A U.S. Navy refueling probe crosses over the South China Sea. Though liquefied natural gas is a viable naval fuel, the dangers of a phenomenon known as rapid phase transition, which could lead to a physical explosion during underway replenishment, must be explored. (Marc Rockwell-Pate)

Abundance **and Utility**

For Military Operations, Liquid Fuels Remain a Solid Choice over Natural Gas

By Bret Strogen and Patrick Lobner

Military energy strategists often recount the British Royal Navy's decision in the early twentieth century to convert ships from coal to oil fuel. This transition improved their capability by reducing fuel handling personnel, increasing ship speed, and doubling travel range, though it required expensive testing and retrofitting of ships with new engines, and introduced risks by relying on a less familiar fuel that would need to be sourced internationally (whereas British coal was plentiful). In hindsight a smart and inevitable decision, at the time many experts argued against the shift. Today, similar to the Royal Navy's decision point a hundred years ago, any shift away from liquid fuels must undergo intense scrutiny to ensure such a transition increases the U.S. military's capability.

In recent years, the DoD has spent nearly $20 billion annually on energy; approximately three-fourths of this energy is considered operational energy (energy required for training, moving, and sustaining military forces) and consists almost entirely of petroleum-based liquid fuels. Despite petroleum's material advantages, depending on a single fuel source entails risk, and the DoD has long-been evaluating alternative fuels that may reduce the military's petroleum reliance without compromising performance.

Perhaps most publicized—and criticized—are DoD initiatives to develop and certify "drop-in" alternative fuels (i.e., fuels that are interchangeable with petroleum-derived fuels and compatible with existing infrastructure and engines). In addition to several biofuels, as discussed in the November 2013 issue of this magazine, the military services have also approved the use of natural gas-to-liquids (GTL) and coal-to-liquids fuels produced via gasification and Fischer-Tropsch (F-T) synthesis. These efforts increase operational flexibility in places where alternative fuels may be integrated into traditional fuel supplies. Although F-T fuels run seamlessly in applications designed for petroleum fuels, the conversion process is energy intensive and facilities are capital intensive. Additionally, there are only five operational GTL plants in the world (two in both Malaysia and Qatar and one in South Africa). As recent developments are increasing the supply of natural gas domestically (and globally), it is worth exploring whether it could be a suitable fuel for our military in its common form.

Even though global consumption of natural gas will soon exceed two-thirds that of liquid fuels on an energy basis, the majority is used for industrial purposes and power generation, not transportation. Nevertheless, Federal mandates have facilitated the DoD's adoption of natural gas for a small fraction of its non-tactical transportation needs—the technology for which has improved notably since civilians drove "gas bag vehicles" during World Wars I and II.

Today, its fleet of about one thousand natural gas vehicles operates across hundreds of bases throughout the country. However, this usage is limited to domestic non-tactical vehicles for predominantly short-

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Challenges to the adoption of natural gas as a tactical fuel: Lack of global distribution infrastructure Greater logistics requirements Incompatibility with existing engines Compromised performance Safety concerns Globally disparate prices

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distance trips. Due to the expense of new natural gas infrastructure and vehicles, it is unclear if this fleet will grow substantially, despite low natural gas prices and policies that favor alternative fuels.

Turning to the DoD's tactical fleet, which includes combat and combat support vehicles, ships, and aircraft, the adoption of natural gas—whether as compressed natural gas (CNG) or liquefied natural gas (LNG)—poses unique challenges.

The first challenge is one which almost any owner of a natural gas vehicle can readily identify—an underdeveloped natural gas refueling infrastructure. Thus consumer "range anxiety" is somewhat warranted: according to the Department of Energy, across the United States there are approximately 1,400 CNG and 100 LNG (public and private) refueling stations, compared to about 150,000 retail fueling stations. While analyzing the number of refueling stations does not provide significant value for the DoD, looking at the global infrastructure that supports those refueling stations definitely does.

As most DoD fuel purchases occur outside the contiguous United States, simply expanding U.S. infrastructure does not address the challenge. Although a few South Asian and South American countries have a more extensive network of CNG refueling stations than the United States, a majority of the world would be unable to support the demand of U.S. forces. In contrast to the approximately 100 million barrels of liquid fuels that are transported across the globe by commercial ocean tankers, trucks, pipelines, aircraft, and rail, comparatively little natural gas is transported to meet U.S. military demands. Any fuel adopted by the Pentagon must be globally available and efficiently distributable.

