NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C.

September 10, 1999

POWERPLANTS GROUP CHAIRMAN'S FACTUAL REPORT

NYC99MA178

A. ACCIDENT

Location:	Near Martha's Vineyard, Massachusetts
Date:	July 16, 1999
Time:	About 2141 Eastern Daylight Time
Airplane:	Piper PA-32R-301, Saratoga II, N9253N

B. POWERPLANT GROUP

Jerome D. Frechette Group Chairman	National Transportation Safety Board Washington, D.C.
Edward F. Malinowski	National Transportation Safety Board Chicago, Illinois
Rocco Viselli	Federal Aviation Administration Valley Stream, New York
Ronald Fosnot	Federal Aviation Administration Vandalia, Ohio
Gregory Erikson	Textron Lycoming Wayne, Illinois
James Brown	Textron Lycoming Williamsport, Pennsylvania
Jay Wickham	Mattituck Aviation Corporation Mattituck, New York
Tom McCreary	Hartzell Propeller Piqua, Ohio
Paul Lehman	New Piper Aircraft, Inc. Port St. Lucie, Florida

C. SUMMARY

On July 16, 1999, about 2141 eastern daylight time (EDT), N9253N, a Piper Aircraft PA-32R-301, Saratoga II airplane, crashed into the Atlantic Ocean approximately 7½ nautical miles southwest of Gay Head, Martha's Vineyard, Massachusetts. The pilot was operating under 14 Code of Federal Regulation (CFR) Part 91 on a night, personal flight from Essex County Airport (CDW), New Jersey, to Vineyard Haven Airport (MVY), Martha's Vineyard. No flight plan had been filed. The pilot and two passengers were fatally injured and the airplane was destroyed. There was no fire.

The U.S. Coast Guard (USCG) and Massachusetts State Police conducted a sea and air search for the airplane and passengers. The U.S. Navy and the National Ocean and Atmospheric Administration (NOAA) conducted the underwater search and recovery. The airplane wreckage was recovered from a depth of about 120 feet on July 21, 1999, and delivered to a hangar at the USCG Air Station (CGAS) Cape Cod, Massachusetts for examination.

The examinations of the engine and propeller by the Powerplant Group did not disclose any preexisting failures or conditions that would have prevented normal engine operation. Further, the investigation team found impact marks on one of the propeller blades and the top of the engine, witness marks inside the propeller, and the engine controls and instruments in the cockpit that indicated high engine power output.

At the conclusion of the examinations at Textron Lycoming and Hartzell Propeller, the parts were returned to the hangar with the other wreckage of N9253N at CGAS Cape Cod. This report summarizes the Powerplant Group's examinations of the engine and propeller at CGAS Cape Cod, Massachusetts and at their respective manufacturers.

D. DETAILS OF THE INVESTIGATION

The Powerplant Group was formed to document the condition of the engine and propeller. The group conducted an external examination of the engine and propeller on July 24, 1999, at the USCG hangar. The group also conducted a teardown examination of the engine at Textron Lycoming, Williamsport, Pennsylvania, and the propeller and propeller governor at Hartzell Propeller, Piqua, Ohio on July 26, and July 28, 1999, respectively.

1.0 ENGINE DESCRIPTION

The airplane was powered by a Textron Lycoming IO-540-K1G5 engine. The IO-540 is a fuel-injected, horizontally opposed, six cylinder, air-cooled, piston engine with a displacement of 540 cubic inches. The engine rotates clockwise[1] and is rated at 300 shaft horsepower at 2,700 rpm. The engine's minimum and maximum rpm, oil temperature, oil pressure, and fuel injector inlet fuel pressure operating limitations are 500 to 2,700 rpm, 75 to 245 degrees Fahrenheit (F), 55 to 95 pounds per square inch (psi), and 20 to 40 psi, respectively.

2.0 PROPELLER DESCRIPTION

The Hartzell HC-I3YR-1RF/F7663DR propeller, is three-bladed single-acting, constant

[1] Engine rotation is viewed from aft looking forward.

speed (variable pitch) non-feathering, non-reversing propeller. The propeller has three forged aluminum alloy blades and a hub. The hub retains the blades and houses the pitch-change mechanism. The piston and cylinder assembly, mounted on the front of the hub, vary the blade angle through a pitch-change fork unit and a knob at the base of each blade root.

The propeller is hydraulically controlled by governor oil pressure acting on the hydraulic servo piston against the forces of the blade's twisting moment and spring. An increase in the oil pressure moves the hydraulic servo piston aft (toward the hub), against the twisting and spring forces, rotating the propeller blades toward high pitch. A decrease in the oil pressure allows the hydraulic servo piston to move forward, which rotates the blades toward low pitch. The maximum blade pitch angle is 32.0 degrees +/- 1.0 degree, the low pitch stop is 12.4 degrees +/- 0.2 degree, at the 30-inch reference station.

