China's Stockpile of Military Plutonium: a New Estimate[1]

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Abstract

While China has kept information about its stocks of fissile materials and nuclear weapons secret, a great deal of new public information on the history of Chinese plutonium production has recently become available. This paper will estimate China's stockpile of plutonium for nuclear weapons by analyzing the new public information about the plutonium production at its two plutonium production complexes. Also, the history of plutonium production and the status of the production facilities are discussed. The author estimates that China currently has stockpiles of about 1.8±0.5 tons of plutonium available for weapons. The new estimated value is significantly lower than most previous independent estimates, which range from 2.1–6.6 tons of plutonium.

HISTORY OF MILITARY PLUTONIUM PRODUCTION

China initiated its nuclear program in mid-1950s and began to construct its plutonium and HEU production facilities in the late of 1950s. China has produced plutonium for weapons at two nuclear complexes: 1) Jiuquan Atomic Energy Complex (also referred as Plant 404), near Yumen in Gansu province. This site includes China's first plutonium reactor, which began operation in 1966, and the associated reprocessing facilities. 2) Guangyuan plutonium production complex (Plant 821), located at Guangyuan in Sichuan province. This was the "third line" plant backing up the Jiuquan complex and also included a plutonium reactor and reprocessing facility. The reactor began operation in 1973. While China has not declared officially that it has ended plutonium production for weapons, based on new public information, it is believed that the Jiuquan and Guangyuan reactors stopped plutonium production in 1984 and 1989 respectively (see Table 1).

China has also built a pilot reprocessing plant for civilian purpose with a capacity of 50 tons heavy metal per year at the Jiuquan complex. It conducted successfully a hot test in last December and would be in full operation soon.

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Table 1: Chinese plutonium production reactors and reprocessing facilities

Site	Period of plutonium production	Status
Jiuquan reactor, Yumen, Gansu	December 1966-1984	Closed down
Guangyuan reactor, Guangyuan, Sichuan	December 1973-1989	Based on “military shift to civilian”, the complex converted to other purposes including aluminum manufacture since 1989. Being decommissioned.
Jiuquan intermediate pilot reprocessing plant, Yumen, Gansu	September 1968- Early 1970s	Closed down
Jiuquan military reprocessing plant, Yumen, Gansu	April 1970-1984	Closed down
Guangyuan military reprocessing plant, Guangyuan, Sichuan	1976- Around 1990	Based on “military shift to civilian”, the complex converted to other purposes including aluminum manufacture since 1989. Being decommissioned.

Jiuquan Complex

The Jiuquan site was selected as China’s first plutonium production complex in 1957. The Jiuquan plutonium production reactor is a light-water cooled, graphite-moderated reactor. It was designed in 1958 with Soviet assistance and construction started in March 1960. When the Soviet Union stopped its aide in August 1960, the initial designs had just been finished for most of the key technology facilities. A small part of the agreed upon equipment had just arrived. The reference material of production technology was not received.[2] Since then China entered a new stage of self-reliance. Given that the reactor construction was far behind that of the Lanzhou gaseous diffusion plant, Beijing decided to take a strategy of “ making concentrated effort to finish the HEU route quickly and seizing the opportunity to develop the plutonium route” (i.e. Tuji yixian (U235 route) and zhuajin erxian (plutonium route). Thus the reactor project was significantly slowed down. After the GDP went into operation in 1964, however, attention returned to completing the Jiuquan reactor.

The reactor reached criticality in October 1966 and then 0.5 percent of design power in December 1966. In 1967 it went into full operation. During the late 1960s and early 1970s, its operation also was affected by the political turmoil of the Cultural Revolution.[3] After 1970, however, the reactor ran without an unscheduled shutdown. During 1974, the reactor was shut down for most of the year for comprehensive tests, repairs and maintenance.[4] The reactor reached its design power by June 1975.[5] Thereafter, the burn-up of the irradiated fuel was increased, and the reactor power was also increased by 10-15 percent through improvements in the cooling system. Its annual days of operation also increased from the original 288 days to 324 days.[6] As a result of these improvements, the plutonium production rate had increased 20% by the end of 1970s (realizing the “1.2 reactor” goal).[7] During the early 1980s, China planned to convert the reactor to the dual mission of producing electric power as well as plutonium.[8] Work started in Sept.1984 and was planned to be completed in 1987, but the modification seems not to have been finished. No electricity substation or transmission lines connected to the site have been seen from recent satellite images. The reactor could be closed in 1984 when the conversion work started.[9] If the reactor were operating, vapor plumes could be detected over its cooling towers by military and commercial imaging satellites.[10]

