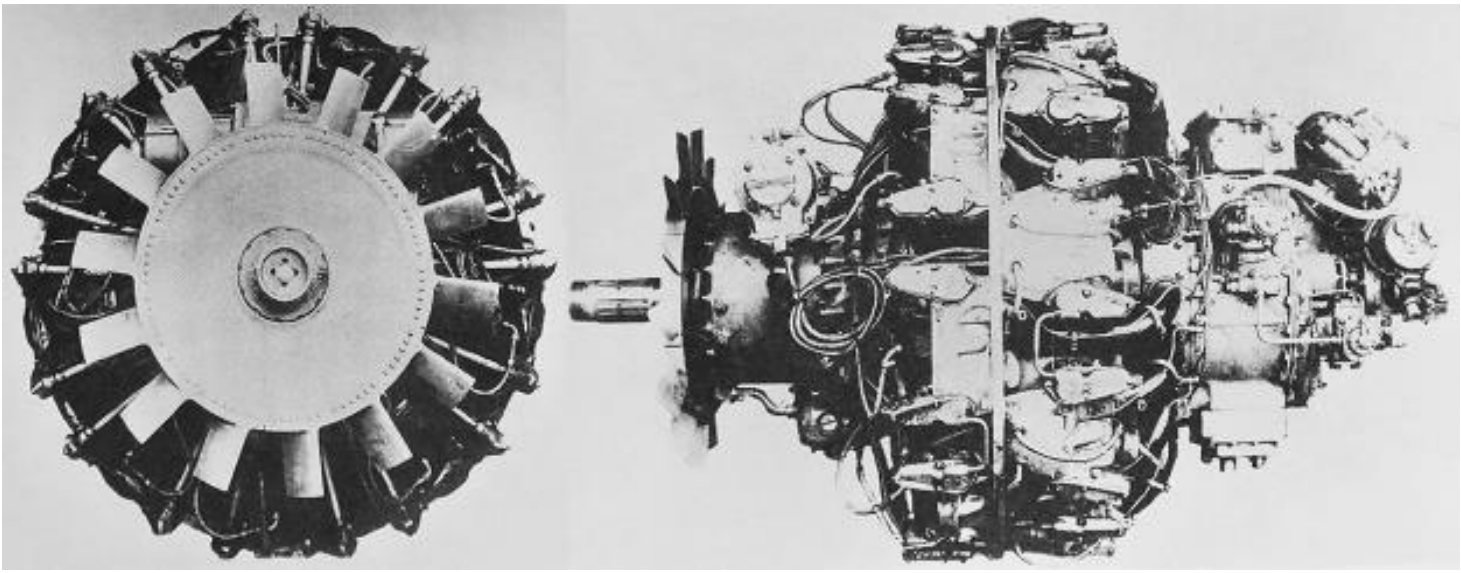
Mitsubishi [Ha-43] (A20 / Ha-211 / MK9)

In 1916, the Internal Combustion Engine Section, Machinery Works (*Nainenki-ka Zokisho*) of the Mitsubishi Shipbuilding Company Ltd (*Mitsubishi Zosen KK*) was formed to build aircraft engines. A number of licenses to build engines in Japan were acquired from various European engine manufacturers. Initially, the engines were of the Vee type. The aircraft engine works was renamed Mitsubishi Aircraft Company Ltd (*Mitsubishi Hokuki KK*) in 1928. In the late 1920s, licenses were acquired to produce the five-cylinder Armstrong Siddeley Mongoose and the nine-cylinder Pratt & Whitney R-1690 Hornet air-cooled radial engines.

