foreign documents and technical articles on robotics. The MITI and the association together compile detailed statistical data on the Japanese robotics industry and on users of robotics, and engage in extensive market research, largely financed by the Government.

Research in robotics in Japan is carried out in universities, research institutes, and private firms much like in the United States. In 1982, university and public research institutions in Japan totaled 153, compared with 79 in 1979. In 1979, about $1.5 million (304.6 million yen) was spent on robotics research by these institutions, although this sum did not cover the salaries of the 350 researchers employed. In 1983, about $4.0 million (963.3 million yen) were spent by these institutions. Most of the research in Japan on robotics, however, is carried out in the laboratories of producer firms. In 1982, the Government of Japan accelerated research in robotics by establishing a 7-year national program to improve the sensor perception, language systems, and motion capability of advanced devices. About 30 billion yen were budgeted for the project, or about $18 million annually.

West Germany

In the early 1970's, manufacturing industries in West Germany were aware that the future competitiveness of the West German economy depended on the utilization of advanced technologies, including robotics. 1/ At that time, not only were robots largely nonexistent in West Germany, but also a technology gap with other industrial countries in robot development had surfaced. 2/ Through efforts undertaken by individual firms, financial support provided by the West German Government, and technical contributions made by German research institutes, the technology gap was largely overcome. 3/ In 1982, about 3,500 industrial robots were in operation in West Germany, ranking that country behind only Japan and the United States. 4/

About 50 firms produce robots in West Germany, with 5 firms together accounting for 70 percent and 10 firms together accounting for 90 percent of production. The largest of these firms is West Germany's largest automotive producer, which has developed considerable technical capability in the production and usage of robotics, much like the development in U.S. automotive firms. The automotive firm has become a competitive force in West German robot production and is extending this force into the U.S. domestic market through an agreement with the largest U.S. producer of appliances. The remaining German robotics firms are producers of automotive parts, machine tools, aircraft, transport equipment, and communications equipment. In addition to the German producers, certain foreign producers, including the leading producers from the United States, Sweden, and Norway, have a leading market position in West Germany. In 1982, West German robotics firms employed about 14,500 persons, producing about 1,600 industrial robots, valued at 260 million deutsche marks ($108 million). 5/

1/ U.S. Department of Commerce telegram, Bonn, West Germany, March 1983.
2/ Ibid.
3/ Ibid.
4/ Ibid.
5/ U.S. Department of Commerce telegram, Bonn, West Germany, March 1983.

Production of robotics in West Germany is organized as part of an association of German producers of machinery. The robotics division of the association is used as a medium for the preparation of statistics on proposals, production, and sales of robots, and for the presentation of new products. The association is used to coordinate technology transfer between research institutes, producers, and users, and to make decisions with respect to product standards. The association also engages in programs to promote sales and in public relations to promote the acceptance of robotics in a country which is currently facing unemployment problems. 1/

During 1977 and 1980-82, as reported by the association, the number of industrial robots in use in West Germany increased from 285 to 3,500 units. As in the United States, these operating robots were largely welding apparatus and paint-spraying equipment (coaters), which together accounted for about 60 percent of robots in use in 1982, as shown in the following tabulation:

Type	1977	1980	1981	1982
Welders------------------	86	477	998	1,728
Coaters------------------	90	155	231	397
Assemblers---------------	2	50	101	122
Loaders/unloaders--------	0	0	374	194
Other--------------------	107	141	597	1,060
Total----------------	285	823	2,301	3,500

The remaining 40 percent was dispersed in various industrial operations, including assembly, forging, material handling, loading/unloading, and research.

In the 1970's, research and development in West German firms and research institutes was undertaken to reduce the existing technology gap in robotics and industrial automation. The reduction of the gap came about largely through internally developed technology, although a few German producers entered into foreign licensee agreements. The largest equipment producer in West Germany entered into an agreement with a Japanese robot producer which subsequently entered into a joint venture with the largest U.S. automotive producer. Another West German firm began robot development as a foreign licensee, but later abandoned this approach in favor of developing its own product line. In the 1980's, German research is not directed at the reduction of a technology gap, but rather at the advancement of the state of the art, particularly in the field of sensors and controls. 2/ Improvements in machine intelligence and awareness have been deemed necessary to produce the types of assembly robots needed to increase the efficiency of West German manufacturing industries. 3/ Since 1974, the West German Government has supported 46 research projects, valued at 76.3 million deutsche marks ($32 million), to improve robotic and other technologies. 4/

1/ Ibid.
2/ U.S. Department of Commerce telegram, Bonn, West Germany, March 1983.
3/ Ibid.
4/ Ibid.

Norway

Norway is distinguished in the field of robotics by a small firm whose technology accounts for 80 percent of the world's industrial painting robots. The robot technology developed by the firm is in use by producers in major developed countries, including those in the United States and Japan. 1/ A U.S. producer has obtained production and marketing rights from the firm for North America, and the fifth largest Japanese producer has obtained similar production and marketing rights for Japan. The firm, which exports about 95 percent of the robots it produces, retains production and marketing rights in Europe. In 1982, the firm's production of robots was valued at an estimated $12 million. A limited number of robots are also produced in Norway by another firm which limits its sales effort to markets in Scandinavia, having entered into an agreement with a producer in the United Kingdom not to serve the remainder of the European market. Major users of robotics in Norway are establishments which have attempted to improve working conditions of people employed in hostile environments, including those employed in painting, welding, and heavy-material handling. At present, an estimated 20 robots are in operation in the various Norwegian industries.

The robotics industry in Norway cooperates closely with the leading research institutes in the country. 2/ These institutes include the Central Institute for Industrial Research, the National Institute of Technology, the Roaglund Research Foundation, and the Christian Michelsen Institute. All of these institutes are involved in robot research either in applications or control technology.

Sweden

Development and production of robots in Sweden are largely accounted for by two firms which are closely tied to each other. The largest firm is a world-class producer of heavy electrical equipment with subsidiaries located throughout Europe and the United States. The firm specializes in arc-welding, spot-welding, and assembly robots. The product lines offered by the firm are sophisticated and expensive devices which account for its relatively low volume of shipments, compared with those of other robot producers. The other Swedish producer is much smaller, with a unit production volume of about one-fourth the size of the leader. Together, the two firms account for about 72 percent of robot production in Sweden. Sweden leads all industrial countries in the utilization of industrial robots as a percentage of employed workers. Sweden operates one robot per 1,000 workers, compared with 4,000 workers in Japan, 8,000 workers in the United States, and 9,000 workers in West Germany. 3/

1/ Information on the robot industry in Norway was gathered by the U.S. Embassy in Oslo and transmitted to the U.S. International Trade Commission, Sept. 16, 1983.

2/ U.S. Department of State airgram, Sept. 16, 1983.

3/ U.S. Department of Commerce telegram, March 1983.

United Kingdom

In 1981, the association representing the British robot industry estimated that 370 to 400 industrial robots were in operation in the United Kingdom. Welding and paint-spraying robots together accounted for about 50 percent of these devices. The remainder was accounted for by machine-loading, machine-unloading, material-handling, and miscellaneous robots.

Domestic producers of robotics in the United Kingdom have been less of a factor in robot production than subsidiaries of U.S. firms. In 1981, the association estimated that domestic firms accounted for only 26 percent of installed industrial robots, compared with imports, which accounted for 74 percent. 1/ Of the imported robots installed, imports from Japan account for 10 percent, imports from other European countries account for 40 percent, and imports from the United States account for 50 percent. A subsidiary of the leading U.S. producer is also the largest producer of robots in the United Kingdom.

To increase the efficiency of its industries, the British Government has begun to emphasize the use of labor-saving devices, particularly industrial robots. The emphasis is appearing in the form of Government support and incentives to promote the development and use of these devices. About $5 million has been provided by the Science Research Council to study future generations of robots, and $54 million has been provided by the Council to demonstrate computer-aided manufacturing schemes. Also, about $1.3 million is provided annually by the National Engineering Laboratory and certain trade associations to study robotics. Under the Product and Process Development Schemes, grants are given for feasibility studies, installation of robots, and the development of new types of advanced robots. 2/ According to the association representing the domestic robot industry, their prototype schemes have not been successful because of funding problems. 3/

Taiwan

Robots are produced in Taiwan by 8 firms in addition to 16 organizations and institutes which develop prototype devices. 4/ A total of 11 types of robots have been produced on the island, 5 of which are assembly robots developed at the Industrial Research Technology Institute (IRTI). The assembly robots developed at IRTI, an autonomous body funded by the Taiwan Government, were transferred at the end of 1982 to five private robot firms which reportedly plan to produce 60 robots annually beginning in 1984. Robots produced in Taiwan during 1984 and 1985 will serve only local markets, and during 1986-90, will serve principally local markets. Exports of robots from Taiwan, therefore, will be a negligible factor in international trade until 1990. Local demand in Taiwan for robots is expected to reach 200 units in 1983, 2,000 units in 1986, and 10,000 units in 1990.

1/ U.S. Department of Commerce, The Robotics Industry, April 1983, p. 28.
2/ Ibid.
3/ Letter received from the Robot Institute of America, Oct. 28, 1983.
4/ Information on the Taiwan industry was compiled by the Department of State and transmitted to the U.S. International Trade Commission in a telegram dated Sept. 28, 1983.

Funds provided by the Government to IRTI for robot research during July 1983-June 1986 will reach $8 million and were budgeted by the Industrial Development Bureau of the Ministry of Economic Affairs. Information on research and development funding past June 1986 is not available. Information on capacity, capacity utilization, and capital expenditures on facilities to produce robots in Taiwan is also not available.

Finland

Production of robotics in Finland is accounted for by two firms, one of which is a licensee of a leading U.S. producer. 1/ The older of the two firms began robot production in 1973, but is noted as a producer of computer-controlled apparatus for loading and unloading machines. More than 90 percent of the firm's output is accounted for by dedicated manipulators designed to handle color television picture tubes. In contrast, only a few robots were produced by the firm during 1978-82, and no production is scheduled for 1983. The other robot producer began production in 1983 under a license agreement reached with a major U.S. producer. Robots produced by the firm are designed for various process applications, including inspection, material handling, welding, and measuring. The firm expects to produce 22 robots in 1983, with an estimated value of $1.2 million. The production and use of robots in Finland have been limited by the country's small manufacturing industries and by a lack of technical personnel experienced in adapting robots to production processes.

Although it is hesitant about projecting future production, the Finnish industry estimates that the firm that began production in 1983 will double production in 1984 and increase production another 50 percent in 1985. A major share of the firm's production is expected to be exported during 1984-90, principally to markets in Scandinavian countries, Eastern Europe, and Austria. Under the terms of the agreeement reached with the U.S. firm, exports to the United States are not permitted. The industry expects the older firm to remain largely in the production of dedicated manipulators for handling color picture tubes. Production of robots in Finland is expected to reach 150 to 200 units by 1990.

Expenditures by the industry in 1982 for land, buildings, and equipment to produce robots ranged between $1.8 million and $2.6 million. Expenditures on research and development are unknown, but are believed to range between 5 and 10 percent of sales. Research and development in Finland is not funded by the Government, nor does the Government engage in administrative practices for the industry's protection.

1/ Information on the Finnish robot industry was gathered by the U.S. Embassy in Helsinki and transmitted to the U.S. International Trade Commission in a telegram, Sept. 6, 1983.

Canada

The robot industry in Canada is limited to a single firm. 1/ Robots are produced by the firm under licenses obtained from a major U.S. producer and a producer in the United Kingdom. The firm has a capacity to produce 100 robots per year, although present production and exports are negligible. Sales prospects in Canada, however, are reportedly improving. Research and development in the country is largely conducted by the government of Ontario, which sponsors a robotics technology center and has purchased some demonstration devices from U.S. firms for training.

Switzerland

Data on Swiss production and capacity utilization for robotics, machine tools, and other industrial products are not available from official sources. In the absence of official data, the information presented on the Swiss robotics industry was obtained by the U.S. Embassy from various industry and scientific sources and from establishments familar with the robotics trade. 2/

Although robots were produced by 20 firms in 1982, production in Switzerland is carried out largely by engineering establishments which developed robots for internal use, principally because the devices needed were not available from outside producers. Some of the firms, however, have begun to develop robots as a major branch of their business. The largest of these firms produces a line of automatic loaders. The other firms are largely engaged in the production of robot-related devices such as dedicated manipulators, pick-and-place apparatus, and grippers.

In 1982, about 40 robots were produced or assembled in Switzerland, and about 50 robots were imported. Further, in 1982, about 200 robots were installed in the country, imported largely from West Germany, Sweden, the United States, and Japan. About 15 percent of these installed devices are believed to be of U.S. origin. According to the information available, no robots produced in Switzerland have been exported, nor is Switzerland expected to become a serious competitor in the production of robots during the next 5 years. In the near future, users of robots, principally the machine tool and watch industries, will be dependent on imported devices.

Research and development in Switzerland is conducted through close cooperation between firms in the industry and the two major technical institutes (Zurich Federal Institute of Technology and Lausanne Ecole Polytechnique Federale). A share of the research is financed by the Swiss Government, although the level of funds provided by the Government is unknown. The R. & D. in Switzerland is largely directed at improving the capabilities of robots and broadening the technical base of the academic staff of the two institutes.

1/ Information on the Canadian robotics industry was transmitted in a telegram of Sept. 26, 1983, from the U.S. Embassy in Ottawa.

2/ The information on the Swiss robotics industry was gathered by the U.S. Embassy in Bern and transmitted to the U.S. International Trade Commission in a telegram, Sept. 9, 1983.

Austria

Production and utilization of robotics in Austria are negligible, and information on the industry is not available, although four firms produce robots. 1/ The largest of these firms produces welding robots under a license from a major Japanese producer. The remaining firms produce free-programmable welding robots and machine-loading robots. In addition, subsidiaries of four foreign robot producers are located in the country, two of which are owned by West German producers and two of which are owned by Swedish producers. Unofficial estimates place the number of operational robots in Austria currently at 70 units, 80 percent of which are believed to be arc welders. According to Austrian sources, 29 of these units were produced by the largest Swedish manufacturer, 20 of which were sold in 1982. No other information is available on the Austrian robotics industry.