China began to develop its military reprocessing program in 1956 and initially developed the Soviet reprocessing technology --precipitation of sodium uranyl acetate with assistance from the Soviet Union. [11]The reprocessing plant was selected in 1958 to be located at the Jiuquan complex. After the USSR stopped its aid in 1960, China began to study and re-evaluate the Soviet provided technology. Given that Chinese experts had some concerns about using this technology for the large reprocessing plant, Beijing decided in 1962 to build first a small intermediate pilot plant (also referred as Small Plant, the first project) and the large military reprocessing plant later (also referred as Large Plant, the second project). China finally decided in 1964 to use the PUREX technology for the small and large plants.

The intermediate pilot reprocessing plant started construction in 1965 and began operation in September 1968. The plant had a design capacity of 0.4 tons of spent fuel per day and operated 250 days a year.[12] It had two parallel production lines of the same design capacity in order to have one line operating when another one stopped. It separated the plutonium for the first China's plutonium bomb test on 27 Dec. 1968. [13] The pilot plant stopped plutonium separation when the larger plant began operating in 1970.

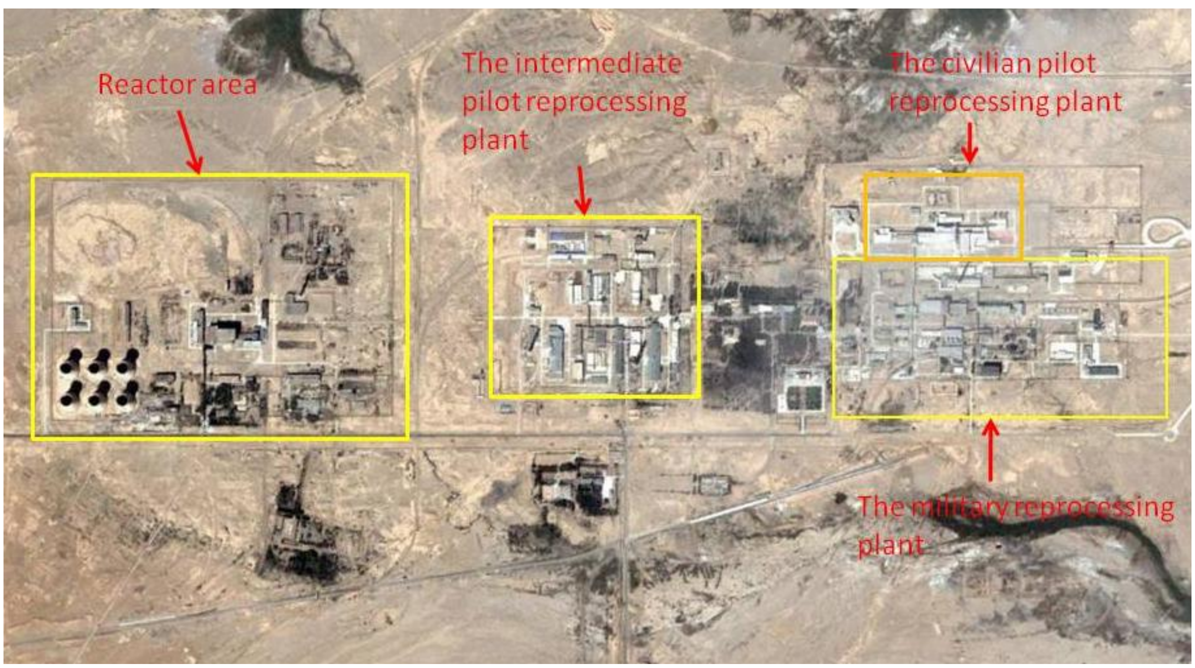

Figure 1: Overview of the Jiuquan nuclear complex. Satellite image from 31 Aug 2007. Credit: DigitalGlobe and Google Earth.

