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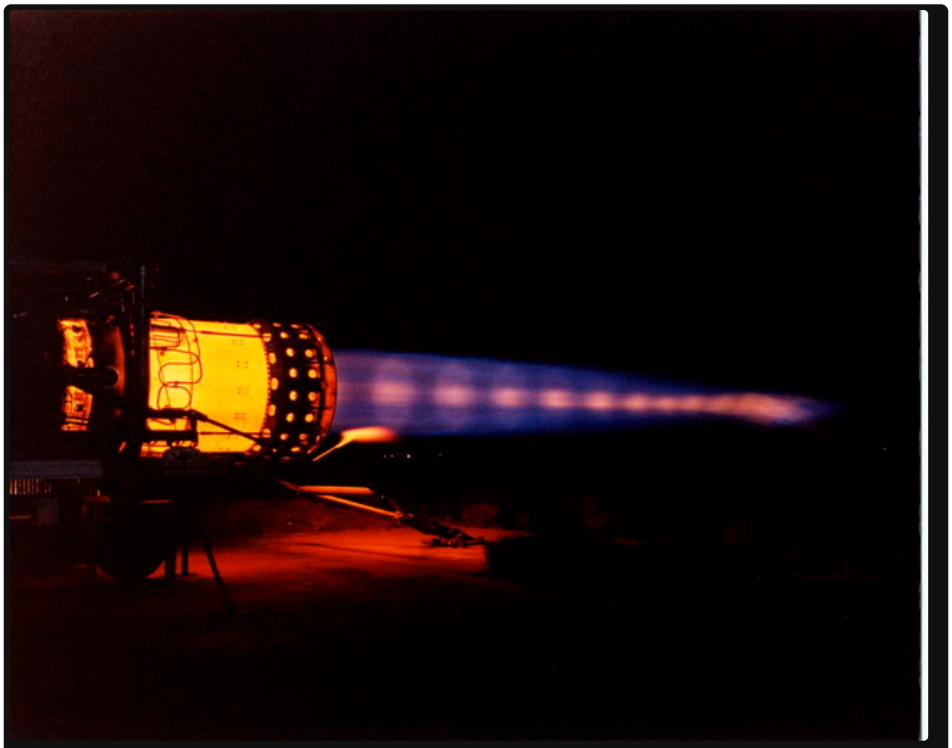
MILITARY-GRADE AWESOME

A Look at the Pratt & Whitney J-58JT11D-20

By **The Professor**, on August 22nd, 2012



A J-58 running on a test stand. Image: Wiki

Good morning everyone.

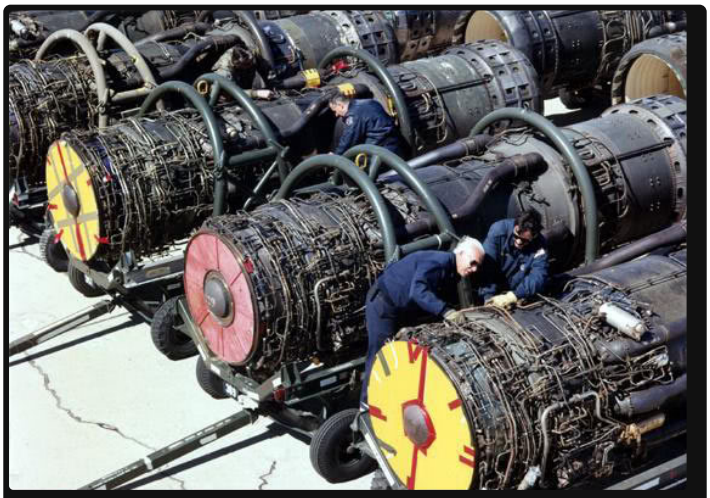
Today I'd like to talk a bit about the engines used on the A-12, YF-12, and SR-71, the Pratt & Whitney J-58JT11D-20 jet engine, more commonly known as the J-58. It was one of the main reasons that the aircraft it was used on could travel faster than a rifle bullet and hold the many speeds records that they still do, and it was all 1950s technology.

