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BRITISH INTELLIGENCE
OBJECTIVES SUB-COMMITTEE

METALLURGICAL EXAMINATION OF JAPANESE KASEI-21 AIRCRAFT ENGINE No. 2189

Originating Agency :

National Defense Research Committee of Office of Scientific Research and Development, War Metallurgy Division.

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Reported by

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32, Bryanston Square, London, W.1.

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ABSTRACT

The Japanese Kasei-21 aircraft engine (Serial No. 2189) was examined for manufacturing methods, materials, and workmanship. A comparison was made between this engine and previously examined Japanese engines, particularly the Kasei Model-15 (Serial No. 151739) and Model-11 (Serial No. 11871).

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steels were clean and of satisfactory aircraft quality. Four general types of alloy steel were used: Ni-Cr-Mo, Ni-Cr-Mo-W, Cr-Mo-Al, and Cr-V. The first two of these types were similar to the British Aircraft 2S-28 series, the third type was similar to modified Nitralloy N-135, but the last had no American or British counterpart. The use of vanadium is unusual in Japanese aircraft structural steels. Silicon appeared to be the primary deoxidant in the steels, although in some cases; aluminum was also used.

Light-metal parts examined showed good casting and forging techniques. Magnesium castings, which customarily have been used for lightly-stressed housings and for the supercharger diffuser, were replaced in the Kasei-21 with aluminum alloy castings. Aluminum alloy pistons were made by forging cast blanks. The cylinder head showed excellent casting practice.

Table 1 lists the ferrous and nonferrous alloys used in the Kasei-21 engine parts and comparisons with the alloys used in the parts of engines previously examined.

ECONOMIC CONSIDERATIONS

The Kasei-21 was so similar to the engines previously examined that the same general conclusions may be drawn. The Japanese used adequate forging machinery for highly stressed parts and machined bar stock for the unstressed assemblies. Carburizing was used rather than induction or other surface-hardening treatments. No sacrifice was made in the quality of materials, nor was any attempt made to conserve manufacturing machinery.

Aluminum alloys were used where earlier models had used magnesium alloys. The chromium content of the exhaust valves was greatly reduced.

TABLE 1. COMPARISON OF MATERIALS USED IN JAPANESE AIRCRAFT ENGINES

Part No.	Name	Type of Material: Kasei-21	Type of Material: Other Engines
10	Cylinder barrel	Modified Nitralloy 135N steel	Nitralloy 135, N, G, and modified steel.
11	Cylinder head	Alcoa 142	Kasei-11, Kasei-15, Sakae-12 1941, Sakae-21, Kinsei-43: Alcoa 142 Homare-11: Alcoa 195 Sakae-12 (1943) - 4% Cu, 4% Si, 1-1/4% Mg, 1/2% Mn, Al base.
12A	Push rod end	SAE 52100 steel	Kasei-11, Kasei-15, Kinsei-43: SAE 52100 steel Homare-11, Sakae-12, Sakae-21: Carburized SAE 1035 steel
14	Rocker arm	.3% C, 3% Ni, 1% Cr, .7% Mo, (ASTM-A17-29-TY-F (+Mo)) steel	(ASTM-A17-29-TY-F(+Mo)) steel
16	Intake valve	.6% C, 4% Cr, 16%W, .6% V, (WD-71660) steel	Kasei-11, Kasei-15: .6% C, 3-1/3% Cr, 12-1/2% W, .55% V steel Homare-11, Sakae-12, Sakae-21, Kinsei-43: Various combinations of Si-Cr-W-Ni-Mo steels
20	Exhaust valve	.4% C, 14% Ni, 3% Cr steel	Kasei-11, Kasei-15: .4% C, 15% Ni, 14% Cr, 3-1/2% W, .2% Mo steel Homare-11, Sakae-12, Sakae-21, Kinsei-43: Various combinations of Si-Cr-W-Ni-Mo steels

TABLE 1. COMPARISON OF MATERIALS USED IN JAPANESE AIRCRAFT ENGINES (Continued)

Part No.	Name	Type of Material: Kasei-21	Type of Material: Other Engines	
46	Crankshaft	.2% C, 4% Ni, 2% Cr, 1% V, .2% Mo (British Aircraft 2S-28 (+W)) steel	Kasei-11, Kasei-15, Sakae-12 (1941), Sakae-21	British Aircraft 2S-28(+W) steel
			Homare-11, Kinsei-43, Sakae-12 (1943)	.3% C, 2% Ni, 2% Cr, .4% Mo steel
47	Crankshaft bolts	.3% C, 3% Ni, 3% Cr, .2% Mo (British Aircraft S.65)	British Aircraft S.65	
48	Propeller shaft	.2% C, 4% Ni, 1-1/2% Cr, 1% W, .2% Mo (British Aircraft 2S-28 (+W))	Kasei-11	British Aircraft 2S-28 steel
			Kasei-15	British Aircraft 2S-28 (+W) steel
			Others	Various combinations of Mn-Ni-Cr-W-Mo steel
49	Bell gear	.2% C, 4% Ni, 1% Cr, .2% Mo steel (British Aircraft 2S-28)	Kasei-11, Kasei-15, Sakae-12, Sakae-21	British Aircraft 2S-28 steel
			Homare-11, Kinsei-43	Nitralloy N-1359 steel
			Others	Various combinations of Ni-Cr-Mo steels
50	Planetary spur gear	Ditto	Kasei-11, Kasei-15	British Aircraft 2S-28 steel
			Sakae-12, Sakae-21, Homare-11, Kinsei-43	Various combinations of Ni-Cr-Mo steels
51	Sun gear	Ditto		Ditto
52	Cam	Ditto		Ditto

TABLE 1. COMPARISON OF MATERIALS USED IN JAPANESE AIRCRAFT ENGINES (Continued)

Part No.	Name	Type of Material: Kasei-21	Type of Material: Other Engines	
53A	Exhaust valve seat insert	.5% C, 11% Ni, 3% Cr, 4% W	Kasei-15	.3% C, 14% Ni, 14% Cr, .4% Mo
			Kasei-11, Sakae-12, Sakae-21, Homare-11, Kinsei-43	.6% C, 6% Mn, 12% Ni, 3.5% Cr
53B	Intake valve seat insert	90-10 aluminum bronze	Kasei-11, Kasei-15, Kinsei-43, Sakae-12, Sakae-21, Homare-11	90-10 aluminum bronze
54	Piston pin	.3% C, 1% Mn, 2% Ni, 3% Cr, .3% Mo steel	Kasei-11	British 2S-28 steel
			Kasei-15	Same as Kasei-21
			Sakae-12, Sakae-21, Homare-11, Kinsei-43	Various combinations of Ni-Cr-W-Mo steels
55	Master rod	.25% C, 3% Ni, 1% Cr, .4% Mo steel (British Aircraft 3S-11)	Kasei-11	British Aircraft 3S-11 steel
			Kasei-15	British Aircraft 3S-11 (-Ni) steel
			Sakae-12, Sakae-21, Homare-11, Kinsei-43	Various combinations of Ni-Cr-W-Mo steels
56	Articulated rod	.4% C, 4.5% Ni, 1% Cr, 2% Mo steel (British Aircraft 2S-28)	Kasei-11, Kasei-15	British Aircraft 3S-11 steel
			Sakae-12, Sakae-21, Homare-11, Kinsei-43	Various combinations of Ni-Cr-W-Mo steels

TABLE 1. COMPARISON OF MATERIALS USED IN JAPANESE AIRCRAFT ENGINES (Continued)

Part No.	Name	Type of Material: Kasei-21	Type of Material: Other Engines
57	Impeller shaft	.4% C, 4% Cr, .5% V	Kasei-11, Kasei-15: British Aircraft 2S-28 steel Sakae-12, Sakae-21, Homare-11, Kinsei-43: Various alloys of Ni and/or Cr and Mo steels
58	Impeller drive gear	.15% C, 2.5% Cr, .2% Mo steel (ASTM-A200-40-Gr4)	Various alloys of Ni and/or Cr and Mo steels
59	Crankcase	Alcoa 17S	Kasei-11, Kasei-15, Sakae-12, Sakae-21, Kinsei-43: Alcoa 17S Homare-11: SAE 4130 steel
60	Piston	Alcoa 142	Kasei-11, Kasei-15, Sakae-12 (1941), Sakae-21, Homare-11, Kinsei-43: Alcoa 142 Sakae-12 (1943): Alcoa 356
61	Blower case	Alcoa 356	Kasei-15, Kinsei-43: Alcoa 356 Sakae-12, Sakae-21, Homare-11: Alcoa A108 Kasei-11: AM240 magnesium
62	Impeller	Alcoa 17S	Alcoa 17S
63	Nose	Alcoa 356	Kasei-15: Alcoa 356 Homare-11, Sakae 12 (1943), Sakae-21: Alcoa 85 Sakae-12 (1941): Alcoa A108 Kasei-11, Kinsei-43: AM-240 magnesium