Belgium

The robotics industry in Belgium is in its infancy, with three firms producing experimental devices. 2/ The robots produced by these firms were developed in their research divisions, which depend on other products as a source of revenue. The first of these robots was developed in 1982, and since that time, a total of 10 devices have been produced. None of the devices have been sold in the open market, and no contracts for future deliveries are in existence. Robot production costs were estimated at $28,000 in 1982 and are expected to reach $50,000 in 1983. Production costs, however, are difficult to separate from R. & D. costs, since the robots produced were developed in the research divisions. Two of the producers specialize in arc-welding and material-handling robots, and the product line of the remaining producer was not reported.

The future of the robot industry in Belgium is difficult to assess. Although the three producers reportedly plan to expand production, certain short-term factors could adversely affect their growth. The size of the producers, each with sales of less than $5 million in 1982, the currently depressed Belgian economy, and high interest rates provide major obstacles for the firms. Further, numerous foreign producers have imported robots into the Belgian market and established themselves as major competitors.

Netherlands

The robotics industry in the Netherlands resembles the industries in other small European countries which lack vehicle production. The limited production in the country is accounted for by three small firms whose principal product lines are loading/unloading robots. 3/ In 1982, production

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1/ Information on the Austrian robotics industry was forwarded to the U.S. International Trade Commission by the Department of State in a telegram, Aug. 17, 1983.

2/ Information on the Belgian industry was collected by the U.S. Department of State and transmitted to the U.S. International Trade Commission in a telegram dated Aug. 17, 1983.

3/ Department of State telegram from the Hague, Sept. 11, 1983 was valued at $1.2 million and is expected to increase to $1.3 million in 1983. 1/

There are about 75 robots installed in the Netherlands, 30 of which are used for joining and welding, 21 for spraying and surface treatment, and 16 for tool-handling and metalworking functions. 2/ The application or use of the remaining robots is unknown. Imports account for a major share of the installed devices. In 1982, the value of imports was estimated at $3.0 million, with Sweden accounting for 30 percent, followed by West Germany (20 percent) and Norway (10 percent). U.S. firms accounted for less than 1 percent. 3/

The robotics industry in the Netherlands is receiving support from the Dutch Government to promote technology. The Dutch Ministry of Economic Affairs has initiated a 2-year, $1 million commission to promote cooperation between the Government and industry, research institutes, technical universities, and robotics organizations. This cooperation is aimed at encouraging robot development, education, and applications. The Dutch Economics Ministry has also allocated $4.5 million to stimulate pilot demonstration of robots and flexible automation systems. These funds are offered in the form of subsidies and loans.

France

The use of robots in France is concentrated in its domestic automotive industry, which accounts for a large share of domestic production of robots. 4/ The automotive industry has employed approximately 250 robots in welding, coating, metalworking, and material-handling applications. Other smaller and more specialized French firms also produce robots. For the most part, French robot users and producers have relied heavily on foreign robot vendors for both technology and equipment in satisfying internal robotics demand. Nearly 60 percent of the installed robot base of approximately 1,000 units in France is composed of imported robots. These installations, which represent approximately 2 percent of the current world robot population, are projected to increase to 5,000 units by 1990. The 1982 value of French production of robots is currently estimated to be less than $28 million.

France currently has one of the lowest levels of automation among industrialized nations, and its domestic robot industry is experiencing difficulty in expanding robot applications outside of the confines of the French transportation industry. In order to remedy this situation and reduce its dependence on imports, the French are actively encouraging foreign robot producers to invest in French production facilities and enter into joint ventures with French firms. A Swedish firm which currently accounts for 20 to

1/ CMP Industry Sector Analysis, the Hague, July 14, 1983, p. 2.

2/ Ibid.

3/ Ibid.

4/ Information on the French robot industry was derived from a number of sources, including: Report of the French Robotics Mission, Lanshaw & Co., San Franciso, December 1982; Dr. Jack Baranson, Automated Manufacturing: The Key to International Competitiveness-And Why the United States is Falling Behind, Developing World Industry and Technology, Inc., 1983; and from information obtained by the U.S. Embassy in Paris.

30 percent of the French robotics market already has plans to build a small robot production facility near Paris. In another major development, a large French electrical firm entered into a bilateral sales agreement with a firm in Japan whereby the two firms would sell equipment into each other's home markets. The French firm is 77 percent owned by a large Swiss manufacturer of electrical equipment. The leading French automaker is currently the only French company involved in marketing robots outside of France. These exports are the result of a joint venture with a U.S. robot producer through which the French company hopes to establish a U.S. presence.

The French Government, through the Robotics Mission of the French Ministry of Research and Technology, has made a major committment towards establishing domestic capabilities in the design, manufacture, distribution, and utilization of robots which would be competitive both within France and in international markets. In pursuit of this goal, the Government has budgeted $350 million during 1983-85 for the purpose of creating an Inter-Agency Robotics Committee, funding research and development on robotics, training robotics specialists, extending low-cost financing to potential robot users, and maintaining various industrial development programs. Over the near term, however, it appears as though the French robotics industry will be heavily dependent on foreign robotics expertise and equipment.

All other

There are other European firms prominent in the development and production of robotics. Most notable is an Italian office equipment firm which produces a line of precision machining robots. The firm also has an existing license agreement with a large U.S. electrical equipment firm which transfers to the U.S. firm the rights to produce and market these devices in North America.

U.S. imports of complete robots

U.S. imports of complete robots for consumption, as reported by respondents to the Commission's questionnaires, increased from 66 units, valued at $3.8 million, in 1979 to an estimated 999 units, valued at $28.9 million, in 1983, or by 15 times in terms of quantity and nearly 8 times in terms of value (table 7). Most of this increase is expected to occur in 1983 as the result of the increases in imports by new firms having established agreements with foreign producers and attempting to establish a market presence.

The largest category of robots imported during the period was loaders and unloaders, which accounted for approximately 25 percent of the quantity and 19 percent of the value of robots entered during the period. The average unit value of these imports was nearly $29,000. The second largest category of imported robots in terms of value (over 16 percent) was coaters, which also represented 12 percent of the quantity of imports during 1979-83. The average unit value of imports of these robots was over $53,000.

Material-handling robots, with a unit value of nearly $42,000, represented nearly 15 and 14 percent of the value and quantity of imports, respectively, during the period. Imports of other robots accounted for over 25 percent of the total quantity of imports entered during 1979-83. Their low average unit value (nearly $23,000), however, which was depressed as the result of imports of a number of low-valued educational robots, accounted for the fact that these robots constituted only 15 percent of the value of total imports.

Combined imports of spot welders and arc welders accounted for 9 and 25 percent of the quantity and value, respectively, of robot imports during 1979-83. The average unit value for spot-welding robots imported during the period was almost $55,000, compared with nearly $44,000 for arc-welding robots. A considerable share of these imports were entered during 1982 and 1983. Assembly and metalworking robots, the latter of which had the highest average unit value ($86,000) during the period, were not a significant factor in terms of total imports.

Table 7.--Complete robots: U.S. imports for consumption, by types, 1979-83

Type	1979	1980	1981	1982	1983 1/	5-year total
	Quantity (units)					
Spot welders	2/	2/	2/	2/	2/	142
Arc welders	2/	2/	2/	2/	2/	184
Coaters	2/	2/	2/	2/	2/	203
Assemblers	2/	2/	2/	2/	2/	72
Material handlers	2/	2/	2/	2/	2/	231
Metalworking apparatus	2/	2/	2/	2/	2/	11
Loaders/unloaders	2/	2/	2/	2/	2/	415
All other	2/	2/	2/	2/	2/	412
Total	66	73	156	376	999	1,670
	Value (1,000 dollars)					
Spot welders	2/	2/	2/	2/	2/	7,793
Arc welders	2/	2/	2/	2/	2/	8,078
Coaters	2/	2/	2/	2/	2/	10,823
Assemblers	2/	2/	2/	2/	2/	4,089
Material handlers	2/	2/	2/	2/	2/	9,617
Metalworking apparatus	2/	2/	2/	2/	2/	949
Loaders/unloaders	2/	2/	2/	2/	2/	11,962
All other	2/	2/	2/	2/	2/	9,328
Total	3,751	4,225	10,620	15,097	28,946	62,639
	Unit value					
Average	$56,833	$57,877	$68,077	$40,152	$28,975	$37,508

1/ Data are based on projections provided by U.S. producers.
2/ Imports, by types, would reveal individual operations of importers.

Source: Compiled from data submitted in response to questionnaires of the U.S. International Trade Commission.

During the period, Japan is currently projected to account for 1,295 units (78 percent) and $35.1 million (56 percent) of total robot imports. Imports from Japan consist of loader and unloader, arc-welding, and "other robots." Imports of these robots from Japan are related to resale agreements established between U.S. firms and Japanese producers, and to a U.S. joint venture. Under the resale agreements, these types of robots are imported by U.S. firms to establish an industry presence in anticipation of future market growth. Under the joint venture, robots are imported largely to serve the requirements of a U.S. automotive producer which is a party to the agreement, and partially to serve the open market. The robots imported from Japan are not usually comparable to those produced in the United States and vary in price and weight handling characteristics.

Imports from Sweden, principally of arc-welding and material-handling robots, accounted for 13 percent of the total value and 5 percent of the total quantity of robots imported during 1979-83. This ranked Sweden second and fourth in importance in terms of the value and quantity, respectively, of U.S. imports. Imports from Sweden are related to a Swedish firm which established production facilities in the United States during 1979-83. The robots imported from Sweden are characterized by superior design and relatively high price.

The second leading source of imported robots in terms of quantity was Norway, which accounted for 8 percent of total import quantity and 11 percent of the imported value of robots. The imports were exclusively of coaters. Imports of robots from West Germany, Italy, and the United Kingdom combined accounted for the remaining 20 percent of the value and 9 percent of the quantity of imported robots. Imports from these sources were largely spot-welding, material-handling, and assembly robots. Imports from these sources are largely related to resale agreements.

As the result of the increase in imports in 1983, a $4.8 million trade surplus in robots is projected for the year. The surplus would represent the continuation of a trend in which the positive balance of trade in robots peaked at $16.5 million in 1980, before declining to a positive $5.2 million in 1982, as shown in the following tabulation:

Year	Balance of trade (1,000 dollars)
1979	5,158
1980	16,541
1981	12,689
1982	5,225
1983 1/	4,792

1/ Data are based on projections provided by U.S. producers and importers.

U.S. imports of subassemblies and parts of robots

According to questionnaire responses, the value of U.S. imports of subassemblies and parts of robots is expected to reach $15.2 million in 1983, compared with $126,000 in 1979, as indicated in the following tabulation (in thousands of dollars):

Item	1979	1980	1981	1982	1983 1/
Robot subassemblies and parts------	126	1,684	3,677	6,685	15,163

1/ Estimated.

A large share of the value of these imports in 1983 were from Japan. Imports of subassemblies and parts increased in relation to imports of complete robots in every year except 1981. This share rose from just over 3 percent in 1979 to an estimated 52 percent in 1983. The value of imported robot subassemblies and parts increased, in relation to the total value of U.S. robot shipments, from less than 1 percent in 1979 to an estimated 9 percent in 1983. This trend indicates increased sourcing of foreign-made robot components by U.S. producers and increased inventories of spare parts by importers.

U.S. Users

The automotive industry provided the initial market for industrial robots, and this market is expected to account for a major share of future robot installations. Other user industries consist of aerospace and home appliances, followed by a host of manufacturing sectors such as plastics, machine tools, metalworking parts, electrical and electronic equipment, chemicals and pharmaceuticals, and heavy industrial and commercial equipment. The use of robots is currently concentrated in fewer than 10 firms, which together reportedly account for approximately one-third of robot usage. Selected principal user industries for robots are discussed below.

Automotive industry

The U.S. automotive industry currently accounts for between 50 to 60 percent of the more than 7,000 U.S. robot installations to date. 1/ The importance of this market mirrors the concerns of U.S. automakers which are employing robots to increase productivity, provide more consistent product quality, save energy, and reduce employee exposure to hazardous work environments. Since the first robots (spot welders) were introduced into the industry more than 22 years ago, robots have found applications in spray painting and coating, assembly, machine loading and unloading, and material handling. Welding robots still remain the largest single class employed by the U.S. auto industry, accounting for an estimated 30 percent of total U.S. robot applications. 2/

1/ Dr. Jack Baranson, op. cit., p. 70.
2/ Ibid.

Of importance in the industry are paint-spraying, machine-loading, machine-unloading, material-handling, and assembly robots. Automotive applications for assembly, machine-loading and machine-unloading robots are anticipated by industry insiders to sustain the largest growth rates through 1990. At that time, industry observers project that as many as 25,000 robots will be employed in automotive production, resulting in a 20-percent labor reduction, evaluated relative to current production levels. 1/

Since 1970, when the largest U.S. auto producer opened its heavily automated Lordstown, Ohio, plant featuring 28 robots in a spot-welding assembly line, the company has supplied its demand for robots from in-house, domestic, and foreign sources. The firm currently has plans to utilize 5,000 robot arms in assembly applications and adapt 4,000 more of these units to machine-loading and machine-unloading operations by 1990. These robots will be jointly designed by the firm and the leading U.S. robot producer. 2/

The auto producer also has plans to install a computerized clamping-welding system called Robogate in seven of its final assembly plants. This system, which was developed by an affiliate of Fiat (Italy) will permit the firm to weld stamped steel panels into complete auto bodies in two or three steps. The current production process requires 40 to 50 steps using workers with hand-held welding guns. The new process is not only expected to improve the consistency of welds, but also reduce worker exposure to a hazardous phase of the assembly process. 3/

The joint venture between the automotive firm and a leading robot producer in Japan represents the firm's major offshore supply line. Through the joint venture, the firm is expected not only to gain marketing expertise from Japan's fifth largest robot producer by volume, but also a source of supply for robots and robot subassemblies.

The auto industry's second leading robot user made its initial large-scale entry into robotics in 1975 with the implementation of 25 spot-welding robots in its Kansas City plant. It was a number of years, however, before any major additions were made to the firm's robot installations. 4/ The firm currently has an installed base of approximately 1,100 robots, most of which are employed in less technically demanding spot-welding, spray-painting, and material-handling applications. 5/ A spokesman for the company has indicated to the Commission staff that

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1/ "Detroit's Jobs That Will Never Come Back," Business Week, May 23, 1983, p. 168.

