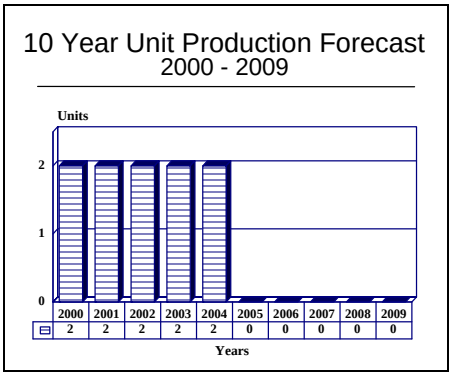
Rolls-Royce Spey SM-1A/C - Archived 6/2001

Outlook

- British, Japanese naval forces keeping production alive
- Tandem power source on the Murasame class destroyers, along with GE LM2500s
- Competing hard against the GE LM2500, LM3000, RB211
- Fast ferries another market segment with future potential



Orientation

Description. Two-shaft, axial-flow, aero-derivative industrial and marine gas generator and gas turbine powerplant, with the marine gas turbine in the 25,000-27,000-hp class.

This report covers only marine propulsion applications of the Spey. For industrial and aviation turbofan applications of the Spey, please consult our *Gas Turbine Forecast* service.

Sponsor

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Status. Production and service.

Total Produced. As of the beginning of 2000, an estimated 111 marine versions of the Spey had been built.

Platform. The Spey SM-1 series gas turbines are used to power frigates, destroyers and air-capable ships.

Price Range. $4.85-$5.0 million for the marine propulsion package (estimated in 2000 US dollars).

Technical Data

Dimensions. Approximate dimensions of the I&M Spey gas generator are as follows:

	Metric	SAE
Length:	2,700 mm	106.3 in
Width:	1,140 mm	44.9 in
Weight:	1,800 kg	3,968 lbs

Approximate dimensions of the complete SM-1 Module (inclusive of gas generator) are as follows:

	Metric	SAE
Length:	7,500 mm	295.2 in
Width:	2,285 mm	89.9 in
Height:	3,390 mm	133.4 in
Weight:	25,700 kg	56,659 lbs

Major components of the SM-1 Module have the following approximate weights:

	Metric	SAE
Gas Generator:	1,800 kg	3,968 lbs
Power Turbine and Exhaust Volute:	6,900 kg	15,212 lbs
Baseplate:	6,900 kg	15,212 lbs
Air Inlet Cascade Bend:	1 000 kg	2,205 lbs
Acoustic Enclosure:	3,300 kg	7,275 lbs
Other Items:	5,800 kg	12,787 lbs

Performance. The approximate performance of the Spey gas generator is as follows:

	Electrical Output	Thermal Efficiency
Electrical Generation		
ISO Pea:	13.6 MW	34.0%
ISO Bas:	12.1 MW	33.5%
	Shaft Output	**Thermal Efficiency**
Mechanical Drive		
Max Continuous:	18,900 hp	35.4%
ISO Base:	16,850 hp	34.9%
Spey SM-1A:	12.75 MW (17,100 shp)	
Spey SM-1C/2C:	19.5 MW (26,150 shp)	

Design Features. The SM1 Module is a complete marine propulsion package offered for naval surface vessels. It comprises a marine Spey gas generator, acoustic enclosure, cascade air inlet bend, ancillary systems, electrical power points and fire protection systems all mounted in a fabricated steel baseplate. It incorporates its own local control facility, with provision for connection to alternative remote control systems from the ship control center. The package is provided complete with heat and noise insulation, a self-contained ventilation system, and NBC protection: it was designed for high shock resistance.

Air Intake. An annular air plenum is fitted to the front of the engine, with compressor bleed air used for anti-icing.

Compressor. A five-stage LP compressor is driven independently and is fitted with the following: titanium alloy rotor blades, 12 percent Cr stator vanes, titanium alloy Stage 1-2 discs, 12 percent Cr steel Stage 3-5 discs, and aluminum alloy casing. An 11-stage HP compressor is fitted with titanium alloy rotor blades for Stages 1-8; 12 percent Cr steel rotor blades in Stages 9-11; 12 percent Cr steel for stator vanes and Stage 1-10 discs and Stage 11 disc in IN901. Pressure ratio is 21.9 for the SM-1C/SM-2C; air mass flow is 66.7 kg/s. Power shaft speed is 5,500 rpm.

