Reassessing China's Military Inventory of Highly Enriched Uranium[1]

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ABSTRACT

Understanding the size of China's stocks of fissile materials is important to assess China's willingness to join a fissile material cutoff treaty (FMCT) and a multilateral nuclear disarmament. China has kept information about its stocks of fissile materials and nuclear weapons secret. The paper will assess China's military inventory of highly enriched uranium (HEU) by analyzing newly available information about China's HEU production at its two gaseous diffusion plants. The history of China's HEU production and the status of the production facilities are also discussed. The author concludes that China currently has stockpiles of about 16±4 tons of HEU available for weapons. This new estimated value is at the low end of most previous independent estimates, which range from 17–26 tons of HEU.

HISTORY OF CHINESE HEU PRODUCTION

China's nuclear weapon program was initiated in 1955 as a result of US nuclear threats during the Korean War and the crises over the off-shore islands in the Taiwan Strait. China began to construct its fissile materials production facilities in the late 1950s, initially with assistance from the Soviet Union. After the USSR withdrew its assistance in mid-1960, China completed mainly by self-reliance those fissile material production facilities and started to produce HEU in 1964 and plutonium in 1966.[2]

China has produced highly enriched uranium (HEU) for weapons at two facilities： Lanzhou gaseous diffusion plant (GDP) which began operating in January 1964 and provided HEU for China's first (October 1964) nuclear test; and Heping GDP, a "Third Line" facility that began operating in 1975. While China has not declared officially that it has ended HEU production for weapons, based on new public information, it is believed that the Lanzhou and Heping GDPs stopped production of HEU in 1979 and 1987 respectively (Table 1).

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Table 1: The enrichment plants that produced Chinese HEU

Site	Isotope Separation Technology	Period of HEU Production	Status
Lanzhou (Plant 504), Gansu	Gaseous diffusion	1964-1979	1980-1997 produced LEU for civilian; Closed and being decommissioned; 2001 converted to CEP for LEU.
Heping (Plant 814), Leshan, Jinkouhe, Sichuan	Gaseous diffusion	1975-1987	Based on "military shift to civilian", could be converted to other purpose including fluorine production.

Lanzhou GDP

In 1958, China started the construction of its first GDP on the Yellow River in Lanzhou, Gansu province. The construction was initially supported with Soviet technology and some equipment. The Soviet Union withdrew all its experts in August 1960, however.[3] Given that the construction of its plutonium production reactor was far behind that of the Lanzhou GDP, Beijing decided to make the construction of Lanzhou GDP its "first priority." The GDP began to produce its weapon-grade HEU [4]on 14 January 1964 and was in full operation in July 1964. It provided the HEU for China's first nuclear test on 16 Oct. 1964.

After the GDP began operation, China continued to develop its understanding of the technology. In the early 1970s, China began to increase the Lanzhou GDP's output capacity with further process improvement, reaching its original design capacity in 1975. China further proposed in 1975 a renovation program to enhance the HEU production during the fifth five-year plan (i.e. 1975-1980). The program included 1) increasing the flow rate of gases through the diffusion barrier; 2) increasing the separation efficiency by reforming the separation membrane; and 3) optimizing the configuration of the cascades.[5] By 1979 China had developed and deployed a new type of separation membrane[6] and it was reported its design capacity had been doubled by the end of 1970s, "One plant becomes Two." [7] In 1978 Lanzhou's capacity was reported as 180 000 SWU per year.[8]

In 1980, soon after the adoption of China's policy of "economic reform and opening," initiated in 1978, the Lanzhou GDP stopped HEU production and shifted to the production of LEU for civilian reactors domestically and abroad.[9] In 1981, its LEU entered into the international market.[10] The plant's capacity was further increased during the 1980s by cascade improvements. By 1985, its diffusion technology reached the world-class level.[11] It was reported in 1989 that the Lanzhou GDP was operating at a capacity of approximately 300 000 SWU per year.[12]