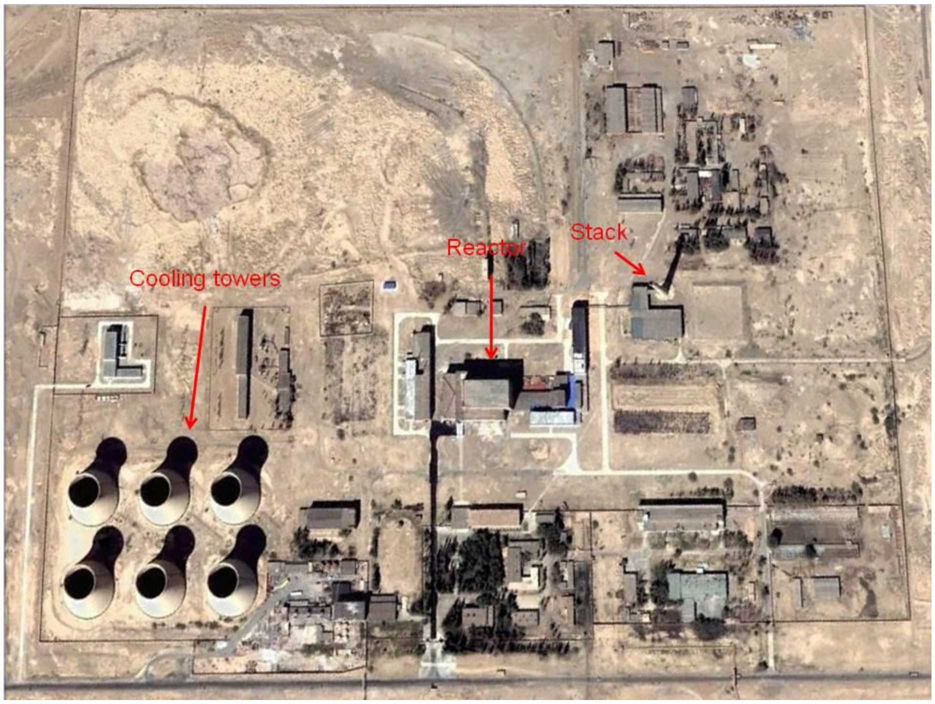

Figure 2: The Jiuquan plutonium production reactor.

Considering the international environment in early 1960, to enhance China's defense, Beijing also urgently needed to construct a large reprocessing plant (the second project). This large plant and the intermediate pilot plant were developed in parallel. In May 1964, Beijing decided to use PUREX technology for the large plant and approved in July 1965 to build the plant within the Jiuquan complex. The large plant started construction in April 1966. Because of the interruption by the Cultural Revolution, the completion of the plant was delayed until early 1970, over one year behind schedule. [14]This plant started operation in April 1970 and stopped plutonium operation in mid-1980s.

Guangyuan Complex

Given Beijing's concern about the increasingly worsening relationship with Soviet Union and US threats to China's nuclear facilities, in the late 1960s, China began to construct a second set of plutonium and HEU production facilities in Southwest China, far from the coast and from the border with the Soviet Union. The sites of these "Third line" facilities were required to be "near mountains, scattered and concealed".

Beijing decided in 1966 to build Fuling plutonium production complex as a "Third Line" project (see following sections). Given the very slow progress of the work in the mined-out caverns and the increasing tensions with Soviet Union, in 1969, Beijing decided to quickly build Guangyuan plutonium production complex (Plant 821) in Sichuan province as a third line project. Like the Jiuquan reactor, the Guangyuan reactor was light-water cooled and graphite moderated. Construction started in 1969, and the reactor achieved criticality in December 1973 and design power by October 1974.[15] It is reported the plutonium production rate of this reactor was increased 30 percent by 1978 (i.e. "1.3 reactor").[16] Thus, combined with Jiuquan's "1.2 reactor," the Jiuquan and Guangyuan reactors became “2.5 reactors” by the end of 1970s.[17] This description reinforces the belief that the Jiuquan and Guangyuan reactors had the similar design power. The Guangyuan reactor site has no cooling towers. It discharged hot water into the nearby Bailongjiang river (see Figure 3).

Based on the new policy of “military shift to civilian,” the plant began to be converted to civilian purposes and became Sichuan Wuzhou Industry Company of CNNC, including aluminum manufacture, starting in 1989 and it is reasonable to assume that it had stopped plutonium production by then. It was reportedly shut down by 1991[18]. The company declared a bankruptcy in 2009[19] and the resident in the complex will move to new living area. Now the complex is being decommissioned, including dealing with the nuclear waste.

