India's Gas Centrifuge Program: Stopping Illicit Procurement and the Leakage of Technical Centrifuge Know-How

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Indian nuclear and government officials have stated that India has an "impeccable" nonproliferation record. Officials go so far as to claim that India does not engage in illicit nuclear procurement and has an exemplary record of preventing nuclear secrets from falling into the wrong hands. ISIS has uncovered a well-developed, active, and secret Indian program to outfit its uranium enrichment program and circumvent other countries' export control efforts. In addition, ISIS has concluded that Indian procurement methods for its nuclear program leak sensitive nuclear technology.

President George W. Bush and Prime Minister Manmohan Singh proposed in July 2005 a plan for resuming "full" US-Indian nuclear cooperation that requires changes in U.S. law and the rules of the 45-nation Nuclear Suppliers Group that currently bar nuclear transfers to states--like India--that do not accept full-scope International Atomic Energy Agency Safeguards (IAEA). The findings of this report suggest that before the United States and other countries engage in nuclear cooperation with India, Indian procurement and export practices should be closely scrutinized. The Indian government should commit to stop conducting illicit procurement for its nuclear facilities, implement steps to better control its nuclear information, and improve its implementation of national and international export controls.

India Rare Earths and the Rare Materials Project

Under the direction of India's Department of Atomic Energy, Indian Rare Earths (IRE) Ltd. of Mumbai, a public-sector undertaking focused on recovering minerals and processing rare earths, procures sensitive materials and technology for a secret gas centrifuge uranium enrichment plant codenamed the "Rare Materials Project" (RMP) outside Mysore, India. The Bhabha Atomic Research Centre (BARC) operates the plant and appears to both coordinate procurements for this facility with IRE and pursue procurements for its own divisions through IRE.

RMP itself is rarely acknowledged by the Indian government as a gas centrifuge plant. The plant started in the late 1980s or early 1990s but has encountered numerous technical problems that have limited its success. RMP is believed currently to provide enriched uranium for civil research reactors, perhaps nuclear weapons, and a fledging naval reactor

program that recently started a prototype naval reactor at Kalpakkam. ISIS has estimated RMP's total enrichment capacity as roughly 5,000 separative work units per year, although this estimate is highly uncertain. At this size, this plant could provide enough enriched uranium for a small naval reactor program and some highly enriched uranium for nuclear weapons, but not enough for India's twin Tarapur light water reactors. Available evidence indicates that BARC is expanding the capacity of RMP and installing more sophisticated centrifuges.

Public information about India's procurement for RMP is also shrouded in secrecy. Nonetheless, ISIS has uncovered IRE's long-standing effort to outfit the RMP by buying sensitive direct nuclear-use and dual-use items from foreign and domestic suppliers. In the case of foreign procurement, IRE, and trading companies procuring on its behalf, do not reveal that the end user is an unsafeguarded uranium enrichment plant. The trading companies may not reveal that they are purchasing for IRE or the Department of Atomic Energy. IRE's methods allow a supplier to easily avoid knowing the true end use of an item and thus the supplier escapes responsibility for providing a dual-use item to a gas centrifuge plant.

Since at least 1984, IRE has regularly placed inconspicuous lists of items in Indian newspapers, such as the *Times of India*, to invite bids from potential suppliers to RMP. This procurement process is commonly referred to as "tendering," where the tenderer is the company that bids to provide the item. Before submitting a bid, called a tender, a prospective supplier or trading agent can purchase, for a small fee, the detailed blueprints, manufacturing instructions, and specifications of a particular item.

An undesirable side effect of this process is the leakage of sensitive nuclear information. To prepare a bid, interested parties can obtain tender documents from IRE that list technical specifications of centrifuge components and centrifuge-related equipment. Although the detailed information may be stamped "proprietary" or similarly marked, this level of classification is relatively low. Company officials who possess this information could sell the item or underlying technology to other customers with the expectation that few legal consequences would result from Indian prosecutors.