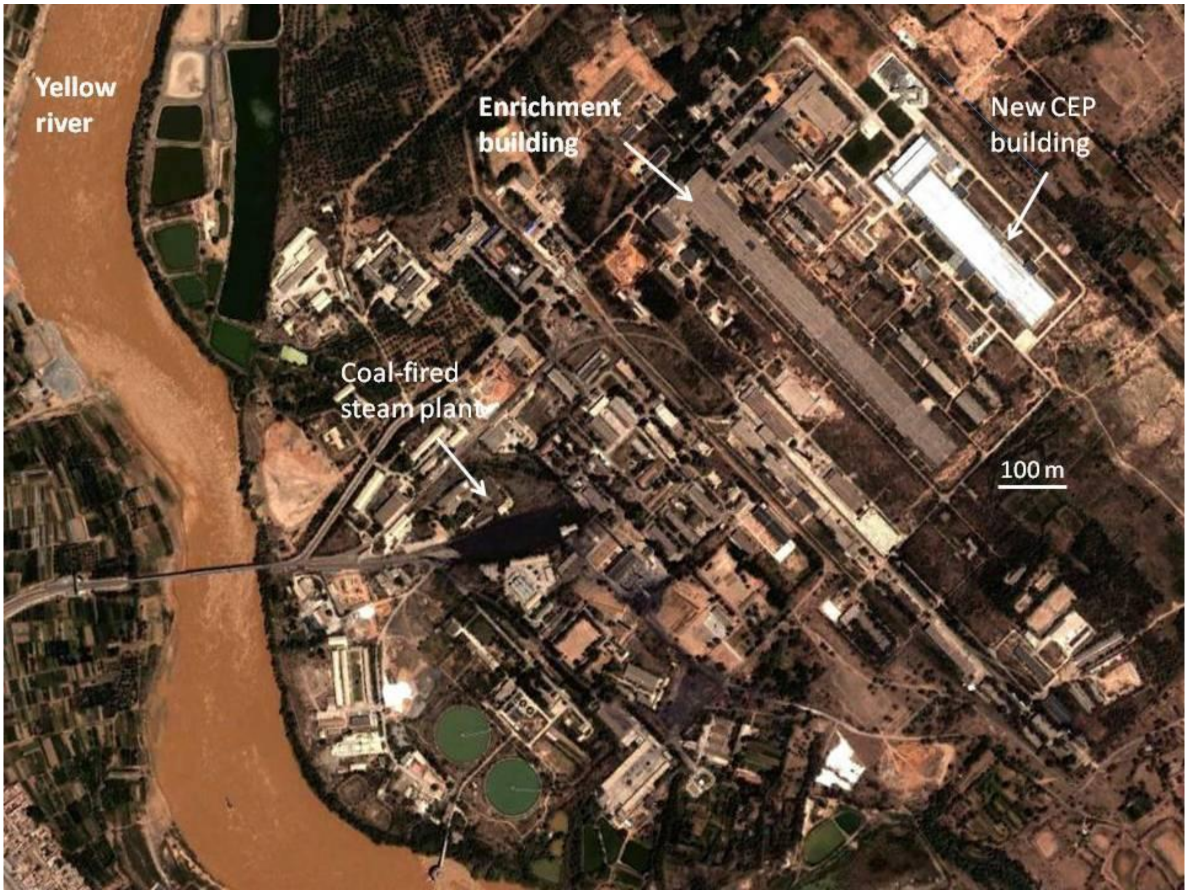

Figure 1: Lanzhou gaseous diffusion plant. Satellite image from 5 July 2004.

Credit: DigitalGlobe and Google Earth.

On 31 May1998 a "technology renovation" project was announced to replace China's gaseous diffusion technology with centrifuge enrichment. In 1999, it was announced that the Lanzhou GDP would soon be decommissioned.[13] A new centrifuge enrichment facility provided by Russia with a capacity of 0.5 million SWU began operation in 2001. This new CEP is producing LEU for civilian purpose.

Heping GDP

Given Beijing's concern about the increasing worsen relationship with Soviet Union and the US threats to target 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, which came into operation in the 1970s. This "Third Line" program was intended to provide China with backup facilities in case the first production facilities were destroyed.

Figure 2: Heping gaseous diffusion plant. Satellite image from 20 Sept. 2008.
Credit: Credit: DigitalGlobe and Google Earth.

