MARINE GAS TURBINES IN THE ROYAL NAVY 1978–9

BY

COMMANDER J. M. KINGSLAND, C.ENG., M.I.MECH.E., R.N.
(*Ship Department*)

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Introduction

The last two years have seen four particularly significant events in the progressive introduction of aero-derived marine gas turbines into service in the Royal Navy:

Acceptance of the first Type 22 frigate
Sea trials of the first ASW cruiser
Introduction of RM1C Tyne to service
Orders placed for SM1A Marine Spey

There has also been continuing reliable service from the Rolls-Royce Marine Tyne and Olympus gas turbines in the standard COGOG configuration used in the Type 21 AMAZON Class frigates and Type 42 SHEFFIELD Class destroyers. There are now 62 shaft sets of this machinery in service or on order for the Royal Navy, and many in service in other navies. Nearly 100 000 hours running experience has been accumulated by the Tyne cruise engine, and over 50 000 hours by the high-power Olympus engine, in R.N. service alone.

The overhaul life of the intensively used Tyne cruise engine has been extended progressively in the light of experience, and in association with a continuing programme of development and improvement.

Development of the SM1A Marine Spey Gas Turbine is now far advanced. Rig trials of new features such as the LP compressor design and the combustion system have been in progress since 1977, and trials in adapted demonstrator engines since 1978. The first RB 244/SM1A engine has been built and has started development trials.

New Ships

The first Type 22 frigate H.M.S. *Broadsword* was accepted in February 1979. This ship uses the standard Tyne/Olympus machinery, but incorporates a number of improvements in the gas turbine installation:

compact intake filtration units;
aft-facing intakes;
stainless steel uptakes; no silencing;
GT module vent by exhaust volute eduction;
all fuel centrifuged.

These improvements are also being incorporated in later Type 42 destroyers under construction.

The first anti-submarine warfare cruiser H.M.S. *Invincible* carried out contractor's sea trials in May 1979, and the ship will be accepted into service shortly. This ship uses two TM3B Olympus gas turbines on each of two shafts in a unitized arrangement. Astern operation is achieved by reversing gearboxes using hydraulic couplings for manoeuvring.

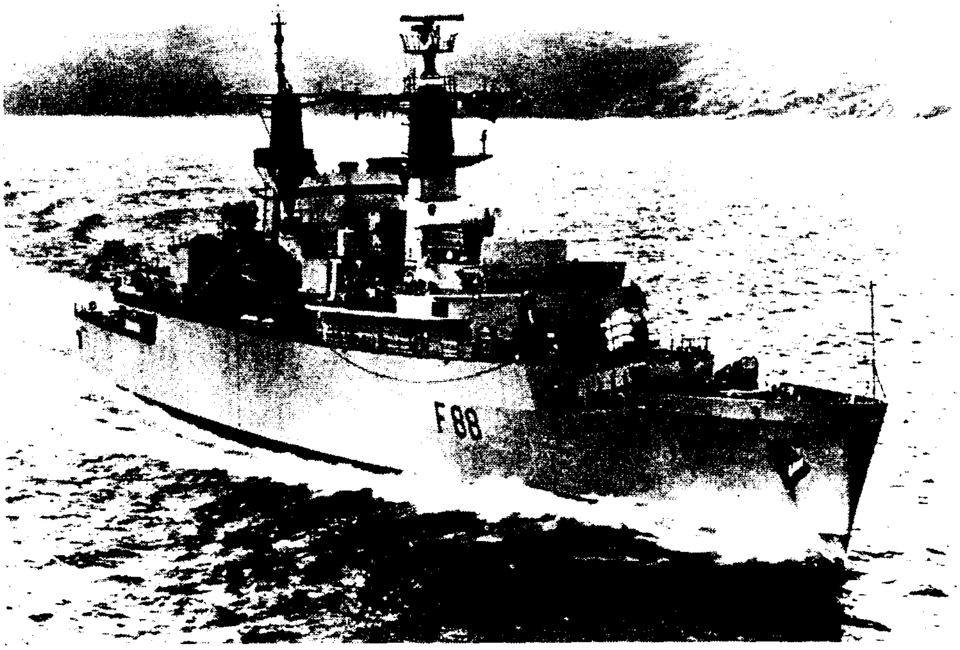

FIG. 1—H.M.S. 'BROADSWORD' ON TRIALS

The gas turbine inlet and exhaust ducting in a large ship such as this with a full flight deck presented new design problems. The configuration of these for one unit was built into the propulsion machinery shore test facility at Rolls-Royce Coventry, England. The cruiser STF included the ship intake filtration equipment, intake and exhaust silencers, and the full propulsion machinery control system.

