Gas Turbine Powered Blue Riband Winner

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ABSTRACT

The high speed yacht "Gentry Eagle" has set a new record for Atlantic Ocean crossing plus two other speed records. The British built, United States owner 110 ft. craft is powered by two diesels and a centerline 4,000 hp marine gas turbine.

The paper will describe all the power plants and the propulsion system for each. Gas turbine mounting, control, inlet and exhaust treatment, and operating scenario will be covered. Craft details will be included.

History of the vessel including performance and speed run details will be noted.

MACHINERY DESCRIPTION

Gas Turbine

The gas turbine used in the craft was a Textron Lycoming TF40 marine gas turbine (Figure 1), similar to that used in the United States Navy LCAC production Hovercraft. The engine consists of a seven stage axial flow, single centrifugal flow compressor, reverse flow annular combustor, two stage compressor turbine and a two stage power turbine. The engine is 55.7 in. long, 34.6 in. wide and 44.3 in. high, weighing 1325 lbs. The engine weight includes standard automotive starter and a 12 gallon sump. The continuous hp rating is 4000 shp, maximum rating is 4600 shp (rating conditions: 1.S.O.).

The engine inlet housing provides cantilever mounting of the compressor - turbine section and also supports the 12 gallon oil sump and accessory gearbox. The engine starter, fuel pump, oil pump and fuel valve-actuator assembly are mounted on the accessory gearbox. The inlet housing front cover supports the output shaft bearings and provides a piloted flange to mount the entire engine close - coupled to the reduction gear. Reduction Gear - The reduction gear provides a 7.65:1 to reduce power turbine speed to 2013 rpm for propeller drive. The first mesh of the gear set is a double helical, 2.34 ratio gear with an overrunning clutch on the low speed shaft. The gear assembly contains its own oil system including raw water heat exchanger, pumps, filters, chip detectors and instrumentation. Gearbox weight is approximately 2000 lbs.

The reduction gear case provides large pads on either side at the output shaft centerline for mounting to the hull longitudinal members. Since propulsion thrust is contained within the propulsor assembly, there is no thrust transmitted by the gear mounts to the hull.

Engine Control System

The control system consists of an instrument panel, electronic control box, engine mounted electrical accessories and interconnecting cables. The instrument panel displays engine rotor speeds and temperatures plus various lighted legends. The electronic
control box schedules automatic starting, provides warning and shutdown signals, drives all instruments and processes power control signals. Power control is provided by a throttle potentiometer on the instrument panel which operates to select gas generator speeds. The output shaft (power turbine) speed governor is used in a topping or overspeed mode only.

Inlet/Exhaust

The engine inlet system consists of simple ducts from each side of the inlet housing, rising vertically through the engine room overhead to a two stage inlet filtration system mounted on the after deck. The engine exhaust system consists of an engine mounted stub tailpipe exhausting into a larger, diffusing pipe through the upper portion of the craft transom. A simple watertight door is used as a closure when the turbine is not operating. An insulated outer shroud is installed between the engine fire shield and exhaust exit.

Diesels

Outboard of the centerline mounted turbine are two M.T.U. model 16V 396 TB94 sequentially turbocharged diesels. Each diesel is rated at 3480 shp. Each diesel is 154 in. long, 72 in. high and 55 in. wide, weighing 16,700 lbs., including gearing. The diesels were installed at the shipyard in the United Kingdom. The craft underwent builder's trials on diesels alone at that time.

It was decided to install the centerline gas turbine system after delivery to the owner at a United States shipyard. Allen Industries, Inc., Seattle, Washington was selected as system supplier and undertook to deliver the engine, reduction gear, control system, and Arneson propeller to Connor Marine, Costa Mesa, California. Connor Marine fabricated a mockup of the engine room in order to devise the inlet, exhaust, and propeller mounting system. Engine, gear, propeller and all the fabricated items from the mockup were then shipped to a shipyard in Florida to meet the craft upon arrival in the United States. The installation of all items of the turbine system into the craft engine room required ten days.

**FIGURE 1A** TF40 INLET DUCTS CENTERLINE LOOKING AFT

**FIGURE 2** "GENTRY EAGLE"

**PROPELLOR DESCRIPTION**

**General**

The "Gentry Eagle" is propelled by twin "wing" diesels driving Model S63S KaMeWa water jets used in combination with the single Textron Lycoming TF40 turbine driving a model ASD16 Arneson surface drive (Figure 2).