China built its second gaseous diffusion plant, the Heping GDP (also referred as Plant 814) under the Third Line Defense Program. The plant is located at the Heping Yizu area of the Jinkouhe County in Sichuan province. The operating experience and expertise from Lanzhou GDP had been applied to the Heping GDP. It is believed to have started operating around 1975. Based on a commercial satellite imagery taken in September 2008(see figure 2), the plant had a slightly larger processing building than that of Lanzhou GDP. No cooling tower has been identified in the imagery. The plant might instead by using a once-through cooling system. It is believed this plant stopped HEU production in 1987.[14] Later, based on China's "military shift to civilian" policy, this plant has converted to other purposes, including fluorine production.

ESTIMATING CHINA'S MILITARY HEU PRODUCTION

HEU Production at the Lanzhou GDP

Without knowing the official data of the operating history and the separative output of the GDP, it is very difficult for an outsider to estimate its HEU production. Estimates based on overflight imagery could have great uncertainties. In July 1963, the US Arms Control and Disarmament Agency (ACDA) made an estimate of the capacity of the Lanzhou GDP based on the area of the roof of the existing processing building, the size of the cooling towers of the GDP, the power of a nearby thermal electric plant believed to be designed to supply the GDP and the capacity of the transformer at the plant's substation.[15] All those facilities had been identified by overflight photography. It was estimated that about 100 MWe could be supplied to the GDP.[16] This amount of electric power was consistent with the calculated capacity of the cooling towers and with the size of the existing building. It was estimated that, after the area of the processing buildings was doubled it probably could produce about 1200-1500kg of weapon grade material per year.[17] In practice, that existing processing building is never been expanded. However, based on that same processing building, the US Defense Intelligence Agency (DIA) estimated in 1972 that the plant was producing about 150-330kg of weapon grade material per year.[18] If the electricity supplied to the GDP can be determined, however, it would be possible to estimate the maximum capacity of the plant. A modern GDP requires about 2500 kW-h of electricity per SWU. It is reported that the Lanzhou GDP achieved world-class efficiency by 1985. If 100 MWe was being supplied to the Lanzhou GDP, it could have had a capacity of 300,000-400,000 SWU/yr.

There is no official information about the separative output of the plant at this early stage. Based on estimate made in 1971, the plant was at the beginning producing about 300 lb of weapon-grade HEU per year (i.e. 136kg).[19] This would be about 22,000 separative work units (SWU) per year at a tails assay of 0.5 per cent. By 1966, the output of the plant had probably doubled because of gradual on-going "process improvements" (not physical expansion) that led to greater efficiency. In 1972, the US Defense Intelligence Agency (DIA) estimated that Lanzhou was producing 150 to 330 kilograms weapons-grade HEU annually.[20] This is equivalent to 24,000-53,000 SWU per year at a tails assay of 0.5 per cent or 30,000-66,000 SWU per year at a tails assay of 0.3 per cent.

Based on the new information, it is estimated that the Lanzhou GDP would have produced about 1.1 million SWU during 1964 to 1979 when it was producing HEU (see figure 4). This would be sufficient to produce about 6 tons of weapon-grade HEU.[21]

