

Heavy Manufacturing of Power Plants

(Updated 29 October 2010)

- **A critical issue for accelerating nuclear power plant construction is the availability of heavy engineering plants to make the reactor components, especially for those units of more than 1100 MWe.**
- **The supply challenge is not confined to the heavy forgings for reactor pressure vessels, steam turbines and generators, but extends to other engineered components.**
- **As with other generation technologies, supply constraints plus escalating steel and energy prices flow on to plant costs.**
- **New investment in major forges and steelmaking lines is dependent on actual orders rather than simply uncommitted plans or vague proposals.**

When the first- and second-generation nuclear power plants were built, they mostly came from integrated suppliers such as Westinghouse in each country, who required little from external suppliers. Today most of a new plant comes from a range of international suppliers, and vendor companies such as Westinghouse are focused on design, engineering and project management. There is demand from customers for maximum local supply, which often means a high level of technology transfer. Westinghouse's readiness to transfer the technology for its AP1000 to China was a major factor in its selection.

For very large generation 3+ reactors, production of the pressure vessel requires, or is best undertaken by, forging presses of about 14-15,000 tonnes capacity which accept hot steel ingots of 500-600 tonnes. These are not common, and individual large presses do not have high throughput – about four pressure vessels per year appears to be common at present, fitted in with other work, though the potential is greater than this. Westinghouse was constrained as of 2009 in that the AP1000 pressure vessel closure head and three complex steam generator parts can only be made by JSW. Areva has a little more choice.

Reactor vendors prefer large forgings to be integral, as single products, but it is possible to use split forgings which are welded together. These welds then need checking through the life of the plant. Also, whereas Generation II reactors might require some 2000 tonnes of forgings, EPR and AP1000 units require about twice the amount.

Westinghouse says that the minimum requirement for making the largest AP1000 components is a 15,000 tonne press taking 350 tonne ingots.

The very heavy forging capacity **in operation** today is in Japan (Japan Steel Works), China (China First Heavy Industries and China Erzhong) and Russia (OMZ Izhora).

New capacity is **being built** by JSW and JCFC in Japan, Shanghai Electric Group (SEC) and subsidiaries in China, and in South Korea (Doosan), France (Le Creusot), Czech Rep (Pilsen) and Russia (OMZ Izhora and ZiO-Podolsk).

New capacity is **planned** in UK (Sheffield Forgemasters) and India (Larsen & Toubro, Bharat Heavy Electricals, Bharat Forge Ltd). In China the Harbin Boiler Co. and SEC subsidiary SENPE are increasing capacity.

Nothing in North America currently approaches these enterprises.* The changed position of the USA is remarkable. In the 1940s it manufactured over 2700 Liberty ships, each 10,800 tonne DWT - possibly pioneering modular construction at that scale (average construction time was 42 days in the shipyard). In the 1970s it had a substantial heavy infrastructure, but today China, Japan, South Korea, India, Europe and Russia are all well ahead of it. Steelmaker ArcelorMittal, based in Luxembourg, now owns the US company which built most US reactor pressure vessels in the 1970s-1980s.

* In the 1970s, requirements were more modest: both US Steel and Bethlehem Steel had 8000 tonne presses and could handle 300 tonne ingots. US forging capacity has not been significantly upgraded since, partly due to lack of integration with steel mills and melt shops to supply the hot steel as 600-tonne ingots.

However, another development is Westinghouse going upstream and setting up factories in USA and China to produce modules for AP1000 reactors. In the USA Global Modular Solutions, a joint venture with Shaw Group, has built a large factory in Louisiana. In China a similar factory was opened in July 2008 by Shandong Nuclear Power Construction Group, apparently with 64% held by SNPTC and 29% by CNEC.

Suppliers of nuclear equipment must be qualified and quality controlled. The American Society of Mechanical Engineers (ASME) nuclear accreditation known as N-stamp is internationally recognized. N-stamp means that the authorized vendor has produced the commercial nuclear-grade components in accordance with the ASME Boiler and Pressure Vessel Nuclear Codes and Standards. It applies to both design and fabrication of components. RCC-M is another international standard developed in France and used outside the USA for nuclear mechanical and pressure components. For China, NNSA registration is linked to US NRC standards, though both ASME and RCC codes are used. ISO-9001 is increasingly important.

| Country or region | Company | Heavy forging press mid 2009 | Heavy forging by 2013 | Max. ingot - tonnes (2013) | NPP sets /year now, 2012 |
|-------------------|--------------------------|---------------------------------|-----------------------|----------------------------|--------------------------|
| Japan | Japan Steel Works | 14,000 t | 14,000 t x 2 | 600 (650) | 6, 12 |
| | JCFC | | 13,000 t from 2010 | 500 | |
| | MHI | Nil, uses forgings to make RPVs | | | double |
| South Korea | Doosan | 13,000 t | 17,000 t from 2010 | 540 | |
| China | CFHI | 15,000 t, 12,500 t | same | 600 | 5, 5 |
| | Harbin Boiler | 8000 t | same | | |
| | Shanghai (SEC) | 12,000 t | 16,500 t | 600 | 2.5, 6 |
| | China Erzhong + Dongfang | 12,700 t, 16,000 t | same | 600 | 5, 5 |
| | Total for China | | | | 12.5, 14 |
| India | L&T | 9000 t | 15,000 t | 600 (in 2011) | |
| | BHEL | | 10,000 t | | |
| | Bharat Forge | | 14,000 t | | |
| Europe | Areva, SFARsteel | 11,300 t | same | 250 | |
| | Sheffield | 10,000 t | 15,000 t ? | 500 ? | |
| | Pilsen Steel | 100 MN (10,200 t) | 12,000 t | 200 (250) | |
| | Vitkovice | 12,000 t | | | |
| | Saarschmiede | 8670 t | 12,000 t (in 2010) | 370 | |

| | | | | | | |
|---------------------|-------------|---------------------------------|----------|-----|------|--|
| | ENSA | Nil, uses forgings to make RPVs | | | | |
| USA | Lehigh | 10,000 t | same | 270 | | |
| Russia | OMZ Izhora | 12,000 t | 15,000 t | 600 | 2, 4 | |
| | ZiO-Podolsk | | | | ?, 4 | |
| South Africa | DCD-Dorbyl | | | | | |

A further issue emerging with manufacturing is metallurgy. Generation III+ plants can use existing metal alloys, but Gen IV plants operating at higher temperatures will require new materials, which will need a long (eg 15-year) lead time to develop. At 700°C degradation problems are much more severe than at today's operating temperatures.