Combustor. Ten interconnected Nimonic cannular combustors, each with a multi-fuel nozzle at the burner head. Location faces are hard-faced to reduce fretting. Casing in 12 percent Cr steel; liner is Nimonic.

Turbines. The LP compressor is driven by a two-stage turbine, with a cooled first LP nozzle. LP blades are Nimonic 105, discs are Nimonic 901, vanes are Cr-Co-Mo steel. HP blades are Nimonic 108 and MAR-M002, discs are Nimonic 901, and vanes are in Stellite 31 and Ni-Cr-Co-Mo steel, respectively. The HP turbine is a two-stage unit with cooled first vanes and blades; LP turbine has Stage 1 vane cooling. Marine Speys have an independent power turbine, usually mounted on the skid, which remains in place when the gas generator is removed. Normally, a two-stage PT is used (unless specified otherwise) with an overspeed trip protection system.

Bearings. The Rolls-Royce squeeze film technique is used to suppress compressor vibration by applying high-pressure oil to the area between the outer race and the casing. The rear turbine bearing is mounted in a snubbed spring housing to minimize out-of-balance forces.

Accessories. Woodward electric governor and fuel metering system. Starting for the Spey SM-1 is by an air start motor. The Spey SM-1 has a self-contained gas generator lubricating oil system, cooler and filters.

Operational Characteristics. The SM-1 Module comprises a marine Spey gas generator, acoustic enclosure, cascade air inlet bend, ancillary systems, electrical power points and fire protection systems, all mounted in a fabricated steel baseplate. It incorporates its own local control facility, with provision for connection to alternative remote control systems from the ship control center. The package is provided complete with heat and noise insulation, a self-contained ventilation system and NBC protection: it was designed for high shock resistance.

Variants/Upgrades

Spey SM-1A. The Spey SM-1A gas turbine is the basic model in the Marine Spey line; it is rated at 17,100 hp (12.75 MW), with a maximum power output of 18,770 hp (14 MW).

Spey SM-1C. An improvement of the Spey SM-1A module has been utilized by the UK Royal Navy. The uprated module, the SM-1C, is rated at 24,138 hp (18 MW), and is projected to have an SFC of approximately 0.382 lb/hph (0.232 kg/kWh). The power increase is achieved by an increased maximum temperature allied with an airflow increase provided by an increased-diameter LP compressor. Other design changes to the SM-1A that have resulted in the SM-1C are: new HP turbine discs; new flame tubes with improved cooling; a new HP1 nozzle profile and advanced cooling; a new HP1 and HP2 turbine blade profile, along with advanced cooling and improved materials; a new profile for the LP1 nozzle; a revised annulus line for the HP turbine; cooled PT casings with improved materials; improved rim sealings; and the use of honeycomb tip seals.

Operating parameters[(a)] of the marine Spey SM-1C are as follows:

	Metric	**SAE**
Shaft Output Power:	18 MW	24,138 hp
Shaft Speed:	5,600 rpm	5,600 rpm
SFC:	0.232 kg/kWh	0.382 lb/hph
Thermal Efficiency:	36.5%	36.5%
Air Intake Flow:	65,9 kg/sec	145.5 lb/sec
Exhaust Mass Flow:	67,1 kg/sec	148.0 lb/sec
EGT:	480°C	896°F
LPC Speed:	8,283 rpm	8,283 rpm
PT Inlet Temperature:	740°C	1365°F
Overall Pressure Ratio:	22.4	22.4

[(a)]Engine performance at 59°F (15°C), fuel having a lower calorific value of 18,300 Btu/lb (42,566 kJ/kg), atmospheric pressure of 14.7 lb/in^2 (101.3 kPa); no external air or power take-offs.

Spey ICR. Further development of the marine Spey was expected to result in an Intercooled Regenerative (or Recuperative) cycle (ICR) unit, to be nominally rated at 22 MW baseload output and 43 percent thermal efficiency. The Spey ICR effort was a return to a partnership of Allison, Garrett, and Rolls-Royce. This engine is also referred to as the **Allison 1220-B2**.

