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PREFACE

The *Industry, Trade, and Technology Review* (*ITTR*) is a quarterly staff publication of the Office of Industries, U.S. International Trade Commission. The opinions and conclusions it contains are those of the authors and do not necessarily reflect the views of the Commission or of any individual Commissioner. The report is intended to provide analysis of important issues and insights into the global position of U.S. industries, the technological competitiveness of the United States, and implications of trade and policy developments.

Inquiries or comments on items appearing in this report may be made directly to the author, or to:

Director of Industries
Industry, Trade, and Technology Review
U. S. International Trade Commission
500 E Street, SW
Washington, DC 20436
Fax: 202-205-3161

Requests for copies of the *ITTR*, or to be added to the mailing list, should be address to the Office of the Secretary, U.S. International Trade Commission, 500 E Street SW, Washington, DC 20436, or by fax: 202-205-2104

Quarterly Review Staff

Larry Brookhart
Robert Hughes

assisted by

Zema Tucker
Sharon Greenfield

Contributing Authors

Christopher Johnson
John Kitzmiller
Karl S. Tsuji
Elizabeth Howlett

Robert A. Rogowsky
Director of Operations

Vern Simpson
Director of Industries

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Free Trade in Information Technology Goods

Christopher Johnson
(202) 205-3488
cjohnson@usitc.gov

John Kitzmiller
(202) 205-3387
kitzmiller@usitc.gov

One of the goals of the United States in the Uruguay Round of multilateral trade negotiations was the elimination, on a reciprocal basis, of all duties in certain product sectors, including the electronic goods sector. The U.S. proposal was known as the "Zero-for-Zero" initiative. Although, certain major U.S. trading partners shared similar objectives in many of these sectors, this goal was not realized for the electronics sector.

Subsequently, in January 1995, the information technology (IT) industry associations of the United States, Europe, and Japan recommended a framework for an information technology agreement that would eliminate most tariffs in the IT sector. Following negotiations, agreement was reached to phase out duties on most information technology products. The agreement, known as the Information Technology Agreement (ITA),[1] was signed by 28 countries and customs territories, including the United States, during the World Trade Organization (WTO) Ministerial meeting in Singapore in December 1996. As of December 1997, the ITA had been adopted by 43 countries representing approximately 93 percent of world trade in information technology products.[2] The agreement requires participants to eliminate their tariffs by January 1, 2000, on a specific list of IT products contained in an annex to the Ministerial Declaration. These products include computers, telecommunications equipment, computer software, semiconductors, and other electronic components and equipment. This article provides background information on the ITA and analyzes the effects it is likely to have on market access for the U.S. electronics industry.

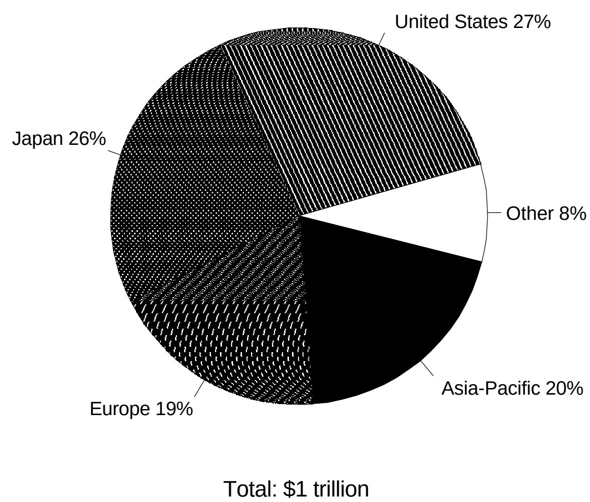
The United States is the global leader in the manufacture of IT products. U.S. production of electronic equipment and components amounted to $274 billion, representing 27 percent of the

[1] For further information on the Information Technology Agreement, see U.S. International Trade Commission (USITC) *Advice Concerning the Proposed Modification of Duties on Certain Information Technology Products and Distilled Spirits*, USITC publication 3031, Apr. 1997.

[2] The participants are Australia, Canada, Costa Rica, Czech Republic, El Salvador, Estonia, European Union (15), Hong Kong, Iceland, India, Indonesia, Israel, Japan, Korea, Liechtenstein, Macao, Malaysia, New Zealand, Norway, Philippines, Poland, Romania, Singapore, Slovak Republic, Switzerland, Taiwan, Thailand, Turkey, and the United States. USITC staff interview with Office of the United States Trade Representative (USTR), December 3, 1997.

world total of $1 trillion in 1996.[3] However, the U.S. IT industry faces strong competition from Japanese, European, and emerging Asian electronic producers for leadership in this important high-technology industry (figure 1). Further, despite its global leadership in production, the United States has sustained a trade deficit in electronics products. In 1996, U.S. imports totaled $179 billion, while U.S. exports amounted to $136 billion, resulting in a trade deficit of $43 billion (figure 2).[4]

Figure 1
Share of world electronics production, 1996

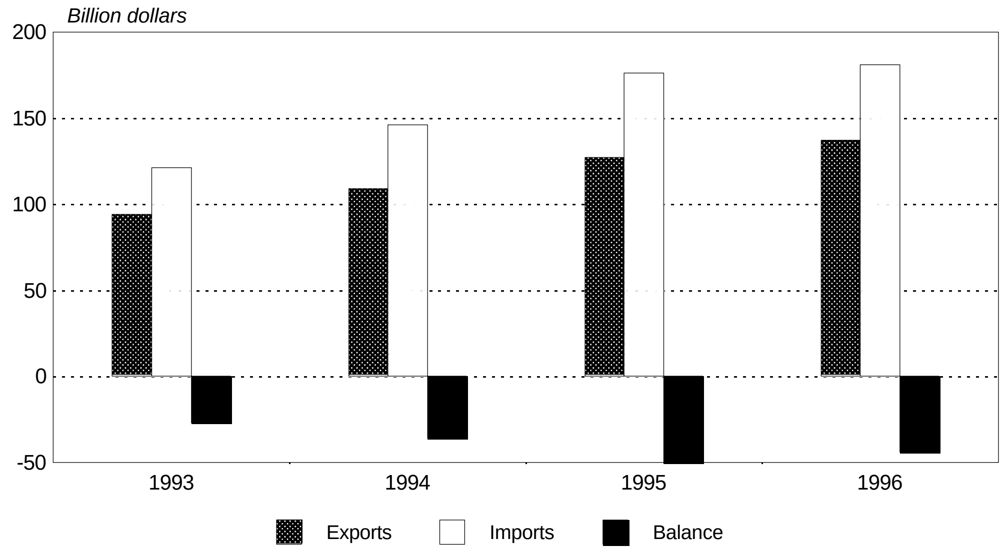


Source: Elsevier, *Yearbook of World Electronics Data*, 1996.

[3] *Yearbook of World Electronics Data 1996* (Oxford, Elsevier Advanced Technology, 1996), Vol. 3, table 2.3.4., p. 13.

[4] Compiled from official statistics of the U.S. Department of Commerce.

Figure 2
U.S. trade balance in information technology products, peripherals, and components, 1993-96



Source: Compiled from official statistics of the U.S. Department of Commerce.

A large portion of the U.S. trade deficit in electronic products is due to the global interdependence of the industry. In today's intensely price-competitive market, U.S. manufacturers rely increasingly on internationally sourced components, foreign production and sales facilities, and strategic joint ventures to enhance their market position. For example, a typical personal computer (PC) designed and manufactured in the United States may contain a floppy drive from Japan, a display monitor produced in Korea, a motherboard from Taiwan, and a hard disk drive manufactured in Singapore. Suppliers of these components may be overseas subsidiaries of U.S. companies or foreign-based companies. In general, the strengths of the U.S. IT industry are in high-value-added activities, such as software, microprocessors, and product design. Final product assembly and production of commodity electronic components and peripherals is largely done abroad, particularly in the rapidly emerging East Asian countries where wage costs are lower.

The ability of electronic producers to reduce costs by securing high-quality products anywhere in the world at the lowest possible prices has become a major competitive factor in the global market. The elimination of trade barriers such as tariffs that increase IT suppliers' relative costs in principal foreign markets can play an important part in improving competitive ability. Although tariffs on many electronic products, such as finished computers and systems, have been reduced significantly or eliminated among major IT-producing countries, remaining tariffs on semiconductors and other important electronic parts and components continue to be regarded as impediments (table 1). For example, in Europe, both U.S. and European

Table 1
Final Uruguay Round tariff rates, effective January 1, 1999, scheduled to be eliminated by the ITA, except as noted, by market and sector

Sector	Markets			
	United States	European Union	Japan	Other Markets
Computers	0-2.4 percent	0-2.5 percent	free	Brazil 15-35 percent [1] Canada free China 9-50 percent [2] India 40 percent Indonesia 40 percent
Software	0-4.8¢/m^2 of recording surface	0-3.5 percent	free	Indonesia 40 percent Korea 13 percent Malaysia 5-10 percent Singapore 1-10 percent Thailand 30 percent
Unrecorded media	free	0-3.5 percent	free	Singapore 0-10 percent Indonesia 40 percent Malaysia 5-20 percent
Telecommunications	0-8.5 percent	0-8 percent	free	Canada 0-8.7 percent Korea 6-13 percent Malaysia 5-30 percent Thailand 5-30 percent
Semiconductors	free	0-14 percent	free	Korea free Taiwan 1-2 percent [3]
Printed circuits	2.7 percent	4.5 percent	free	Taiwan 7.5 percent
Capacitors	3.5-9 percent	2.7-3.7 percent	free	Korea 13 percent Singapore 10 percent China 15-40 percent [2] Taiwan 1.25-12.5 percent[3]
Resistors	0-6 percent	2.7 percent	free	Korea 13 percent Singapore 10 percent China 15-40 percent[2] Taiwan 1.25-12.5 percent[3]
Office machines	0-1.9 percent	0-6 percent	free	Canada 0-2.6 percent Brazil 20-35 percent[1]
Semiconductor manufacturing and testing equipment	free	0-6.7 percent	free	Thailand 5-40 percent Indonesia 5-40 percent China 15-40 percent[2]
Measuring, testing, analyzing instruments	0-3.5 percent	0-4.2 percent	free	Korea 8-13 percent Taiwan 0-12.5 percent
Silicon wafers	free	6.5 percent	free	India 8 percent Australia 8 percent

[1] Brazil is not a signatory to the ITA, therefore, this duty will not be eliminated.
[2] China is not a signatory to the ITA, therefore, this duty will not be eliminated. All tariff rates for China are unbound as China is not a member of the WTO.
[3] All tariff rates for Taiwan are unbound as Taiwan is not a member of the WTO; however, Taiwan is a signatory to the ITA.
Source: Compiled by the staff of the USITC.

computer anufacturers increasingly have criticized relatively high EU tariffs on certain semiconductors and other electronic components.[5]

ITA Initiative

The elimination of tariffs on electronic products was a major U.S. objective in the Uruguay Round negotiations of the General Agreement on Tariffs and Trade (GATT). That sector was included as one of the so called "zero-for-zero" sectors in which U.S. trade negotiators hoped to achieve total elimination of tariffs by major trading partners. However, although complete duty elimination was achieved in a number of product sectors, agreement was not reached in the electronics sector despite strong support by business interests in the United States, the EU, Japan, and Canada. In view of continued U.S. support for tariff elimination in a number of sectors, including electronics, the *Uruguay Round Agreements Act* (URAA)[6] authorized the President to continue negotiations in the electronics sector.[7]

In January 1995, the IT industry associations of the United States, Europe, and Japan[8] agreed to a set of industry recommendations to the G-7 meeting in Brussels on the Global Information Infrastructure (GII). One of their key recommendations was to eliminate tariffs on most products in the IT sector through the adoption of an ITA.[9] As a follow-up, U.S. and EU business and industry leaders, meeting in Seville in November 1995 for the Trans-Atlantic Business Dialogue (TABD), urged their political leaders to vigorously pursue the ITA the following month in Madrid, when they were to discuss revitalization of the Trans-Atlantic partnership.[10] On December 3, 1995, President Clinton and leaders of the EU announced an

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[5] European industry and trade association officials, interviews by USITC staff, Frankfurt, Munich, Ivrea, Paris, and London, May 6-24, 1993; European Association of Manufacturers of Business Machines and Information Technology (Eurobit), *European IT Competitiveness in a Distorted Market Environment: Consequences of EC - 14% - Tariff on Semiconductors for European Information Technology Manufacturers* (Frankfurt: Eurobit, 1991); *European Information Technology Observatory 1996* (Frankfurt: European Economic Interest Grouping, 1996), pp. 10-40; and Eurobit, "U.S. and European Industry of Information and Communications Technology Agree On Total Removal of Tariff Barriers," *Press Release*, May 2, 1996, p.1.

[6] Uruguay Round Agreements Act (URAA), Public Law 103-465, 108 Stat. 4809, Dec. 8, 1994.

[7] The SAA, for example, cited the partial success achieved in the negotiations to eliminate tariffs in some sectors, but noted that this objective was not met in the electronics sector and certain other sectors. The SAA declared that "obtaining further reductions and elimination of duties in these sectors is a priority objective for U. S. multilateral, regional, and bilateral negotiations." Statement of Administrative Action, House Document No. 103-316, Vol. 1, pp. 700-03.

[8] Information Technology Industry Council (ITI), European Association of Manufacturers of Business Machines and Information Technology Industry (Eurobit), and Japan Electronic Industry Development Association (JEIDA).

[9] Information Technology Industry Association, *Industry Recommendations for an Information Technology Agreement*, Apr. 1996.

[10] Over 100 U.S. and European business leaders met in Seville, Nov. 10-11, 1995, to conduct a Trans-Atlantic Business Dialogue aimed at improving the Trans-Atlantic marketplace, strengthening the multilateral system, and preparing concrete recommendations on how to boost trade and investment across the Atlantic. U.S. Department of State telegram, "Trans-Atlantic Business Dialogue: Commission Press Preview on Seville Conference," message reference No. 011442, prepared by U.S. Mission to EU, Brussels, Nov. 7, 1995.

initiative known as the New Trans-Atlantic Agenda (NTA), which set up a framework for U.S.-EU cooperation in several areas and called for a number of actions to further common U.S.-EU interests, including cooperation in the areas of economics and trade.[11] Among other things, the political leaders announced recommendations closely tracking those previously urged by business leaders with regard to an ITA that would eliminate most tariffs in the electronics sector.[12]

The ITA obtained an important endorsement from the leaders of the Asia-Pacific Economic Cooperation (APEC) forum[13] economies meeting in the Philippines on November 25, 1996, who called for the conclusion of an "information technology agreement by the WTO Ministerial Conference that would substantially eliminate tariffs by the year 2000, recognizing the need for flexibility as negotiations in Geneva proceeded."[14] An ITA was drafted during the Ministerial meeting in Singapore in December 1996 and a Ministerial Declaration on Trade in Information Technology Products was issued on behalf of representatives of countries accounting for well over 80 percent of world trade in these products. By December 1997, the ITA covered 43 countries representing approximately 93 percent of world trade in information technology products. Table 2 illustrates some of the major product groupings covered by the agreement.

Potential Benefits of the ITA

The ITA has received broad public support among U.S. IT industry representatives.[15] Many organizations assert that an agreement eliminating tariffs on electronics products and components will accelerate the globalization process already underway, further expanding

[11] The text of the Trans-Atlantic Agenda is reprinted in *U.S. Department of State Dispatch*, Dec. 4, 1995, vol. 6, No. 49, pp. 894-897.

[12] Ibid; and U.S. Chamber of Commerce, International Division, *The Future of Trans-Atlantic Trade Relations: A U.S. Business Perspective*, Nov. 1995; "Trans-Atlantic Business Dialogues, Overall Conclusions," summary reprinted in *Washington Trade Daily*, Dec. 8, 1995, full final text provided by the U.S. Department of Commerce; and U.S. Department of State, Bureau of Public Affairs, "Fact Sheet: The New Trans-Atlantic Agenda," Dec. 1995.

[13] APEC was established in 1989 as an informal forum to promote economic cooperation in the Pacific Rim region. Since that time, APEC has expanded its membership, developed into a more formalized institution with a Secretariat located in Singapore, and adopted an ambitious trade agenda. Membership in APEC numbers 18 economies: Australia, Brunei, Canada, Chile, the People's Republic of China, Hong Kong, Indonesia, Japan, Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, the Philippines, Singapore, Taiwan, Thailand, and the United States.

[14] Mark Felsenthal, "APEC Leaders Urge Conclusion of Information Technology Pact," *BNA International Trade Daily*, Nov. 26, 1996, pp. 1-3.