Large nuclear power plants 1,000MWe+ usually have low-speed (1500 rpm) turbines, such as Siemens Arabelle, which are more reliable and efficient. The generators however are heavier than those with the 3000 rpm turbine, and the price is also higher.

The following fills in some detail:

Japan

The largest and best-known supplier of heavy forgings is Japan Steel Works (JSW), founded in 1907 by two British companies and a Japanese partner – Hokkaido Steel & Iron Co. It produces large forgings for reactor pressure vessels, steam generators and turbine shafts, and claims 80% of the world market for large forged components for nuclear plants. It has the distinction of supplying the pressure vessels for the first two 1650 MWe Areva EPR plants in Finland and France.

It is contracted to supply Areva with large forged parts until at least 2016. Areva has said that this, along with its own capacity and other partnerships, will secure its supplies of large components for the five to six nuclear plants per year it expects to build in the medium term. Areva has also acquired 1.3% equity in JSW.

<http://www.jsw.co.jp/en/>

At JSW's Muroran plant on Hokkaido it has 3000 to 14,000 tonne hydraulic forging presses, the latter able to take 600-tonne steel ingots, and a 12,000 tonne pipe-forming press. Its capacity to 2007 had been only four reactor pressure vessels and associated major components per year, but this is in the process of tripling to twelve by 2012. A JPY 50 billion (\$523 million) expansion was completed in March 2010, and a second phase of JPY 30 billion (\$314 million) will be complete in 2011. A second 14,000 tonne forging press was commissioned early in 2010. Muroran also manufactures steam generator components, generator & turbine rotor shafts, clad steel plates and turbine casings for nuclear power plants.

JSW has been manufacturing forgings for nuclear plant components to US Nuclear Regulatory Commission standards since 1974, and around 130 JSW reactor pressure vessels are in service around the world. The company has said that one of its main targets is to supply nuclear reactor pressure vessels to the Chinese and American markets, and it has advance orders from GE-Hitachi for ABWR and ESBWR components, as well as EPR pressure vessels. New orders are coming from China and USA as well as Europe, and more from Japan are expected.

IHI Corporation, formerly Ishikawajima-Harima Heavy Industries, is one of Japan's leading heavy machinery manufacturers, with its 19th and 20th century origins in shipbuilding. Its Energy Plant segment provides boilers, gas turbines, nuclear power equipment, BWR pressure vessels and

containment vessels, and also oil and gas plants. It holds a 3% interest in Westinghouse and collaborates with Toshiba in building power plants. It expects to make pressure vessels and steam generators for Toshiba and Westinghouse PWR nuclear plants. In February 2009 it received an order from Westinghouse for two AP1000 reactor containment vessels for a US plant. A three-way agreement with Toshiba and Doosan in 2008 is expected to result in Doosan's expertise being available to IHI.

<http://www.ihl.co.jp/index-e.html>

Mitsubishi Heavy Industries Ltd. (MHI) will spend JPY 15 billion (\$138 million) to double its capacity to make nuclear reactor pressure vessels and other large nuclear components by 2011. However, it does not have its own forging capacity. Also MHI will triple production space and add processing tools at its factory in Akashi, Hyogo Prefecture. The company aims to reduce the time to make a reactor vessel from three years to two, and to triple annual sales to 600 billion yen in ten years from 200 billion yen in 2007.

MHI has contracts to supply two 1700 MWe APWR nuclear reactors to TXU/Luminant in Texas for Comanche Peak, and now expects orders for about four reactors in Japan. Currently the Kobe shipyard, established in 1905, makes reactor pressure vessels up to 590 tonnes for the APWR. In 2007 it reached a milestone of 50 reactor vessel heads for domestic and overseas nuclear plants and 100 steam generators. In 2009 MHI announced that with Comex Nucleaire it would supply six 300-tonne replacement steam generators for EdF plants in France, to be made at its Kobe shipyard, delivery to begin in 2013.

<http://www.mhi.co.jp/en/index.html>

Kobe Steel manufactures forged pressure vessels up to 2000 tonnes, 6.8 m diameter and with 450 mm walls for the oil industry.

<http://www.kobelco.co.jp/english/mach-eng/products/energy/pressure/index.html>

Babcock-Hitachi KK was set up by Babcock & Wilcox of UK in 1908 as a boiler parts supplier. In 1953 it became a joint venture of Hitachi Ltd with B & W and in 1987 the Hitachi Group took it over. It produces reactor pressure vessels, steam generators, containment vessels and other nuclear power equipment. It has supplied 15 pressure vessels for nuclear plants and is also focused on major components for high temperature gas-cooled reactors and fast breeder reactors.

<http://www.bhk.co.jp/english/2energy/04nuclear/nc0.html>

The Japan Casting & Forging Corporation (JCFC) was founded in 1970 as a joint venture of Nippon Steel Corp. and Mitsubishi Steel Manufacturing Co. It commissioned an 8000 tonne press the following year and has expanded operations since. It will commission a 13,000 tonne forging press in 2010 and can use 500 tonne ingots.

<http://www.jcfc.jp/e/index.html>

South Korea

Doosan Heavy Industries is currently undertaking a major investment in casting and forging capacity, including a 17,000 tonne forging press which will come on line about 2010. Its Changwon plant has a 13,000 tonne press operational. It has contracts from Westinghouse and Shaw to supply reactor pressure vessels and steam generators for four new AP1000 reactors in USA, as well as two of the four being built in China at Sanmen and Haiyang. Some steam generator and pressure vessel forgings for the two Chinese AP1000s have been subcontracted to China First Heavy Industries. In June 2010 it signed a \$3.9 billion contract to supply heavy reactor components

and turbines to KEPCO for four APR-1400 reactors in UAE. It has also received about US\$ 700 million worth of contracts from Westinghouse since May 2008 for nuclear reactors and other equipment. It also has an agreement with IHI which is related to expanding production of heavy components. It expected to win a record \$9.4 billion of orders in 2008, with about 60% coming from overseas. It also has a new arrangement with IHI (see Japan section above).