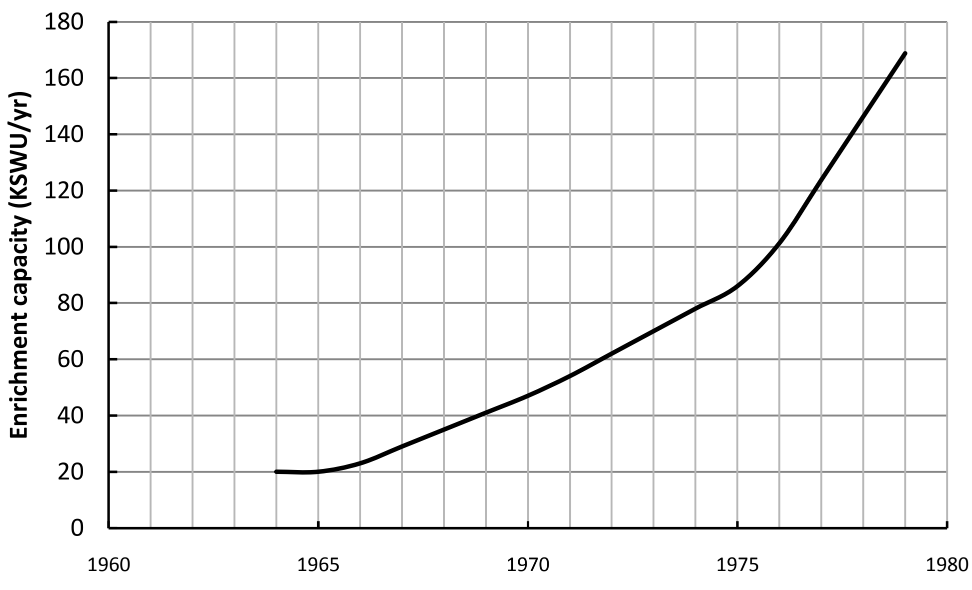

Figure 3: Lanzhou GDP SWU production during the period when it was producing HEU (thousands of SWU/yr).

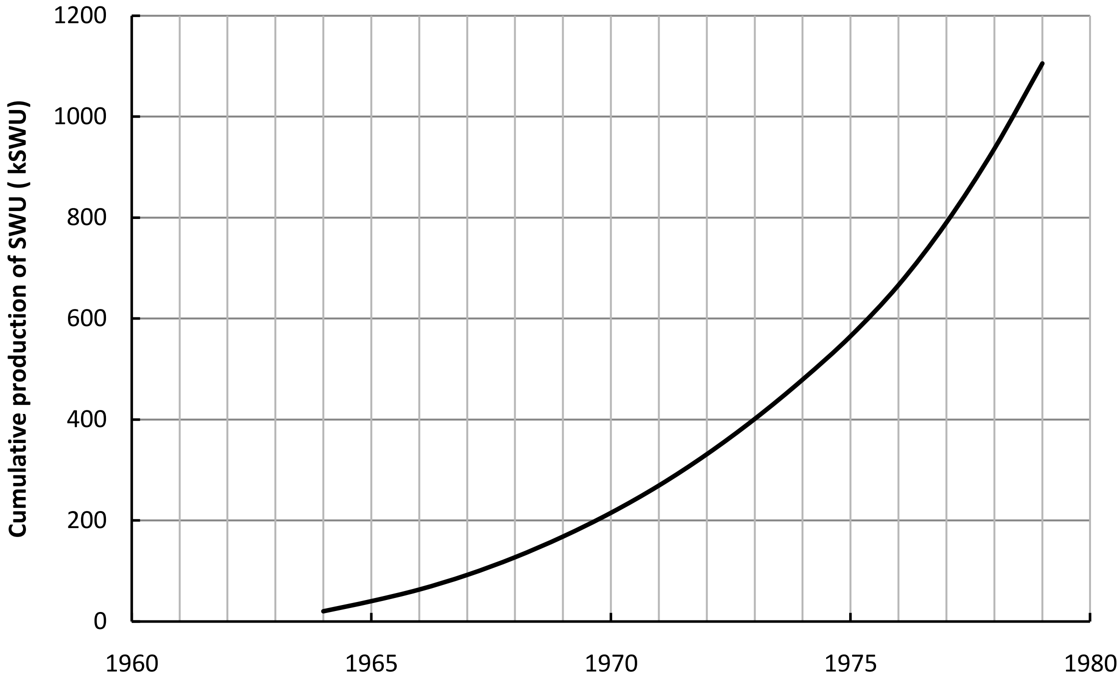

Figure 4: Cumulative production of SWU at Lanzhou GDP (thousands of SWU).

HEU Production at the Heping GDP

In 1972, the US Defense Intelligence Agency estimated that this plant could produce 750-2950 kg of weapon-grade uranium per year.[22] This would correspond to about 120,000 - 470,000 SWU per year at a tails assay of 0.5 per cent, or 150,000-590,000 SWU per year at a tails assay of 0.3 per cent. Since this estimate was made several years before the plant's operation, it is not clear whether it based on the existing building or on the assumption that the building would be expanded as was done mistakenly for the Lanzhou GDP in the 1963 ACDA report.[23] In any case, an estimate based only the roof area of the processing building would have great uncertainty.