In addition to public advertisements, IRE has also invited tenders directly from specific companies. Little is publicly known about these solicitations for tenders, but IRE may have developed long-term relationships with certain companies, may view a particular company as the only source for an item, or might depend on a certain company when it needs an item quickly.

Based on information from knowledgeable European and US officials, IRE has received a wide variety of equipment, components, and materials for RMP from overseas companies through the IRE procurement system. In addition to acquiring from abroad many of the necessary items to build and operate RMP, IRE has sought to obtain sufficient equipment and know-how so that India could domestically manufacture many sensitive items for RMP. Although the centrifuge program has become less dependent of foreign supply over the last two decades, IRE continues to seek sensitive equipment,

spare parts for previously imported equipment, and subcomponents for items assembled domestically.

Collection of Public Advertisements

To better understand IRE's procurement strategy for RMP, ISIS collected almost two hundred IRE public advertisements that were posted in the *Times of India* from 1984 through 2005. Each advertisement contained several specific requests for items. Many of these requests directly mentioned RMP or were likely for RMP. The latter determination was based on the type of product requested, the use of a particular procurement office, and the consistent numbering system that the office used to classify each item.

Although IRE has several different procurement offices and projects, the items discussed here originate from advertisements placed by a particular office in Mumbai. The procurement office in Mumbai uses a distinct code that sometimes mentions RMP and has requested sophisticated items that can be associated with a gas centrifuge program. The other offices invite offers for items that do not appear associated with a gas centrifuge plant and are typical of the projects publicly associated with IRE.

The Mumbai office's advertisements sometimes include BARC acronyms, such as CETG and CTD. CETG is an acronym for BARC's Chemical Engineering and Technology Group, and CTD stands for the Chemical Technology Division, a subdivision of CETG. Both CTD and CETG are associated with the centrifuge program, typically called the "high speed rotor" project by Indian officials. This is an apt allusion to a centrifuge program, because a rapidly spinning tube or rotor is the basis of a centrifuge. According to the 1996 and 1997 annual reports of BARC's Laser and Plasma Technology Division, CTD possessed "high speed rotors." Both BARC and IRE have cited CTD when soliciting bids for RMP. Because of the immense secrecy that surrounds RMP and India's gas centrifuge program, however, the exact organizational relationship between RMP and CETG or CTD is unknown.

A senior Indian BARC official who was key in the effort to purchase equipment for the RMP in Europe in the 1980s was Shri Bishweswar Bhattacharjee. He was appointed head of BARC in 2001 and was publicly recognized as former project director of RMP and leader of the team that designed, installed, and successfully commissioned the "high speed rotor" project. In the late 1990s, the BARC website listed him as the director of the CETG. Another major BARC participant in overseas procurement for RMP was T.K. Bera, who became the head of CETG after Bhattacharjee and was publicly identified in the 1990s as a senior manager of the RMP.

Specific Advertisements

Through this procurement system, IRE has sought a wide variety of equipment, components, and materials for RMP from domestic and overseas suppliers. Solicited items have included high-strength flow-formed maraging steel tubes and the machining

of sensitive bellows that appear to be centrifuge rotors, maraging steel discs that could be for centrifuge end caps, and items that could be subcomponents of centrifuge bottom bearings and motor stators. Other items include displacement sensors that can measure centrifuge rotor velocity, vacuum pumping and measurement systems, specialized valves, and subcomponents of valves and vacuum pumping systems. In addition, IRE has sought many machine tools, measuring equipment, vacuum furnaces, and welding equipment that are associated with gas centrifuge manufacturing.

Appendix 1 has a sample of advertisements that either list RMP as the customer or appear to be for the gas centrifuge program at RMP. The advertisements are grouped into several categories, including construction projects, component manufacturing, vacuum equipment, uranium hexafluoride production and handling, and centrifuge manufacturing equipment.

