

INSIDE: MISS BUDWEISER BARES ALL!

POWERBOAT

THE WORLD'S LEADING PERFORMANCE BOATING MAGAZINE

JULY 2002 | U.S. \$4.50 | CANADA \$7.75 VISIT US ON THE WEB @ <http://www.powerboatmag.com>

THE
FAST
AND
THE
FURIOUS

11
CATS
SHATTER
THE
100-MPH
MARK

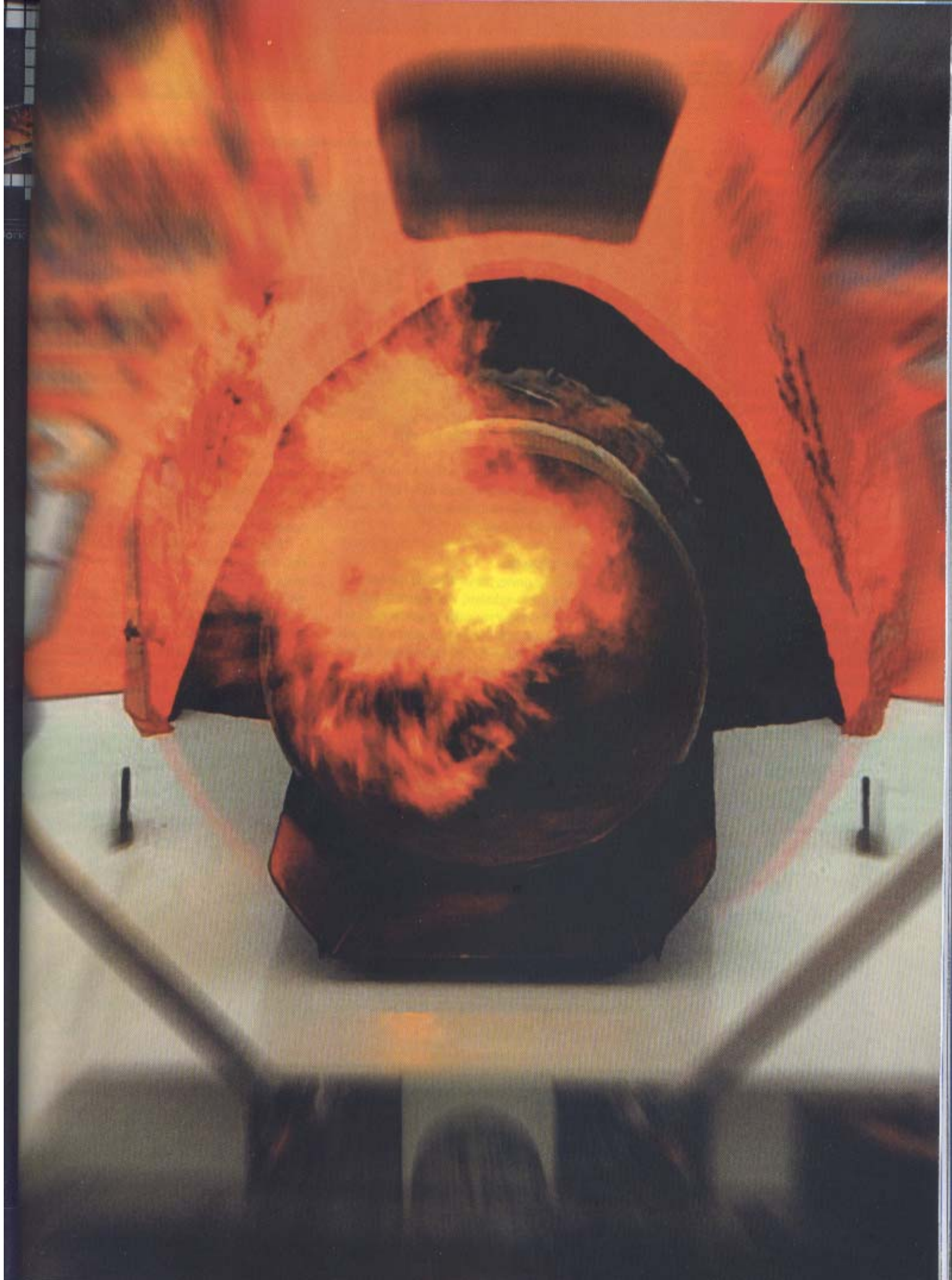
2002 THE BOYS ARE BACK
APFA OFFSHORE BLASTS OFF IN DAYTONA BEACH