<http://www.doosanheavy.com/eng/index.asp>

Doosan also has an agreement with China National Nuclear Corporation (CNNC) for supply of heavy forgings and equipment for further projects in China, apparently in the 1000 MWe category.

In 2009 Doosan bought Czech turbine maker Skoda Power, and is setting up Doosan Power Systems (DPS) to oversee Skoda Power and Doosan Babcock as its power solutions business in Europe and the Americas. Skoda's proprietary steam turbine technology completes the suite from reactor steam supply to generators, and positions it for engineering-procurement-construction (EPC) contracts for new nuclear power plants.

KEPCO subsidiary Korea Power Engineering Co. Inc. (KOPEC) was established in 1975 and received ASME N-stamp accreditation in October 2009. It has designed and built 14 nuclear power plants and developed the AP1400 reactor for which it received an international engineering award. It has also been involved with design work on the Westinghouse AP1000 reactor, and with Bechtel on a US nuclear plant. It was floated as a public company in December 2009. However it is essentially an engineering services company, not a manufacturer.

<http://www.kopec.co.kr/eng/main.asp>

China

China's heavy manufacturing plants can make about seven sets of pressure vessels and steam generators per year, a doubling from 2007, but this is projected to rise to 20 sets per year by 2015. The National Development & Reform Commission (NDRC) in 2006 authorized major investment by three major fabricators, all state-owned. However, it appears that China cannot yet make large pumps and valves independently, and UK's Sheffield Forgemasters supplies these for AP1000 reactors globally.

Early in 2010 the State Nuclear Power Technology Corporation (SNPTC), which is in charge of deployment of new reactor technology, announced that ten engineering enterprises had been qualified to provide equipment for Generation-III nuclear plants. The newly-qualified qualified suppliers are: China First Heavy Industries (CFHI); Harbin Power Equipment (Qinhuangdao) Co; Harbin AC/DC Motor Co; Shanghai Electric Nuclear Power Equipment Co (SENPE); Shanghai First Machine Tool Works; Dongfang (Guangzhou) Heavy Machinery Co Ltd; Deyang Heavy Equipment Co; Dalian Heavy Industry and Crane Co; Taiyuan Heavy Industry Co Ltd; and Shenyang Turbo Machinery Co.

China First Heavy Industries (CFHI) - also known as YiZhong - was founded in 1954 in the northern steel-belt Heilongjiang province of Manchuria and is now one of China's key industrial enterprises. While nuclear equipment accounts for only about 5% of its business, it produces pressure vessels for nuclear power plants up to 1080 MWe CPR-1000 (eg Hongyanhe1, Yangjiang 1-4, Ningde 3-4, Fuqing 1-2, Fangjiashan 1-2, Qinsahn II-4), steam generators for Yangjiang 1-3 and Ningde 3-4, pressurizers for Qinshan II-4, and pressure vessels for Chasma in Pakistan. It is supplying some steam generator and pressure vessel forgings for China's first two AP1000 units as a subcontractor to Doosan, and is to supply AP1000 pressure vessel and steam generators for Haiyang 1, as well

as CGNPC's first AP1000 units at Dafan/Xianning. It commissioned a 15,000 tonne (150 MN) open-die hydraulic press at end of 2006 – then claimed to be the world's largest, and it has also been using a 12,500 tonne (125 MN) press. In June 2009 it poured a 580 tonne ingot for a nuclear plant turbine rotor, and forged this in August

CFHI announced in December 2007 that it had gained approval from the NDRC to invest CNY 2.3 billion (US\$ 337 million) in expanding its production capacity further. In 2009 it could provide three sets of equipment for large PWRs and is aiming for five sets by 2015. Located in Qiqihar, Heilongjiang Province in Northeast China, the project is going to double the company's annual production of molten steel and increase pressed forging capacity to 240,000 tonnes per year. Its target is to build the "world's largest casting and forging steel base" by 2010, and in November 2009 it announced that it had invested CNY 5 billion to achieve this.

The first set of core equipment for China's Experimental Fast Reactor was designed and manufactured by CFHI and the China Institute of Atomic Energy, representing considerable R&D. <http://www.cfhi.com/yjzt/en/>

The Shanghai Electric Heavy Industries Group Corporation (SEC), founded in 1925, includes heavy engineering and it manufactures pressure vessels, steam generators and pressurizers for PWRs, and had a 12,500 tonne forging press by 2005, and added a 16,500 tonne press in 2008. It imported a Japanese heavy forging press in 2008 for its base in Minhang, and aims to be producing up to six sets of PWR equipment per year in 2011. It had invested CNY 6 billion in its Minhang and Lingang plants by mid 2009. SEC supplied pressure vessel and steam generators for Qinshan II-1 CNP-600 and has contracts for pressure vessels and steam generators for Haiyang-2 and Taohuajiang AP1000s, Changjiang CNP-600, and Ningde-2 CPR-1000. It also has contracts for 24 CPR-1000 steam generators, including Qinshan II-4, Hongyanhe-1, Ningde-2, Fangjiashan-2 and Haiyang-2. It will also supply major components for the Shandong HTR.

A major SEC subsidiary is Shanghai Electric Nuclear Power Equipment Co Ltd (SENPE) with a new nuclear fabrication plant at Lingang. This is increasing ingot capacity to 600 tonnes, allowing fabrication of both AP1000 and EPR components. A CNY 1 billion second phase of this Lingang plant is due on stream in 2012, almost doubling capacity. SENPE says that Lingang will become the world's largest and most concentrated base for nuclear equipment by that time. In 2009 SENPE could make 2.5 sets of PWR equipment per year including pressure vessels and steam generators. Another important subsidiary, Shanghai First Machine Tool Co. is the only domestic supplier of reactor vessel internals and control rod drive mechanisms, with capacity increasing to six sets per year in 2010 and then ten sets per year. It has an 85% market share (100% for CPR-1000 reactors). Other SEC subsidiaries are Shanghai Heavy Machinery Company, specializing in forging and casting, and Shanghai Boiler Co Ltd.. <http://www.chinasec.com/en/index.asp>

China National Erzhong Group Co Ltd (formerly China Second Heavy Industries Corp) is located inland at Deyang, in Sichuan province. It started production in 1971 and claims to be the largest heavy machine-building base in China, with assets of CNY 4.7 billion. China Erzhong can produce 600-tonne ingots and has a 125 MN (12,700 tonne) hydraulic press and added a 160 MN (16,300 tonne) press in 2009. In 2009 it forged China's biggest low-speed 1100 MW generator rotor for Dongfang Electric, which was successfully tested under Alstom supervision. (It is also constructing the world's largest hydraulic press, an 80,000-tonne die forging machine, costing CNY 1.5 billion and due on line in 2010, for large aircraft manufacture.)