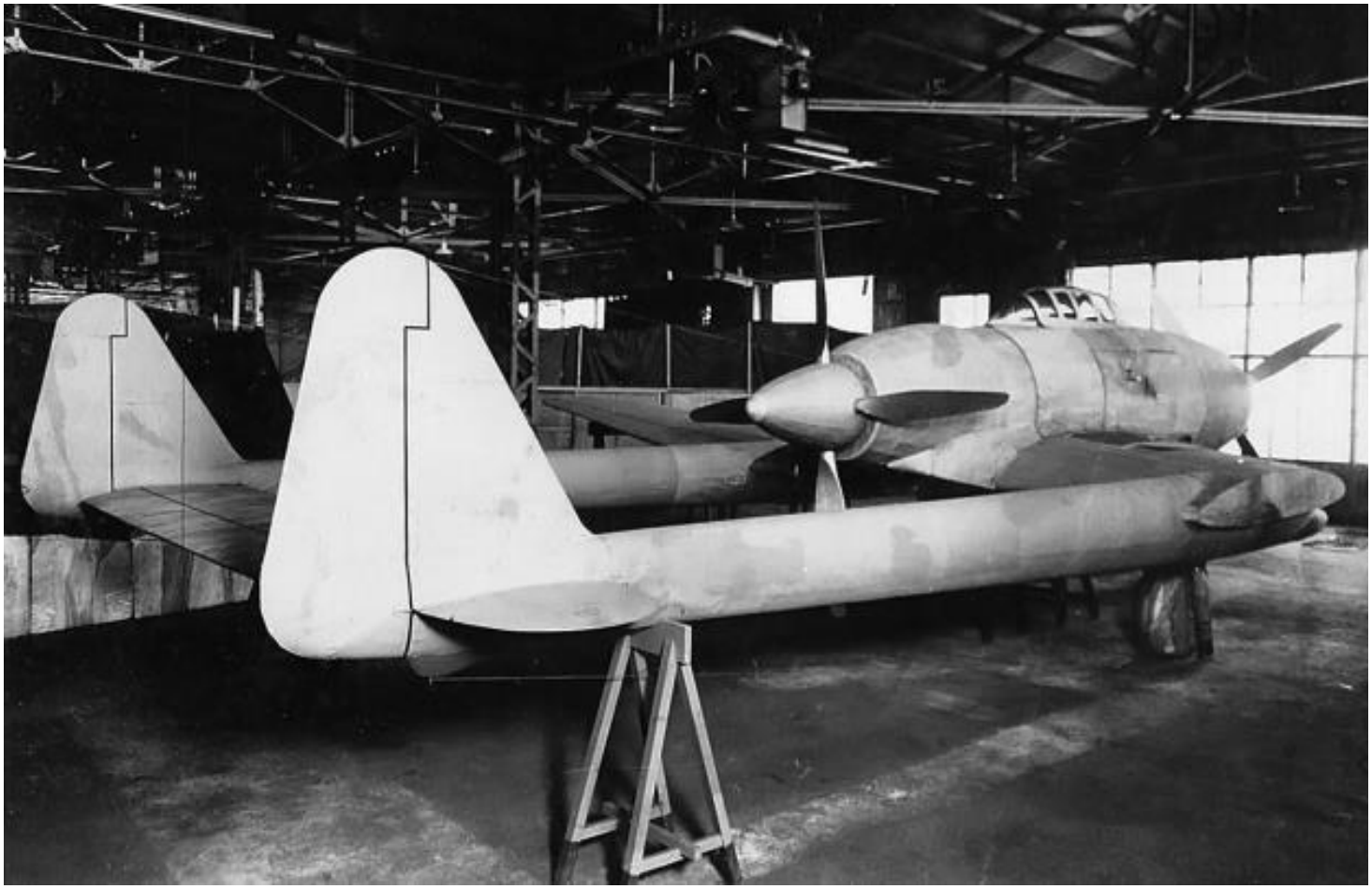


Front and side views of the Mitsubishi [Ha-43] (A/20 / Ha-211 / MK9). The engine performed well but was underdeveloped. Its development and production were slowed by bombing raids and materiel shortages. The engine powered two of Japan's best next-generation fighters, the A7M2 and Ki-83. While the aircraft were excellent, the war was already lost.

In 1929, Mitsubishi built the first aircraft engine of its own design. Carrying the Mitsubishi designation A1, the engine was a two-row, 14-cylinder, air-cooled radial of 700 hp (522 kW). This engine was followed in 1930 by the A2, a 320 hp (237 kW) nine-cylinder radial. A larger 600 hp (477 kW) nine-cylinder engine, the A3, was also built the same year. None of these early engines were particularly successful, and only a small number were built: one A1, 14 A2s, and one A3. However, Mitsubishi learned many valuable lessons that it applied to its next engine, the A4 Kinsei.

The two-row, 14-cylinder A4 was developed in 1932 and was initially rated at 650 hp (485 kW). The A4 had a 5.51 in (140 mm) bore, a 5.91 in (150 mm) stroke, and a total displacement of 1,973 cu in (32.33 L). In 1934, Mitsubishi consolidated its subsidiaries and became Mitsubishi Heavy Industries Ltd (*Mitsubishi Jukogyo KK*). Also in 1934, an upgraded version of the A4 engine was developed as the 830 hp (619 kW) A8 Kinsei. The Kinsei was under continual development through World War II, and numerous versions of the engine were produced. Ultimately, the last variants were capable of 1,500 hp (1,119 kW), and production of all Kinsei engines totaled approximately 15,325 units.

In mid-1941, Mitsubishi began work on an 18-cylinder engine that carried the company designation A20. The engine was intended to be lightweight and produce 2,200 hp (1,641 kW). The A20 design was developed from the Kinsei, although the 18-cylinder A20 really only shared its bore and stroke with the 14-cylinder engine—it is not even clear if the pistons were interchangeable. The team at Mitsubishi designing the A20 engine were Kazuo Sasaki—main engine section; Kazuo Inoue, Ding Kakuda, and Mitsukuni Kada—supercharger and auxiliary equipment; Katsukawa Kurokawa—propeller gear reduction; Shigeta Aso—engine cooling; Shuichi Sugihara—fuel injection system, and Shin Nakano—turbosupercharger. The A20 eventually carried the Imperial Japanese Army (IJA) designation Ha-211, the Imperial Japanese Navy (IJN) designation MK9, and the joint designation [Ha-43]. For simplicity, the joint designation will primarily be used. However, few sources agree on the engine's various sub-type designations, and there is some doubt regarding their accuracy.



The mockup of the Tachikawa Ki-94-I illustrated the aircraft unorthodox configuration. With its two [Ha-43] engines, the fighter had an estimated top speed of 485 mph (781 km/h). However, its complexity led to its cancellation and the pursuit of a more conventional design.

The Mitsubishi [Ha-43] had two rows of nine cylinders mounted to an aluminum crankcase. The crankcase was formed by three sections. Each section was split vertically through the centerline of a cylinder row, with the middle section split between both the front and rear cylinder rows. Each crankshaft section contained a main bearing to support the built-up, three-piece crankshaft. An additional main bearing was contained in the front accessory drive. The cylinders were made up of a steel barrel screwed and shrunk into a cast aluminum head. Each cylinder had one intake valve and one sodium-cooled exhaust valve. The valves were actuated by separate rockers and pushrods. Unlike the Kinsei engine, the [Ha-43] did not have all of its pushrods at the front of the engine. The [Ha-43] had a front cam ring that drove the pushrods for the front cylinders, and a rear cam ring that did the same for the rear cylinders. When viewed from the rear, the cylinder's intake port was on the right side, and the exhaust port was on the left. Sheet metal baffles attached to the cylinder head helped direct the flow of cooling air through the cylinder's fins. Cylinder numbering proceeded clockwise around the engine when viewed from the rear. The vertical cylinder atop the second row was No. 1 Rear, and the inverted cylinder under the front row was No. 1 Front.