A spare gas turbine change unit is carried in each engine room, which can be fitted by the staff without outside assistance, even at sea.

As in the Type 22 frigates, GT module ventilation is by exhaust volute eduction; both types of ship also use the Decca ISIS system for data logging and dynamic data recording.

A list of modern all-gas-turbine ships in service or building for the Royal Navy is given in TABLE I. Also still in service are the Proteus engines in the fast patrol craft, the G6 propulsion gas turbines in the COUNTY Class destroyers and TRIBAL class frigates, and Ruston Allen and Lucas auxiliary gas turbines described in previous papers.[1, 3]

TABLE I—*R.N. Gas Turbine Ships*

Type 21 Frigates	*Type 22 Frigates*	*Type 42 Destroyers (DDG)*	*ASW Cruiser*
01 *Amazon*	01 *Broadsword*	01 *Sheffield*	01 *Invincible*
02 *Antelope*	02 *Battleaxe*	02 *Birmingham*	02 *Illustrious*
03 *Active*	03 *Brilliant*	03 *Cardiff*	03 *Ark Royal*
04 *Ambuscade*	04 *Brazen*	04 *Coventry*	
05 *Arrow*	05 *Boxer*	05 *Newcastle*	
06 *Alacrity*	06 *Beaver*	06 *Glasgow*	
07 *Ardent*	07–08 not yet named	07 *Exeter*	
08 *Avenger*		08 *Southampton*	
		09 *Nottingham*	
		10 *Liverpool*	
		11 *Manchester*	
		12–15 not yet named	

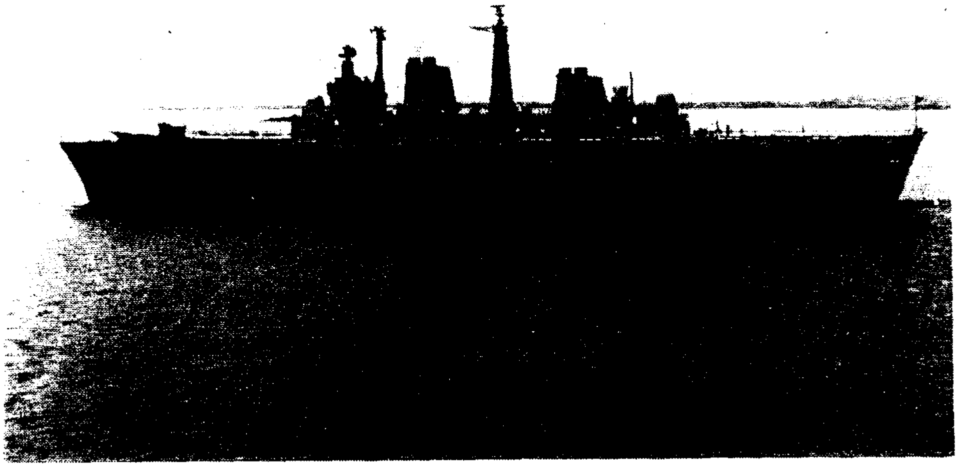

FIG. 2—ASW CRUISER H.M.S. 'INVINCIBLE'

RM1C Marine Tyne

This is an uprated version of the RM1A which it will eventually completely supersede in naval service; the power is 4 MW (5340 bhp). Its development was described by Cdr. T. R. Shaw in 1974.[1] The first production engine completed a 2000 hour endurance trial at the National Gas Turbine Establishment (NGTE) Pyestock, England in December 1977. In early 1978, engines were installed in H.M.S. *Ambuscade* and in two frigates of the Royal Netherlands Navy, where they have now accumulated a total of 5000 hours of sea experience.

A programme has been started to modify the RM1A engine modules to enable them to accept the uprated engine—without losing their ability to accept the original engines during the transition period. These modifications are minor, and involve mainly the primary gearbox, fuel control system and instrumentation.