TABLE 1. COMPARISON OF MATERIALS USED IN JAPANESE AIRCRAFT ENGINES (Continued)

Part No.	Name	Type of Material: Kasei-21	Type of Material: Other Engines
64	Diffuser	Alcoa 356	Kasei-11, Kasei-15, Kinsei-43: AM 244 magnesium Sakae-12, Sakae-21: AM 240 magnesium Homare-11: Alcoa A108
65	Master rod bearing	70-30 Cu-Pb	Kasei-11, Kasei-15, Kinsei-43, Sakae-12 (1941), Sakae-21: 70-30 Cu-Pb Sakae-12 (1943), Homare-11: 65% Cu, 33% Pb, 1% Ni, 1% Fe
66	Piston pin bearing	85-15 Cu-Sn	Kasei-11, Kasei-15, Sakae-12, Sakae-21, Kinsei-43: 85-15 Cu-Sn Homare-11: 88% Cu, 4% Sn, 4% Pb, 4% Zn
67	Rocker arm shaft bearing	85-15 Cu-Sn	85-15 Cu-Sn
68	Impeller bearing	80-15-5 Cu-Pb-Sn	Kasei-15: 4% Cu, 2-1/3% Sn, 2% Mg, Al base Kasei-11, Sakae-12, Sakae-21, Kinsei-43, Homare-11: 80-15-5 Cu-Pb-Sn
69	Front cam bearing	85-15 Cu-Sn	Kasei-11, Kasei-15, Kinsei-43: 85-15 Cu-Sn Homare-11, Sakae-12, Sakae-21: 5% Cu, 89% Sn, 6% Sb babbitt

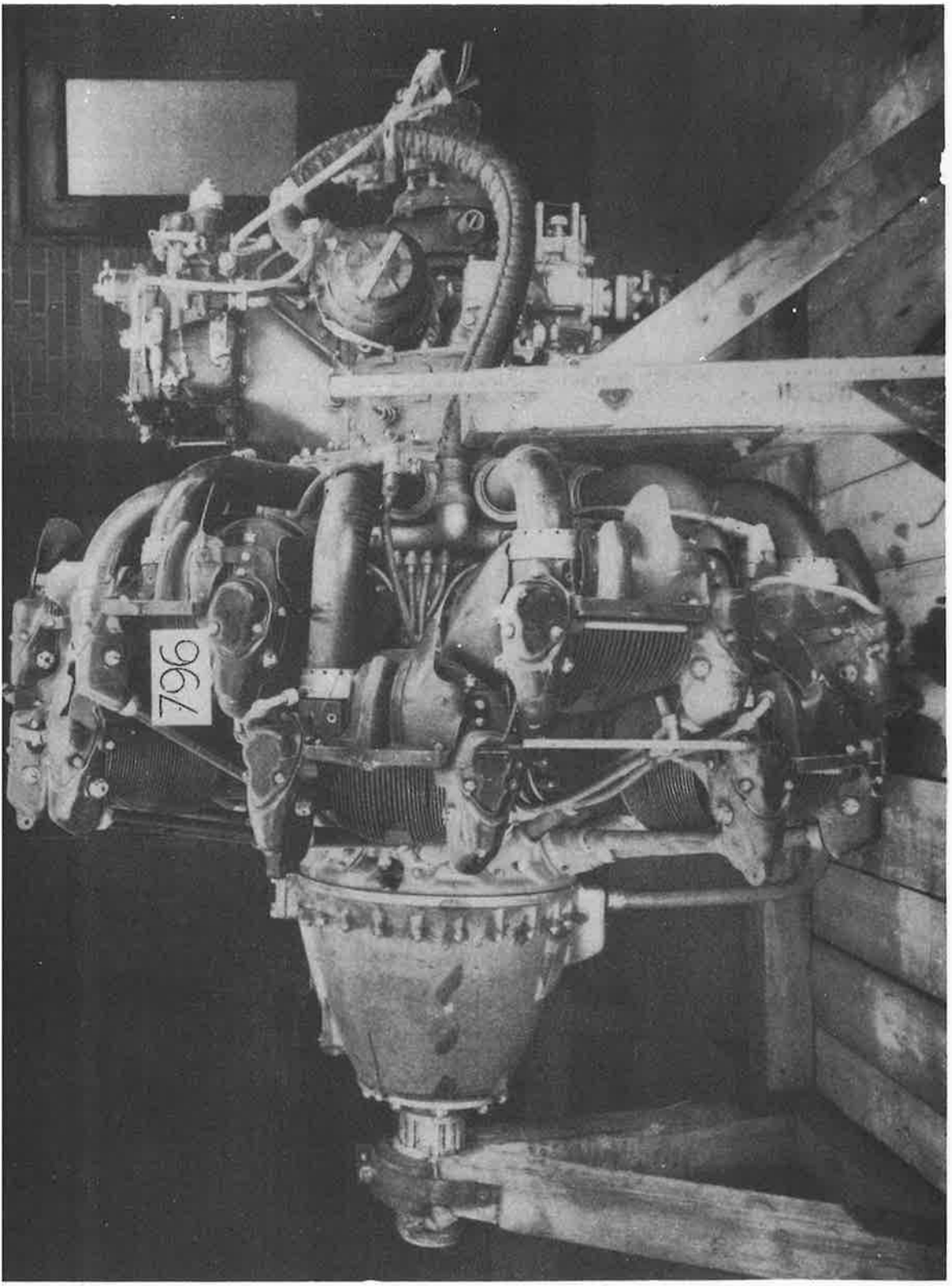

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Figure 1. Side View of Kasei-21 Engine (CEE#2075) As-Received