Erzhong Group (Zhenjiang) Heavy Equipment Ltd is located at Zhenjiang City, Jiangsu Province, of the Yangtze River Delta, and is the second production base for China Erzhong, including a foundry and forge.

China Erzhong supplies forgings to Dongfang (Guangzhou) Heavy Machinery Co's (DFHM) plant near the coast, which is on track to produce three sets of CPR-1000 equipment per year by 2010. It was formerly known as Guangzhou Guangzhong (Nansha) Machinery Co Ltd. It supplied the first Chinese-made 1000 MWe reactor pressure vessel (for Ling Ao) in June 2009. DFHM was established in 2003 by Dongfang Electric (now 57%) and China Erzhong, with local investors. It has had a close relationship with Japan Steel Works since 2006, and imports large forged components for pressure vessels and steam generators from JSW. China Erzhong also plans to invest CNY 2.4 billion in setting up another production base in the Jiangsu province for large-sized forging products.

China Erzhong won the contract to supply reactor pressure vessel forgings and primary piping for the Taohuajiang AP1000 reactors.

The Erzhong Group (Deyang) Heavy Equipment Ltd has a major pipe contract with State Nuclear Power Engineering Corporation for AP1000 units at Sanmen and Haiyang. The main pipe connecting pressure vessel and steam generators is the only key equipment on the nuclear island of the initial AP1000 reactors that China will manufacture domestically.

<http://www.china-erzhong.com/>

China Dongfang Electric Corporation (DEC) is based inland at Chengdu, Sichuan province. It was founded in 1984 and an important subsidiary, Dongfang Electric Corporation Ltd (formerly Dongfang Electric Machinery Co Ltd), is listed in Hong Kong and Shanghai, and in April 2009 announced a CNY 5 billion capital raising. Dongfang has the largest market share for turbine generators, and is the main contractor for Qinshan II. It produces everything from reactor pressure vessels and steam generators through to turbine generators. Its steam generators will equip Hongyanhe 1-4, Ningde 1-4, Fuqing 1-2 and Fangjiashan 1-2 projects, and its turbine generators: LingAo II plus those four, due to its close relationship with CGNPC.

A subsidiary, the Dongfang Boiler Group Co Ltd (DF), manufactures large capacity power plant boilers including components of PWRs and is working with Areva to manufacture all heavy nuclear components for Ling Ao phase II and other CGNPC projects: Hongyanhe 2-4, Ningde 1, and steam generators for Fuqing 1-2. It has ASME N-stamp accreditation for boilers and pressure vessels. In November 2007 a 68% share of it, plus all of Dongfang Turbine Co, was purchased from the state by DEC for US\$ 2.8 billion. DEC works closely with Erzhong, and also has a link with Babcock-Hitachi. A 2006 joint venture with Areva produces nuclear pumps, for Ling Ao phase II and Ningde.
<http://www.dongfang.com.cn/> <http://www.dfem.com.cn/>

The Harbin Boiler Co. (formerly Harbin Boiler Works) founded in 1954 is the largest utility boiler manufacturer in the country and is supplying steam generators for China's AP1000 reactors at Sanmen 2 and CPR-1000s at Yangjiang 4. It is supplying pressurizers for Yangjiang 1-4 and Ningde 3-4. It bid for AP1000 pressure vessels. It has been producing steam generators for plants up to 600 MWe and has supplied 600 utility boilers with a total capacity of over 53,000 MW, covering one third of the total installed capacity of thermal units manufactured domestically in more than 180 power plants in 29 Chinese provinces, municipalities and autonomous regions, plus exports to 23 countries. It has an 8000 tonne press. Parent company Harbin Power Equipment

Co. Ltd (HPEC) is supplying 1200 MWe steam turbines and generators for the four Sanmen and Haiyang AP1000 units under licence from Mitsubishi Heavy Industries (MHI).

http://www.hbc.com.cn/INTRODUCTION_ENGLISH.htm

Shandong Nuclear Power Equipment Manufacturing Co Ltd (SNPEMC) was set up in 2007 by the State Nuclear Power Technology Corporation which holds a 64% share, with subsidiaries of CNNC holding the remainder. SNPEMC designs and manufactures AP1000 reactor components, containment vessels and equipment. It is responsible for the fabrication of equipment modules, structural modules, primary pipelines and equipment for conventional island, as well as fabrication of equipment for other nuclear power plants. In 2008 a new factory was commissioned to produce structural, piping and equipment modules for Westinghouse's AP1000 reactors. Shandong Nuclear Power Construction Group built that facility in just 11 months. SNPEMC has the capacity to build containment vessels and other equipment for two AP1000s each year, and has gained the international ASME N-stamp accreditation. At Sanmen, where the first AP1000 is under construction, the first module - of 840 tonnes - from Shandong has been lifted into place. A further 18 modules to be used in the reactors' construction weigh in excess of 500 tonnes. In November 2009 SNPEMC signed an agreement with Harbin Turbine Co to manufacture AP1000 components. <http://www.snpehc.com.cn>

Xi'an Nuclear Equipment is a CNNC subsidiary located in Shaanxi province and specialises in pressurizer, safety injection tank and related nuclear island equipment. It is certified as one of the nation's nuclear pressure equipment suppliers and has participated in the Qinshan I project, Pakistan's Chashma and Qinshan II extension project. It is supplying pressurizers for Qinshan II-3, Fangjiashan 1-2 and Fuqing 1-2.

<http://www.xa524.com/index1y.htm>

Chong Ming Nuclear Power and Heavy Container Forging Manufacture Project is being built at Qingdao in Shandong province. Chong Ming Energy Ltd is investing CNY 3 billion to produce heavy forgings for power generation equipment, heavy chemical industry and shipbuilding. Some 80,000 tons of heavy forgings would be produced annually from late 2012.