3.0 ENGINE AND PROPELLER HISTORY

No maintenance records were obtained from the owner/operator. The following model numbers, serial numbers, and hours of operation for the engine and propeller were obtained from the maintenance records at Mattituck Aviation Corporation or the individual components:

Engine model	IO-540-K1G5
Engine Total Time	663.5 Hours #
Engine Time on May 22, 1998	387.1 Hours @
Engine Serial number	L-25552-48A
Propeller Model	HC-I3YR-1RF/F7663DR
Propeller Total Time	663.5 Hours #
Propeller Serial Number	HK63A

Hours from accident airplane's engine tachometer.
* The engine was manufactured at Textron Lycoming on March 30, 1995, and installed on N9253N at the Piper Aircraft Company on January 5, 1996.
@ The cylinders were removed on May 22, 1998, at Mattituck Aviation Corp, Mattituck, New York, to comply with a Textron Lycoming service bulletin. Corrosion was subsequently discovered inside the engine. Maintenance records indicate that Mattituck Aviation disassembled the engine, bored the cylinders, and reassembled the engine with new rings, camshaft, and several new valve tappets.

E. ON-SITE INVESTIGATION

Side scanning sonar images discovered the airplane wreckage at the depth of approximately 120 feet, along a path about 120 feet long. Remotely operated vehicle (ROV) video images revealed that the engine was separated from the engine mount; it was attached to the firewall by engine control cables. The ROV images also revealed that one of three propeller blades had separated from the propeller hub and the propeller was separated from the engine. U.S. Navy divers recovered the engine and propeller on July 21, 1999. The examinations of the engine and propeller took place approximately three days after their recovery from the Atlantic Ocean.

1.0 ENGINE

The engine was separated from the engine mount truss. The structural tubing on the right side of the engine mount truss was missing. The engine mount truss was deformed to the right and fractured in numerous locations. The upper left, and both lower mount ears on the engine were fractured. The upper right engine mount ear was bent.

The tops of the Nos. 1, 3 and 5 cylinder heads[2] had missing components and displayed a line of damage parallel to the engine's longitudinal axis. The missing components were the No. 1 cylinder's rocker box cover, rocker arms, rocker shaft, and top spark plug; and the No.1 and 3 cylinder's shroud tubes and push rods were separated from the engine. The cooling fins along the top of the cylinder heads were crushed, cracked, and splayed apart; and the push rods and shroud tubes on the No. 5 cylinder were severed.

The engine displayed impact damage but no fire damage. The engine's fuel pump and oil sump displayed widespread erosion and partial disintegration, consistent with saltwater corrosion. Approximately four inches of the engine tachometer drive cable remained attached to the engine. The cable was twisted and curled along its four-inch length. The throttle, governor and mixture control cables and lines to the left oil cooler were cut by the Powerplant Group to facilitate examination.

The propeller, engine cowling, right oil cooler, alternator, air conditioning compressor, fuel injection servo, No. 1 exhaust tappet unit socket, No. 1 and 3 hydraulic tappet units, Nos. 1, 2, 4 and 5 intake manifolds, Nos. 1, 3 and 5 exhaust manifolds, and a portion of the right magneto were separated from the engine. The propeller, right oil cooler, alternator, air conditioning compressor, and fuel injector servo were recovered. The left and right oil coolers were crushed. Approximately 30 to 40 drops of fluid was drained from the fuel injector servo. The fluid had the appearance, texture, and smell of gasoline and was later discarded.

The propeller governor, engine starter, vacuum pump, left magneto, engine driven fuel pump, and fuel injection spider remained attached to the engine. The vacuum pump was removed for examination by the Airworthiness Group. The vacuum pump drive was intact. The starter ring gear support assembly was fractured, the ring gear was distorted, and the crankshaft flange was bent. The oil filter housing was fractured from its mounting flange and the oil filter was crushed. The oil fill tube and dipstick were fractured. The No 3 intake manifold pipe was crushed and torn. All the cylinder head drain tubes and the No.2 cylinder intake and exhaust shroud tubes and push rods were damaged.

