7-22-2026

CMSI Translations #33: A Super-AIP Submarine Under the Bayi Flag

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TRANSLATIONS

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A Super-AIP Submarine Under the Bayi Flag

A Discussion on the Requirements and Technological Profile for the Chinese Navy's "Small-Reactor" Nuclear Submarines[1]

By Ming Di[2]

Foreign media sources believe that, in recent years, the Chinese Navy has shown keen interest in “small-reactor” nuclear submarines—vessels utilizing compact nuclear reactors as air-independent propulsion (AIP) systems—and do not rule out the possibility that engineering trials have already been conducted. So, what exactly is the Chinese Navy’s requirement for such submarines, and through what technical pathways might this requirement be realized?

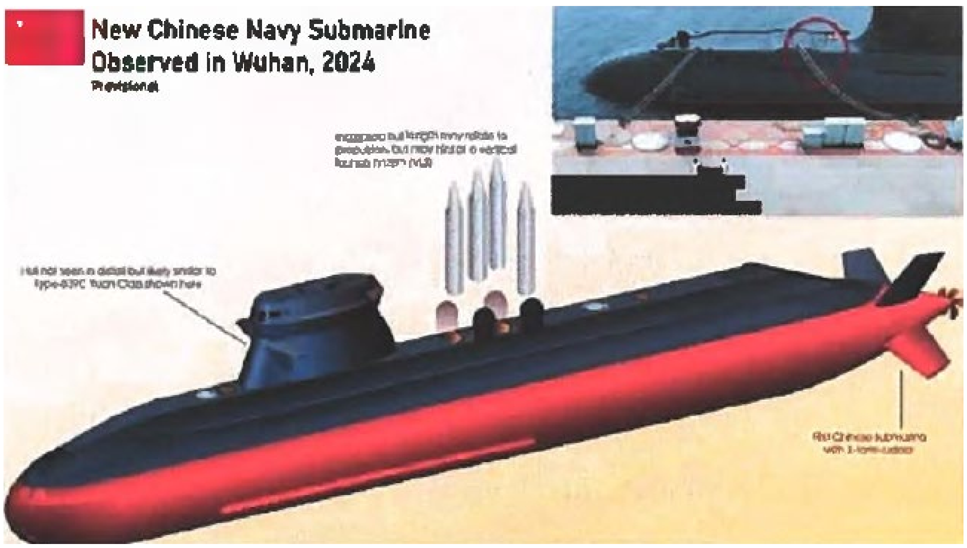
Historical Context

Nuclear submarines utilizing small reactors as their AIP systems—often referred to as “small reactor” nuclear submarines—effectively function as a form of “super-AIP” submarine. Their combat effectiveness falls somewhere between that of conventional AIP submarines and nuclear-powered submarines. Moreover, their construction cycle is shorter than that of traditional, large-displacement nuclear attack submarines, and the cost of procuring them is also significantly lower. At the same time, because the tonnage of “small-reactor” nuclear submarines is comparable to that of conventionally-powered submarines (or, at least, it does not significantly exceed theirs) they offer the advantage of high maneuverability while operating in the shallow waters near the coast. Consequently, the concept attracted widespread attention as soon as it was

[1] 鸣镝 [Ming Di], 八一军旗下的超级 AIP 潜艇-----中国海军的“小堆”核潜艇需求与技术面貌讨论 [A Super-AIP Submarine Under the Bayi Flag—A Discussion on the Requirements and Technological Profile for the Chinese Navy's "Small-Reactor" Nuclear Submarines], 舰载武器 [*Shipborne Weapons*], no. 3B (March 2025), pp. 17-23.
[2] **Translator’s Note:** “Ming Di” is a pseudonym.

proposed. However, the vast majority of countries are constrained by technical and political factors, leaving them unable to seriously pursue development in this arena of underwater weaponry. China, on the other hand, is clearly different. When it comes to developing nuclear submarines powered by small reactors, China is not constrained by political factors, and, furthermore, it possesses the requisite technical foundation and resources. More importantly, given China's complex national defense environment, the Chinese Navy has a strong need for such nuclear submarines.

Enhancing the underwater combat capabilities of the Chinese Navy is a call of the times. To mark the 70th anniversary of the People's Navy Submarine Force, the National Defense and Military Channel of China Media Group visited a submarine unit subordinate to the Northern Theater Command Navy [cont'd below]



There is much heated discussion in foreign media about whether China's new conventional submarine is actually a nuclear-powered vessel utilizing a "small reactor." While this is, of course, impossible to confirm, [the situation] certainly leaves plenty of room for speculation. (Image source: US Naval Institute News)