SPEED

& technology issue

BUILDING THE PERFECT BEAST: MERCURY RACING'S PRO MAX 300X OUTBOARD • ABSOLUTE POWER:
AN IN-DEPTH LOOK AT WHY THE TURBINE ENGINE IS KING • SENDING SIGNALS: RADIO-CONTROL TRIM







ABSOLUTE POWER

AN IN-DEPTH LOOK AT WHY THE TURBINE ENGINE IS KING.

A typical turbine engine in an Unlimited hydroplane produces something along the lines of 2,650 horsepower and weighs 600 pounds. For comparison, one APBA Offshore Super Cat engine produces around 750 horsepower and weighs about 1,000 pounds. Why such a difference in the horsepower-to-weight ratio?

Volume.

Well, there are lots of factors, but much of it has to do with a turbine engine's properties and how it runs. It still extracts power by vaporizing and burning fossil fuel—suck, squeeze, burn and blow—but it goes about it a completely different way.

"The engine itself deals mainly in volume, not compression," said Butch Coming, a leading turbine engine builder at Competition Specialties in Auburn, Wash. "It's only got a six-to-one compression ratio.

"The major difference between a piston engine and a turbine engine is that a piston engine can only do it [cycle] one at a time within the cylinder," Coming continued. "And on a turbine engine, they have one whole section of the engine that is dedicated to that all the time. The compressor is always compressing. The intake is always drawing and you have continual combustion, and continual exhaust, which is where they extract their power."

STORY BY BRETT BECKER

Opposite: Well, turbines aren't really supposed to blow flames out the back as part of their normal operation, but it sure makes for a good photo. Unburned gases ignite in the exhaust stream of the *Miss Elm Pkcs* Unlimited hydroplane, powered by a T-55 L-7 engine.



Corning spent 13 years in the U.S. Army, 10 of them working on CH-47 Chinook helicopters. The Vietnam War-era twin-rotor Chinook was powered with Avco Lycoming T-55 L-7 turbines, the power plant of choice for Unlimited hydroplanes. The T-55, the T-53 and Pratt & Whitney's PT6 are some of the most popular engines used in marine applications.

"We did one boat with a pair of PT6's, and it was just a little Skater, but for marine installations, we really like the T-55 for the higher horsepower or the T-53 for the little bit lower horsepower applications," said John Cosker of Marine Performance in Port Orange, Fla., which is currently building a couple of twin-turbine-powered boats. "They're about the easiest to start and run. They are, in the end, pretty docile turbines."

As if 2,650 horsepower is ever docile.

The turbine engine's smoothness stems from its design. It's made up entirely of rotating assemblies. Conversely, a typical piston engine contains reciprocating mass, such as connecting rods, pistons, lifters, pushrods, rocker arms, valves and springs, all of which involve back-and-forth movement—and, inherently, vibration.

"When you look at the turbines, they're a very sophisticated, highly-engineered piece of machinery that, first off, has to be dependable," said Ed Mosmiller, president of Integrated Turbine Service LLC in Baltimore. "You just can't have a helicopter falling out of the sky because it dropped a valve or threw a rod or something like that."

TURBINE AND TURBOFAN

One of the myths of Unlimited hydroplanes unravels the first time you see they actually have a propeller. That's because they run on turboshaft engines, which produce "shaft horsepower" not turbofans, which produce thrust.

The difference is that a turboshaft engine spins an output shaft, which can be run through a gear box or transmission to drive a propeller. A turbofan engine runs on the same principle, but creates thrust, which is what pushes a jet airplane. Marine applications—99.9 percent of them—use turboshaft engines, what most people just call turbines.

