Critical Technology Assessment:
Fine Grain, High Density Graphite

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PREPARED BY

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I. Executive Summary

The Bureau of Industry and Security (BIS) conducts critical technology assessments to examine the impact of export controls on key existing or emerging technologies that are subject to the Export Administration Regulations (EAR). For a given technology sector, BIS evaluates the scope and impact of current U.S. export controls, foreign export control practices, the sector's economic status, and the foreign availability of product substitutes.

This assessment examines the effects of export controls on U.S. manufacturers and exporters of fine grain, high density graphite subject to the EAR for missile technology (MT) and anti-terrorism (AT) reasons under Export Control Classification Number (ECCN) 1C107.a on the Commerce Control List (CCL). The parameters of 1C107.a stem from controls established by the Missile Technology Control Regime (MTCR).

In this assessment, BIS specifically examined:

- The application of ECCN 1C107.a and related licensing practices;
- Foreign export control practices on fine grain, high density graphite;
- Economic status of the U.S. fine grain, high density graphite industry; and
- Foreign availability (i.e., availability-in-fact, non-U.S. source, sufficient quantity, and comparable quality) of fine grain, high density graphite from other major producers, with a focus on China and India.

Based on data received from survey respondents and other sources, BIS concludes the following:

- Compared with other countries exporting artificial graphite, the United States is gaining market share, but the U.S. export licensing process for fine grain, high density graphite controlled by ECCN 1C107.a, especially to China, requires more license conditions and places additional burden on its exporters in comparison to the processes of other MTCR members, placing U.S. exporters at a competitive disadvantage;
- The foreign availability of fine grain, high density graphite to China and India cannot be determined at this time; and
- The existing MTCR control parameters for fine grain, high density graphite controlled by ECCN 1C107.a under the EAR are more restrictive than similar controls in China and do not reflect current production capabilities or usability of graphite for use in rockets or missiles.

Accordingly, BIS recommends that the U.S. Government (USG):

- Amend the EAR to establish a "fast-track" review system for license applications submitted for the export of fine grain, high density graphite controlled by ECCN 1C107.a destined for Australia, the EU, Japan, New Zealand, Norway, and Switzerland in order to put U.S. exporters on a more even playing field as their European competitors; and

- Submit a proposal to the MTCR to change the technical control parameters for fine grain, high density graphite. Specifically, a control parameter for the coefficient of thermal expansion (CTE) should be added, and the grain and size parameters should be revised to ensure that only that material suitable for missile technology-related uses is controlled. These changes would then be reflected in ECCN 1C107.a.

II. Introduction

A. Assessment Overview

BIS conducts critical technology assessments to examine the impact of export controls on key existing or emerging technologies subject to the EAR. These technologies are dual-use, meaning they have both civilian and military applications. For a given technology sector, BIS evaluates the scope and impact of current U.S. export controls, foreign export control practices, the sector's economic status, and the foreign availability of similar material.

This assessment examines the scope and impact of U.S. export controls on U.S. manufacturers and exporters of fine grain, high density graphite that is subject to the EAR for MT and AT reasons under ECCN 1C107.a of the CCL, which can be found in Supplement No.1 to Part 774 of the EAR.[1]

BIS surveyed several relevant manufacturers and end-users and evaluated export data and the availability of fine grain, high density graphite from foreign manufacturers. BIS also evaluated export control practices of MTCR member countries and non-MTCR countries. In addition, BIS conducted a foreign availability analysis to determine whether fine grain, high density graphite of comparable quality is available-in-fact from non-U.S. sources to countries that are not members of the MTCR and in quantities sufficient to render the U.S. export control of these items ineffective.

B. Origin of Assessment

Two factors influenced the Office of Technology Evaluation's (OTE's) initiation of this assessment:

- U.S. industry concerns that the export of fine grain, high density graphite is more limited under U.S. export controls than it is under foreign export controls; and

- Receipt of foreign availability data (i.e., brochures, marketing materials, website references) on Chinese fine grain, high density graphite.

III. Product Description

This assessment focuses on fine grain, high density graphite subject to the EAR that is controlled under ECCN 1C107.a. This type of graphite is also referred to as artificial graphite, isotropic graphite, and specialty graphite. Artificial graphite is a form of carbon that has a high thermal and

[1] Related controls subject to the export licensing authority of the Nuclear Regulatory Commission (NRC) include: graphite having a purity level of less than 5 parts per million "boron equivalent" (ECCN 0C005); and graphite with a boron content of less than 5 parts per million and a density greater than 1.5 grams per cubic centimeter that is intended for use other than in a nuclear reactor (ECCN 1C298).

electrical conductivity, has lubricating properties, and is chemically inert. It also has high thermal shock resistance and low thermal expansion. According to the MTCR Annex Handbook, "[g]raphite is the only known material that doubles in strength as the temperature increases from room temperature to 2,700ºC. Carbon particles are combined with pitch, a viscous coal tar residue, in a suitable mold and subjected to heat and pressure. The resulting block can be easily machined into the required part."[2] Fine grain, high density graphite is used to create very strong, heat-resistant parts which have both civilian and military uses.

A. Measures of Performance

There are many measures of performance used by industry in evaluating graphite products, but the primary measures are bulk density, coefficient of thermal expansion, compressive strength, flexural strength, grain size, hardness, resistance, and tensile strength.[3]

Bulk Density: The weight per unit volume of material.

Coefficient of Thermal Expansion (CTE): The extent to which a material will expand in length for each degree of temperature increase.

Compressive Strength: The maximum compressive load a material can withstand before buckling.

Flexural Strength: The ability of a material to resist fracture while bent or flexed.

Grain Size: The diameter of a grain.

Hardness: The degree to which a material will resist cutting, abrasion, penetration, bending, and stretching.

Resistance or Specific Resistance: Ability of a material to resist passage of electrical current through its bulk or on a surface.[4]

Tensile Strength: The greatest longitudinal stress or stretching force a material can sustain without breaking.

B. Civilian Applications

There are a multitude of civilian applications for fine grain, high density graphite. It is used in crucibles, ladles, and moulds for molten metals and in blast furnace linings and fixtures. Because of its low absorption of neutrons and strength at high temperatures, graphite is used in nuclear reactors. Due to its high electrical conductivity, graphite is also used for electrodes and brushes in electric motors, as well as in solar energy applications. Graphite can also be used for biomedical applications and as a lubricant or coating to reduce friction and corrosion.

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[2] MTCR Annex Handbook (Federation of American Scientists, 2002) 120.
[3] All definitions, except where indicated, were obtained from the Glossary of Engineering Materials Definitions, MatWeb http://www.matweb.com/tools/glossary.aspx
[4] Electronic Concepts, Inc., Glossary of Terms, http://www.electronicconcepts.com/dictionaryterms.asp

C. Military Applications

The primary military applications for fine grain, high density graphite are reentry vehicle nose tips, thrust tabs, heat shields, and nozzle throats of missiles. Graphite is the preferred material for these items because of its ability to withstand extremely high temperatures while maintaining its strength and shape. It is also inexpensive, light weight, easy to machine, and easy to replace compared to other materials.