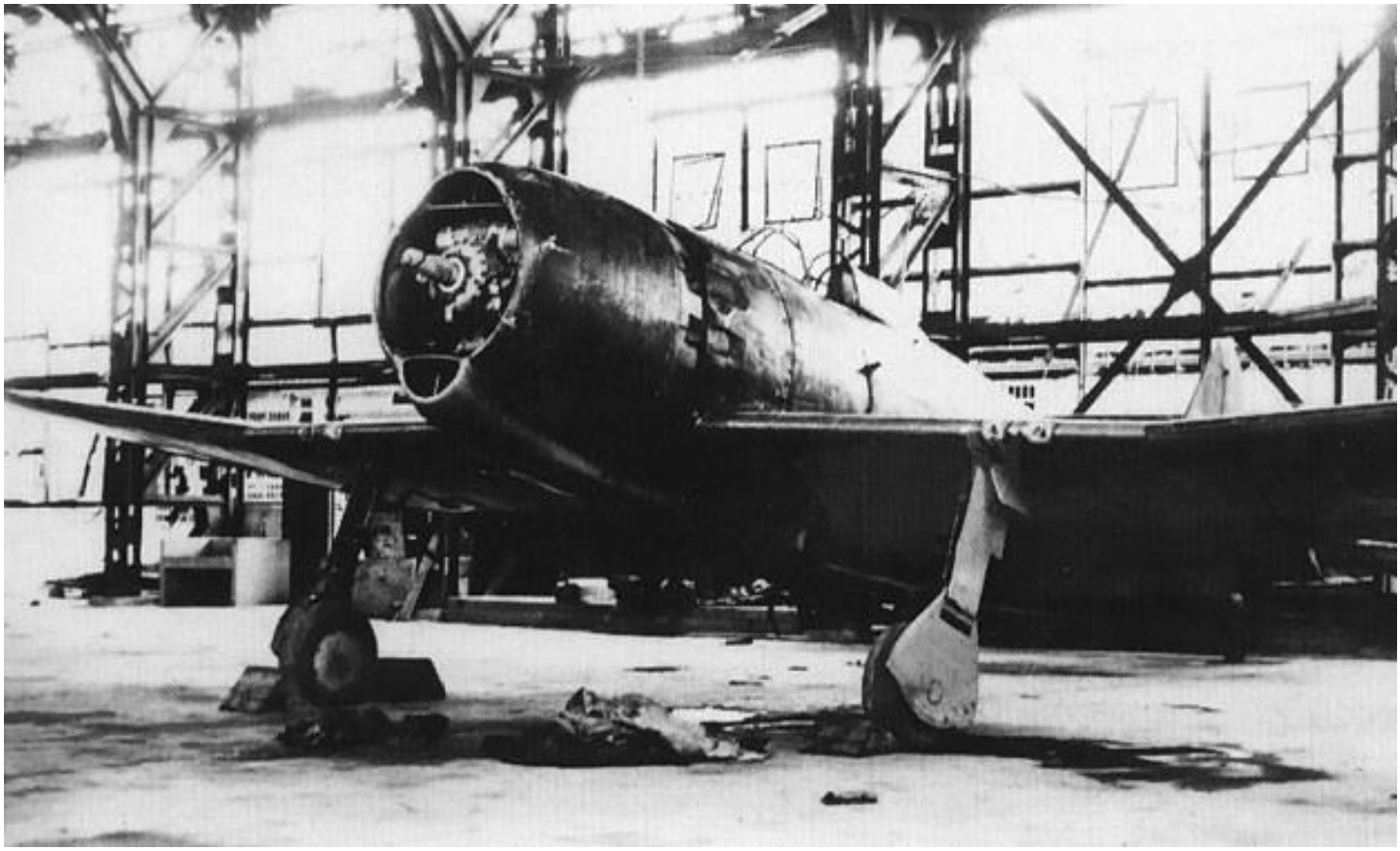
At the front of the engine was the propeller gear reduction and the magneto drive. Planetary gear reduction turned the propeller shaft clockwise at .472 times crankshaft speed. Each of the two magnetos mounted atop the gear reduction fired one of the two spark plugs mounted in each cylinder. One spark plug was located on the front side of the cylinder and the other was on the rear side. A 14-blade cooling fan was driven by the propeller shaft and mounted in front of the gear reduction. Not all [Ha-43] engines had a cooling fan. At the rear of the engine was an accessory and supercharger section. The single-stage, two-speed, centrifugal supercharger was mechanically driven by the crankshaft. Individual intake runners extended from the supercharger housing to each cylinder. The intake and exhaust from the front cylinders passed between the rear cylinders, with the exhaust running above the intake runners. The supercharger's inlet was directly behind the second row of cylinder. Behind the inlet was a fuel distribution pump that directed fuel to an injector installed by the inlet port of each cylinder.

The 18-cylinder [Ha-43] had a 5.51 in (140 mm) bore a 5.91 in (150 mm) stroke, and displaced 2,536 cu in (41.56 L). The basic engine with its 7.0 to 1 compression ratio and single-stage, two-speed supercharger produced 2,200 hp (1,641 kW) at 2,900 rpm and 10.1 psi (.69 bar) of boost for takeoff. Military power was 2,050 hp (1,527 kW) at 3,281 ft (1,000 m) in low gear and 1,820 hp (1,357 kW) at 21,654 ft (6,600 m) in high gear. Both power ratings were produced at 2,800 rpm and 8.1 psi (.56 bar) of boost. Anti-detonation (water) injection was available, but it is not clear at what point it was used—most likely for military power and above. The engine was 48 in (1.23 m) in diameter, 82 in (2.09 m) long, and weighed 2,161 lb (980 kg).