> "*To experience a J58 in full burner close up and personal is hard to describe. Picture a gigantic blow torch, 40 inches in diameter, putting out a blue-yellow-orange flame over 50 feet long. Imagine standing 30 feet from this, feeling the vibration and heat. You wear both foam plugs and earmuffs. Your ears still ring afterward, because the sound is conducted through your body. The back half of the engine transforms from dull gray to bright orange, seemingly transparent. The flame has little three-dimensional diamond shaped shock patterns about every two feet. I lost count at 13. It is both frightening and beautiful, an amazing demonstration of perfectly controlled power.*" From **J-58 Last Run**

The J-58 established several firsts: it was the first engine to be flight-qualified by the USAF for mach 3, it was the first jet engine (and perhaps the only one) rated for continuous afterburning, it was the first engine to use its fuel as hydraulic fluid, and one of the first engines to make extensive use of exotic high-temperature alloys.

The J-58 is what is called a variable cycle engine, meaning an engine that operates efficiently at different airspeeds, such as subsonic, transonic, and supersonic. The engine functioned as a turbojet and as a fan-assisted ramjet, and was one of the first bypass jet engines (although very atypical) put into service. The engine had a 9-stage, axial flow, single spool compressor, a two-stage axial flow turbine and was rated at ~32,500 lbs. of thrust at full afterburner.

The J-58 was a big bastard too. I don't have the dimensions at hand (can't find the damned things), but this next picture shows several mechanics amongst a crowd of J-58s on stands and gives a good sense of scale:



215.940 inches in length, 55.43 inches maximum diameter. Image from rcuniverse.com

Ah, here we go: 17 feet 10 inches long (cold) with a maximum diameter of 4 feet 9 inches.

J-58 engine on display at Boeing Field. Image by Will Campbell

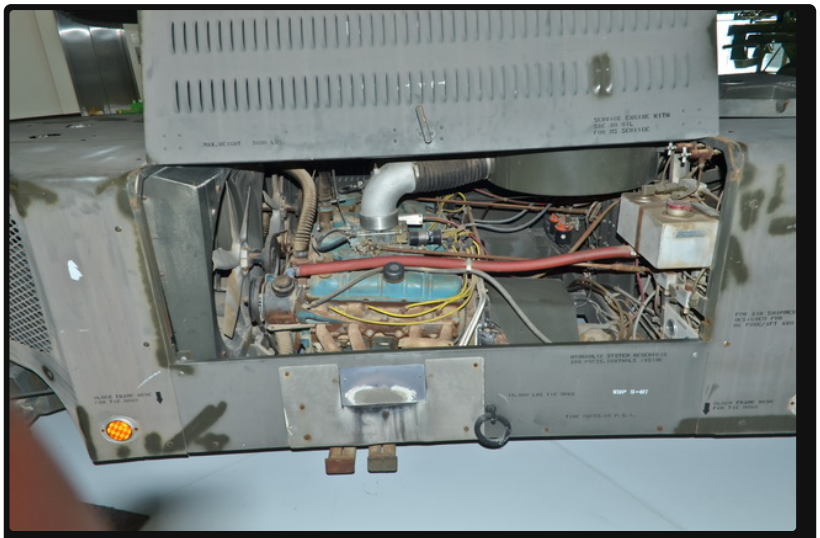
A Brief History

The J-58 wasn't purpose-built for the A-12, at least not at first. In the early 1950s the engine was ordered by the US Navy for use in the **Martin P6M Seamaster** mach 3 flying boat that the Navy was trying to develop. The P6M started out using **Allison J71-A-4** engines and then switched to P&W J-75s as the J-58 weren't ready due to development problems. There were a great many failures of the J-58 in testing, many failing catastrophically with the engines being destroyed when something failed in the compressor section (for example), or just blowing off the rear half of the engine if the afterburner liner failed. The J-58 had its initial test run on December 24, 1957.

In 1959 the Navy cancelled the P6M due to political and budgetary considerations, and development on the J-58 was forced to halt, much to P&W's dismay.