Before explaining the process of starting a turbine engine, it might be easier to begin with how it runs. Once you have a basic understanding of how air flows through the engine, mixes with atomized fuel and burns, it will be easier to understand how the starting process works.

AIR TRAVEL

A turbine draws air in through the front or, depending on design, through the side or center. It varies with the engine's intended application. Corning's experience lies primarily with the T-55, but all turbine engines function on the same principles.

Air enters the engine, "past an inlet guide vane assembly, which directs the air at the most efficient angle into the first-stage compressor blades,"

Corning said. "When you pass the inlet guide vane, you'll go through seven stages of axial compression."

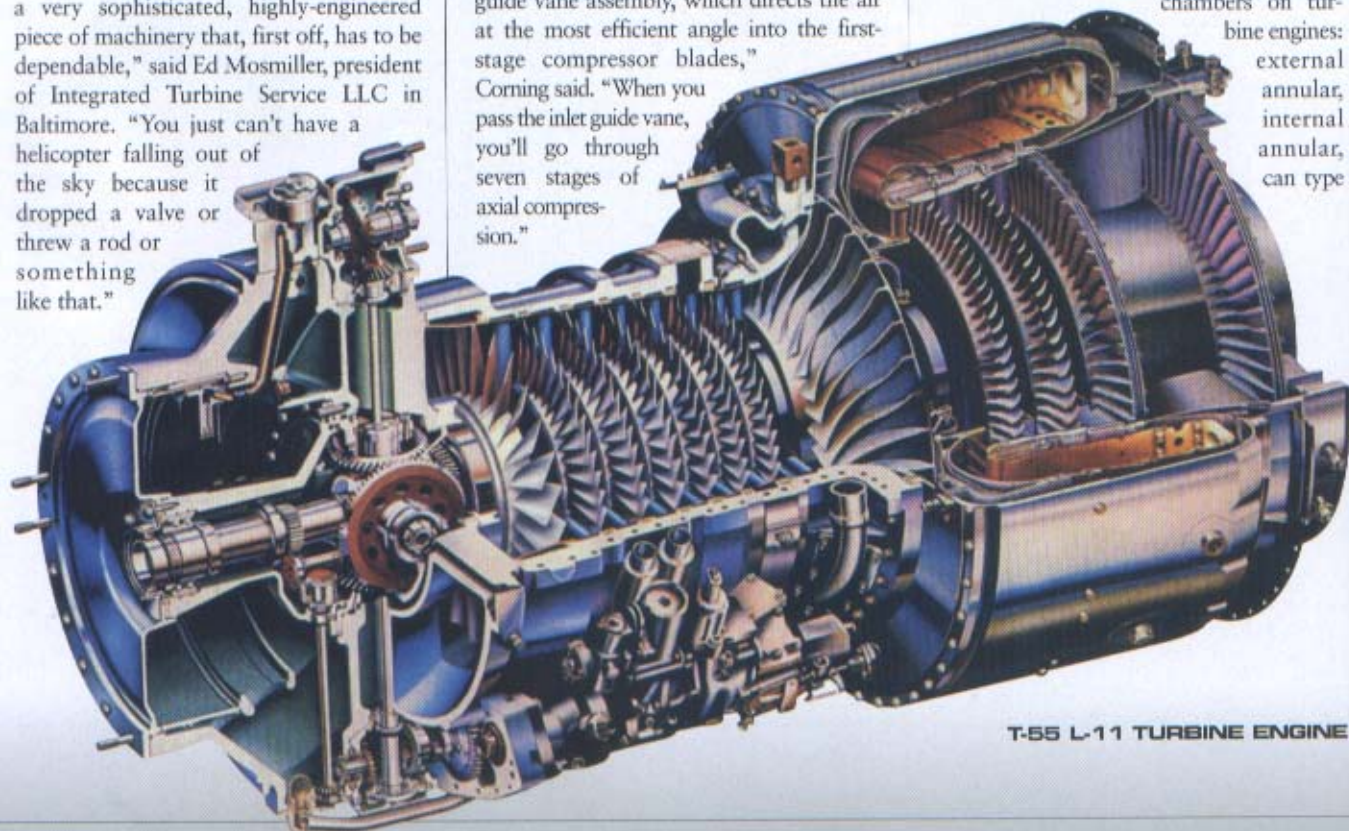
In layman's terms, the air is forced through the compressor section by seven compressor wheels. Think of a compressor wheel as a fan with a large number of angled blades. If you've ever seen the front of a jet engine, you have an idea of what compressor wheels look like. Now picture seven of them rotating in unison on one hollow shaft.