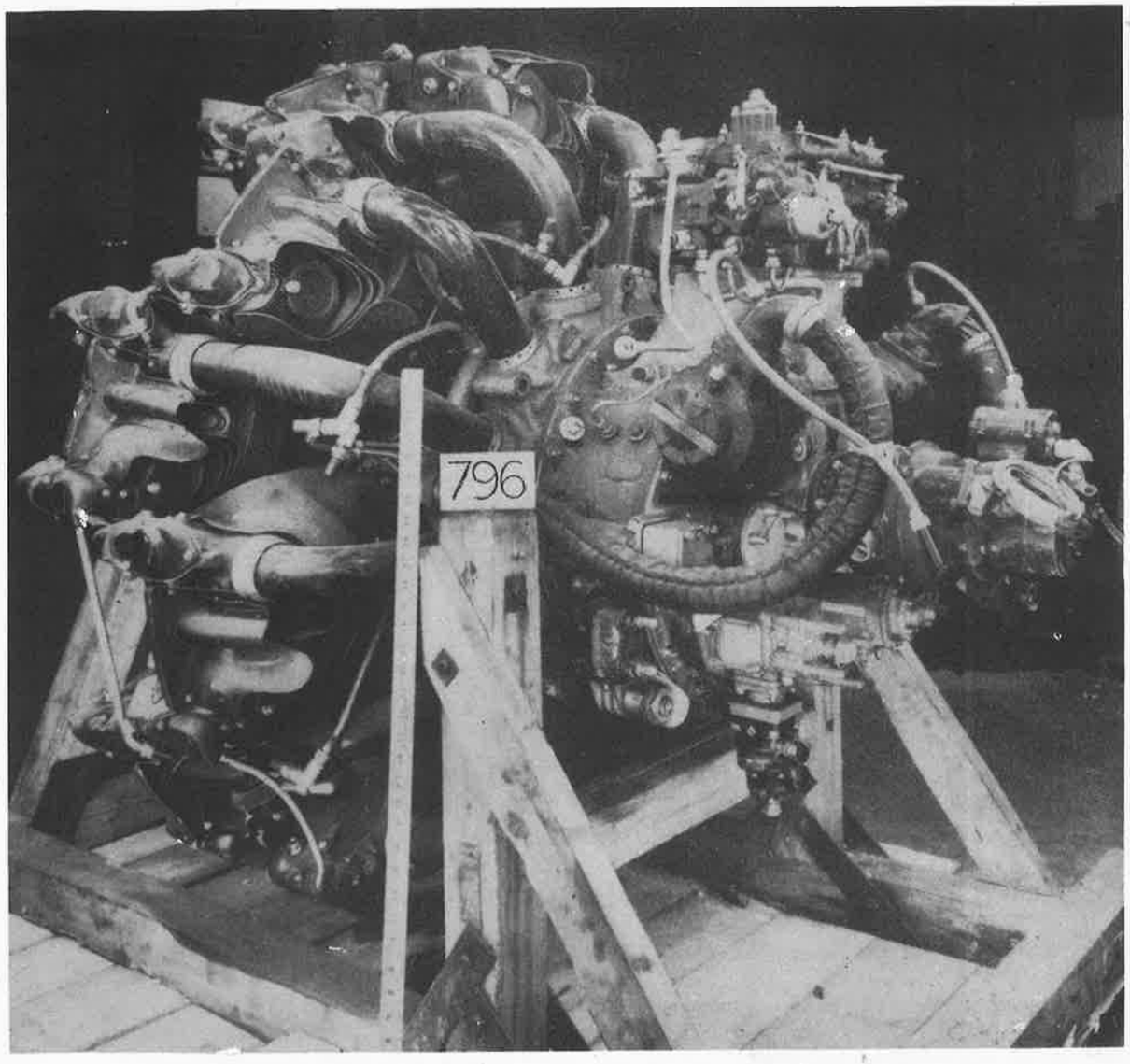

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Figure 2. Rear View of Kasei-21 Engine (CEE#2075) As-Received

DISCUSSION OF RESULTS

The analyses of all the ferrous and nonferrous parts examined are listed in Tables 2 and 3, respectively. General data are given in Table 4. The parts are discussed in detail under the appropriate sub-assembly sections.

POWER SECTION

The exterior of the power section is presented in Figure 3, and a detailed view showing the rods and crankshaft is given in Figure 4.

Crankcase

The three sections of the crankcase were forged and machined from solution heat-treated and aged Alcoa 17S type alloy. However, the sections were insufficiently solution heat treated before aging, and not all of the $CuAl_2$ was dissolved. The forging flow lines conformed very closely to the contours of the particular sections. Physical properties of the alloy, shown in Table 4, were in line with those obtained in this country for the hardness of 85 Vickers used by the Japanese. Each aircraft engine crankcase examined was similar in design and material to the one under discussion, with one exception; namely, the crankcase of the Homare-11 engine which was similar in design, but forged from an SAE 4130 type steel and zinc plated.

Crankshaft

The three-piece crankshaft was forged and machined from British Aircraft 2S-28 type steel with tungsten additions. Heat treatment consisted of quenching and tempering the parts after carburizing the throws 0.035". Macroetching showed that the original dendritic pattern was broken up and that the grain flow was good. Tensile properties were normal, but the percentage reduction of area was high for a hardness of 380 Vickers (Table 4).

Previous examinations of other engines showed that the 1941 and 1942 Sakae and the Kasei engines were the only ones using crankshafts

made from the previously mentioned type alloy. Steels with 2% less nickel, no tungsten, and with the same amounts of the other alloying elements, were used for crankshafts in the 1943 Sakae and other type engines.

Crankshaft bolts in the Kasei-21, as well as in the other engines, were machined from bar stock of British Aircraft S.65 type steel, which contained 1% less nickel and 1% more chromium than the steel in the crankshaft. No tungsten was added. The bolts were quenched and tempered to the hardness of the crankshaft.

Master and Articulated Rods

The master rod was forged and machined from medium carbon-nickel-chromium-molybdenum steel similar to British Aircraft 3S-11 alloy. The articulated rod was forged and machined from British Aircraft 2S-28 type steel which contained the same amount of chromium, but 1-1/2% more nickel and 0.2% less molybdenum than the master rod steel. Each rod was quenched and tempered to an average hardness of 375 Vickers. The master rod bearing was a 70-30 copper-lead alloy cast to a depth of 0.035" on a low-carbon steel backing.

Previous analyses of articulated rods of the Kasei-11 and -15 engines showed that the rods were made from the same type steel as found in the master rod of the Model-21. Master rod steel on the Model-15 was similar to the British 3S-11 type, but only residual nickel was found. Master rod bearings on each of the previous engines examined were similar to the copper-lead alloy on the Kasei-21, with the exception of the bearings on the Homare-11 and on the 1943 Sakae-12; these bearings contained 1% nickel and 1% iron in addition to the copper and lead.

Piston

A cast blank of Alcoa 142 type alloy was forged and machined to produce the piston. The piston was solution heat treated and aged to a hardness ranging from 123 Vickers at the center of the crown to 145 Vickers at the skirt. Pistons examined in other engines were made in a similar manner and from the same type alloy. One exception was the 1943 Sakae-12, which had pistons forged from Alcoa 356 type alloy.

The piston pin on the Kasei-21 engine was cut from tubing or machined from bar stock and quenched and tempered to a hardness of 549 Vickers. The medium-carbon steel used was alloyed with 1% manganese, 2% nickel, 3% chromium, and 0.3% molybdenum. The piston pin on the Kasei-15 was made from the same type alloy as the Kasei-21; the pin on the Kasei-11, from a steel similar to that covered by British Aircraft 2S-28 specification. The Kasei-11 and -15 pins were case carburized 0.020" and then quenched and tempered.

The piston pin bearing on the Kasei-21 was cast from 85-15 copper tin bronze. With one exception, the piston pin bearings on other engines examined were also 85-15 copper-tin bronzes. The Homare-11 bearing was of copper-tin alloyed with 4% zinc and 4% lead.

CYLINDER ASSEMBLY

The cylinder assembly is shown as disassembled in Figure 5.

Cylinder Barrel and Head

The Kasei-21 cylinder barrel was forged and machined from Nitralloy 135M type alloy steel. After quenching and tempering to a core hardness of 274 Vickers, the bore was nitrided 0.010". The

steel was clean. All changes of section on the barrel had generous fillets, and fine machining cuts were used in the finishing operation. Outside surfaces were covered with black paint, the analysis of which showed the presence of alkyd vehicles.

Forged, quenched, and tempered Nitralloy 135 type alloy steels were used by the Japanese on each of the cylinder barrels previously examined. Nitrided cases varied in depth from 0.002" to 0.010". A white layer was found on the case of the Kasei-15 barrels.

The cylinder head on the Kasei-21 engine was a slightly porous sand casting which was solution heat treated and aged. Alcoa 142 type aluminum alloy was used for the heads. Numerous cores were used to produce the intricate shape and form.

Previous examinations of cylinder heads showed that the Japanese used Alcoa 142 type alloy extensively. The only exceptions were found on the Homare-11 and the 1943 Sakae-12 engines. In the former, a plain copper-silicon Alcoa 195 type alloy was used, and in the latter an aluminum alloy containing 4% copper, 4% silicon, 1-1/4% magnesium and 1/2% manganese.

Valve Seat Inserts

The exhaust valve seat inserts of the Kasei-21 engine were forged from an austenitic steel containing 0.5% carbon, 11% nickel, 3% chromium, and 4% tungsten; and solution heat treated. Examinations of exhaust valve seat inserts from other engines revealed that all but one were forged from a high-manganese austenitic steel containing approximately 0.6% carbon, 6% manganese, 12% nickel, and 3.5% chromium with or without molybdenum additions. The exception was the Kasei-15 insert which was fabricated from austenitic steel containing 0.3% carbon, 14% nickel, 14% chromium,

and 0.4% molybdenum.

The intake valve seat insert on the Kasei-21 was forged and machined from an aluminum-bronze alloy. Intake valve seat inserts on the other Kasei engines and on the Kinsei-43 engine were cast from aluminum-bronze. The other engines examined had intake inserts which were forged from the same type high-manganese austenitic steel used on the majority of the exhaust valve seat inserts described above.