Japan's Morimatsu Group, which has diverse engineering operations in China, established the Shanghai Morimatsu Pressure Vessel Co in Pudong in 1990, to manufacture locally for Chinese nuclear power projects. It has ASME N-stamp accreditation.

<http://en.morimatsu.com.cn/>

India

In India, Larsen & Toubro Ltd., the country's biggest engineering and construction company, makes reactor pressure vessels for the country's PHWRs and fast breeder reactor, and steam generators. It has a 9000 tonne press and plans 15,000 tonne capacity for ultra-large forgings, and holds ASME N-stamp accreditation. It has been involved in supply of equipment, systems and services for nearly all the PHWR reactors that have been indigenously built, including manufacture of calandrias, end-shields, steam generators, primary heat transport system and heat exchangers. In September 2009 it secured an order for four steam generators for Rajasthan 7 & 8, having supplied similar ones for Kakrapar 3 & 4.

Larsen & Toubro (L&T) plans to form a 20 billion rupee (\$463 million) joint venture with state-run Nuclear Power Corp. of India (NPCIL) to build a new plant for domestic and export nuclear forgings at its Hazira, Surat site in Gujarat state by 2011. NPCIL will hold a 26% stake. The plant will handle

600-tonne ingots and have a very large forging press to supply finished forgings for nuclear reactors, pressurizers and steam generators, and also heavy forgings for critical equipment in the hydrocarbon sector and for thermal power plants. According to Government officials, discussions are under way with French firms for industrial cooperation in the manufacture of PWR equipment in India. This would be to enhance the competitiveness of French reactors worldwide.

Early in 2009, L&T signed four agreements with foreign nuclear power reactor vendors. The first, with Westinghouse, sets up L&T to produce component modules for the Westinghouse AP1000 reactor. It said that this would enable the two companies "to utilize indigenous capabilities for the turnkey construction of nuclear power plants including supply of reactor equipment and systems, valves, electrical & instrumentation products and fabrication of structural, piping and equipment modules for Westinghouse AP1000 plants." The second agreement was with Atomic Energy of Canada Ltd (AECL) "to develop a competitive cost/scope model for the ACR-1000." In April L&T signed an agreement with Atomstroyexport primarily focused on components for the next four VVER reactors at Kudankulam, but extending beyond that to other Russian VVER plants in India and internationally. Then in May it signed an agreement with GE Hitachi to produce major components for ABWRs - the two companies hope to utilize indigenous Indian capabilities for the complete construction of nuclear power plants including the supply of reactor equipment and systems, valves, electrical and instrumentation products for ABWR plants to be built in India.
<http://www.larsentoubro.com>

Following the 2008 removal of trade restrictions, Indian companies led by Reliance Power (RPower), NPCIL and Bharat Heavy Electricals (BHEL) plan to invest over US\$ 50 billion in the next five years to expand their manufacturing base in the nuclear energy sector.

State-owned Bharat Heavy Electricals (BHEL) (BHEL) claims to be the largest engineering and manufacturing enterprise in India in the energy-related infrastructure sector, and has provided some 80% of the heavy equipment for India's indigenous nuclear power program. It is supplying the steam generators for the first 700 MWe series of reactors, at Kakrapar, based on its design for the 540 MWe units. It is in the process of doubling its production capacity over four years from 10,000 MWe of plant per year (Dec '07), and planned to spend \$7.5 billion in two years building plants to supply components for reactor units of 1,600 MWe. It also planned to set up a 50-50 venture with NPCIL that will supply components for nuclear plants of 700 MWe, 1,000 MWe and 1,600 MWe. It is planning to install a 10,000 tonne forging press. It is also setting up an office in Shanghai in 2009 to source castings and forgings.

BHEL has set up a joint venture with NPCIL to supply turbines for nuclear plants of 700 MWe, 1,000 MWe and 1,600 MWe and to seek overseas partners to provide technology for this enterprise. In July it announced that it was close to finalising a European partner to take 30-35% of this joint venture.

BHEL in 2008 set up a joint venture with Heavy Engineering Corp (HEC) for making castings and forgings for nuclear power plants, based on upgrading HEC's plant. BHEL was planning to set up a greenfield manufacturing base in India for nuclear forgings and was in talks with UK-based Sheffield Forgemasters International Ltd and Japan's Kobe Steel for possible joint ventures in nuclear forgings. Then in March 2009 BHEL said it was likely to join the Areva-Bharat Forge joint venture to produce nuclear castings and forgings, instead of going it alone, this intention being confirmed in July. Shortly after, it announced a ten-year technology transfer agreement with Sheffield Forgemasters for large power plant components. Another joint venture is with NPCIL and a foreign partner to make steam generators for 1000 - 1600 MWe plants.

<http://www.bhel.com>

Bharat Forge Ltd (BFL) is a multinational company which claims to be among the largest and technologically most advanced manufacturers of forged and machined components, mostly for the automotive industry. It is said to be the world's second-largest forging company and is extending its activities into the power sector. In 2008 it formed a joint venture with Alstom primarily for manufacturing state-of-the-art supercritical power plant equipment in India, though the enterprise may extend to nuclear applications. In January 2009 it signed a memorandum of understanding with Areva to set up a joint venture in casting and forging nuclear components for both export and the domestic market, by 2012.

BFL has commissioned a 400 tonne forging press at Pune, and a 15,000 tonne press is due to be commissioned by 2012. BFL is part of the Kalyani Group - a US\$ 2.4 billion conglomerate.

<http://www.bharatforge.com/>

HCC (Hindustan Construction Co.) has built more than half of India's nuclear power capacity, notably all 6 phases of the Rajasthan Atomic Power Project and also Kudankulam. It specializes in pre-stressed containment structures for reactor buildings. In September 2009 it formed a joint venture with UK-based engineering and project management firm AMEC PLC to undertake consulting services and nuclear power plant construction. HCC has an order backlog worth 10.5 billion rupees (\$220 million) for nuclear projects from NPCIL and expects six nuclear reactors to be tendered by the end of 2010.