Between each compressor stage is a stationary compressor vane, which is circular, like the wheels, and serves to direct the air at the most efficient angle onto the next stage.

After the seven stages of axial compression, air goes through one stage of centrifugal compression, which actually draws the air up and out to the outer edge of the engine. At this point, the air is moving rapidly out of the compressor section, and is quite agitated. For the engine to work, the incoming air needs to slow and its flow needs to be smooth.

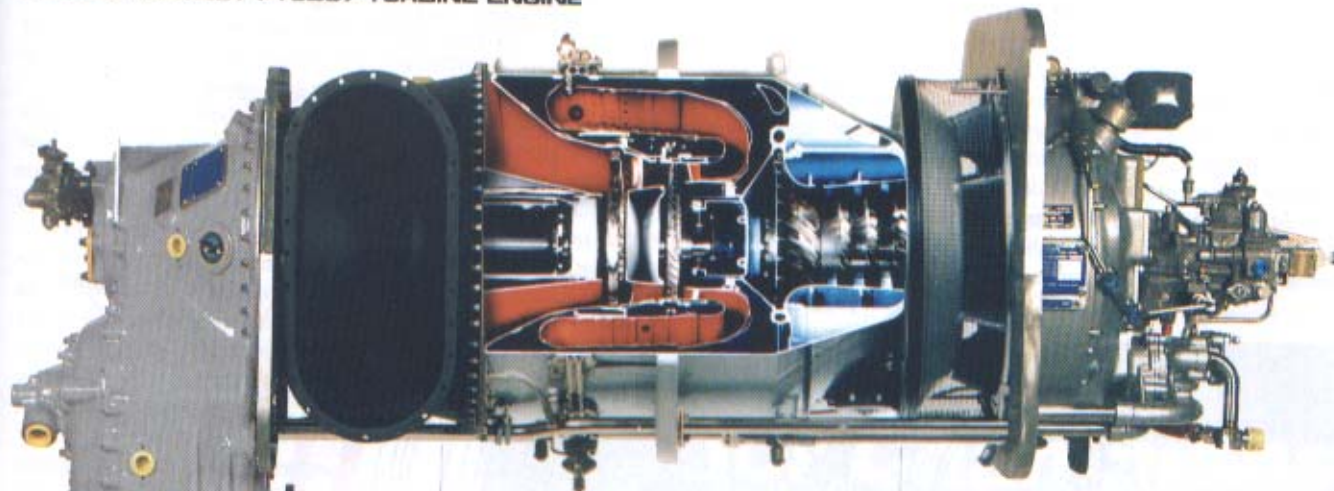
"From there, you'll enter what they call the diffuser assembly," Corning said. "Its main purpose is to slow the velocity of the air and increase the compression. When it exits the compressor, the air is pretty turbulent. It (airflow) goes through these vanes and straightens out as it enters the combustion chamber area."

There are four basic types of combustion chambers on turbine engines:
 external
 annular,
 internal
 annular,
 can type



T-55 L-11 TURBINE ENGINE

PRATT & WHITNEY PT6B37 TURBINE ENGINE



and can annular. Annular simply means that the chamber forms a ring. The T-55 engine has an external annular combustion chamber, which means it surrounds the power-turbine wheel assemblies that actually drive the output shaft. The engine is designed this way because it decreases the overall length of the engine, which was important in its original application.

When the incoming air enters the combustion chamber liner, it changes direction 180 degrees and begins moving forward. It enters the combustion chamber liner through about a thousand small holes, which vary in size from an eighth-inch to a quarter-inch.