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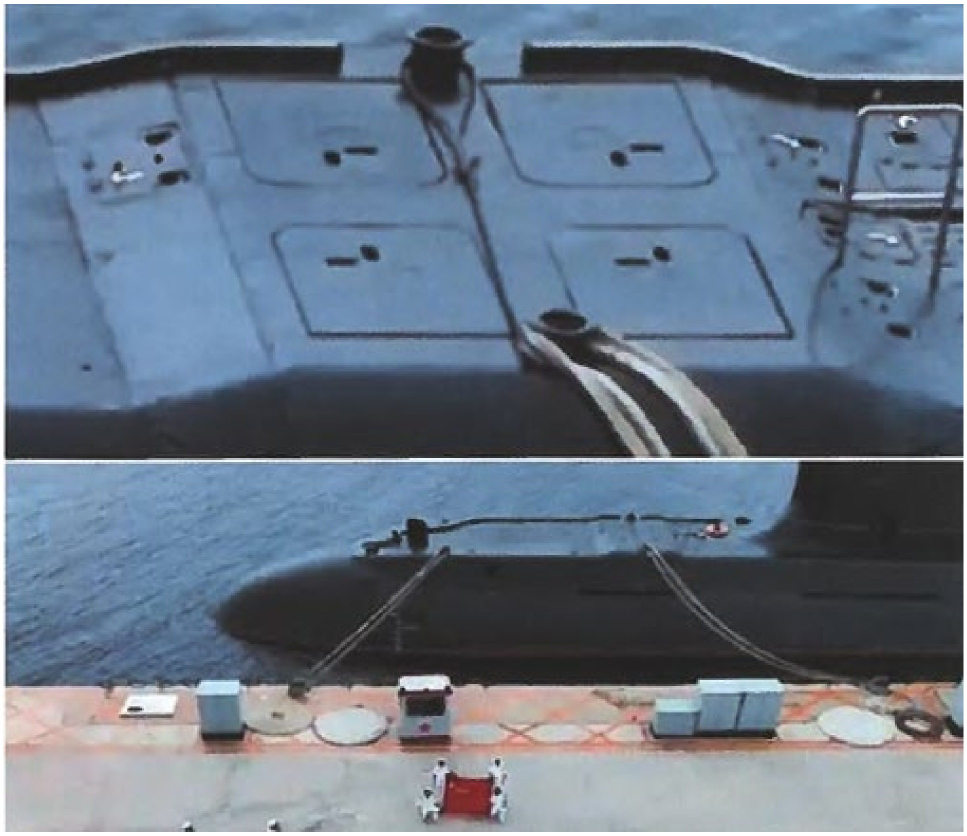

The vertical launch system employed by the Type 032 test submarine is considered one of the factors contributing to the increased length of China's new conventional submarines, though this is not the primary focus of attention (see top and bottom images)

Nuclear propulsion is one option among the various AIP systems employing different technical approaches. Furthermore, in terms of overall performance, nuclear propulsion surpasses non-nuclear AIP systems such as Stirling engines and fuel cells.

Foreign media reports indicate that the Chinese Navy's new conventional submarine not only features X-shaped stern rudders but also has a noticeably elongated hull section (see top and bottom images)

to explore the birthplace of China's naval submarine operations. In this report, a commanding officer from the relevant unit revealed a crucial piece of information to the public: the equipment development of the Chinese Navy's submarine force has shifted from an emphasis on "prioritizing conventional capabilities" to a strategy of "equipping both nuclear and conventional capabilities, with a primary focus on nuclear."[3] This not only implies an expansion of the nuclear submarine force and the enhancement of traditional conventional submarines through the application of nuclear propulsion technology, but also suggests that these actions are likely already underway.

For example, in late July 2024, U.S. media commentator and naval expert Tom Shugart posted a satellite image on social media. The image, captured by U.S. company Planet Labs on April 26, 2024, shows a newly launched conventional submarine docked at a Chinese conventional submarine manufacturing facility. Not far ahead of this submarine on the water's surface sat a "Hangor"-class conventional submarine, clearly built by China for the Pakistan Navy. A few days later, H.I. Sutton, a prominent U.S. military analyst, published an article in *Naval News* suggesting that this new Chinese submarine could be the most powerful conventional submarine in the world and noted that it might be equipped with hypersonic anti-ship missiles, which would pose a significant threat to the U.S. Navy. Compared to the "Hangor" class and the well-known

[3] **Translator's Note:** The original Chinese is 核常兼备，以核为主.

Type 039 series, this new submarine exhibits three distinct differences. First, the stern rudder configuration has shifted from the cruciform layout traditionally used on Chinese conventional submarines to a novel X-shaped arrangement. Second, the sail appears identical to that of the previously revealed Type 039C submarine. And third, the section of the hull aft of the sail is noticeably longer than that of the “Hangor” class. Foreign media estimates the new submarine’s total length at 83-85 meters, whereas the Type 039A measures approximately 77 meters in length.

It is generally believed that lengthening the hull of a conventional submarine serves two purposes: the first is installing vertical launch modules; the second is accommodating an AIP system. Judging by the recent modifications to the Chinese Navy’s renowned Type 032 test submarine, the installation of missile vertical launch tubes is a possibility—as these tubes are substantial in size. However, there is a strong hope that the extended section also incorporates a dedicated AIP compartment. AIP technology is nothing new to the Chinese Navy, and China validated various AIP technical approaches quite early on. Mid-to-late production batches of the Type 039 conventional submarine series were essentially equipped with AIP, and even the exported “Hangor”-class vessels are, in fact, AIP-capable. However, China’s new conventional submarine featuring X-shaped stern rudders is significantly longer than the “Hangor”-class vessels. It is difficult to attribute this solely to the addition of a vertical missile launch section. In that case, is this an atypical AIP submarine? To put it more bluntly, could this be a submarine powered by a “small reactor”? Clearly, this is what people are hoping for.