The high-altitude Tachikawa Ki-74 was built around a pressure cabin for high-altitude flight. The aircraft most likely has [Ha-43] engines with a 14-blade cooling fan. The [Ha-42] engine had a 10-blade cooling fan. The exhaust from the turbosupercharger can be seen on the right side of the image.

[Ha-43] design work was completed in October 1941. The first engine was built at the Mitsubishi No. 2 Engine Works (*Mitsubishi Dai Ni Hatsudoki Seisakusho*), which was located in Nagoya and developed experimental engines, and was finished in February 1942. As the [Ha-43] was being tested, Mitsubishi proposed in April 1942 to use the engine for its new A7M fighter. The first [Ha-43] engine for the IJA was completed in August 1942. In September 1942, the IJN selected the 2,000 hp (1,491 kW) Nakajima [Ha-45] engine for the A7M1 and many of its other high-powered fighter projects under development. This setback inevitably slowed development of the [Ha-43]. At the time, there were no applications for the engine, with the IJA feeling it was too powerful and the IJN selecting the Nakajima engine. Two more [Ha-43] engines, one each for the IJA and IJN were completed in November 1942.

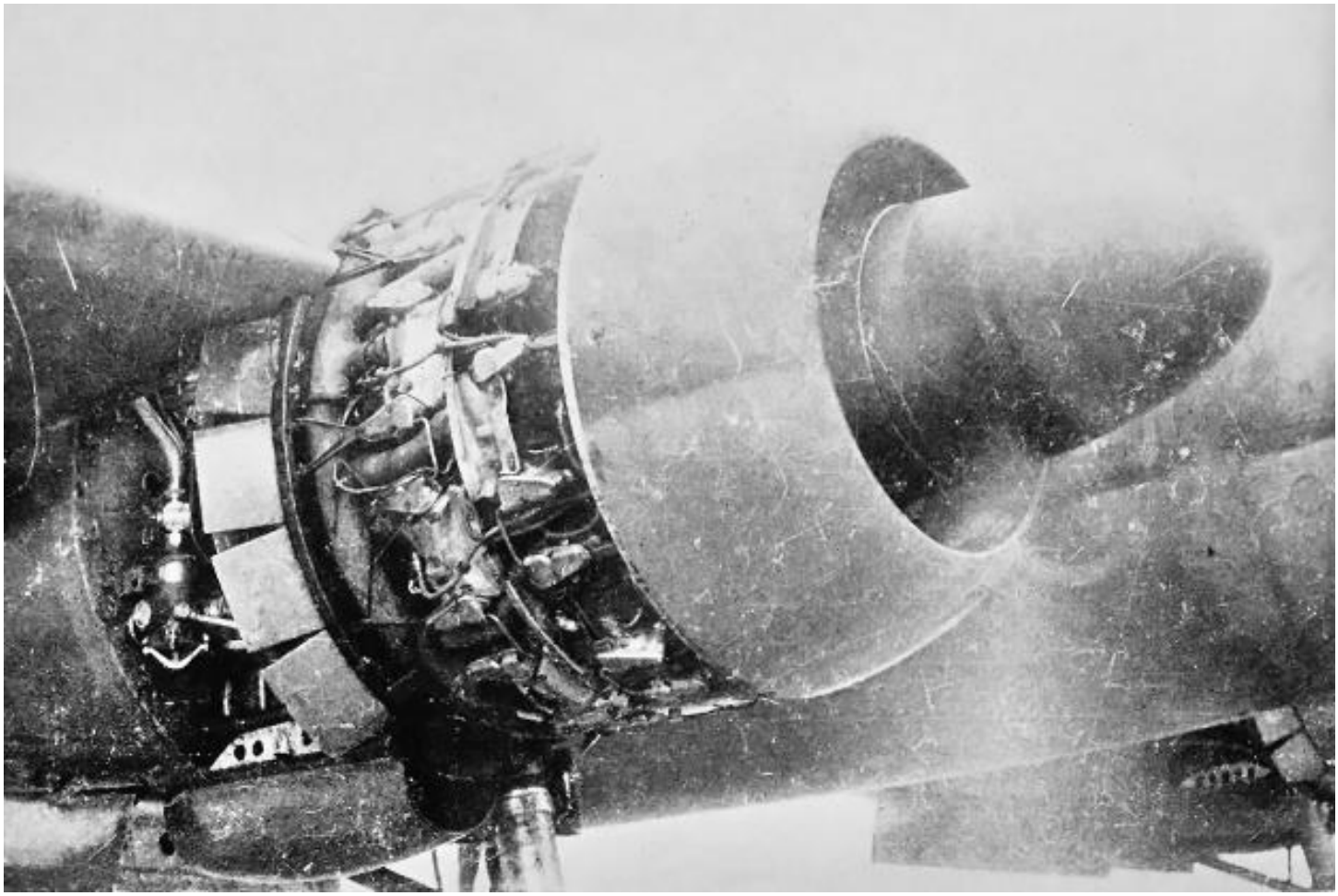
Mitsubishi continued development at a slow pace, hampered in part by difficulties with designing turbine wheels for the engine's remote turbosupercharger. It was not until June 1943 that the [Ha-43] passed operational tests and began to be selected for installation on several aircraft types and not just projects. The first [Ha-43]-powered aircraft to fly was the third prototype of the Tachikawa Ki-70. The Ki-70 was a twin-engine reconnaissance aircraft with a glazed nose and twin tails. Originally powered by two 1,900 hp (1,417 kW) Mitsubishi [Ha-42] engines, the aircraft's performance was lacking, and the third prototype was built with two turbosupercharged [Ha-43] 12 (IJA Ha-211-IRu) engines. The [Ha-43] 12 produced 2,200 hp (1,641 kW) for takeoff; 1,930 hp (1,439 kW) at 16,404 ft (5,000 m); and 1,750 hp (1,305 kW) at 31,170 ft (9,500 m). First flying in late 1943, the [Ha-43] 12-powered aircraft still underperformed, and the engines were unreliable. Development of the Ki-70 was abandoned.



