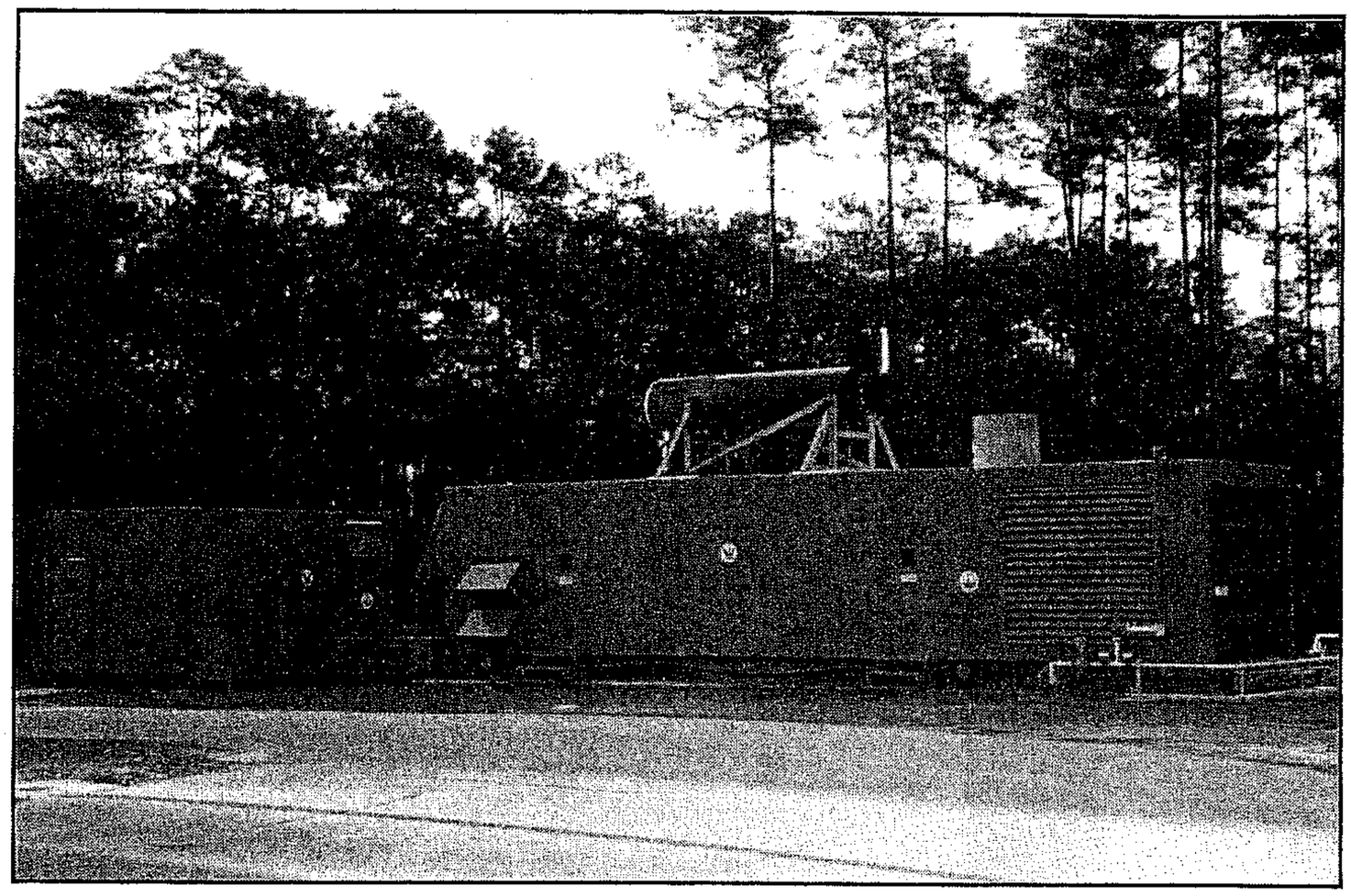


The EMD-powered dual-fuel generator set installed at the U.S. Navy submarine base in King's Bay, Georgia, U.S.A. The control house is at left.