It was the subject of a preliminary design study carried out for the US Navy: the upgraded unit is expected to have an overall performance comparable with that of

many marine diesels, while retaining a significantly higher power-to-weight ratio. The flexibility of such a unit would allow the one engine type to be fitted for both cruise and boost roles.

Spey SM-2 and SM-3 Marine Modules. Two lightweight marine modules, the SM-2 and SM-3, are intended for smaller corvettes, strike missile craft and surface-effect ships. The SM-2 comprises the Spey gas generator and power turbine mounted in a common base plate, without the integral acoustic enclosure and air intake. For the lighter SM-3, there is a rigid connection between the gas generator and power turbine, with supports at three points for mounting directly to the vessel: this configuration of the Spey is seen as well suited to the needs of small craft, SWATH ships, hydrofoils, and surface-effect ships.

Approximate dimensions/operating parameters of the SM-1 and SM-3 are as follows (SM-2/SM-3):

	Metric	**SAE**
Length:	6 069/6 620 mm	240/260.6 in
Width:	2 286/2 060 mm	90/81.1 in
Height:	2 794/2 353 mm	110/92.6 in
Weight[(a)]*:*	15 960/8 300 kg	35,185/18,300 lbs
Shock Resistance		
Vertical:	20 *g*/12 *g*	20 *g*/12 *g*
Lateral:	6 *g*/3 *g*	6 *g*/3 *g*
Axial:	6 *g*/6 *g*	6 *g*/6 *g*

[(a)]Inclusive of gas generator.

As of this writing, no orders have been announced for either the Spey SM-2 or SM-3 marine engines.

Spey SM-2C. The Spey SM-2C gas generator is rated at 26,150 hp (19.5 MW).

Program Review

Background. Rolls-Royce began development of the non-aero Spey in 1974. The initial market thrust of the Spey development program was marine systems, building upon the learning and experience of the Olympus propulsion modules. The Spey was designed to fill the gap in power between the Olympus (with approximately 28,000 bhp), and the Tyne (with 6,000 bhp).

UK. The UK Royal Navy uses the SM1A module in two vessel classes. In the first, the 4200-ton Type 23 Duke class frigate, the Spey is used in a CODLAG capacity with four Paxman Valenta 1,750 horsepower diesels and two GEC 1.5 MW electric motors. Sixteen ships of this class have been ordered, with the last being under construction. The lead vessel of the series, the *Norfolk* (F230), was commissioned in November 1989 and the last one will probably be commissioned in 2001.

In the second vessel class, the slightly older 4,850 ton Type 22 Broadsword class frigate, the Spey module is used for the vessel *Brave* (Batch 2, vessels no. F94) in a COGOG capacity. The other Spey-powered vessels of the Type 22 Class – vessels F92, F93, F95 and F97 – use the Rolls-Royce turbine with the Tyne RM1C in a COGAG configuration. All ships were launched by the end of January 1988. The subsequent four Batch 3 frigates use the SM1C version of Spey.

Japan. A number of Japan Maritime Self-Defense Force ship programs include the Spey SM1A propulsion module. The first is the 5,500 ton Hatakaze class missile destroyer. Two ships compose this class, with each ship capable of carrying SSMs, Harpoons, ASROCs, and torpedo tubes in addition to 20 mm Phalanx CIWSs and 5 inch (127 mm) guns. This vessel class uses a COGAG arrangement with two Rolls-Royce Olympus TM3Bs for boost and two Spey SM1As for cruise power.

The second of the Japanese ships to use the SM1A is the 4,200 ton Asagiri class guided missile destroyer. The ships use four Spey SM1A gas turbine modules (COGAG) providing 54,000 bhp. Eight vessels have been launched.

In addition, the 5,100 ton Murasame class is powered by a pair of SM1Cs, in conjunction with two GE LM2500s on each ship. Kawasaki produces the SM1Cs under license, with major components coming from Rolls. A total of at least eight ships are envisioned for Japan, with production ongoing. This particular ship class represents the strongest market for the

Rolls-Royce Spey, along with the Dutch De Zeven Provincien class ships.