**The Water Jets**

Reduction gear ratio of 1.87:1 on the ZF BU7755 gear boxes give a maximum final drive speed of 1150 rpm on the water jets. Construction of both water jets and surface drives is of naval bronze in combination with stainless steel for shafting, hinge pins, fittings, hydraulic actuators, and the 32 in. diameter waterjet impellers.

Steering, forward and reverse thrust, is provided through use of conventional buckets which control effective jet thrust by deflection of the jet stream. During low speed handling, such as docking maneuvers, individual controls on each jet allow multi-plane asymmetric thrust for improved lateral control. At cruising speeds, jet thrust is electronically synchronized to maintain a stabilized flight path. Inlet screens normally installed at the mouth of the jet intakes were removed to maximize performance. Although this provided a thrust performance improvement of up to 15 percent, the unobstructed inlets fell prey to everything from logs, tires, plastic garbage can lids and lobster pot floats! Tire removal required vessel haulout - fortunately not encountered during the crossing. Installed weight of each drive, including inlet tube comprised 3100 lbs. not including weight of entrained water (2 tons).

**The Surface Drive**

Both water jets and surfacing drive utilize electronically controlled, hydraulically actuated systems for steering. The Arneson drive steering is normally fixed during vessel operation, its steering cylinder providing only small adjustments for corrections to eliminate steering torque when all three units are in operation. Surface drive 25 degree
vertical trim capability allows entire drive and propeller to be lifted out of the water, thus eliminating attendant drag when not in use. The surfacing propeller is a Model REXP5 Rolls 35 in. diameter, 15 degree, 5 blade cleaver geometry, with unedited cambered sections, with extreme radial pitch variance and annexed trailing edge design. Installed weight of ASD16 Arneson drive is 1815 lbs. Propeller weight is 150 lbs.

CRAFT DESCRIPTION

The Gentry Eagle, designed specifically for the Transatlantic challenge is considered today to be the largest ever race boat, and with the 62 hour, 7 minute, 47 second crossing, it is the fastest vessel of its type ever constructed.

Figure 4 shows the Eagle under construction in 1987 at the Vosper Thornycroft Shipyard in Portsmouth, United Kingdon. General specifications are as follows:

Vessel Design: Peter Birkett
Builder: Vosper Thornycroft (UK) LTD.
Length, overall 109.9 ft. (33.5 meters)
Maximum beam 24 ft. (7.3 meters)
Deadrise 18 degrees
Hull V bottom, aluminum, fully welded
Wheelhouse Welded aluminum framework, rivet-bonded skin
Fuel tanks Combination integral and flexible fuel cells with capacity of 16,000 gallons (50 tons)
Accommodations Shower, toilet, keyhole bunks for eight
Wheelhouse layout Dual driving station, navigating station, engineer's station off duty seating: four

CONSTRUCTION

Vessel construction is of typical marine 5086 aluminum welded rib and stringer construction with skin thickness ranging from 1/4 inch at keel and hull bottom to as little as .060 in. in wheelhouse superstructure. Placement of 3/16 in. t-section transverse ribs on 16 in. centers are jointed with longitudinal stringers on two ft. centers creating the hull bottom. Skin thickness is 1/4 in. from keel and seven ft. outboard for entire vessel length. Remainder of bottom is 6 NM to chine and 4 NM from chine to sheet. Four 6 x 6 x 1/4 in. lifting strakes further stiffen hull's bottom.
CRAFT PERFORMANCE

Diesels

Initial sea trials were made in England in April, 1988 before turbine installation. Data is summarized below:

Reported Data:

- Vessel weight: 53-1/2 tons
- Engine rpm: 2140
- Jet rpm: 1144
- O.A.T.: 11 degrees C
- Water temp.: 8 degrees C
- Measured speed: 56 kt
- Single engine: 36 kt

According to test reports, the Eagle was able to achieve a planing speed of 36 knots with single engine performance. In subsequent tests at slightly higher gross weights (55 tons) in Florida, the vessel was unable to achieve planing speed. Twin engine performance did confirm 56 knots, even at the higher gross weight.

Turbine and Diesels

Installation of the turbine, surface drive, inlet, exhaust, fuel and electrical system was done after the vessel arrived in Florida. In May of 1988, after completion of initial sea trials, the Gentry Eagle was deck loaded and shipped to South Carolina and then driven to Miami for turbine installation. Construction of a mockup prior to vessel arrival simplified the task. Installation required approximately 500 man hours.