DUAL-FUEL ENGINE CONVERSIONS EVALUATED BY U.S. NAVY

THE United States Navy operates a number of generator sets powered by General Motors Electro-Motive diesel engines. These containerized sets, with outputs of about 1500 kW, provide temporary power to various facilities throughout the United States.

The generator sets sometimes operate in areas where they are not able to meet the local regulatory requirements for stationary engine exhaust emissions. Although transportable, the sets must comply with the emission regulations for stationary equipment because of their planned time on site (up to four years).

In seeking ways to reduce emissions from these two-stroke locomotive type engines, the Navy has evaluated dual-fuel conversions operating on a compression ignition cycle, using up to 94% natural gas and 6% diesel pilot fuel. The Navy has conducted an evaluation and test program under the direction of Dr. Norman L. Helgeson, at the Naval Facilities Engineering Service Center in Port Hueneme, California.

Of the Navy's many diesel engines, those installed in its MUSE (mobile utility support equipment) units for temporary electrical power were the first Navy off-road engines to be affected by emissions regulations. Most of the units are powered by an EMD 645 engine, and when burning diesel fuel do not meet the emission requirements in many areas of the country.

The large number of MUSE units in inventory and the cost of replacement requires that retrofit technology be acquired for bringing them into compliance. In addition to reducing emissions, the applied technology has to meet several other requirements. A capability for firing diesel fuel must be maintained to meet the Navy's operational commitments. Also, full generator power capability must be maintained and reliability equal to or better than that of the diesel-only configuration is needed. Operational costs must also not escalate appreciably beyond those incurred when operating as a diesel-only engine.

To demonstrate emissions reductions while meeting these requirements, the Navy decided to convert a 1500 kW generator set to dual-fuel operation using a technology developed by Energy Conversions, Inc. The system was first demonstrated by ECI and the Burlington Northern Railroad (*D&GTW*, November 1993).

The changes made for dual-fuel operation of these engines included using turbochargers rather than Roots blowers for charge air compression, changing the piston crown design to improve fuel-air mixing and to reduce the compression ratio from 14.1 to 12.8, and altering the head configuration to allow admission of natural gas into the chamber using electronic rather than mechanical controls. Charge-air cooling was increased and the injector rack controls were modified. A new automated control system for remote operation was also designed and installed.

The conversion and shakedown tests for the unit were completed in July 1995. Initial test results of the system, which injects natural gas into the EMD 645 engine at low pressure (6.9 bar), show that it has been effective in reducing NO_X emissions while providing reliable full-power production from the engine. At the same output (1580 kW), NO_X emissions were reduced from 14.1 g/kWh before conversion, to 3.2 g/kWh in dual-fuel operation. Particulate emissions were also reduced, from 0.47 down to 0.28 g/kWh, while CO emissions increased, from 0.34 to 15.3 g/kWh.

The unit was subsequently shipped to the submarine base in King's Bay, Georgia, U.S.A., where it started operations in September 1995 for a year-long operational test. As part of this test, Gas Rail USA, represented by Southwest Research Institute, worked with the Navy to provide fuel metering and instrumentation equipment to assist in the performance evaluation.