The pause in development however, was brief. Lockheed had been doing preliminary work on **Project Gusto**, a project for a new aircraft to be used to overfly the Soviet Union instead of the U-2. The designs that Lockheed made were called “Archangel” internally, with the evolving designs being numbered Achangel-1, Archangel-2, etc, and finally being shortened to A-1, A-2, etc. When the design had reached iteration A-11, Lockheed won the contract and started working with Pratt & Whitney to resume work on the J-58 in early 1960.

Progress on the J-58 was slow (from Lockheed’s point of view), and the aircraft, now named A-12, was ready before the engines were. In April of 1962 the A-12 was flown for the first time and used P&W J-75 engines. It wasn’t until October of 1962 that a J-58 engine was ready to be flown in an A-12.



A J-58 start cart on display at Boeing Field. Image by Will Campbell

Special Needs

Because of the high temperatures generated by the engine and air friction from the aircraft travelling at mach 3+, the J-58 required special silicone-based lubricants that won’t degrade (?) at +550^{o} and that are solid at room temperature, requiring the engine oil to be preheated before firing the engines. The engines used an AG330 starter cart that had two Buick Wildcat engines connected to a common driveshaft that spun the J-58 to 3,200 RPM in order to fire them up.

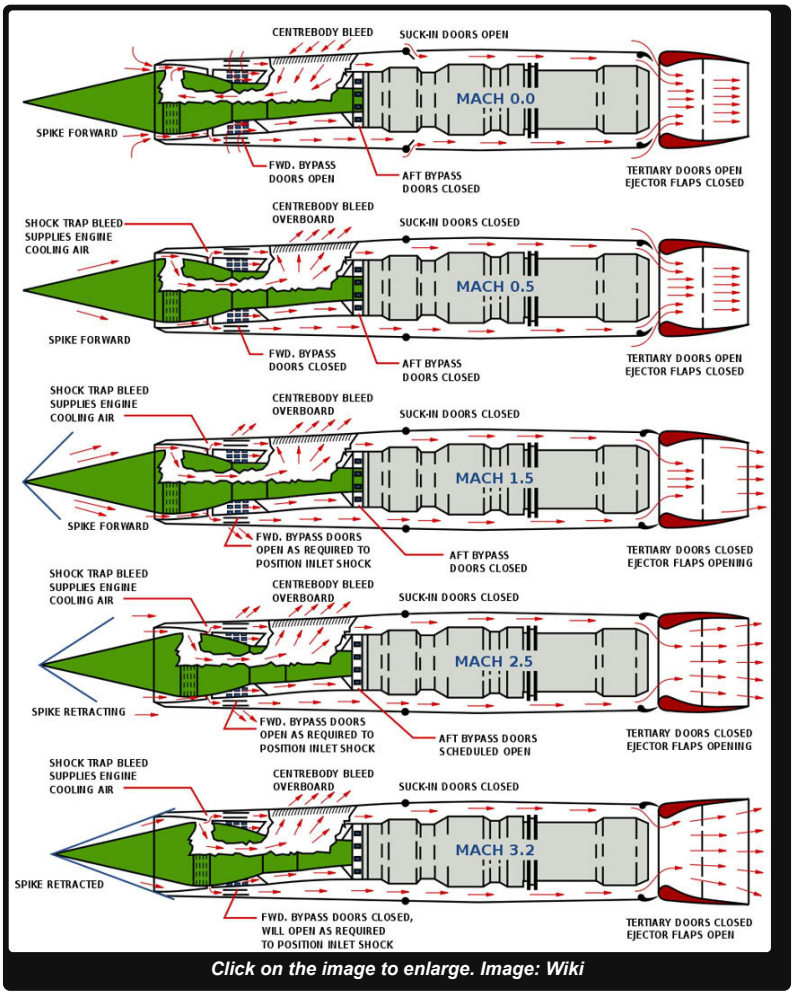
TEB dump. Image from enginehistory.org

A new fuel was required for the engine due to the harsh operating conditions it would be working under. JP-7 jet fuel was developed by the USAF for use in its supersonic aircraft. It has a high flash point, and with a boiling point of around 550^{o}F it is thermally stable enough to be used in aircraft that get incredibly hot from travelling at mach 3+. Because of these features, JP-7 is hard to ignite at normal temperatures, so a chemical 'starting fluid' that ignites spontaneously with oxygen called **triethylborane** (TEB) is injected into the engine to start it and to ignite the afterburner in flight. The J-58 carries about 20 ounces of TEB in a special pressurized tank which is *"[sufficient] for at least 16 starts, restarts, or afterburner lights; this number was one of the limiting factors of SR-71 endurance, as after each air refueling the afterburners had to be reignited.*"[**Wiki**]