IV. Export Controls

A. U.S. Export Control Regulations

Fine grain, high density graphite is controlled by the EAR under ECCN 1C107, subparagraph a (1C107.a). Controls for 1C107.a derive from Category II of the Equipment, Software and Technology Annex of the MTCR. Specifically, ECCN 1C107.a applies to:

- Fine grain graphites with a bulk density of 1.72 g/cm^3 or greater, measured at 15ºC, and having a grain size of 100 micrometers or less, usable for rocket nozzles and reentry vehicle nose tips as follows:
    - Cylinders having a diameter of 120 mm or greater and a length of 50 mm or greater;
    - Tubes having an inner diameter of 65 mm or greater and a wall thickness of 25 mm or greater and a length of 50 mm or greater;
    - Blocks having a size of 120 mm x 120 mm x 50 mm or greater.

Exports of this graphite are controlled for MT and AT reasons under ECCN 1C107.a, and no license exceptions apply, except for shipments to Canada. There are instances when a Missile Technology Assurance (MTA) condition may be placed on a license to export an MT-controlled item by the State Department. The State Department will seek to obtain a government-to-government assurance regarding the end-use of the item in order to make sure exporting it does not violate existing agreements. It could take more than 30 days to obtain this assurance, and if a MTA cannot be attained from the appropriate government, the export license will most likely be denied.

Additionally, Section 1512 of the Strom Thurmond National Defense Authorization Act for Fiscal Year 1999 requires certification from the President of the United States to the U.S. Congress at least 15 days prior to the export of any item controlled for missile technology reasons to China that the export will not measurably improve Chinese missile or space launch capabilities. The President delegated this authority to the Secretary of Commerce on September 29, 2009.

Exports of graphite are also subject to the Enhanced Proliferation Control Initiative (EPCI), or "catch all" controls. These controls impose a licensing requirement on the export and reexport of items which the exporter "knows" or "is informed" will be used in connection with weapons of mass destruction (WMD) activities.

1. History of U.S. Export Controls for Graphite

Fine grain, high density graphite was first added to the CCL in September 1991. The control was added in order to bring BIS regulations in line with the dual-use controls that had been revised by the Coordinating Committee for Multilateral Export Controls (COCOM).[5] The specific graphite control added was for "fine grain recrystallized bulk graphites (with a bulk density of at least 1.72 g/cc measured at 15 degrees C) … useable for rocket nozzles and reentry vehicle nose tips."[6] This control was revised in September 1994 to conform to MTCR revisions, and added "a particle size of 100 x 10^{-6}m (100 microns) or less" as a control parameter for fine grain recrystallized bulk graphites.[7]

Four years later in January 1998, BIS revised the CCL to remove license exception availability for MT controlled items. The control for fine grain recrystallized bulk graphites was also revised to change the bulk density parameter to "1.72 g/cm^3 or greater."[8]

In May 2002, as a result of changes to the MTCR Annex, BIS revised the control for fine grain recrystallized bulk graphites to include the existing size and shape parameters.[9] The latest revisions to the control were made in July 2006 to conform with additional changes to the MTCR Annex.[10] The word "recrystallized" was removed from the control, as it was deemed to be an obsolete term no longer used by industry. The word "particle" was also changed to "grain."

2. BIS Licensing Data

BIS processed 347 export license applications for fine grain, high density graphite controlled by ECCN 1C107.a from 2005-2008, of which 276 (79.5%) were approved. The majority of graphite approved for export was intended to be used as crucibles, ladles, and moulds for molten metals, in blast furnace linings and fixtures, and as electrodes and brushes. A large increase of license applications in 2008 was due to one exporter that previously believed the graphite it produced was uncontrolled. Sixty-eight of the applications were returned without action (RWA) to the applicants, mostly due to incomplete applications or pursuant to the applicant's request. The remaining three applications were denied due to risk of diversion to unauthorized end users and/or end uses. Figure 1 contains a breakdown by year of BIS determinations of these export license applications.

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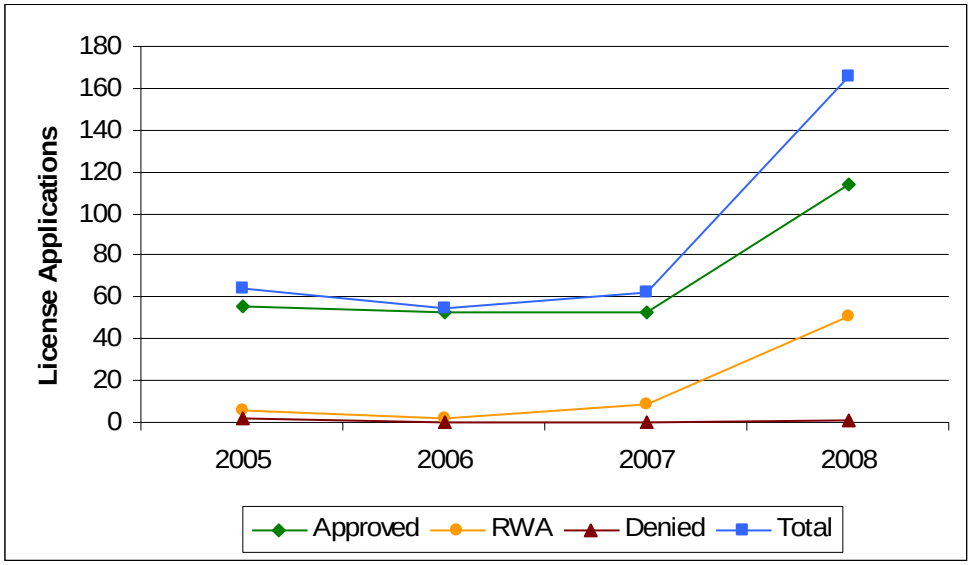
[5] COCOM was an international export control regime created in 1949 to control the transfer of military technology to the Warsaw Pact countries. It was abolished in 1993 and replaced by the Wassenaar Arrangement in 1996.
[6] United States, Department of Commerce Bureau of Export Administration, Revision of Commodity Control List, 56 FR 42824 (Washington: GPO, 1991).
[7] United States, Department of Commerce Bureau of Export Administration, Missile Technology Control Regime (MTCR); Revisions to the CCL, 59 FR 49798 (Washington: GPO, 1994).
[8] United States, Department of Commerce Bureau of Export Administration, Implementation of the Wassenaar Arrangement List of Dual-Use Items; Revisions to the Commerce Control List and Reporting Under the Wassenaar Arrangement, 63 FR 2452 (Washington: GPO, 1998).
[9] United States, Department of Commerce Bureau of Industry and Security, Revisions to the Export Administration Regulations as a Result of the September 2001 Missile Technology Control Regime (MTCR) Plenary Meeting, 67 FR 35428 (Washington: GPO, 2002).
[10] United States, Department of Commerce Bureau of Industry and Security, Revisions to the Export Administration Regulations Based on the 2005 Missile Technology Control Regime Plenary Agreements, 71 FR 43043 (Washington: GPO, 2006).