Based on new public information, a reasonable guess can be made, however. One major purpose of the Third Line program was to duplicate the first plutonium and HEU production facilities so that China would have a backup system in case the first production system was destroyed. Moreover, when Beijing decided to build the Third Line fissile material production facilities, its first production facilities were just coming into operation and there was no reason for Beijing to build significantly larger facilities just for backup purpose. In fact, the second plutonium production reactor at Guangyuan, which was built as a third line facility, has the same design power as the first one at Jiuquan.[24] Using the reactor case as a guide, we assume that the capacity of the Heping plant was not significantly larger than that of the Lanzhou plant. It is also assumed that the Heping plant, like the Lanzhou plant, roughly doubled its capacity by the end of the 1970s. This is consistent with a report on an unofficial Chinese website that the output of Heping plant before it closed was around 200,000 to 250,000 SWU per year.[25] Based on the new information, it is estimated that the Heping GDP would have produced about 2.7 million SWU during 1975 to 1987 when it was producing HEU (see figure 6). This would be sufficient to produce about 14 tons of weapon-grade HEU.[26]

Together, the Lanzhou and Heping gaseous diffusion plants would have produced roughly 3.8 million SWU, enough to make about 20 tons of weapon-grade HEU.

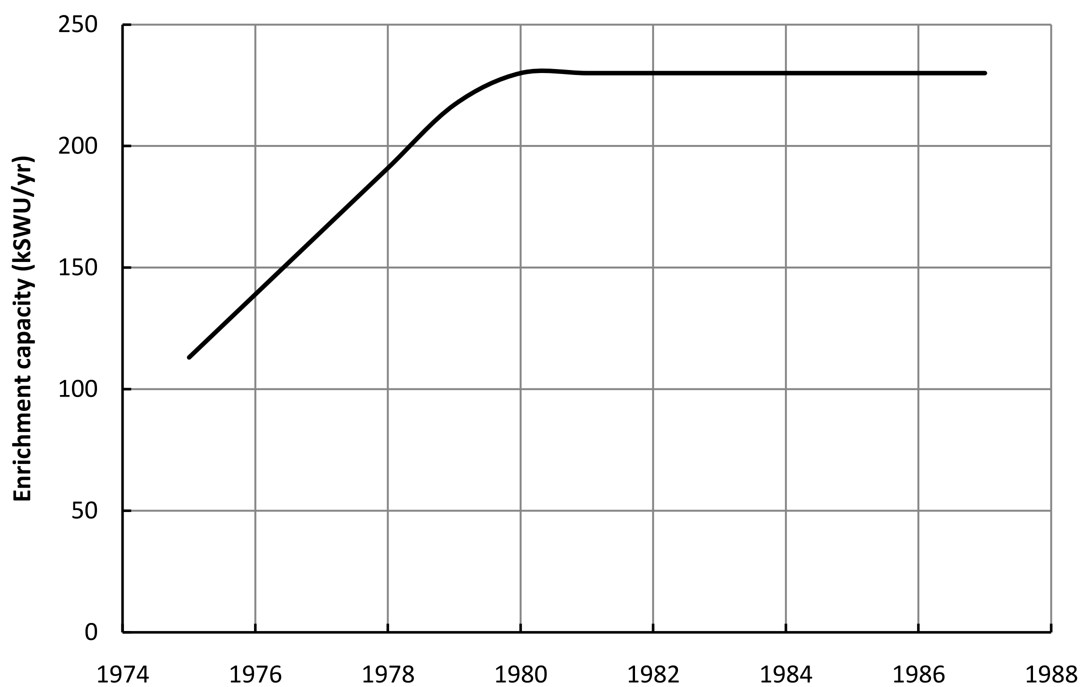

Figure 5: Heping GDP SWU production during the period when it was producing HEU (thousands of SWU/yr).