2/ "GM"s Ambitious Plans To Employ Robots," Business Week, Mar. 16, 1981, p. 31.

3/ Ibid.

4/ John Teresko, "Robots Come of Age, But is Management Ready to Put Them to Work,") Industry Week, Jan. 25, 1982, p. 39.

5/ "Production: Flexible Automotive Manufacturing Takes Share," Automotive Industries, January 1983, p. 17.

the rationale behind many of these installations was as much related to worker safety and quality-control considerations as to increased productivity and material savings. The firm reportedly has attempted to implement robot technology into more technically critical and sophisticated assembly, machine-loading, and machine-unloading, and arc-welding operations with mixed success. The limitations of current robot accuracy, repeatability, and flexibility were cited by officials as key factors in the inability to automate particular production operations. In spite of these problems, the firm at this time is projecting an installed base of 7,000 robots by 1990. 1/ In support of this commitment, a Robotic Automation Consulting Center was recently opened by the company, which will function as a service organization to its various divisions. The center will have the expressed function of finding new in-house applications for robots, qualifying robots for use in these applications, and training company personnel. 2/

Despite the use of advanced automation second to none in the automotive industry, the installed robot base of the third largest U.S. automotive firm has lagged somewhat behind the other two major producers. The firm should have one of the world's most technically advanced production facilities, however, when its Windsor, Ontario, Canada plant commences production of minivans in 1984. To date, the firm has employed primarily spot-welding and less advanced robots in its production facilities. One large order for spot-welding robots from a domestic producer was placed in 1982. 3/ The firm estimates that nearly 1,000 robots will have been employed in its stamping, assembly, and diversified operations plants by 1988. The firm recently placed an order for a two-arm, assembly robot whose back-to-back arm configuration is said to speed production. 4/

In response to Commission questionnaires, U.S. automakers reported the purchase of 2,787 industrial robots from U.S. suppliers during 1979-83. 5/ Nearly one-half of all purchases from domestic sources during 1979-83 were made in 1981. Purchases of spot-welding robots, which peaked in 1981, represented nearly 60 percent of total automotive industry robot purchases during the period. The other substantial categories of robots purchased during the 5-year period were material handlers, coaters, and loaders and unloaders, which combined accounted for an additional one-third of purchases. In contrast to domestic purchases, U.S. automakers reported they purchased 293 robots from foreign sources during 1979-83. Slightly over one-third of these purchases were spot-welding robots. Coating and loading and unloading robots represented approximately another one-third of the foreign purchases during the period.

The automotive industry estimates that between 1984 and 1986, its future purchases of robots will reach 5,684 units. 6/ At this level of purchases,

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1/ "Production: Flexible Automotive Manufacturing Takes Share," Automotive Industries, January 1983, p. 17.

2/ Ibid.

3/ From statement of Walter K. Weisel, president, Prab Robots, Inc., "Report to Stockholders, Prab, Inc., 1982 annual report.

4/ Roger Rowand, "Manufacturing Makes a Move Into the Future," Automotive News Detroit Extra, May 23, 1983.

5/ One company was unable to provide data on purchases prior to 1981. Purchases for the second half of 1983 were estimated by all respondents.

6/ One company was unable to provide an estimate for 1986 purchases.

the U.S. industry could consume approximately one-third of the estimated 1984-86 output of U.S. robot producers. A breakdown of the future automotive industry purchases shows estimated acquisitions of spot-welding robots falling to just over one-quarter of all future purchases. Purchases of loading and unloading robots are projected to account for nearly another one-quarter of acquisitions, and material-handling and assembly robots together are expected to account for nearly one-third of these 86 purchases. All of the automotive companies responding to the Commission's questionnaires indicated that they would accept bids from both foreign and domestic suppliers while attempting to obtain the equipment necessary to satisfy their internal needs.

Aircraft industry

The aircraft industry trails the automotive industry in robot installations by a considerable margin despite its heavy reliance on CAD/CAM and other high-technology production processes. This is due in part to the nature of aerospace construction which is heavily dependent on the use of fasteners as opposed to welds (spot welders are the largest category of robot in automotive use). It also has to do with the longer retooling cycles in aircraft construction. As model variations are less prevalent in the aircraft industry and production runs shorter than in the automotive industry (several hundred units compared with thousands of units), industrial process equipment must be operated longer to recoup the investment committed to it. In part, this accounts for the fact that although the current generation of robots first appeared some 3 years ago, there has been no great rush by aircraft producers to employ them. Airframe manufacturers are, in many cases, evaluating robots on their few high-volume parts production runs while gaining experience in applying them to small-batch assembly. Although robots can be adapted to handle the small-batch assembly which is prevalent in the industry, the lack of advanced technology (especially sensor technology) to increase robot production flexibility and the current high cost of robots and their installation have limited the economic feasiblity of numerous potential robot assembly functions. Robots are, however, currently being looked upon to supplant manual operations in areas where there is a critical need to eliminate human-introduced quality variations. The leading U.S. aerospace users of robots are discussed below.

A leading Texas producer of military aircraft currently employs 12 robots in its F-16 fighter plane assembly lines in Fort Worth. The number of robots in use by this division is expected to rise to about 40 or 50 before 1990. The firm is currently employing 10 robots in hole drilling for understructure and tail skin on its aircraft and another two robots in material-handling and pilot-hole-drilling operations. The firm is also evaluating robots for simple assembly operations, and company officials have indicated that the future cost of robots will be one of the principal factors affecting increased robot use. 1/

The largest U.S. producer of aircraft is cautiously evaluating robots in a number of areas in its various divisions. Its aerospace division is using

1/ Mark Sfiligoj, "General Dynamics Plans to Quadruple Use of Robots in F-16 Plant by 1990," American Metal Market/Metalworking News, May 9, 1983, p. 9.

robots for metalworking operations on its air-launched cruise missle (ALCM) and has future plans to use robots in parts-cleaning and tool-changing operations. The ALCM production line currently is the firm's highest volume assembly area, and, thus, robot integration into these operations is receiving its most critical review. 1/ At its commercial airplane division, a spray-painting robot which applies hazardous chromate paint was justified more on eliminating worker exposure to a hostile environment than on economic grounds. Future installations at this division are expected to include a robot equipped to perform ultrasonic inspection of cowling panels and to attach adhesive studs to the back of decorative interior wall panels. 2/ The firm's military aircraft division has installed robots to spray primer on 737 aircraft and to inspect 757 and 767 engine cowlings and wheel well doors. 3/ In both applications, when compared to that of its human counterpart, the precision of the robot installation was a key factor effecting the production changeover.

The aircraft producer is currently sharing its research and development efforts on robots between its aerospace division, which is evaluating electronics applications, and it commercial airplace division, which is looking into mechanical uses. Application engineering information is also readily exchanged between the two divisions. In the electronic area, the firm is investigating assembly robots with enough "artificial intelligence" to permit the automated assembly of printed circuit boards without human intervention and is working toward integrating robots with its sophisticated computer-aided design system and with its numerically controlled machine tools. 4/

In the California plants of a leading producer of military aircraft, the big push in robot technology is aimed at the development of automated machining centers. A typical center (or automated flexible machining cell) would consist of eight four-axis, single-spindle, horizontal machine tools capable of automatic drilling, reaming, boring, tapping, milling, and profiling multiple parts during a single machine load. Each machine would have a 60-tool magazine to expedite tool changes. Each machining cell would have an automated (robotic) cleaning module and two automated inspection stations. Remote control carts would be loaded automatically by robotic devices with work to be processed, proceed to the appropriate machine tool and load it, then unload the machined pieces and transport them to the cleaning and inspection stations. After these operations are performed, the cart would unload the finished parts and repeat the cycle. Robotic devices would perform almost all of the machine loading and unloading and material-handling operations in the cells. This machining cell technology is expected to be adopted by many companies in the industry. 5/

1/ Richard G. O'Lone, "Boeing Approaching Use of Robots Cautiously," Aviation Week & Space Technology, Aug. 2, 1982, p. 53.

2/ Ibid., pp. 59 and 60.

3/ These components are manufactured in Wichita, Kan., and then shipped to Seattle, Wash., for final assembly.

4/ Richard G. O'Lone, op. cit., pp. 58 and 59.

5/ "Automatic Machining Center Aids B-1B Productivity Effort," Aviation Week & Space Technology, Aug. 2, 1982, pp. 46 and 47.

The push into factory automation by another California aircraft firm resulted from a decision by the U.S. Air Force to change the wing configuration on a military transport produced by the firm. Although production of this plane ceased 9 years ago, 77 of these planes are still in service. The relatively large numbers of planes in service and R. & D. funding provided through the U.S. Department of Defense's technology modernization program encouraged the firm and its wing subcontractor to implement automated equipment in a number of areas. In its Georgia division, the firm has two robots performing routing operations on the wing assemblies, and the subcontractor employs a single robot to deburr wing panels using an attachment which spins abrasive fibers. This application has reduced deburring time from 25 to 35 hours to 3-1/2 hours. Future robot uses for robots by the firm and its subcontractors include fuel cell sealing, small-parts painting, flame spraying, and waterjet and conventional routing. 1/

The cooperation between the Air Force and the Georgia division of the firm is an example which is being repeated throughout the aerospace industry. The Air Force currently has cooperative programs established with 13 other major manufactures as part of what is officially called Conceptual Design for Computer Integrated Manufacturing, or Project 1105. Project 1105 is an extension and expansion of the Air Force's technology modernization programs. The project is currently headed by a Texas firm and includes major U.S. aircraft producers and research institutions. 2/

About $250 million has been budgeted by the Air Force through 1985 to increase the manufacturing efficiency and productivity of the aerospace industry. Much of this funding will be used to spur the $1 billion to $2 billion investment by firms in the aerospace industry, which is felt will be needed by 1990 to bring widespread aerospace "factories of the future" to reality. 3/ The percentage of these funds which will ultimately be dedicated for the purchase of robots is unknown. In 1983, however, an estimated $5.7 million will be spent on the installation of robot systems. 4/

Home appliance industry

The home appliance industry is a highly competitive business in which competitive pricing and thin profit margins have combined to prompt manufacturers to implement numerous cost-cutting measures. The major U.S. manufacturers have, however, adopted some quite different strategies to improve their operation efficiency and increase worker productivity. As a result of these contrasts, the home appliance industry may represent one of the better future object lessons with respect to the economic rationale behind implementing robot technology.

1/ Edward H. Kolcum, "C-5A Wing Modification Using Advanced Methods," Aviation Week & Space Technology, Aug. 2, 1982, pp. 51 and 52.

2/ Al M. Senia, "Airforce ICAM Project Paves the Way for the Factory of the Future," Iron Age, Jan. 21, 1983, pp. 50 and 51.

3/ Ibid., p. 151.

4/ Dr. Edith Martin, op. cit.

The industry leader has embarked on an ambitious spending program which is designed to revitalize the company's 30-year-old factories. With 1982 appliance sales of $2.9 billion, the firm plans to invest a total of $1 billion in its facilities, much of which will be directed toward increasing the level of automation in its plants. 1/ A total of 145 robots will be installed in the firm's appliance plants by the end of 1983, more than installed in any other division of the company. 2/ Additional robots are expected to be installed, although the projected total is not known.

In contrast to the activities of the industry leader, the second and third leading producers are generating production efficiences through a combination of operational consolidations, tight fiscal and inventory controls, and concessions from labor. 3/ Although these firms are evaluating new technology such as robots, few robots have been installed in the companies. Instead, the firms have tightened their control over inventory and commitment of corporate funds to capital investment. The companies have gained some major salary concessions from their employees and have plans to further reduce vacations and other labor fringes. Products have also been redesigned to reduce and standardize parts and assemblies and to minimize the level of expensive model variations. In short, the firms have chosen to streamline their operations by trimming internal waste rather than committing funds to future labor-saving and productivity-boosting equipment. 4/

U.S. Market

The domestic market for robots has received considerable attention with respect to its actual size and growth rate. According to a recent report published by the U.S. Department of Commerce, 5/ the domestic market is expected to increase to $270 million in 1983 from $203 million in 1982. According to responses to Commission questionnaires, the market actually appears to be much smaller and is currently showing only modest growth. In 1982, apparent U.S. consumption did not exceed $137 million, being about 33 percent smaller than most projected estimates.

The overestimation of the market and its growth rate is related to a number of factors, including conflicting media coverage and alternate types of equipment competing for capital investment funds. Conditions in the market for robotics were described as follows by a spokesman for the industry: 6/ (1) The media situation is not reflective of the commercial scene. Although there is an overabundance of robots available at this time, and the country is in a recession, firms not knowledgeable about the market gather from media articles that they had better get into the robot business that it is going to be so big they can't affort to miss it and (2) With this encouragement, some of the largest firms in the United States have taken a shortcut to get into

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1/ Lisa Miller Mesdag, "The Appliance Boom Begins," Fortune, July 25, 1983, pp. 52 and 54.
2/ Ibid., p. 54.
3/ Ibid.
4/ Ibid., pp. 52 and 54.
5/ U.S. Department of Commerce, The Robotics Industry, April 1983, p. 16.
6/ Transcript of the hearing, Sept. 7, 1983, p. 28.

the business and have gone into offshore licenses, manufacturing agreements, joint ventures, etc. There are more vendors than buyers, but there still is a lot of press coverage. What has happened is that people have discovered robots, but they haven't started to buy them yet.

Conditions in the market are also reflected by the attitudes and decisions of engineering personnel responsible for providing justification for purchasing robots in user industries. The Institute of Industrial Engineers (IIE) recently conducted a comprehensive survey on ways productivity can be increased in U.S. industries and institutions. 1/ The IIE represents more than 40,000 professional engineers whose principal goal is productivity improvement. About 81 percent of the engineers responding to the survey reported that their firms had invested in automated equipment, and 29 percent had invested in robotics. The engineers responding to the survey rated automated equipment as a more effective means for improving productivity than robotics. The relatively lower rating given robotics by members of IIE compared with that given to automated equipment for improving productivity partially explains the low utilization rate of robotics in U.S. industries.