[15] Industry representatives issuing statements in support of APEC's endorsement of the ITA on Nov. 25, 1996, included Michael Maibach, Vice-President for Government Affairs, Intel Corp.; Eric Nelson, Vice President of the Telecommunications Industry Association; Chris Padilla, Vice President, Lucent Technologies, Inc; Jeff Wier, Vice President, Software Industry Association; Thomas Ehrgood, trade counsel to Digital Equipment, Corp.; Joseph Tasker Jr., Vice President for Federal Government Affairs, Compaq Computer Corp.; the Software Publishers' Association; the Information Technology Industry Council; the Electronics Industry Association; and the American Electronics Association.

Table 2
Product landscape: Major products covered by the Information Technology Agreement

Computer Hardware	Computer Software	Semiconductors and Electronic Components
PCs Workstations Minicomputers Mainframes Supercomputers CPUs Keyboards Displays Printers Bridges Routers	Diskettes Floppy disks Magnetic tapes CD-Roms Application software Multimedia software	Microprocessors Microcontrollers Memory devices Discrete devices Diodes Laser devices Optoelectronic devices Passive components Linear circuits Smart cards Printed circuit board assemblies Capacitors Resistors
Telecommunications Equipment	**Semiconductor Manufacturing and Test Equipment**	**Other Electronic Products**
Switching equipment Multiplexers Facsimile machines Telephone sets Telephone answering devices Voice messaging equipment Cellular phones Cellular transmission systems Satellite network equipment	Wafer stepper aligners Wafer handlers Ion implanters Thermal processors Grinding machines Polishing machines Epitaxial deposition machines Laser cutters Certain microscopes Clean room equipment	Analytical instruments Certain office machines Digital photocopiers Indicator panels Automatic teller machines Electronic translators

Source: World Trade Organization, *Ministerial Declaration of Trade in Information Products*, Singapore, Dec. 13, 1996.

two-way trade between the United States and its principal trading partners in a large variety of these products.[16] They also state that elimination of remaining tariffs by principal trading partners in this industry will benefit U.S. producers by enabling them to become more price-competitive in foreign markets where tariffs are still relatively high and thereby improve global market access for their products.[17]

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[16] American Electronics Association (AEA), "AEA Scores Big Victory with Free Trade in Information Technology," *AEA IMPACT*, Jan./Feb. 1997; "Cisco Systems Supports Information Technology Agreement to Eliminate Tariffs on Networking and Telecommunications Equipment," *News Release*, Dec. 13, 1996; IBM, "IBM Australia Chief Applauds Government Support of Information Technology Agreement," *IBM Information in Australia*, Aug. 6, 1997, p. 1; and John M. Peterson, "The Information Technology Agreement: A Major Advancement for Free Trade," *Exporter*, Jan. 1997, pp. 1-4.

[17] ITI, "The Information Technology Agreement: A Proposal of the Information Technology Industry Council," *ITI Online: Public Policy*, 1996, p. 4.

The elimination of tariffs on IT products should result in increased market access in all of the participating countries in the ITA. In the United States, tariffs are relatively low in most IT sectors and it is unlikely the ITA will dramatically increase access to these U.S. markets. The ITA would liberalize access significantly in a few sectors where tariffs are higher, specifically capacitors, resistors, and certain telecommunications equipment.

The effect of IT tariff elimination in the EU is likely to be more significant, since EU tariffs are higher than U.S. tariffs on a number of products. Suppliers of capacitors, resistors, silicon wafers, office machines, telecommunications equipment, and most unrecorded media to the EU market are all likely to benefit from the tariff eliminations of the ITA. Further, improved access to the EU market will likely become more important over time because of the addition of new members. While the EU presently consists of 15 members, 13 other countries have applied for membership.[18] As additional countries join the EU, they must adopt the common EU tariff schedule and agree to abide by trade agreements entered into by the EU, thus offering the same market access as the EU.

Despite recent economic concerns, some of the greatest opportunities for increased market access may be in the developing nations of Asia. The rapidly expanding economies, large populations, expansion of communications infrastructures, and growing disposable income in Asia will multiply the importance of trade in IT products. The largest potential markets in Asia are India and Indonesia, where most duties are between 30 and 40 percent; Malaysia and Korea, ranging as high as 30 percent; Taiwan, between 5 and 15 percent; and Singapore, with duties as high as 10 percent. Japan and Hong Kong are the only major participants in which there should be little or no change in market access as a result of ITA tariff elimination, since the final Uruguay Round tariffs of zero on IT products for both of those countries are to be fully implemented by January 1, 1999.

The increased market access due to the ITA should largely benefit the U.S. industry.[19] The United States currently has the most competitive IT industry in the world, with the broadest range of products and most advanced technology. Thus, U.S. companies generally should fare better than competitors in more open markets, where trade-distorting tariffs are not a factor. In addition, U.S. companies also are likely to benefit from elimination of the remaining U.S. tariffs on electronic components used in domestic production. In the increasingly price-sensitive global IT market, successful companies have found it necessary to outsource components that they cannot manufacture domestically on a competitive basis. Elimination of remaining U.S. tariffs on many components will enable U.S. high-technology producers to procure high-quality components at the lowest cost anywhere in the world and allow U.S. electronics producers to concentrate on their core competencies in designing and manufacturing high value-added, finished products.[20]

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[18] Europa, http://europa.eu.int/en/agenda/appmen.html, March 10, 1997. The 13 countries are Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia, Switzerland, and Turkey.

[19] U.S. and European industry representatives and investment analysts, telephone interviews by USITC staff, Aug. 7, 1996 and Dec. 5, 1997.

[20] U.S. industry representatives, telephone interviews by USITC staff, Aug. 6-7, and Oct. 25-26, 1996.

Remaining Obstacles

The ITA will increase market access opportunities; however, some areas still need improvement. For example, several of the fastest growing developing country markets in the world for IT are not signatories to the ITA, and thus have not committed to full market access for participants in the agreement. China is widely regarded as having significant market opportunities for IT products, but is not a signatory to the ITA. Although market opportunities in Brazil have improved recently because of strengthened intellectual property rights protection, elimination of informatics restrictions, and lowering of other restrictions such as export requirements, suppliers continue to face relatively high Brazilian tariffs.

Further, the benefits of duty elimination as a result of the ITA could be tempered by nontariff barriers in any country.[21] Anticompetitive practices, nontransparent government procurement, inadequate intellectual property rights protection, discriminatory standards measures, and customs reclassification are among the measures that have impeded foreign market access for IT products in the past and could affect trade in the future. For example, representatives of the U.S. capacitor industry have alleged that they will not benefit from an ITA solely focused on the elimination of customs duties. U.S. capacitor and resistor manufacturers contend that U.S. tariffs are essential for protection against countries such as Japan and Korea which are alleged to have erected highly effective nontariff barriers.[22] U.S. producers allege that anticompetitive practices in certain Asian countries allow foreign competitors to take market share away from U.S. companies. Therefore, U.S. manufacturers assert that the U.S. Government should pressure Asian countries to eliminate nontariff measures that restrict access to their markets from U.S. producers before reducing U.S. tariffs.[23]

Similarly, U.S. producers of certain telecommunications equipment pointed out that while the ITA was designed to deal with tariff barriers, “the barriers to exports are not tariffs but nontariff barriers.”[24] Some of the largest potential export markets, such as Japan, have zero tariffs on these products but market penetration for foreign producers remains low. Some of the nontariff measures cited include (1) cartel-like behavior by firms that excludes imports, (2) government procurement that demonstrates a preference for domestically manufactured products, (3) investment performance requirements that link market access to the transfer of technology and investment in the home market, and (4) the discriminatory application of standards and product certification procedures.[25]

[21] ITI, "Hi Tech Coalition Submits Recommendations to USTR on Next Round of ITA Negotiations,” *News Release*, Sept. 30, 1997, pp. 1-2.

[22] U.S. industry representatives, telephone interview by USITC staff, May 21, 1997; and Gina Roos, “ITC Takes Note of ITA Challenge,” *Electronic Buyers’ News*, May 19, 1997, pp. 34-36.

[23] Ibid.; and Bettyann Liotta, “Cap Makers to Sue USTR--U.S. companies Seeking Injunction on ITA, *Electronic Buyers’ News*, pp. 1-3, Apr. 11, 1997.

[24] "Spirted Talks Help Uncork Global High-Tech Trade,” Journal of Commerce, Dec. 13, 1996, p. 14; Seth Schiesel, “Still a Long Road for Freer Global Technology Trade, New York Times, Dec. 21, 1996, pp. 37-39; and U.S. industry representatives, telephone interviews by USITC staff, Feb. 10-12, 1997.

[25] Division Vice President and Director of Public Policy, Corning, Inc., “The Other Side of the ITA,” Testimony Before the House Ways and Means Committee, Subcommittee on Trade, 1997.

U.S. industry officials also have expressed concern about recent tariff decisions in Europe that have reclassified certain electronics products into higher tariff classifications, some of which fall outside the ITA.[26] For example, early in 1996, the United Kingdom and Ireland reclassified local area network (LAN) equipment as telecommunications equipment, subject to higher duty rates, which are scheduled to be eliminated under the ITA. In addition, PCs with television capabilities were reclassified as television receivers, which are not covered by the ITA and have higher duty rates than PCs. The UK and Ireland are alleged to use customs classification procedures to achieve protection for their consumer electronics sectors.[27] Due to these classification issues, U.S. industry representatives were adamant that a successful ITA must provide certainty regarding tariff treatment, such that elimination of tariffs on products covered by the ITA cannot be erased by arbitrary customs classification practices or decisions that place products into categories not covered by the ITA.[28]

Outlook

Information technology and the ability to use it efficiently are universally considered fundamental to global economic growth and welfare.[29] International trade in information technology products plays a key role in the development of the information industries themselves and in the dynamic expansion of the global economy. For example, the World Bank estimates that the world's economies will require $1.5 trillion in capital over the next decade for high-quality infrastructure, advanced information technology, and telecommunications systems.[30] In such a global market, "tariff barriers are an anachronism."[31] The ITA was described as the first concrete demonstration of the WTO's ability to move forward in concert with these realities of the changing world around us.[32]

More countries are expected to join the ITA. Egypt, Guatemala, and Panama have all indicated their intention to join the ITA. Further, countries currently negotiating accession to the WTO, such as China and Russia, likely will face IT tariff liberalization and market access requirements as conditions of membership in that body.[33] Market access opportunities for exporters of IT

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[26] Mark Felsental, "Despite Information Technology Accord, U.S., EU at Odds Over Computer Equipment," *BNA International Trade Daily*, Mar. 27, 1997, p. 1; and Office of the United States Trade Representative, "ITA a Done Deal!," *Press Release*, Mar. 26, 1997, p. 2.

[27] "Info Tech Agreement: Background for Embassy Information," U.S. Department of State Cable 181609, Aug. 7, 1996.

[28] Ibid.; and ITI, "ITA Negotiations at a Critical Juncture," *News Release*, Sep 11, 1996, pp. 1-3.

[29] WTO Ministerial Declaration on Trade in Information Technology Products, Singapore, Dec. 13, 1996; ITI, "The Information Technology Agreement: A Proposal of the Information Technology Industry Council," *ITI Online: Public Policy*, 1996, p. 4; and European Information Technology Observatory 1996 (Frankfurt: European Economic Interest Grouping, 1996), pp. 10-40.

[30] World Bank estimate, 1997.

[31] Eurobit, "U.S. and European Industry of Information and Communications Technology Agree for Total Removal of Tariff Barriers," *EUROBIT Press Release*, May 2, 1996, pp. 1-2.

[32] WTO Ministerial Declaration on Trade in Information Technology Products, Singapore, Dec. 13, 1996; and WTO, "Statement of the Honorable Charlene Barshefsky: Acting United States Trade Representative" (WTO/MIN(96)ST/5), Ministerial Conference, Singapore, Dec. 9, 1996.

[33] Chinese President Jiana Zemin expressed China's intention to join the ITA upon accession to the WTO in discussions with President Clinton in Washington, DC in October 1997. "Transcript of

(continued...)

products to those countries would be enhanced when accession to the WTO occurs if ITA participants are successful in obtaining duty reductions in products on the ITA product list from all countries acceding to the WTO.[34]

Increased market access would also be facilitated with expanded product coverage and the resolution of remaining product classification and nontariff issues in a series of follow-on discussions among ITA participants now being referred to as "ITA II."[35] The discussions, which began on September 30, 1997, focused on discrepancies between current tariff nomenclature and emerging technology that could affect the market access improvements of the ITA, new products that should be included in the ITA, and possible acceleration of duty reductions already agreed to. Discussions also included the possible expansion of the ITA to ensure a "tariff-free environment" for products and services delivered over the Internet, and on nontariff barriers affecting products already subject to the ITA, such as standards, testing, and certification measures that apply to IT products.[36] The goal of the ITA II discussions is to agree by September 1998 on a new list of products on which all duties, and nontariff barriers, will be eliminated by the year 2000.[37]

U.S. Government and industry representatives assert that a successful ITA should lead to greater market access and increased trade in the information technology industry while also benefitting other businesses by lowering costs, improving productivity, and expanding new services.[38] This is expected to happen because greater access to IT at lower prices is expected to stimulate the competitive ability of an increasing number of manufacturing and service industries that rely heavily on IT, including small- and medium-sized companies in all countries.[39] Information technology is also increasingly important for financial, retailing, health care, and numerous other service activities that are instrumental to the manufacturing sector.**#**

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[33] (...continued)
Clinton, Jiang Press Conference," *White House Press Release*, Oct. 29, 1997, p. 2.

[34] U.S. Department of State telegram, "Information Technology Agreement Meets Deadline," message reference No. 000615, prepared by U.S. Mission, Geneva, Feb. 3, 1997.

[35] Such discussions were foreseen in an annex to the original agreement that provides that participants in the ITA meet periodically to review the product coverage specified in the attachments to the agreement and consider whether, in the light of technological developments or experience in applying the tariff concessions, the product coverage should be modified to incorporate additional products; in addition, they should consult on non-tariff barriers to trade in information products. The annex further specifies that participants shall meet as often as necessary, but no later than September 30 1997, to consider any divergences among them in classifying information technology products. In this regard they agreed on the common objective of achieving, where appropriate, a common classification for these products, within existing HS nomenclature, giving consideration to interpretations and rulings of the World Customs Organization.

[36] Ibid.; "Global Information Tech Talks Move Ahead," *Journal of Commerce*, Dec. 5, 1997; and ITA Coalition, letter to Executive Secretary, USTR, Sept. 30, 1997.

[37] Ibid.

[38] U.S., European, and Japanese industry representatives, personal and telephone interviews by USITC staff, 1997. WTO, "Statement of the Honorable Charlene Barshefsky: Acting United States Trade Representative" (WTO/MIN(96)ST/5), Ministerial Conference, Singapore, Dec. 9, 1996; and EUROBIT, The European IT Industry Welcomes the Consensus Reached at the WTO Ministerial Conference in Singapore," *EUROBIT Press Release,* Dec. 13, 1996, pp. 1-2.

[39] "GBT/ITA," State 010500, Jan. 13, 1997.

Factors Affecting the Commercialization of New Manufacturing Processes for Materials

Karl S. Tsuji
(202) 205-3434
tsuji@usitc.gov

Commercializing innovative processing technologies to enhance industrial competitiveness has become an important consideration among both private-sector representatives and policy makers. By producing materials more efficiently or with superior properties, new manufacturing processes for materials (NMPM) may boost the competitiveness of a wide range of materials-using sectors of the economy. The economic potential of innovative technologies, and policy and regulatory actions promoting their commercialization, provide significant incentives to private firms considering NMPM as a means of keeping pace in an increasingly competitive marketplace. However, barriers to developing and adopting NMPM can be formidable because of economics, technical factors, corporate culture, and regulations. This article examines how these various factors promote or impede NMPM commercialization; highlights the diverse efforts of private industry, government, and academia to overcome existing barriers; and presents both public- and private-sector recommendations to improve the commercialization process for NMPM. This concludes the USITC series of ongoing Office of Industries research on NMPM, which is being compiled in a staff research study anticipated for release early in 1998.

> **Note**: A glossary of technical terms (highlighted within the article by ***bold italics***) appears at the end of this article.

New manufacturing processes for materials (NMPM) encompass both innovative manufacturing processes for producing materials and advanced materials that can result from such processes, and may be developed by a private firm, through collaborative efforts of several firms (***internal technology development***), or adopted from outside sources (***external acquisition of technology***). For example, sol-gel processing technologies produce materials with specialized mechanical and thermal properties from the gel state for various architectural and automotive applications.[1] NMPM also include improved production techniques for conventional materials, such as direct ironmaking technologies that avoid the increasingly costly

[1] Vincent DeSapio, "Sol-Gel: Industry Seeks to Commercialize Energy-Saving Technology for Existing and Emerging Markets," *Industry, Trade, and Technology Review*, USITC, Dec. 1995, pp. 13-26.

and hazardous coking process for steelmaking.[2] NMPM can even spur further technological advancements, as when increased use of aluminum, polymer composites, and other specialized lightweight materials in automobile designs prompted development of new bonding and joining technologies.[3]

Commercialization of innovative technologies is driven by two different, but related forces. Where firms seek technical solutions to specific needs, ***market pull*** provides the force for an invention to find a commercial application. For example, nylon was developed by the DuPont Chemical Company primarily in response to demand by hosiery manufacturers for a more plentiful and less-costly substitute for silk. In contrast, where innovators seek suitable end-use markets for innovations, ***technology push*** provides the underlying basis from which entirely new applications or markets are possible. DuPont successfully applied its Teflon polymer to numerous end uses, the two most familiar being nonstick surfaces on cookware and water-resistant but breathable Gore-Tex for outdoor clothing.