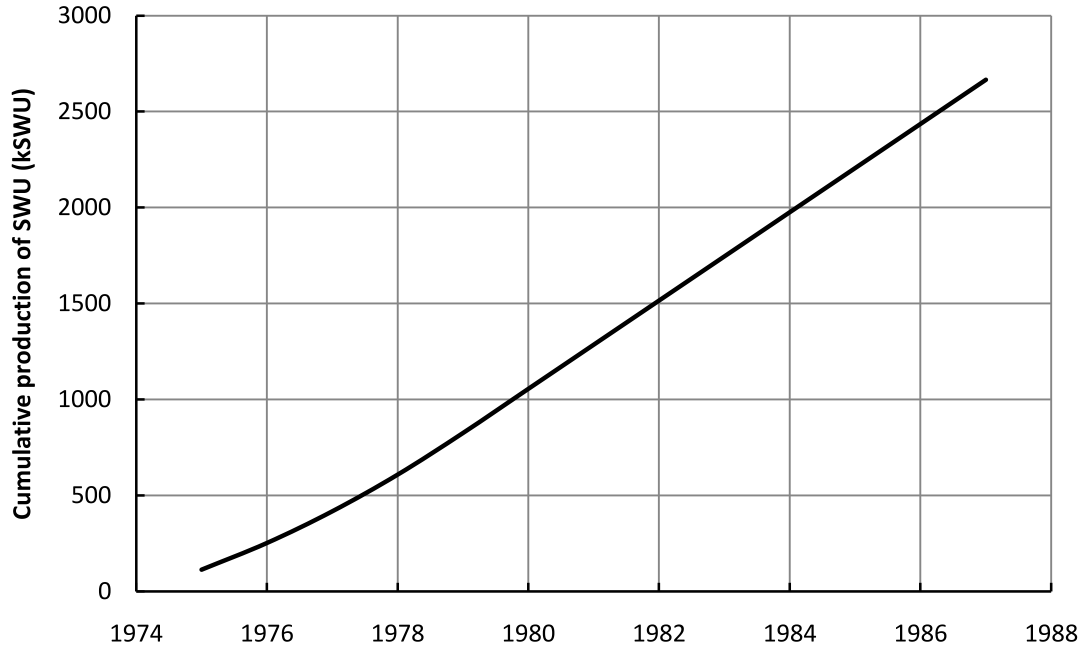

Figure 6: Cumulative production of SWU at Heping GDP (thousands of SWU).

Enrichment Work Used for Non-weapon Purposes

The Lanzhou and Heping GDPs would have supplied about 0.7 million SWU of enriched uranium for several non-weapon purposes as shown in table 2. [27] This corresponds to about 4 tons of weapon-grade uranium (90% U235), assuming a tails assay of 0.3 percent.

Table 2: Enrichment work used for non-weapon purposes

Activity	Millions of SWUs consumed
Research-reactor fuel	0.20
Naval-reactor fuel	0.17
Tritium-production-reactor fuel	0.01
Enriching reprocessed uranium recovered from the plutonium production reactors	0.15
Process losses	0.04
Nuclear tests	0.15
Provided to Pakistan?	0.01
Total	0.73

Military Inventory of HEU

The total SWUs produced by the Lanzhou and Heping GDPs could have produce roughly 20 tons of weapon-grade HEU. Subtracting the SWU consumption for enriching uranium for the non-weapon purposes, China's military inventory of weapon-grade HEU would be about 16 tons. Assuming an uncertainty of 25 percent,[28] China's military inventory of weapon grade HEU would be about 16±4 tons of HEU for weapons. This new estimate is significantly lower than previous estimates, which range from 17–26 tons of HEU.[29]

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] *China Today: Nuclear Industry, op cit.,* p.172.

[4] China's highly enriched uranium is assumed to be 90% uranium-235. *China Today: Nuclear Industry, op cit.,* p.177.

[5] *China Today: Nuclear Industry, op cit.,* p.179-180.

[6] *China Today: Nuclear Industry, op cit.,* p.179..

[7] There is no official information about this but some Chinese public media mention it. See, e.g. Xie Wuzhan, "504 Chang: Gongheguo Nongsuoyou Shiyue de Lingpaozhe," *Gansu Ribao* (in Chinese) (" Plant 504: the leading runner of the cause of China's uranium enrichment", *Gansu Daily*) May31, 2008.

[8] "Mainland China Talking to French, Germans, about Nuclear Power," *Nucleonics Week*, (12 Jan 1978).