The survey findings of the IIE are also consistent with views held by a certain U.S. firm which produces end products in high volume. The corporate director for manufacturing operations of the world's largest producer of computers believes that although robots always seem to surface as an effective way of doing work, it is not wise to assume robots are a necessity. 2/ With an established base of 500 robots in the firm, the official claims that the optimum manufacturing ratio is 10 percent automation and 90 percent manual or nonautomated processes. 3/ The official claimed that the usual way by which robots are justified in U.S. industries through the elimination of direct labor is a failure. Direct labor accounts for only 5 to 15 percent of product cost, although indirect labor (including plant overhead) accounts for 15 to 25 percent. 4/ The official also indicated that product redesign to adapt production to automated processes is the most cost-effective means of increasing productivity. "In those cases robotics is a device looking for an application." 5/

The low level of demand for robots in the domestic market is also influenced by the way robots are being introduced into user industries. About 90 percent of the robots sold today are integrated with existing equipment which is often 10 to 20 years old. 6/ The integration of the robot with old equipment is one of the biggest problems for the industry, and this situation is expected to continue for the balance of this decade. 7/ Not surprisingly, the cost to adapt a robot to existing equipment along with necessary tooling and programming costs is often higher than the initial cost of the robot. According to responses to Commission questionnaires, purchasers reported that the median cost of making robots operational varied between 175 and

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1/ Institute of Industrial Engineers News, Sept. 26, 1983, pp. 1 and 2.
2/ Robot Insider, Oct. 14, 1983, p. 3.
3/ Ibid.
4/ Ibid.
5/ Ibid.
6/ Transcript of the Hearing, Sept. 7, 1983, p. 29.
7/ Ibid., p. 30.

500 percent of the purchase price, depending on the type of robot acquired. When these costs are added to the purchase price, firms have shown even greater reluctance to purchase robots, especially with existing high interest rates, capital shortages, and low plant utilization rates.

According to conversations with industry officials, a clear domestic strategy for marketing robots has yet to emerge in the industry. Initially, robots were marketed directly to large end users through negotiated contracts. They point out that negotiated contracts are still characteristic of sales to large users, but that a different approach is required with small and midsize purchasers, since these firms usually lack the resources and technical personnel to evaluate robots in their own facilities. Instead, they must depend on the robot producers or follow the developments in large firms where robots are installed. Compared with machine tools and similar equipment, robots are more difficult to market. 1/

Robots are not devices which are essential to the operation of a factory. A machine tool such as a lathe is required to cut a diameter, or a mill is required to machine a surface, but a robot is provided only as a substitute for a worker. 2/ Field interviews with producers and users indicate that small and midsize buyers must be convinced that the operations in their plants will be improved by the purchase of a robot. Caution is exercised to avoid large expenditures on devices which are neither as cost effective as advertised nor live up to their expectations. Further, they pointed out that the robot producer competes with machine tool producers or producers of automated equipment who have relationships already established with these buyers. These competing producers point out potential problems and deficiencies in robots to the buyers. Industry sources point out that the robot producer must overcome these problems, and for new producers entering the market, they must overcome added problems in product recognition and acceptance. Both the reliability of the robots produced by new firms and the new firm's corporate behavior are unknown to the small and midsize purchasers.

To promote the sales of robots, a diversified marketing approach has been developed by domestic producers. A combination of magazine advertisements, trade show displays, demonstrations at producers' plants, and plant tours arranged with existing robot users are typical. According to industry marketing personnel, the most promising strategy, however, is a systems approach whereby a systems house which employs the necessary technical personnel demonstrates the economic feasibility of using robots in a system integrated with machine tools, inspection equipment, or other types of devices. The robot is demonstrated by the systems house in a manner that simulates a factory setting and is sold as part of the system. Unlike with marketing machine tools, distributors are seldom used in marketing robots. 3/

Apparent U.S. consumption of robots is expected to reach $164 million in 1983, increasing from $23 million in 1979 (table 8). Imports decreased from

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1/ According to conversations between the Commission staff and numerous marketing personnel of the U.S. robot industry.

2/ Subrata N. Chakravarty, "Springtime For An Ugly Duckling," Forbes, Apr. 27, 1981, p. 59.

3/ According to conversations between the Commission staff and numerous marketing personnel of the U.S. robot industry.

16.4 percent of apparent consumption in 1979 to 8.9 percent in 1980, and then increased to 11.0 percent in 1982. Imports are expected to reach 17.7 percent of apparent consumption in 1983.

Table 8.--Robots: U.S. producers' shipments, exports of domestic merchandise, imports for consumption, and apparent consumption, 1979-83

Year	Producers' shipments	Exports	Imports	Apparent consumption	Ratio of imports to consumption
	1,000 dollars				Percent
1979	28,077	8,909	3,751	22,919	16.4
1980	64,059	20,766	4,225	47,518	8.9
1981	113,385	23,309	10,620	100,696	10.5
1982	142,845	20,322	15,097	137,620	11.0
1983 2/	168,654	33,738	28,946	163,862	17.7

1/ Estimated.

2/ Data for 1983 are based on projections provided by U.S. producers and importers.

Source: Compiled from data submitted in response to questionnaires of the U.S. International Trade Commission.

Although the domestic market has grown slower than expected, U.S. producers project that by 1988, production will reach more than 22,000 units, having increased from more than 3,300 units in 1984, as shown in the following tabulation:

Year	Quantity 1/ units
1984	3,395
1985	5,167
1986	8,940
1987	14,149
1988	22,223

1/ Data are not included for 1 firm which was unable to supply estimates.

This expected increase in output amounts to an average annual growth rate of 59 percent, compared with a present growth rate of about 18 percent. When small educational or instructional robots reported in questionnaire responses are removed from these projections, future production is expected to increase from 3,000 robots in 1984 to 8,900 in 1988, resulting in an average annual increase of 34 percent. Assuming the present average unit value of an educational robot is $3,000 and the present average unit value of other robots is $65,000, the expected value of U.S. production will reach about $807 million. Assuming that importers will retain their current 18-percent share of the domestic market, the market will approximate $1.0 billion in 1988.

Competitive Assessment

Competitive factors affecting the sale of U.S.- and foreign-produced robots include price, performance features, availability, supplier relationships, servicing/training, and marketing and distribution. Performance features include design, productivity, durability, and energy efficiency. When these factors are considered in the aggregate, it appears that U.S. firms producing robots have an overall competitive advantage in the domestic market vis a vis the position of foreign producers except in price and lower maintenance costs. A summary of responses received from U.S. purchasers is shown in the tabulation below. Detailed responses by types of robots purchased are shown in tables E1 and E2 of appendix E.

Source of robot	Lower purchase price	Servicing/ training	Performance features			Supplier relationship	Availability	
			Superior design	Durability	Lower maintenance		Equipment	Spare parts
Foreign	399	77	301	119	147	154	189	49
Domestic	336	567	455	210	98	308	448	581

Source: Compiled from data submitted in response to questionnaires of the U.S. International Trade Commission.

Prices

The importance of price in the sale of robots depends on product differences and sophistication. In the sale of spot-welding, loading/ unloading, and material-handling robots, price is a critical factor, since these devices are less differentiated, whether they are produced by foreign firms or domestic firms. These types of robots have been installed in motor-vehicle plants worldwide, and both the manufacturing processes and the robots used in these motor-vehicle plants vary little from country to country. Certain differences can occur, however, in loading/unloading and material-handling robots, depending on their weight-lifting capabilities.

During 1979-83, the weighted average purchase price of domestically produced spot welders was about $88,000, compared with about $90,000 for foreign-produced devices, resulting in a $2,000 advantage for U.S. producers (table 9). U.S. producers also enjoyed a price advantage of about $7,000 in loading/unloading robots ($63,000 compared with $70,000) during the period, although a price disadvantage of $8,000 was realized for material-handling robots. However, the price difference in material-handling robots, according to industry sources, was related to the heavy-duty rating of the arms of the U.S.-produced devices.

Other types of robots, with the exception of metalworking devices, are more differentiated, and price comparisons become less distinct and meaningful. The price of metalworking robots depends on their weight-lifting capabilities, and on their ability to serve more than one machine. During 1979-83, the average prices of U.S.-produced metalworking robots was about $20,000 higher than those of foreign-produced devices.

With assembly robots, foreign producers serve the industry by assembling electronic products and printed circuit broads, domestic producers largely serve applications requiring greater load capacities. Prices of foreign-produced assembly robots averaged about $43,000 during 1979-83; prices of domestically produced devices averaged about $106,000.

Coating robots are divided into two classes of devices, making price comparisons difficult. Sophisticated robots used in applications where surface treatment is critical, such as in motor-vehicle painting, are priced from $140,000. Coating robots used in less critical applications, such as in painting containers and fixtures, range in price between $40,000 and $90,000. Prices of imported coating robots have averaged about $82,000 during 1979-83, compared with about $168,000 for U.S.-produced devices.

The price of arc-welding robots produced by U.S. firms have averaged about $105,000 during 1979-83, compared with $71,000 for foreign-produced devices. The price of arc-welding robots is affected by the types of sensors they employ and their seam-tracking capabilities. The types of devices can vary in capability from those engaged in simple tack-welding operations to those engaged in complex welding applications, where the welding rate and bead uniformity are critical.

With regard to the miscellaneous "other" types of robots, prices of domestically produced devices have averaged about $82,000 during 1979-83, compared with those of imported devices, which averaged about $101,000. It sould be noted, however, that this category contains a wide variety of robots whose applications are unknown. Price ranges for all robot types, both foreign- and domestically produced, are also shown in table 9 for each year during 1979-83.

Table 9.--Robots: Range and average prices 1/ of foreign- and domestically produced equipment, by types, 1979-83 2/

(In thousands of dollars)

Type and year	Domestically produced				Foreign-produced			
	Low	Med.	High	Weighted average	Low	Med.	High	Weighted average
Spot welders:								
1979	60	65	90	64	3/	3/	3/	3/
1980	65	80	92	67	65	3/	3/	65
1981	65	88	214	94	111	111	213	123
1982	38	77	190	68	3/	3/	3/	3/
1983	65	83	160	78	50	86	112	87
Average	-	-	-	88	-	-	-	90

See footnotes at end of table.

Table 9.--Robots: Range and average prices 1/ of foreign- and domestically produced equipment, by types, 1979-83 2/--Continued

(In thousands of dollars)

Type and year	Domestically produced				Foreign-produced			
	Low	Med.	High	Weighted average	Low	Med.	High	Weighted average
Arc welders:								
1979----------	65	150	3/	108	118	175	3/	165
1980----------	44	3/	3/	44	121	211	3/	144
1981----------	65	110	150	121	41	65	125	52
1982----------	84	100	150	103	42	51	88	65
1983----------	33	95	100	90	29	73	73	37
Average-----	-	-	-	105	-	-	-	71
Coaters:								
1979----------	45	3/	3/	45	104	3/	3/	104
1980----------	50	100	103	92	90	125	3/	108
1981----------	100	110	422	329	43	102	142	83
1982----------	65	115	210	113	61	90	104	87
1983----------	20	103	170	138	60	90	197	80
Average-----	-	-	-	168	-	-	-	82
Assemblers:								
1979----------	40	3/	3/	40	3/	3/	3/	3/
1980----------	45	239	3/	109	3/	3/	3/	3/
1981----------	40	90	213	123	100	125	3/	108
1982----------	30	67	105	90	30	87	3/	50
1983----------	43	62	250	106	12	50	77	40
Average-----	-	-	-	106	-	-	-	43
Material handlers:								
1979----------	38	60	100	51	3/	3/	3/	3/
1980----------	27	54	125	75	3/	3/	3/	3/
1981----------	24	80	150	68	27	36	3/	34
1982----------	25	80	199	77	13	74	170	108
1983----------	20	70	150	78	38	58	104	66
Average-----	-	-	-	75	-	-	-	67
Metalworking apparatus:								
1979----------	85	203	3/	176	3/	3/	3/	3/
1980----------	71	91	117	95	3/	3/	3/	3/
1981----------	80	208	3/	92	3/	3/	3/	3/
1982----------	35	63	445	63	70	3/	3/	70
1983----------	47	140	233	154	73	120	3/	85
Average-----	-	-	-	100	-	-	-	80
Loaders/unloaders:								
1979----------	4	70	80	36	3/	3/	3/	3/
1980----------	23	50	90	34	12	134	3/	55
1981----------	25	65	100	59	15	3/	3/	15
1982----------	15	65	125	57	45	55	88	82
1983----------	16	71	131	86	38	75	112	70
Average-----	-	-	-	63	-	-	-	70

See footnotes at end of table.

Table 9.--Robots: Range and average prices 1/ of foreign and domestically produced equipment, by types, 1979-83 2/--Continued

(In thousands of dollars)

Type and year	Domestically produced				Foreign-produced			
	Low	Med.	High	Weighted average	Low	Med.	High	Weighted average
All other:								
1979	83	3/	3/	83	3/	3/	3/	3/
1980	54	100	160	125	3/	3/	3/	3/
1981	22	103	264	179	76	165	312	179
1982	26	60	450	99	50	90	163	99
1983	47	86	175	64	25	64	109	64
Average	-	-	-	82	-	-	-	101

1/ Prices are net delivered prices (less discounts and allowances) of the robots delivered to the purchasers' U.S. facilities.
2/ Data for 1983 are projected.
3/ Purchases not reported.

Source: Compiled from data submitted in response to questionnaires of the U.S. International Trade Commission.

Performance features

U.S. purchasers reported that superior design, durability, and low maintenance of U.S.-produced assembly, material-handling, metalworking, and loading/unloading robots were important purchasing considerations (table E-1, app. E). The recognized strength of U.S. producers in these product areas is related to expertise gained in supplying the U.S. automotive industry. U.S. produced robots supplied to the automotive industry are more often designed for heavy-duty use because of the importance of reliability.

With respect to foreign-produced devices, U.S. purchasers cited that in buying arc-welding, coating, assembly, material-handling, and loading/unloading robots, performance features (along with price) were important considerations (table E-2, app. E). Sales of foreign-produced arc-welding and coating robots have increased in the domestic market reportedly as the result of an acknowledged edge in technology and design. Sophisticated coating technology, as previously indicated, has not been available to U.S. producers until recently. Foreign-produced assembly, material-handling, and loading/ unloading robots, however, were most often light-duty versions of devices available from domestic producers. In a number of cases, the domestic purchaser chose the foreign robot rather than the domestic product because of unwanted weight-handling capabilities which resulted in a higher price.