The Mitsubishi A7M2 Reppu (Strong Gale) with its [Ha-43] 11 engine did not have a cooling fan like the A7M1. As a result, the cowling was redesigned with a larger opening and scoops for the engine intake (top) and oil cooler (lower). Note that the individual exhaust stacks were grouped together, mostly in pairs.

In 1943, Tachikawa designed the tandem-engine, twin-boom Ki-94-I (originally Ki-94) fighter powered by two [Ha-43] 12 (IJA Ha-211-IRu) engines. The cockpit was positioned between the two engines, which were mounted in a push-pull configuration in the short fuselage that sat atop the aircraft's wing. The front and rear engines both turned four-blade propellers. The front propeller was 10 ft 10 in (3.3 m) in diameter, and the rear was 11 ft 2 in (3.4 m) in diameter. After a mockup was inspected in October 1943, the design was judged to be too unorthodox and complex. This resulted in a complete redesign to a more conventional single engine aircraft, the Ki-84-II, which was powered by a 2,400 hp (1,790 kW) Nakajima [Ha-44] engine.

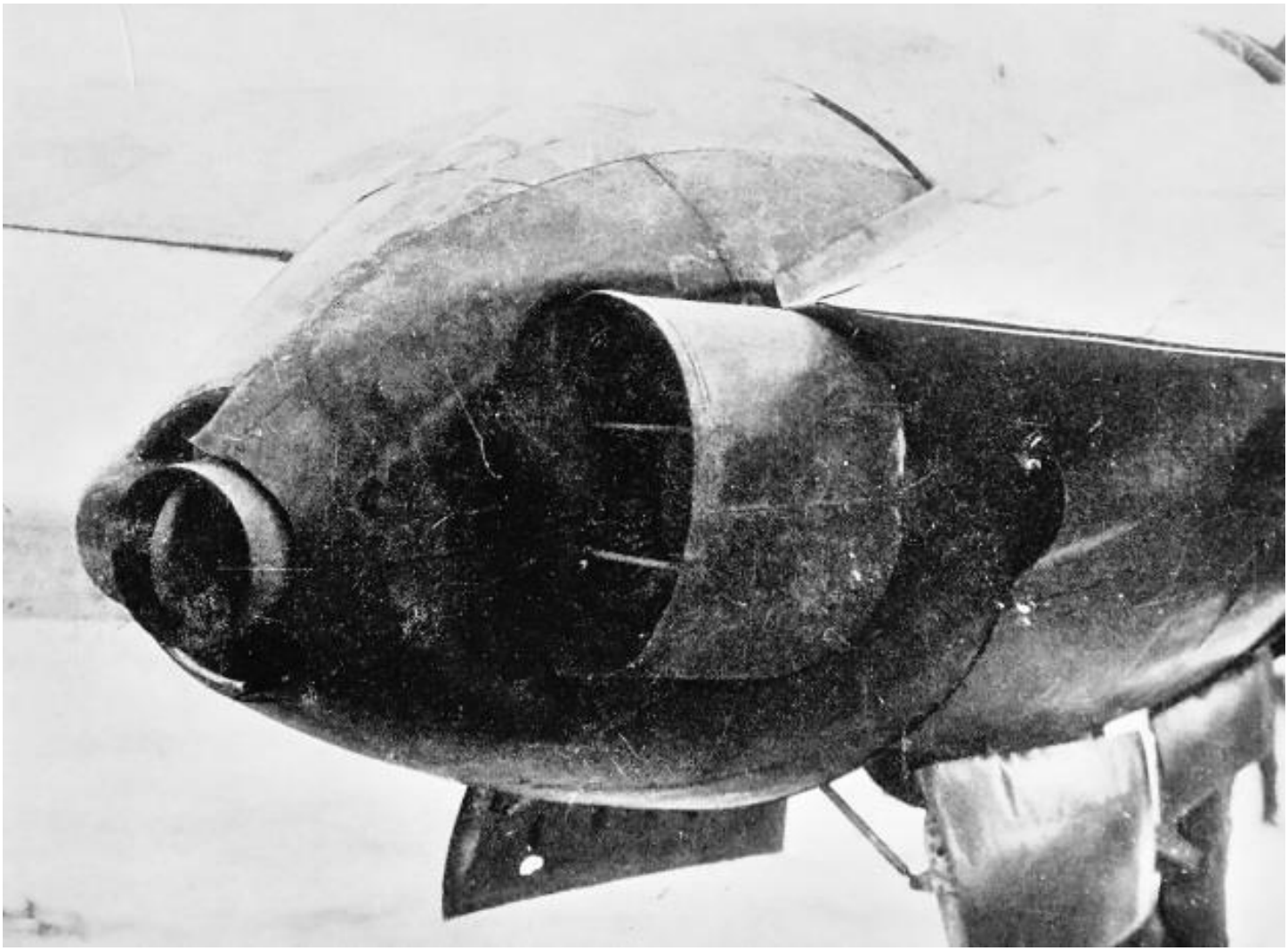
In early 1944, two [Ha-43] 12 (IJA Ha-211-I) engines were installed in the Tachikawa Ki-74, a pressurized, high-altitude, long-range reconnaissance bomber with a conventional taildragger layout. With only the mechanical two-speed supercharger, the [Ha-43] 12 produced 2,200 hp (1,641 kW) for takeoff; 2,020 hp (1,506 kW) at 3,281 ft (1,000 m) in low gear; and 1,800 hp (1,342 kW) at 16,404 ft (5,000 m) in high gear. The Ki-74 made its first flight in March 1944, and turbosupercharged [Ha-43] 12 (IJA Ha-211-IRu) engines were installed in the second and third prototypes. The turbosupercharger was located behind the engine on the outer side of the nacelle and improved the aircraft's performance at altitude. However, the [Ha-43] engines were still under development and suffered from reliability and vibration issues. Subsequent Ki-74 aircraft used larger and less-powerful Mitsubishi [Ha-42] engines.