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Behind the shift in development thinking of “equipping both nuclear and conventional capabilities, with a primary focus on nuclear” lies a change in the maritime threats China faces. Factors such as the potential intervention of external forces in a Taiwan conflict, the risk of maritime supply lines being severed, and the increased frequency of nuclear strikes or deterrence maneuvers by potential adversaries have compelled the Chinese Navy to adjust its countermeasures accordingly.

The Demand for “Small-Reactor” Nuclear Submarines

Currently, more than 40 countries possess submarines, but the majority operate conventionally-powered vessels that lack the technical capabilities of nuclear-powered attack submarines. Currently, only China, Russia, the United States, the United Kingdom, and France possess nuclear-powered attack submarines. Although India and Brazil have plans to build such submarines, they will not achieve substantial operational capacity in the foreseeable future.

A significant portion of the Chinese Navy's conventional submarines have been equipped with AIP systems; however, non-nuclear AIP submarines still fall short in terms of overall combat performance.

In response to the rise of the Chinese Navy, the U.S. Navy has adjusted its nuclear submarine deployment structure, stationing 60 percent of its fleet in the Asia-Pacific region with the aim of gaining an advantage over China's undersea capabilities. Meanwhile, as part of the first pillar of the so-called "AUKUS" alliance, Australia is also set to acquire nuclear-powered attack submarines from the United States and the United Kingdom. In terms of numbers alone, the balance of undersea power between the West and China in the Asia-Pacific region has already become skewed.

It has been suggested that China could adopt a two-pronged approach to address deficiencies in its underwater capabilities. One strategy is to increase the production capacity for nuclear-powered attack submarines, aiming to bolster the "tip of the spear" of its underwater forces with larger, more advanced vessels. The other strategy involves enhancing overall combat capabilities through the use of "super-AIP" submarines while the production of the next-generation nuclear attack submarines ramps up. Once the new generation of attack submarines has ramped up production, these "super-AIP" submarines will also shoulder the heavy responsibility of further establishing a numerical advantage in underwater combat capabilities. What exactly are these "super-AIP" submarines? Put plainly, this term often refers to nuclear submarines—often called "small-reactor" submarines—that utilize compact nuclear reactors as their AIP systems.

"Small-reactor" nuclear submarines are of immense importance to the Chinese Navy. China possesses vast maritime territory and an extensive exclusive economic zone, a reality that necessitates the PLA Navy maintaining an underwater force that is substantial in both size and quality.

China became a nuclear submarine-operating nation as early as the 1970s. Generally speaking, other such nations have gradually phased out conventional submarines in favor of an all-nuclear fleet. Such is the case for the United States and France. The UK, too, shifted to an all-nuclear fleet after briefly operating four "Upholder"-class submarines. The Soviet Union (Russia) is the sole exception, owing to its unique geographical conditions. The Black Sea and the Baltic Sea are essentially landlocked; not only are they narrow and shallow, but access to the open ocean is constrained by narrow straits and international treaties, making them unsuitable for the entry and exit of nuclear-powered submarines and appropriate only for the deployment of conventionally-powered submarines. Furthermore, political considerations regarding military aid also played a role in the Soviet Union's (Russia's) development of conventionally-powered submarines. Soviet (Russian) nuclear submarines are deployed exclusively within the Northern Fleet and the Pacific Fleet, a fact that is very telling.

China possesses only coastal areas and no inland seas. A fully nuclear-powered fleet is, in fact, precisely what is needed to break through the First Island Chain. This implies that the Chinese Navy's underwater combat capabilities ought to be entirely nuclear-powered. However, due to various constraints, nuclear-powered attack submarines were, for a long time, an extremely expensive luxury for the Chinese Navy. Consequently, the Chinese Navy has been compelled to adopt an underwater combat force structure composed of a large number of conventional submarines supplemented by a small number of nuclear-powered attack submarines. This is, of course, far from ideal, and the Chinese Navy has long sought to address the situation, working not only to improve the technology and production rates of its nuclear-powered attack submarines but also to equip its conventional submarines with AIP systems.

In actual combat operations, diesel-electric conventional submarines have revealed shortcomings such as low underwater cruising speeds and the need to surface frequently for battery charging, making them highly vulnerable to detection and attack. Consequently, they are typically assigned missions involving surveillance, maritime blockade, and area patrols—tasks that often entail an element of ambush.

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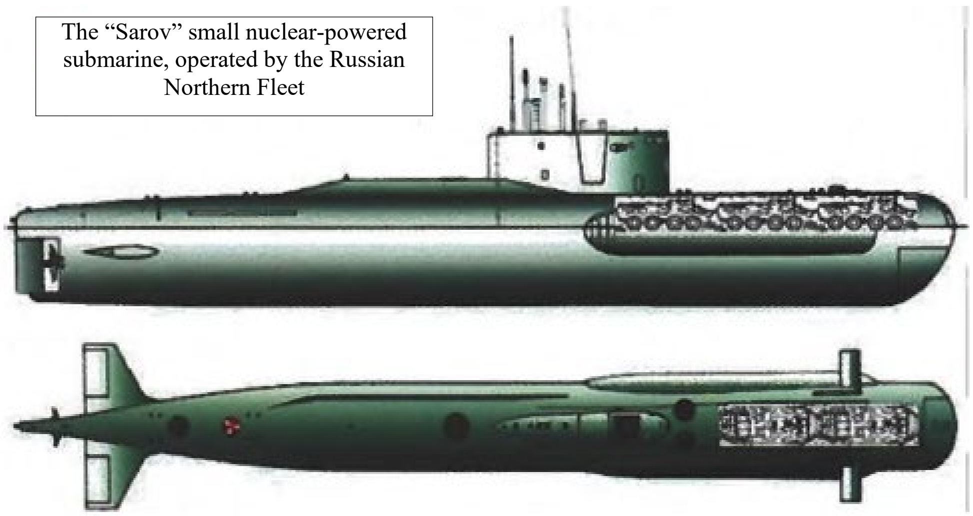
Foreign media has observed that the sail of China's new conventional submarine resembles that of the latest improved Type 039 variant, yet there are significant differences in the stern rudder and the submarine's length (see top and bottom images).