The high-tension wiring harness was damaged and found severed at numerous locations. The high-tension leads were severed from all the spark plugs except the No. 4 top plug. The Nos. 1, 2, 3, and 6 injector lines were separated from their respective nozzles and the No.'s 1, 2, and 3 injector nozzles were separated from their respective cylinders. The top and bottom spark plugs in cylinders 2, 4 and 6 and the bottom plugs in cylinders 1, 3, and 5 were in place and intact. The top plugs in cylinders 3 and 5 were fractured. The spark plugs were removed and visually examined. Pressurized air escaped from the No. 6 cylinder during spark plug removal. All examined spark plug electrodes were salt water-soaked and coated with a white sludge; otherwise

[2] Cylinders on an IO-540 engine are numbered from 1 through 6 from front to rear as they are installed on the crankshaft. As a result, odd numbered cylinders are on the right side of the engine and even numbered cylinders are on the left.

all electrode ends appeared to be in serviceable condition. The examined spark plugs were sprayed with oil as a corrosion preventative and reinstalled.

2.0 PROPELLER

Each propeller blade was retained in their respective hub sockets; however, one blade was noted to be fractured in the shank area. The propeller hub mounting flange was fractured; otherwise the hub was intact. Two pieces of the propeller spinner dome remained attached to the spinner bulkhead around the cutouts of the No. 1 and 2 blades[3]. The remaining portion of the dome was separated and not recovered or identified. The spinner bulkhead was bent aft and all the dome screws remained in place. The bending damage to the blades is documented in the teardown section of this report.

F. ENGINE AND PROPELLER TEARDOWN

The engine was disassembled at Textron Lycoming, Williamsport, Pennsylvania, and the propeller and propeller governor at Hartzell Propeller, Piqua, Ohio on July 26, and July 28, 1999, respectively.

1.0 ENGINE

The propeller was manually placed in front of the engine such that the leading edge of the No. 1 blade was aligned with the line of damage on the tops of the right cylinders. The nicks, contour and indentations on the leading edge of the propeller matched the contour of the line of damage on the tops of the Nos. 1, 3, and 5 cylinders.

The mount pad, shaft and rotating magnet of the right magneto was in place on the engine. The body of the right magneto was missing and never recovered. The drive cushions to both magnetos were in place and intact. The left magneto was in place and intact; however, all the high tension leads were severed at the distributor cap. The ignition timing of the left magneto could not be determined; however, the magneto's installed position appeared similar to other properly timed magnetos. Manual rotation of the left magneto activated the impulse coupling and generated a spark between the center of all six high-tension leads and their respective braided wire shielding.

A test harness was installed on the left magneto, and the magneto was bench-tested. The magneto failed to generate sparks across a 1/8-inch gap during the bench test.

The fuel injector servo was received detached from the engine and missing its idle mixture lever. The fuel injector servo filter screen was removed and inspected; no contamination was noted. Rust-colored water filled the fuel filter cavity. Inspection of the flow divider revealed that the diaphragm was intact, the stem worked freely, and that the divider was filled with fluid that smelled like gasoline.

The oil filter was cut open and the oil filter element was free of contamination. The oil suction screen was removed and inspected with no contamination noted. Rust-colored water filled the oil cavity. The oil pump body, splines, drive and driven gears were in operable condition

[3] Blades on this propeller are numbered 1 through 3 to coincide with the markings on the hub.

and the pump rotated freely by hand. The forward induction section of the oil sump was eroded away exposing the crushed and torn No. 2 intake tube. The sump was free of metallic contamination with the front brackets to the oil sump baffle collapsed.

The external damage to the cylinders and cylinder heads were described above. An attempt to rotate the crankshaft with a hand tool following the removal of each cylinder and piston revealed that the crankshaft was not free to rotate until all the cylinders and pistons were removed from their installed positions.

The heads of each piston and the intake and exhaust ports in each cylinder were coated with a layer of moist white sludge. The cylinders and pistons were disassembled and the sludge was removed with a solvent. The piston rings, wrist pins, plugs, intake and exhaust valves did not exhibit any evidence of abnormal wear or operation. The cylinder walls of all six cylinders were cross-hatched,[4] Nitrided,[5] and did not exhibit any evidence of abnormal wear or operation.

The accessory case was removed to expose the oil pump and the accessory- and cam-drive gears. The accessory- and cam-drive gears were in place and intact. Rotation of the crankshaft revealed that the camshaft and accessory gear timing marks were properly timed and did not exhibit any evidence of abnormal wear or operation. The crankcase and crankshaft assembly were intact when disassembled. The case halves, crankshaft, camshaft, main bearings, connecting rods, and connecting rod bearings did not exhibit any evidence of abnormal wear or operation. The nose (front) seal was smeared with room temperature vulcanizing (RTV).