As the incoming air "bleeds" into the combustion chamber liner, it mixes with the jet-A fuel vapors, which enter through 28 atomizers around the chamber's circumference. This is where the fuel is lighted.

"It's like 28 little blowtorches," Corning said. "Once you're lit, if you took everything away from the engine, all the gauges, all the electricity, as long as it had fuel (and incoming air), it would continue to run until it was out of fuel."

Mosmiller offered another analogy.

"A turbine—I hate to say it this way—is more similar to an oil burner that would be in a heating unit in your house," he said. "You're just feeding it fuel and it's constantly burning."

This is where the black magic begins. Because the combustion chamber liner is made of a sheet of hastelloy, a nickel-chromium-molybdenum alloy, and not cast iron, as in a piston-engine, the flame must not contact the combustion chamber liner. If it did, the 1,600-degree flame could burn a hole in the combustion chamber liner. Here's where those thousand holes come into play again.

"The holes are designed to keep the flame centered within the combustion chamber liner," Corning said. "If those become blocked or obstructed in any way, the flame pattern can actually come out and hit the edge of the liner, and either warp it or burn a hole through it."

With the holes suspending the flame inside the combustion chamber liner, the heated air expands forward till it hits what's called the curl assembly. For spatial reference, the curl assembly is located on the back side of the compressor diffuser.

"The curl assembly does exactly what it sounds like," Corning said. "It actually turns the air again 180 degrees and gets it going aft."

The expanding aft-traveling exhaust enters what's called the gas-producer nozzle, a circular vane that directs the air at the most efficient angle onto the first turbine wheel.

Opposite: This cutaway illustration shows a T-55 L-11 engine, which differs from the L-7 in that it has an extra wheel in its power-turbine section. Notice the bevel-gear shafts that come from the starter housing atop the engine, around the compressor and output shafts, to the accessory gear box, which drives the fuel control and oil pump. The bleed band wraps around the compressor section, just left of the external pipe. Top: Pratt & Whitney's PT6B37 is a "hot-shaft" engine used in helicopters and turboprop aircraft. Right: Marine Turbine Technologies installed a PTE in a 2001 Advantage 28 Cat owned by Ken Wilcoxson of Napa, Calif. The system uses a brake caliper to squeeze a rotor attached to the output shaft to allow for shifting.