Another major challenge is that, unlike most alternative fuels being explored by the DoD (including GTL fuels), natural gas is not a "drop-in" fuel. The Pentagon designed its forces around a "one battlefield, one fuel" construct, and would have to undertake a long-term, expensive, and large-scale effort to both retrofit platforms and build new platforms with a capability to use natural gas. Conversely, "drop-in" alternative fuels, while not necessarily globally available, do not require refitting of engines or draining of pipes and tanks that usually handle traditional fuels.

Supposing the global natural gas infrastructure matured and the DoD developed a natural gas force, would the DoD force be a better, more capable force? It appears not.

First, CNG and LNG have a significantly lower volumetric energy density than traditional liquid fuels (despite a higher gravimetric energy density), and furthermore, natural gas engines do not deliver notably superior performance—such as greater power density or energy efficiency—over traditional fuel engines. This leads to two important realities. First, larger fuel tanks are needed to maintain a comparable range. Second, more fuel (by volume) needs to be moved around the world to accomplish the same mission, while simultaneously accommodating both compressed or cryogenic transport requirements and longer refueling times. Growing its already stretched logistics tail is something the DoD should not do, especially given the logistical challenges that the military encounters in high-threat contested environments.

Second, there is uncertainty as to whether natural gas tactical platforms would be as safe as their traditional fuel equivalents. Military platforms are designed to be robust for the combat conditions likely to be encountered in the battlefield. As was vividly seen during the past decade, threats such as improvised explosive devices posed grave dangers to U.S. forces and vehicles. Natural gas has different flammability properties than traditional liquid fuels, and as CNG tanks are under high pressure, further investigation of burst and fire hazard risks—particularly under simulated combat conditions—would be required. At sea, LNG poses an additional consideration if the U.S. Navy continues its extensive use of underway replenishment: LNG, under certain conditions, may undergo a phenomenon known as rapid phase transition, a near spontaneous generation of vapors as cold LNG is vaporized from the heat gained upon contact with open water—leading to a physical explosion. As underway replenishment is conducted in very close ship-to-ship proximity, the risks of an LNG spill would have to be explored.

Finally, for the time being it is unlikely that the DoD would reap notable cost savings, despite the low cost of natural gas relative to petroleum in the United States. Again, because the military purchases a majority of its fuel overseas, and there is not yet a global price of natural gas (unlike petroleum), the DoD would pay regional market prices that exceed U.S. prices; for example, the average natural gas price in Europe was approximately three times higher, and in Japan four times higher, than the U.S. price over the last two years. Hence, the department's cost-benefit analysis is much different than that of commercial and municipal heavy duty fleet operators—many of which have already started converting their trucking fleets to natural gas.

In totality, these challenges present a difficult case to advocate for the widespread adoption of natural gas for military platforms. The growing demand for natural gas in industrial applications, commercial vehicles, and other mobility applications is mainly fueled by cost and environmental factors—not utility. Overseas, Norway has been strongly encouraging the development of maritime LNG platforms with passenger ships, product tankers, and offshore support vessels. Domestically, large rail carriers, tugboat operators, and the U.S. Coast Guard are evaluating natural gas (LNG in particular), as it may be suitable for routine domestic routes where refueling infrastructure can be assured. Some researchers have even explored the potential costs and benefits of LNG-fueled commercial aircraft. And on highways, companies like Cummins and Westport Innovations have advanced "dual fuel" truck engine technology, pushing engine performance closer to parity with traditional diesel counterparts.

As engine technologies advance and natural gas infrastructure grows, a few of the challenges related to the Pentagon's specific requirements may diminish. For the foreseeable future, however, the DoD's use of CNG or LNG will remain limited to non-tactical vehicles or applications with well-defined domestic missions, and the department's use of GTL fuels will likely remain the primary form in which natural gas may be used (albeit indirectly and infrequently) for operational purposes. Nonetheless, so long as natural gas is being used for applications that enable it to displace demand for petroleum—whether for transportation, military, or industrial purposes—the DoD and the nation may expect to have improved access to affordable fuels. ■

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