Push Rod End

Machined SAE 52100 type steel was used in fabricating the push rod ends for the Models-21,-15, and -11 Kasei engines. The tips were differentially heat treated with resulting Vickers hardnesses ranging from 800 in the head to 225 in the shank.

Machined and carburized SAE 1035 type steel was used on push rod ends of the other type engines examined, with the exception of the Kinsei-43 rod end, which was machined from SAE 52100 type steel and differentially heat treated.

Rocker Arm

The rocker arm on the Kasei-21 engine was forged and machined from steel comparable to that covered by ASTM specification A17-29-TY-F, but with a high molybdenum content. Heat treatment consisted of quenching and tempering to a hardness of 400 Vickers. Flow lines, typical of good forging practice, were revealed by macroetching. Corrosion was prevented by a thin coat of cadmium. Rocker arm shaft bearings were cast 85-15 copper-tin bronzes.

Examinations of the rocker arms of the Models-11 and -15 Kasei engines and of the other engines showed that the same type alloys, manufacturing methods, and heat treatment were used on these parts throughout. The rocker arm shaft bearing on each engine was also cast from 85-15 copper-tin alloy.

Valves

Structurally, the valves of the Kasei-21 engine were very similar to those of the other Japanese engines examined. The intake valve on the Kasei-21 was upset from bar stock to form the head, after which the entire valve was quenched and tempered and the stem tip locally hardened. The exhaust valve, which was of the sodium-filled type with stellite on the valve seat and stem tip, was forged, quenched, and tempered, and then nitrided 0.001" to 0.002" on the stem. The exhaust valves on the Kasei-21 engine had plugs inserted into the stems after sodium filling. No plug was found in the Kasei-11 and -15 exhaust valves; the stems of these were forged shut.

The steel used in making the intake valve on the Kasei-21 engine was similar to WD-71660 alloy. The intake valve steel on the Kasei-11 and -15 was similar to the Kasei-21 intake valve steel, but had 1% less chromium and 4% less tungsten as shown in Table 4. Steel used in the exhaust valves on the Kasei-21 contained 0.4% carbon, 14% nickel, and 3% chromium. Kasei-11 and -15 exhaust valve steel had similar amounts of carbon and nickel, but the chromium content was raised to 14%, with 4% tungsten and 1/4% molybdenum also added. The other engine valve steel were varied combinations of Si, Ni, Cr, W, V, and Mo.

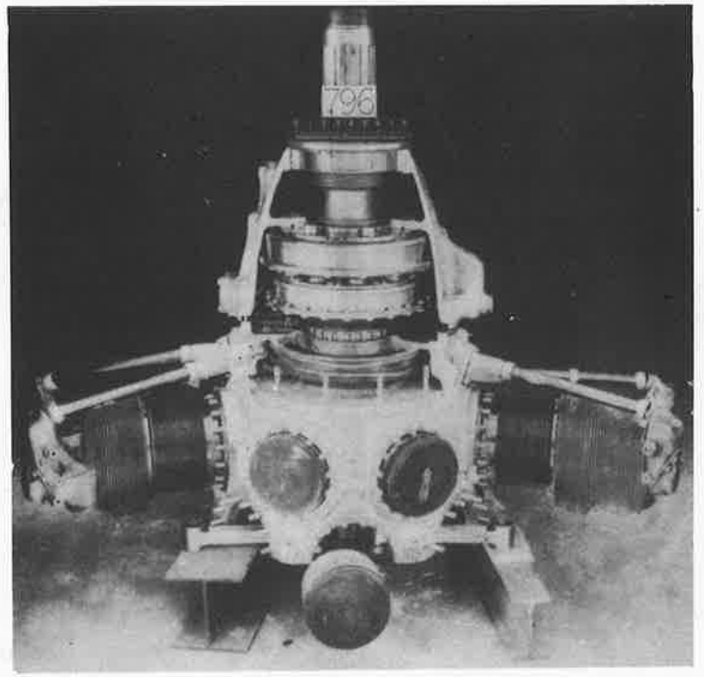

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Figure 3. Exterior of Power Section With Cylinders and Pistons - Kasei-21 Engine (CEE #2075)

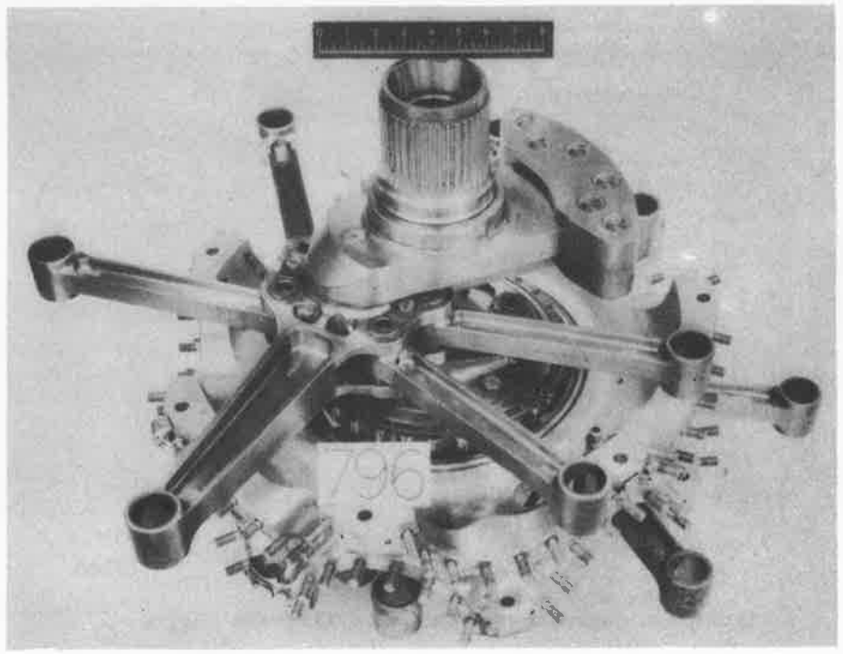

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Figure 4. Details of Power Section, Showing Rods and Crankshaft - Kasei-21 Engine (CEE #2075)

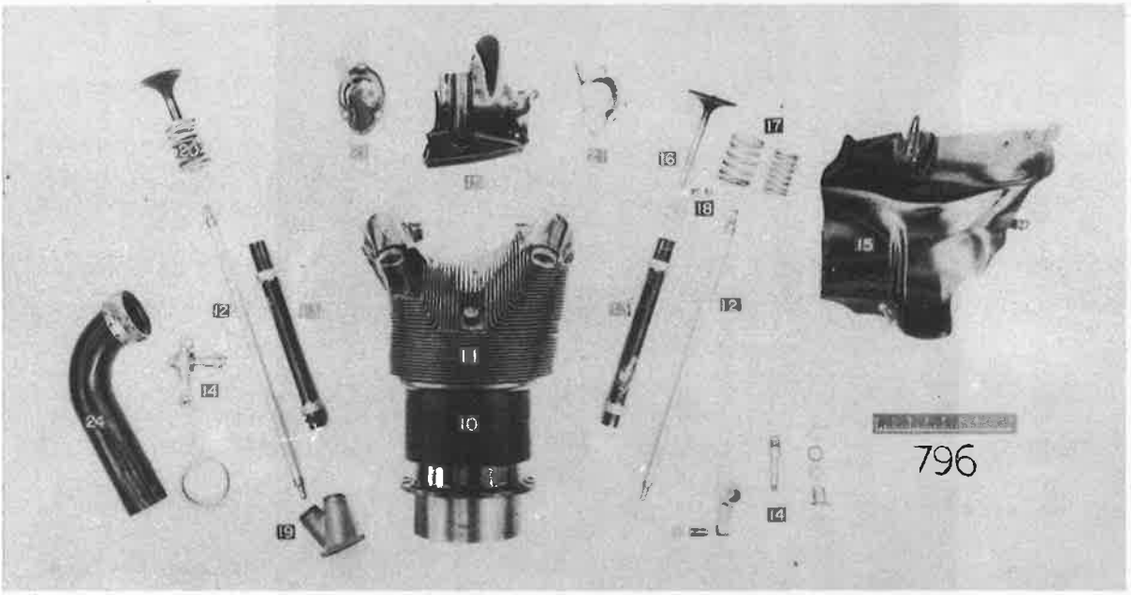

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Figure 5. Disassembly View of Kasei-21 Cylinder Disassembly