Advances in NMPM have revolutionized entire industries, often with dramatic impact upon markets and international trade. In the steel industry, for example, continuous casting of molten steel into slabs, as an alternative to the more capital- and labor-intensive conventional ingot-casting, was first commercialized around 1960; today, more than 80 percent of all molten steel produced in the Western world is continuously cast.[4] Refinement of continuous casting and scrap-based electric-arc furnace steelmaking technologies enabled lower-cost "mini-mills" to displace the conventional large-scale integrated mills in many bar, rod, and light-structurals markets by the late 1980s.[5] More recently, further process improvements to continuous casting enabled mini-mill penetration into the higher value-added plate, sheet, and coil markets, once the sole domain of the integrated mills.[6] Recognizing that invention, application, and dissemination of innovative technologies have an important role in enhancing growth in

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[2] Cheryl Badra, "Direct Ironmaking: a Case Study in Government and Industry Cooperation to Commercialize New Manufacturing Processes for Materials," *Industry, Trade, and Technology Review*, USITC, May 1995, pp. 31-42.

[3] Susan H. Lusi, "Alternative Materials in the U.S. Automotive Industry Promote Development of Joining and Bonding Technology," *Industry, Trade, and Technology Review*, USITC, Oct. 1997, pp. 13-23.

[4] Donald F. Barnett, "Harnessing New Technologies: Key to Winning," *Steel Survival Strategies XII, World Steel Dynamics* (Paine Webber, New York, NY, June 17, 1997), pp. 213-238.

[5] Mini-mills' shares of long-products shipments in the U.S. steel industry in 1990 were estimated at 83 percent for wire rods, 65 percent for merchant bars, 35 percent for cold-finished bars, and 100 percent for light-structural shapes. By 1997, estimated mini-mill shares for these products rose to 95 percent for wire rods, 78 percent for merchant bars, 55 percent for cold-finished bars, and 100 percent for structural shapes. Ibid.

[6] Mini-mill shares of flat-product shipments in the U.S. steel industry in 1997 were estimated at 40 percent for plate, 30 percent for hot-rolled sheet, 10 percent for cold-rolled sheet, and 12 percent for hot-dipped galvanized sheet. With the exception of plate, mini-mills shipped only 2 to 4 percent of these products in 1990. Ibid.

industrial productivity, both public-[7] and private-sector agencies[8] identified commercialization of NMPM as a crucial element in maintaining U.S. economic prosperity.

Incentives for Developing and Adopting NMPM

The incentives encouraging the use of innovative materials processing to maintain long-term competitive ability arise from both outside and within the firm. The marketplace is increasingly competitive, as the pace of technological innovation accelerates with shrinking product life-cycles and with the rapid diffusion of capital and technology.[9] Commercialization of innovative technologies is also encouraged by government policy and regulatory changes. Since the 1980s, the Federal Government's role in strengthening the nation's technology development has evolved from a customer relationship toward a partnership with the private sector. Some important actions reflecting this shift include a formalized Federal policy that actively promotes transfer of government-funded innovations from Federal agencies to the private sector; changes to patent regulations to allow industrial partners exclusive ownership of patentable government-funded innovations; and changes in antitrust regulations to allow for collaboration on pre-competitive research and development (R&D).[10]

A firm's primary consideration in developing and adopting innovative technologies is their potential to enhance corporate economic performance. For example, numerous process technology improvements, taken together, have enabled steelmakers to reduce their operating costs and improve product quality (table 1). Other innovations, such as cokeless ironmaking technologies and conversion of furnace dusts and rolling-mill sludges into pig iron,[11] are designed to reduce costs of pollution control, waste disposal, and site remediation. Mini-mills with thin-slab continuous casting technologies can be constructed at one-fifth the cost of integrated mills with conventional casting technology and incur about 10-percent lower annual operating costs.[12] By enhancing economic performance, firms are more able to

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[7] Richard J. Brody, *Effective Partnering, a Report to Congress on Federal Technology Partnerships*, Office of Technology Policy, U.S. Department of Commerce (Washington, DC, Apr. 1996); Executive Office of the President, Office of Science and Technology Policy, *Total Materials Cycle, the Pathway for Technology Advancement, 1995 Federal Research and Development Program in Materials Science and Technology, a Report by the Materials Technology Subcommittee, Committee on Civilian Industrial Technology, National Science and Technology Council* (Washington, DC, Dec. 1995); and U.S. Congress, Office of Technology Assessment (OTA), *Innovation and Commercialization of Emerging Technologies*, OTA-BP-ITC-165 (Washington, DC, Sept. 1995).

[8] Paul Allaire, Jack Sheinkman, and Thomas E. Everhart, *Endless Frontier, Limited Resources, U.S. R&D Policy for Competitiveness*, Council on Competitiveness (Washington, DC, Apr. 1996).

[9] Ibid.

[10] The changing roles of the Federal Government in encouraging U.S. industry to innovate were reviewed in the first article in this series: Dana Abrahamson, "New Manufacturing Processes for Materials: Government Policies and Programs Towards Commercialization," *Industry, Trade, and Technology Review*, USITC, Mar. 1995, pp. 5-13.

[11] Badra, "Direct Ironmaking."

[12] The investment required for a mini-mill of minimum efficient scale (about 2 million tons per year capacity) can be constructed for about $200 per annual ton of production capacity ($400 to $500 million per mill) for producing flat-rolled steel products. In contrast, construction of an integrated

(continued...)

Table 1
Advancements in process technology and product quality in the steel industry

Process step	Integrated-mill 1987	Integrated-mill 1997	Mini-mill 1987	Mini-mill 1997	Selected improvements to steelmaking technologies	
Steelmaking—						
Tons per day (*per furnace*)	3,000	4,500	2,150	2,800	1970	Bottom blowing—basic oxygen furnace
					1985	Direct current—electric arc furnace
Electricity use (*kwh/ton*)	25	25	485	430	1985	Advanced ladle refining
					1986	Ultra-high pressure oxygen injection—electric arc furnace
					1990	Liquid iron in electric arc furnace
Continuous casting—						
Tons per day (*per strand*)	2,000	3,500	2,100	2,750	1960	Conventional casting
					1988	Slim-slab casting (100-mm minimum thickness)
					1989	Thin-slab casting (50-mm minimum thickness)
Yields (*percent*)	97.0	97.5	97.5	98.0	1994	Thin-slab casting squeeze (20-mm minimum thickness)
					1997	Strip casting (10-mm minimum thickness), stainless steel
					2000(p)	Strip casting (10-mm minimum thickness), carbon steel
Hot-strip rolling mill—						
Tons per day	10,500	12,000	2,000	4,700	1975	Quick-change rolls
Yields (*percent*)	95.5	96.5	95.5	97.5	1988	Light gauge (<1.7 mm)
					1994+	Ultra-light gauge (<1.0 mm)
Cold-rolling mill—						
Tons per day	5,000	6,800	950	1,950	1995	Two-stand reversing cold-rolling mill
					1994+	Ultra-light hot-rolled as cold-rolled substitute

(p) - projected.

Source: Donald F. Barnett, "Harnessing New Technologies: Key to Winning," World Steel Dynamics, Paine Webber Inc. (New York, NY, June 17, 1997), pp. 215-238 and telephone interview with A. Cramb, Jan. 1998.

strategically position themselves in the marketplace. Adoption of thin-slab casting enabled Nucor Corporation to be the first company world-wide to build a new, flat-rolled mini-mill in the United States in the late 1960s, reportedly from a perception that this technology provided a means of overcoming the large-scale capital and production entry barriers to an industry segment dominated by the integrated mills.[13]

[12] (...continued)
steel mill of minimum efficient scale (3 to 6 million tons per year capacity) is estimated to exceed $1,000 per annual ton of production capacity ($4 to $5 billion per mill). Charles Yost, "Thin-Slab Casting/Flat-Rolling: New Technology to Benefit U.S. Steel Industry," *Industry, Trade, and Technology Review*, USITC, Oct. 1996, pp. 21-29.

[13] Ibid.

Confronting the Barriers to Commercializing NMPM

Numerous barriers hinder commercialization of innovations (table 2). Among the most significant barriers are the long time-horizon and high costs, which limit profitability and make it difficult for a firm to recoup its investment in successful projects. This is most likely when patent protection expires near the end of development, or in industry sectors with short life-cycles.[14] The experience of AlliedSignal Incorporated in commercializing a new product made with amorphous metals demonstrates how a combination of approaches may be necessary to address the numerous barriers that can simultaneously impede the commercialization process (see text box). Likewise, the magnitude of investment often required to bring an innovation to commercialization may be more than a firm can feasibly finance alone, given the anticipated rate of return; many firms have scaled back "in-house" research efforts or closed down their R&D facilities entirely.

Table 2
Barriers to commercialization of new manufacturing processes for materials

Source of barrier	...to developing NMPM	...to adopting NMPM
Time horizon	Failure to recognize lengthy R&D period needed (often a decade or more) to develop a market for an innovation.	Failure to recognize lengthy learning and adjustment period needed to achieve desired product quality.
Technological	Resulting material's properties are not entirely suitable for existing market application; underdeveloped markets in some cases.	Resulting material's properties are not entirely suitable for specific industry application. NMPM may be more suitable for a new state-of-the-art facility and retrofit may not match scale production economies.
Financial or economic performance	Magnitude of required investment, given anticipated returns. Resulting products with high unit cost may be suitable only in industries requiring specific material properties. Limited initial production capacity or market demand, especially for improved or new materials.	Capital cost exceeds anticipated returns. Resulting products with high unit cost may be suitable only in industries requiring specific material properties. Existing process technology may embody sunk costs or possess lengthy remaining economic life.
Corporate culture	Organizational separation among units involved in R&D process; differences in attitudes and values among units. Counterproductive territoriality among organizational units; suspicion of projects originating outside of unit.	Risk-adverse or risk-neutral approach to decision making; receptive to innovative NMPM but adopts wait-and-see approach.
Regulatory environment	Inflexible codes and standards preclude use of resulting material. Antitrust regulations inhibit collaborative R&D.	Inflexible codes and standards preclude use of resulting material. Strategic considerations prevent NMPM from being acquired by economic rivals or hostile foreign powers.

Source: Compiled by USITC staff from various government documents and industry publications.

[14] Thomas W. Eagar, "Bringing New Materials to Market," *Technology Review*, Feb./Mar. 1995, pp. 43-49.

Producing amorphous metals using the rapid solidification process: 20 years to commercialization.

The rapid solidification process cools molten metals extremely quickly to an amorphous metal (AM) in which the atoms are randomly spaced, as opposed to the ordered structure of conventionally cooled metals. Given the excellent magnetic properties of iron-based AM alloys, electrical distribution transformer cores made of these alloys consume 60 to 70 percent less energy than those with the most efficient conventional silicon-steel cores. If all U.S. distribution transformers used AM alloy cores, the annual operating cost savings could exceed $3 billion (based on the average residential rate for electricity), according to AlliedSignal (AS) Incorporated, the developer of this technology.

Processing technology was the most significant barrier identified in developing rapid solidification; perfecting the process took AS almost 20 years. Many other potential barriers were avoided because AS received development assistance from a Federal laboratory, had regulatory agency support, and had close cooperation from the industry's standards-setting organization. The technology, when applied to making distribution transformers, was accepted by end users (electric utilities) in the United States with minimum reservations, and AM transformers captured 12 percent of the U.S. market during 1990-95. Recently, however, utilities have been reluctant to switch to these transformers because energy costs are decreasing in real terms, and the economic incentive for installing AM transformers (which cost 10 to 15 percent more) is decreasing.

Source: Compiled by USITC staff from company publications and interviews of company representatives.

Corporate culture also may contribute to delays and cost overruns because of organizational separation between technical and business units, and differences in goals and values.[15] Private firms use various combinations of approaches to overcome such cultural tendencies, employing cross-functional teams and enhancing communication between functional units were most commonly reported.[16] Mobil Oil Company relies extensively upon both strategies to develop and maintain its core technical competencies, including advanced catalytic processing for refining petroleum and synthesizing chemicals.[17] Another approach to encourage interaction between technical and business units is centralizing technological functions.[18] For example, by centralizing new-product development and integrating representatives from all functional units into development teams, production and marketing difficulties at Chrysler Corporation can be anticipated before finalizing product designs. Because the design of a product determines a large share of production costs, Chrysler anticipates significant reductions in both final product costs and development time through this approach.[19] Likewise, the existence of formalized project plans and written procedures, which provide early agreement between the business and

[15] For example, an innovation is successful to a technician if it can be produced in a laboratory, but for management, if it can be manufactured and survive in the marketplace.

[16] See: John J. Wise, "An Evolving Partnership, Mobil has Adopted a Number of Innovative Practices Designed to Strengthen its Technology/Business Partnership and Expedite the Transfer of Its Technology," *Research-Technology Management*, vol. 38, No. 6, Nov./Dec. 1995, pp. 37-41; Charles E. Bosomworth and Burton H. Sage, Jr., "How 26 Companies Manage their Central Research," *Research-Technology Management*, vol. 38, No. 3, May/June 1995, pp. 32-40; and Derek L. Ransley and Jay L. Rogers, "A Consensus on Best R&D Practices," *Research Technology Management*, vol. 37, No. 2, Mar.-Apr. 1994, pp. 19-26.

[17] Wise, "An Evolving Partnership."

[18] Mobil found that previously separate product laboratories and technical service units often slowed the transfer of technological developments to business divisions, and were duplicative at a time when it was under pressure to cut costs. Ibid.

[19] Steven W. Irwin, *Technology Policy and America's Future* (St. Martin's Press, New York, NY, 1993).

research units, eliminates false starts and defines responsibilities that would otherwise take time to evolve. Incorporating lessons learned from past project plans also contributes to success; Mobil relies extensively on formal mechanisms for reviewing project progress, including post-project auditing to learn from its experiences.[20]

In addition to these factors, technical barriers may hinder the adoption or commercialization of NMPM. New materials may be initially unsuitable for existing market applications because they exhibit significantly different specifications or physical properties than conventional materials, or because of their high initial unit costs. For example, despite considerable weight savings and long-run cost savings of aluminum metal matrix composites (MMC), the automobile industry was hesitant to substitute this advanced material for steel and cast iron in drive shafts and brake rotors because of significantly higher initial per-unit material costs, higher machining costs, and the large amount of capital investment necessary to retrofit process lines. To commercialize this new material, Duralcan approached the U.S. automotive industry to try aluminum MMC in limited production runs to demonstrate the material's reliability and potential long-run cost-effectiveness (see text box).

Producing aluminum metal matrix composites using the stir-casting process: technical and economic barriers delay commercialization.

Metal matrix composites (MMC) consist of a metal or metal alloy (matrix) with a reinforcing material (usually ceramic) dispersed throughout. Duralcan, a subsidiary of Alcan Aluminum Limited, developed a proprietary stir-casting technique to produce aluminum MMC, which are reinforced by particles of silicon carbide or aluminum oxide. Aluminum MMC offer comparable stiffness, corrosion resistance, and abrasion resistance as conventional steel or cast iron, but with considerable weight savings. In automobile drive shaft and brake-rotor applications, aluminum MMC save 18.0 and 7.5 pounds, respectively.

However, automobile manufacturers have been reluctant to adopt this new material for technical and economic reasons. Aluminum MMC cost $1.50 to $2.00 per pound (depending on production volume) compared with $0.90 per pound for aluminum, $0.50 per pound for steel, and $0.20 per pound for cast iron. Fabrication costs are higher than for conventional materials because parts made of aluminum MMC must be finished with diamond tools. Entire assemblies would have to be redesigned to fully exploit the advantages of this advanced material. Also, manufacturers are particularly sensitive to product-safety concerns, which limit use for brake components.

To commercialize aluminum MMC, Duralcan sought closer links with the U.S. automotive industry by approaching manufacturers directly, setting up a marketing arm in the Detroit area, and even relocating production facilities. A decade after Duralcan was formed to manufacture and commercialize this advanced material, General Motors and Chrysler Corporation are trying aluminum MMC parts in limited production runs of drive shafts and brake rotors; such trials will allow aluminum MMC parts to prove their reliability and long-run cost-effectiveness. Other industry sectors have turned to aluminum MMC for specific applications, including specialized bicycle frames, sporting goods, and even snow tire studs. These applications present less volume potential but nevertheless encourage sales and market development of aluminum MMC.