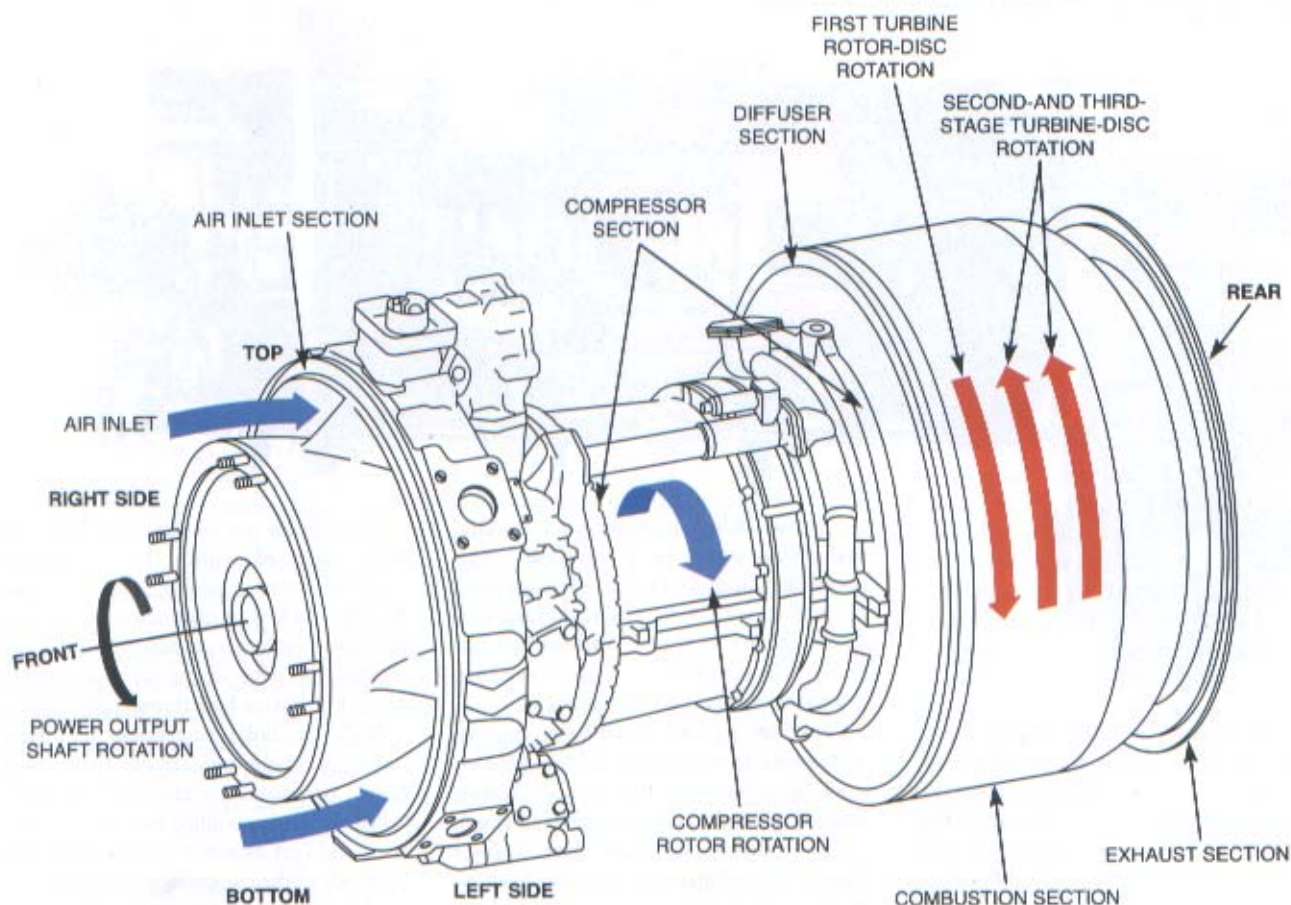


ILLUSTRATION BY RICK JIMENEZ

This wheel turns the (seven-stage) compressor section of the engine, which you'll recall is where the whole process began. To help clarify, the compressor section and the first turbine wheel all spin counter-clockwise, as viewed from the rear of the engine, on the hollow compressor shaft.

Finally, here's where the engine makes its power. In the T-55 L-7 engine, the first turbine wheel doubles as the gas-producer nozzle, also known as N1, which directs the air at the most efficient angle onto the power-turbine wheels. The power-turbine wheels, called N2, spin on a solid shaft, which rotates clockwise inside the hollow shaft of the compressor section.

"When it (exhaust) exits the gas producer wheel, it goes through the two power turbine wheels, which drive the output shaft," Corning said. "And on the T-55 engine, the output shaft comes out the front of the engine. It's known as a cold-shaft engine."

On some engines, such as the Pratt & Whitney PT6, the output shaft comes out the engine's rear. These are, obviously, hot-shaft engines. Once the exhaust has

passed the power-turbine wheels, it is evacuated to the atmosphere.

FIRING IT UP

Now that you know how the intake, compression, combustion and exhaust processes work, it will be easier to understand how you start a turbine engine.

A turbine engine uses ignitors to provide the initial spark. Remember, once a turbine is lighted, it will continue to run as long as it has fuel and air.

In the case of the T-55, it uses a large capacitor, which draws a charge from the batteries to power the ignitors. If you've ever witnessed an Unlimited hydroplane take off from the docks, that snapping sound you hear is the ignitors.

As the starter rolls the motor over, the ignitors will spark twice a second for 10 seconds. Then, once the engine lights, the ignitors cease. Think of ignitors as you would glow plugs in a diesel engine, which also are used only for starting. The principle is the same.

FUELING THE FIRE

Fuel is introduced to the combustion chamber liner through the atomizers, the "28 little blowtorches" that are inside the combustion chamber liner. Fuel pressure is supplied by the fuel-boost pump, which is driven by the accessory gear box. The system, at least on the T-55, consists of two fuel manifold halves, with 14 atomizers on each.