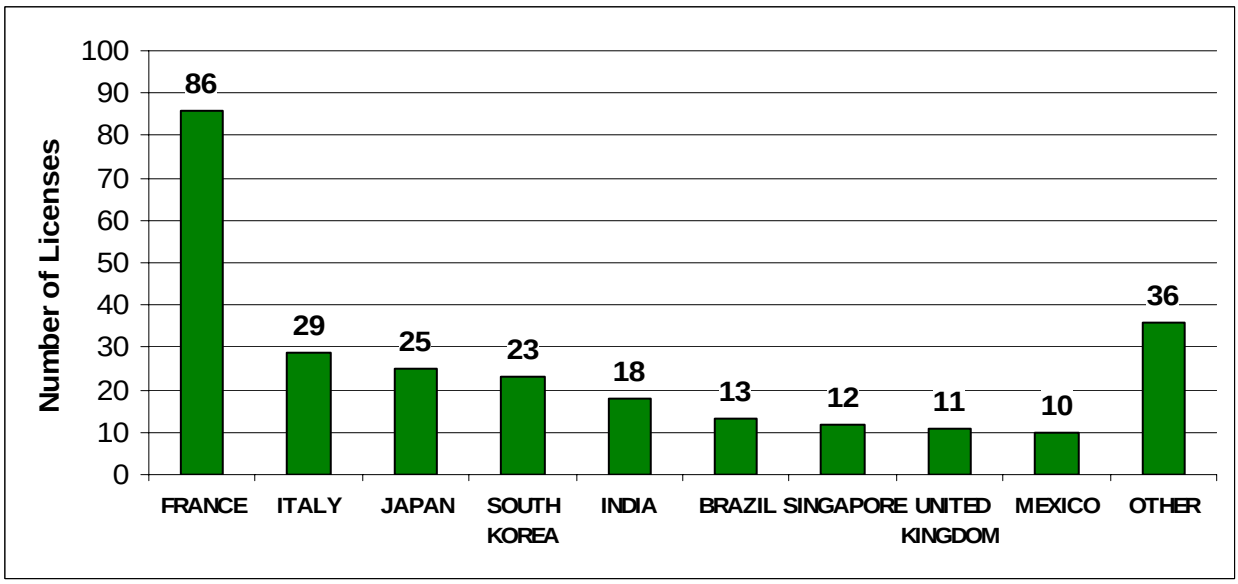
Figure 1: 1C107.a Export License Applications Processed by BIS from 2005-2008



Source: ECASS

BIS licensed exports of fine grain, high density graphite to 29 different countries between 2005 and 2008. The top ten destinations by number of licenses approved, representing 82 percent of the total licenses issued for ECCN 1C107.a from 2005 to 2008, are detailed in Figure *2*.[11]

Figure 2: Top Ten Destinations by Number of Licenses Approved 2005-2008



Source: ECASS

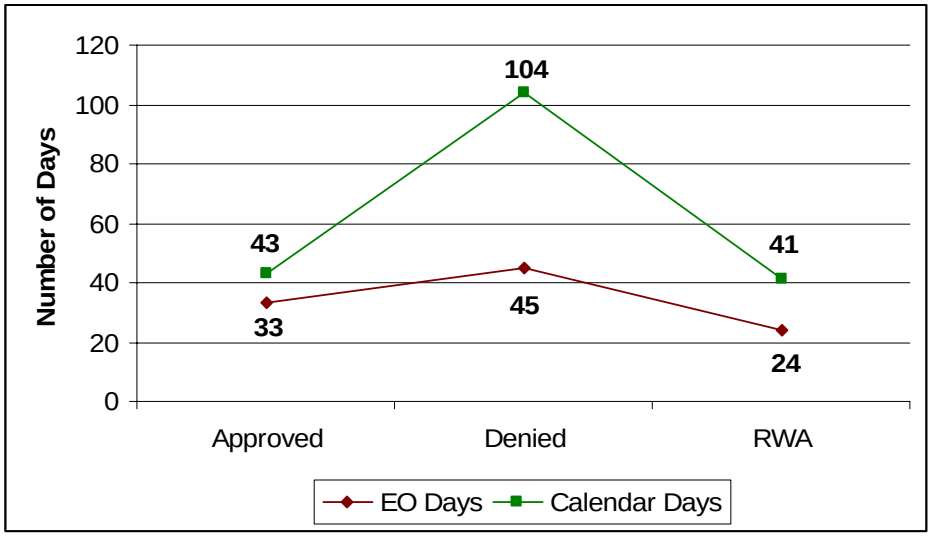
Under Executive Order (EO) 12981, BIS and other interagency partners have 39 days (Executive Order or EO days) to make a determination on an export license application once it is received from the applicant. This 39 day clock can be stopped and the case can be "held without action" (HWA) for specific reasons, including: 1) waiting for the applicant to provide additional information about

[11] The other destinations include: Taiwan, Germany, Malaysia, Austria, Thailand, Colombia, Argentina, Norway, South Africa, China, Chile, Luxembourg, The Netherlands, Peru, Poland, Ukraine, and Venezuela.

the intended export (e.g., information on the end-user, end-use, or technical specifications of the item or technology to be shipped); 2) the interagency cannot agree on the disposition of the application, and the case is escalated to the Operating Committee (OC); or 3) the case is escalated from the OC to the Advisory Committee on Export Policy (ACEP).

Figure *3* shows the difference between the average number of EO days and the average number of calendar days for license application determinations by type (i.e., approved, denied or RWA) for ECCN 1C107.a, respectively. This data shows that an exporter filing an export license application for items controlled under this ECCN will wait anywhere from one to three and a half months, on average, for a decision on their application. This does not include the additional time that would be needed for Presidential certification if an export license application were approved for China for fine grain, high density graphite controlled by 1C107.a. The average time it takes a U.S. exporter to obtain an export license for a 1C107.a item for Australia, Canada, EU members, Japan, New Zealand, Norway, or Switzerland is six weeks. When compared to the overall BIS average processing time for all licenses over the same years, approved and RWA 1C107.a licenses took slightly longer to process, while 1C107.a license denials were processed in a slightly shorter time.

Figure 3: Average Number of EO and Calendar Days for Processing of 1C107.a Export License Applications by Type for 2005-2008



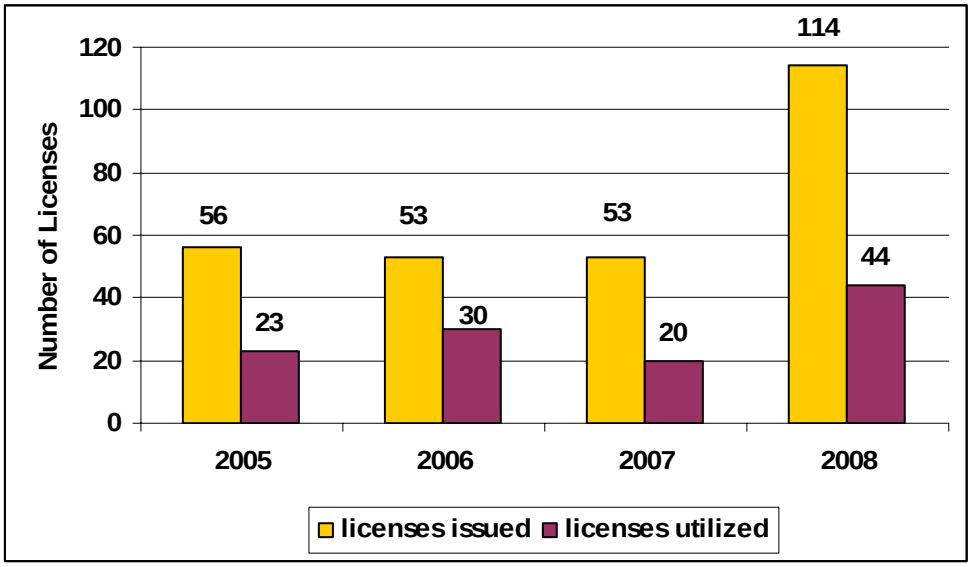
Source: ECASS

3. Licensed Shipments

The number of export licenses issued and the dollar value noted on these licenses is not a true measure of the number of items that are actually exported. An examination of shipping data, as detailed in Figure *4*, shows that 117 (42.4%) of the export licenses BIS issued from 2005-2008 for the export of fine grain, high density graphite controlled under ECCN 1C107.a were utilized.[12]

[12] BIS licenses are valid for two years in most cases. Therefore, some of the licenses BIS issued in 2007 and 2008 reflected in Figure *4* may still be utilized by the exporters until they expire in 2009 or 2010, but historical trends show that the likelihood of utilization decreases as the expiration date of the license draws near.