Like the A7M2, the Mitsubishi Ki-83 also did not use a cooling fan on its [Ha-43] engine. However, the Ki-83 did have a turbosupercharger which helped it achieve its very impressive performance of at least 438 mph (705 km/h) at 29,530 ft (9,000 m). Note the sheet-metal baffles on the cylinder heads.

In the summer of 1944, Mitsubishi was given permission to install a [Ha-43] 11 (IJN MK9A, similar to the [Ha-43] 12) engine in an A7M1 airframe, creating the A7M2. The Mitsubishi A7M *Reppu* (Strong Gale) was a carrier-based fighter intended to replace the A6M Zero. The A7M1 prototypes had underperformed with the 2,000 hp (1,491 kW) Nakajima [Ha-45] engine selected by the IJN. The [Ha-43]'s installation in the A7M2 was conventional, and the aircraft made its first flight on 13 October 1944. Performance met expectations, and the A7M2 was ordered into production. Subsequently, manufacturing of the [Ha-43] started to ramp up, with 13 engines being built in March 1945. The following month, [Ha-43] 11 production was sanctioned at the Mitsubishi No. 4 Engine Works (*Mitsubishi Yon Hatsudoki Seisakusho*) in Nagoya. On 1 May 1945, Mitsubishi No. 18 Engine Works (*Mitsubishi Dai Juhachi Hatsudoki Seisakusho*) was established in Fukui city to build [Ha-43] 11 engines for the IJN, while the No. 4 Engine Works would build engines for the IJA. As events played out, only seven or eight A7M2s were built by the end of the war, the No. 18 Engine Works never produced a complete engine, and bombing raids prevented the March 1945 [Ha-43] production numbers from ever being eclipsed.

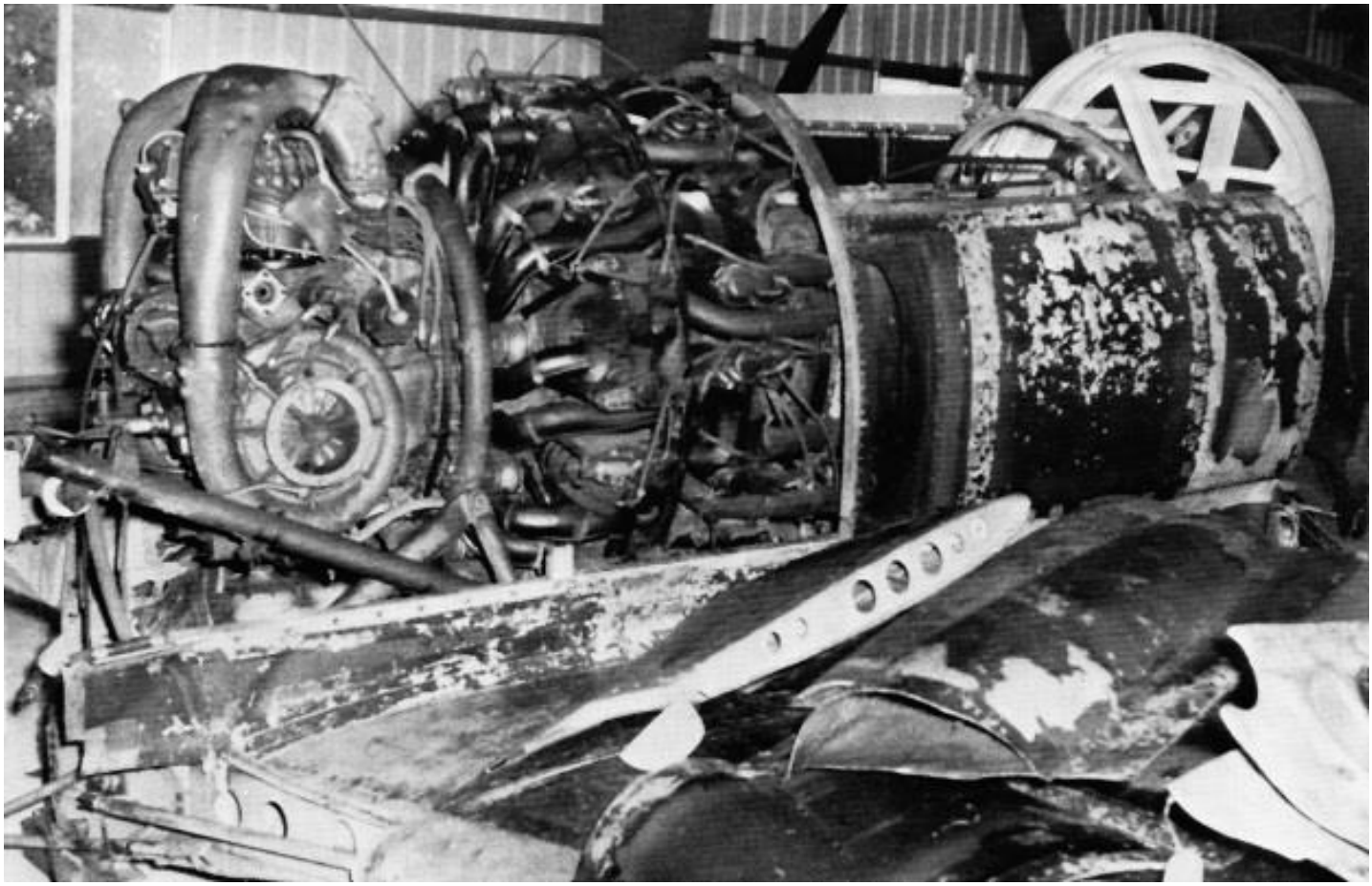
Further developments of the A7M were planned, such as the A7M3 powered by a [Ha-43] 31 (IJN MK9C) engine with a single-stage, three-speed mechanical supercharger. The [Ha-43] 31 produced 2,250 hp (1,678 kW) for takeoff; 2,000 hp (1,491 kW) at 5,906 ft (1,800 m) in low gear; 1,800 hp (1,342 kW) at 16,404 ft (5,000 m) in medium gear; and 1,660 hp (1,238 kW) at 28,543 ft (8,700 m) in high gear. The three-speed supercharger added about 5.4 in (138 mm) to the engine's length and 88 lb (40 kg) to the engine's weight, increasing the respective totals to 87 in (2.22 m) and 2,249 lb (1,020 kg). The A7M3-J would incorporate the [Ha-43] 11 engine with a turbosupercharger installed under the cockpit to produce 2,200 hp (1,641 kW) for takeoff; 2,130 hp (1,588 kW) at 22,310 ft (6,800 m); and 1,920 hp (1,432 kW) at 33,793 ft (10,300 m). While the A7M2 did not have a cooling fan, one was used in the A7M3 and A7M3-J designs.