The system has a primary side, which delivers fine flow used for starting and bringing the engine up to idle, and a secondary side. The secondary side is coarser and flows more fuel, and is used when the engine is in its power band, so it can get the amount of fuel it needs to maintain the desired power setting.

That setting is determined by the fuel control, which is computer-controlled on modern turbines, mechanical in the case of the T-55.

"It uses fly-weight governors ... so when it starts programming fuel, it's moving a servo back and forth until the fly weights hit the right spring tension, what's called the 'null' setting," Corning said, agreeing that it works something like a governor in an

automatic transmission. "When the fly weights reach the same rpm as the spring tension, the engine will stop at that rpm."

"We're talking 1950s technology," he continued. "Now, it's done with a little black box. There's just a pump on the engine and a computer program in a little black box about as big as the palm of your hand."

"How were people in the 1940s smart enough to develop this, when you didn't have all the tools that are available today?" Mosmiller asked, rhetorically. "We have CAD systems. In those days, that technology wasn't there. For people to be that smart, you really have to give them credit."

COOLING AND LUBRICATION

Twenty-five percent of incoming air is used to make power. The other 75 percent is used for cooling and seal pressurization. The cooling part is pretty self-explanatory: Incoming air cools the engine as a natural part of the process. Seal pressurization isn't quite so obvious.

"Most of the seals are carbon-face seals," Corning explained. "They divert air pressure to the back side of seals. As long as the air pressure is higher than the oil pressure on the inside, it helps keep it in."

Lubrication systems can be either dry-sump or, in the case of the T-55, wet sump. Its reservoir is inside the forward inlet housing. Oil pumps can be positive-displacement gerotor-style or vane-style.

Most of the oiling is needed in and around the bearings and shafts at the engine's center and at the accessory-drive gear box. Getting the oil to the right place can be tricky. The T-55 uses external and internal lines to move oil around, and a simple-yet-ingenious heat exchanger that uses fuel to cool the oil.

LET IT BLEED

Despite using only 25 percent of the incoming air to make power, a turbine engine doesn't even need all of that at lower rpm. This is why it has a bleed band.

"At low rpm, the engine is bringing in way more air than what it can use," Corning explained. "If they try to force it all through, it'll either blow the flame out or put the engine into a stall. The bleed band will stay open until you reach approximately 75 percent rated power and then it will close, and the engine can use all the gas and air it's getting."

In its original design, the fuel control closed the bleed band, which wraps around the compressor section, but in Unlimited

hydroplanes, the engine runs so far above its specified fuel consumption that it had an adverse effect on bleed-band closure.

"We were having a problem with the bleed bands opening on the high side," Corning explained, adding that this was when teams began using aftermarket bleed-band actuators. "And when your bleed band opens at power, you lose approximately 30 percent of your horsepower."

COMPRESSOR STALL

Something you'll hear sometimes at an Unlimited race is a compressor stall. It can sound like a banging or a sharp, well, "fuffing" coming from the intake side of the engine.

"A compressor stall happens anytime your combustor pressure exceeds the compressor exit pressure," Corning explained. "If they lift (off the throttle) really quickly and the compressor starts to spool down,

The 1st Choice for Champions

MARINE TECHNOLOGY

FOUNTAIN

SCISM

Shaping the future of offshore.



US-1
Our 1st National Championship

Our 1st world record Supercat
139.88mph with Twin 750hp
Drives, 9700lbs
Raising the record by 11mph.



POWERBOAT 2001

Our 1st Powerboat Product
Excellence Award
132mph with full cabin.



Our 1st Supercat model to be
banned from APBA for
unfair advantage.
(Surface Drives model)



Our 1st Supercat Light 38
Race & Race Pleasure.
Race or Pleasure? You decide.

TNT Custom Marine 305-931-3157
Grewinger's Performance 618-797-2628
Pier 57 901-689-4000
Lake Cumberland 606-677-0939
National Marine 330-369-6030

MERCURY
MerCruiser

Marine Technology, Inc.