A curious thing about JP-7 is that it's not a distillate fuel, such as kerosene. It's made from a witch's brew of petrochemical blending stocks that give the fuel a very low concentration (less than 3%) of highly volatile chemicals.

Another thing about JP-7 that I found very interesting is that it has a special cesium compound added to it, something called A-50, that helps to disguise the radar signature of the aircraft's exhaust plume.

"*The fuel flowing into the engine is used as a **coolant** to cool the engine, **hydraulic fluid**, **oil**, TEB tank, afterburner nozzle actuator control lines, air conditioning systems, and the parts of the airframe subjected to aerodynamic heating.*" [**Wiki**]



Click on the image to enlarge. Image: Wiki

Changing Operating Modes

The J-58 had to operate as a turbojet at subsonic speeds, but as the speed increases past mach 1.5 and the altitude exceeds 30,000 feet ,the turbojet loses efficiency and the engine must operate more as a ramjet, until at mach 3+ and over 80,000 feet in altitude 80% of the engine thrust comes from the air inlet system.

The diagram above shows how the air flow through the engine changes at different mach numbers by opening and closing various bypass doors and flaps, and through the positioning of the inlet spike in the variable-geometry inlet. The spike and forward bypass doors were normally automatically controlled by an Air Inlet Computer, but could be operated manually by the pilot. The rear bypass doors were manually controlled only. "*The spike altered the flow of **supersonic** air, ensuring **subsonic** airflow at the engine inlet. The conical spikes are locked in forward position below 30,000 feet. Above that altitude they are unlocked. Above Mach 1.6 airspeed they are retracted approximately 1-5/8 inch (4 cm) per Mach 0.1, up to total of about 26 inches (66 cm).*" [**Wiki**]

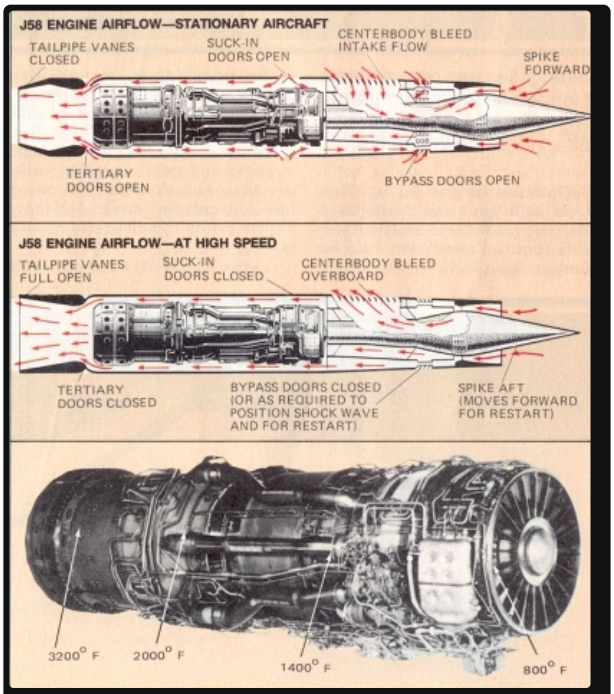
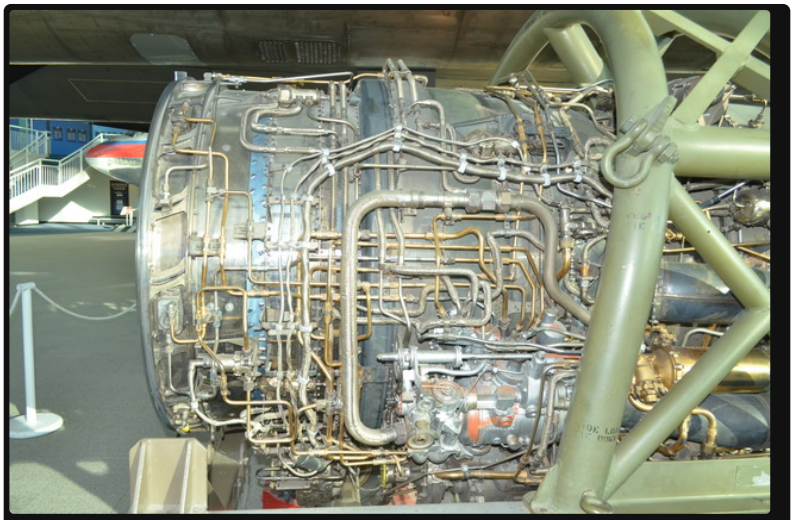