An advertisement from late 2005 appears to be soliciting supercritical centrifuge rotors, whose design, manufacturing methods, and distribution are tightly controlled by other governments. The advertisement requests the manufacture of 1,225 millimeter long, thin-walled, flow-formed and intermediate annealed, ultra precision maraging steel tubes with an outer diameter of 150 millimeters. These tubes would be made on a sophisticated machine that "flow-forms," or thins, a tube to the required specifications. The advertisement requires the use of MDN-350 grade preforms that would be produced domestically by Mishra Dhatu Nigam Limited (MDN, commonly called Midhani). This preform is a thick tube made out of 350 grade maraging steel. This request is likely intended for a domestic manufacturer, although the advertisement does not impose such a restriction.

Other advertisements describe construction projects at RMP. Figure 1 is a commercial satellite image of what is believed to be RMP, located by using information in a 1987 IRE advertisement (see Appendix 1). Another IRE advertisement dated September 2000 specified the construction of a new pulsed power secure fence at RMP with a total length of 2,500 meters. The circumference of the outer fence of the facility in the image is about 2,500 meters.

Hiding Procurement

When IRE procures internationally for the Indian centrifuge program, it does not reveal the true end-use of items. In addition, trading companies, typically private export/import companies or wholesalers, may take steps to hide the true end use of tendered items.

In a standard enquiry made in 2005, IRE asked for dual-use measuring equipment that may be for a gas centrifuge. The IRE leaflet stated that the goods should be sent to CTD Stores, BARC, Trombay, Mumbai. Unless information about the association of CTD to RMP was sought out by the supplier, a company could have unknowingly supplied a division of BARC, an ostensibly civilian nuclear research operation, with items that could have been used in an unsafeguarded gas centrifuge program.

Trading companies that purchase tender documents have contacted foreign firms to supply the items sought in the advertisements. In their interactions with overseas suppliers, these trading companies do not reveal the true end use of the items. In one instance in 2004, IRE posted public advertisements for components of measuring equipment that appear slated for use in a gas centrifuge plant. Two Indian trading companies simultaneously attempted to procure the items overseas without revealing that the end user was IRE.

In at least one case, an Indian trading company may have used an off-shore partner to seek tendered items. The relationship between this off-shore South Asian company and the Indian trading company was obscured, and the off-shore company attempted to procure items without revealing their end use.

Deceptive or illicit procurement by Indian companies is not confined to IRE. In August 2005, an Indian ordnance factory may have attempted to use both a Polish company and a Europe-based Egyptian trading firm to obtain controlled equipment, namely a three-roller four-axis CNC flow-forming machine, from a European supplier. The accompanying specifications showed that it could be used to manufacture missile casings. The Egyptian trading company requested the machine in Europe and raised the suspicions of a potential supplier. The potential supplier, who requested anonymity, stated that the request originated from Bipromasz Bipron Trading in Poland, a new European Union (EU) member eligible to receive items from other EU members without any export scrutiny by the supplier. The supplier stated that he learned that the end user was in India, although he did not provide its name. During the same month, an Indian ordnance factory posted a tender advertisement on-line that contained technical data and typographical errors that were identical to the request from the Egyptian middleman.

Ironically, India's gas centrifuge program procured through individuals who also played key roles in the illicit nuclear trading network led by the Pakistani A. Q. Khan. In the late 1980s and early 1990s, according to South African court documents, a key member of the network located in South Africa organized the production and delivery to India of flow meter units that were specifically designed for a uranium hexafluoride application, implying their use in a gas centrifuge program. When the client experienced malfunctions in the units, the seller sent one of his employees to the Indian customer to fix the units. Based on the court documents, this supplier may have provided additional sensitive items to the Indian centrifuge program, including feed and withdrawal equipment for centrifuge cascades.