(CEE #2075)

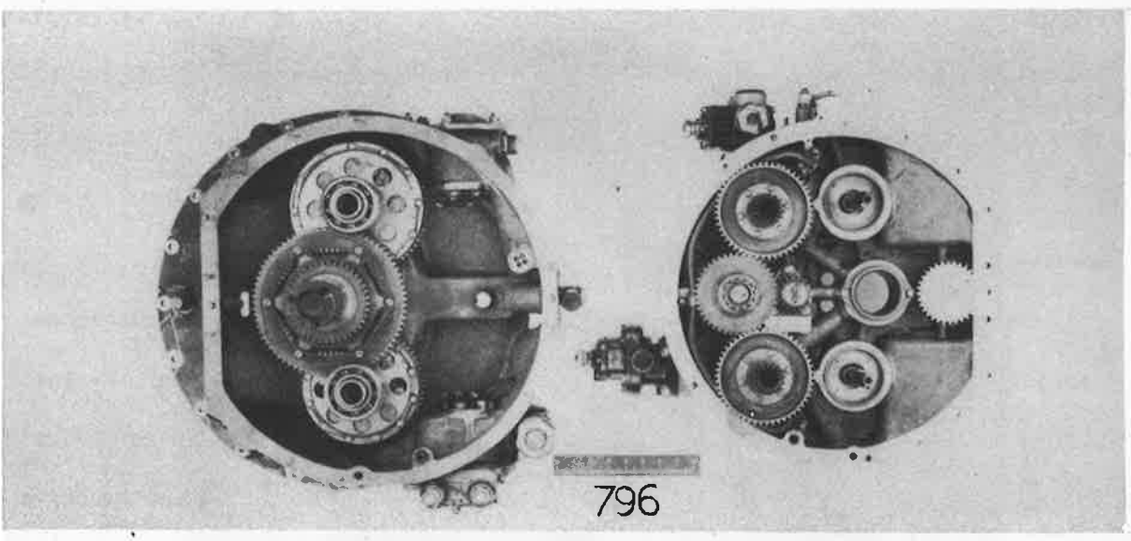

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Figure 6. Gear Case of Kasei-21 Aircraft Engine

(CEE #2075)

NOSE SECTION

Figure 7 illustrates the nose section showing the reduction gearing system and Figure 8, the cam-ring housing and associated portion of the power section. The Kasei-21 engine is the first one examined which had a primary and secondary bell gear system.

Cam, Bell Gear, Sun Gear, and Planetary Spur Gear

The nose-section cam and gears of the Kasei-21 engine were forged and machined from a modified British Aircraft 2S-28 type steel. Wearing surfaces were carburized 0.020" to 0.030", and then the pieces were quenched and tempered to an average core hardness of 435 Vickers and an average case hardness of 700 Vickers. The cam bearing was cast from an 85% copper - 15% tin-bronze alloy. The bearing showed good workmanship and quality.

Each of the previously examined Kasei nose section cams and gears were made from the same type steel and in the same manner as the ones under discussion. However, the bell gear in the Sakae engines were forged from Nitralloy 135G type alloy and nitrided 0.010". Cams, sun gears, and planetary spur gears in engines other than the Kasei type were forged from a wide variety of alloy steels, carburized, quenched, and tempered. The cam bearings of the Kasei-11 and -15, and the Kinsei-43 engines were cast 85-15 copper-tin bronzes; those of the Homare-11, Sakae-12, and Sakae-21 engines were cast copper-tin-antimony babbitts.

Propeller Shaft

The Kasei-21 propeller shaft was hammer-forged British Aircraft 2S-28 type steel with a tungsten addition, quenched, and tempered to

a VDH of 362. Tensile tests yielded a normal tensile strength value and a high reduction of area value, as shown in Table 4.

The propeller shaft of the Kasei-11 engine was forged from the same type steel as used on the Kasei-21; that of the Kasei-15 was forged from a similar type steel without tungsten additions. Tensile properties were in line with those of the Kasei-21 shaft. Other engine propeller shafts were fabricated in the same manner from a wide variety of alloy steels.

Nose

The Kasei-21 nose was cast from an Alcoa 356 type aluminum alloy. The slightly porous casting was modified (probably with sodium) and solution heat treated and aged to a hardness of 82 Vickers. With only two exceptions, noses on engines examined were cast from Alcoa 356 (9-1/2% Si-1/2% Mg), Alcoa 85 (5% Si-4% Cu), or Alcoa #108 (5-1/2% Si - 4-1/2% Cu) type aluminum alloys. These exceptions were the Kasei-11 and Kinsei-43 noses which were cast from an AM-240 type magnesium alloy (9% Al).

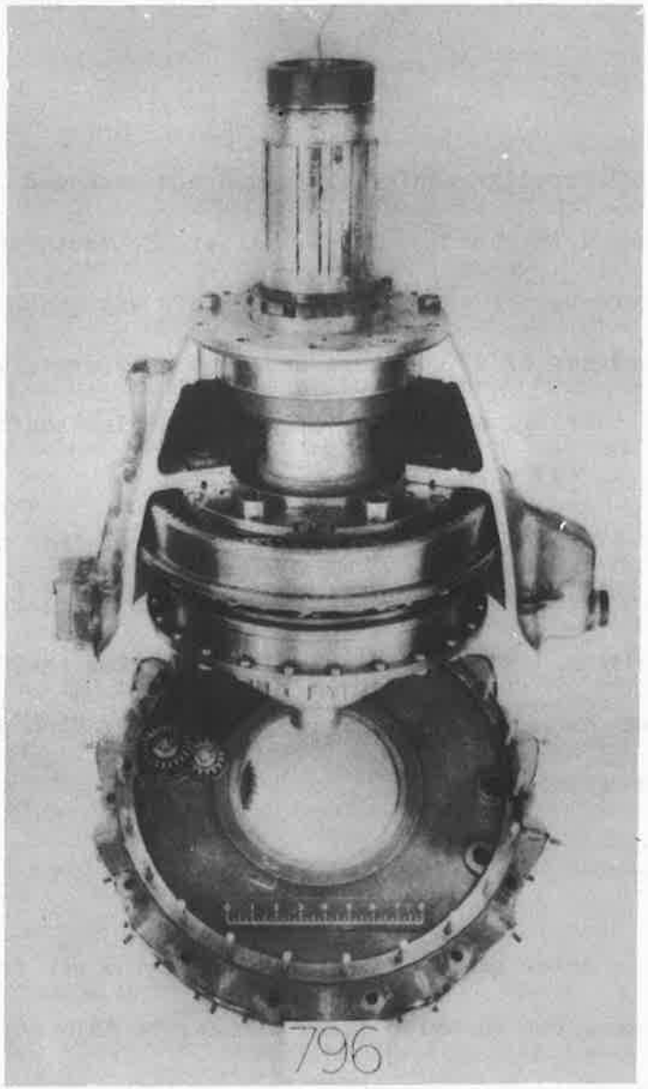

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Figure 7. Nose Section Showing Reduction Gearing Kasei-21 (CEE #2075)

SUPERCHARGER AND BLOWER SECTION

The blower case, diffuser, and impeller assemblies are presented in Figure 9. The gear case, which was not examined, is shown in Figure 6.

Impeller Shaft

The Kasei-21 impeller shaft was forged and machined from a medium carbon, 4% chromium, 1/2% vanadium steel. After the teeth and other wearing surfaces were carburized 0.030", the shaft was quenched and tempered to a core hardness of 410 Vickers and a case hardness of 735 Vickers The impeller shaft bearing, which fits into the tubular shaft, was a cast tin-bronze containing 14% lead.

Previously examined shafts, from engines other than Kasei models, were forged from steels alloyed with varying amounts of nickel and/or chromium and molybdenum. The Kasei-11 and -15 impeller shafts were manufactured in the same manner as the Kasei-21 shafts; British Aircraft 2S-28 type Ni-Cr-Mo steel was used.

Impeller Drive Gear

The impeller drive gear of the Kasei-21 engine was forged and machined from a low-carbon chromium steel similar to ASTM A200-40-Gr4, which is used principally for seamless tubing in this country. Gear teeth were carburized 0.030" before quenching and tempering to hardnesses similar to those of the impeller shaft.