Image from wvi.com

The position of the spike and the bypass doors work together to position the supersonic shockwave precisely in the air inlet, but sometimes the shockwave can be expelled from the engine, causing an unpleasant event called an “unstart”. An unstart causes a violent yaw in the aircraft, throwing the pilot and RCO around in their cockpits (and probably scaring the crap out of them for just a teeny second). The Air Inlet Computer is supposed to detect the condition and quickly reposition the spike to recapture the shockwave, but there were evidently cases where the pilots had to correct the condition manually. If an unstart goes uncorrected, the resulting yaw “*is described by SR-71 pilots as though the nose and tail are trying to swap ends.*”[**wvi.com**] The Air Inlet Computer was an analog device and was later upgraded in the SR-71s to the digital automatic flight and inlet control system (DAFICS), which greatly reduced the number of unstarts.

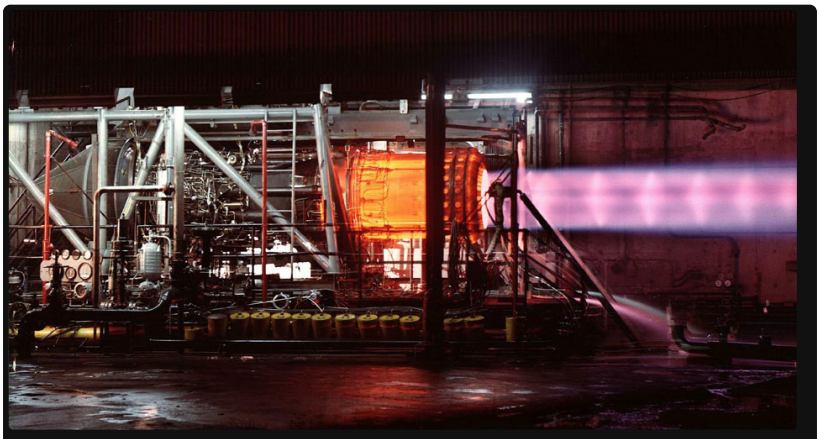


J-58 engine on display at Boeing Field. Image by Will Campbell

The End of the Road

With the cancellation of the SR-71 program in 1989, the only aircraft that used the J-58 were two SR-71s loaned to NASA by the USAF in 1990. Congress decided to re-activate 3 SR-71 in 1994 against the will of the USAF and certain politicians, and in 1998 the planes were permanently retired and so was the J-58. NASA had something like 40 or 50 spare engines, and most of them were given to museums around the country.

A great story of what was very probably the last time a J-58 was run can be found **here**.



A J-58 running on a test stand. Image: Wiki

Note: In this post I've tried to put together a short history of the development of the J-58 and how it was operated. I've had to use several different sources for all of the various bits of information, and not all of the sources agree on everything, so I've almost certainly gotten some events or facts wrong. Be merciful.

References

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Lockheed A-12

Lockheed SR-71 Blackbird

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