The reprocessing plant at the complex started operation in 1976 and reached its design capacity in 1977.[20] The reprocessing plant probably also closed around the end of 1980s.

Figure 3: Overview of the Guangyuan nuclear complex. Satellite image from 31 August 2007. Credit: DigitalGlobe and Google Earth.

Figure 4: The Guangyuan plutonium production reactor.

ESTIMATING CHINA'S MILITARY PLUTONIUM PRODUCTION

Plutonium Production at the Jiuquan Complex

In the absence of information about the power of the reactor, estimates on the plutonium stock would be very uncertain. The plutonium production rate is dependent on the thermal power of the reactor, the capacity factor, and the amount of plutonium produced per megawatt-day of operation. The capacity factor can be estimated by knowing the frequency of the reactor's shutdowns for refueling. This could be observed by satellite imagery through observing the visible plume over the cooling towers at the site. The amount of weapon-grade plutonium produced per megawatt-day of operation is also known reasonably accurately. It is usually just under 1 gram per megawatt-day. Thus the key parameter for an outside estimate of the plutonium production is the power of the operating reactor. One approach to estimating the reactor's power is through the size of its six cooling towers, which can be determined from a satellite image. It is estimated that the reactor power would be between 110 and 640 MWth. [21] But, this is still a big range.

An estimate on the power of Jiuquan reactor can, however, be guided by newly declassified information about China's unfinished 816 nuclear project. The Fuling plutonium production complex (Plant 816) was built in caves under a mountain located in Fuling in Sichuan province. The intention was to build three 80 MWe light-water cooled, graphite-moderated, plutonium-production reactors and associated reprocessing facilities.[22] Beijing decided in 1966 to build this plutonium production complex as a "Third Line" project. It started construction in February 1967.

Given the very slow progress of the project, Beijing made concentrated effort to finish the Guangyuan complex quickly since 1969. With the completion of the Guanyuan complex, Beijing had no urgent needs for finishing the 816 project. In 1984, based on its new judgment of the international security situation, Beijing decided to end the 816 project. By then the project had finished about 85 percent of the required civil engineering, installed over 60 percent of the plant equipment, and completed almost all the auxiliary facilities. None of the reactors were ever loaded with fuel. The plant was converted to a civilian purpose (fertilizer production) and, in 2003, the project was declassified. Part of the site was opened as a domestic tourist attraction in 2010.

Figure 5: Left: Entrance to the Fuling nuclear complex. The sign in Chinese above the tunnel reads, “816 Underground Nuclear Project.” 373. Right: Project 816 reactor control room.[23]

If the 816 project was to build reactors with a total thermal power of 240 MWt, it may be assumed the Jiuquan reactor had a similar design power. In fact, the Guangyuan reactor also had the same design power as the Jiuquan reactor.

Based on the new information, it is estimated that the Jiuquan reactor could have produced a total of about 0.9 tons of weapon-grade plutonium.[24]

Plutonium Production at the Guangyuan Complex

It shout be noted that most previous estimates assumed that the Guangyuan reactor had a power twice that of the Jiuquan reactor and the power of the reactor increased twice as well.[25] Based on the new information, it is assumed here that the Guangyuan reactor has a design power of 250 MWt, i.e. the same design power as that of the Jiuquan reactor, and plutonium production rate increased to 30 percent. Thus it can be estimated that the Guangyuan reactor could have produced a total about 1.1 tons of weapon-grade plutonium. [26]