A programme has also been started to convert RM1A engine change units to the RM1C standard, and the first two engines have been completed.

A small number of new problems, and aggravated versions of old problems, have arisen during endurance trials and sea experience, which has emphasized that:

(*a*) uprating can introduce unexpected difficulties due to, for example, increased temperatures in non-critical components, alterations to vibration modes, etc.;

(*b*) even minor redesign in secondary systems can introduce new problems;

(*c*) such problems may not be revealed during comparatively short development trials.

Examples of these problems have been the deterioration of non-metallic oil seals, and the cracking of compressor inlet guide vanes; simple solutions to both these problems have been quickly developed. Uprating has also resulted in some buckling of Nimonic 75 flame tubes, which are satisfactory in the RM1A, and these will be replaced in C 263. Some cracking has also been experienced in HP nozzle guide vanes, and an improved cooling arrangement is under development, During uprating, minor redesign of an oil scavenge system from a bearing introduced a new seal leakage problem and increased oil consumption, for which a modification has been developed.

Perhaps the most surprising defect following uprating has been increased corrosion on the pressure faces of the HP turbine blades. In redesigning the turbine, the previous forged Nimonic 115 design was replaced by a blade in cast IN 738 with a standard pack aluminized protective coating, and increased cooling air flow. This material and coating have proved very successful in the Olympus HP turbine, and the disappointing performance in the RM1C Tyne is difficult to explain satisfactorily, though there are a number of possible theories, A coating which has demonstrated greatly improved corrosion resistance in engine trials under simulated marine conditions is being introduced into service; this is the platinum aluminide LDC2. Meanwhile research is continuing on the basic mechanism of corrosion attack and on advanced blade materials and coatings.

TM3B Marine Olympus

The Marine Olympus has continued to give reliable service, though usage as the high-power engine in COGOG ships has been little more than 500 hours per year on average, which is very much less intensive than the usage of the Tyne cruising engines. This illustrates a basic characteristic of all plants such as COGOG and CODOG, where a large gas turbine is used at high powers only: the pressure on overhaul resources and spares for the cruising engine are much higher than they would be in a multiple engine installation such as the all-Olympus ASW Cruiser.

One result of low usage in the current frigates and destroyers is that, apart from premature removals, there has been little opportunity to incorporate design improvements other than those in readily accessible areas of the engine, particularly in the earlier ships. Full stripping at overhaul is an indispensible source of information on which to base design improvement, and low usage has meant that this has been slow to develop for the Marine Olympus.

An aspect of marine service which experience has highlighted is that salt corrosion is likely to attack all parts of a gas turbine, and not just those in the air/gas path. It has been found necessary to apply protective coatings, or to change materials, in several areas such as compressor and turbine disks, labyrinth seals, and in stator casings and diaphragms. Corrosion in these areas seldom progresses far enough to affect performance or reliability at the present overhaul life, but the cost of components rejected at overhauls, due both to direct corrosion or to consequential strip damage, is not acceptable. At the extended life now envisaged, the effects of corrosion on performance and reliability could become significant if corrective measures were not taken.

Two failures requiring engine removal have illustrated the sensitivity of the aero-derived gas turbine to apparently minor defects, and have emphasized the importance of excellent workmanship and thorough inspection during manufacture, and following overhaul or maintenance. In one failure, a drilling was omitted from a fuel system banjo connection to a burner, and in the other, a small light fairing plate on a combustion chamber snout was inadequately secured. In both these cases severe turbine damage resulted.

Following further development and endurance testing of improved design features such as IN 738 HP turbine blades and long life smoke-reduced combustion ware, engines with these modifications are now about to enter service at greatly increased planned overhaul lives.