The turbosupercharger installed in the Ki-83's left engine nacelle. The large duct on the right was for the exhaust after it passed through the turbosupercharger. The outlet at the end of the nacelle was from the wastegate. Both were positioned to provided additional thrust. The Ki-83 had a ceiling of 41,535 ft (12,660 m).

In the fall of 1944, two [Ha-43] 12 (IJA Ha-211-IRu) engines were installed in the Mitsubishi Ki-83. The Ki-83 was a twin-engine heavy fighter with a conventional taildragger layout. A turbosupercharger was placed in the rear of each engine nacelle. Fresh air would enter the turbocharger near the rear of the nacelle on the outboard side, be compressed, and then flow to the engine through an air box in the upper nacelle. The engine's exhaust was expelled from the turbocharger on the inboard side of the nacelle, and a wastegate was positioned at the end of the nacelle. The exhaust arrangement provided some additional thrust. Each engine turned an 11 ft 6 in (3.5 m) diameter, four-blade propeller. The Ki-83 made its first flight on 18 November 1944, but with the main focus on single-engine interceptors, only one was built before the Japanese surrender.

In April 1945, a [Ha-43] 42 (IJN MK9D) was installed in the Kyushu J7W1 *Shinden* (Magnificent Lightning), an unconventional pusher fighter with a canard layout. The [Ha-43] 42 had two-stage supercharging, with the first stage made up by a pair of transversely-mounted centrifugal impellers, one on each side of the engine. The shaft of these impellers was joined to the engine by a continuously variable coupling. The output from each of the first stage impellers joined together as they fed the normal, two-speed supercharger mounted to the rear of the engine and geared to the crankshaft. The [Ha-43] 42 produced 2,030 hp (1,514 kW) at 2,900 rpm with 9.7 psi (.67 bar) of boost for takeoff. Military power at 2,800 rpm and 5.8 psi (.40 bar) of boost was 1,850 hp (1,380 kW) at 6,562 ft (2,000 m) in low gear and 1,660 hp (1,238 kW) at 27,559 ft (8,400 m) in high gear. An extension shaft approximately 29.5 in (750 mm) long extended back from the engine to a remote propeller reduction gear box. The gear reduction turned the 11 ft 2 in (3.40 m), six-blade propeller at .412 times crankshaft speed and also drove a 12-blade cooling fan that was 2 ft 11 in (900 mm) in diameter.



The [Ha-43] 42 (IJN MK9D) installed in the Kyushu J7W1 Shinden, pictured while the aircraft was in storage at the Smithsonian National Air and Space Museum's Paul E. Garber facility. The front of the aircraft is on the left. One of the two transversely-mounted, first-stage superchargers can be seen left of the engine, and the ducts from both superchargers can be seen joining together as they feed the mechanically-driven supercharger at the rear of the engine. Note that the exhaust stacks are flowing toward the front of the engine (rear of the aircraft).

Since the engine was mounted with the propeller shaft toward the rear of the aircraft, it incorporated new cylinders with the exhaust port on the side opposite of the intake port. The intake port faced toward the supercharger (front of the aircraft), and the exhaust port faced toward the propeller (rear of the aircraft). The engine's individual exhaust pipes were used to help the flow of air through the cowling and oil coolers. After flowing through the oil cooler on each side of the aircraft, air was mixed with the exhaust from four cylinders and ejected out a slit on the side of the fuselage just before the spinner. The ejector exhaust helped draw air through the oil coolers. The same was true for the exhaust from the lower six cylinders, which was ducted into an augmenter that helped draw cooling air through the engine cowling and out an outlet under the spinner. The exhaust from the remaining four cylinders, which were located on the top of the engine, exited via two outlets arranged atop the cowling to generate thrust.