Source: Compiled by USITC staff from industry publications and interviews of company representatives.

Collaboration between private firms—

Direct firm-to-firm collaboration is ideal for resolving the classic risk-associated problem of hesitancy on the part of materials producers to invest in expanding production capacity for a

[20] Wise, "An Evolving Partnership."

new high-performance product where its potential market niche is small, and likewise, the hesitancy of materials users to invest in switching to such products with limited availability. To speed up commercialization, U.S. Steel worked closely with Chrysler Corporation to fine-tune its newly developed steel sheet with an iron-zinc coating to be compatible with the latter's painting system. In anticipation of a major market for its output, U.S. Steel could justify the expenditure for substantial modifications to its electrogalvanizing process to produce the new iron-zinc steel sheet. Furthermore, the time span from concept to full-scale manufacturing was 3 to 4 years, compared with 10 or more years to commercialize new products in the past.[21]

To side-step the time and expense of the earlier stages of the R&D process, private firms may elect to adopt innovations developed by outside sources in either a partially or fully commercialized state. Two well-established mechanisms are ***licensing*** and ***strategic partnerships***. For a license-granting firm, licensing its technology can be an alternative to expending resources to develop new markets and scale up to full commercial production. The mutual benefits attendant with licensing are illustrated by the Boeing Company's 1993 agreement with Grumman Corporation to apply Grumman's patented electromagnetic forming process for torque-tube joints in commercial aircraft, a deal that could be worth $10 million over the next 10 years.[22]

In a strategic partnership, two firms agree to share marketing and commercialization of a product or process created by one firm but developed by the other. This arrangement enables the originating firm to commercialize an innovation despite lack of technical expertise, skilled personnel, sufficient funding, or adequate capital equipment. Martin Marietta used a strategic partnership to commercialize high-strength aluminum alloys and metal matrix composites, as the company's core business is not materials production.[23] For this case, important considerations for selecting a strategic partner were that the two firms should compete in different market segments and have similar organizational cultures, a high level of management commitment, a defined strategy to aggressively develop and commercialize the technology, and the technical ability to work closely together. With both licensing and strategic partnerships, the acquiring firm receives access to a technological innovation with less investment in R&D, but must finance fine-tuning the innovation for application, and must develop detailed marketing plans. A significant positive feature of such partnerships is that commercial applications are developed concurrently with technical development. For Martin Marietta's technologies,

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[21] John Schriefer, "Increasing R&D's Productivity," *New Steel*, vol. 12, No. 6, June 1996, pp. 72-78.

[22] Torque tubes are aluminum and steel drive-shaft assemblies that are part of the control system that raise and lower the flaps and slats on aircraft wings. The Grumman process extends the service life of the torque tube by strengthening the joint between the tube and fittings. Grumman has used electromagnetic forming for more than 20 years in the production of military aircraft, although this is the first commercial application of this technology. Grumman also offers this process for automotive and other high-stress, rotary-motion applications. Anthony L. Velocci, Jr., "Ventures Rife with Marketing Pitfalls," *Aviation Week and Space Technology*, vol. 139, No. 19, Nov. 8, 1993, pp. 59-61.

[23] John A.S. Green, John Brupbacher, and David Goldheim, "Strategic Partnering Aids Technology Transfer, Martin Marietta Finds Technology Transfer Through Strategic Partnerships a Rapid, Effective and Successful Tool for Developing Novel Engineered Materials," *Research Technology Management*, vol. 34, No. 4, July/Aug. 1991, pp. 26-31.

markets may be already partially developed by strategic partners who are often major customers.[24]

An alternative to adopting from outside a firm is pre-competitive collaboration with other firms. This approach to commercialize NMPM enables participants to spend R&D funds more efficiently and helps reduce duplication of expenditure and effort, especially in the early phases of a project.[25] Private firms may form ***horizontal consortiums*** to tackle problems common to an entire industry, although the firms remain competitors in the marketplace. An increasing number of ***vertical consortiums*** are being formed among firms from the various stages of production, as manufacturers increasingly interact with suppliers and customers to develop innovative technologies. For example, the 5-year Advanced Process Control Research Program, coordinated by the American Iron and Steel Institute, includes steelmakers, industry suppliers, and Federal laboratories[26] collaborating in the development of advanced sensor and process-control technologies to improve steelmaking efficiency and reduce energy consumption and emissions.[27] Factors for successful consortiums include long-term commitment and active participation of members (including management), access to members' marketing and manufacturing capabilities, and a focused technology strategy.[28] Furthermore, potential benefits are maximized with partners whose R&D capabilities are complementary.

Looking to R&D institutions as sources of innovative technologies—

Collaboration with Federal laboratories and research universities rather than competitors may be preferable to some firms, especially due to intense interfirm rivalries and problems of sharing intellectual property rights. In addition, R&D institutions offer access to technical expertise and advanced facilities that would be too expensive for most firms to build and operate (e.g., high-powered computational and sophisticated analytical capabilities).

The abilities of the 700+ Federal laboratories to develop and commercialize NMPM depend to a great degree on the mission of the supporting agency and past experience. A notable example is the extensive collaborative effort between the U.S. polymer industry and the National Center for Agricultural Utilization Research to develop less expensive, more versatile, advanced superabsorbent polymers. The results of this research not only enabled the polymer industry to regain its domestic market share from foreign competitors, but also to enter new markets abroad (see text box). Although collaborative mechanisms range from informal sharing of information (through laboratory publications, workshops and seminars, and technical

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[24] Ibid.

[25] Eagar, "Bringing New Materials to Market."

[26] Schriefer, "Increasing R&D's Productivity."

[27] Potential annual energy savings for the U.S. steel industry anticipated from the six projects are estimated at 16.5 trillion BTUs, which could cut costs to the industry by $103 million. Furthermore, potential NO_x emissions could be cut by an estimated 13,000 metric tons, SO_x by 80,600 metric tons, and particulate matter by 33,100 metric tons. National Renewable Energy Laboratory, *Technology Partnerships, Enhancing the Competitiveness, Efficiency, and Environmental Quality of American Industry*, for the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of Industrial Technologies, DOE/GO-10095-170 DE95004086 (Washington, DC, Apr. 1995).

[28] Tim Stevens, "Success in Numbers: A Research Consortium Can Yield Big Payoffs to Member Companies, If They Do It Right," *Industry Week*, vol. 243, No. 7, Apr. 4, 1994, pp. 45-48.

consultations) to the use of Federallaboratory facilities, employee exchanges, and licensing, three mechanisms were most frequently cited as promising future payoffs: industry-sponsored research, contract research, and cooperative R&D.[29]

Superabsorbent starch-based polymers: commercializing Federal laboratory innovations for revival and expansion of domestic industry.

Superabsorbent polymers are used in air filters, to mop up spills and absorb wastes, to reduce watering requirements of crops, and in numerous products in the construction, electrical, petroleum, and chemical industries. The specific absorbency of polymers allows some mixed liquids to be readily separated, for example, extracting water from diesel fuel or gasoline.

In the 1980s, the U.S. polymer industry was losing its market share to foreign competition in the $1-billion-a-year domestic market, particularly to producers of petroleum-based synthetic absorbents. Scientists at the Department of Agriculture's National Center for Agricultural Utilization Research (NCAUR) revisited past research and relied upon extensive links with industry to identify existing and potential applications; product performance requirements; and production, equipment, and market needs. Industry engineers and researchers were invited to observe and comment during laboratory preparation of the polymer, and NCAUR scientists collaborated with industry to resolve technical problems during scale-up to commercial production.

This public-private collaboration resulted in improved starch-based polymers that are more absorbent, effective for a broader range of substances, and less expensive than other absorbent polymers. As a result, the domestic polymer industry regained its standing in the domestic market, and opened new markets as U.S. manufacturers began selling overseas.

Source: George Fanta and William Doane, "Researchers Starch Up Soggy U.S. Polymer Industry," *Winners in Technology Transfer* (Federal Laboratory Consortium for Technology Transfer, Washington, DC, 1994).

The use of ***cooperative research and development agreements*** (CRADAs) has mushroomed since their inception in 1986 because of unique advantages over other forms of industry-Federal laboratory collaboration.These advantages include exclusive ownership of patent rights for the industrial partner, protection of proprietary information, and royalty shares for government researchers. To some critics, the CRADA program is too generous to industrial partners who essentially pay half the R&D costs,[30] and some industry officials have criticized the long delays

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[29] Based on two surveys of chief technical officers and laboratory directors of industrial firms by the Georgia Institute of Technology. There was less enthusiasm for licensing agreements because many laboratory innovations needed further development at initial licensing to bring them to commercial success. Cited in: David Hughes, "Industry Seeks Expertise in Federal Lab Interaction," *Aviation Week & Space Technology*, vol. 139, No. 19, Nov. 8, 1993, pp. 56-58; and J. David Roessner and Alden S. Bean, "How Industry Interacts with Federal Laboratories," *Research Technology Management*, vol. 34, No. 4, July/Aug. 1991, pp. 22-25.

[30] Both partners provide relatively equal amounts of resources (facilities, equipment, personnel, expertise, and funding) to the agreement, but the Federal laboratory cannot provide appropriated funds. Dan Cordtz, "Bye-Bye, Dr. Strangelove, Threatened with Extinction by Politicians, U.S. Weapons Labs are Dying to Help Business," *Financial World*, vol. 164, No. 2, Jan. 17, 1995, pp. 32-

for CRADA approval.[31] In contrast, supporters have questioned the wisdom of firms paying the entire cost, which would reportedly turn laboratories into "job shops," a shortcoming the CRADA program was designed to discourage.[32]

Industry also has a long history of interaction with research universities. Although universities are capable of long-range basic research, it is on a relatively small scale compared with the Federal laboratories, and is usually confined to specific academic disciplines. These factors, plus academia's emphasis on freedom of inquiry, can be problematic in meeting private industry's need for multi-disciplinary, applied R&D assistance. To bridge these cultural differences, many academic institutions have developed technology transfer centers to coordinate and facilitate customized assistance. This type of collaboration is most common for incremental improvements to existing technologies or products.[33]

Taking advantage of government technology-commercialization programs—

At all levels of government, there are programs to promote the transfer of technology from R&D institutions to private industry, particularly to small- and medium-size business.[34] At the state and local level, for example, there are some 390 technology-commercialization programs.[35] These vary in structure, focus, and range of services, from providing technical assistance to small businesses, promoting industry collaborations, and offering literature search capabilities, to financing small businesses and giving start-up assistance to small technology-based firms or regional industries. Despite successes, these efforts reportedly are sometimes criticized not only for lacking expertise, but also for wasting funds because of inefficiencies, program overlap, and bureaucratic snarls.[36] Awareness of local technology-commercialization resources was reported to be low among small manufacturers, but use increased with extent of prior use.[37] It also has been reported that small firms generally are in greater need of "off-the-shelf" technologies,

[30] (...continued)
37.

[31] From quarterly surveys of its CRADA partners, Sandia National Laboratory found that the program was responsive to industry queries, and technical goals and milestones were being met, but the time required to conclude agreements needed to be reduced. William B. Scott, "Technology Transfer Support Wavers," *Aviation Week & Space Technology*, vol. 143, No. 17, Oct. 23, 1995, pp. 57-60.

[32] Charryl Berger, deputy director of the Los Alamos National Laboratory Industrial Partnerships Office, cited in: Cordtz, "Bye-Bye, Dr. Strangelove."

[33] Robert Killoren, "University-Industry Interactions, Room for Diversity," *SRA Journal*, vol. 25, No. 2, June 1994, pp. 31-35.

[34] Federal-agency programs encouraging U.S. industry to innovate were reviewed in Abrahamson, "New Manufacturing Processes for Materials: Government Policies and Programs Towards Commercialization."

[35] U.S. Congress, OTA, *Innovation and Commercialization of Emerging Technologies*.

[36] Paul Proctor, "Regional Agencies Help Small Firms Get Foothold," *Aviation Week & Space Technology*, vol. 143, No. 17, Oct. 23, 1995, p. 62.

[37] Based on a study of survey results from 120 small manufacturing firms in middle Tennessee. John Masten, G. Bruce Hartmann, and Arief Safari, "Small Business Strategic Planning and Technology Transfer, the Use of Publicly Supported Technology Assistance Agencies," *Journal of Small Business Management*, vol. 33, No. 3, July 1995, pp. 26-37.

particularly computer-aided drafting and manufacturing software, and applying computerized techniques to the factory floor for statistical process control and inventory control.[38]

Outlook: Further Actions for Effective Commercialization of NMPM

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Despite considerable progress toward commercializing innovative technologies, observations of key participants in the process suggest that continued efforts are needed to promote development and adoption of NMPM. Standards for test methods and materials design should be developed,[39] taking into account factors such as increased performance of advanced materials and degree of risk for the application. For example, given the stronger, more fracture-resistant steels that are now readily available, materials specifications for pressure-vessel boilers are currently over-specified, being nearly the same as they were 50 years ago.[40] In those cases where a single firm cannot afford to underwrite extensive testing of an advanced material, pooling the cost of risk assessment may be helpful.[41] Evaluation of NMPM also could be improved by increased standardization of design-related, materials-property databases.[42] For certain R&D areas that are seldom tied directly to commercial applications, it is reported that the government may need to take the lead, especially in supporting research to characterize and understand new materials, and in developing advanced computational tools for new-material design methods, and life-cycle performance analysis techniques.[43]

For private industry, reported recommendations focus on developing and expanding markets for advanced materials.[44] Collaborations to tailor an advanced material to meet specific end uses and increase production and market capacity include:

- Establishing direct links with the ultimate end users of a material rather than just the immediate customer.

- Increased mutual sharing of proprietary technical information and marketing strategies between materials suppliers and users. Also, increased joint ventures between materials suppliers and users.

- Incremental introduction strategies to improve existing products and build market demand for an advanced material.

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[38] William H. Miller, "Federal Help, Don't Laugh, The Commerce Dept's. Expanding System of Manufacturing Technology Centers is Trying to Show That the Feds Can be Useful," *Industry Week*, vol. 242, No. 14, July 19, 1993, pp. 55-61.

[39] Materials Advisory Board, *Commercialization of New Materials for a Global Economy*.

[40] Eager, "Bringing New Materials to Market."

[41] Ibid.

[42] Materials Advisory Board, *Commercialization of New Materials for a Global Economy*.

[43] Office of Science and Technology Policy, *Total Materials Cycle, the Pathway for Technology Advancement.*

[44] Eager, "Bringing New Materials to Market;" and National Materials Advisory Board, *Commercialization of New Materials for a Global Economy*.

Partnerships with private industry reportedly can be improved through a number of specific policy changes by the Federal Government:

- Improve the continuity of Federal R&D resources to reduce fiscal unpredictability .[45]

- Reform export-control regulations on **dual-use technologies** that may unnecessarily interfere with interactions between U.S. firms and foreign partners, restrict access to foreign technical bases, or limit U.S. firms' access to international markets (see text box).[46]

> **Extremely fine metallic-membrane filters: posing a $2 billion dual-use technology dilemma.**
>
> Martin Marietta was interested in applying metallic membrane technology to commercial filtration applications ranging from effluent treatment to purification of orange juice, with an estimated potential of $2 billion in commercial business by 2000. This technology has been developed by Oak Ridge National Laboratory for use as extremely fine filters in the gaseous diffusion process for purifying uranium. Declassification of this technology was halted by concerns about the Iraqi government's efforts to upgrade its nuclear processing capabilities.
>
> Source: Thomas G. Donlan, "The Price of Progress, Scientific Advances Require Sound Investment Policies and Clear Goals," *Barron's*, vol. 74, issue No. 26, June 27, 1994, p. 62.

- Improve the speed, flexibility, and predictability of negotiating, implementing, and funding industry partnership agreements with Federal laboratories.[47]

- Promote timely and wide dissemination of information on Federally funded innovations and R&D partnership opportunities[48] by establishing a centralized materials database.

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[45] Allaire, Sheinkman, and Everhart, *Endless Frontier, Limited Resources*.

[46] National Materials Advisory Board, *Commercialization of New Materials for a Global Economy*. Private firms also impose barriers deliberately for strategic considerations, especially to preserve trade secrets and protect economically valuable innovations from competitors. Likewise, foreign economic rivals also screen the acquisition of economically valuable innovations by U.S. firms.

[47] Brody, *Effective Partnering*.

[48] National Materials Advisory Board, *Commercialization of New Materials for a Global Economy*; and Brody, *Effective Partnering*.