Each type of Japanese engine previously examined had a different type of clutch system. The steels in each of the impeller drive gears were alloyed with varying amounts of nickel, and/or chromium, and molybdenum.

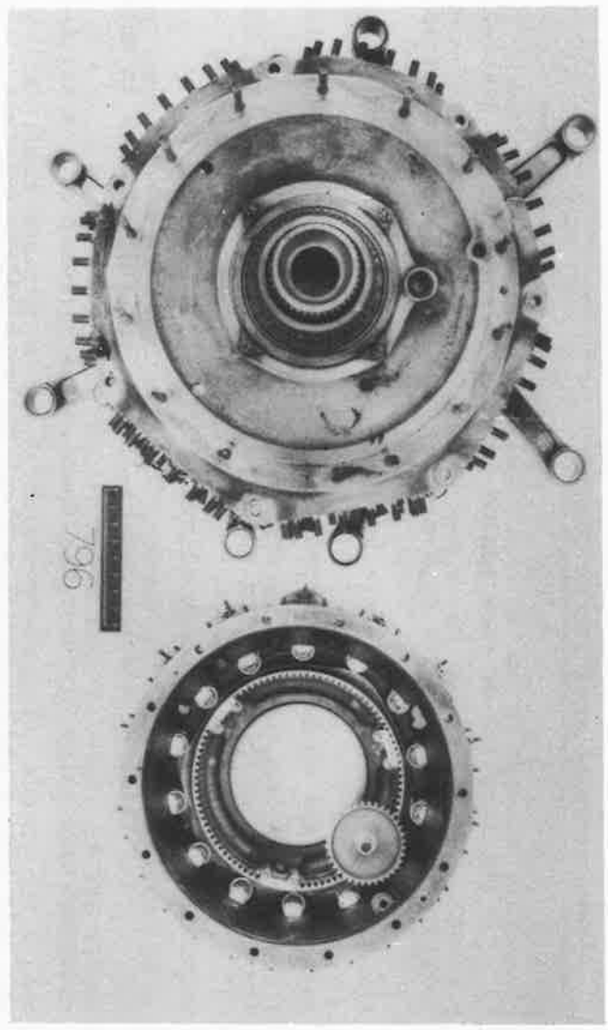
Impeller, Diffuser, and Blower Case

The impeller on each engine examined, including the Kasei-21, were forged from Alcoa 17S type aluminum alloys, solution heat treated, and aged to an average Vickers hardness of 110. The impeller bearing on each engine was an 85-15-5 copper-lead-tin alloy, with the exception of the Kasei-15 impeller bearing which was a 4% copper, 2-1/3% tin, 2% magnesium, and aluminum-base alloy.

The Kasei-21 and the Homare-11 were the only engines in which an aluminum-base alloy diffuser was found. The diffuser of the Kasei-21 was cast from a sodium-modified Alcoa 356 type alloy, and that of the Homare-11 from an Alcoa A108 type alloy. Magnesium-base alloys were used in casting the diffusers for the other Japanese aircraft engines examined - AM-244 alloy in those of the Kasei-15 and Kinsei -43, and AM-240 on the diffuser of the Sakae-12. Each magnesium alloy diffuser was in the as-cast condition.

The blower case on the Kasei-21 engine was sand cast from modified Alcoa 356 type alloy. Analyses of blower cases from the previously examined engines showed that about an equal number of cases were cast from silicon-aluminum alloys similar to Alcoa 356 and from silicon-copper-aluminum alloys similar to Alcoa A108. The Kasei-11 blower case was the only one cast from a magnesium-base alloy (AM 240 type).

LHG:ABW:DOL:HWG/mab
September 5, 1945



37150

Figure 8. Cam Ring Housing and Associated Portion of Power Section Kasei-21 (CEE #2075)

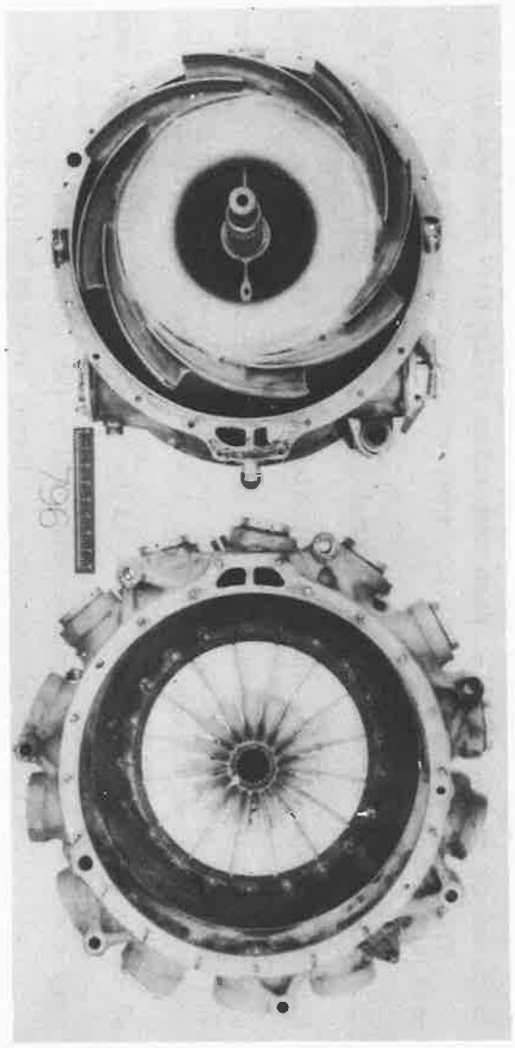


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Figure 9. View of Blower Case, Diffuser, and Impeller Kasei-21 (CEE #2075)

RESTRICTED

TABLE 2. ANALYSES OF SELECTED FERROUS PARTS FROM JAPANESE KASEI-21 AIRCRAFT ENGINE

BMI No.	Name	C	P	S	Mn	Si	Ni	Cr	W	V	Mo	Cu	Sn	Al	Ti
796-10	Cylinder barrel	0.33	0.024	0.026	0.58	0.28	0.16	1.56	<0.04	<0.02	0.40	0.26	0.043	1.01	0.004
796-12A	Push rod end	0.98	0.029	0.022	0.48	0.28	0.33	1.40	<0.04	<0.02	0.05	0.11	0.047	0.036	0.005
796-14A	Rocker arm	0.32	0.019	0.012	0.59	0.23	3.19	1.30	<0.07	<0.02	0.67	0.20	0.038	0.006	0.005
796-16	Intake valve	0.59	0.008	0.020	0.23	0.23	0.26	4.32	15.5	0.63	0.03	0.13	-	-	-
796-20	Exhaust valve - body	0.38	0.029	0.006	0.42	0.25	14.4	3.18	<0.04	<0.02	0.04	0.29	0.074	<0.005	-
796-20A	Exhaust valve - hard facing	-	-	-	-	1.89	0.20	23.6	5.90	-	61.6 Co	-	-	-	-
796-46	Crankshaft	0.15	0.012	0.007	0.53	0.28	3.90	1.67	1.00	<0.02	0.18	0.20	0.005	0.009	<0.004
796-47	Crankshaft bolt	0.32	0.015	0.014	0.55	0.22	3.00	2.95	<0.04	0.024	0.61	0.18	0.044	0.005	<0.004
796-48	Propeller shaft	0.19	0.015	0.008	0.69	0.22	4.22	1.72	0.90	<0.02	0.23	0.20	0.046	0.018	0.004
796-49A	Bell gear	0.16	0.010	0.011	0.55	0.25	4.40	0.89	<0.04	<0.02	0.24	0.20	0.043	0.010	0.005
796-49B	Bell gear	0.14	0.020	0.016	0.71	0.26	4.60	0.99	<0.04	0.022	0.18	0.20	0.069	0.005	0.005
796-50	Planetary spur gear	0.15	0.018	0.023	0.47	0.18	4.70	0.85	<0.04	<0.02	0.09	0.16	0.041	0.008	<0.004
796-51	Sun gear	0.12	0.021	0.026	0.48	0.15	4.50	0.80	0.19	<0.02	0.24	0.20	0.075	<0.005	0.006
796-52	Cam	0.24	0.014	0.022	0.56	0.14	4.70	0.93	0.05	<0.02	0.18	0.25	0.065	<0.005	0.005
796-53A	Exhaust valve seat insert	0.54	0.024	0.019	0.33	0.26	10.7	2.90	4.00	0.079	0.03	0.17	-	-	-
796-54	Piston pin	0.27	0.015	0.015	1.00	0.24	1.72	2.70	<0.04	<0.02	0.29	0.25	0.091	<0.005	<0.004
796-55	Master rod	0.25	0.016	0.015	0.55	0.20	3.08	1.22	0.05	<0.02	0.37	0.21	0.028	<0.005	<0.004
796-56	Articulated rod	0.38	0.027	0.031	0.56	0.21	4.43	1.10	0.08	<0.02	0.18	0.26	0.045	<0.005	0.005
796-57	Impeller shaft	0.41	0.017	0.023	0.19	0.58	0.27	4.18	<0.04	0.49	<0.03	0.15	0.040	<0.005	<0.004
796-58	Impeller drive gear	0.14	0.014	0.020	0.84	0.26	0.27	2.33	<0.04	<0.02	0.23	0.21	0.050	0.020	<0.004