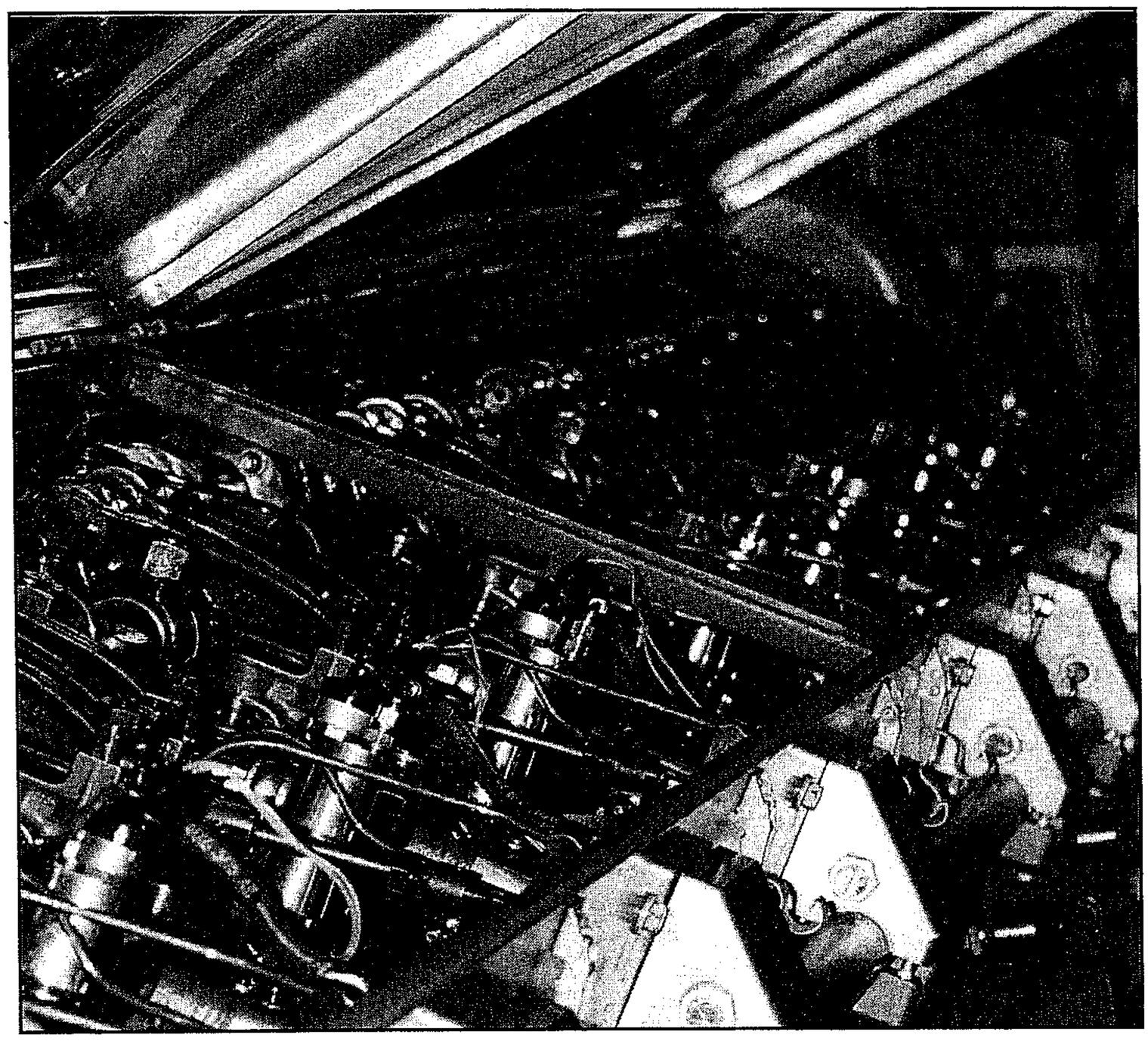
Engine			Emissions		
Fuel	**Power (kW)**	**Speed (r/min)**	**NOx (g/kWh)**	**CO (g/kWh)**	**Particulates (g/kWh)**
Diesel (before conversion)	1580	900	14.1	0.34	0.47
Dual-Fuel	1791	900	4.6	12.3	–
Dual Fuel	1580	900	3.2	15.3	0.28

Initial exhaust emission test results of the 1500 kW MUSE generator set, before and after conversion to dual-fuel operation.

The dual-fuel conversion was an important step forward in reducing NO_X emissions while maintaining full power capability. However, the 70% NO_X reduction achieved is still not sufficient to permit the operation of MUSE engine generators in some areas of the United States. Therefore, additional engine modifications are being considered to gain further NO_X emissions reductions.

These modifications have centered on the use of preignition chambers and/or separate diesel injection igniters. Test results show that NO_X emissions for dual-fuel engines can be reduced to the level of 1.3 g/kWh while also reducing CO, hydrocarbon and particulate emissions; and that the required diesel pilot fuel can be reduced to about one percent. Although the use of prechambers in engines is a familiar concept, their use with dual-fuel engines has been somewhat limited to date.

Successful demonstration of a dual-fuel EMD-645 engine with pilot ignition would further bring the Navy's stationary dual-fuel units to the level of NO_X required by the most restrictive emissions regulations for stationary engines in the United States. ■



Close-up view under the valve covers of the EMD dual-fuel engine, showing the gas fuel manifold and electronically controlled gas valve injectors.