- Pare agency bureaucracies and decentralize decision making to allow laboratory directors to implement their own strategies and be accountable for supporting commercial applications.[49]

- Increase partnerships with small- and medium-sized technology firms.[50]

- Coordinate Federal programs with State programs,[51] especially to improve the effectiveness of small business in commercializing innovative NMPM[52] and to reduce overlap in State programs.[53]

For research universities, reported recommendations specific to NMPM focused on disseminating updated knowledge about advanced materials:[54]

- Include advanced-materials selection and design in the materials engineering curriculum.

- Promote continuing education for materials engineers on technological advancements and practice-oriented training for materials technicians.

- Promote programs for faculty and graduate students to gain experience in industrial laboratories as a means of promoting links between university and private-sector R&D.

- Increase partnerships with small- and medium-sized firms specializing in technology.[55]

Private industry, government, and academia continue to commercialize innovative NMPM in response to economic and regulatory incentives. The numerous interactive and often interlinked

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[49] Allaire, Sheinkman, and Everhart, *Endless Frontier*, *Limited Resources*; and National Materials Advisory Board, *Commercialization of New Materials for a Global Economy*.

[50] Lewis M. Branscomb, Aetna Professor Emeritus of Public Policy and Corporate Management Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, *Testimony, Hearing of the Subcommittee on Science, Technology and Space of the Senate Committee on Commerce, Science and Transportation*, Apr. 16, 1997.

[51] Federal partnerships with State programs are essential because states are much closer to the practical need of local businesses through the efforts of State colleges and universities and State commerce and transportation agencies. At their 1997 meeting in Washington, DC, the State Governors created a formal structure for linking Federal and State research teams in partnership. John H. Gibbons, Assistant to the President for Science and Technology, *Technology Partnering: Can You Count on the Government?* (Federal Technology Report, McGraw-Hill Companies, Inc., Washington, DC, Mar. 3, 1997).

[52] Brody, *Effective Partnering*.

[53] Walter H. Plosia, Executive Director, North Carolina Alliance for Competitive Technologies, "State and National Strategies for Promoting Innovation and Stimulating Economic Development," *Trends in Industrial Innovation, Industry Perspectives and Policy Implications*, 1997 Sigma Xi Forum, Arlington, VA, Nov. 20-21, 1997.

[54] Allaire, Sheinkman, and Everhart, *Endless Frontier*, *Limited Resources*; and National Materials Advisory Board, *Commercialization of New Materials for a Global Economy*.

[55] Branscomb, *Testimony, Hearing of the Subcommittee on Science*.

approaches devised by these participants have evolved through time to address many of the barriers that impede development and adoption of such innovative technologies. The extent to which the above suggestions can be implemented will have significant bearing upon the pace of technological innovation, which, in turn, impacts industrial competitiveness in a rapidly changing and increasingly globalized marketplace.**#**

Glossary of Terms

Consortium	A joint R&D agreement among private firms to develop a technology of common interest to participants. Government agencies and research universities also may participate in or organize such ventures.
Cooperative research and development agreement (CRADA)	A formalized joint R&D agreement between private industry (either a single firm or multiple firms) and a Government agency, national laboratory, or research university.
Defense conversion	Reorienting an institution's R&D efforts from defense-related to commercial, non-defense-related applications.
Dual-use technology	Innovations with both commercial and military applications.
External acquisition of technology	Innovations brought into a firm from an outside source. Also referred to as "technology acquisition." Contrast with *internal technology development*.
Horizontal consortium	An industry *consortium* whose member firms normally compete in the same or related markets. Contrast with *vertical consortium*.
Internal technology development	Innovations developed by a firm from within, through successive functional units involved in the R&D process. Contrast with *external acquisition of technology*.
Licensing	An agreement granting an acquiring firm access to the licensor's technology.
Market pull	Technology development spurred specifically when a solution is sought by the market to meet an existing technical need. Contrast with *technology push*.
New manufacturing processes for materials (NMPM)	Any manufacturing process that can produce materials more efficiently than can conventional processes, or can produce materials with superior properties compared with conventional materials, or both. NMPM also could result in entirely new materials.
Strategic partnership	A joint R&D agreement between two private firms to commercialize a technology initially developed by one, but in need of further development by the other to bring the technology to the marketplace.
Technology push	Technology for which there is currently no commercial market, but developers seek commercial applications after its development is under way or completed. Contrast with *market pull*.
Vertical consortium	An industrial *consortium* whose members do not all compete in the same or related marketplaces, but rather are drawn from the various stages of production (e.g., materials suppliers, finished-product manufacturers, etc.). Contrast with *horizontal consortium*.

Thermoplastic Elastomers in the Auto Industry: Increasing Use and the Potential Implications

Elizabeth Howlett
(202) 205-3365
ehowlett@usitc.gov

Thermoplastic[1] elastomers[2] (TPEs) are a group of specialty rubbers that combine the elasticity of thermoset[3] rubbers with the processing advantages of plastic materials. TPEs have continued to enjoy growth in a wide range of applications during the 1990s. The automobile industry, which is currently the largest consumer of TPEs, is expected to increase its use of these materials by more than 7 percent between 1995 and 2000, to reach 1.1 billion pounds.[4] During the same period (1995-2000), consumption of thermoset rubber for all industries is estimated by industry sources to increase to 38.2 billion pounds, an average annual growth rate of 2.7 percent. By comparison, total TPE consumption is expected to increase from 1.9 to 2.5 billion pounds, an average annual increase of 5.6 percent.[5] The disparity in growth rates is indicative of a growing trend in certain sectors, such as the auto industry, toward replacing thermoset rubbers and rigid thermoplastics (e.g., polyvinyl chloride) with thermoplastic elastomers. In addition, auto producers are developing new products specifically designed to use the unique characteristics of TPEs. This article provides an overview of the advantages that TPE materials offer manufacturers, examines use of TPEs in the auto industry, and briefly looks at the role of TPEs in other sectors.

Thermoplastic elastomers (TPEs) are a rapidly growing class of specialty rubber materials that demonstrate a unique combination of performance and processing characteristics, blending both thermoplastic (or plastic) and rubber properties. Compared with rubbers, plastics are generally easier to process because they can be reshaped with heat and do not have the temperature restrictions of thermosets. For these reasons, manufacturers typically prefer to work with plastic materials if possible. For some purposes, however, the elastic properties of thermoset rubbers

[1] Thermoplastic materials are those that can be reshaped with the application of heat.

[2] Materials that ". . . can be stretched to at least double their length at room temperature and, on the removal of the tension, quickly return to their original length." K.F. Heinisch, *Dictionary of Rubber* (New York: Halstead Press Book, 1966), p. 189. The term elastomer is essentially synonymous with rubber; the two words will be used interchangeably throughout this article.

[3] Thermoset materials are those that cannot be reshaped through the application of heat because of the existence of chemical bonds that cannot be broken through changes in temperature.

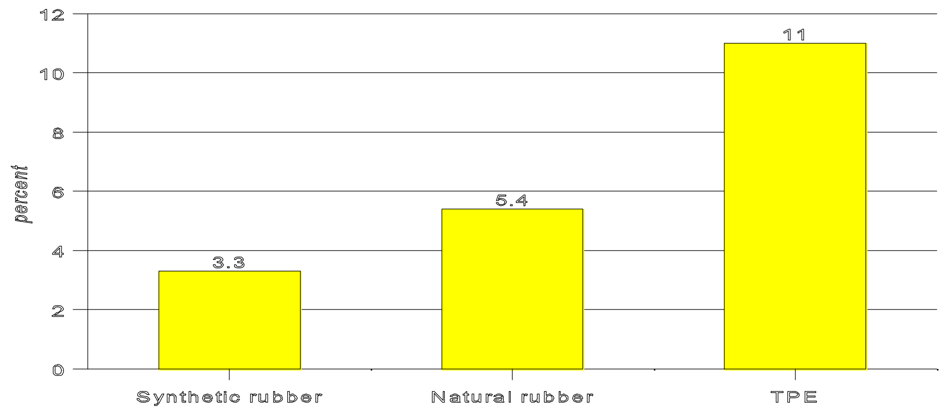
[4] Marc S. Reisch, "Thermoplastic Elastomers Target Rubber and Plastics Markets," *Chemical and Engineering News (C&EN)*, vol. 74, No. 32 (August 5, 1996), p. 11.

[5] Reisch, "Thermoplastic Elastomers," p. 10.

are favored over the comparable rigidity of plastics.[6] By offering a combination of the easy processing of a thermoplastic component and the elasticity of a rubber, TPEs have become desirable for many applications, particularly in the auto industry.[7]

World consumption of both natural and synthetic thermosetting rubber has been relatively stable in recent years, while TPEs have experienced steady growth[8] (figure 1), estimated at 11 percent over the 3-year period of 1995-97. Total worldwide consumption in 1996 for synthetic and natural rubber, totaling 21.2 billion pounds and 13.2 billion pounds, respectively, far exceeded the 2.0 billion pounds of TPE consumed in the same year.[9] The automobile industry reportedly consumes 31 percent of all TPE produced.[10]

Figure 1
Growth in world rubber consumption during 1995-97, by type, in percent



Source: Compiled by USITC staff from data obtained from the IISRP website (http://www.iisrp.com/) on Sept. 10, 1997.

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[6] Most elastomers owe their elasticity to crosslinking, by which molecular bonds are formed across polymer chains, allowing the material to sustain significant deformation and still return to its original shape once deforming stress has been eliminated. By comparison, thermoplastic materials, which lack the crosslinks that allow for elasticity, are typically more rigid than thermosets. However, they do not take a permanent shape through initial processing; with minimal effect on performance and processing, plastics can be reshaped by applying heat. P.W. Allen, *Natural Rubber and the Synthetics* (London: Crosby Lockwood, 1972), pp. 14-15.

[7] A TPE comprises at least two intertwined polymer systems, where one is a rigid thermoplastic material and the other is a soft elastomeric material. The TPE is intended to be used between the softening temperature of the two polymers. When temperatures fall below the softening point of the rigid phase, it acts as a backbone to restrict movement of the soft phase polymer. However, when heated above the softening temperature of the hard phase, the TPE loses its shape and becomes a viscous liquid. The hard phase resolidifies upon cooling, allowing for reshaping of the material. For thermoset rubbers, modifying shape to a significant degree involves the cleavage of chemical bonds. Charles A. Rader, “Thermoplastic Elastomers: Non-tire Market Share Up to 11% as Production Reaches 420,000 Tonnes,” *Modern Plastics*, vol. 72, No. 12 (Mid-November 1995), p. B-56.

[8] Reisch, “Thermoplastic Elastomers,” p. 11.

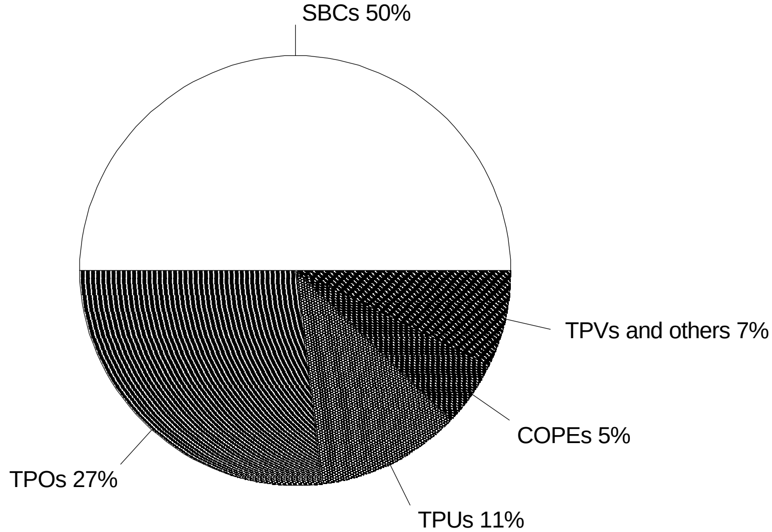
[9] Information obtained from the International Institute of Synthetic Rubber Producers’ website (http://www.iisrp.com/) on Sept. 4, 1997.

[10] Kerri Walsh, "Automotive End Uses Drive Demand,” *Chemical Week*, vol. 159, No. 25 (June 25, 1997), p. 36.

Materials classified as TPEs generally fall into five groupings, as outlined in the text box on the following page.[11] Styrene block copolymers (SBCs) are the most commonly used TPE (figure 2), accounting for about 50 percent of consumption. However, it has been projected that thermoplastic olefins (TPOs), used extensively in the North American auto industry, will have an average annual growth of almost 10 percent for model years 1995-2005, increasing from 165.0 million pounds to 425.0 million pounds (table 1).[12] The majority of the TPOs currently are used in the exterior[13] of vehicles, although the most substantial growth will come from increased use for interior applications, such as airbag covers.[14] Annual growth rates during 1995-2005 for TPOs in the auto industry are estimated at more than 9 percent for exterior parts compared with 34 percent for interior parts.[15]

Figure 2

Share of TPE consumption, by type, by percentage, 1995



Source: Marc Reisch, "Thermoplastic Elastomers Target Rubber and Plastics Markets," *C&EN,* vol. 74, No. 32 (August 5, 1996), p. 14.

[11] There is no consensus on the exact types of TPEs, but the five classes used here are reasonably common.

[12] Bernie Miller, "TPO Takes the Fast Lane to Big-Time Applications," *Plastics World*, vol. 53, No. 10 (October 1995), p. 43.

[13] Exterior automotive parts include bumpers, cladding and side trim, wheel flares, and front grilles.

[14] Other interior applications include skins to cover dashboards and door panels, improving their tactile properties.

[15] Although use of TPOs in underhood body parts, including air intakes, boots and bellows, and splash shields, exceeded that of interior parts for 1995, it is anticipated that by 2005 interior parts will use 34.1 million pounds, while underhood parts will use 28.6 million pounds. Miller, "TPO Takes Fast Lane," p. 43.

Major Types of Thermoplastic Elastomers

- ***Styrene block copolymers (SBCs)*** are the least expensive ($0.70-$2.50 per pound) and most commercially successful category of TPEs. SBCs include three main subcategories: styrene-butadiene-styrene (SBS), styrene-isoprene-styrene (SIS), and styrene-ethylene-butylene-styrene (SEBS). SBS is frequently used in footwear, consumer products, asphalt, and polymer modification. Its most significant shortcoming is poor resistance to oil and high temperatures. SIS is frequently used in the adhesives industry because of its softness and ease of combining with resins, oils, and solvents. The most recent innovation, SEBS, was designed to be resistant to oxidation and weather; it is well-suited to applications such as automotive weatherstripping and cable coatings.

- ***Thermoplastic olefinics (TPOs)*** are composed of a thermoplastic, such as polypropylene, that has been blended with an unvulcanized rubber. TPOs can be relatively rigid materials, with hardness ranging from 60 Shore A to 60 Shore D at room temperature. For this reason, they are used in applications such as automobile bumpers and fascias, where impact resistance is critical. While TPOs have fair resistance to some chemicals, their resistance to chlorinated hydrocarbon solvents is low. TPOs generally fall within the price range of $0.75-$1.00 per pound.

- ***Thermoplastic urethanes (TPUs)*** have soft segments of either a polyester or polyether macroglycol paired with hard segments that are the product of the reaction between low-molecular-weight glycol and diisocyanate. TPUs are noted for high UV resistance, excellent tear strength, and good abrasion resistance, which make them a good alternative to traditional rubbers. TPUs are attractive to the auto industry because they do not need a primer before being painted. Significant weaknesses include poor resistance to strong acids and steam. TPUs are typically priced at $2.50 or more per pound.

- ***Thermoplastic copolyester elastomers (COPEs)*** have alternating hard segments, usually an ester, and soft segments, usually an ether, which give them a unique set of performance characteristics. COPEs are relatively easy to process, are resistant to oil and many chemicals, and have good flex resistance across a broad range of temperatures. Their high cost ($2.40-$3.60 per pound) prohibits use in many applications, although they are suited for use in selected blow-molded auto underbody parts.

- ***Thermoplastic vulcanizates (TPVs)*** have two phases, a finely dispersed thermoset rubber phase and a polyolefin continuous phase. The vulcanized rubber phase improves compression set, chemical resistance, and thermal stability. Because of the superior processing characteristics of TPVs, they are seen as a reasonable replacement for thermoset rubbers even though the cost of raw materials for TPVs is higher. TPVs generally cost between $1.40 and $2.00 per pound and are used in automotive boots and bellows, hose and tubing, and other applications.

Source: Compiled by USITC staff from “Elastomers and Rubbers: Thermoplastic Elastomers,” *Machine Design,* vol. 68 , No. 3 (Feb. 8, 1996), p. 82; Malcolm Thompson, “TPEs Open the Door to Better Designs,” *Machine Design*, vol. 65, No. 15 (July 23, 1993), pp. 47-49; Charles A. Rader “Thermoplastic Elastomers: Non-tire Market Share Up to 11% as Production Reaches 420,000 Tonnes,” *Modern Plastics*, vol. 72, No. 12 (Mid-November 1995), p. B-57.