Onward Proliferation

Proliferant states are known to target India's industries, according to US officials. With India's rapid industrialization, much of which is based on technology from developed countries, India's attractiveness to proliferant states can be expected to increase. India is engaged in many export promotion schemes, as its companies seek foreign markets. Onward proliferation is expected be become a serious problem.

Onward proliferation occurs when a company obtains a controlled item from overseas and retransfers it to a proliferant state or terrorist group without proper authorizations. Proliferant states and smuggling networks use such tactics to avoid export controls in supplier states. They engage companies in a state that has poorly implemented or enforced export control laws but is a member of the Nuclear Suppliers Group or has another special status and is thus eligible to receive controlled items with relatively little scrutiny from suppliers. The Khan network used this strategy in South Africa to receive sensitive items from Europe and then retransferred the items illegally to Pakistan, Libya, and other countries. An indirect type of onward proliferation happens when companies buy, reverse-engineer, and manufacture equipment obtained from overseas and then export the duplicated equipment to foreign customers.

Items that IRE imported to outfit RMP, such as vacuum pumps, vacuum furnaces, machine tools, vacuum bellows-sealed valves, and canned motors for centrifugal pumps, could be transferred to the private sector. The canned motors and high vacuum-sealed valves are already on a BARC list of new technologies available for such transfer.

For several decades, Indian government entities and private companies have worked around international sanctions by developing their own dual-use products based on designs or reverse-engineered equipment from more industrialized states. In one case, an Indian vacuum pump company named Precise Vacuum Systems Pvt. Ltd. advertises that some of its vacuum pumps are "manufactured [based] on technology drawings of a world leader in vacuum pump technology." The company's web site says that these pumps offer high performance at a fraction of the cost of equivalent pumps obtained overseas. Reverse engineering and marketing of dual-use items is believed to be widespread in India and is expected to increase as India develops further.

Indian national export controls are the main restraints to prevent illegal or dangerous exports from Indian companies. However, India's control system is poorly implemented, and its export control officials are inexperienced. Many Indian companies are unaware of national export laws, and government outreach programs are in their infancy. With private Indian companies committed to sales both domestically and internationally, Indian export controls are inadequate to provide assurance that dangerous exports or re-exports will not occur.

Findings

Suppliers need to be suspicious of Indian procurement activities for its nuclear program, particularly for its unsafeguarded nuclear programs. In addition, India's past and current procurement practices raise troubling issues for the proposed expansion of US-Indian cooperation in nuclear or nuclear-related areas.

For India to become a responsible member of the international community, it must stop illegal or questionable overseas procurements for its nuclear program. India also needs to ensure that private trading companies are not violating or seeking loopholes in export control regimes as they procure items for Indian nuclear establishments. The Indian

government needs to provide assurances that the Department of Atomic Energy and its sub-entities will not seek from abroad nuclear direct-use or dual-use items without clarifying the end-use of the item prior to sales and, if necessary, obtain export licenses or approvals listing the true end-use of the item. In addition, without such a change in procurement practices, any Indian commitment to clearly separate military and civilian nuclear facilities is not credible and is essentially unverifiable.

The government of India should change the dangerous tendering process that spreads uranium enrichment technology. It also needs to ensure that any companies and trading agents that have purchased sensitive tender documents do not sell the underlying know-how or items described in these documents to other companies or countries.

The Indian government needs to ensure that spin-offs from its gas centrifuge program do not lead to nuclear proliferation. In particular, the government needs to ensure that privatization initiatives and other efforts to sell items based on the dual-use items originally obtained or developed for the gas centrifuge program are not exported to nuclear weapons programs or other centrifuge programs. Ensuring that exports are legal and are not contributing to proliferation will remain a major challenge for India for many years.

Some of these issues should be addressed through legislation implementing the US-India proposal for "full" nuclear cooperation announced in July 2005. To encourage India to discontinue illicit nuclear procurement, Congress should include a requirement that the Executive Branch must annually certify that private or governmental Indian entities have not been found to have engaged in illicit procurement for Indian nuclear facilities and activities.