The following table summarizes part numbers, serial numbers and other numbers found on the major parts or components:

Component - (Make)	Part Number	Serial Number	Other Numbers
Propeller governor - Hartzell	V5-4	A867J	PC10
Left magneto-Slick 6351	66LC35SDNN	94030012	
Right magneto-Slick 6350	66LP-0SCNN	95020037	
Fuel servo unit - Precision	RSA-10ED1	70102002	2524273-12
Flow divider - Bendix	2524232-2	0101133	
Fuel pump - AC	154737411	Not available	
Spark Plugs - Champion	REM 38 E		
Starter - Prestolite	MZ 4218		
Alternator	Not available		
Crankcase	11F20020-S3		1847 (match No.)
Connecting rod bearing	74309		
Exhaust rocker arms	21185		
Intake rocker arms	21186		
Front main bearing	LW-13885		
Counterweights	LW-19210		

[4] Cross-hatching on the inside wall of the cylinder describes the crisscrossing marks left by the honing process. The marks provide a roughness that holds oil during the break-in period without sacrificing adequate smooth bearing surface for piston rings.
[5] Nitriding is a case-hardening process in which the surface of the steel is changed by the infusion of ammonia gas. While in a furnace, the ammonia gas (NH3) disassociates into nitrogen and hydrogen allowing the nitrogen to combine with the aluminum in the steel cylinder to form aluminum nitrides, which are hard and wear-resistant. Aluminum is used as an alloying agent in the steel cylinder.

Connecting rod	LW-19332	
Main bearing	LW-13683	
Tappet body	72877	
Intake valve	LW-13622-AC B-R09255	
Exhaust valve	LW-16740 NA-R04240	
Oil pump body	78531	
Oil pump gears	LW-18109, LW018198	
Crankshaft	13F27727	V15995
Camshaft	LW-13908 LW-19340 ASS'Y	
Plunger	SL-78290-AP	
Cylinder	LW-12993	
Piston	L-10207	

2.0 PROPELLER

The propeller was disassembled, and examined at Hartzell Propeller and the findings analyzed by Hartzell engineering to help determine engine power output at the moment of impact. The power at impact can sometimes be analytically approximated if certain parameters are known such as engine rpm, aircraft speed, atmospheric pressure and temperature and propeller blade pitch angle. Propeller blade pitch angle can be obtained from witness marks that were formed inside the propeller during the impact sequence. These witness marks are used to approximate a corresponding ($\beta 30$)[6] for each blade. It must be noted that rpm, airspeed, and atmospheric conditions must be assumed or approximated in the absence of hard data and that the horsepower calculations use a computer model based on theoretical blade pitch angles in undisturbed airflow (normal to plane-of-rotation), constant rpm, and uniform atmospheric conditions.

The majority of the hub's, S/N A29964A, mounting flange was fractured around the circumference. The majority of flange material surrounding each bolt hole was missing. The fractured edges of the flange in the vicinity of the bolt holes were deformed toward the engine. The hydraulic actuating cylinder (S/N E8625) was in place and intact. Trace amounts of water and no significant amount of oil was found in the cylinder. The forward end of the cylinder was deformed inward on one side. The surface of the cylinder was wrinkled in the deformed area. The spring had corrosion, otherwise appeared to be in serviceable condition. The pitch-change rod also had corrosion and was slightly bent. One of three Delrin[7] bushings on the pitch-change fork were crushed.

The preload plates had witness marks in the vicinity of the knob cut-outs. The witness marks were square-shaped and matched the dimensions of the pitch-change knob end caps. The angles for each preload plate formed by the witness mark, the center of preload plate, and the hub split-line were calculated by Hartzell engineering and are shown below:

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[6] $\beta 30$ refers to the angle of the blade chord line at the 30-inch reference station relative to the plane-of-rotation of the propeller.

[7] A Delrin bushing is a button-sized and -shaped polyethylene bushing, attached to the pitch-change fork, that prevents metal-to-metal contact of the fork and preload plate.

Propeller Blade Witness Mark Angles. Propeller S/N HK63A

Preload Plate	Mark relative to Split-line	Mark relative to β30
No. 1	11°/12°	34°/33° *
No. 2	14°/18°	31°/27° *
No. 3	12°	33° *

* The preload plate rotated to its maximum pitch stop corresponds to a β30 of 32 degrees.

The No. 1 blade, S/N H74480BV, was rotated within its socket to the approximate (-)60-degree position,[8] bent aft 5 to 10 inches from the blade butt approximately 65 degrees, and twisted toward low pitch. The No. 1 blade had four semi-circular indentations in the leading edge located at 5, 7, 11¼, and 13¼ inches from the tip. The pitch-change knob had been sheared from the surface of the blade butt.