Data shown below:

- Vessel weight: 63 ton 110 ton
- Total HP: 10,800 10,800
- Waterjet rpm: 1,150 1,150
- Prop rpm: 1,970 1,650
- Vessel speed max: 72 Kt 56 Kt
- Prop pitch: 45 in. 45 in.

CROSSING DESCRIPTION

History

The Blue Riband Trophy is awarded to winners of perhaps the oldest ocean race in history; namely the Transatlantic Sea Crossing. From New York Harbor's Ambrose Light to England's Bishop Rock Light, spanning nearly 3,000 nautical miles, this race dates back as far in history as 1838 when the 236 ft. English steam-powered ship "Great Western" covered the distance in just over 12 days, averaging 10 knots. Since then the record has been broken 39 times with such vessels as the Lusitanis, Mauretania, Normandy, Queen Mary and SS United States in the victor's column. In 1986 for the first time in 34 years, England reclaimed the title as "Virgin Atlantic Challenger II" lowered the mark to 80 hours, 31 minutes, covering the distance at 37 knots.

PRELIMINARY RUNS - 1988

In preparation for the 1988 record attempt, the Gentry Eagle set two speed records. On June 3 the 362 mile Miami-Nassau-Miami record was raised to 52 Kt, beating the old record by 50 minutes. On June 10, the Eagle captured the Chapman Trophy by setting a new Miami-New York speed record, covering the 1257 mile distance in 19 hours, 17 minutes and 27 seconds, averaging over 56 knots.

On July 24, 1988, after a month and a half delay while waiting for sea conditions to improve, the Gentry team at last launched their assault on the North Atlantic. The anticipated weather window failed to materialize and the four to six ft. sea conditions worsened. The waves grew steadily until they reached 15 to 20 feet. Some 1400 miles into the 3400 mile trip, sea water contaminated the fuel because of stress leaks in the boat's bottom. A spray strake ripped from the bottom and was ingested in a water jet intake. Less than half the electronic gear was working. Removing the spray strake required three separate attempts in 15 ft. seas. Due to the doubtful success of the mission, it was decided to abandon the attempt, return to port and reschedule the effort for the following year.

THE RECORD RUN - 1989

Exactly one year to the day, July 24, 1989 at 8:49 EDT, the Eagle departed Ambrose Light at 50 knots, headed for England. This year weather was picture perfect. Calm seas prevailed throughout the journey. Estimated maximum wave height of six feet was seen for only six of the 62 hour crossing. Diesel engine rpm was set at 1950 corresponding to 3000 hp per side. Turbine rpm was at 98 percent gas producer speed, also providing 3000 hp. Average fuel consumption for the trip was 434.8 gallons per hour for the 62 hour, 7 minute, 47 second crossing. "Destiny" loaded 13,948 gallons of fuel at the half-way point in just 52 minutes! Vessel speed averaged 48 knots for the entire trip. The time to cross was reduced by 18 hours and 23 minutes, knocking nearly 23 percent off the old mark. Figure 5 shows the different courses
plotted in 1988 and 1989. The decision to take a more southerly course was made to miss reported fog, icebergs and growler sightings southeast of New Foundland. Control centers in Greenwich, Connecticut and Isles of Scilly, England, maintained hourly contact with the Eagle team. Constant plots of progress, fuel consumption, weather conditions and crew well-being were maintained. The turbine engine ran all but the last few hours of each leg being shut down to conserve fuel on leg one when calculated flows indicated greater consumption than was actually realized. On leg two, the second half, turbine use was discontinued when following sea conditions hindered maximum speed potential. Operating 52 of the 62 hours crossing the turbine did contribute significantly to what is now a truly difficult record to better.

FUTURE ATTEMPTS

As of this writing, at least four countries and a half-dozen vessel designs are in work the the goal of breaking this new Atlantic Challenge record. All new efforts are being planned around non-stop crossing attempts. In all but one instance, this will involve larger craft and more hp. Most all designs are based upon gas turbine power. Being considered for propulsion among various groups are: waterjet, surfacing drives and a newly developed controllable pitch surfacing drive system. Vessel lengths of over 200 feet with turbine power totalling over 30,000 hp are on the drawing boards. It seems certain the oldest powerboard race in history will sponsor still more innovations in high performance watercraft as men and their machines try to break the record held by the Gentry Eagle.