SM1A Marine Spey

The development of the SM1A Marine Spey engine for introduction to service in the Royal Navy in the 1980's was described at the 1978 conference.[2] Design

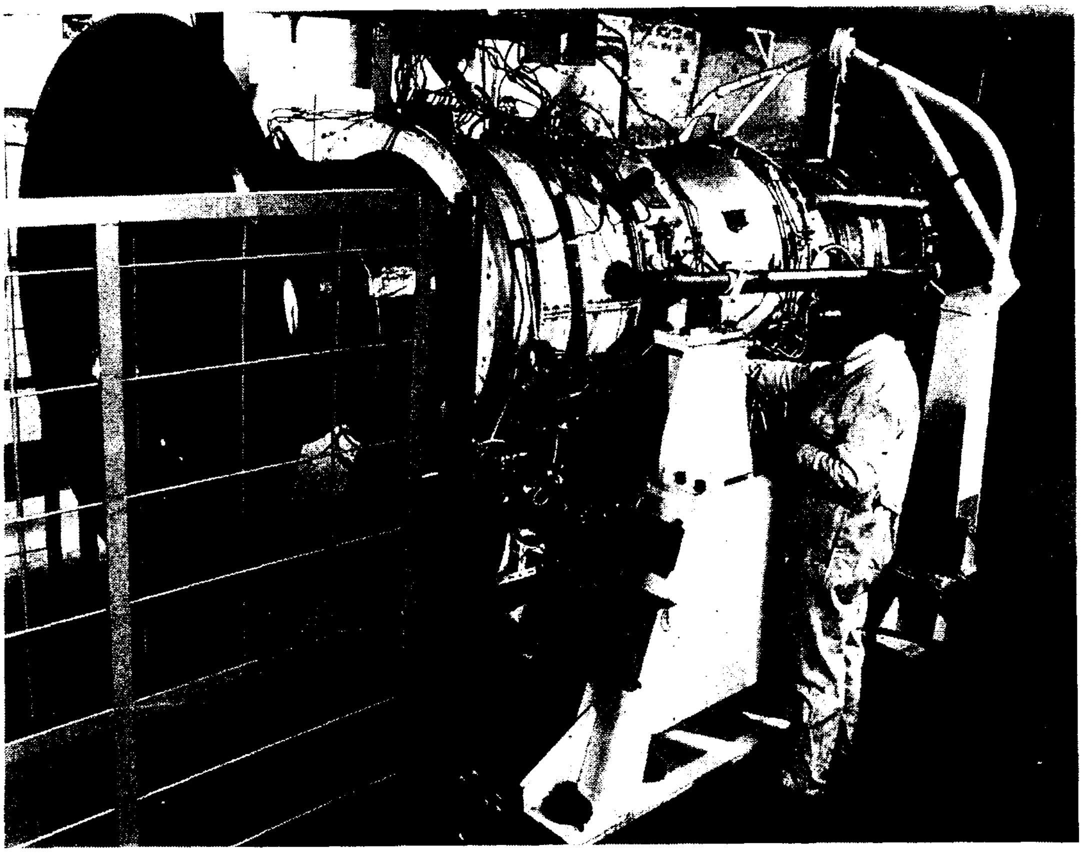

FIG. 3—SPEY GAS GENERATOR ON TRIAL

Courtesy Rolls-Royce Photo Services

and testing is now well advanced, and engines have been ordered for endurance testing at NGTE Pyestock.

The Admiralty Test House at NGTE will be extended to provide a new test bed for the SM1A, completing in 1982. This will include new dynamometers and water systems, pumps and cooling towers. A new control room with data processing equipment and other test house services and facilities will also be provided.

Testing at NGTE will be on the same lines as previous Tyne and Olympus endurance trials; the marine environment will be simulated by salt injection into the intake air and fuel, and a realistic operating cycle will be followed. An electronic simulator for development testing of the overall propulsion controls and secondary surveillance is also being constructed at NGTE.

For the development of the SM1A/RB244 itself, testing of redesigned features, such as the LP compressor, combustion system, and electronic fuel controls, have been in progress in rigs since mid 1977, and in demonstrator engines since mid 1978. Engine trials of the initial standards of the fuel control system, and of the pre-mix injector combustion system (i.e. the 'reflex airspray burner' or RAB) have been particularly encouraging.

The first actual RB244 gas generator was completed in October 1979, and has started trials. There have been some changes to the original design, mainly concerning materials; three significant changes have been made:

(*a*) HP turbine blades—IN738 replaced by IN792 to improve creep strength;

(*b*) Compressor stator vanes—IN718 replaced by Jethete with anti-corrosion coating;

(*c*) Power turbine disks—FV535 replaced by FV448 to improve life.

A version of the engine module enclosure has been designed to give the option of sideways removal of the engine change unit, and the NGTE module will include this feature.