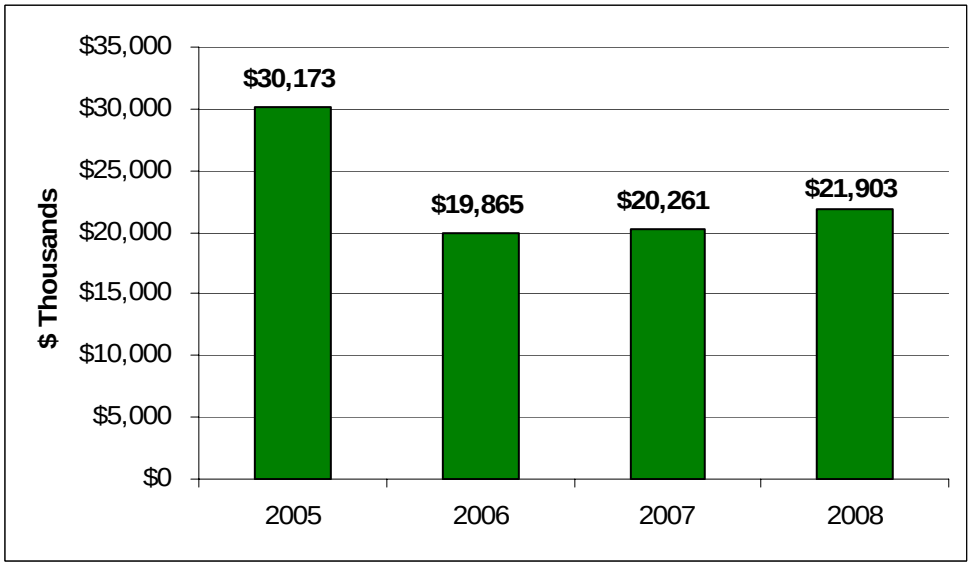
Figure 4: Number of BIS Export Licenses issued in 2005-2008 for 1C107.a Items Utilized by Exporters



Sources: ECASS, U.S. Census Bureau

Exports of fine grain, high density graphite controlled under ECCN 1C107.a require a license for all destinations except for Canada, and may sometimes be subject to license conditions. Figure *5* indicates that the value of licensed exports of 1C107.a items dropped significantly from 2005 to 2006, but showed a steady increase through the end of 2008, with a net loss over the period.[13]

Figure 5: Licensed Exports of 1C107.a Items for 2005-2008 ($ Thousands)



Source: ECASS

In an attempt to compare U.S. and global exports of fine grain, high density graphite, BIS used data from the U.S. Census Bureau to identify relevant Harmonized Tariff Schedule (HTS) numbers at

[13] [13] Figure *5* reflects licensed exports on an annual basis, which may represent several years of export licenses.

the 10 digit level, the most detailed level of categorization, for fine grain, high density graphite controlled under ECCN 1C107.a. Ninety-eight percent of all licensed exports of 1C107.a items were listed under HTS code 3801100000.

As Table *a* shows, licensed exports under this HTS code represent 21 percent of total exports from 2005 to 2008. Licensed exports of 1C107.a items make up a small percentage of total HTS code exports because HTS code 3801100000 corresponds to "artificial graphite," which includes all types of artificial graphite, and not just graphite controlled under ECCN 1C107.a.

Table a: HTS Code 3801100000 Shipments for 2005-2008

HTS Code	Value of Total HTS Code Exports	Value of Relevant Licensed Exports	% of Relevant Licensed Shipments
3801100000	$430,394,715	$ 90,765,855	21%

Sources: ECASS, U.S. Census Bureau

HTS codes are harmonized between all countries only at the six digit level. In order to compare U.S. and global trade data, BIS converted HTS code 3801100000 to its six digit level form, 380110. This six digit level HTS code was then used to assess relevant artificial graphite export patterns abroad.

Table *b* shows how artificial graphite exports have almost doubled globally from 2005-2008, rising 76 percent from $367 to $637 million. Leading nations in the export of artificial graphite, in descending order, include Japan, the United States, the European Union, and China. Each of these four exporter entities had more than $100 million in total annual dollar exports in 2008.

Table b: Leading Global Exporters of Artificial Graphite 2005-2008 (in $ thousands)

Country	**2005**	**2006**	**2007**	**2008**	**% Change 2005 - 2008**
Japan	$112,322	$136,775	$156,651	$202,339	80.1%
United States	$75,358	$91,528	$112,016	$151,490	101%
EU27 (External Trade)	$105,363	$105,883	$104,184	$125,220	18.8%
China	$36,719	$53,791	$80,730	$106,282	189.4%
India	$4,470	$4,810	$23,128	$27,851	523.1%
Brazil	$631	$978	$6,613	$10,279	1,529%
Mexico	$6,561	$4,120	$4,503	$8,565	30.5%
Canada	$11,326	$11,311	$2,884	$7,495	-33.8%
Russia	$9,124	$7,963	$3,279	$3,190	-65%
Hong Kong	$2,336	$2,184	$1,673	$1,682	-28%
South Korea	$2,432	$2,162	$2,433	$1,224	-49.7%
Singapore	$654	$859	$1,027	$1,075	64.4%
Malaysia	$37	$470	$975	$545	1,373%
Taiwan	$338	$323	$ 307	$382	13%
Global Total	**$367,677**	**$423,165**	**$500,411**	**$647,628**	**76.1%**

Source: Global Trade Atlas

Based on 2008 data, the United States is in the second position, with 23.4 percent of the global value of exports of artificial graphite.[14] Behind the United States in the forth position lies China, with 16.4 percent of the global value of exports.

Brazil proved to be the fastest growing exporter nation of artificial graphite across all reporting years and countries at 382 percent, on average per year, followed by Malaysia (343%), India (130%), and China (47%). It is not possible to determine how much of these increases in exports are due to fine grain, high density graphite controlled under ECCN 1C107.a.

Japan, the United States, and the European Union, in each of the last four years, combined for at least 70 percent of global artificial graphite exports. Prospects for the United States retaining the second export market share position are strong due to positive growth rates, as detailed in Table *c*. The U.S.'s position, however, could be jeopardized by the significant increase in China's market share; China has experienced considerable growth in the European and Southeast Asian markets. Again, it is not possible to determine how much of each nation's market share is attributable to fine grain, high density graphite controlled under ECCN 1C107.a.