To further expand the operational scope of conventional submarines and enhance their combat effectiveness, it is essential to equip them with AIP systems.

Currently, most active-duty conventional submarines worldwide have an underwater range of only 15-30 nautical miles when traveling at maximum speed using electric motors. Even at low speeds, their range is limited to 400-500 nautical miles. In contrast, conventional submarines equipped with AIP systems not only possess significantly extended underwater endurance but also the capability for impressive high-speed underwater dashes over short durations. For instance, Germany's Type 212 AIP submarine boasts an operational range of up to 1,683 nautical miles, while the newer Type 214 boasts an even greater range and is capable of remaining submerged for 15-20 days. These factors grant commanders greater flexibility in deploying submarine forces, allowing them to better leverage the submarines' offensive capabilities. In the context of current anti-submarine blockade zones spanning 50 to 300 nautical miles, the continuous underwater endurance of AIP-equipped submarines allows them to penetrate large enemy blockade zones and return without surfacing to recharge, thereby vastly enhancing their ability to break through enemy lines while submerged. Furthermore, AIP submarines can execute covert, long-range mine-laying blockade missions—a feat difficult for standard conventional submarines to achieve. Furthermore, in operational use, conventional submarines face issues such as limited underwater endurance, restricted deep-penetration capabilities, and a tendency to be detected when surfacing periodically to recharge. Their combat capabilities vary, which creates numerous constraints regarding the deployment, [cont'd below]

The "Sarov" small nuclear-powered submarine, operated by the Russian Northern Fleet



optimal mix, and enhancement of the overall combat effectiveness of submarine forces in joint campaigns or cooperative combat operations. However, the application of AIP technology to conventional submarines has significantly enhanced their continuous underwater endurance and overall combat effectiveness while also increasing the flexibility of underwater force deployment.

A small-scale nuclear-powered AIP system can be viewed as a compromise between nuclear submarines and conventional submarines. Compared to traditional non-nuclear AIP submarines, submarines equipped with AIP systems powered by small nuclear reactors offer advantages such as greater underwater endurance, high system efficiency, a long service life, and superior maneuverability, while eliminating reliance on hydrogen or oxygen fuels.

For submarines equipped with either heat engine-based or fuel cell-based AIP systems, underwater endurance depends primarily on the amount of fuel and oxidizer carried. Among these factors, the oxidizer is the primary constraint for both types of AIP systems. Given a fixed quantity of liquid oxygen, the underwater endurance of a submarine equipped with a fuel cell AIP system is approximately double that of one equipped with a Stirling engine AIP system, and a submarine equipped with a fuel cell AIP system has approximately twice the endurance of one equipped with a Stirling engine AIP system for a given quantity of oxygen carried. However, this endurance remains limited. In contrast, submarines equipped with small-scale nuclear-powered AIP systems possess, for a period of time, virtually unlimited underwater endurance.

In terms of underwater safety alone, submarines equipped with small-scale nuclear AIP systems exhibit the lowest exposure rate, followed by those with fuel-cell AIP systems, while those with Stirling-engine AIP systems have the highest exposure rate. Compared to conventional nuclear submarines, "small-reactor" AIP submarines prioritize simpler thermodynamic architectures, superior inherent safety, less demanding support requirements, easier and more convenient operation, shorter construction periods, and lower total lifespan costs.

In fact, the design dimensions of small nuclear power reactors are compatible with the principal dimensions of most current conventional submarines; they can readily fit within the seven-meter-diameter pressure hulls of 2,000- to 3,000-ton class conventional submarines. Consequently, these small nuclear powered AIP systems can be utilized both for newly constructed submarines and for the retrofitting of existing submarines. Small nuclear-powered AIP systems are well suited for platforms with smaller displacements; by installing such a system without significantly altering the submarine's overall propulsion architecture, the vessel can achieve underwater propulsion without relying on an external air supply.

Furthermore, compared to traditional nuclear reactors, the reactor in a small-scale nuclear-powered AIP system features a simple structure and low cost. At the same time, compared to conventional reactors, the reactor within the small-scale nuclear AIP system operates at lower pressures and temperatures, thereby simplifying the operational process. Furthermore, operators and maintenance personnel can assume their duties after undergoing standard technical training, thereby reducing training costs.