Particular emphasis has been placed on reliability and maintenance, and on preparation for support of the engine in service. A full-scale mock-up has been constructed as an aid to module design, which is also being used for the methodical assessment of maintenance operations and component exchange. Reliability is the subject of formal analysis, study, and review. A detailed programme has been made of all the activities needed to supply handbooks and other instructions, and spares and other material for support, from first introduction to service.

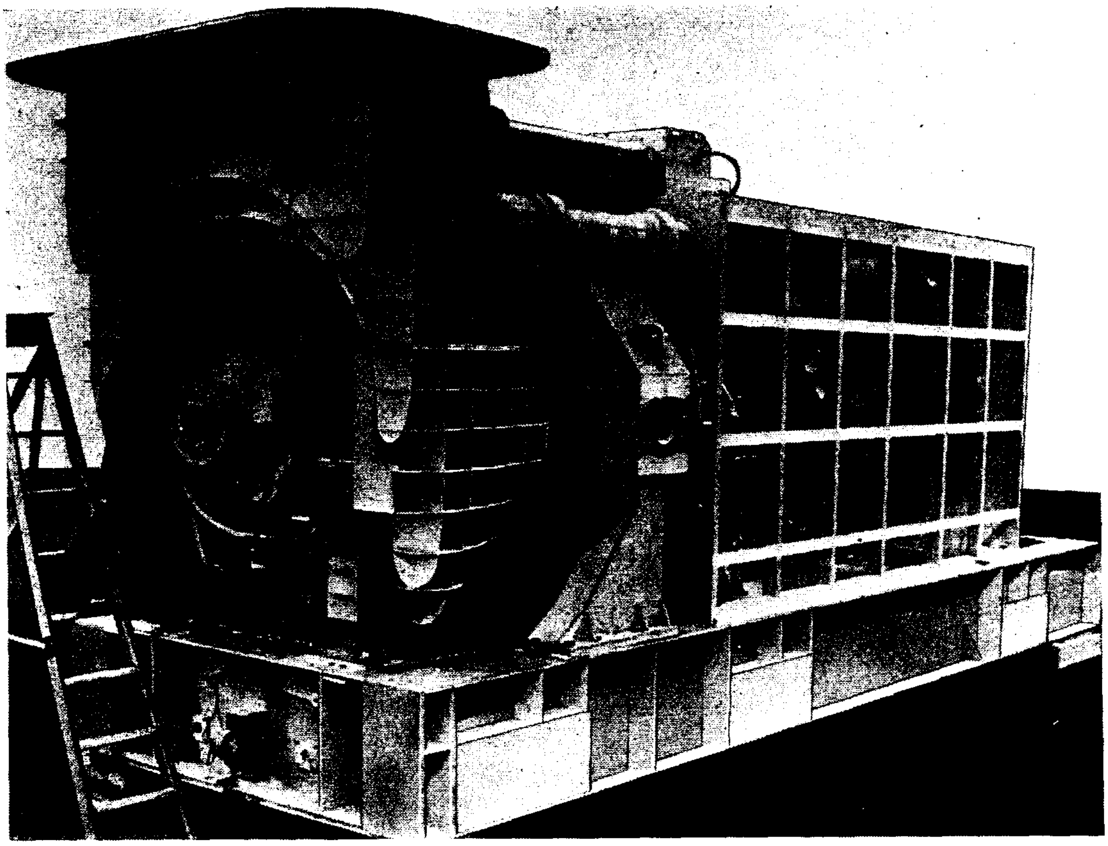

FIG. 4—SM1A MODULE MOCK-UP

Upkeep Policy

A full description of the Royal Navy's approach to the logistic support and upkeep of marine gas turbines was given by Wright in the 1976 conference.[4] Despite some duplication, it is worth reiterating the salient points and relating these to present policies on engine overhaul and life, on which are based the need for further engine development, modifications, overhaul facilities, installation design, and engine health monitoring requirements.

The R.N. approach to upkeep has been based on the following considerations:

(*a*) The overriding importance of avoiding serious breakdown, with possible mission failure and extensive engine damage.

(*b*) The difficulty of assessing engine condition *in situ* despite endoscopes and other aids to health monitoring.

(*c*) The difficulty of carrying out any but the most superficial stripping in place, and the special experience, training and equipment needed to do this correctly.

