

IntelliJet™ Performance Advantages

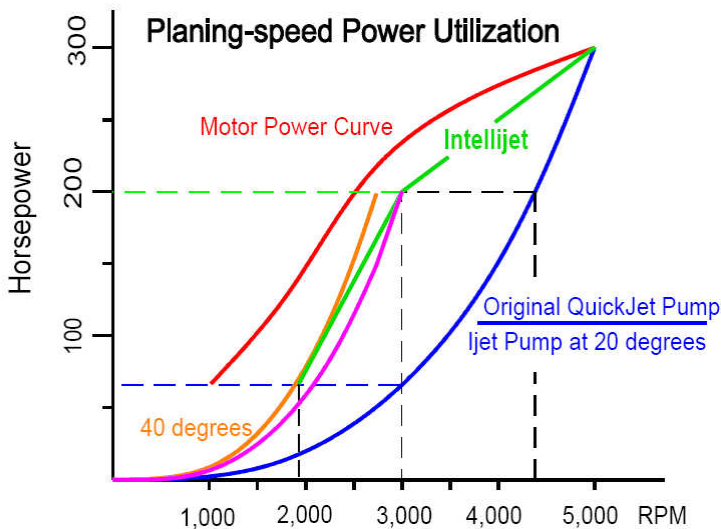
This paper compares the performance of our new IntelliJet™ to our first-generation QuickJet in cruising, bollard-pull, and low-speed maneuvering. This comparison is partly based on demonstrated performance to date and partly theoretical. The approach here is intuitive. The hard physics and technical data behind these explanations are covered in our patent disclosures, technical presentations, and other white papers.

The QuickJet was a substantial advance over the marine jets commonly used in recreational boats. With the same motor, it had about twice as much low-speed thrust as those jets and was about equal to propeller drives in acceleration. Video documentation of this performance is available at www.ijet.com.

The IntelliJet™ improves on the QuickJet by incorporating a variable-pitch propeller pump under computer control to gain many performance and safety advantages.

Cruising Performance

Most recreational boats spend 90% to 95% of their time cruising along on plane, so propulsion systems are designed to operate most efficiently in this range. The IntelliJet™ computer controls the pitch on the pump to use the motor most efficiently, which is similar to the function of the automatic transmission of a modern car. The following graph illustrates how the IntelliJet™ uses the motor more efficiently and develops more thrust when the boat is cruising along on plane.



The blue curve on the right is the power demand curve on the original QuickJet and is also the power demand curve of the IntelliJet™ with the pump blades set to about 20 degrees. The orange curve is the power demand of the IntelliJet™ when the pump blades are set to about 40 degrees.

The computer controls the blade angle between the orange and blue curves to generate the green IntelliJet™ power demand. For example, the pink curve is the 35

degree power demand curve that the program sets at 3,000 rpm. This control strategy keeps the power demand close to the most efficient power supply curve of the motor, which is just what the transmission in an automobile does to get the best fuel economy and emission control. A recreational boat that is planing along between 25 and 40 mph has a power demand in the range of 70 to 200 hp, depending on the load, speed, and acceleration. Here is a comparison of the motor rpm in that range:

HP	IntelliJet™	QuickJet	Thrust Ratio
70	1900 rpm	3000 rpm	$3000/1900 = 1.58:1$
200	3000 rpm	4400 rpm	$4400/3000 = 1.47:1$

The IntelliJet™ engine rpm is reduced by about 33% over the 70 to 200 hp range, which commonly reduces fuel consumption by 20% or more in automobiles.

The pump shaft rpm is also reduced by the same 33%, which has another useful consequence; thrust is increased by about 50% for the same power input. This is a natural consequence of propulsion physics: nozzle velocity is proportionate to rpm; and thrust is inversely proportionate to nozzle velocity; so thrust is inversely proportionate to rpm. At 70 hp 3000 rpm/1900 rpm is 1.58:1. That's 58% more thrust for the same 70 horsepower input.

The IntelliJet™ uses about 20% less fuel AND produces about 50% more thrust over the entire range of cruising speeds and loads, so it uses about 60% less fuel in this range to produce the same thrust.

All of this assumes the inlet drag and the hydraulic power loss in the inlet are the same for both systems. In fact, the Intellijet™ has higher inlet velocity, which means that there is less difference between the boat speed and the pump inlet velocity. When the incoming water has to slow down up less to get into the pump, there is less power to be recovered and generally less power lost in the inlet. Also the hydraulic power recovered in the inlet generates more thrust at the lower nozzle velocity of the IntelliJet™.

All told, the IntelliJet™ consumes about 60% less fuel than the QuickJet, which already had a lower nozzle velocity and other efficiency advantages over conventional jets.

Bollard Pull and Getting Up on Plane

The above explanation is pretty accurate from about 20 mph to top speed, because the pump and nozzle are sized to work with the hydraulic power recovered in the inlet duct at such speeds.