Under the U.S.-India agreement, India is expected to boost imports of a wide range of dual-use and high-tech items from supplier states including the United States. India needs to take additional steps to ensure that imported dual-use items are not retransferred or reverse-engineered and sold to states hostile to the United States for the purpose of making nuclear weapons. Because of the possibility that such items could be sold to states hostile to the United States, Congress should also require an additional Executive Branch annual certification that Indian companies or government-controlled entities have not engaged in trade that contributes to nuclear programs in countries which have not joined or have violated the Nuclear Non-Proliferation Treaty or are suspected of having a secret nuclear weapons program.

Figure 1: Satellite image showing the site believed to house India's gas centrifuge enrichment facility near Mysore.

Appendix 1: Sample of IRE and BARC Advertisements, with Annotation[1]

RMP Site Construction

Internal Electrification, cabling, lightning protection, street lighting, etc. at RMP, Mysore; at Project Site at Rare Materials Plant (located) at 19 kms away from Mysore on Mysore-Hunsur Road, Ratnahally Complex, Yelwal P.O. (7/87, RMP/E-5/87).
[This advertisement gives the location of the RMP facility, see Figure 1.]

Supply, site preparation including civil, mechanical, electrical works, installation, erection, testing, commissioning of 1.5 mtrs. high wall top configuration Pulsed Power Securing fencing over the existing 2,500 mtrs. long stone perimeter wall at RMP, Yelwal, Mysore (9/18/00, PE-387-P/TPT).
[This advertisement appears intended to upgrade the security of the RMP facility.]

Possible Centrifuge Component Manufacturing

Precision machining of special steel Thin Rod-R(L) with spherical tip (11/14/03, TP-83-MDD).
[This advertisement may be for making a subcomponent of the bottom bearing of a centrifuge.]

Aluminium extruded tubes of 195 mm OD and 25 mm wall thickness conforming to IS-733 (11/14/03, TP-85-MDD; 9/24/04, TP-296). Aluminium extruded tubes of 195 mm OD and 25 mm wall thickness (1/20/06, TP-719).
[These advertisements may be for the outer casing of a centrifuge. Indian Standard (IS)]

Ultra fine laser machining of intricate patterns on pellets with miniature spherical surface (1/14/04, TP-102).
[This advertisement may be for producing the spiral grooved pattern on the small ball that is part of the bottom bearing of a gas centrifuge.]

Close Die Forging, heat treatment in electric furnace, inspection and supply of "Disc II E (B2)" from free issue High Nickel alloy MDN-350 grade steel material (9/29/04, TP-277).
[This advertisement describes a grade-350 maraging steel preform that could be intended to be machined into end caps or baffles for a gas centrifuge rotor assembly.]

Manufacture and supply of (O.D.) 150mm x 1225mm long Thin Wall Flow Formed Interstage Annealed Ultra Precision Tubes made out of MDN 350 grade free issue extruded preforms as per specification (12/17/05, TP-672/TPT).
[This advertisement may be for a tube for a supercritical centrifuge rotor assembly.]

Hydro-forming of single convolution on free issue Thin Wall Flow Formed Ultra-Precision Straight Cylindrical Tubes (9/2/03, PE-558-CETG). Hydro-forming of single

[1] Annotations are in brackets. Unless otherwise, all advertisements are from IRE.

convolution on free issue 150 mm diameter thin wall flow formed ultra-precision straight cylindrical tubes (1/20/06, TP-702). Hydro-forming of single convolution on free issue 190 mm diameter thin wall flow formed ultra-precision straight cylindrical tubes (1/20/06, TP-692).
[These advertisements may be to solicit the production of highly sensitive bellows on centrifuge rotors.]