Table 1
North American TPO usage in cars and light trucks for 1995, and projected usage for 2000 and 2005, in million pounds; annual growth rate, 1995-2005

Application	1995	2000	2005	Annual growth rate, 1995-2005 (*Percent*)
Type of part:				
Exterior:				
Bumper systems (incl. fascia, trim, strips)	100.0	220.0	280.0	10.8
Cladding, side trim	20.0	35.0	35.0	5.8
Wheel flares	6.0	6.5	6.8	1.2
Front grilles	3.0	8.0	12.0	14.9
Other trim	18.5	22.6	28.5	4.4
Subtotal, exterior parts	147.5	292.1	362.3	9.4
Interior:				
Airbag cover	1.8	6.3	8.1	16.3
PVC skin replacement	0	10.0	20.0	([1])
Other interior	0	4.0	6.0	([1])
Subtotal, interior parts	1.8	20.3	34.1	34.2
Underhood, Body:				
Air intake (blow mold)	13.4	18.3	22.0	5.1
Boot, bellows (blow mold)	0.2	0.4	0.6	11.6
Splash shields	2.0	4.0	6.0	11.6
Subtotal, underhood/body parts	15.6	22.7	28.6	6.2
Total	**164.9**	**335.1**	**425.0**	**9.9**
Comparative measures:				
Vehicles produced (*million*)	13.0	13.3	13.5	0.4
Pounds/vehicle	12.7	25.2	31.5	9.5

[1] Not applicable because the quantity is zero for the initial year under consideration.

Source: Bernie Miller, "TPO Takes Fast Lane to Big-time Applications," *Plastics World,* vol. 53, No. 10 (October 1995), pp. 42-48.

Processing Advantages of TPEs

The major advantages of TPEs over thermoset rubbers relate to processing, particularly the option of processing TPEs on equipment that is used for plastic extrusion[16] or injection molding.[17] By comparison, traditional rubbers require slow batch processing using capital-intensive machinery.[18] TPEs also can be made in specific grades because they are produced in continuous processes, whereas it is much more difficult to achieve consistent specifications for

[16] Extrusion, a common plastics processing technique, involves heating the material in a cylinder and then forcing it through a die with a rotating screw. Sheets, rods, bars, and tubes can be made by extrusion. Douglas M. Considine, ed., *Chemical and Process Technology Encyclopedia* (New York: McGraw-Hill Book Company, 1974), p. 884.

[17] Injection molding is a process in which granulated thermoplastic materials are heated and then forced into a mold of the desired item. Usually the molds are standardized, which limits the part sizes and shapes that can be made. Considine, ed., *Chemical and Process Technology Encyclopedia,* p. 883.

[18] Reisch, "Thermoplastic Elastomers," p. 11.

the materials produced in batch processing because of slight variations in the conditions for each batch.[19]

Thermoset rubber is limited in its processing methods, in part because of low temperature constraints required to prevent premature vulcanization.[20] By comparison, a number of more specialized processing techniques are possible with certain TPEs. For example, film and sheet extrusion and thermoforming[21] processes are being developed to use TPOs in "soft-skin" applications in car interiors. After extrusion, the TPO is then thermoformed to a more rigid material, thereby improving the feel of the end product.[22] Although the thermoplastic polyvinyl chloride (PVC), which has excellent tactile characteristics, is currently the most common material used for thermoformed products, TPO use in mid-priced cars is growing in popularity because of its superior UV resistance, better color stability, and lower weight.[23] Low-pressure injection molding is also opening TPOs to new soft-feel applications. In this process, a composite of TPO skin and polyolefin[24] foam is placed in a mold, and polypropylene[25] is then injected under low-pressure conditions. In one step, the producer generates a finished part with no adhesive materials required.[26]

Blow molding,[27] which is not an option for thermoset article manufacturers, also has been pursued by TPE producers. Because of easier processing and the ability to generate extremely thin parts, blow-molded TPEs reportedly offer significant cost savings[28] over injection-molded hollow parts made of thermoset rubbers.[29] For this reason, TPEs are becoming a popular material choice for hollow products, such as bottles, convoluted boots, and bellows.[30]

Innovations in TPE processing techniques, especially molding, are likely to produce an increase in part consolidation, meaning that one single large part takes the place of several smaller parts.[31] Parts consolidation is attractive to the auto industry because it reduces assembly and

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[19] Peter Mapleston, "New Grades and Processes Expand TPE Capabilities," *Modern Plastics*, vol. 73, No. 5 (May 1996), pp. 64-65.

[20] Vulcanization is the industrial process in which raw rubber is heated with sulphur and certain other chemicals to achieve the crosslinks that "set" thermoset rubbers. Heinisch, *Dictionary of Rubber*, p. 189.

[21] Thermoforming is a process in which a sheet of material is heated and then pulled (by vacuum, pressure, or a mechanism) onto a form or mold. This process is effective for low-cost parts with large surface areas; the costs of tooling are low and there are no restrictions on part size. Considine, ed., *Chemical and Process Technology Encyclopedia*, p. 884.

[22] Sherman, "New Applications Breed New Ways to Process TPOs," p. 16.

[23] Miller, "TPO Takes Fast Lane," p. 43.

[24] A polymer based on any of the olefins, which are carbon-based molecules with the basic formula of C_nH_{2n}.

[25] A thermoplastic polymer of propylene.

[26] Sherman, "New Applications Breed New Ways to Process TPOs," p. 16.

[27] In blow molding, a thin cylinder, called a parison, is extruded and then inserted in a split mold; the parison is then pneumatically pressed into the mold to produce a thin, hollow part. Considine, ed., *Chemical and Process Technology Encyclopedia*, p. 884.

[28] Estimates of cost savings associated with TPE processing are not available.

[29] Rader, "Thermoplastic Elastomers," p. B-58.

[30] Ibid.

[31] Eller, "Interiors," p. 52.

disassembly cost and leads to improved energy efficiency.[32] For example, a new design for an intermediate steering shaft[33] that incorporated TPE components reduced the number of parts from 13 to 3; this lowered the cost of the product by about 20 percent.[34]

TPEs, like all thermoplastic materials, are recyclable. Because of the efforts by industry to minimize processing waste, the ease of recycling TPEs provides a considerable advantage over thermoset rubbers. In processing TPEs, scrap can be returned to the manufacturing lines after simple drying and regrinding steps. Individual finished products can be recycled as well, although the process is slightly more involved than for scrap.[35] This is attractive to the auto industry[36] since many of the rubber components of a car are discrete parts, and it is therefore possible to remove an individual component and use its material in the production of another item.[37] The average car, exclusive of tires, contains about 26 pounds of rubber, offering a substantial incentive for automakers to use TPEs in place of thermosets.[38]

For parts processors currently producing thermoset rubber articles, there are some disadvantages to switching to TPE materials. First, the type of equipment used for TPE parts is very different than that which is used for thermosets, requiring a significant additional investment in new equipment to convert to TPE materials. Even though the upfront cost of thermoplastic processing equipment is less than that for thermosets, the additional investment and time required to learn a new processing technique may be considered prohibitive by a thermoset rubber producer.[39] Additionally, raw materials for TPEs are generally more expensive than materials for thermoset rubber production, although lower production costs[40] reportedly offset this additional expense in many instances.[41]

The most significant disincentives to using TPEs in place of thermoset rubbers are based on performance characteristics. High-grade thermoset rubbers offer superior blends of abrasion resistance, flexural strength, deformation resistance, and, most notably, heat resistance when compared with TPEs. In applications that require strong performance in these areas, the processing advantages of TPEs are insufficient to justify their use. For example, because TPEs are affected by heat, they are not used in place of thermoset rubbers in automobile tires, currently the largest single application for rubbers.[42]

Applications in the Auto Industry

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[32] Eller, "Interiors," p. 49.

[33] An automobile part that connects the steering shaft to the steering gear and serves to isolate the driver (via the steering wheel) from imperfections in the driving surface.

[34] "A New Feel for the Road," *Automotive Production*, vol. 108, No. 7 (July 1996), p. 22.

[35] Rader, "Thermoplastic Elastomers," p. B-58.

[36] For more information on the recycling of post-industrial and post-consumer TPOs to produce resins for use in automobiles, please see the following journal article: Lindsay Brooke, "Like a Virgin," *Automotive Industries*, vol. 177, No. 4 (April 1997), pp. 105-109.

[37] Mapleston, "New Grades and Processes," p. 65.

[38] Ibid.

[39] Rader, "Thermoplastic Elastomers," p. B-56.

[40] Estimates of cost savings associated with TPE processing are not available.

[41] Rader, "Thermoplastic Elastomers," p. B-58.

[42] Reisch, "Thermoplastic Elastomers," p. 11.

Experimentation with new materials is fairly common in the automobile industry, and the combination of properties of TPEs has attracted automobile and auto parts producers for original equipment (OE) as well as the replacement markets. Initially, TPEs were used primarily for applications that had been dominated by thermoset rubbers, but the scope of uses for TPEs is expanding. Increasingly, applications requiring the characteristics of thermoplastic materials such as PVC have begun switching to TPEs. TPEs can reportedly offer considerable savings to automakers over thermosets on the basis of processing costs,[43] and TPE parts can be 15 to 30 percent less expensive than comparable goods of other thermoplastics.[44] Additionally, auto producers' concern with minimizing vehicle weight, which has been buffered by claims that gas consumption could be lowered by 750,000 barrels per day if carmakers were to reduce automobile weight by 25 percent during this decade,[45] has led to increasing use of plastic materials in place of metals.[46]

Current Applications

Early, less sophisticated thermoplastics elastomers were chosen mainly for their low cost, low-temperature impact resistance, and potential for recycling. The auto industry found use for these materials, generally TPOs and SBCs, in applications with low-performance requirements, such as bumper guards, air dams, wheel well liners, rubstrips, dashboard trim, grommets, and step pads. Recent technical developments have strengthened the performance of TPOs for use in higher stress automotive products, including bumper fascia, cladding, and side trim. Producers reportedly are able to reduce the wall thicknesses of these parts by using TPEs, resulting in cost savings[47] and shorter processing times, with superior performance over other plastic materials.[48]

The application of TPOs in the auto industry has expanded to significant interior and underhood parts as well. The replacement of PVC skins in several key uses, including skins for instrument panels, door trim panels, and consoles, is a boon for TPO producers. The thermoplastic elastomers perform better in several areas, including long-term property retention and simplified recycling, when compared with PVC; however, TPEs are not typically used for soft skins in high-end automobiles because their tactile qualities are considered to be inferior to those of PVC.[49]

Several types of TPEs are high in cost,[50] which has limited their use in the auto industry. However, there are cases in which other factors somewhat offset the importance of cost in choosing a material. For example, glass fiber-reinforced TPUs have been introduced as a lighter substitute for steel in vehicle body panels. In addition to offering energy efficiency through lower vehicle weight, TPUs have excellent structural integrity, low warpage, dimensional

[43] Ibid.

[44] Miller, "TPO Takes Fast Lane," p. 43.

[45] Jim Callari, "Playing the Resin Game," *Plastics World*, vol. 53, No. 9 (September 1995), p. 115.

[46] John Couretas, "Material Assets: Suppliers of Metals, Plastics Battle for a Bigger Share of Vehicle Content," *Automotive News*, No. 5701 (February 24, 1997), p. 32i.

[47] Estimates of cost savings associated with TPE processing are not available.

[48] Miller, "TPO Takes Fast Lane," pp. 42-43.

[49] Ibid., p.47.

[50] As indicated in the text box, there is a broad range of TPEs, which vary significantly in price.

stability, and high paintability (with no primer required).[51] High-priced COPEs are generally used only in high-performance parts, such as the constant velocity boot, "where functional integration enables them to replace traditional materials."[52] COPEs also are favored over thermosets for these types of parts because the products made from these thermoplastic elastomers typically do not need to be replaced during the lifetime of the vehicle.[53]

As the development of TPVs has flourished (detailed below), automakers have found increasing use for these materials, such as in the corner sections of window seals. Formerly an application for thermoset rubber, use of TPVs allows producers to avoid finishing steps, including trimming and bonding, and expedites the overall production process from approximately 3 minutes to a matter of seconds.[54]

In most of the aforementioned parts, a TPE has been used as a replacement for thermoset rubber or another plastic material. However, TPEs are not limited to serving as replacements for other materials in existing applications. There are some products that have been developed with TPEs as the primary materials employed from the outset. For example, airbag designers have used a variety of thermoplastic elastomers in their effort to create an effective yet inexpensive product. There is still considerable design experimentation to be done on these parts, especially in light of recently released information on potential hazards related to their use.[55] However, the TPE combination of firm yet flexible properties seems particularly well-suited for these products. Given the expected magnitude of the market for airbags, this reportedly bodes well for TPE producers.[56]

Developments and Future Applications

TPE producers have been active in developing highly specialized materials intended for specific end uses. There also has been significant research and development of new processing techniques to maximize performance characteristics, while minimizing the quantity of material and time required for production of each article. Some significant innovations in the auto industry are outlined below.

Considerable progress has been made in the area of TPVs. For example, one recent development is a TPV grade that can be foamed in a water-based extrusion process; the material is then used in the production of the hoodseals of a Japanese recreational vehicle.[57] In another innovative extrusion process, TPVs are coextruded with another thermoplastic (e.g., polypropylene) to produce a single component with distinct rigid and soft sections. The dual nature of these materials makes them particularly useful for producing seals: the rigid segments anchor the seal in place while the soft segments perform the sealing function. Given the wide

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[51] Martin O'Neill, "High-Performance Markets Drive TPU Innovation, Growth," *Modern Plastics*, vol. 74, No. 3 (March 1997), p. 71.

[52] Mapleston, "New Grades and Processes," p. 65.

[53] Ibid.

[54] Ibid.

[55] Information obtained from the Airbag Options website (http://www.airbag.net/) on January 8, 1998.

[56] Mapleston, "New Grades and Process," pp. 66, 68.

[57] Robert D. Leaversuch, "TPEs Address Emergent Needs in Molded Automotive Interior Parts," *Modern Plastics*, vol. 73, No. 4 (April 1996), p. 93.

variety of automotive seals, each with particular requirements depending on the section of the vehicle involved, there is likely to be considerable material and process development in this area. Industry experts have predicted that auto seal producers will continue to pursue easily processed, low-priced replacements for the thermoset rubbers currently in use.[58]

TPUs are often considered to be too expensive for use in most auto parts, especially compared with lower priced TPOs and TPVs. However, there has been substantial research on the possibility of alloying TPUs with any of several lower grade materials. The price reduction could be significant enough to warrant such combinations, in spite of the compromise on performance.[59]

A new processing technique that looks promising for the production of a variety of auto parts employs robotic[60] extrusion technology to cover hard materials with a soft TPE profile. The innovation was first used in Europe to produce an automotive belly pan,[61] and auto parts manufacturers are anticipating a wide range of new applications, including engine encapsulation parts, sunroof profiles, and edged protection for metal parts.[62] Using this technique, the TPE is extruded through a flexible, heated hose; robots shape the profile to the rigid substrate, which can be made of any material that can withstand the heat and mechanical constraints of the process. With minor modifications to the robot's program, part specifications can be altered to meet a wide variety of needs. By comparison with the injection molding methods (see footnote 17) that are used in similar applications, robotic extrusion reportedly lowers tooling costs,[63] gives flexibility to adjust to production of different parts, produces tight tolerances, and allows for a variety of hollow shapes.[64]

Outlook for TPE Producers

The growing popularity of TPEs is not limited to the auto industry. Several other sectors also are expected to demonstrate high average annual growth rates for TPE use during 1995-2000 (table 2), even surpassing growth in the auto industry. Although the auto industry is likely to continue as the leading consumer of TPEs, medical products will be a particularly strong area of growth, followed by consumer products and construction.[65] TPEs offer the medical industry considerable benefits over thermoset rubbers on toxicological grounds; certain unhealthful chemical additives required for the vulcanization process, such as heavy metals (e.g., tellurium

[58] Robert D. Leaversuch, "New Applications Extend End-Use Penetration," *Modern Plastics*, vol. 74, No. 1 (January 1997), p. 75.

[59] Patrick Toensmeier, "TPE Formulations Show New Versatility," *Modern Plastics*, vol. 72, No. 5 (May 1995), p. 75.

[60] The name of this processing technique reflects the role of robots in shaping the extruded material.

[61] According to an auto industry expert, an automotive belly pan is used to cover the bottom of an automobile, thereby smoothing airflow under the vehicle and reducing noise.

[62] "TPE Robotic Extrusion," *Machine Design*, vol. 69, No. 2 (Jan. 30, 1997), p. 108.

[63] Estimates of cost savings associated with TPE processing are not available.