TABLE 3. ANALYSES OF SELECTED NONFERROUS PARTS FROM JAPANESE KASEI-21 AIRCRAFT ENGINE

BMI No.	Name	Si	Cu	Mg	Fe	Mn	Ni	Al	Sn	Pb	Ti
796-11	Cylinder head	0.30	4.20	1.20	0.8	-	2.0	Base	-	-	-
796-53B	Intake valve seat insert	-	88.5	-	-	0.50	-	10.5	-	-	-
796-59	Crankcase	0.36	4.00	0.44	0.26	0.49	-	Base	-	-	-
796-60	Piston	0.33	4.30	1.50	0.35	-	2.0	Base	-	-	-
796-61	Blower case	9.4	<0.05	0.5	0.31	0.20	-	Base	-	-	<0.02
796-62	Impeller	0.29	3.80	0.65	0.55	0.59	-	Base	-	-	-
796-63	Nose	9.5	<0.05	0.5	0.37	0.20	-	Base	-	-	<0.02
796-64	Diffuser	9.4	<0.05	0.5	0.32	<0.02	-	Base	-	-	<0.02
796-65	Master rod bearing	-	70.06	-	0.35	-	-	-	0.4	30.1	-
796-66	Piston pin bearing	-	84.4	-	-	-	-	-	14.78	-	-
796-67	Rocker arm shaft bearing	-	84.6	-	-	-	-	-	14.8	-	-
796-68	Impeller shaft bearing	-	78.3	-	-	-	-	-	6.7	14.5	-
796-69	Front cam bearing	-	84.6	-	-	-	-	-	14.9	-	-

TABLE 4. METALLURGICAL DATA ON PARTS FROM JAPANESE KASEI-21 AIRCRAFT ENGINE (BMI #796-CEE #2075) AND COMPARISON WITH KASEI-11 AND -15 ENGINES

BMI No.	Name	VDH	Type of Material	Remarks
796-10	Cylinder barrel	Case 996 Core 274	Kasei-21: Nitralloy 135 N type steel Kasei-15: Nitralloy 135 modified steel Kasei-11: Nitralloy 135 modified (with low Al) steel	Kasei-21,-15 -11: forged and machined, quenched and tempered, clean, covered with black paint; Kasei 21: nitrided 0.010" total; Kasei 15: nitrided 0.014" total - 0.001" white layer; Kasei 11: nitrided 0.008" total.
796-11	Cylinder head	94	Kasei-21: Alcoa 142 alloy Kasei-15: Alcoa 142 alloy Kasei-11: Alcoa 142 (with low Ni) alloy	Kasei-21,-15,-11: sand cast with cores, solution heat treated and aged, slightly porous, covered with black paint.
796-12A	Push rod end	885 to 255	Kasei-21: SAE 52100 type steel Kasei-15: SAE 52100 type steel Kasei-11: SAE 52100 (plus 0.8% W) type steel	Kasei-21,-15,-11: machined with differentially hardened tips, clean.
796-14A	Rocker arm	401	Kasei-21: 0.3% C-3% Ni-1% Cr-0.7% Mo steel Kasei-15,-11: 0.25% C-3% Ni-1% Cr-0.4% Mo steel	Kasei-21,-15,-11: forged and machined, quenched and tempered, clean, Cd coated.

TABLE 4. (Continued)

BMI No.	Name	VDH	Type of Material	Remarks
796-16	Intake valve	Tip 570 Body 400	Kasei-21,-15,-11: 0.6% C-4% Cr-16% W-0.6% V steel Kasei-15-11: 0.6% C-3% Cr-12% W-0.6% V steel	Kasei-21,-15,-11: solid type, forged and machined, quenched and tempered, stem tip locally hardened.
796-20	Exhaust valve	Stellite 670 Body 400	Kasei-21: 0.4% C-14% Ni-3% Cr steel Kasei-15,-11: 0.4% C-15% Ni-14% Cr-4% W-0.2% Mo steel	Kasei-21,-15,-11: sodium-filled type, stellite on valve seats and stem tips, quenched and tempered, stems nitrided 0.001/0.002". Kasei-21: forged and machined, plug inserted in stem after sodium filling. Kasei-15 and -11: forged and machined, no plugs.
796-46	Crankshaft	Case 521 Core 380	Kasei-21,-15,-11: 0.2% C - 4% Ni-2% Cr-1% W-0.2% Mo steel	Kasei-21,-15,-11: forged and machined, throws carburized 0.035", quenched and tempered, good grain flow, clean steel, Kasei-21: T.S. 174,000 p.s.i., Y.S. (0.2% offset) 124,000 p.s.i. El. in 1"-19%, R.A. 62%.

-24a-

TABLE 4. (Continued)

BMI No.	Name	VDH	Type of Material	Remarks
796-47	Crankshaft bolt	384	Kasei-21: 0.3% C-3% Ni-3% Cr-0.2% Mo steel Kasei-15,-11: 0.3% C-3% Ni-3% Cr-0.6% Mo steel	Kasei-21,-15,-11: machined, quenched and tempered.
796-48	Propeller shaft	362	Kasei-21,-11: 0.2% C-4% Ni-15% Cr-1% W - 0.2% Mo steel Kasei-15: 0.2% C-4% Ni-1.5% Cr-0.2% Mo steel	Kasei-21,-15,-11: forged and machined, quenched and tempered, Cd coated; clean steel. Kasei-21; T.S. 160,000 p.s.i., Y.S. (0.2% offset) 131,000 p.s.i., El. in 1" - 20%. R.A. 62%.
796-49A	Bell gear	Case 718 Core 462	Kasei-21: 0.2% C-4% Ni-1% Cr-0.2% Mo steel Kasei-15: 0.15% C-4% Ni-1% Cr-0.4% Mo steel Kasei-11: 0.1% C-4% Ni-1% Cr steel	Kasei-21,-15,-11: forged and machined, only wearing surfaces of teeth carburized 0.030", quenched and clean steel.
796-49B	Bell gear	Case 685 Core 435	Kasei-21: 0.1% C-4.5% Ni-1% Cr-0.2% Mo steel	Same as 796-49A
796-50	Planetary spur gear	Case 766 Core 399	Kasei-21: 0.2% C-5% Ni-1% Cr steel Kasei-15,-11: 0.2% C-4% Ni-1% Cr-0.2% Mo steel	Kasei-21,-15,-11: forged and machined, only wearing surfaces of teeth carburized 0.020"/0.030", quenched and tempered.