At lower boat speeds, there is less power recovered in the inlet duct, which reduces the total power at the nozzle. A larger nozzle would be required for peak pump efficiency. Nearly all marine jet designers choose to make the nozzle too small to allow the efficient operation of the pump at low speeds, so that it will be closer to the ideal size with the inlet power recovered in the inlet at planing speeds. This is generally true of all marine jets, including IntelliJet™ and QuickJet. The overly restrictive nozzle is most extreme when the boat is held in place by a line attached to an immovable post in the water, commonly called a "bollard." This is the basis of the "bollard-pull" or "static

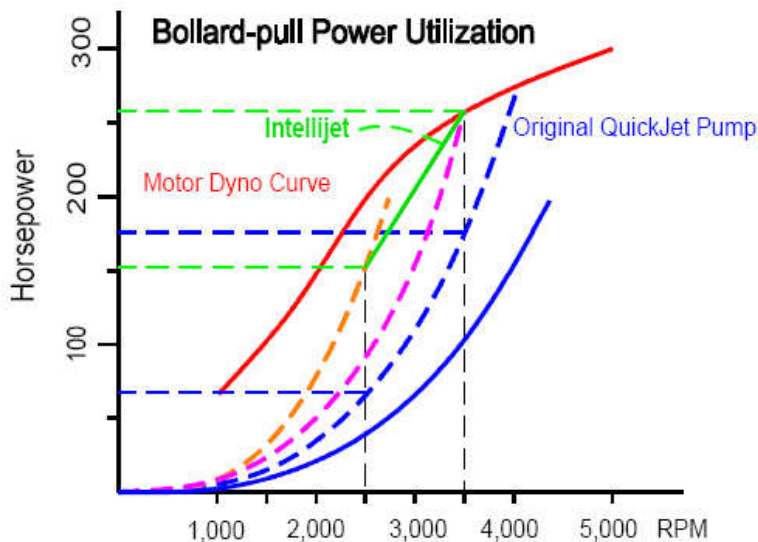
thrust”, which is commonly used as a test of low-speed thrust for conventional marine jets.

In addition to the nozzle restriction, pump cavitation can also limit the bollard pull, particularly in small, high-rpm conventional jets. Cavitation is equivalent to spinning the tires on a car, when it is trying to pull a bollard or a tree. Rather than spinning the tires, the jet pump suction creates a vacuum in which the water boils. The pump loses traction on the water vapor. The results are the same in both cases: a lot of noise and limited pull.

The IntelliJet™ and QuickJet pumps are larger and slower than conventional jet pumps and less prone to cavitation. Like most conventional marine jets, both these systems are designed so that cavitation is reduced by the restrictive nozzle at low speeds. The thrust that is lost to nozzle restriction would otherwise be lost to cavitation, so the designer effectively gets two losses for the price of one.

The QuickJet bollard pull was never tested, because it was never an issue. The already heavy boat carrying six people was able to pull up a water skier on one ski, as seen in the video. As you might expect, the IntelliJet™ does somewhat better.

The following graph of Bollard-pull power transfer is consistent with the “Planing-speed Power Utilization” graph on page 1 but shows the effects of pump flow restricted by the nozzle.



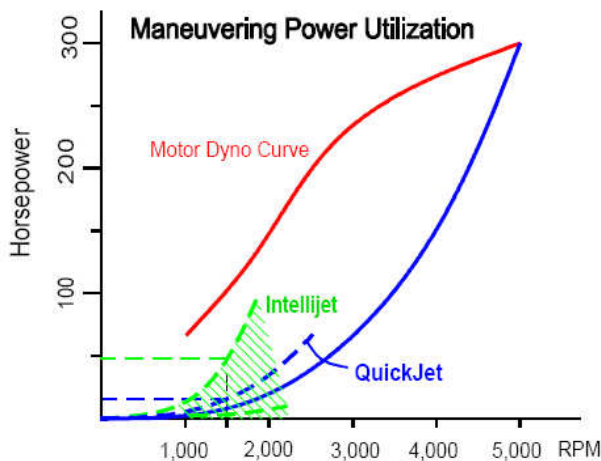
The dashed pump power curves indicate flow-restricted pump operation, which increases pump power demand and moderately reduces pump efficiency. The dashed blue curve is the power demand of the QuickJet pump at zero boat speed. The solid blue line is left in just to be consistent with the first graph, but it is not operative here.

The green IntelliJet™ program line again results from adjusting the pump blades for efficient motor operation. Here the program stalls the motor at 3500 rpm by setting the pink power demand curve. This is done to get maximum thrust within the limits of pump cavitation. The IntelliJet™ has 100% more thrust than the QuickJet at 2500 rpm, but only about 30% more at 3500 rpm, where both systems are limited by cavitation.

The QuickJet's cavitation was scarcely noticeable, as the boat accelerated quickly. By the time the boat reached its maximum hull drag at 10-15mph, the motor was able to follow the dashed blue line up to 4000 rpm without noticeable cavitation.

Low-speed Maneuverability

Finally, we consider low-speed maneuverability. In the graph below, the QuickJet maneuvering power, shown on the dashed blue line, was already excellent. The full-pitch maneuvering power of the IntelliJet™ is shown on the upper dashed green curve. Note that at 1500 rpm the full-pitch maneuvering power of the IntelliJet™ is about 3x greater than the QuickJet.



The hatched green area is the IntelliJet™'s range of the continuously variable forward pitch in the maneuvering mode. This gives the operator a continuous range of forward thrust from full pitch to neutral. This continuous range extends into reverse thrust, where the operator also enjoys continuously variable thrust.

In summary, the IntelliJet™ has a 3x advantage over the QuickJet in low speed thrust. Both systems give the operator immediate control over the direction and magnitude of the thrust without waiting for gears to mesh.

Other Features and Benefits

The IntelliJet™ uses reverse pitch in the pump to achieve reverse thrust, which eliminates the need for the reversing bucket. Without the bucket, the IntelliJet™ is shorter and narrower than the QuickJet.

The IntelliJet™ has unprecedented safety features. The reversing buckets on conventional jets are a hazard to people in the water. They act as a bludgeon in going from forward to reverse, and can crush arms and legs caught in the mechanism. The IntelliJet™ not only eliminates these hazards, but is also designed around inherently safe sliding fits to eliminate any possible pinch points in its operation.

The IntelliJet™ is the system of the future. It is naturally suited for further computer control features, starting with other operator interfaces, like joysticks, and extending to fly-by-wire control strategies commonly used in airplanes.