In short, some countries can acquire "small-reactor" AIP submarines by integrating new technologies into existing conventional submarines, [cont'd below]

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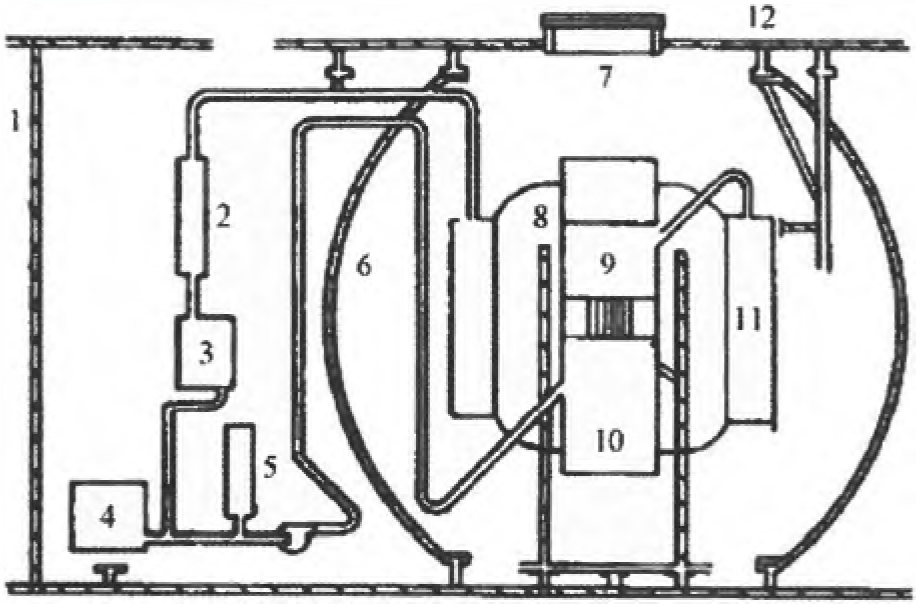
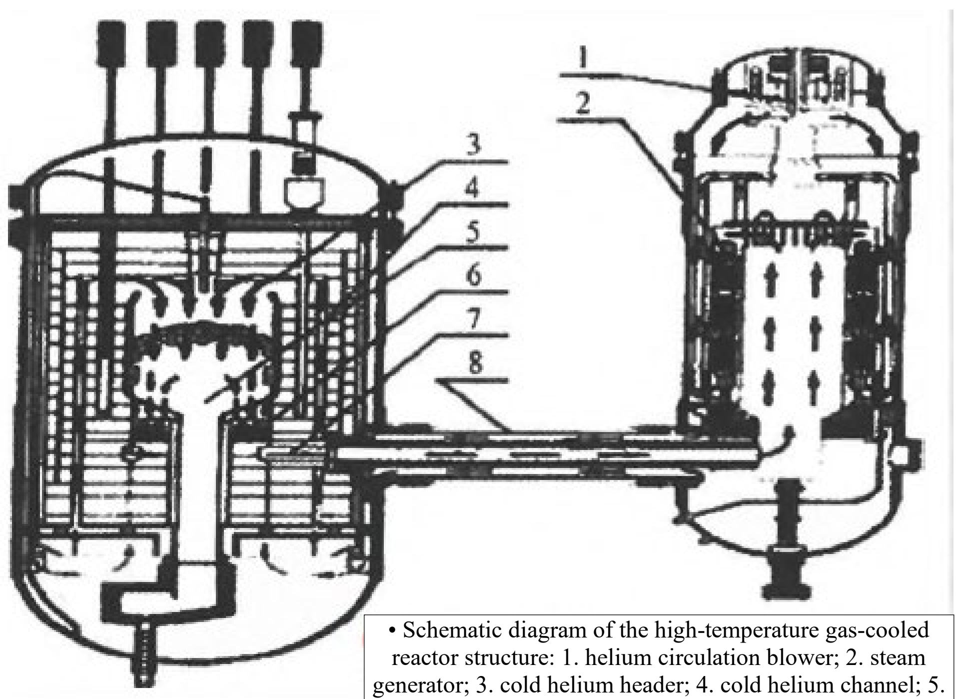
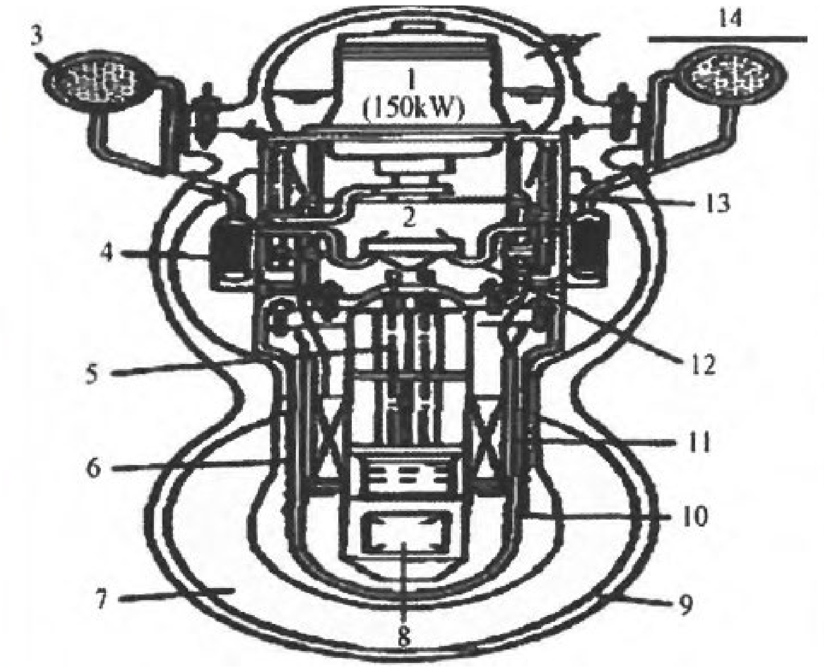