<http://www.hccindia.com/>

National Thermal Power Corporation (NTPC) plans to diversify into nuclear power, and has formed joint ventures in heavy engineering with BHEL and Bharat Forge. It is also creating a joint venture with NPCIL and BHEL to sell 220 MWe PHWR units abroad.

Europe

Areva in 2006 purchased France's SFARsteel, one of the leading worldwide manufacturers of large forged parts. It claims a strategic position in Europe for fabrication of very heavy mechanical components (up to 360 tonnes in one piece), including reactor pressure vessels and steam generators. It has an 11,300 tonne forging press and a 7500 tonne one. Its four production facilities are located in the Le Creusot basin in central France. The integration of SFARsteel into Areva's Equipment Business Unit has boosted its capability to supply new generation reactors, and in particular the EPR.

http://www.sfarsteel.com/presentation_a.php

Areva's Creusot Forge subsidiary in Burgundy specializes in large forged components and announced recently that it was investing to increase production of heavy nuclear components, including large reactor pressure vessels. In particular the nozzle shell ring for the EPR requires capacity to forge a 500 tonne ingot and only JSW can do this now. This investment will consolidate a second source of supply for EPR components, additional to Japan Steel Works.

Since 1975 Areva's Chalon/St. Marcel facility, also part of the Burgundy Nuclear Partnership grouping, has produced steam generators and pressure vessels up to 500 tonnes for all the French power reactors as well as exports - some 76 pressure vessels and vessel heads, 63 replacement heads, and 292 steam generators, including those for Olkiluoto-3 EPR. In April 2009 Areva announced that it planned to almost double the capacity of the plant for heavy components, from 1.7 to 2.7 EPR sets of equipment per year.

The Burgundy Nuclear Partnership was formed by Sfarsteel and others to provide a coherent nuclear supply chain.

In 2008 Areva announced the launch of an investment program in Le Creusot to increase Areva's production capacity of forged nuclear components, enabling EPR reactor vessels to be manufactured there. The plan first involved increased heavy ingot production at the Industeel works, part of ArcelorMittal. Secondly it involved further investment in Creusot Forge to increase production of pressure vessels and steam generators.

<http://www.industeel.info/>

The UK's Sheffield Forgemasters International, founded in the 1750s and subject to a management buyout in 2005, is the only UK company with ASME N-stamp accreditation. It has a 10,000 tonne press which takes 300 tonne ingots, and had finalised £170 million financing to install a 15,000 tonne forging press to handle 500 tonne ingots. After long negotiation, the UK government agreed to lend £80 million, Westinghouse offered about £50 million in advance payments, and the last £20 million came from bank loans. The press was expected to be commissioned in 2013, and would have enabled the company to manufacture all heavy components for EPR and AP1000 reactors, but the new UK government in June 2010 cancelled the loan arrangement and the prospect is now uncertain.

Sheffield Forgemasters also makes casings for high pressure reactor coolant pumps, capable of pumping water at up to 430,000 litres per minute of coolant through a reactor core. In 2008 the company won a contract to supply 16 tonne stainless steel casings for the Westinghouse AP1000 reactors at Sanmen nuclear power plant in China and for two states in USA. It also supplies reactor coolant pump casings for Korea's APR-1400 reactors, via KSB in Germany. It has also produced heavy forgings for UK nuclear power plants. In 2008 it signed an agreement with China's Harbin Electric Co. (HEC) to produce a range of large-scale complex engineering products for civil nuclear, steam and hydro power plants in China. In 2009 it won contracts for Argentina (Embalse), and entered a ten-year £30 million technology transfer agreement with Bharat Heavy Electricals (BHEL) for large power plant components.

<http://www.sheffieldforgemasters.com/>

In 2010 Cammell Laird, a shipbuilder, and Nuvia, with many years nuclear experience, formed a partnership to bid for construction of nuclear power plant modules.

<http://www.clbh.co.uk/> <http://www.nuvia.co.uk/>

Saarschmiede at Voelklingen, Saarland, commissioned a 120 MN (12,000 tonne) open die forging press in May 2010, capable of taking 370 tonne ingots at up to 1290°C. It produces turbine and generator shafts, and with the new press will be capable of forging all AP1000 components. Saarschmiede aims to be one of the top three forges worldwide, focused on power generation components.

<http://www.saarschmiede.com/english/unternehmen/index.html>

Spain's Equipos Nucleares SA (ENSA), based in Madrid, provides a lot of heavy equipment for Westinghouse plants. In April 2009 GE Hitachi signed a strategic agreement for ENSA to manufacture and supply reactor pressure vessels for new GE Hitachi-designed ESBWR and ABWR units. In February 2009, Japan Steel Works supplied the first of six forgings required to fabricate one ESBWR reactor pressure vessel, and ENSA anticipates completing the manufacturing process by mid-2012. It produces reactor pressure vessels, steam generators and

other components at its factory on the north coast of Spain for nuclear power plants in several countries, including the USA, China, South Korea, South Africa, France and Sweden. ENSA exports 85% of its production.

<http://www.ensa.es/>

In Italy, Ansaldo Nucleare was set up in 1989 as a subsidiary of Finmeccanica Group under Ansaldo Energia. It is based in Genova and specializes in the design, construction and servicing of nuclear power plants. It has played a major role in building Romania's Cernavoda 2 reactor.

<http://www.ansaldonucleare.it>

The major Czech nuclear engineering company Skoda JS, at Plzen, was taken over by Russia's OMZ Group in 2004. Since 1980 Skoda JS has manufactured 24 sets of complete VVER reactors including reactor pressure vessels, internals, control rod drive mechanisms etc. for plants such as Temelin and Mochovce. Steam generators were procured from Vitkovice. In 2005 Areva placed an order with Skoda JS to supply EPR reactor internal parts for the Finnish Olkiluoto 3 plant and in 2009 similarly for China's Taishan 1 plant. □

www.skoda-js.cz/en

Pilsen Steel (formerly Skoda Steel) is a sister company to Skoda JS, also at Plzen, and undertakes heavy forging. It has a 100 MN (10,200 tonne) forging press and can produce 200 tonne ingots in its foundry. In 2010 it will upgrade the press to 12,000 tonnes. It claims a long tradition in nuclear manufacturing and has supplied forged parts for 24 VVER pressure vessels (440 and 1000 MWe) as well as steam generators. With Skoda JS, it has been an OMZ subsidiary since 2004, and expects to get ASME and RCC-M accreditation in 2010 as well as Chinese NNSA registration.