Availability

Availability in 1983 has not been an important factor in the sale of robots. During 1979-82, U.S. purchasers did cite availability as an important factor in their decision to buy spot-welding, loading/unloading, material-handling, and assembly robots from U.S. producers (table E-1, app. E). However, a large share of these decisions were made early in the period when import levels were low and foreign producers were not well established in the U.S. market. At present, purchasers report that foreign-produced robots comparable with domestically produced types are available for most applications. In some cases, U.S. purchasers did indicate a preference for a particular type of prime mover or mechanical feature which was not available from either a foreign or domestic source. These product differences are being reduced as foreign and domestic producers redesign their products to meet the varying preferences of domestic users.

Availabilty of spare parts was cited by U.S. purchasers as an important consideration. Purchasers cited that domestic producers held an advantage over foreign producers in making spare parts available on a timely basis (table E-1). According to a large U.S. producer, foreign suppliers are increasing their U.S. inventories to overcome this disadvantage.

Supplier relationships

Supplier relationships are largely created through previous robot installations or through corporate agreements. With a larger installed base in the United States, U.S. producers have established stronger supplier relationships than foreign producers, although this could be affected in the future by the joint venture of the largest U.S. automotive producer. U.S. purchasers rated U.S. supplier relationships relatively high in their decision to buy all types of robots except metalworking and assembly robots (table C-1). Metalworking and assembly robots were purchased largely on the basis of superior design. Supplier relationships were ranked relatively low by U.S. purchasers in buying arc-welding, coating, and metalworking robots from foreign producers, and moderately low with other robot types (table E-2). The supplier relationships between foreign producers of robots and U.S. firms are influenced, in part, by previously established supplier relationships in other product lines.

Servicing/training

U.S. producers currently hold an advantage over foreign producers in servicing U.S. robot installations and in providing training to domestic production personnel, according to U.S. purchasers. Only in those cases in which U.S. purchasers were located close to the U.S. agents of foreign robot producers were service and training cited as reasons for purchasing foreign equipment. Servicing/training was the most frequently given reason for purchasing spot-welding, arc-welding, and coating robots, and the second most offered reason for purchasing material-handling and loading/unloading robots from U.S. suppliers (table E-1). Foreign producers of robots are disadvantaged in providing service and training on equipment sold in the U.S. market because of their general lack of U.S. service and marketing networks. Many foreign manufacturers have had to rely on U.S. sales' agents to provide these services. As indicated earlier, inadequate inventories of spare parts have contributed to the ability of foreign producers to service U.S. customers.

Marketing and distribution

The manner in which a robot is marketed depends on the size of the user and the quantity of robots sold. With large users, quotations are requested from potential robot suppliers on the basis of specifications provided by the user. After the quotations are received and evaluated, a contract is awarded, usually on the basis of lowest evaluated price. The evaluated price takes into account delivery, expected performance, and other considerations. Spot-welding, coating, loading/unloading, and material-handling robots are usually marketed in this manner, since they are most often sold to large firms. To some extent, however, all types of robots are sold in this fashion.

With small and midsized firms, robots are marketed through inquiries received at trade shows, from advertisements, and other sources. The inquiries are followed up by engineers or technical personnel who evaluate the requirements of the potential buyers. Suggestions and alternatives regarding robot applications are provided by these technical representatives. Usually, many of these inquiries must be followed up before a sale is made. Robot producers reported that the cost associated with marketing in this manner is one of the major reasons the industry is not profitable. Robots are also marketed through turnkey operations and, increasingly, as part of larger manufacturing systems.

Although foreign-produced robots are marketed in the same fashion as domestically produced robots, the foreign producer is usually disadvantaged. Foreign-produced robots are rarely sold directly by the producer. Instead, the foreign producer must rely on a U.S. partner or sales agent over whom control is limited.

Future competition in robotics

In 1970, there was much optimism in the U.S. robotics industry. At that time, producers predicted that U.S. shipments of robots would reach $1.0 billion by the early 1980's. In 1983, U.S. shipments will not exceed 19 percent of that amount. Despite the lack of expected growth, U.S. producers are optimistic and expect production to increase by an average annual rate of 59 percent during 1984-88. When judged against the industry performance during recent years, this expected growth may be difficult to reach. "In the robotics field, Japan is far ahead both in terms of production and installation. A significant point is that demand for these systems is apparently much stronger and more extensive in Japan than it is in the U.S. This has profound implications for the international competitive position of the U.S. industry in the 1980's." 1/

Each year during 1979-83, the industry failed to make a profit. Across the five years 2/, industry losses will have amounted to about 28 percent of net sales. The poor financial performance of these producers may serve as a drag on expansion even if the expected demand for robots becomes a reality. Competitive conditions in the domestic market are also a source of concern to domestic producers. U.S. producers' shipments to the domestic market are

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1/ Dr. Jack Baranson, Automated Manufacturing: The Key to International Competitiveness-And Why the United States is Falling Behind, 1983, p. 3, 4.
2/ Data for 1983 are projected.

expected to increase by about 10 percent during 1983, and imports are expected to increase by 92 percent. According to industry sources, in the future, imports could accelerate, with U.S. producers purchasing more foreign robots to counter the pricing policies of foreign producers in the market. Numerous marketing agreements which have been negotiated between domestic and foreign robot producers would tend to support this contention. In addition, Japanese producers are also currently experiencing a soft demand for robots, with the market for robots in Japan described as glutted. 1/ Despite this, demand in Japan remains significantly higher than in the United States. Japanese robot producers usually look to export markets when sales in their domestic market fail to grow. Competition from Japanese producers could not only increase in the U.S. market because of conditions in the Japanese market, but also competition could increase in Western Europe, where U.S. producers currently hold a strong market position.

In addition to the poor financial performance of U.S. producers and increased foreign competition, other conditions are present in the industry which could adversely affect their expected growth rate. Research and development in the United States is largely directed at the design of more complex devices. These machines, when developed, are likely to be expensive and serve a more limited market because of their price. Little research is being directed to the development of simple machines which integrate human operators into the system. Japanese producers have directed a sizable share of their effort in this direction to produce relatively less expensive machines which can be more easily diffused through their industries.

Only a limited number of robots have been installed in U.S. small and midsized firms. Penetration into these firms will become necessary to expand production output. The development of standard interface systems will be needed so that robots can be more easily demonstrated and adapted to the manufacturing environment. At present, the costs of making a robot operational can reach 500 percent of the purchase price of the robot. These additional costs present an added burden to smaller firms and make justification for purchasing robots even more difficult.

Finally, flexible manufacturing systems (FMS) and other forms of automation are looming large as a factor in end-product industries. The future role that robotics will play in these systems has not been fully developed, although robots currently play the role of loaders/unloaders and material handlers within automated cells of these systems. How the role of robotics will be expanded depends on what the future capabilities of robots are, particularly in the areas of improved grippers, sensors, and machine repeatability, and whether FMS's are changed in such a manner that the robots are incorporated in the systems and no longer identified as robots.

1/ "Robots Bump into Glutted Market," Business Week, Apr.4, 1983, p. 45.

Appendix A

Notices of Institution of Investigation No. 332-155 and Announcement of Public Hearing in Connection Therewith

Federal Register / Vol. 48, No. 47 / Wednesday, March 9, 1983 / Notices 9871

[332-155]

Competitive Position of U.S. Producers of Robotics in Domestic and World Markets

AGENCY: International Trade Commission.

ACTION: The Commission, on its own motion, instituted investigation No. 332-155, under section 332(b) of the Tariff Act of 1930 (19 U.S.C. 1332(b)), for the purpose of gathering and presenting information on the competitive position of the U.S. robotics industry in domestic and international markets. The study will assess capital, labor, technology, and other economic factors affecting the manufacture and use of robotics in the United States and in foreign countries. The effects of the increasing application of robotics on the operations of domestic and foreign automobile, aircraft, and appliance industries will be explored.

EFFECTIVE DATE: February 23, 1983.

FOR FURTHER INFORMATION CONTACT: Mr. Nelson Hogge, Machinery and Equipment Division, U.S. International Trade Commission, Washington, D.C. 20436 (Telephone 202-523-0377).

Written Submissions: While there is no public hearing scheduled for this study, written submissions from interested parties are invited. Commercial or financial information which a party desires the Commission to treat as confidential must be submitted on separate sheets of paper, each clearly marked "Confidential Business Information" at the top. All submissions requesting confidential treatment must conform with the requirements of section 201.6 of the Commission's *Rules of Practice and Procedure* (19 CFR 201.6). All written submissions, except for confidential business information, will be made available for inspection by interested persons. To be assured of consideration by the Commission in this study, written statements should be received by the close of business on August 12, 1983. All submissions should be addressed to the Secretary, United States International Trade Commission, 701 E Street NW., Washington, D.C. 20436.

By order of the Commission.

Issued: March 1, 1983.

Kenneth R. Mason,

Secretary.

[FR Doc. [illegible] Filed [illegible]; [illegible] am]

BILLING CODE [illegible]

with the requirements of section 201.6 of the Commission's Rules of Practice and Procedure (19 CFR 201.6). All written submissions, except for confidential business information, will be made available for inspection by interested parties. All submissions should be addressed to the Secretary at the Commission's office in Washington, D.C.

Issued: April 18, 1983.

By order of the Commission.

Kenneth R. Mason,

Secretary.

[FR Doc. 83-11256 Filed 4-26-83; 8:45 am]

BILLING CODE 7020-02-M

[332-165]

Competitive Position of U.S. Producers of Robotics in Domestic and World Markets

AGENCY: International Trade Commission.

ACTION: The Commission will hold a public hearing for the purpose of affording all interested parties an opportunity to present views on the competitive position of the U.S. robotics industry in domestic and international markets. The initial notice of the investigation indicating the scope of the study, contact persons, and other related information was published in the Federal Register of March 9, 1983 (48 FR 9971).

Public hearing: A public hearing in connection with the investigation will be held in the Commission Hearing Room, 701 E Street N.W., Washington, D.C. 20436, beginning at 10:00 a.m., e.d.t., on September 7, 1983. All persons shall have the right to appear by counsel or in person, to present information and to be heard. Request to appear at the public hearing should be filed with the Secretary, United States International Trade Commission, 701 E Street NW., Washington, D.C. 20436, not later than August 30, 1983.

Written submissions: In lieu of or in addition to appearance at the public hearing, interested persons are invited to submit written statements concerning the investigation, by September 1, 1983. Commercial or financial information which a submitter desires the Commission to treat as confidential must be submitted on separate sheets of paper, each clearly marked "Confidential Business Information" at the top. All submissions requesting confidential treatment must conform

Appendix B

Witnesses Appearing at the Public Hearing

TENTATIVE CALENDAR OF PUBLIC HEARING

Those listed below appeared as witnesses at the United States International Trade Commission's hearing:

Subject : The Competitive Position of U.S. Producers of Robotics in Domestic and World Markets

Inv. No. : 332-155

Date and time: September 7, 1983 10:00 a.m.

Sessions were held in connection with the investigation in the Hearing Room of the United States International Trade Commission, 701 E Street, N.W., in Washington.

WITNESS AND ORGANIZATION:

Webster, Chamberlain and Bean--Counsel
Chicago, Illinois
on behalf of

Robot Institute of America, Dearborn, Michigan

Walter K. Weisel, President

Donald A. Vincent, CAE, Executive Vice President

Francis Flitner, Global Projects Coordinator, DeVilbiss, Inc.

Michael Radeke, Vice President and General Manager of Cincinnati Milacron, Inc.

Lori Lachowitz, Manager, RIA

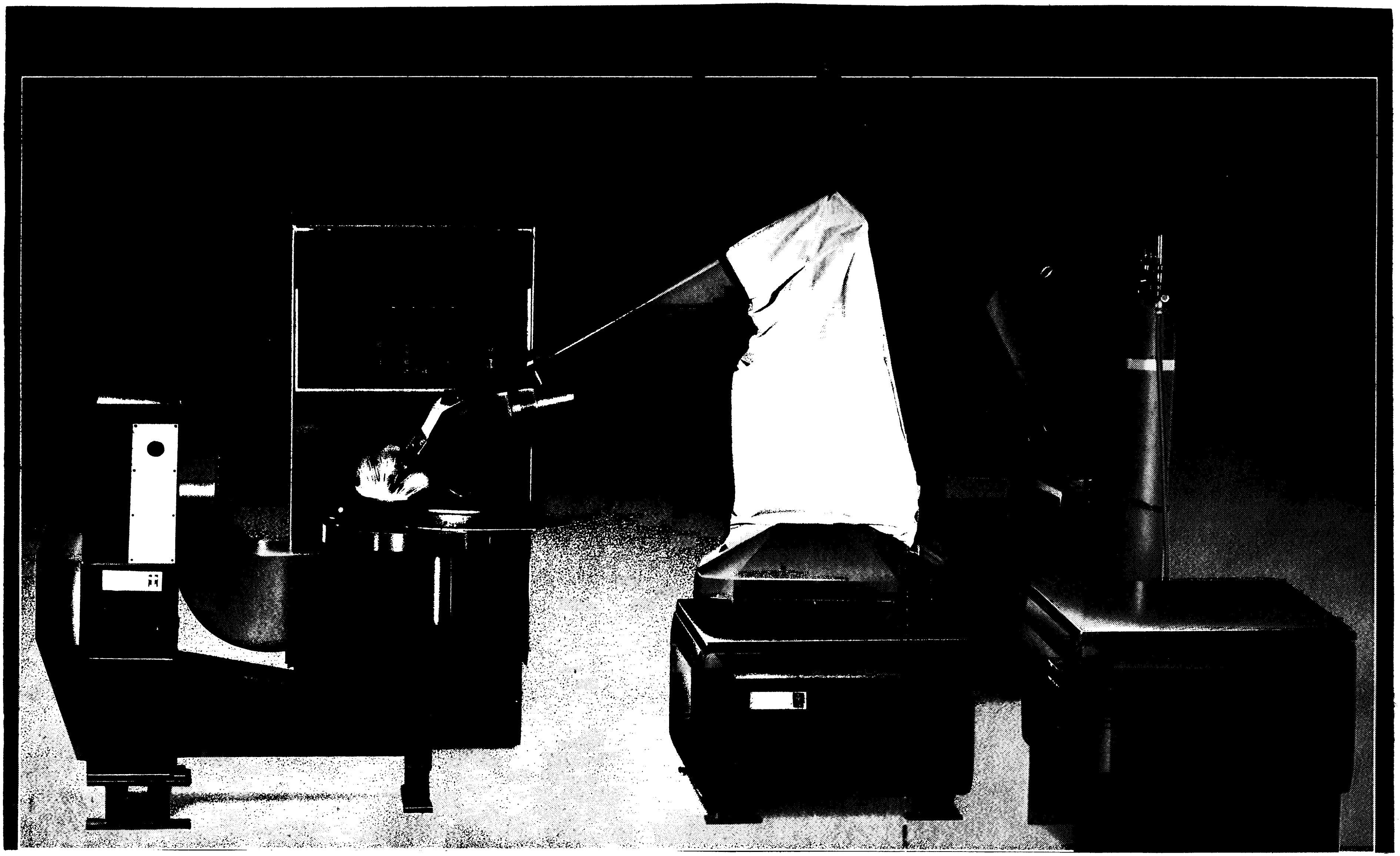
Alan Dye--OF COUNSEL

Bruce D. Potts, Treasurer, GMF Robotics Corporation

Appendix C

Robotics Illustrations

Figure C-1.--Arc-welding robot system.