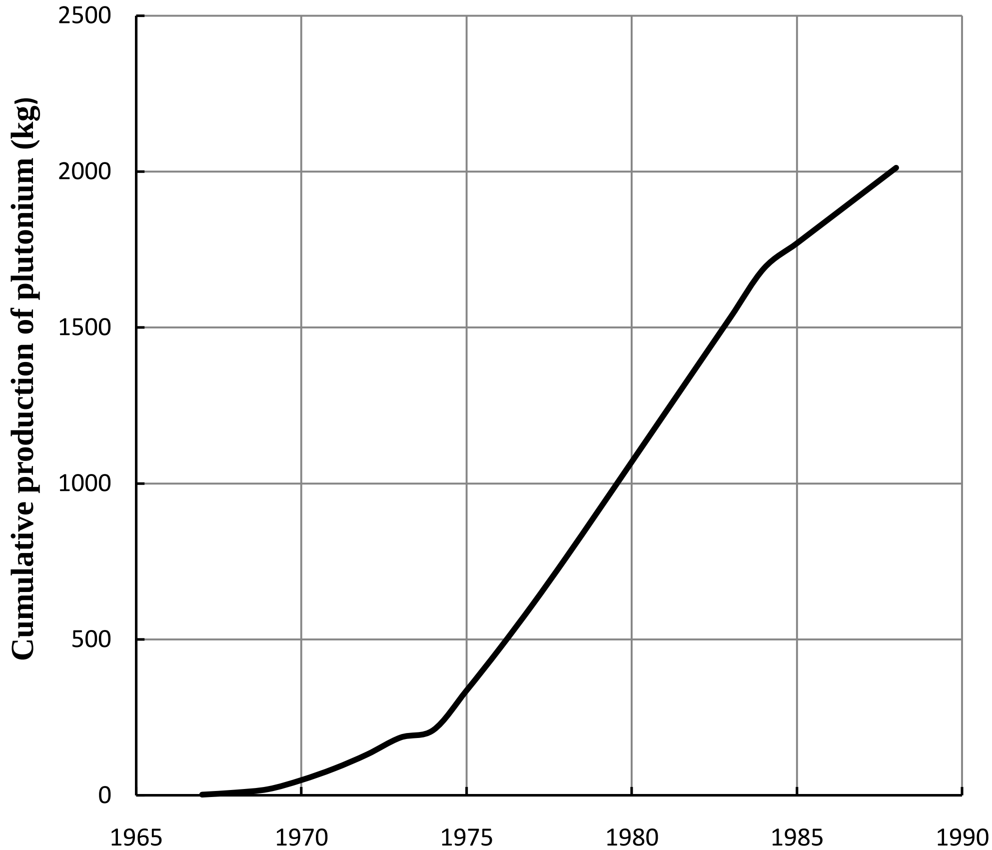

Figure6: Total cumulative production of weapon-grade plutonium by Jiuquan and Guangyuan reactors

Table 2: Estimates of Chinese military plutonium stocks

Plutonium (tons)	Source
3.5 ± 1.5 tons	David Wright and Lisbeth Gronlund, 'Estimating China's Production of Plutonium for Weapons,' *Science and Global Security*, 2003
4.35± 2.25 tons	David Albright and Corey Hinderstein, "Chinese Military Plutonium and Highly Enriched Uranium Inventories," 2005
4 ± 2 tons	David Albright, et al, *Plutonium and Highly Enriched Uranium 1996*
2.25 ± 0.55 tons	1999 DOE estimate quoted in Robert S. Norris and William M. Arkin, "World Plutonium Inventories," *Bulletin of the Atomic Scientists*, Sept/Oct.1999, p. 71
1.8 ± 0.5tons	This author's estimate

Together, China's two plutonium production reactors produced an estimated 2 ± 0.5 tons of weapon-grade plutonium.[27] It is estimated that about 200 kg of plutonium have been consumed in China's nuclear tests.[28] Thus, its current inventory of weapon-grade plutonium would be 1.8± 0.5 tons available for weapons. The new estimates are significantly lower than most previous independent estimates, which range from 2.1 to 6.6 tons of plutonium (see Table 2). This new estimates show that China could have the smallest military stockpile of plutonium available for weapons among the five acknowledge nuclear weapon states.

NOTES AND REFERENCES

[1] More details could be read in Hui Zhang, " China" chapter of *Global Fissile Material Report 2010: Balancing the Books.* Princeton, NJ: Princeton University, 2011. www.fissilematerials.org/ipfm/site_down/gfmr10.pdf; Hui Zhang, "China's HEU and Plutonium Production and Stocks," *Science & Global Security* 19, no. 1 (January-April 2011): 68-89. http://belfercenter.ksg.harvard.edu/files/huizhangSGS2011.pdf.

[2] Li Jue, Lei Rongtian, Li Yi and Li Yingxiang, eds., *China Today: Nuclear Industry,* China Social Science Press, Beijing, 1987 (in Chinese).

[3] W. Lewis and L. Xue, "Chinese Strategic Weapons and the Plutonium Option," *Critical Technologies Newsletter* (US Department of Energy: Washington, DC, April-May 1988), pp12-13.

[4] *China Today: Nuclear Industry, op cit.,* p.211.