The fourth surface ship class in Japan using the Spey is the 2,550 ton Abukuma class frigate, featuring two SM1As and two 3000 hp Mitsubishi diesels in a CODOG configuration. Six vessels have been launched.

Spey and Olympus engines for all Japanese surface combatants are supplied by Rolls-Royce's licensee in Japan, Kawasaki Heavy Industries. As of the beginning of 1999, an estimated 59 Marine Spey machines had been delivered by this licensee.

It appears that Japan is continuing the construction of the Murasame class destroyers beyond the 11 units originally envisioned. This means that the demand for the Industrial Speys will also be sustained, since it is understood that the power arrangement of these ships continues to be based on the use of two GE LM2500s in concert with two Rolls-Royces.

Rumors that Japan is in the process of designing a new, much larger ship class are creating some uncertainty regarding the country's surface combatant plans. This new ship, expected to displace well over 10,000 tons, could, according to some observers, make current 5,000 ton destroyers obsolete in the next 10 years. On the other hand, this may not impact the Murasame program at all, but rather the other, older classes. In short, Japan appears to remain a very buoyant market for these engines.

The Netherlands. In February 1984, the government of the Netherlands ordered four 3320-ton Karel Doorman class guided missile frigates from shipbuilder Koninklijke Maatschappij de Schelde: subsequent plans called for an additional four vessels. The ship design was configured to use twin Spey SM1A modules (CODOG) with two 4000-hp Werkspoor cruise diesels; however, since that time, vessel F 828 has been uprated to use the Spey SM1C. The SM1C may be used to refit all vessels of this class.

The SM1C is also the variant chosen for the 4400-ton De Zeven Provincien class anti-aircraft frigate, a.k.a. LCF. They will use two 26,150 shp Speys in a CODOG capacity, the diesels being two Stork-Wärtsilä 16V6STs, rated at a total of 11,424 shp.

The engines to be fitted for the German counterpart of this same class, the F124 Sachsen, will be GE's LM2500s (one each, in concert with two MTU diesels). The Spanish sister ship, the F-100 class, is also equipped with GE's LM2500s (two each, supported by two Caterpillar diesels packaged by Bazan).

US Navy Requirement. The US Navy selected the Rolls-Royce intercooled, regenerative cycle Spey (Spey ICR) for a research and development program designed to produce an engine with the power output of the current GE LM2500 but with much lower fuel consumption, smaller size and installed weight.

The first application for the Rolls-Royce engine, which could be built in Canada by Rolls-Royce or in the US by Allison (which has a license to produce the powerplant), is not known. It is difficult to foresee a market penetration opportunity for the Rolls-Royce engines in this fleet so heavily relying on GE's LM2500 power.

Now that the US Navy has publicly announced its plans to go with all-electric propulsion as the prime mover for its future (surface) ships, the matter has become one of choosing an appropriate generator that will produce the necessary electricity on board, feeding the electric propulsion motors in addition to the hotel power. In this application, the ICR WR-21 of Rolls-Royce may perhaps stand a chance, but it is difficult to see Spey (or Trent) become an engine of choice in the USN otherwise.

Commercial Vessels. Twin SM1A modules have been chosen for the Australian International Catamaran (INCAT) 110 meter passenger-carrying ferry, the *Wavepiercer*. The SM1As will develop in excess of 17,100 shp.

Fast ferries are the very sector that Rolls-Royce is heavily targeting with its marine turbines (both Spey and Trent). Rolls-Royce is emphasizing the ease of installation of the engines as well as the long experience of the OEM as a power provider for ships of various types.

The aero-derivative characteristics of Spey, including its twin-spool, high-efficiency design, are also played up in the Rolls-Royce efforts to find applications in the field of high-speed ferries, emphasizing the flexibility of the engine's design.

Applications in Smaller Craft. The downsized SM-2 and SM-3 variants of the Spey for fast-attack craft and missile boats are, nevertheless, considered unlikely to be a significant factor in the turbine market. Most craft in these categories rely strictly on diesel propulsion. Gas turbines do have many advantages over diesels in terms of power availability and power curve characteristics, reliability and maintainability, while their smaller size and high power-to-weight ratios offer significant design advantages. However, these advantages are offset by the environment into which these craft are largely sold.