[64] "Robotic Extrusion Molds Soft Materials over Rigid Substrates," *Machine Design*, vol. 69, No. 11 (June 5, 1997), p. 96.

[65] Reisch, "Thermoplastic Elastomers," p. 13.

and selenium) and aromatic hydrocarbons (e.g., dibenzoyl-p-quinone dioxime), are unnecessary in production of TPEs.[66]

Table 2
Estimated world growth for thermoplastic elastomers, by industry, 1995-2000

Industry sector	1995	2000	Average annual growth
	----*(Million pounds)*-----		(*Percent*)
Motor vehicles	798	1,133	7.3
Footwear	503	593	3.3
Industrial machinery and equipment	463	653	7.1
Consumer products	236	346	8.0
Wire and cable	130	165	4.9
Medical products	99	174	11.9
Construction	62	90	7.7
Other	44	64	7.8
Total	2,335	3,218	6.6

Source: Marc S. Reisch, "Thermoplastic Elastomers Target Rubber and Plastics Markets," *Chemical and Engineering News,* vol. 74, No. 32 (August 5, 1996), p. 13.

Regional Consumption

North America is currently the leading regional consumer of TPEs in the world (table 3), which is consistent with its position as the leading consumer of rubbers. According to the International Institute of Synthetic Rubber Producers, North American consumption of TPEs was expected to grow at a high rate during 1995-97, especially in comparison with that of the second largest consumer, Western Europe. The tepid projected growth in consumption for Western Europe has been attributed to the region's sluggish economy. Latin America, the Commonwealth of Independent States, and the Middle East and Africa all showed gradual growth during 1995-97.[67] Data on Asian TPE consumption are not available; however, as indicated by recent business developments (see following section), growth in Asian markets would seem likely.[68] China in particular has been a significant consumer of TPEs for use in its footwear industry.[69]

Table 3
TPE consumption, by region, in million pounds, 1995-97

Region	1995	1996[1]	1997[2]	Average annual growth, 1995-97 *(percent)*
North America	831.0	913.6	976.4	8.4
Western Europe	694.3	694.3	722.9	2.0

[66] Rader, "Thermoplastic Elastomers," p. B-58.

[67] The IISRP website (http://www.iisrp.com/) on September 4, 1997.

[68] However, it should be noted that these developments arose prior to the recent economic problems in Asia, and at this time there is no firm indication as to how TPE consumption will be affected.

[69] The Economist Intelligence Unit, "World Rubber Trends and Outlook," ch. in *Rubber Trends: The Worldwide Rubber Industry, 1st quarter 1997* (London: The Economist Intelligence Unit, 1997), p. 21.

Table 3
TPE consumption, by region, in million pounds, 1995-97

Latin America	26.7	30.9	33.1	11.3
Commonwealth of Independent States	19.8	22.0	22.0	5.4
Middle East and Africa	13.2	13.9	14.8	5.9
World	1,924.1	2,027.7	2,135.7	5.4

[1] 1996 figures are based on partial year data.
[2] 1997 figures are forecasts by IISRP.

Source: Compiled by USITC staff from data obtained from the International Institute of Synthetic Rubber Producers' website (http://www.iisrp.com/) on Sept. 4, 1997.

Business Developments for TPE

Business activity involving TPE has thrived recently. While the following is not an exhaustive list of business developments in TPEs, the information cited is indicative of the growth anticipated by the chemical industry.

In North America, expansion of TPE capacity is ongoing. An earlier indication that thermoplastic elastomers were becoming serious competitors with rubber and plastics was the emergence of a joint venture by two large chemical companies. In January of 1991, Monsanto Chemical Co. and Exxon Chemical Co. joined forces to form Advanced Elastomer Systems (AES), a company intended to draw on the parent companies' strengths to develop innovative thermoplastic elastomers.[70] Similarly, on April 1, 1996, DuPont Dow Elastomers was created as a joint venture between DuPont Chemical Co. and Dow Chemical Co., with a focus on the creation of specialized elastomer materials.[71]

Other developments followed. Bergmann Kunststoffwerk of Germany, a part of the M.A. Hanna Group of Ohio, has invested in a new production facility in Spain. The site will increase the company's TPE production by 25 percent.[72] Additionally, an Asian company, Taiwan Synthetic Rubber (TSR), purchased a 30 percent stake in a U.S. TPE producer, J-Von. TSR plans to use the investment as an opportunity to expand its TPE technical capabilities as well as its U.S. marketing experience. Conversely, J-Von expects the arrangement to help gain entry to the Asian market, for both sales and investment.[73] Another Asian company, Kuraray (Japan), has pursued the possibility of building a TPE plant in Texas, given the significant demand for its products in the United States and Europe. After 3 years of marketing in the American and European markets, Kuraray is interested in building a production facility to supplement its 10,000 metric ton (about 22 million pounds) plant in Japan, ideally with a geographical advantage for the U.S. market.[74] With the stated goal of capturing 20 percent of the world TPE market, DSM (Netherlands) recently invested in increased production capacity

[70] "AES, an Instant Giant, Says It Will Catalyze Big Expansion of TPE Field," *Modern Plastics,* vol. 68, No. 3 (March 1991), p. 16.
[71] Information obtained from the DuPont Dow website (http://www.dupont-dow.com/) on Sept. 16, 1997.
[72] "Business Briefs," *Modern Plastics*, vol. 73, No. 3 (March 1996), p. 19.
[73] "TSR Invests in China, Thailand, U.S." *Chemical Week*, vol. 158, No. 10 (March 13, 1996), p. 21.
[74] "Kuraray May Build Texas Plant," *Chemical Week*, vol. 159, No. 14 (April 9, 1997), p. 12.

at its plant in Belgium; the new capacity triples the previous level to 15,000 metric tons (about 33 million pounds) annually.[75]

In March 1996, it was reported that the Taiwanese TPO and TPU producer Polystar Engineering Plastics Co. was acquired by two other Taiwanese companies: Tong Yang Industry Co., an auto parts producer, and Integral Chemistry. Reportedly, Tong Yang sought a local source of TPOs for its annual production of 600,000 bumpers, the majority of which are exported to the United States, and 120,000 instrument panels. Prior to this acquisition, Tong Yang was importing about 13.2 million pounds of TPOs annually.[76] In Iwakuni, Japan, the Toyobo Co. built a plant designed for production of 7.7 million pounds of copolyester elastomer annually. Without the new facility, Toyobo was already producing 5.5 million pounds of TPEs per year, most of which were sold to Southeast Asian auto parts producers.[77] Additionally, Dow Elastomers established its Asian headquarters in Singapore in 1996 to begin marketing TPE in the region. About 15 percent of the company's sales are to the Asia-Pacific region, and there is an expectation for this percentage to rise to 25 to 30 percent by 2001, as significant growth is anticipated in consumption of wire and cable, automobiles, and footwear. DuPont Dow has long-term plans to set up production facilities in the region.[78]

Conclusions

The prospects for TPEs in the auto industry seem promising. As cars continue to become lighter in weight and more energy efficient, automakers and parts producers are expected to continue to experiment with new and innovative materials. Research and development to find more efficient, faster, and more effective processing methods is also likely to persist as an integral facet of design for the auto industry. Moreover, as parts consolidation and recycling of parts (and materials) become increasingly important objectives, the auto industry will continue to experiment with alternative materials. Because of the ease of processing, potential for recycling, and performance characteristics of thermoplastic elastomers, the auto industry can be expected to find increasing use for these materials in the future. Average annual growth of TPE use in the motor vehicle sector between 1995 and 2000 is estimated at 7.3 percent, projected to reach 1.1 billion pounds in 2000 (table 2). In North America, TPOs specifically are expected to increase from 165 million pounds in 1995 to 335 million pounds in 2000 and 425 million pounds in 2005 (table 1).

In spite of the optimistic growth rates anticipated for TPE, it should be noted that TPEs remain a fairly small portion of total elastomer (including natural and synthetic thermoset rubber) consumption. While use of TPEs will continue to grow from a broader scope of applications, certain performance constraints, particularly the lack of heat resistance, will curtail their application in specific areas. As noted earlier, the largest end use for rubbers is tires, an application for which TPEs are considered unacceptable.

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[75] "DSM Starts Up Rubber TPEs," *Chemical Week*, vol. 159, No. 14 (April 9, 1997), p. 30.
[76] "TPE Supplier Acquired by Taiwan Companies," *Modern Plastics*, vol. 73, No. 3 (March 1996), p. 23.
[77] "Business Briefs," *Modern Plastics*, vol. 73, No. 3 (March 1996), p. 23.
[78] " DuPont Dow Slates Singapore for Base," *Modern Plastics*, vol. 73, No. 6 (June 1996), p. 25.

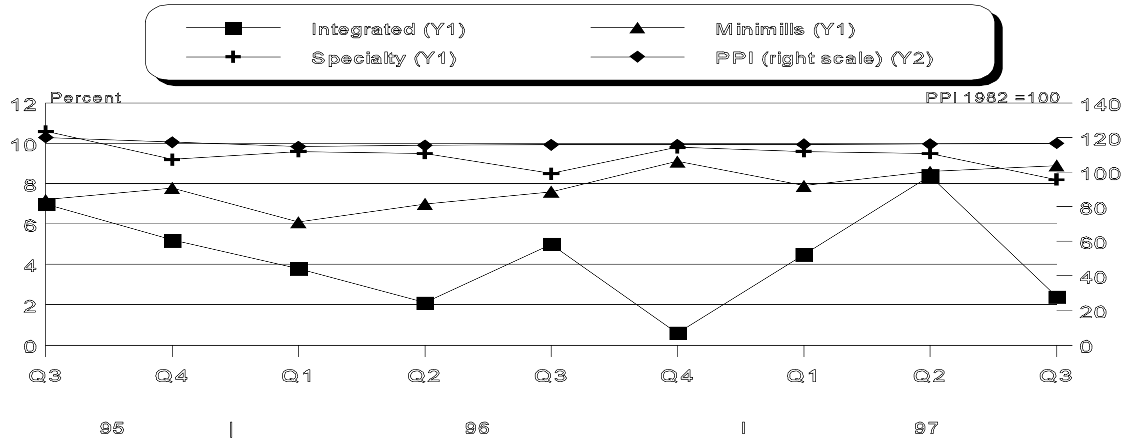
Overall, world production of TPEs is increasing to keep up with demand, and growth is expected to continue at a high rate. Because TPE producers and the auto industry, the largest current user of TPEs and frequent driving force for material development, have an established relationship, it does not seem likely the auto industry will encounter a shortage of materials as a result of the rise in TPE use in other sectors, such as the medical industry. Many possibilities remain for the auto industry to improve the performance, appearance, and efficiency of its products, and there seems to be a commitment from TPE producers to play a significant role in this process.**#**

APPENDIX A
KEY PERFORMANCE INDICATORS OF SELECTED INDUSTRIES

- **STEEL** (Tracy Quilter, 202-205-3437/tquilter@usitc.gov)
- **AUTOMOBILES** (Laura A. Polly, 202-205-3408/polly@usitc.gov)
- **ALUMINUM** (Karl S. Tsuji, 202-205-3434/tsuji@usitc.gov)
- **FLAT GLASS** (James Lukes, 202-205-3426/lukes@usitc.gov)
- **SERVICES** (Christopher Melly, 202-205-3461/melly@usitc.gov)

STEEL

Figure A-1
Steel industry: Profitability by strategic group[1], producer price index for steel products



PPI = Producer Price Index
[1]Operating profit as a percent of sales. Integrated group contains 9 firms. Minimill group contains 8 firms. Specialty group contains 5 firms.

Source: Individual company financial statements and U.S. Bureau of Labor Statistics.

- The profitability decline from the second quarter 1997 to the third quarter 1997 for integrated producers results from a reduction in operating income. LTV Corp. experienced a net operating loss in the third quarter due to the closure of its Pittsburgh coke plant. Wheeling-Pittsburgh incurred a special charge resulting from the resolution of its 10 month work stoppage that ended in August.
- Minimills continue to experience a rise in profitability as sales prices and volume increased during the third quarter. Ameristeel cited increased production levels, lower average unit costs and a shift in the product mix towards higher margin finished steel products as contributing to higher margins.[1] Scrap prices have remained relatively stable. Workers at CF&I in Colorado began a work stoppage in October which most likely will impact the sector's profitability in the fourth quarter.
- Bethlehem Steel Corp. and Lukens Inc. announced a "definitive" merger agreement on December 15, in which Bethlehem planned to acquire Lukens to combine their plate capabilities with a view towards rationalization of facilities and improved efficiency. However, Allegheny Teledyne made an offer for Lukens only days later; as a result, Lukens' shareholders filed a class action suit to prevent the Bethlehem-Lukens merger until all offers have been considered.

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[1]Ameristeel Corporation Form 10-Q, filed Nov. 14, 1997.

Table A-1
Steel mill products, all grade

	Q3 1997	Percentage change, Q3 1997 from Q2 1997	Jan.-Sept. 1997	Percentage change, YTD 1997 from YTD 1996[1]
Producers's shipments *(1,000 short tons)*	26,525	-0.5	78,420	4.0
Imports *(1,000 short tons)*	7,854	-4.1	24,076	16.5
Exports *(1,000 short tons)*	1,601	9.5	4,454	14.8
Apparent supply *(1,000 short tons)*	32,778	-1.8	98,042	6.4
Ratio of import to apparent supply *(percent)*	24.0	[2]-0.5	24.6	[2]-1.8

[1]Based on unrounded numbers.
[2]Percentage point change.

Note.-Because of rounding, figures may not add to the totals shown.

Source: American Iron and Steel Institute.

STEEL

Table A-2
Steel service centers

Item	Sept. 1997	Percentage change, Sept. 1997 from Jun. 1997[1]	3rd Quarter 1997	3rd Quarter 1996
Shipments (*1,000 net tons*)	2,466	2.4	7,266	6,772
Ending inventories (*1,000 net tons*)	7,226	0	7,226	6,761
Inventories on hand (*months*)	2.9	([2])	2.9	2.9

[1]Based on unrounded numbers
[2] Not applicable
Note.--Because of rounding, figures may not add to the totals shown.
Source: Steel Service Center Institute.

- The Steel Service Center Institute (SSCI) reported the overall average daily shipping rate through October 1997 to be 7 percent above the rate achieved for the same period in 1996. Of the seven categories tracked by SSCI, stainless products and carbon tubing experienced the greatest gains.[1] Additionally, survey responses indicate that the steel service center industry anticipates a shortage of structurals within the next three months.[2]

- Domestic capacity utilization decreased slightly to 87.6 percent.[3] Markets for steel mill products remain robust as demand from the construction industry continues to be strong. Long products producers reported a greater backlog of orders compared to last year along with high rebar activity in the Midwest and in the South.[4]

- Import penetration decreased somewhat from the previous quarter as total imports decreased by 332,104 short tons to 7.9 million short tons.

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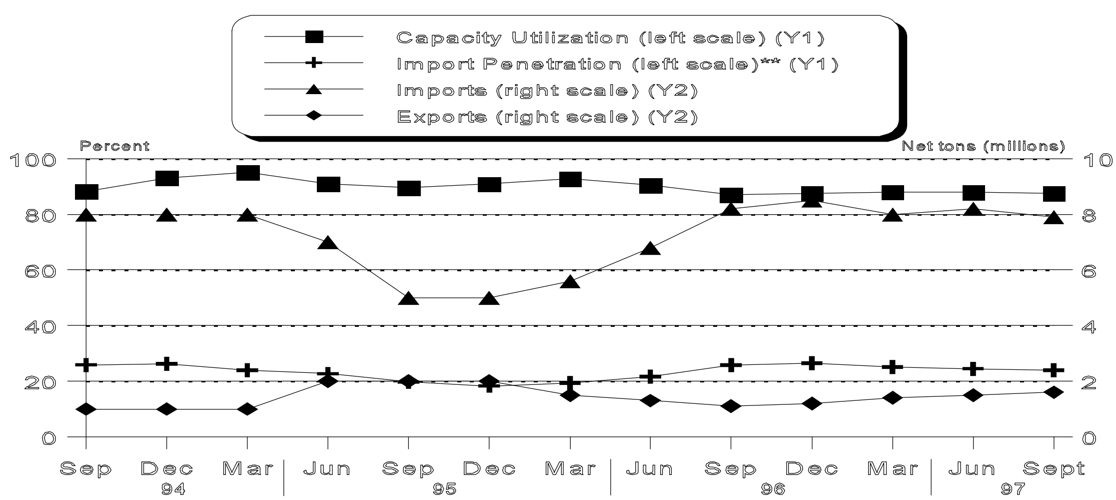
[1] Steel Service Center Institute News Release, Nov. 25, 1997.
[2] Steel Service Center Institute Business Conditions Report, Nov. 11, 1997.
[3] American Iron and Steel Institute, Sept. 1997.
[4] Corinna C. Petry, "Long Products Sizzle Due to Building Boom," *American Metal Market*, Sept. 8, 1997, p.1.