The No. 2 blade, S/N H74481BV, was fractured 5½ inches from the blade butt. The fracture surface was granular and irregular across the surface. The No. 2 blade was rotated within its socket to the approximate (-)27-degree position, bent aft 5 to 10 inches from the blade butt approximately 40 degrees, bent an additional 60 degrees at 2/3-span, and twisted toward low pitch. The pitch-change knob had been sheared from the surface of the blade butt.

The No. 3 blade, S/N H74477BV, was rotated within its socket to the approximate (-)210-degree position, bent aft 5 to 10 inches from the blade butt approximately 50 degrees, bent aft an additional 90 degrees 6 inches from the tip, and twisted toward low pitch. The pitch-change knob had been sheared from the surface of the blade butt.

Airplane speed, ambient temperature, and pressure data collected by the Safety Board during the accident investigation was provided to Hartzell engineering to calculate the horsepower required to achieve a β30 between 27 degrees and 34 degrees. Airplane speed was based on a radar data analysis and was estimated to range from 225 to 250 knots. The ambient temperature and pressure was standard sea level conditions plus 16 degrees F. Engine rotational speeds were based on possible cruise rpm settings between 2,300 and 2,600, and a maximum setting of 2,700 rpm. An engine rotation speed of 2,750 rpm was included based on the engine rpm gauge reading recovered from the accident airplane. Hartzell engineering limited β30 between 26 and 32 degrees based on the maximum pitch stop of 32 degrees.

The following table shows the engine horsepower required and the thrust output of the HC-I3YR-1RF/F7663DR propeller for the range of airplane and engine rotational speeds provided to Hartzell engineering:

[8] The blade rotation angle refer to angle formed by the chord angle at the 30-inch reference station relative to the propeller's plane-of-rotation. Minus indicates a negative angle-of-attack relative to the propeller's plane-of-rotation.

Propeller Model: HC-I3YR-1RF/F7663DR										
Flight Condition: Sea Level, ISA + 16 deg. F					Data Analytically Estimated					
Blade Angle @ 30 in. radius			26 Deg.		28 Deg.		30 Deg.		32 Deg.	
			HP	Thrust (lb)	HP	Thrust (lb)	HP	Thrust (lb)	HP	Thrust (lb)
	2750 RPM	225 Ktas	285	384	437	602	599	806	770	998
		240 Ktas	191	213	345	443	512	659	688	861
		250 Ktas	126	94	279	333	449	559	629	766
	2700 RPM	225 Ktas	243	322	387	533	542	738	704	927
		240 Ktas	152	154	297	377	457	592	626	739
		250 Ktas	90	35	233	269	395	492	569	701
	2600 RPM	225 Ktas	168	207	294	404	432	595	578	779
		240 Ktas	85	41	209	253	350	454	503	649
		250 Ktas	28	-78	149	146	291	357	448	559
	2500 RPM	225 Ktas	105	100	213	286	335	464	465	637
		240 Ktas	29	-65	133	137	256	328	392	510
		250 Ktas	-20	-184	78	32	200	232	338	422
	2400 RPM	225 Ktas	52	-1	143	177	250	345	366	506
		240 Ktas	-14	-167	69	29	175	211	294	382
		250 Ktas	-55	-289	20	-77	122	116	242	297
	2300 RPM	225 Ktas	10	-97	84	74	176	234	278	386
		240 Ktas	-44	-267	18	-74	105	101	209	265
		250 Ktas	-75	-394	-25	-182	57	7	159	180
		NOTE: @ 32 degree blade angle and a maximum of 300 hp, the operational regime is limited to the f								

The propeller governor was intact. The governor oil filter screen was free of contamination. Residual oil flowed from the propeller governor when the pump was manually rotated. Several small non-magnetic fragments were in the oil. The governor contained a gear-type constant-displacement pump, which was disassembled and inspected. The flyweights, speeder spring, and pilot valve did not exhibit any evidence of abnormal wear or operation. The inside walls of the gear element had scrape marks that extended approximately 25 percent around the circumference of both the driven and idler gear wells. The governor was reassembled and tested for operation on the Hartzell test stand. The test results were as follows:

<u>Propeller Governor Model V-5-4 S/N A867J</u>

Parameter	Specification	Actual
Rpm	2560 +/- 10	2472
Pressure relief	275-300 psi	290 psi
Internal leakage	8 ounces/min.	< 1 ounce/min.
Pump capacity	8-12 gallons/min.	10.8 gallons/min.

[redacted]

Jerome D. Frechette,
Powerplant Group Chairman

9/10/99