Table c: Global Market Share for Artificial Graphite (2005-2008)

Country	2005	2006	2007	2008	Net Change in Market Share 2005 - 2008
Japan	30.5%	32.3%	31.3%	31.2%	0.7%
United States	20.5%	21.6%	22.4%	23.4%	2.9%
EU27 (External Trade)	28.7%	25.0%	20.8%	19.3%	-9.3%
China	10.0%	12.7%	16.1%	16.4%	6.4%
India	1.2%	1.1%	4.6%	4.3%	3.1%
Brazil	0.2%	0.2%	1.3%	1.6%	1.4%
Mexico	1.8%	1.0%	0.9%	1.3%	-0.5%
Canada	3.1%	2.7%	0.6%	1.2%	-1.9%
Russia	2.5%	1.9%	0.7%	0.5%	-2.0%
Hong Kong	0.6%	0.5%	0.3%	0.3%	-0.4%
South Korea	0.7%	0.5%	0.5%	0.2%	-0.5%
Singapore	0.2%	0.2%	0.2%	0.2%	0.0%
Malaysia	0.0%	0.1%	0.2%	0.1%	0.1%
Taiwan	0.1%	0.1%	0.1%	0.1%	0.0%

Source: Global Trade Atlas

4. Impact of Export Controls

Export controls are affecting the ability of fine grain, high density graphite manufacturers in the United States to export and remain competitive globally. U.S. exporters are required to obtain an individual validated license for every export of an item controlled for MT reasons to all destinations except Canada pursuant to the Export Administration Act of 1979, as amended (EAA). The average time it takes a U.S. exporter to obtain an export license for a 1C107.a item for Australia, Canada, EU members, Japan, New Zealand, Norway, or Switzerland is six weeks, whereas EU exporters are not required to obtain individual validated export licenses for 1C107.a items destined for the same

[14] In 2007, the United States surpassed the European Union as the second largest global exporter of artificial graphite.

countries under Community General Export Authorization EU001.[15] Additionally, the United States is the only MTCR member that requires a certification from a head of state for exports to China, and since this certification requirement entered into force in 1998, only eight licenses for the export of a 1C107 item to China have been issued.

BIS surveyed seven exporters of graphite in the United States that export the type of graphite controlled for export by ECCN 1C107.a. Three of these companies have manufacturing facilities in the United States, and five are subsidiaries of non-U.S. companies. Four companies specifically stated they have lost sales due to U.S. export licensing requirements.

At least two U.S. manufacturers believe the Presidential certification process negatively impacts business. One company stated that it "is now penalized in the market place because it must identify each distributor, customer of a distributor, sub-distributor, and end user, which is a time-consuming and difficult endeavor. If [a U.S. company] manages to identify a complete supply chain, then it must apply for a license and wait until the President grants a waiver and reports to Congress before it can export its graphite. In contrast, [a company with Chinese production facilities] can receive and ship an order in the same day. This puts [the U.S. company] at a substantial competitive disadvantage …"

One exporter said it explored the possibility of establishing production of fine grain, high density graphite in the United States, but ultimately decided not to do so because of U.S. export controls. The company said, "It is essential that an affiliate company within [our group] have the ability to send its product with relative ease to other [group] members for their use in further production or regional sales. The delays caused by specific export license application processing for export/reexport of U.S. fine grain graphite under U.S. export regulations to any country other than Canada are viewed as non-competitive and an impediment to the conduct of business. … This was a key factor in the [company] decision to eliminate production of fine grain graphite in the U.S."

Other exporters also said the time it takes to apply for and receive U.S. export licenses has caused delays and affected their competitiveness. One exporter shared the following, "The export licensing process can be very time consuming. We have submitted approximately 200 licenses in the past 5-10 years with approvals being received in 4-26 weeks. This disparity can be difficult in a competitive environment where other suppliers are not as constrained."

Another manufacturer echoed this sentiment, saying, "Obtaining a license for China in other countries certainly does not take a year, require a Presidential certification, and restrict end-users like the U.S. process does. … Compliance with U.S. regulations is a costly, time consuming process." Because of the export license process, the manufacturer's parent company moved manufacturing and sales to China outside of the United States, causing the U.S. company to lose business.

Survey respondents also pointed to license conditions as negatively impacting their competitiveness. One manufacturer said, "We are not aware that any of the other countries attempt to control the end-use and re-export of the graphite to the extent that the U.S. Department of

[15] EU001 cannot be used if the exporter is informed that the item is or may be used for biological, chemical, or nuclear weapons or for a military end use (http://trade.ec.europa.eu/doclib/docs/2009/june/tradoc_143390.pdf).

Commerce does." A second manufacturer stated that the number of conditions placed on a U.S. export license has made its product less attractive to foreign purchasers.

B. Foreign Competition

1. Foreign Manufacturers

Outside the United States, the primary fine grain, high density graphite manufacturers are located in France, Germany, and Japan. These manufacturers have robust capability to manufacture fine grain, high density graphite that rivals graphite produced by American manufacturers. There are also fine grain, high density graphite manufacturers located in China and India.[16]

The European market is dominated by two manufacturers, Carbone Lorraine and SGL Group. Both companies have extensive lines of fine grain, high density graphite. Overall, these two companies combined have at least 27 grades of graphite that have a grain size of 100 micrometers or less and a bulk density greater than or equal to 1.72cm^3. Both companies have production facilities in China and branch offices in the United States.

The Japanese market is dominated by four domestic manufacturers: Tokai Carbon, Toyo Tanso, Nippon Techno-Carbon, and Ibiden Company. Overall, these four companies have at least 55 grades of graphite that have a grain size of 100 micrometers or less and a bulk density greater than or equal to 1.72cm^3. Three of these companies have production facilities in China, and three companies have branch offices in the United States.

While not as dominant as their European and Japanese counterparts, there are a number of companies in China and India that are active in the market. There are at least 19 companies in China advertising their ability to manufacture or export fine grain, high density graphite. Of those, 15 advertise grades of graphite that have a grain size of 100 micrometers or less and a bulk density greater than or equal to 1.72cm^3, and seven promote their graphite as useable in military and nuclear applications.[17] In India, two companies were identified as advertising their ability to manufacture fine grain, high density graphite. One company, Graphite India, advertises at least two grades of graphite that have a grain size of 100 micrometers or less and a bulk density greater than or equal to 1.72cm^3 and promotes them as useable in military applications.

2. Foreign Export Control Practices

The MTCR is an informal group of nations that coordinate their national export controls on goods and technology that can contribute to missile proliferation. In the United States, all exports of MT-controlled items for all destinations except Canada require an individual validated license. In contrast, EU exporters can apply for a Community General Export Authorization (EU001) through the export licensing authority of an EU member state that, upon approval, allows them to export fine grain, high density graphite, among other dual-use items controlled for MT-reasons, to end-users within the EU, Australia, Canada, Japan, New Zealand, Norway, Switzerland, and the United

[16] Non-U.S. manufacturers of fine grain, high density graphite were identified by comparing their manufactured graphite with the technical parameters established in 1C107.a.

[17] Three additional companies list military and/or nuclear activities as possible uses for graphite in general.

States without having to obtain individual validated licenses.[18] Such exports are only subject to any post-shipment reporting requirements established by a particular member country.

Additionally, the MTCR contains a "no-undercut" policy, whereby member countries have committed to honor all export license application denials made by MTCR members. This ensures that no single member of the MTCR will have a commercial competitive advantage over any other member.