60 Source: Product literature of Trallfa A/S, Bryne, Norway.

Figure C-2.--Spot-welding robot station.

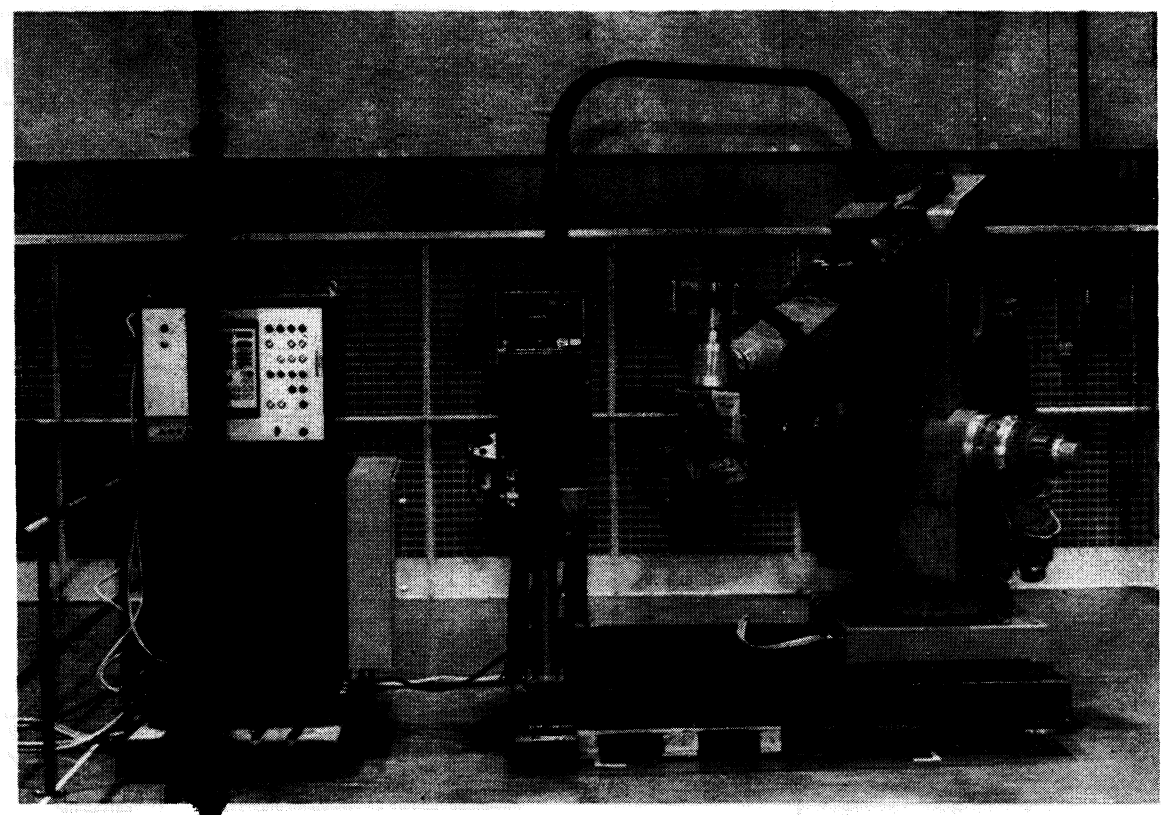
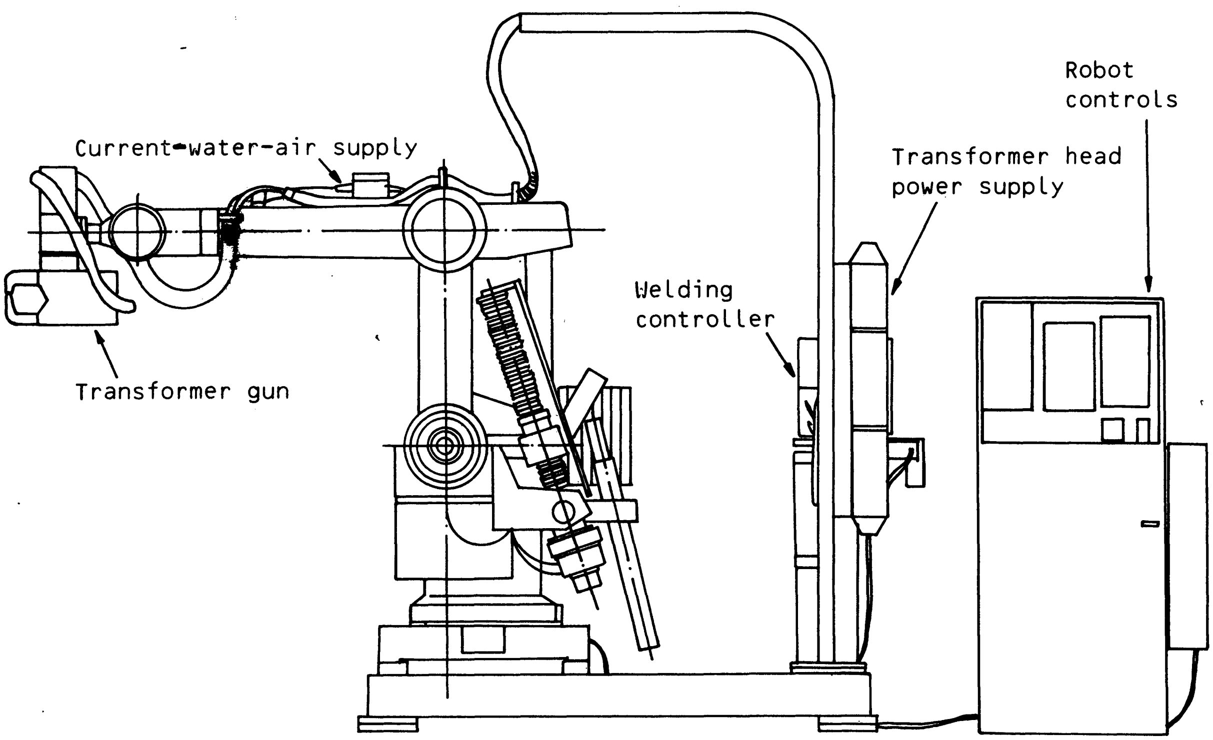


Figure C-3.--Different units in a spot-welding robot station.



Source for figures C-2 &C-3: 12th International Symposium on Industrial Robots, 6th International Conference on Industrial Robot Technology, June 9-11, 1982, Paris, France, p. 267.

Figure C-4.--System configuration and functions of intelligent assembly robot.

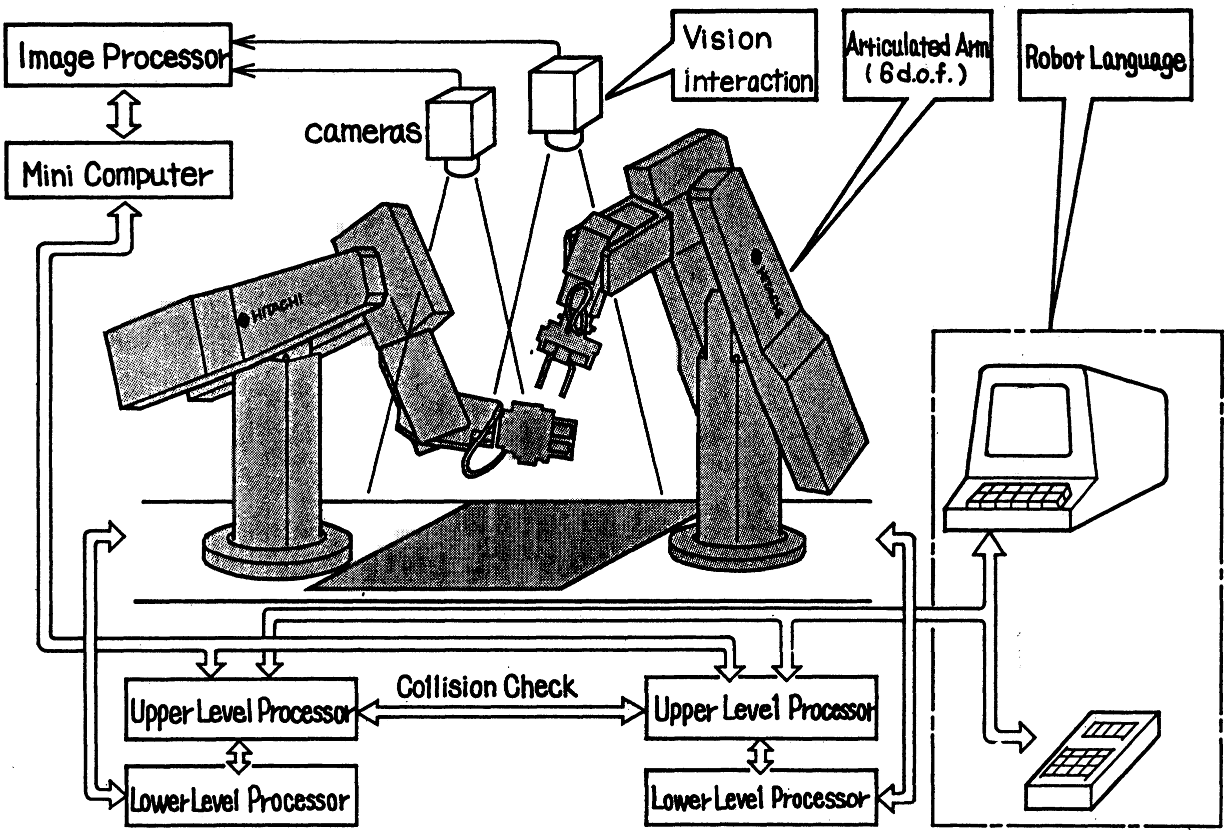
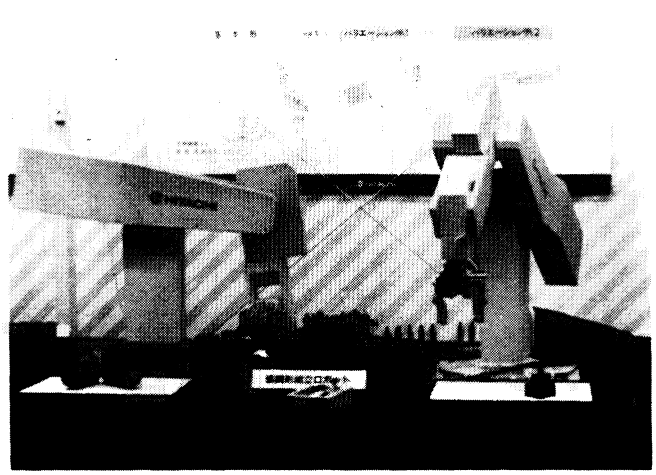
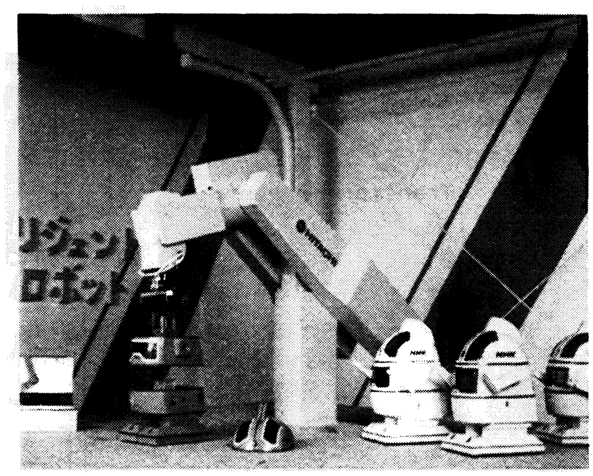


Figure C-5.-- Intelligent assembly robot.



(a) toy train assembly



(b) toy robot assembly

Source for figures C-4 & C-5: 12th International Symposium on Industrial Robots, 6th International Conference on Industrial Robot Technology, June 9-11, 1982, Paris, France, p. 116.

Figure C-6.--Gluing robot package.