Schematic diagram of the AMPS-1 reactor unit structure: 1. power compartment; 2. preheater; 3. steam generator; 4. water treatment unit; 5. pressurizer; 6. coolant storage tank; 7. inlet/outlet; 8. shielding; 9. reactor core; 10. reactor vessel; 11. attenuator; 12. hull profile



• Schematic diagram of the high-temperature gas-cooled reactor structure: 1. helium circulation blower; 2. steam generator; 3. cold helium header; 4. cold helium channel; 5. reactor core; 6. hot helium channel; 7. hot helium header; 8. hot gas duct



Schematic diagram of an integrated, compact, low-temperature pressurized water reactor: 1. generator; 2. turbine; 3. condenser; 4. evaporator; 5. control rod drive mechanism; 6. thermal insulation; 7. radiation shielding; 8. reactor core; 9. pressure vessel; 10. reactor vessel; 11. steam generator; 12. turbine outlet; 13. feedwater pump; 14. seawater

thereby significantly enhancing submarine performance and rapidly maximizing underwater combat capabilities within a relatively short timeframe.

Technical Profile

Given that "small-reactor" AIP submarines (or "small-reactor" nuclear-powered submarines) can rapidly enhance overall underwater combat capabilities, what exactly will China's "small-reactor" AIP submarines look like? This is undoubtedly a subject of great interest.

The concept of an AIP submarine utilizing a "small-scale reactor" has, in fact, already been realized in engineering practice. In 1985, the Soviet Union installed a VAU-6 small-scale nuclear reactor on a Project 633 diesel-electric submarine (hull number B-68) in an attempt to extend the vessel's underwater endurance. Despite significant cuts to military spending following the Cold War, Russia built the "Sarov"—a small-displacement submarine equipped with a VAU-6 compact nuclear reactor—for the Northern Fleet. The vessel was originally designed in the 1980s, but its construction was repeatedly delayed due to the dissolution of the Soviet Union, and it was not actually delivered to the Russian Navy until more than a decade later.

Russian sources indicate that the "Sarov" submarine was developed based on a water jet-propelled "Kilo"-class submarine. Designated as Project 20120, it measures 98 meters in length and has a draft of seven meters. Compared to the "Kilo"-class submarine, the "Sarov" differs significantly in appearance and incorporates a small nuclear propulsion module (resulting in an underwater displacement of 3,950 tons, whereas the water jet-propelled PL877B submarine has an underwater displacement of 3,050 tons). The VAU-6 small-scale reactor installed on the vessel is not used for direct propulsion, but rather for charging the batteries. It provides a continuous power supply to the submarine's batteries, thereby extending its underwater endurance. In addition, the “Sarov” boasts excellent acoustic stealth capabilities, making it an outstanding platform for intelligence gathering. This submarine has an endurance of 45 days, a crew of 52, and an operating depth of 300 meters. Of course, the “Sarov” is, on the whole, a technologically outdated experimental submarine; it serves merely to demonstrate the feasibility of deriving and developing “small-reactor” AIP submarines based on existing, mature, non-nuclear AIP submarine designs.

In this regard, the Type 039C serves as an excellent platform for the Chinese Navy to develop submarines featuring “small-reactor” AIP systems. A brand-new variant can be created by inserting a dedicated module containing a small nuclear reactor. A small nuclear-powered AIP system with an output of 100kW can be applied to submarines with a displacement of 1,000 tons, while systems with outputs of 400kW and 1MW can be used on submarines with a displacement of 2,000 tons or more.

Reactor designs for “small-reactor” AIP systems impose extremely high requirements, necessitating inherent safety, a compact structure, a high degree of automation, long core life, and good economic performance.

Currently, reactor types suitable for “small-reactor” AIP systems in conventional submarines include pulsed reactors, high-temperature gas-cooled reactors, and small integral pressurized water reactors. The AMPS-1000, a 1,000kW small-scale pulsed nuclear power system developed by Canada’s ESC Group, is suitable for use in 2,000-ton class conventional submarines. This system utilizes uranium-zirconium hydride [cont’d below]