Under Japan's export control system, companies can export fine grain, high density graphite, a Category II item under the MTCR, to MTCR member countries under a bulk export license.[19] The bulk export license is valid for three years and does not require a specific foreign importer to be listed or an existing relationship between the Japanese exporter and foreign importer. Exports of fine grain, high density graphite from Japan to companies outside of MTCR member countries require an individual export license or a special bulk export license.[20]

With respect to licensing to China, U.S. exporters of fine grain, high density graphite are most disadvantaged compared to other regime members by the Presidential certification requirement. The close relationship between Chinese companies and the Chinese government can make it difficult to distinguish between civilian and military end-users and end-uses of this material in China. The process of obtaining Presidential certification can greatly extend the time it takes an exporter to obtain a license to export fine grain, high density graphite to China.

In addition, China is not a member of the MTCR, so its export controls in this area may not be as stringent as those of MTCR member countries.[21] Although sanctions can be enforced by MTCR member countries on China should it allow the sale of missile technology items to a customer that was previously denied those items from an MTCR member, China is not obligated to adhere to the "no-undercut" policy of the MTCR.

China does have export controls for missiles and missile-related items and technologies in place that require an export license for fine grain, high density graphite. The Chinese export control for fine grain, high density graphite, located in Part II of China's control guidelines, "The Missiles and Missile-Related Items and Technologies Export Control List," reads as follows:

(3) Fine grain bulk artificial graphites having the following features measured at 20ºC:
  (a) With a bulk density of at least 1.72g/cm^3;
  (b) With a tension rupture strain of at least 0.7 percent;
  (c) With a heat expansion coefficient less than or equal to 2.75 x 10^{-6} (measured at temperatures from 20ºC to 982ºC).[22]

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[18] EU001 cannot be used if the exporter is informed that the item is or may be used for biological, chemical, or nuclear weapons or for a military end use (http://trade.ec.europa.eu/doclib/docs/2009/june/tradoc_143390.pdf).
[19] Export Control System in Japan, Feb 2007, Center for Information on Security Trade Control, Japan http://www.cistec.or.jp/english/export/ECSJ-Feb07.pdf
[20] A Japanese special bulk export license requires the exporter to have a "continuous trade relationship" with the foreign importer and make annual reports of export activity.
[21] China submitted an application for membership to the MTCR in 2004, which remains under review by MTCR member states.
[22]http://english.mofcom.gov.cn/aarticle/policyrelease/domesticpolicy/200709/20070905093191.html

The heat expansion coefficient (CTE) parameter, which is not present in the MTCR or U.S. regulations, allows Chinese manufacturers to export fine grain, high density graphite with a CTE above 2.75 x 10^{-6} without an export license, while U.S. manufacturers would need an export license for the same material.

India, which also exports fine grain, high density graphite, is not a member of the MTCR. However, India announced during the MTCR's 2005 plenary meeting that it intended to adhere unilaterally to the MTCR guidelines.[23] To that end, India's controls on graphite, set forth in its "Special Chemicals, Organisms, Materials, Equipment and Technologies (SCOMET) List," contain the following control:

> "Fine grain re-crystalised bulk graphites and pyrolytic or fibrous reinforced graphites usable for rocket nozzles and re-entry vehicles nose tips;"[24]

The SCOMET List control for fine grain, high density graphite does not include the bulk density and size parameters contained within the MTCR Annex. The impact this difference in controls has on India's exports of fine grain, high density graphite is unknown.

V. Evidence of Foreign Availability

Foreign availability is an assessment BIS conducts to evaluate the effectiveness of U.S. export controls. The criteria for making a foreign availability determination is that an item of comparable quality must be "available-in-fact" to a country, from a non-U.S. source, in sufficient quantity to render the U.S. export control of that item ineffective.

A. Available-In-Fact

An item is "available-in-fact" to a country if that country: (1) indigenously produces the item; (2) can obtain the item from another country that does not restrict the export of that item; or (3) can obtain the item from a country whose export controls are not effective or licensing approval policy is pro forma for an item. BIS has no evidence that countries that are members of the MTCR have in place ineffective export control policies.

BIS has identified China as the country with the largest indigenous production capability of fine grain, high density graphite outside of the MTCR members. While China does have export controls in place that cover fine grain, high density graphite, the control has an additional parameter for CTE that is not present in the controls for graphite of MTCR members.[25] This extra parameter makes the Chinese export control for fine grain, high density graphite less restrictive than the comparable U.S. export control, as it allows graphite with a CTE higher than 2.75 x 10^{-6} to be exported without a license.

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[23] MTCR Plenary Meeting of the MTCR Madrid, Spain 12-16 Sept 2005 http://www.mtcr.info/english/press/madrid.html

[24] SCOMET Guidelines, Sep 2007, Directorate General of Foreign Trade, India http://dgftcom.nic.in/exim/2000/scomet2007.htm

[25] This additional parameter of the Chinese export regulations controls graphite "with a heat expansion coefficient less than or equal to 2.75 x 10^{-6} (measured at temperatures from 20ºC to 982ºC)"

BIS also identified India as a non-MTCR member country with indigenous production capability of fine grain, high density graphite. India does have export controls in place for fine grain, high density graphite, but the effectiveness and restrictiveness of these controls are unknown.

Additionally, since China and India are not members of the MTCR, they are not bound to the "no-undercut" policy to which MTCR members adhere. Thus, customers that are denied fine grain, high density graphite from a MTCR member country can simply obtain this material from one of these countries.

BIS was able to locate technical, grade-specific information for fine grain, high density graphite produced by 11 Chinese companies and one Indian company listed in Table *d* below.[26] Some of the material produced by these companies would be controlled for export from the U.S. under ECCN 1C107.a. Nine of the listed companies reported exporting their products worldwide.

Table d: Fine Grain, High Density Graphite Companies in China and India

China	
China Carbon Graphite Group, Inc.	Beijing XinCheng Sci-Tech Development Inc.
Chengdu Rongguang Carbon	Jieshi Carbon Material Co.
Qing Dao Liyikun Carbon Development	Xuzhou Carbon Co
Beijing Great Wall Co.	Nantong San Jie Graphite Products Manufactured Co.
Shanghai Carbon Co.	Sinosteel Jilin Carbon, Ltd.
Dalian Thrive Mining Co.	
India	
Graphite India	

Sources: Websites

The indigenous production capability of China and India and the ability of other countries to obtain fine grain, high density graphite from China with less restrictive export control requirements makes fine grain, high density graphite "available-in-fact."

B. Non-U.S. Source

To qualify as being of non-U.S. source, items: (1) cannot be goods of U.S. origin, subject to export controls; (2) cannot be foreign manufactured items that are the direct product of U.S. technical data; and (3) cannot be foreign-made items incorporating parts, components, or materials of U.S. origin that exceed predefined thresholds.[27]

BIS confirmed through its review of licensing data that no export licenses for fine grain, high density graphite technology have been issued to any company in China or India under ECCNs 1E001, 1E101, or 1E103. Three companies in MTCR-member countries have joint ventures in China: Toyo Tanso of Japan co-founded a brush products company with Shanghai Lixin Tanso Manufacturing Factory; SGL of Germany owns 60 percent of an expanded graphite company with

[26] Additional companies producing fine grain, high density graphite for which BIS was unable to locate grade-specific technical data include: Tangshan Kimwan Special Carbon & Graphite Co. (China), LuoYang GuanQi Industrial & Trade Co. (China), Qingdao Jiacheng Graphite Products (China), Qinyuan Graphite Production Factory (China), Xinghe Xingyong Carbon (China), Brilliant Charter Ltd (China), Shanghai Xi Li Carbon Co. (China), and Heg Ltd (India).
[27] Refer to Parts 734 and 772 in the Export Administration Regulations (EAR) for additional detail.