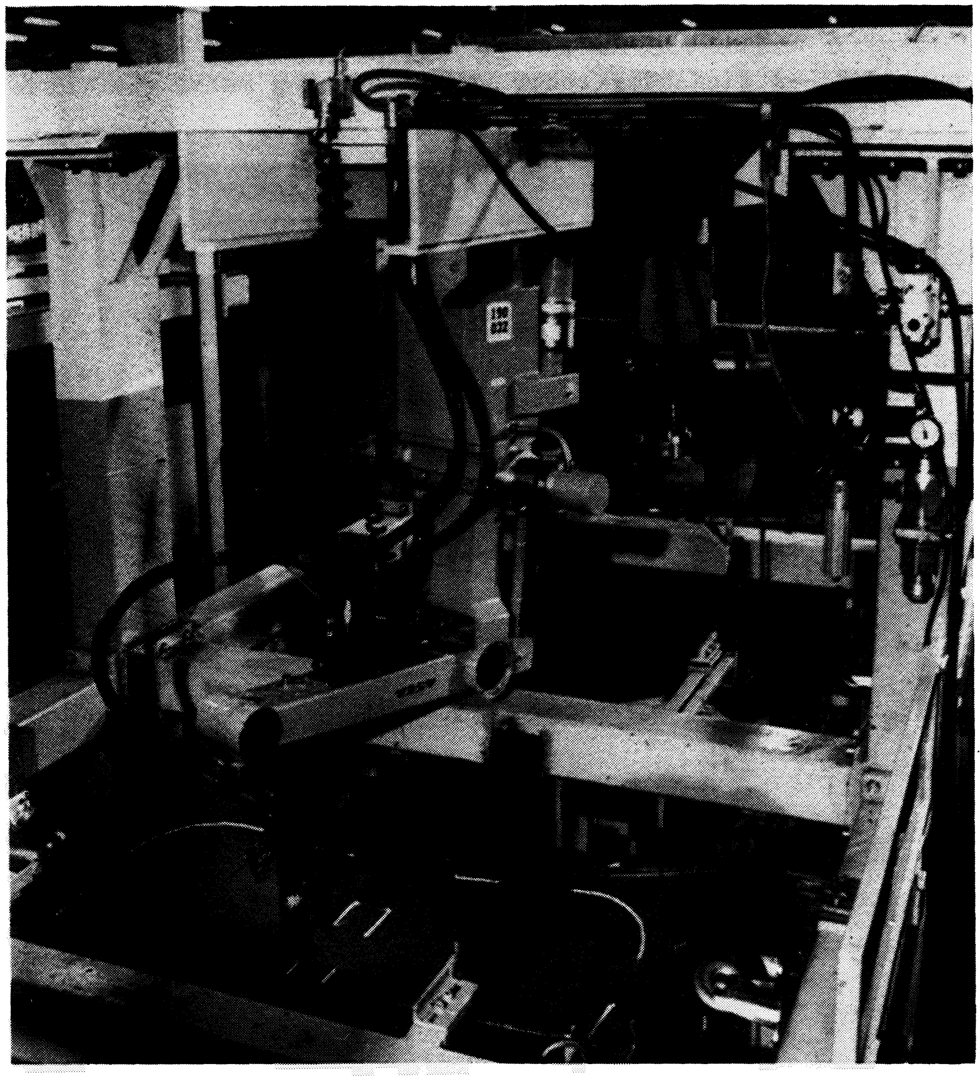
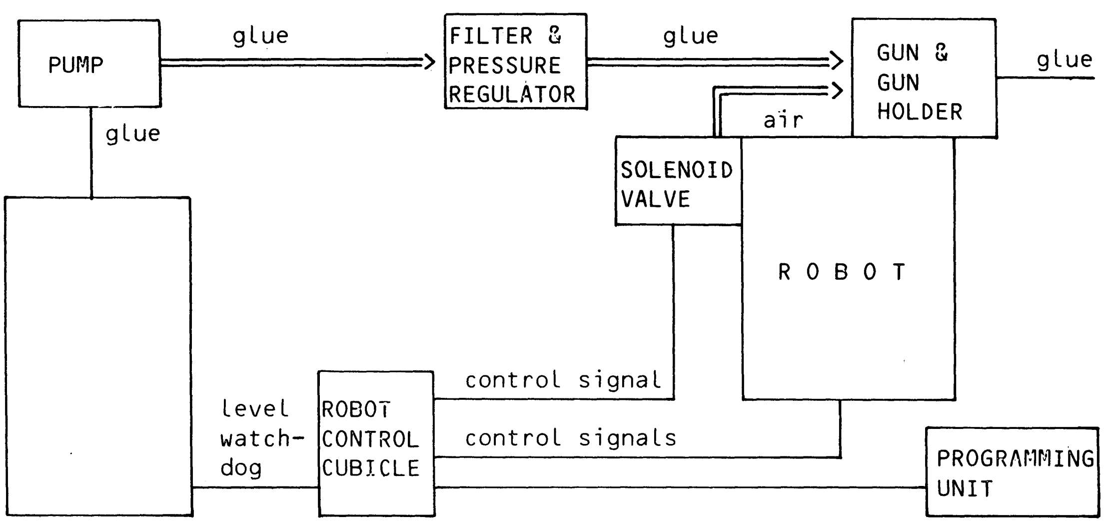


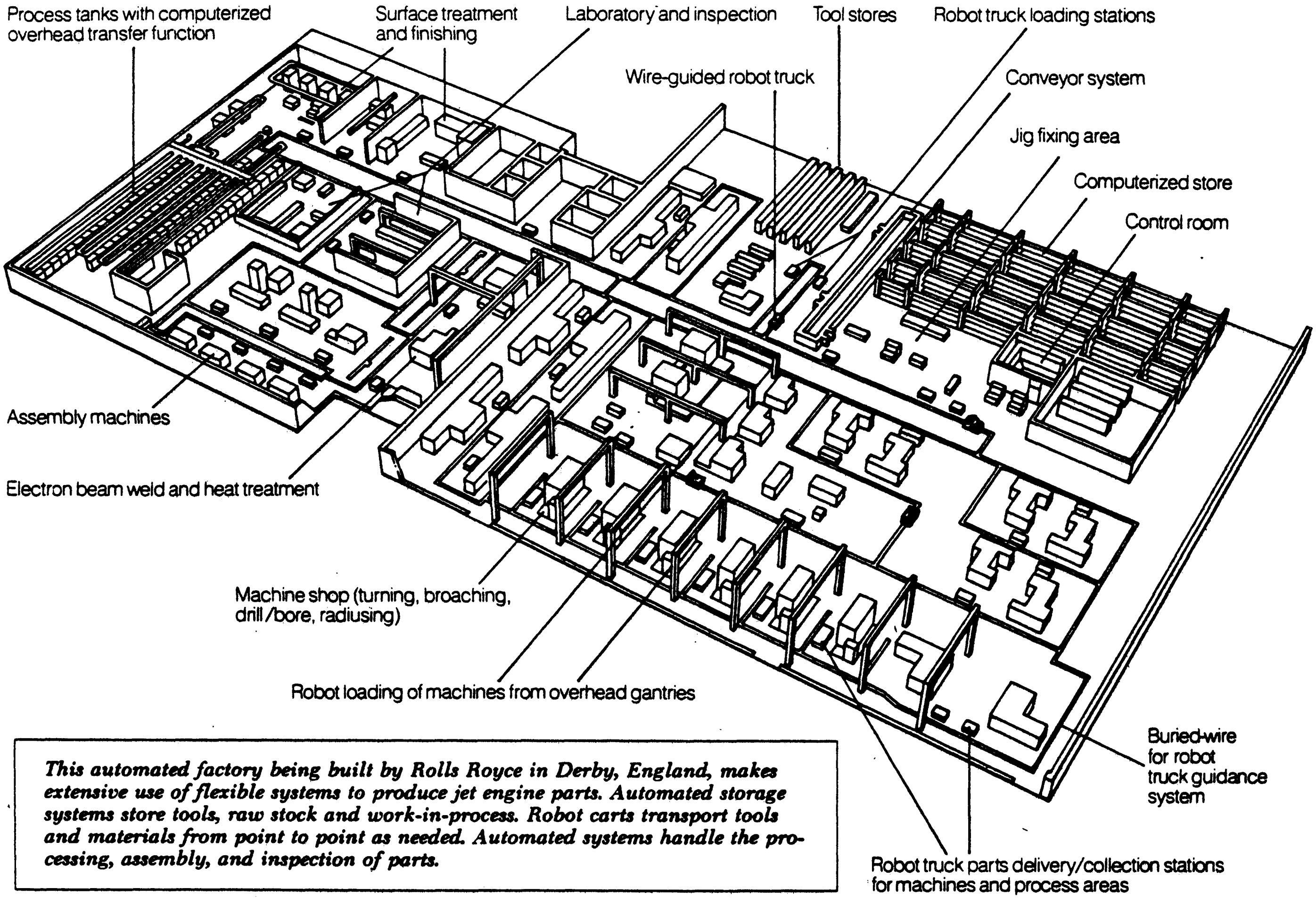
Figure C-7.--Main functions in a gluing robot package.



Source for figures C-6 & C-7: 12th International Symposium on Industrial Robots, 6th Industrial Conference on Industrial Robot Technology, June 9-11, 1982, Paris, France, p. 269.

Figure C-8.--A finishing robot spray painting metal shutters.

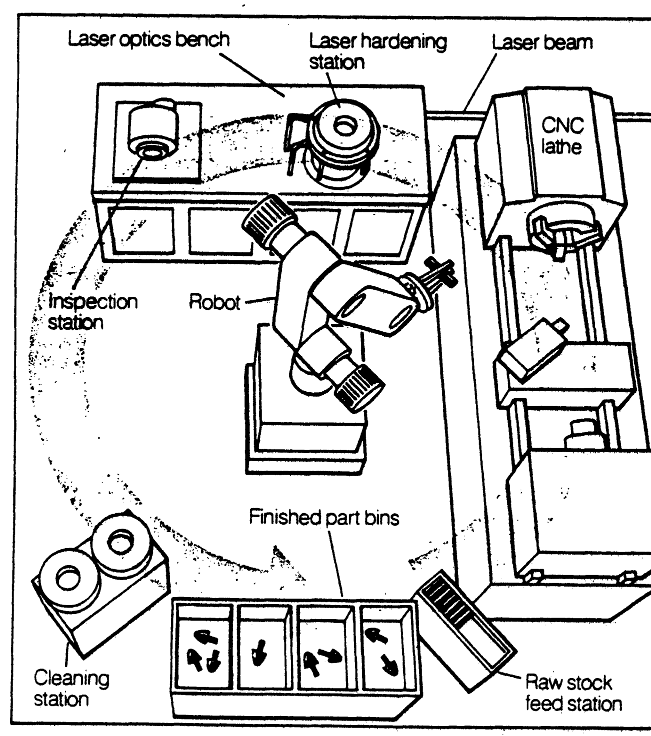
Source: Picture courtesy of the Devilbiss Co., Ann Arbor, Mich.



This automated factory being built by Rolls Royce in Derby, England, makes extensive use of flexible systems to produce jet engine parts. Automated storage systems store tools, raw stock and work-in-process. Robot carts transport tools and materials from point to point as needed. Automated systems handle the processing, assembly, and inspection of parts.

Figure C-9.--Automated factory in which robots are employed in flexible automation systems. ↑

Figure C-10.--Automated machining system in which a single robot performs all load/unload and material-handling operations. →



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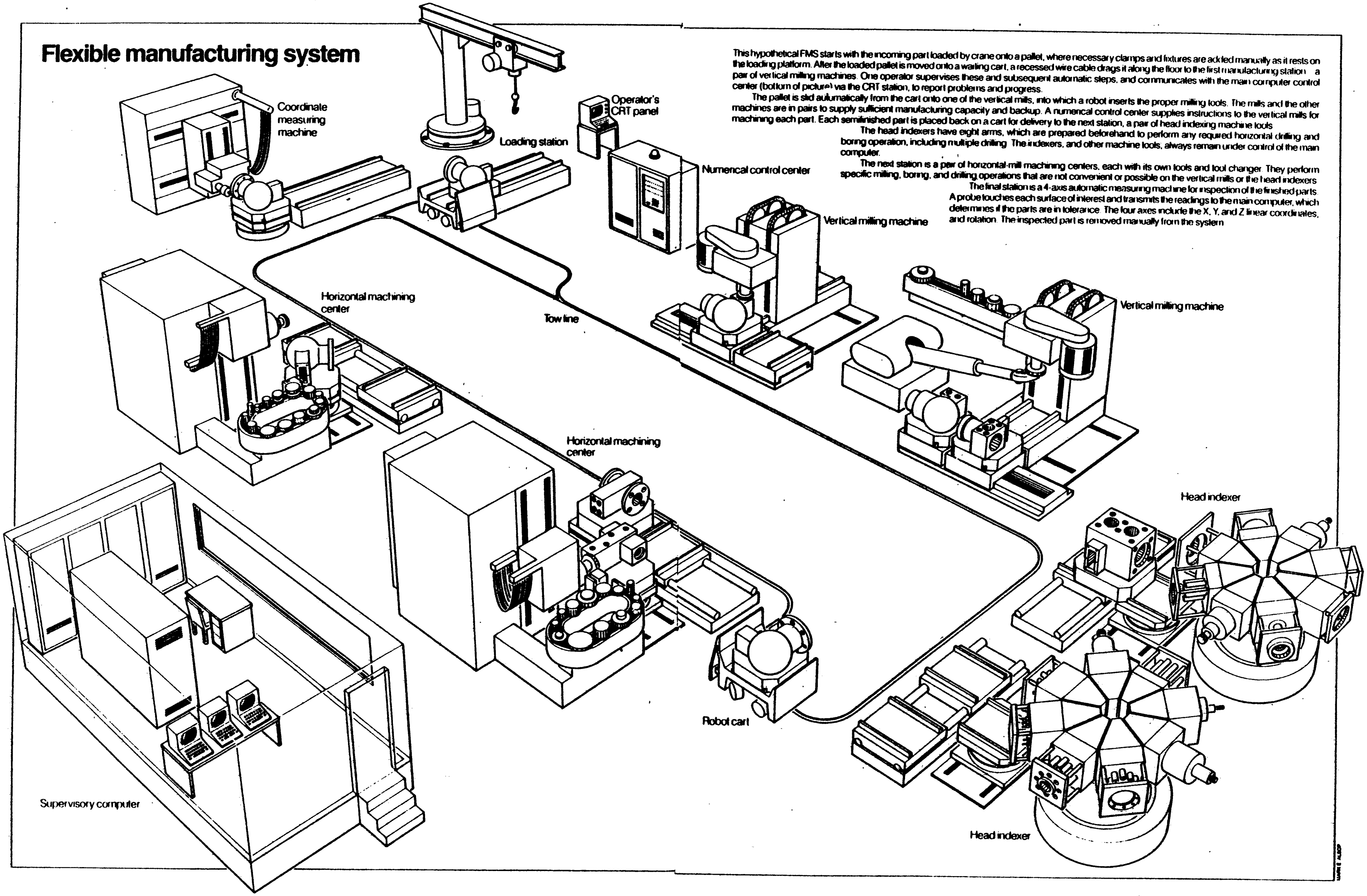
This experimental machining system developed by the IIT Research Institute produces various types of valve plugs automatically. At left, the cell's robot loads raw stock into a lathe, holds a plug in a laser hardener, and drops a finished plug into a bin. A supervisory computer (not shown) directs the cell's activities.