Fabrication, testing, inspection, packing and supply of CRGO Silicon Steel Torroidal Cores. 2,200 Nos. (10/7/97, PE-105-E); and manufacture, assembly, winding, inspection, testing, packing and delivery to our site of Strip Wound Toroidal Core Stators with Winding (6/29/04, TP-199-RMP).
[These advertisements may seek subcomponents of motor stators.]

Centrifuge Test Equipment

Non-contact displacement sensor specification: As per the enclosed document. Quantity: 700 nos. (2/16/05, posted for RMP by BARC)
[This advertisement is likely for a measuring device that can measure the rotation of a rapidly spinning tube. Such a device would be useful in the research and development of supercritical centrifuges and cascades.]

Vacuum Equipment and Items

150M^3/hr Dry Vacuum Pump module consisting of five roots pumping stages in line fitted with hermetically sealed capped motor built-in nitrogen purge system control (3/31/98, PE-173-P).
[This advertisement seeks a vacuum pumping system that is similar to systems ordered earlier for RMP.]

'Helicoflex' or equivalent vacuum seals type HN-100-200 with aluminum lining and Music spring steel wire, as per specifications (1/85, RMP/P-43); ceramic to metal vacuum feedthroughs (with plugging receptacles) as per specifications (4/85, RMP/M-65); and direct coupled, vane type two-stage oil sealed rotary vacuum pumps complete with accessories (1/86, RMP/P-301).
[Various types of vacuum-related equipment, all of which have RMP in the tender number and were likely procured for use in RMP.]

Vacuum Measuring Equipment

Supply of HF compatible Pirani Gauges and Digital Pirani Meters with ON/OFF Controller (6/3/04, TP-177).
[This advertisement may be to acquire spare parts for vacuum measurement equipment used in a centrifuge cascade that is able to operate in a corrosive environment without mentioning uranium hexafluoride.]

Centrifuge Manufacturing Equipment

Tungsten inert gas (TIG) welding set consists of Rectifier, HF Control unit, Cooling system, welding torch standard accessories and spares as per specifications (4/85, RMP/P-123).

Design, manufacture and supply of 6-axis CNC Numerically controlled Filament winding machine as per specifications - one complete unit (9/24/99, PE-324-P/TPT).
[This advertisement may be for a computer-numerically controlled (CNC) machine tool to wind carbon fiber rotors.]

Universal measuring machine for high accuracy measurement with universal probe head, high speed computer, hardware and versatile application, soft-ware laboratory, as per specifications (1/85, RMP/P-63); roundness and form measuring machine as per our specifications (12/84, RMP/P-66); inspection machine (multi-gauging type) for measuring run outs of cylindrical objects as per specifications (4/85, RMP/P-113); and vertical dynamic balancing machine with analyzer accessories and spares as per the specifications (3/85, RMP/P-101).
[Various types of measuring equipment, all of which have RMP in the tender number and were likely sought for use in the manufacture and assembly of gas centrifuges.]

Uranium Hexafluoride Production and Handling

Moisture meter for measurement of water content in gases as per specifications (1/85, RMP/P-73); gas chromatographic analytical system for determination of corrosive gas mixtures comprising of fluorine (0 to 50%), hydrogen fluoride (0 to 15%), volatile fluoride (0 to 40%), and nitrogen (0 to 95%) as per specifications (2/85, RMP/P-75); and HF detectors for the automatic and continuous detection of highly toxic hydrofluoric acid vapor in the environment as per the specifications (3/85, RMP/P-92).
[Various types of measuring equipment, all of which have RMP in the tender number and were likely procured for use in the production and handling of uranium hexafluoride.]

One piece gas-tight chemical protection suits for whole-body protection fitted with face cuff made of buty 1 material and fitted with ventilation systems as per specifications. Four suits are required to be supplied (2/16/05, posted for RMP by BARC, DPS/RMP/PUR/LP/11155).
[This advertisement seeks chemical protection suits that may be intended for situations involving uranium hexafluoride or its dangerous precursors.]