[9] It is often assumed this plant stopped HEU production for weapons in 1987 . However, based on some new available information and discussions with some Chinese experts, this author assumes that this plant stopped HEU production around 1980 and switched to LEU production since then. See also, e.g. "Zhongguo Younongsuo ji Ranliao Yuanjian Zhizao (in Chinese)" 28 March 2009. (In English, " China's uranium enrichment and fuel fabrication" http://www.cnnuclear.cn/2009/0328/189.html

[10] *China Today: Nuclear Industry, op cit.,* p.180.

[11] *China Today: Nuclear Industry, op.cit.,* p.180.

[12] Ann MacLachlan, and Mark Hibbs, "China Stops Production of Military Fuel: All SWU Capacity Now for Civil Use," Nuclear Fuel, November 13, 1989.

[13] Hibbs, M., 'China Said To Be Preparing For Decommissioning Defense Plants,' *Nuclear Fuel,* (17 May 1999), p. 11

[14] David Albright and Corey Hinderstein, "Chinese Military Plutonium and Highly Enriched Uranium Inventories," (Institute for Science and Security, 30 June 2005).

[15] "Summary and Appraisal of Latest Evidence on Chinese Communist Advanced Weapon Capabilities," US Arms Control and Disarmament Agency, ACDA-957, July 10,1963.

[16] *Ibid.*

[17] *Ibid.*

[18] US Defense Intelligence Agency, *People's Republic of China Nuclear Weapons Employment Policy and Strategy,* Report no. TCS-654775-72, (DIA: Washington, DC, March 1972). .

[19] Charles Murphy, "Mainland China's Evolving Nuclear Deterrence," *Bulletin of the Atomic Scientists*, January 1972, pp. 28-35.
[20] US Defense Intelligence Agency, *'People's Republic of China Nuclear Weapons Employment Policy and Strategy,' op.cit.*
[21] It is assumed that: from 1964 to 1965, about 20,000 SWU/yr at a tails assay of 0.5 per cent; from 1966 to 1970, a linear increase from 20,000 to 50,000 SWU/yr at a tails assay of 0.5 per cent; from 1971 to 1975 a linear increase from 50,000 to 90,000 SWU/yr at a tails assay of 0.3 per cent. It is assumed that the plant reached its design capacity in 1975, and that the output of the plant doubled its design capacity by the end of 1970s; from 1976 to 1979 a linear increase from 90,000 to 180,000 SWU per year at a tails assay of 0.3 per cent; and HEU production stopped in 1980, and the plant produced LEU from 1980 until 1997 when it stopped operation. See also, Hui Zhang, "China's HEU and Plutonium Production and Stocks," *op.cit*.
[22] US Defense Intelligence Agency, *People's Republic of China Nuclear Weapons Employment Policy and Strategy*, *op.cit.*
[23] *ACDA-957, op.cit.*
[24] Hui Zhang, "China's HEU and Plutonium Production and Stocks," *op.cit*. p.80.
[25] See, e.g. e.g. "Zhongguo Younongsuo ji Ranliao Yuanjian Zhizao (in Chinese)," *op.cit.*
[26] It is assumed that: from 1975 to 1979, a linear increase from 100,000 to 230,000 SWU per year. This is based on our estimate above that the Lanzhou GDP reached its design capacity of 90,000 SWU per year in 1975 and that Heping plant had a similar design capacity; from 1980 to 1987 the plant maintained the same level of 230,000 SWU per year at a tails assay of 0.3 per cent; and the plant ended HEU production in 1987. See also, Hui Zhang, "China's HEU and Plutonium Production and Stocks," *op.cit.*
[27] Hui Zhang, "China's HEU and Plutonium Production and Stocks," *op.cit*. p.72-76.
[28] One contribution to the ±25% uncertainty assumed for the estimated HEU production is due to the range of possible tails. For natural uranium feed producing 90% HEU, at a given separative work capacity, a tails assay of 0.5 % would produce about 25% more HEU than a tails assay of 0.3%. There is no official information about tails assays in China's gaseous diffusion enrichment program.
[29] This is significantly less than the 21.5 ±4.5 tons of HEU estimated in "Chinese Military Plutonium and Highly Enriched Uranium Inventories," *op. cit.*