Sinyuan Industrial Material Co. and owns 75 percent of a specialty graphite company with Shanxi Quanhai Graphite Co.; and Tokai Carbon of Japan has a joint venture in a carbon machining company with Dalian Jinqi Carbon Co. and Fuji Carbon Co.

Another way Chinese companies could acquire fine grain, high density graphite production technology is indirectly through wholly-owned foreign enterprises. The presence of companies from MTCR member countries in China provides easier access to this technology than otherwise gained through indigenous research, as those companies have more contact with Chinese nationals. Through export licenses that permit sharing of production data, those companies also can transfer technology to Chinese nationals. While foreign companies operating in China are still subject to the export regulations of their home country, the presence of fine grain, high density graphite production in China creates an opportunity for Chinese graphite manufacturers to acquire knowledge about advanced production processes from a more highly trained workforce. At least five companies headquartered in MTCR member countries – Carbone Lorraine in France, SGL Carbon in Germany, and Toyo Tanso, Nippon Techno-Carbon, and Tokai Carbon in Japan – have production facilities in China.

According to their websites, 11 Chinese companies and one Indian company have graphite production facilities. Six Chinese companies and one Indian company report having research and development activities and facilities. In addition, two of these companies, China Carbon Graphite Group and Chengdu Rongguang Carbon, report having Chinese patents for graphite production technology and processes. Table *e* below lists the companies with reported production facilities in China and India; companies in italics also have reported research and development facilities.

Table e: Companies Producing and Developing Fine Grain, High Density Graphite in China and India

China	
China Carbon Graphite Group, Inc.	*Beijing XinCheng Sci-Tech Development Inc.*
Chengdu Rongguang Carbon	Jieshi Carbon Material Co.
Qing Dao Liyikun Carbon Development	Xuzhou Carbon Co
Beijing Great Wall Co.	Nantong San Jie Graphite Products Manufactured Co.
Shanghai Carbon Co.	*Sinosteel Jilin Carbon, Ltd.*
Dalian Thrive Mining Co.	
India	
Graphite India	

Sources: Websites

The indigenous production and development capability of China and India and the lack of technology transfer from the United States makes fine grain, high density graphite qualify as non-U.S. source.

C. Sufficient Quantity

Another foreign availability criterion is sufficient quantity, which refers to the quantity of an item that meets a country's military needs so that U.S. exports of the item to that country would not make a significant contribution to its military potential.

With two identified companies, India may not have the indigenous capability to produce fine grain, high density graphite in sufficient quantity, but China, with 19 or more indigenous fine grain, high density graphite producers and exporters and with less restrictive export control laws than MTCR member countries, has the potential ability to produce this material in sufficient quantity to meet domestic demands.

Of the 11 indigenous Chinese graphite producers with available technical data, the six listed in Table *f* are each producing six or more distinct grades of fine grain, high density graphite that have a grain size of 100 micrometers or less and a bulk density greater than or equal to 1.72cm^3. These grades meet an array of additional performance measures, including Coefficient of Thermal Expansion (CTE), Compressive Strength, Flexural Strength, Tensile Strength, and Resistivity.

Table f: Companies in China Producing Six or More Grades of Fine Grain, High Density Graphite

China Carbon Graphite Group, Inc.	Chengdu Rongguang Carbon
Qing Dao Liyikun Carbon Development	Beijing Great Wall Co.
Nantong San Jie Graphite Products Manufactured Co.	Shanghai Carbon Co.

Sources: Websites

Moreover, six indigenous Chinese manufacturers, identified in Table *g*, advertise annual production numbers on their websites. Only two companies, Chengdu Rongguang Carbon and Shanghai Carbon Co., list annual production numbers for types of graphite that could be fine grain, high density graphite; it is unknown how much fine grain, high density graphite other Chinese manufacturers produce. However, it can be inferred from these figures that Chinese companies are capable of manufacturing several thousand metric tons of fine grain, high density graphite.

Table g: Annual Production Capacity of Fine Grain, High Density Graphite in China

Company	Annual Production (metric tons)	Type of Graphite Produced
China Carbon Graphite Group	15,000	All graphite products
Beijing XinCheng Sci-Tech Development Inc.	15,000	All graphite products
Chengdu Rongguang Carbon	1,000	Isotropic high-purity graphite
Jieshi Carbon Material Co.	10,000	All graphite products
Xuzhou Carbon Co.	20,000	All graphite products
Shanghai Carbon Co.	2,000	Specialty graphite products

Sources: Websites

The number of companies in China producing fine grain, high density graphite outnumbers the number of companies conducting the same business in MTCR member countries. Compared to the 19 identified Chinese manufacturers, the United States has two major manufacturers, Europe has two, and Japan has four. Table *h* below lists annual production numbers attributed to companies in MTCR member countries, and shows that these companies produce more fine grain, high density graphite than their Chinese counterparts.[28] However, Chinese manufacturers do not need to produce more than their international competitors in order to meet domestic demand.

[28] Annual production numbers include fine grain, high density graphite produced at company locations outside of MTCR member countries.

Table h: Annual Production Capacity of Fine Grain, High Density Graphite in MTCR Countries

Company	Annual Production (metric tons)	Type of Graphite Produced
Nippon Techno-Carbon (Japan)	5,850	Isotropic graphite
Tokai Carbon (Japan)	9,000	Fine carbon
Toyo Tanso (Japan)	15,000	Isotropic graphite
Carbone Lorraine (France)	12,000	Isostatic graphite
SGL Carbon (Germany)	5,000	Isostatic graphite

Sources: Websites

Nine of the identified indigenous graphite manufacturers in China report that they are exporting their products to end users outside of China. According to data collected by U.S. Customs and Border Protection, three of the identified Chinese companies have exported artificial graphite into the United States. Additionally, the company Graphite Australia advertises on its website that it obtains a majority of the specialty graphite it sells from Shanghai Carbon Company; four of the five grades of specialty graphite sold by Graphite Australia have a grain size of 100 micrometers or less and a bulk density greater than or equal to 1.72cm^3.[29]

An analysis of Chinese imports and exports of artificial graphite reported under HTS code 380110, provided in Table *h*, shows that China has imported more artificial graphite than it exported, giving the country a negative trade balance. While it is not possible to determine how much of the artificial graphite imported and exported by China is comprised of fine grain, high density graphite, some trends can be seen.

Table h: Chinese Imports and Exports of Artificial Graphite 2006-2008

	2004	2005	2006	2007	2008
Imports	$44,237,755	$55,597,885	$65,396,644	$91,363,632	$133,179,803
Exports	$22,526,856	$36,719,591	$53,791,905	$80,790,842	$106,282,425
Trade Balance	-$21,710,899	-$18,878,294	-$11,604,739	-$10,572,790	-$26,897,378

Sources: Global Trade Atlas

China's trade deficit in artificial graphite decreased from 2004 to 2007, before increasing in 2008. This increase could be due to a recent surge in nuclear power plant construction in China, as nuclear reactors require artificial graphite to operate.[30] Even more telling, Chinese exports of artificial graphite grew 371 percent from 2004 to 2008, while Chinese imports grew at a lesser but significant rate of 201 percent. Therefore, the data infers that while imports are growing, Chinese companies are relying more on domestic sources of artificial graphite.