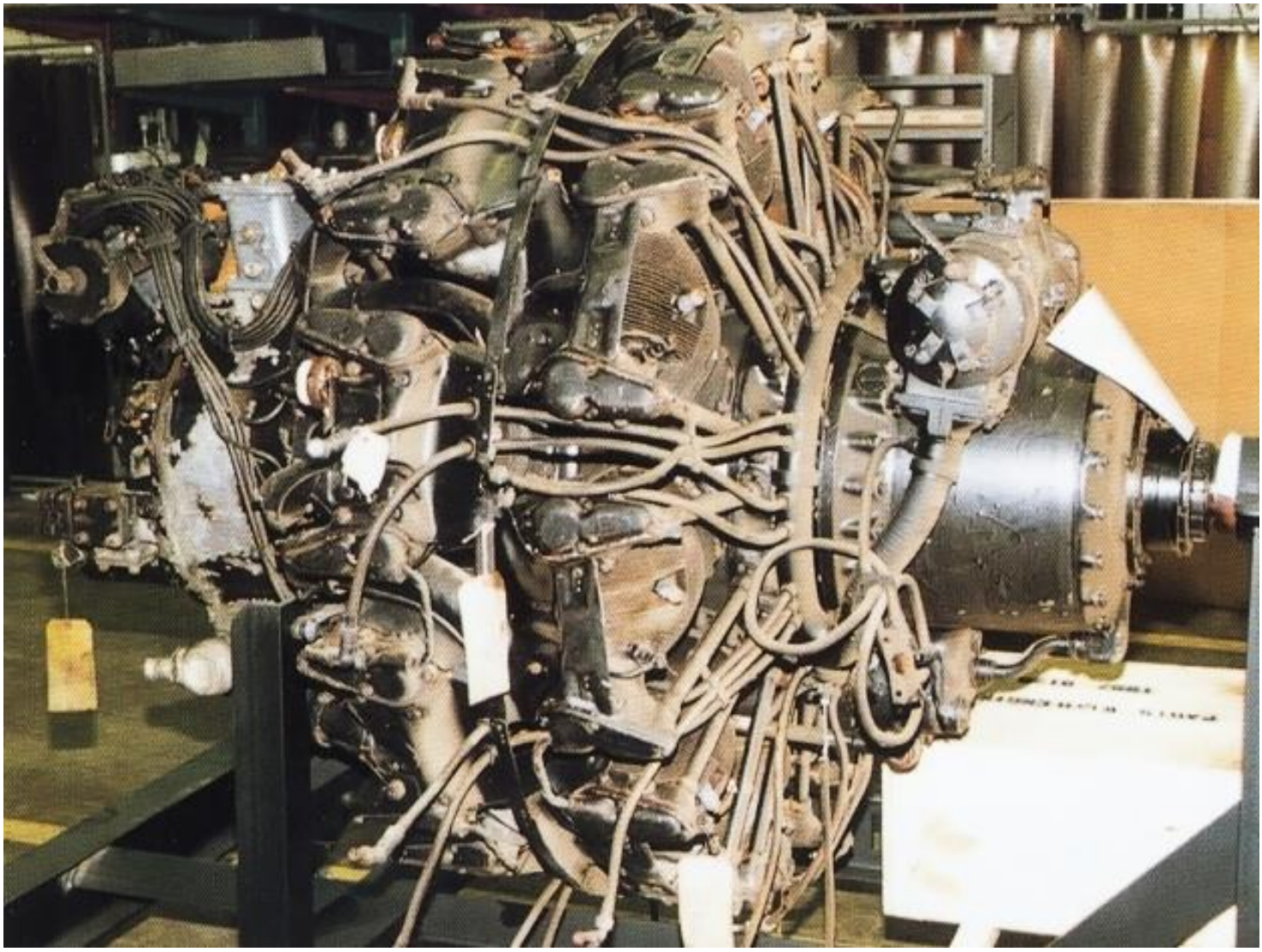
The J7W1 made its first flight on 3 August 1945. The third J7W1 was planned to have a [Ha-43] 43 engine that used a single impeller for its first-stage, continuously variable supercharger and produced an additional 130 hp (97 kW) for takeoff. Production J7W1 aircraft would be powered by a 2,250 hp (1,678 kW) [Ha-43] 51 engine with a single-stage, three-speed, mechanical supercharger replacing the two-stage setup with the continuously variable first stage. The engine would turn a four-blade propeller, 11 ft 6 in or 11 ft 10 in (3.5 m or 3.6 m) in diameter. However, only the first J7W1 was completed by war's end.

The [Ha-43] 11 engine with cooling fan in storage as part of the Smithsonian National Air and Space Museum's collection. Note the rust on the steel cylinder barrels. The spark plug wires are disconnected and desiccant plugs have been installed to help preserve the engine. (Tom Fey image)

In January 1945, construction commenced on the Mansyu Ki-98 (or Manshu Ki-98), a twin-boom pusher fighter with tricycle undercarriage. A single, turbosupercharged [Ha-43] 12 (IJA Ha-211-IRu) engine turning an 11 ft 10 in (3.6 m) four-blade propeller would power the aircraft. With the exception of the turbosupercharger, the installation was similar to that of the J7W1 with an extension shaft and remote propeller gear reduction. The prototype was ready for assembly when it was destroyed in August 1945 to prevent its capture by Soviet forces.

In addition to the aircraft listed above, the [Ha-43] was selected to power a number of aircraft projects that were not built. Plans were initiated to use the [Ha-43] to repower a number of different production aircraft that used the 2,000 hp (1,491 kW) Nakajima [Ha-45]. However, none of these retrofit redesigns were carried out before the end of the war. From 1942 to 1945, the production run of the [Ha-43] amounted to only 77 engines, and it was not fully developed by the end of the war.

At least three [Ha-43] engine survive, and all three are held by the Smithsonian National Air and Space Museum. One engine does not have a cooling fan and is probably a [Ha-43] 11 for a A7M2. The second engine is a [Ha-43] 11 with a cooling fan. The third engine is a [Ha-43] 42 still installed in the J7W1 prototype. All of the engines are in storage and not on display.



The fanless [Ha-43] 11 engine held by the Smithsonian National Air and Space Museum. The fuel distribution pump with its 18 lines can be seen atop the rear of the engine. The small-diameter lines appear to be made of copper.

Sources:

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