[5] *Ibid.*p.212.

[6] *Ibid.*p.213-214.

[7] Zhou Zhi, "Hegongyue 404 Jidi Chuangyue Huiyi," ("Recollections of the pioneering work of Plant 404"), the author is the former vice minister of the former Ministry of Nuclear Industry) 19 Aug. 2007; http://qkzz.net/Announce/Announce.asp?BoardID=17100&ID=10015168

[8] *China Today: Nuclear Industry, op. cit.,* p.91.

[9] See also, Mark Hibbs, "China Said to be Preparing for Decommissioning Defense Plants," *Nuclear Fuel,* 17 May 1999.

[10] Hui Zhang and Frank N. von Hippel, "Using Commercial Imaging Satellites to Detect the Operation of Plutonium-Production Reactors and Gaseous-Diffusion Plants,“ *Science & Global Security,* 2000, Vol. 8, p.219.

[11] *China Today: Nuclear Industry, op. cit.,* p.218.

[12] *China Today, Nuclear Industry, op.cit.,* p.227.

[13] *Ibid,* p.231..

[14] *China Today, Nuclear Industry, op.cit.,* p.232-233.

[15] Zheng Jingdong, retired senior engineer from Plant 821, blog, " Zai Qiangjian 821 Chang de Rizi Li,“ "The days of racing to complete the Plant 821") (in Chinese) September 26,2009 http://blog.163.com/zjd_8213701/blog/static/33582026200982663110991/.

[16] Zheng Jingdong, The days of racing to complete the Plant 821") (in Chinese), op.cit. ; " Liangwei Hedian Gongchen de zhihui Rensheng, Jiangsu Gonggong Kejiwang Wendang: *Ren Wu*," ("The intelligent life of two heroes of nuclear power," document web of Jiangsu public science and technology: *People*) (in Chinese)14 May 2007, http://hi.baidu.com/lovechild/blog/item/f43d1a7a00a1eaec2e73b359.html

[17] "The intelligent life of two heroes of nuclear power," *op.cit.*

[18] See, e.g. Robert Norris, et al., Nuclear Weapons Databook, Vol V: *British, French, and Chinese Nuclear Weapons, op.cit.*p.350.

[19]See, e.g. http://www.cnnc.com.cn/publish/portal0/tab283/info47848.htm
[20] See, e.g. Zheng Jingdong, The days of racing to complete the Plant 821") (in Chinese), *op.cit.*
[21] Hui Zhang, "China's HEU and Plutonium Production and Stocks," *op.cit.* p.80.
[22] See, e.g. News from Chongqing Cable TV, April 26, 2010.(in Chinese) file:///C:/Documents%20and%20Settings/hzhang/Desktop/ChinaFMproduction/816video.html; "Former nuclear plant opening as tourist attraction," China Daily, April 13,2010. http://www.chinadaily.com.cn/china/2010-04/13/content_9719335.htm
[23] Source: <http://news.qq.com/a/20100426/000;http://news.qq.com/a/20100426/000373 3.htm.
[24] Between 1967 and June 1975, it is assumed that the reactor power increased linearly from 0.5% of design power to a full design power, assumed to be 250 MWt. The capacity factor during 1967-69 is assumed to be 40 percent and thereafter about 80% (288 days per year) except for 1974, during which the reactor was mostly down for maintenance. From July 1975 through the end of 1979, the reactor linearly increased its plutonium production rate to 1.2 times of the design rate, as reported for the end of 1979. From 1980 until shutdown in 1984, the plutonium rate stayed at 1.2 times the design rate.
[25] See, e.g. David Wright and Lisbeth Gronlund, "Estimating China's Production of Plutonium for Weapons," Science and Global Security, Volume 11, 2003; David Albright and Corey Hinderstein, Chinese Military Plutonium and Highly Enriched Uranium Inventories, ISIS, 30 June 2005.
[26] From December 1973 to October 1974, it is assumed that the reactor power is increased to 250 MWth with a capacity factor of 40 percent. From November 1974 to December 1978, the plutonium production rate was increased linearly 1.3 times. From 1979 to 1988, the reactor maintained the 1.3 times production rate until 1988.
[27] The uncertainty of ± 25% stems primarily from the uncertainty of the initial design powers of the two reactors.
[28] Hui Zhang, "China's HEU and Plutonium Production and Stocks," *op.cit.* p.81.