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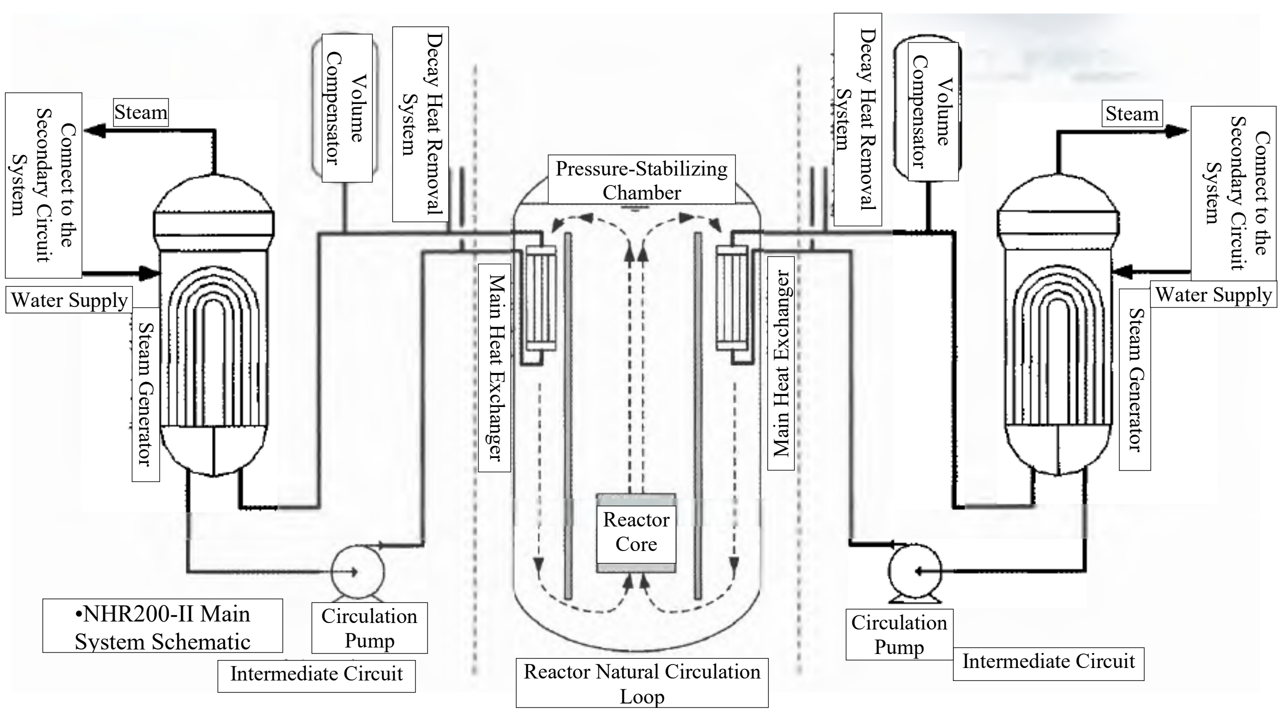

•NHR200-II Main System Schematic

alloy fuel elements and integrates with a low-temperature, low-pressure Freon conversion system. It is characterized by good safety, excellent fission-product retention, a compact structure, a long service life, and mature technology. Additionally, it features a large negative temperature coefficient, capable of reducing power to the watt level within seconds, making it particularly well-suited for the widely varying operating conditions of submarines.

The AMPS-1000 nuclear power system was developed based on the earlier AMPS-1 model. In 1987, American General Atomics and Canada's ESC Group jointly developed the AMPS-1 propulsion system for submarines. This system delivers an output of 100 kilowatts and can power a submarine at full speed for 1,300 days. The ESC Group has proposed a design in which a module equipped with a small nuclear reactor is inserted into a conventional submarine, enabling hybrid propulsion using both nuclear and diesel-electric power systems. When submerged, the submarine can be propelled by either nuclear or battery power. Using nuclear propulsion, the submarine can maintain continuous underwater travel for extended periods at a speed of approximately 10 knots. When the submarine's battery power is depleted, the onboard nuclear power system can recharge the batteries. In safe waters, the snorkel system and diesel engines can also be used to rapidly recharge the batteries. Therefore, the scheme proposed by ESC demonstrates significant practical utility.

It is worth noting that China made an early start on the technical development of small-pulse reactors. In 1991, the Nuclear Power Institute of China developed a uranium-hydrogen tube-in-pool pulse reactor. Featuring good safety and low cost, it achieved a maximum pulse peak power of 3,420MW and a steady-state power of 1,000kW and, following technical modifications for submarine application, could be used in [cont'd below]

The X-shaped stern rudder is better suited for high-power "small-reactor" AIP systems.

"small-reactor" AIP systems.

High-temperature gas-cooled reactors utilize all-ceramic fuel elements and employ graphite as both the moderator and structural material. By using helium, nitrogen, or other gases as coolants—replacing the water used in pressurized water reactors—they can achieve operating temperatures exceeding 700°C, far higher than the 330°C of light-water reactors or the 550°C of liquid-metal reactors. It boasts a thermal efficiency of up to 40 percent (compared to just 33 percent for light-water reactors) and possesses exceptional inherent safety, eliminating the need for complex and costly dedicated safety systems. Consequently, many countries have therefore strongly emphasized the development of high-temperature gas-cooled reactors. In 1967, the

United States completed the 40MW Peach Bottom experimental high-temperature gas-cooled reactor. France built eight Magnox-type gas-cooled reactors, and Japan completed the small High-Temperature Engineering Test Reactor (HTTR) in 1999. China's HTR-10 high-temperature gas-cooled reactor was also connected to the grid for power generation in 2003. High-temperature gas-cooled reactor technology is becoming increasingly mature. Following modifications for submarine application, it is set to become one of the primary reactor types for "small-reactor" AIP systems in conventional submarines.