Source: <u>High Technology</u>, July 1983, p. 37.

Figure C-11 .--Flexible manufacturing system.



Source: High Technology, July 1983, p. 34.

Appendix D

Portions of the Tariff Schedules of the United States Annotated (1983)
Relating to U.S. Import Classifications of Industrial Robots

Explanation of the rates applicable to industrial robots and parts

The rates of duty in column 1 are most-favored-nation (MFN) rates, and are applicable to imported products from all countries except those Communist countries and areas enumerated in general headnote 3(f) of the TSUSA. 1/ However, such rates do not apply to products of developing countries which are granted preferential tariff treatment under the Generalized System of Preferences (GSP) or under the "LDDC" column.

The rates of duty in the "LDDC" column are preferential rates (reflecting the full U.S. MTN concession rate for a particular item without staging of duty reductions) and are applicable to products of the least developed developing countries designated in general headnote 3(d) of the TSUSA which are not granted duty-free treatment under the GSP. If no rate of duty is provided in the "LDDC" column for a particular item, the column 1 rate applies.

The rates of duty in column 2 apply to imported products from those Communist countries and areas enumerated in general headnote 3(f) of the TSUSA.

The GSP is a program of nonreciprocal tariff preferences granted by the United States to developing countries to aid their economic development by encouraging greater diversification and expansion of their production and exports. The GSP, implemented by Executive Order No. 11888, of November 24, 1975, applies to merchandise imported on or after January 1, 1976, and is scheduled to remain in effect until January 4, 1985. It provides for duty-free treatment of eligible articles imported directly from designated beneficiary developing countries. Eligible articles are identified in the column marked "GSP" with an "A" or "A*." The designation "A" means that all beneficiary developing countries are eligible for the GSP, and "A*" indicates that certain developing countries, specified in general headnote 3(c) of the TSUSA, are not eligible.

1/ The only Communist countries currently eligible for MFN treatment are the People's Republic of China, Hungary, Romania, and Yugoslavia.

GSP	Item	Stat. Suffix	Articles	Units of Quantity	Rates of Duty 1	Rates of Duty LDDC	Rates of Duty 2
			Subpart B. - Elevators, Winches, Cranes, and Related Machinery; Earth-Moving and Mining Machinery				
			Subpart B headnotes:				
			1. This subpart does not cover — (i) cranes or other machines mounted on vehicles, on vessels or other floating structures, or on other transport equipment (see part 6 of this schedule); or (ii) agricultural implements (see subpart C of this part).				
			Mechanical shovels, coal-cutters, excavators, scrapers, bulldozers, and other excavating, levelling, boring, and extracting machinery, all the foregoing, whether stationary or mobile, for earth, minerals, or ores; pile drivers; snow plows, not self-propelled; all the foregoing and parts thereof:				
A	664.06	00	Peat excavators	No.	2.5% ad val.	Free	35% ad val.
A	664.07		Backhoes, shovels, clamshells, draglines, and wheel-type front-end loaders		3.5% ad val.	2% ad val.	35% ad val.
		10	Backhoes, shovels, clamshells and draglines	No.			
		20	Wheel-type front-end loaders	No.			
A	664.08		Other		3.8% ad val.	2.5% ad val.	35% ad val.
		10	Drilling or boring machines	No.			
		20	Tracklaying-type front-end loaders	No.			
		30	Other machines	No.			
		40	Parts (including parts for articles provided for in items 664.06 and 664.07)	X			
A	664.10		Elevators, hoists, winches, cranes, jacks, pulley tackle, belt conveyors, and other lifting, handling, loading, or unloading machinery, and conveyors, all the foregoing and parts thereof not provided for in item 664.06, 664.07, or 664.08		3.5% ad val.	2% ad val.	35% ad val.
		05	Industrial robots	No.			
			Other:				
		15	Elevators, including freight, and moving stairways	No.			
			Conveyors:				
		25	Belt	No.			
		31	Other	No.			
		44	Hoists	No.			
		55	Overhead traveling cranes	No.			
			Jacks:				
		56	Hydraulic	No.			
		57	Other	No.			
		59	Winches	No.			
		60	Other, except parts	No.			

Note: For explanation of the symbol "A" or "A*" in the column entitled "GSP", see general headnote 3(c).

G S P	Item	Stat. Suf-fix	Articles	Units of Quantity	Rates of Duty 1	Rates of Duty LDDC	Rates of Duty 2
A	678.35		Machines used for molding or otherwise forming rubber or plastics articles, and parts thereof..................	....	4.7% ad val.	3.9% ad val.	35% ad val.
		10	Machines used for molding or otherwise forming pneumatic tires..................................	No.			
			Other machines:				
			Injection-molding machines:				
		15	Of a type used for processing rubber or other thermosetting materials.........	No.			
		17	Of a type used for processing thermo-plastics materials.......................	No.			
			Extrusion machines:				
		22	Of a type used for processing rubber or other thermosetting materials.........	No.			
		24	Of a type used for processing thermo-plastics materials.......................	No.			
		35	Blow-molding machines.........................	No.			
		45	Other...	No.			
			Parts:				
		55	Of machines used for molding or otherwise forming pneumatic tires......................	X			
		70	For injection-molding machines................	X			
		75	For extrusion machines........................	X			
		80	For blow-molding machines.....................	X			
		85	Other...	X			
A	678.40	00	Automatic vending machines, and parts thereof...........	X.......	4.7% ad val.	3.9% ad val.	35% ad val.
A	678.45		Tobacco leaf stripping or cutting machines; industrial cigar- or cigarette-making machines, whether or not equipped with an auxiliary packaging device; all the foregoing and parts thereof..........................	....	5.1% ad val.	4.2% ad val.	35% ad val.
		20	Industrial cigarette-making machines...............	No.			
		40	Parts of the foregoing.............................	X			
		60	Other..	X			
	678.48	00	Flight simulating machines and parts thereof............	X.......	Free		35% ad val.
A*	678.50		Machines not specially provided for, and parts thereof..	....	4.4% ad val.	3.7% ad val.	35% ad val.
			Audio tape players:				
		01	Designed exclusively for motor-vehicle installation..................................	No.			
			Other:				
		03	AC only..................................	No.			
			Other:				
		05	Without speakers, other than headphones, earphones or headsets............................	No.			
		07	Other..............................	No.			
			Combination machines containing tape players:				
			Radio-tape player combinations:				
			Designed exclusively for motor-vehicle installation:				
		09	Cartridge type......................	No.			
		12	Other, including cassette............	No.			
			Other:				
		55	Not capable of battery operation..........................	No.			
			Other:				
		59	Without speakers other than headphones, earphones and headsets...................	No.			
		61	Other..........................	No.			

Note: For explanation of the symbol "A" or "A*" in the column entitled "GSP", see general headnote 3(c).

GSP	Item	Stat. Suffix	Articles	Units of Quantity	Rates of Duty 1	Rates of Duty LDDC	Rates of Duty 2
A*	678.50 (con.)		Machines not specially provided for, and parts thereof (con.):				
			Combination machines containing tape players (con.):				
			Phonograph-tape player combinations and radio-phonograph-tape player combinations:				
			Radio-phonograph-tape player combinations:				
		65	Cartridge type	No.			
		66	Other	No.			
		67	Other	No.			
		72	Combinations incorporating a Citizens Band (CB) transceiver	No.			
		75	Other	X			
			Other:				
			Industrial robots and parts thereof:				
		86	Robots	No.			
		87	Parts	X			
		95	Other	X			
	678.51	00	If Canadian article and original motor-vehicle equipment (see headnote 2, part 6B, schedule 6)	X	Free		

Subpart J. - Parts of Machines

Subpart J statistical headnote:

1. For the purposes of statistical reporting of ball bearings provided for under item 680.37, a radial bearing is one primarily designed to support its load perpendicular to the shaft axis.

GSP	Item	Stat. Suffix	Articles	Units of Quantity	Rates of Duty 1	Rates of Duty LDDC	Rates of Duty 2
A	680.05	00	Molding boxes for metal foundry	No.	7.6% ad val.	5.7% ad val.	45% ad val.
A	680.07	00	Molders' patterns for the manufacture of castings	No.	5.1% ad val.	4.2% ad val.	50% ad val.
			Molds of types used for metal (except ingot molds), for metallic carbides, for glass, for mineral materials, or for rubber or plastics materials:				
			Molds used for rubber or plastics materials:				
	680.11	00	Shoe machinery molds	No.	Free		Free
A	680.12		Other		4.7% ad val.	3.9% ad val.	35% ad val.
		10	Injection	No.			
		15	Compression	No.			
		20	Blow	No.			
		25	Bladder operated (tire)	No.			
		30	Other	No.			

Note: For explanation of the symbol "A" or "A*" in the column entitled "GSP", see general headnote 3(c).

G S P	Item	Stat. Suf-fix	Articles	Units of Quantity	Rates of Duty 1	Rates of Duty LDDC	Rates of Duty 2
A	683.65	00	Electric lighting equipment designed for motor vehicles, and parts thereof	X	2% ad val.	Free	25% ad val.
	683.66	00	If Canadian article and original motor-vehicle equipment (see headnote 2, part 6B, schedule 6)	X	Free		
			Portable electric lamps with self-contained electrical source, and parts thereof:				
A*	683.70	00	Flashlights and parts thereof	No.	30% ad val.	25% ad val.	35% ad val.
A*	683.80	00	Other	X	10.3% ad val.	6.9% ad val.	40% ad val.
			Industrial and laboratory electric furnaces and ovens; electric induction and dielectric heating equipment; electric welding, brazing, and soldering machines and apparatus and similar articles for cutting, and parts thereof:				
A	683.90		Welding machines and apparatus, and parts thereof		3% ad val.	2% ad val.	35% ad val.
		05	Industrial robots	No.			
			Other:				
			Arc welding machines:				
			Non-rotating type:				
		10	AC transformer type	No.			
		20	Other	No.			
		30	Rotating type	No.			
		40	Other welding machines and apparatus	No.			
		50	Parts	X			
A	683.95		Other		3.8% ad val.	2.5% ad val.	35% ad val.
		20	Furnaces and ovens, and parts	X			
		30	Induction and dielectric heating equipment, and parts	X			
		50	Soldering irons and guns and other soldering machines, and parts	X			
		70	Other	X			

Note: For explanation of the symbol "A" or "A*" in the column entitled "GSP", see general headnote 3(c).

Appendix E

Reasons for Purchasing Domestic and Foreign Robots

Table E-1.--Robots: Reasons cited by U.S. purchasers for acquiring robots from domestic sources

Reasons for domestic purchases	Robots							
	Spot welders	Arc welders	Coat- ers	Assem- blers	Material handlers	Metal work- ing appara- tus	Loaders unload ers	Other
Lower purchase price (delivered)	28	14	21	35	77	7	119	35
Servicing/Training	98	35	49	56	105	14	154	56
Favorable financing terms	0	7	0	0	7	0	7	0
Favorable warranties	28	14	14	7	14	7	28	14
Performance features:								
Superior design	35	21	35	70	84	28	119	63
Higher productivity (man-hour out- put ratio	0	0	0	21	21	0	7	0
More durable	49	14	0	21	49	0	56	21
Less maintenance	28	0	0	7	28	0	35	0
Energy efficiency	7	0	0	0	0	0	14	0
Other (specify)	21	0	0	28	49	14	28	21
Other (specify)	21	0	0	14	63	0	35	14
Shorter delivery time	35	14	0	21	28	7	56	42
Availability	77	21	28	56	63	21	119	63
Supplier relationship	63	35	28	14	49	7	77	35
Ability to add to or upgrade robot capability	28	7	14	14	28	7	42	14
Availabity of spare parts	98	28	49	49	112	21	161	63
Compatibility with existing systems	21	35	14	7	49	0	63	21
Changeover time (for different production runs)	7	0	7	0	7	0	7	7
Lower installation costs	0	0	0	0	21	0	7	7

Source: Compiled from data submitted in response to questionnaires of the U.S. International Trade Commission.

Table E-2--Robots: Reasons cited by U.S. purchasers for acquiring robots from foreign sources

Reasons for foreign purchases	Robots							
	Spot welders	Arc welders	Coat-ers	Assem-blers	Material handlers	Metal-work ing appara-tus	Loaders unload-ers	Other
Lower purchase price (delivered)	21	14	35	77	70	28	119	35
Servicing/Training	0	7	21	7	14	0	21	7
Favorable financing terms	0	0	0	7	7	0	0	0
Favorable warranties	7	0	7	0	0	0	0	0
Performance features:								
Superior design	7	21	49	56	56	0	70	42
Higher productivity (man-hour out- put ratio	7	14	7	28	14	7	28	7
More durable	7	0	7	35	14	0	42	14
Less maintenance	7	14	7	35	14	0	49	21
Energy efficiency	14	0	0	7	7	0	14	7
Other (specify)	14	7	7	7	14	7	7	21
Other (specify)	14	21	14	7	14	0	14	0
Shorter delivery time	21	7	21	7	14	7	21	21
Availability	7	21	28	28	21	14	42	28
Supplier relationship	14	0	7	28	42	0	42	21
Ability to add to or upgrade robot capability	7	14	21	21	7	0	14	7
Availabity of spare parts	0	7	7	14	7	0	7	7
Compatibility with existing systems	0	0	42	7	7	0	28	7
Changeover time (for different production runs)	0	0	14	0	0	7	0	0
Lower installation costs	0	7	21	21	7	0	14	7

Source: Compiled from data submitted in response to questionnaires of the U.S. International Trade Commission.

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