<http://www.pilsensteel.cz/en/?m=100&lx=en>

A separate Czech company, Skoda Power, produces steam turbines, heat exchangers and other heavy equipment, and was taken over by Doosan in 2009.

<http://www.doosanskoda.com/live/cme1.htm>

Skoda Praha in Prague is owned by CEZ and is an engineering company involved with secondary circuits and coal-fired plants.

<http://www.skodapraha.cz/en/>

The Czech Vitkovice Group said in 2007 that its heavy machinery division could upgrade facilities to produce heavy nuclear forgings in two years. It already produces pressure vessels and steam generators for nuclear plants using a 12,000 tonne forging press.

<http://www.vitkovice.cz/en/>

Russia and Ukraine

Russia's main reactor component supplier is OMZ's Izhorskiye Zavody facility at Izhora which is doubling the production of large forgings so as to be able to manufacture three or four pressure vessels per year from 2011. This represents a RUR 12 billion (\$430 million) investment. OMZ is expected to produce the forgings for all new domestic AES-2006 model VVER-1200 nuclear reactors (four per year from 2016), plus exports. At present Izhora can produce the heavy forgings required for Russia's VVER-1000 reactors at the rate of two per year and it is manufacturing components for the first of two Leningrad II VVER-1200 units and for Novovoronezh II, as well as Belene and Tianwan VVER-1000s. These forgings include reactor pressure vessels, steam generator shells, reactor internals, and heavy piping. It shipped steam generator shells to ZiO-

Podolsk for finishing.

In 2008 the company was rebuilding its 12,000 tonne hydraulic press, claimed to be the largest in Europe, and a second stage of work will increase that capacity to 15,000 tonnes. In mid 2009 Izhora commissioned a furnace complex enabling production of 600-tonne ingots and 5.5 metre diameter forging shells for nuclear reactors. This was announced as the first stage of its expansion to produce four sets of nuclear reactor components per year. The 600-tonne ingot capacity will also enable production of large rotors for low-speed turbines. Izhora is keen to start manufacturing steam generators for large nuclear plants.

Parent company Objedinenyye Mashinostroitelnye Zavody (OMZ - Uralmash-Izhora Group) itself is the largest heavy industry company in Russia, and has a wide shareholding but is controlled by Gazprom. It specializes in engineering, production, sales and maintenance of equipment and machines for the nuclear power, oil and gas, and mining industries, and also in the production of special steels and equipment for other industries. Izhorskiye Zavody became part of the company in 1999, and Skoda Steel (incorporating forging and foundry sections) and Skoda JS joined in 2004. Skoda Steel was renamed Pilsen Steel in 2007. See Europe section for these.

OMZ-Spetsstal has announced that it has received a five-year licence from Rostekhnadzor, the Federal Environmental, Industrial and Nuclear Supervision Service, for the manufacture of equipment for nuclear power plants. It supplies to Izhora.

<http://www.omz.ru/eng/>

Atomenergomash (AEM) was set up in 2006 as a holding company, part of Atomenergoprom under Rosatom, to gain control of the supply chain for new plants. It claims to be the leading company in Russia for major components of nuclear power plants, controlling over 40 facilities, and to be the only Russian source of steam generators for nuclear plants, through ZiO-Podolsk near Moscow (see below). In 2009, 62% of its US\$ 505 million turnover was in nuclear equipment. AEM is concerned to diversify its source of supply from OMZ, and is talking with Energomash-Atom mash which was set up in the 1970s at Volgograd as (then) principal nuclear equipment supplier. AEM is also considering developing its own capacity to make VVER pressure vessels, possibly in collaboration with an international company.

Krasnye Barrikady shipyard and Engineering Company AEM-Technologies have been mentioned as alternatives to Izhorskiye Zavody to supply reactor pressure vessels. (unconfirmed)

The Power Machines Company (JSC Silovye Mashiny Concern, or Silmash) was established in 2000 and brought together a number of older enterprises including Leningradsky Metallichesky Zavod - LMZ (established 1857), Elektrosila (est 1898), Turbine Blades Factory, etc. Siemens holds 26% of the stock. Silmash makes steam turbines up to 1200 MWe, including the 1000 MWe turbines for Atomstroyexport projects in China, India and Iran, and has supplied equipment to 57 countries worldwide. It is making 1200 MWe turbine generators for the Leningrad and Novovoronezh II nuclear plants. It plans to produce 1200 MWe low-speed (1500 rpm) turbines at a new plant by 2013, and is considering Volgogradsk-4 (Rostov), Seversk-1 & 2 and Belarus-1 & 2 as possible customers for these. A significant amount of Power Machines' business is in Asia.

<http://english.power-m.ru/>

The Russian EnergyMachineBuilding Company (REMCO) was established as a closed joint stock

company in Russia in 2008, amalgamating some smaller firms, with half the shares owned by Atomenergomash. It is one of the largest manufacturers of complex heat-exchange equipment for nuclear and thermal power plants, oil and gas industry. Its subsidiaries include JSC Machine-Building Plant ZiO-Podolsk and JSC Engineering Company ZIOMAR.

<http://www.rusenergomash.ru/eng/>

JSC Machine Building Plant ZiO-Podolsk near Moscow is one of the largest manufacturers designing and producing equipment for nuclear power and other plants. It has made equipment, including steam generators and heat exchangers, for all nuclear plants in the former USSR. It is increasing capacity to four nuclear equipment sets per year, investing RUR2.9 billion by 2015, one third of this by the end of 2009. It appears to be majority owned by Atomenergomash, with EMAlliance (PJSC EnergoMashinostroitelny Alliance - 24%) and Renova Group (25%). It was founded in 1919 and was formerly known as the Ordzhonikidze engineering plant in Podolsk.) It is making the reactor pressure vessel and other main equipment for the BN-800 fast reactor at Beloyarsk as well as steam generators for Novovoronezh, Kalinin-4, Leningrad and Belene. The BN-800 reactor pressure vessel is 13 metres in diameter, and a unique 16-meter rotary-table milling machine is needed to manufacture it, using South Korean steel.