The Chinese are able to indigenously produce fine grain, high density graphite at a level that supports their domestic demands and global exports, including to non-MTCR member states.

[29] Shanghai Graphite and Carbon, 2007, Graphite Australia, 13 Oct 2009 <http://www.graphite-australia.com/shanghaigraphitecarbon.html>

[30] CER Focus Report: China Carbon Graphite Group, Inc., 7 May 2009, Crystal Equity Research, 21 Oct 2009 <http://www.crystalequityresearch.citymax.com/f/CHGI_Focus_Report_5-7-09.pdf>

D. Comparable Quality

An item is of comparable quality to an item subject to the EAR if it possesses the characteristics specified in the Commerce Control List (CCL) for that item, and is alike in key characteristics that include, but are not limited to: (1) function; (2) technological approach; (3) performance thresholds; (4) maintainability and service life; and (5) any other attribute relevant to the purpose for which the control was placed on the item.

There are no published standards used by industry to assess the quality and functionality of artificial graphite. Instead, the industry uses several different performance measures.[31] Comparing the different grades of fine grain, high density graphite manufactured inside and outside of MTCR member countries using these measures depends on the final application or end use of the graphite. Because of the many and disparate end uses for graphite, broad comparisons using these parameters are infeasible. Comparisons between the graphite producers must therefore be made based on CCL control parameters, which are based on the parameters set by the MTCR.

The characteristics specified in the CCL for fine grain graphites are that they have a grain size of 100 micrometers or less, have a bulk density greater than or equal to 1.72cm^3, and meet size requirements for cylinder, tube, and block shapes. Manufacturers in MTCR member countries and in non-MTCR member countries can easily produce graphite that fulfills the grain and shape size characteristics, making these measures inadequate to measure comparable quality. The ability to meet the bulk density characteristic specified in the CCL, however, varies between companies, making it the only available measure of comparable quality.

As stated previously, at least 11 Chinese manufacturers are capable of producing varying grades of fine grain, high density graphite that have a bulk density greater than or equal to 1.72cm^3. In addition, two survey respondents indicated they had tested samples of graphite from China and found the material to be fully competitive with U.S.-produced graphite. However, two other survey respondents said fine grain, high density graphite they imported from China was found to be of substandard quality. One of these companies indicated that graphite with a high bulk density could still fail in high temperature, high pressure applications.

A different characteristic or measurement is needed to determine the comparability of the fine grain, high density graphite manufactured by different companies. One possible characteristic widely used by industry is the coefficient of thermal expansion (CTE). As stated previously, CTE is the extent to which a material will expand in length for each degree of temperature increase.[32] A material with a low CTE does not expand much when exposed to temperature increases, and therefore has a high thermal shock resistance. The higher the CTE of a material, the more the material expands under high temperature stresses.

The graphite used in rocket nozzles and reentry vehicle nose tips must withstand extreme and sudden temperature changes. Therefore, graphite with a high thermal shock resistance is more suitable for this purpose, since it has better material stability than graphite with a low thermal shock resistance.[33] Furthermore, BIS issued a commodity classification for a U.S. company, stating

[31] The most commonly used performance measures are defined in Section III of this report.
[32] CTE is normally expressed as inch per inch per ºC, or "x 10^{-6}(in/in)/ºC."
[33] Albers, Tracy et al, "Low CTE Highly Isotropic Graphite," US Patent 7,658,902 B2. 9 Feb 2010.

graphite made using the company's proprietary process that has a CTE greater than 6.0 x 10^{-6} and with a bulk density less than 1.5 g/cc is not controlled under 1C107. This suggests fine grain, high density graphite with a CTE higher than 6.0 x 10^{-6} might not be suitable for rocket nozzles and reentry vehicle nose tips, and CTE would therefore be a good parameter to use to compare graphites.

Out of the identified Chinese manufacturers of fine grain, high density graphite, only four had available technical data on the CTE of the graphite they produce. The CTE of graphite produced by Chinese companies ranges from 2.5 to 5.5, which can be seen in Table *i*. In comparison, the CTE of fine grain, high density graphite produced by companies in MTCR member countries ranges from 1.2 to 12.0. It is clear that companies subject to MTCR controls are capable of manufacturing graphite with higher and lower CTEs than their Chinese counterparts.

Table i: CTE of Fine Grain, High Density Graphite

Company	**Country**	**CTE (x 10^{-6}/°C)**
Chengdu Rongguang Carbon	China	4 – 5.5
Qing Dao Liyikun Carbon Development	China	3.9 – 4.7
Beijing Great Wall Co	China	3 – 4.6
Dalian Thrive Mining Co	China	2.5 – 5.5
Carbone Lorraine	France/United States	3.8 – 7.2
SGL Carbon	Germany	2.0 – 6.1
Ibiden Graphite	Japan	3.8 – 6.5
Tokai Carbon	Japan/United States	3.3 – 5.5
Toyo Tanso	Japan/United States	3.0 – 12.0
Poco Graphite	United States	7.6 – 8.2
GrafTech International	United States	1.2 – 3.8

Sources: Websites

According to the Chinese export control regulations, fine grain, high density graphite is only controlled if it has a CTE of "less than or equal to 2.75 x 10^{-6}." This means most of the Chinese-manufactured graphite with available CTE data can be exported from China without a license, even if it meets the grain size and bulk density parameters of the control. This is in direct contrast to U.S. export control regulations, which require a license for fine grain, high density graphite no matter the material's CTE.

Although the CTE measurement aids in the comparison of graphite produced by China and India, the claims of inferior quality and the inability to obtain accurate performance data on the graphite manufactured by Chinese companies makes it impossible to determine the comparable quality of Chinese-made fine grain, high density graphite. The absence of a comparable quality determination prevents BIS from making a determination about the foreign availability of this material.

VI. Conclusion and Recommendations

BIS concludes that:

- Compared with other countries exporting artificial graphite, the United States is gaining market share, but the U.S. export licensing process for fine grain, high density graphite controlled by ECCN 1C107.a, especially to China, requires more license conditions and places additional burden on its exporters in comparison to the processes of other MTCR members, placing U.S. exporters at a competitive disadvantage;

- The comparable quality and thus the foreign availability of fine grain, high density graphite to China and India cannot be determined at this time; and

- The existing MTCR control parameters for fine grain, high density graphite controlled by ECCN 1C107.a under the EAR are more restrictive than similar controls in China and do not reflect current production capabilities or usability of graphite for use in rockets or missiles.

Accordingly, BIS recommends that the USG:

- Amend the EAR to establish a “fast-track” review system for license applications submitted for the export of fine grain, high density graphite controlled by ECCN 1C107.a destined for Australia, the EU, Japan, New Zealand, Norway, and Switzerland in order to put U.S. exporters on a more even playing field as their European competitors; and

- Submit a proposal to the MTCR to change the technical control parameters for fine grain, high density graphite. Specifically, a control parameter for the coefficient of thermal expansion (CTE) should be added, and the grain and size parameters should be revised to ensure that only that material suitable for missile technology-related uses is controlled. These changes would then be reflected in ECCN 1C107.a.