117 Avalon Ind. Pky. Wentzville, MO 63385 Tel: (636) 639-1166 Fax: (636) 639-1188
Email: marinetechinc@earthlink.net www.marinetechinc.com



your combustor pressure is still exceedingly high, the air, instead of trying to go out through the back of the engine is trying to come out through the front of the engine. And that's that bang you hear, is when the air actually changes direction.

"Another thing that can cause that is the bleed band itself is set so that at low rpm, it opens up because the engine is taking in way more air than it needs," he continued.

"If they don't have that set right, and the engine is trying to spool down a little bit, it'll bang before it opens. And usually when it does bang, it forces the bleed band to open and stabilize the air flow."

You won't hear that sound at an airport.

SUPPORT SYSTEM

As you would imagine, the compressor and power turbine shafts rotate on ball bear-

ings—it's all ball bearings!—lubricated by the pump with, in most cases, synthetic turbine oil. The T-55 has seven main bearings.

The first bearing supports the front end of the compressor. The second supports its aft end. There is a small roller bearing beneath the No. 1 bearing on the front of the engine that supports the midspan of the power-turbine shaft, which you'll recall spins inside the hollow compressor shaft. Power-turbine wheels are supported by two bearings behind the last wheel. It uses a matched set of bearings side by side. The very front of the engine also has a matched set of bearings.

SHUTDOWN

To shut down a turbine engine, all you have to do is cut off the fuel flow to the engine, and they will spool down and stop. Most engines have two, redundant shutoff systems.

So by now you're ready to scrap your blown big-blocks in favor of a pair of turbines, right? Turbines run on jet-A or diesel fuel. They'll even run on kerosene. Not so fast.

Turbines are incredible, yes. But because of their nature, namely that they don't idle efficiently or lend themselves to shifttable transmissions and Bravo One drives, there is a matter of getting them to work in a pleasure boat. That's another story in itself, with a growing industry to support marine-turbine use in pleasure boats.

At least now you know what's whirling around inside them. ●

MARINE TURBINE SHOPS AND RESOURCES

COMPETITION SPECIALTIES, 2402 W. Valley Hwy. N., Auburn, WA 98001, 253-833-6211, www.compspecialties.com.

FIRESTORM TURBINES, 712 Hastings Ave., Innisfil, Ontario, Canada L9S 1Z3, 705-790-7702, www.firestrm.ca.

INTECH MARINE, P.O. Box 1611, Brockville, Ontario, Canada K6V 6E6, 613-345-5673.

INTEGRATED TURBINE SERVICE LLC, 7604 Energy Pkwy., Baltimore, MD 21226, 410-360-2216, integratedturbine@erols.com.

MARINE PERFORMANCE, 947 Alexander Ave., Port Orange, FL 32129, 386-322-4220, www.marineperformance.com.

MARINE TURBINE TECHNOLOGIES, 298 Louisiana Road, Franklin, LA 70538, 337-924-0298, www.marineturbine.com.

WHISPERING TURBINES INC., 543 Whispering Pines, Hamilton, MT 59840, 406-363-3284, www.whisperingturbines.com.

Stellings

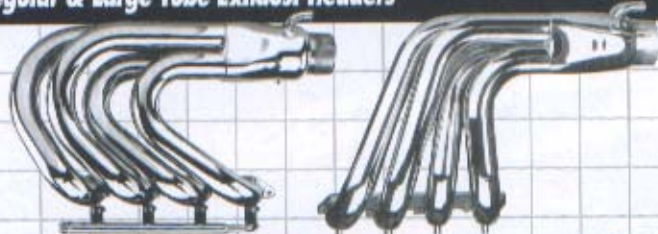
MARINE PRODUCTS

Cast Aluminum
Performance Exhaust
Manifolds



For Big Blocks

Regular & Large Tube Exhaust Headers



NEW!!

Extension Boxes



TRS to Bravo

#3 to #5

Bravo

Fabricated #6 Box

Stellings

MARINE PRODUCTS

3316 E. ANNADALE AVENUE
FRESNO, CALIFORNIA 93725
TEL: 559/485-9394