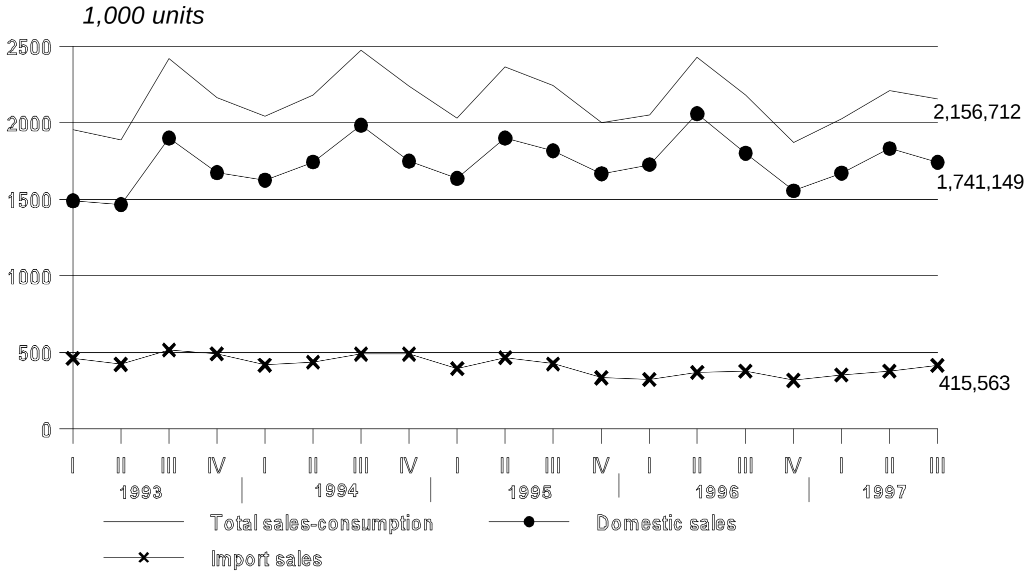
Figure A-2
Steel mill products, all grades: Selected industry conditions



**Import share of apparent open market supply.
Source: American Iron and Steel Institute.

AUTOMOBILES

Figure A-3
U.S. sales of new passenger automobiles, by quarter



Note.--Domestic sales include all automobiles assembled in Canada and imported into the United States under the United States-Canadian automobile agreement; these same units are not included in import sales.

Source: *Automotive News*; prepared by the Office of Industries.

Table A-3
U.S. sales of new automobiles, domestic and imported, and share of U.S. market accounted for by sales of total imports and Japanese imports, by specified periods, Jan. 1996-Sept. 1997

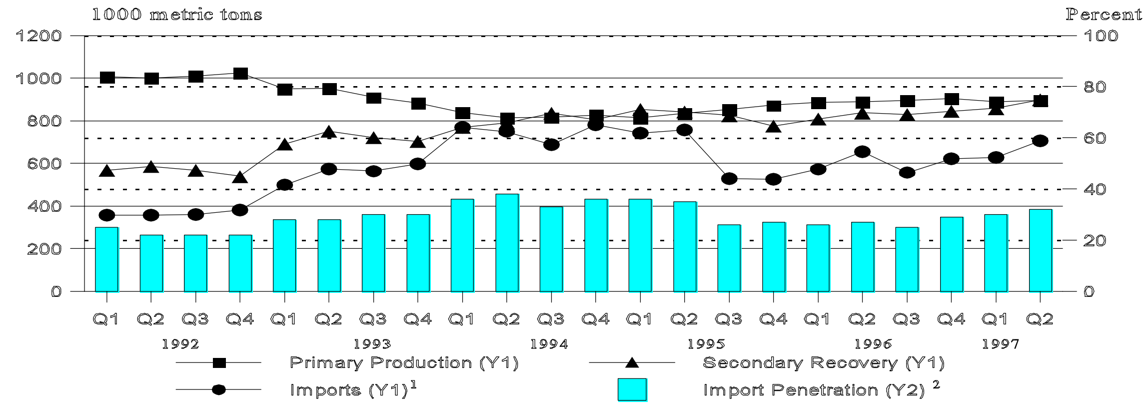
Item	July-Sept. 1997	Jan-Sept. 1997	Percentage change- July-Sept. 1997 from Apr.-June 1997	Percentage change- Jan.-Sept. 1997 from Jan.-Sept. 1996
U.S. sales of domestic autos (*1,000 units*)[1]	1,741	5,244	-4.9	-6.1
U.S. sales of imported autos (*1,000 units*)[2]	416	1,150	9.6	7.3
Total U.S. sales (*1,000 units*)[1, 2]	2,157	6,394	-2.4	-3.9
Ratio of U.S. sales of imported autos to total U.S. sales (*percent*)[1, 2]	19.3	18.0	12.3	11.7
U.S. sales of Japanese imports as a share of the total U.S. market (*percent*)[1, 2]	10.1	9.3	19.3	10.0

[1] Domestic automobile sales include U.S.-, Canadian-, and Mexican-built automobiles sold in the United States.
[2] Does not include automobiles imported from Canada and Mexico.

Source: Compiled from data obtained from *Automotive News*.

ALUMINUM

Figure A-4
Aluminum: Selected U.S. industry conditions--

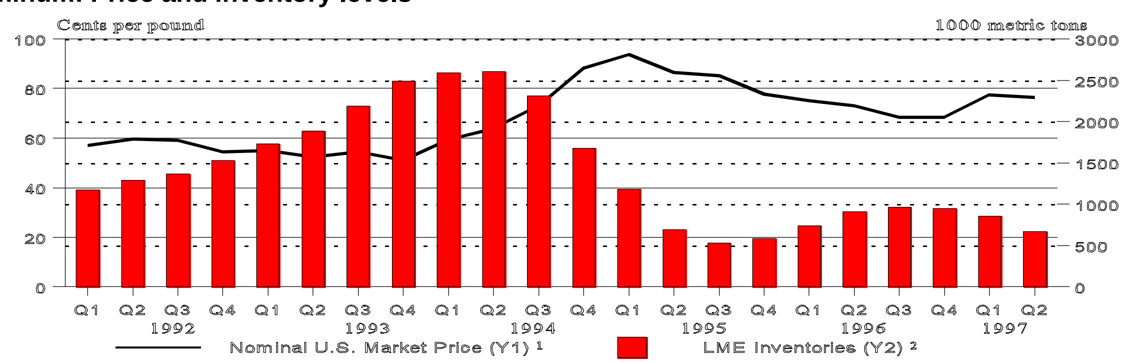


[1] Crude forms (metals and alloys) and mill products (e.g. plates, sheets, and bars) for consumption.
[2] Percent share of imports to apparent domestic supply.

Source: U.S. Geological Survey.

- Robust conditions in the global aluminum industry continued through second quarter 1997. Order rates and price premiums for physical delivery of ingot remained high in the major global consuming regions. Inventory levels on the LME declined for a third straight quarter, dropping 182,000 metric tons (21 percent) to 671,000 metric tons, the lowest level since early 1996. However, LME prices remained largely unchanged as consumers remained less concerned about metal availability due to anticipated restarts of idled smelter capacity, lack of significant speculative interest, and inventories held outside the LME.
- In the U.S. aluminum industry, strong shipments of all mill products (except for can stock) and lack of drawdown of consumer inventories continued through second quarter 1997. Domestic ingot production, currently at near capacity, was up less than one percent from the previous quarter's level to nearly 1.8 million metric tons. Imports increased by 12 percent to 705,000 metric tons to meet increased orders; import penetration rose two percentage points to 32 percent. With consumers anticipating capacity restarts and producer price-hike announcements failing to hold, the U.S. price for primary ingot dropped slightly (0.8 cents per pound) to 76.6 cents per pound during second quarter 1997.
- In second quarter 1997, the Department of Justice (DOJ) closed a probe of antitrust allegations against the major U.S. aluminum producers without further action. This probe investigated the role of producers in the negotiation of the 1994 Memorandum of Understanding (MOU), a multinational agreement to restore supply-demand balance to the global aluminum industry. A previous DOJ probe of MOU-related pricing policies on can sheet was also closed in fourth quarter 1996 without further action against the industry. In an unrelated civil case, a March 1996 class-action lawsuit against the industry alleging price-fixing is pending in the Federal Court of Appeals after being dismissed last July by the U.S. District Court.

Figure A-5
Aluminum: Price and inventory levels--

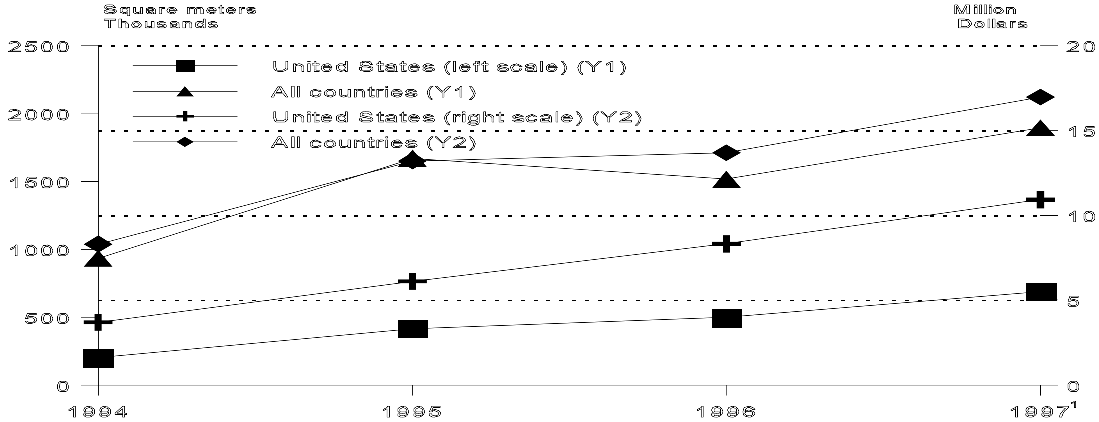


[1] Quarterly average of the monthly U.S. market price of primary aluminum ingots.
[2] End of quarter inventories.

Sources: U.S. Geological Survey, World Bureau of Metal Statistics, and Metals Week.

FLAT GLASS

Figure A-6
Average monthly Japanese imports of flat glass, by quantity, from the United States and all countries, 1994-97



[1]January-July.
Source: Compiled from official statistics of the Ministry of Trade and Industry, Japan.

Background

- The U.S.-Japanese agreement on Japanese market access for imports of flat glass[1] for the period 1995-99 seeks to increase access and sales of foreign flat glass in Japan through such means as increased adoption of nondiscriminatory standards and expanded promotion of safety and insulating glass.[2] Average monthly Japanese imports from all countries doubled under the agreement to 1.9 million square meters ($17 million) in 1997, with imports from the United States more than tripling in volume to 700,000 square meters ($10.9 million). However, the United States rated the results in opening the Japanese market over the past year as poor at the second annual review of the agreement in May 1997,[3] and in July 1997, twenty-six members of the United States Senate and fifty-three members of the House of Representatives requested the President to urge Japan to significantly improve its performance during the remainder of the agreement. The U.S. Trade Representative cited the low volume of foreign glass in the Japanese distribution system in its 301 report in October 1997 and sought consultations with the Japanese on the matter in the same month.

Current

- Discussions held in Tokyo in October 1997 failed to address U.S. concerns.[4] The U.S. Government requested an examination of whether the relationship between Japanese glass manufacturers and distributors constitutes a violation of antimonopoly law; the Japanese saw no indication of such a violation and did not support such a study. The Japanese pointed out that the share of all imports in the Japanese flat glass market increased from 7.88 percent in 1994 to 14.23 percent in the first half of 1997, and the share of imports from the United States increased from 1.71 percent to 5.15 percent.[5] The U.S. Government responded that the share of imports is still low, and while there has been an increase in imports by companies that have capital affiliation with Japanese companies, there has been little increase in imports by U.S. companies without such ties.[6] Discussion of this matter is expected to resume at the next annual session in the spring.

[1] Flat glass is largely unworked; it may be surface ground or polished and have an absorbent, reflecting or non-reflecting coating, but it has not been tempered, laminated, bent, edge-worked, engraved, drilled, enameled, or otherwise worked. Safety glass (tempered or laminated) and insulating glass are also covered under the U.S.-Japanese agreement on flat glass.

[2] USITC, "Flat glass," *Industry, Trade, and Technology Review*, Oct. 1995, p. 42.

[3] U.S. Department of State (USDOS) telegram, "Glass: Second Annual Review of the Agreement," message reference no. 05113, prepared by U.S. embassy, Tokyo, June 12, 1997.

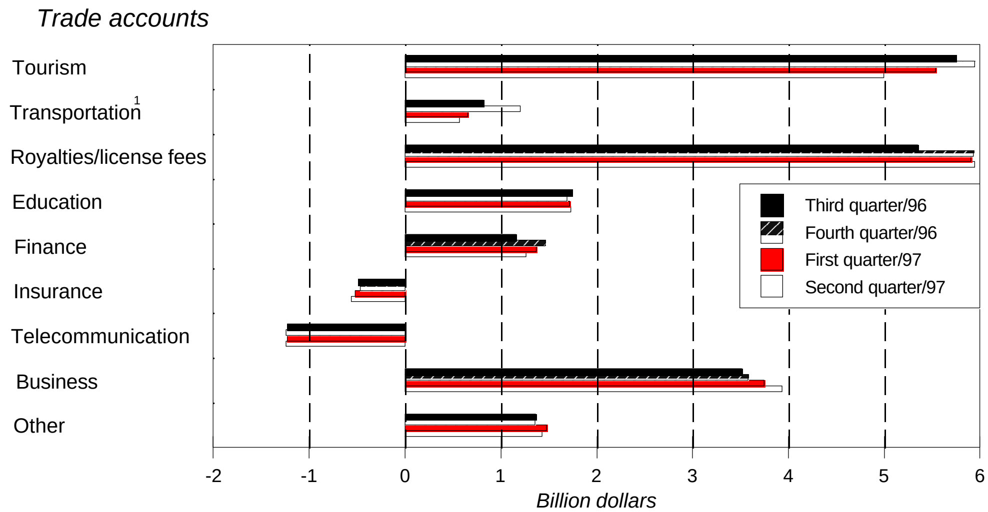
[4] USDOS telegram, "Glass: Press on Review Meeting," message reference no. 09261, prepared by U.S. embassy Tokyo, Oct. 23, 1997, retrieved from NewsEdge/Web Nov. 12, 1997.

[5] Ibid.

[6] Ibid.

SERVICES

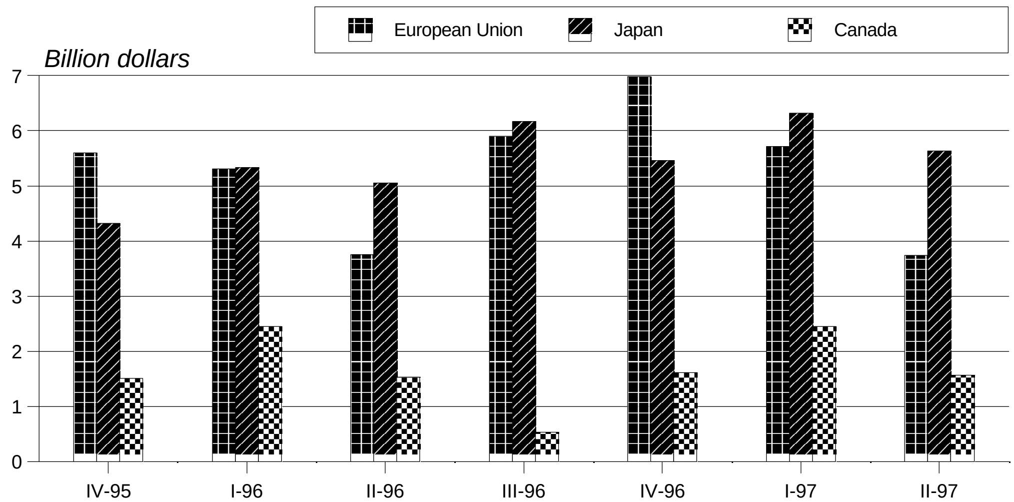
Figure A-7
Balance on U.S. service trade accounts, third quarter 1996 through second quarter 1997



[1] Includes port fees.

Source: Bureau of Economic Analysis, *Survey of Current Business*, Oct. 1997 table 3, p. 81.

Figure A-8
Surpluses on cross-border U.S. service transactions with selected trading partners, by quarter, 1995-97[1]



[1] Figures reflect private-sector transactions only; military shipments and other public-sector transactions have been excluded.

Source: Bureau of Economic Analysis, *Survey of Current Business.*, table 10, Oct.1 997, pp . 88-91.