Incipient defects have been discovered in some engines returned for overhaul, which were completely unsuspected despite rigorous inspection in the ships concerned. Full stripping in an overhaul facility was the only way that these could possibly have been revealed.

There has therefore been a strong reluctance to attempt a policy of overhaul on condition, and the policy is to start with a fairly conservative life between overhauls, expressed in terms of running hours, and gradually to extend this on a carefully established basis.

This policy also has the advantage that planning of the utilization of overhaul facilities, and supporting spares, is made easier. More frequent opportunities may also be made to update the modification state of engines.

The original planned overhaul lives of the Tyne and Olympus were proved by endurance testing at NGTE Pyestock under realistic operating conditions and a simulated marine environment. These lives have since been extended on the following basis:

(*a*) The reliability of the original life must be proved by significant operating experience at sea, supported by subsequent satisfactory strip inspections.

(*b*) For minor extensions of overhaul life (e.g. by 500 hours), sample engines are given an intensive *in situ* inspection at expiry of their normal life, and they are then run on. A special strip examination is given at the next overhaul.

(*c*) For major extensions (e.g. by some 2000 hours), engines must incorporate a specified package of design improvements arising from the development programme. The proposed extension must also be proved as originally by shore endurance testing.

A time and cost saving interim step has been the return of engines for only limited refurbishment, when the life-limiting items are replaced. The final objective is to eliminate all such limited items within the planned life, which the Royal Navy intend to extend so that replacement will not normally be required between ship refits.

From the first introduction of aero-derived gas turbines to R.N. service, it has been the intention that onboard maintenance operations on engines would be minimized. Experience has shown, however, that many minor defects can very easily be repaired by the ship's staff *in situ*, provided that the necessary parts and work instructions are available. This is mainly applicable to accessible ancillary items such as fuel pumps, starter motors, and on-engine instrumentation. To avoid unnecessary exchange of engines or prolonged loss of availability, studies have been carried out to identify work which is within the capability of the ship's staff without the need for special skills or equipment, and to supply the supporting parts, assemblies, and repair instructions. A similar exercise has been carried out for work by Dockyard staff.

Engine Health Monitoring

It has been the aim to give ships of the Royal Navy the means themselves to detect the development of serious incipient defects, and the means to detect significant loss of performance in their gas turbines.

At present these means comprise the fitted instrumentation including vibration monitors, magnetic chip detectors, and endoscopes for internal inspection, with the necessary package of instructions and guidance on their use and interpretation.

Ships also have the support from shore of a naval COGOG propulsion specialist team, a naval vibration analysis team, and the advice of a laboratory specializing in the rapid analysis of lub. oil from operational engines by spectrometric means and ferrography (the Naval Air Materials Laboratory at

Fleetlands, Gosport). However, as Commander T. Jefferis pointed out at the 1978 Gas Turbine Conference[3], shore support may quite possibly not be available in a useful timescale.

The Royal Navy are therefore investigating equipment which could be carried in ships, which would be simple both to use and to interpret, to strengthen their EHM capability. The first device of this kind is a tester to quantify the debris collected by magnetic plugs, which by simple trend analysis can indicate increased wear rates.

As sea experience with aero-derived gas turbines accumulates, the possibility of special techniques to monitor particular life-limiting features is attractive.

Accurate measurement of engine performance in a ship, with the comparatively simple instrumentation normally available has proved difficult to achieve without an unacceptable burden on staff. The need to correct for ambient conditions is a complication fairly easy to overcome; the need for accurate and consistent instrumentation is more difficult to achieve. Means of improving performance measurement are being investigated; the microprocessor offers a very suitable means of storing and processing the relevant information, but the sensors and transducers needed to provide data reliably and without elaborate routines to maintain accuracy are a greater problem.

Conclusion

The gas turbine is rapidly becoming the dominant means of propulsion in surface ships of the Royal Navy, a trend emphasized by the introduction of the ASW Cruiser and Type 22 frigate, and the development of the SM1A Marine Spey for ships in the 1980's. The success of this means of propulsion has been long established; further refinements in installation design and ship application and in upkeep methods will be needed to realize the full potential of this type of machinery.

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Any views expressed are those of the author and do not necessarily represent those of the Ministry of Defence.

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