However, high-temperature gas-cooled reactors operate at high temperatures and pressures. In contrast, small, low-temperature integrated pressurized water reactors offer greater advantages as "small-reactor" AIP systems for conventional submarines. This type of nuclear reactor integrates key components—such as the core, steam generator, main pumps, and control rod drive mechanisms—within a single, compact pressure vessel. As early as the 1980s, Tsinghua University designed and constructed the NHR5—an experimental low-temperature heating reactor with a thermal power of 5MW—to meet residential heating needs. The NHR5 incorporates technical features such as an integrated layout, full-power natural circulation, and internal hydraulically driven control rods. Construction of the test reactor began in March 1986; it first achieved criticality in November 1989 and reached full power on December 16, 1989. It subsequently continuously operated at full power for 100 hours. During three consecutive winter heating seasons of operation, the 5MW reactor demonstrated a heating availability of up to 99 percent, excellent load-following capabilities, convenient power regulation, and significant energy-saving effects,

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and its operational availability reached an internationally advanced level. Subsequently, addressing market demands for residential heating, seawater desalination, and industrial steam, Tsinghua University continued to tackle key technical challenges, completing the R&D and preliminary design for the NHR200-II. The NHR200-II is capable of supplying saturated steam at 1.6Mpa and 201°C, and its safety design features further improvements over that of the NHR5.

China does not lack the necessary key technical capabilities for developing "small-reactor" AIP submarines, and the depth of its research has reached a substantial level. Of course, in terms of actual engineering practice, the scope of the Chinese Navy's "small-reactor" AIP submarine technology does not end here. After all, equipping a submarine with an AIP system powered by a small reactor results in a significant boost to overall performance compared to non-nuclear AIP submarines. In this context, adhering to the original submarine design to accommodate a non-nuclear AIP system would inevitably constrain performance improvements; therefore, a certain degree of redesign is unavoidable. For instance, the new Chinese conventional submarine reported by foreign media features an X-shaped rudder configuration that differs from previous designs.

Compared to traditional cruciform tail configurations, X-shaped tail configurations offer submarines superior maneuverability and control surface efficiency and safety, while also helping to significantly reduce the submarine's acoustic signature during operation. However, at a more fundamental level, the X-rudder configuration is clearly better suited for "small-reactor"

AIP submarines, which feature vastly enhanced energy capabilities and maneuverability. This is likely the key reason for the shift from cruciform to X-shaped rudders.

Potential Tactical Employment

The potential tactical employment of the Chinese Navy's "small-reactor" AIP submarines is another topic of interest. Non-nuclear AIP submarines typically undertake combat missions characterized by ambush-style tactics such as surveillance, maritime blockade, and area patrol operations. The application of "small-reactor" AIP technology enables conventional submarines to extend their underwater endurance and increase propulsion power. This not only significantly enhances their survivability, but also improves their maneuverability.

While traditional non-nuclear AIP technology does extend the underwater endurance of conventional submarines, its performance and power output fall short of meeting the demands of full-spectrum warfare, serving merely to reduce the probability of detection to some extent. After the adoption of "small-reactor" AIP technology, with its high durability and high power density, [cont'd below]

Regardless of whether the new conventional submarine with an X-shaped stern rudder reported by foreign media represents a further improvement on an existing model or an entirely new design, it reflects the rapid development of China's submarine program—a program characterized by the construction of increasingly advanced nuclear-powered and conventionally-powered submarines.

Foreign media sources believe that China's "small-reactor" AIP submarine is a derivative based on the Type 039C platform


Images of China's new conventional submarine as reported by foreign media

the operational employment of conventional submarines will undergo a fundamental transformation.

Once small-reactor AIP technology elevates the performance metrics of conventional submarines to levels approaching those of nuclear submarines, the optimization of their operational modes will manifest in the following three areas: first, expanding the scope of ambush and hunting operations, extending the duration of underwater patrols, and increasing the probability of successful engagement; second, enabling the control of vast maritime areas relying solely on submarines, or ensuring a certain level of blockade effectiveness even without complete air superiority; and third, leveraging the integrated "3S" technologies—comprised of geographic information systems (GIS), satellite global positioning systems (GPS), and remote sensing (RS) image-processing systems—to support maritime combat formations in executing missions. This system enables capabilities such as acquiring battlefield environmental data (hydrological, meteorological, and target-related), establishing command-and-control links, and providing decision support for combat operations. Within the framework of joint maritime-air operations, and taking its particular characteristics into account, this system can enhance the reconnaissance, surveillance, and strike effectiveness of joint blockade forces.

Conclusion

In recent years, China's efforts regarding underwater equipment have arguably rivaled those of its aircraft carrier program, and the overall technological capabilities for nuclear reactor miniaturization and conventional submarine platforms have already matured considerably. There are no fundamental issues with combining the two systems. If these "small reactors" can operate continuously for a sufficiently long period—potentially eliminating the need for nuclear fuel replacement through the submarine's entire service life—then their daily operational and maintenance costs could be kept within a relatively ideal range. This new type of AIP submarine, featuring a conventional propulsion system as the primary power source and a low-power "small reactor" as an auxiliary power source, may well represent the future direction of development for the Chinese Navy's conventionally powered submarines.

Whether the new Chinese conventional submarine that has been generating intense discussion in foreign media is in fact a "small-reactor" nuclear submarine cannot currently be confirmed, leaving considerable room for speculation. After all, driven by the advancement of the nation's overall industrial and technological capabilities, the development of new equipment for the Chinese Navy has shifted from a "steady incremental" approach to a phase of "explosive growth," frequently surprising the public with the "inadvertent" appearance of new equipment. Thus, anything is possible.