<http://www.podolskmash.ru/lang-en/predpr.html>

<http://www.em-alliance.com/en/holding/company>

In April 2007 Alstom and Atomenergomash set up a joint venture, 51% owned by AEM, to manufacture the Arabelle low-speed turbine generator in Russia. This Alstom Atomenergomash LLC joint venture, in which both parties are investing EUR 200 million, is established next to ZiO-Podolsk. It includes the technology transfer of Alstom's state of the art Arabelle steam turbine and generator, available up to 1750 MWe. First production is expected in 2011 with output reaching three 1200 MWe turbine and generator sets per year in 2014.

In September 2007 Mitsubishi Heavy Industries (MHI) signed an agreement with Russia's Ural Turbine Works (UTZ) to manufacture, supply and service gas and steam turbines in the Russian market. Under the agreement, MHI, Japan's biggest machinery maker, will license its manufacturing technologies for large gas turbines and steam turbines to UTZ - part of the Renova Group. The agreement also calls for a joint venture to be established in Russia to provide after-sales service.

Ukraine's JSC Turboatom at Kharkov, established in 1934 and now 75.2% government-owned, is among the leading world turbine-building companies. It specializes in steam turbines for thermal and nuclear power plants, and has the capacity to produce 8000 MWe of such per year, with individual units up to 1100 MWe. It has supplied 110 turbines totalling 50 GWe for 24 nuclear power plants. Ukrainian power plants employ 47 Turboatom-made turbines and 43 Russian ones.

<http://www.turboatom.com.ua/en>

North America

The USA has seen a decline in nuclear engineering facilities. In the mid 1980s there were about 440 facilities with N-stamp accreditation from the ASME and hence able to produce commercial nuclear-grade components. This number halved, only partly due to industry consolidation, but had recovered to 255 by mid 2008.

Babcock & Wilcox Nuclear Power Generation Group (B&W NPG, formerly BWX Technologies), a subsidiary of McDermott International, specializes in the management of nuclear materials, facilities, and technologies and has been the main N-stamp accredited manufacturer of nuclear

power generation components. It is currently the only US manufacturer of nuclear reactor pressure vessels and claims domination of the North American steam generator market. It has made most US Navy nuclear propulsion systems. In 2006 it entered an agreement with Areva to produce EPR components for UniStar at its Mount Vernon, Indiana plant. In 2009 it supplied to Areva the first of two replacement reactor pressure vessel heads for PG&E's 1100 MWe Diablo Canyon reactors, using forged blanks from Japan Steel Works.

Its Babcock & Wilcox Canada associate has provided nuclear services and more than 200 steam generators as well as reactor vessel closure heads to clients around the world. It is contracted to provide two steam generators for Bellefonte 1, delivered in 2015, if TVA proceeds with that project. B&W boilers equip more than 270,000 MW of installed capacity in over 90 countries
http://www.babcock.com/business_units/nuclear_power_gen_group/

In 2008 the Shaw Group and Westinghouse created a joint venture Global Modular Solutions which has built a \$100 million factory at Lake Charles, Louisiana, to produce structural, piping and equipment modules for new nuclear power plants utilizing Westinghouse's AP1000 technology. It is expected to employ up to 1400 people when fully operational from November 2010, and is part of an emerging world network of such factories – preceded by one in China.

<http://www.shawgrp.com/>
<http://www.westinghousenuclear.com/index.shtml>

Also in 2008 Areva set up a \$360 million joint venture with Northrop Grumman Shipbuilding to build a factory at its shipyard at Newport News, Virginia, where nuclear powered vessels for the US Navy are built. It will be known as Areva Newport News, and be 67% owned by Areva but drawing on Northrop Grumman's extensive experience related to naval reactors. The facility is designed to be a twin of Areva's Chalon-St Marcel plant in France, which has a major backlog. From mid 2013 it will take major components forged elsewhere and finish them ready for installation. Areva Newport News is expected to produce components for at least seven EPR reactors in the USA as well as more for export, at the rate of one set per year - comprising reactor pressure vessel, four steam generators, four reactor coolant pumps, plus pressurizers and piping. Areva wants 80% of the components for its US reactors to be made in USA.

Lehigh Heavy Forge in Bethlehem, Pennsylvania has been operating for more than a century and claims to be the only heavy forge facility in North America and to manufacture the largest and most complex open-die forgings there for a wide variety of industries, but does not yet have ASME's N-stamp accreditation. It has the largest open die press in North America, of 10,000 tonnes capacity, which can handle ingots up to 3.3 metres diameter and 270 tonnes.

http://www.lhforge.com/lh_home.htm

Chicago Bridge & Iron Co (CB&I) has been awarded a \$150 million engineering, procurement, fabrication and construction (EPFC) contract by Westinghouse to build the first two containment vessels for AP1000 reactors in southeastern USA, plus two more for USA. CB&I has built 130 containment vessels around the world, including 75% of those for currently-operating US nuclear plants. It has also built 41 reactor pressure vessels and holds all relevant ASME accreditations.

<http://www.cbi.com/>

However, metal forgings will continue to be done overseas, and Areva purchased Sfarsteel, a producer of steel forgings whose assets include Creusot Forge. Areva and B&W hope eventually to have similar forging capability in USA. In 2006 Areva ordered heavy forgings for the first UniStar EPR plant in the USA from SFARsteel. These reactor pressure vessel and steam generator

components were to be finished at Chalon-St Marcel facility in France or at B&W in Indiana.

GE-Hitachi has made reservations and placed orders with JSW to contract specific forgings for its ABWRs and ESBWRs. It had "almost 100% of its supply team chain lined up and in place for the ESBWR" and was proceeding with ABWR.

South Africa

DCD-Dorbyl is the largest mechanical engineering concern in Southern Africa. It is a Black Economic Empowered company which is recognised as an industry leader. Its Heavy Engineering Vereeniging subsidiary was established in 1946 and lists PBMR components among its traditional markets, and PBMR demonstration plant as well as PWR equipment as new markets. It has a 1000-tonne press and major rolling capacity. Westinghouse is intending to contract for it to make steam generators and pressure vessels for AP1000 reactors in North America and Europe.
<http://www.dcd-dorbyl.com>