Most FAC operators are small navies and conceive of their naval capabilities within the context of sea denial. Such countries usually have significant diesel engine support facilities for their civilian economies and can draw on that infrastructure, both for support personnel and for logistics provisions. The civilian economies of these countries provide the necessities for running a diesel-powered navy, while less experience exists with gas turbine technology among such players. Diesel fuel is also less expensive and in greater supply in those regions. Finally, the technology involved in diesel construction is not as sophisticated, and therefore a greater proportion of support needs can be met from internal resources than would be possible with gas turbines.

Funding

Funding for the development of the Marine versions of the Spey was provided under UK MoD contract.

Recent Contracts

Contractor	Award ($ millions)	Date/Description
Royal Netherlands Navy	16.5	*March 28, 1996* – Four Spey SM-1C engines for the first two De Zeven Provincien class frigates, with deliveries starting in 1998.
Royal Netherlands Navy	17	*May 6, 1997* – Follow-on order for engines on the De Zeven Provinciens, covering the second set of two ships. Deliveries likewise in 1998.

Timetable

Month	Year	Major Development
Aug	1957	Aero Spey engine design begins
Dec	1972	Marinized Spey study begins
4Q	1976	SM-1A gas turbine design completed
	1981	Speys ordered for Type 22 and Japanese DD/FF vessels
4Q	1983	First production-standard SM-1As delivered
Nov	1985	Spey ICR contract awarded
Sep	1987	Spey SM-1C gas generator first run accomplished
Mar	1996	Contract for the Royal Netherlands Navy for first two new frigates
May	1997	Follow-on order for the above, covering the other two ships
Thru	2009	Continued search for additional applications

Worldwide Distribution

Japan. 6x2 Spey SM-1C on Abukuma class FFG; 8x4 Spey SM-1A on Asagiri class FFG; 2x2 Spey SM-1A on Hatakaze class DDG; 8x2 Spey SM-1C on Murasame class DDG, three under construction, more envisaged.

The **Netherlands.** 8x2 Spey SM-1A/C on Karel Doorman class FFG, 4x2 SM-1C ordered/installed for De Zeven Provincien class DDG.

UK. 18x2 Spey SM-1A/C on Type 23 FFG (13 built, three more being completed); 4x2 Spey SM-1A on Type 22/3 FFG; 4x2 Spey SM-1A on four of six Type 22/2 FFG.

Forecast Rationale

Rolls-Royce's efforts with reference to the Spey are being directed to the fast ferry market, not only for Europe but also for the Far East/Pacific arena. Meanwhile, Rolls Royce has shifted its main marketing focus to the Westinghouse/Rolls-Royce RB211 family, leaving the Speys out in the cold to fight for existing customers or those wanting to continue buying this engine which is already in wide use in their fleets.

Japan's plans to build a much larger class of surface warships, displacing 10,000+ tons, is an interesting twist in the tale of the venerable Spey. This is already a very popular machine in the Japanese fleet, and the Murasame class construction only seems to continue as each year goes by. While it is understood that the new major surface combatant (be it a destroyer or a cruiser) will make obsolete some of the older 5,000 ton destroyers now in the fleet, there is no reason to believe that the Murasame series will stop at nine, or even at 11, which has also been anticipated as the breakoff point. Instead, it may be that more Murasames will be built, and those beyond unit number nine will be of the "Improved Murasame Class," also known as "DD10."

In other words, Japan appears to be on track to build both more Murasames (which will continue to be dual-powered by Rolls-Royce and GE, with two engines from each) *and* a new class of major surface combatants. The power selection for the new class is not yet known, but at least the Murasame class will keep the Spey demand buoyant in the years to come.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

			High Confidence Level				Good Confidence Level			Speculative			
Designation	**Application**	**Thru 99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**Total 00-09**
SPEY SM-1A/C	DD/FF (JMSDF)	61	2	2	2	2	2	0	0	0	0	0	10
SPEY SM-1A/C	Prior Prod'n:	50	0	0	0	0	0	0	0	0	0	0	0
Total Production		111	2	2	2	2	2	0	0	0	0	0	10