-24b-

TABLE 4. (Continued)

BMI No.	Name	VDH	Type of Material	Remarks
796-51	Sun gear	Case 603 Core 407	Kasei-21,-15: 0.1% C-4% Ni-1% Cr-0.25% Mo steel Kasei-11: 0.15% C-4% Ni-1% Cr steel	Kasei-21,-15,-11: forged and machined only wearing surfaces of teeth and collar carburized 0.030", quenched and tempered.
796-52	Cam	Case 722 Core 421	Kasei-21,-15,-11: 0.25% C-4.5% Ni-1% Cr-0.2% Mo steel	Kasei-21,-15,-11: forged and machined, wearing surfaces of teeth and cam, and inside plate surface carburized 0.030"/0.040", quenched and tempered.
796-53A	Exhaust valve seat insert	189	Kasei-21: 0.5% C-11% Ni-3% Cr-4% W steel Kasei-15: 0.3% C-14% Ni-14% Cr-0.4% Mo steel Kasei-11: 0.5% C-8% Mn-12% Ni-3% Cr steel	Kasei-21,-15,-11: forged and machined. Kasei-21: solution heat treated. Kasei-15,-11: solution heat treated and aged.
796-53B	Intake valve seat insert	194	Kasei-21,-15,-11: aluminum bronze	Kasei-21,-15,-11: forged and machined.
796-54	Piston pin	549	Kasei-21,-15: 0.3% C-1% Mn-2% Ni-3% Cr-0.3% Mo steel	Kasei-21,-15,-11: tubing or machined from bar stock, quenched and tempered.

TABLE 4. (Continued)

BMI No.	Name	VDH	Type of Material	Remarks
796-54	Piston pin (continued)	549	Kasei-11: 0.3% C-5% Ni-2% Cr-0.5% Mo steel	Kasei-15,-11: carburized 0.020"
796-55	Master rod	386	Kasei-21: 0.25% C-3% Ni-1% Cr-0.4% Mo steel Kasei-15: 0.3% C-2.5% Cr-0.3% Mo steel Kasei-11: 0.3% C-3.5% Ni-1.5% Cr-0.4% Mo steel	Kasei-21,-15,-11: forged and machined, quenched and tempered, clean steel. Kasei-21: slight fretting on bearing contact surface, T.S. 167,000 p.s.i., Y.S. (0.2% offset) 160,000 p.s.i., El. in 2"-13%.
796-56	Articulated rod	362	Kasei 21: 0.4% C-4.5% Ni-1% Cr-0.2% Mo steel Kasei-15,-11: 0.3% C-3.5% Ni-1% Cr-0.4% Mo steel	Kasei-21,-15,-11: forged and machined, quenched and tempered. Kasei-21: T.S. 157,000 p.s.i., Y.S. (0.2% offset) 144,000 p.s.i., El. in 2" - 12%.
796-57	Impeller shaft	Case 735 Core 410	Kasei-21: 0.4% C-4% Cr-0.5% V steel Kasei-15: 0.15% C-4% Ni-1% Cr-0.2% Mo steel Kasei-11: 0.15% C-4% Ni-1% Cr-0.5% Mo steel	Kasei-21,-15,-11: forged and machined, only wearing surfaces of teeth carburized 0.030", quenched and tempered, Cd coated.

TABLE 4. (Continued)

BMI No.	Name	VDH	Type of Material	Remarks
796-58	Impeller drive gear	Case 603 Core 432	Kasei-21: 0.15% C-2.5% Cr-0.2% Mo steel Kasei-15: 0.3% C-1% Cr-0.3% Mo steel Kasei-11: 0.2% C-4.5% Ni-1% Cr steel	Kasei-21,-15,-11: forged and machined, only wearing surfaces of teeth carburized 0.030", quenched and tempered.
796-59	Crankcase	85	Kasei-21,-15,-11: Alcoa 17S alloy	Kasei-21,-15,-11: forged and machined in 3 sections, solution heat treated and aged. Kasei-21: $CuAl_2$ incompletely dissolved, T.S. 44,000 p.s.i., T.S. (0.2% offset) 23,000 p.s.i El in 1"-17%, R.A. 22%.
796-60	Piston	145 to 123	Kasei-21,-15,-11: Alcoa 142 alloy	Kasei-21,-15,-11: forged and machined from cast blank, solution heat treated and aged, good finish.
796-61	Blower case	83	Kasei-21,-15: Alcoa 356 type alloy Kasei-11: 9% Al, 0.3% Mn, bal. Mg alloy	Kasei-21,-15: cast and machined modified, Kasei-21: anodized, green paint, solution heat treated and aged. Kasei-15,-11: as cast, blue paint.

TABLE 4. (Continued)

BMI No.	Name	VDH	Type of Material	Remarks
796-62	Impeller	107	Kasei-21,-15,-11: Alcoa 17S type Al alloy	Kasei-21,-15,-11: forged and machined, solution heat treated, and aged.
796-63	Nose	82	Kasei-21,-15: Alcoa 356 type Al alloy Kasei-11: 9% Al-0.3% Mn-bal. Mg alloy	Kasei-21,-15,-11: cast and machined, solution heat treated and aged, slightly porous. Kasei-21,-15: modified.
796-64	Diffuser	102	Kasei-21: Alcoa 356 type alloy Kasei-15: 2.5% Al-.03% Mn-2.3% Zn-0.4% Si-bal. Mg alloy Kasei-11: 4.5% Al-0.3% Mn-2.6% Zn-0.2% Si-bal. Mg alloy	Kasei-21,-15,-11: cast and machined, slightly porous. Kasei-21: modified, solution heat treated and aged. Kasei-15,-11: as-cast.
796-65	Master rod bearing	Cu-Pb 37 Steel 200	Kasei-21,-15,-11: Cu-Pb alloy and low-C steel	Kasei-21,-15,-11: Cu-Pb cast on low-C steel backing. Cu-Pb 0.035" thick, Pb uniformly distributed, backing machined from annealed tubing. Kasei-21: slight fretting on backing.
796-66	Piston pin bearing	158	Kasei-21,-15,-11: bronze	Kasei-21,-15,-11: cast and machined, normal porosity.

TABLE 4. (Continued)

BMI No.	Name	VDH	Type of Material	Remarks
796-67	Rocker arm shaft bearing	141	Kasei-21,-15,-11: bronze	Kasei-21,-15,-11: cast and machined, normal porosity.
796-68	Impeller shaft bearing	70	Kasei-21,-15,-11: leaded bronze	Kasei-21 -15,-11: cast and machined, normal porosity, Pb uniformly distributed.
796-69	Front cam bearing	137	Kasei-21,-15,-11: bronze	Kasei-21,-15,-11: cast and machined, normal porosity.

TABLE 5. GENERAL INFORMATION ON JAPANESE AIRCRAFT ENGINES WHICH WERE COMPARED WITH KASEI-21 NO. 2189 ENGINE

Model and Serial No.	CEE No.	Date of Manufacture and Manufacturer	C.S.R.D. Report No.
Kasei-11 #11871	20500	December 19, 1941 Mitsubishi Jukogyo K.K.	4826
Kasei-15 #151739	4233	Last half of November, 1943 Mitsubishi Jukogyo K.K.	4826
Sakae-12 #124676	20505	November or December, 1943 Nakajima Hikoki K.K.	4982
Sakae-12 #121592	2751	1941 Nakajima Hikoki K.K.	4063
Sakae-21 #21327	2963	September, 1942 Nakajima Hikoki K.K.	4234
Kinsei-43 #185784	2414	October, 1942 Mitsubishi Jukogyo K.K.	4420
Homare-11 #11515	2065	November 1943 Nakajima Hikoki K.K.	5199

TABLE 6. MARKINGS AND WEIGHTS OF PARTS OF KASEI-21 AIRCRAFT ENGINE (BMI NO. 796, CEE 2075)

BMI Part No.	Name	Wt. in Grams	Markings
10	Cylinder barrel	4550	(1) 825 28 26
11	Cylinder head	10900	108 2189 365 H A 1495-8 505 098 W Y
12	Push rod	290	M
14	Rocker arm assembly	430	T 203 2 - M 4 T 102
15	Baffles	720 each	K 7 - K D
16	Intake valve	370	352 4
17	Valve spring - large	150	M# 1986-4 6330 M2100-4-3480
	- small	106	M# 1691-4-480 M# 1592-10-21580
	- seat	55	T206 M K -
18	Valve spring retainer collets - large	12	1 R 97 100
	- small	9	8 - 76
19	Push rod coupling	165	6 Y 195 MK 1
20	Exhaust valve	435	HL 157 4
24	Intake manifold	425	
36	Starter	18200	KDO 0 1 Y 132

TABLE 6. (Continued)

BMI Part No.	Name	Wt. in Grams	Markings
38,39 50	Planet gear assembly	19000	T 211 278 N 115 - M H108 T 224 106 N - M 115 F 100 2 1893 KX 637 M T224 212N - M 115 L T 107784 G - K M 23 5 B M 17 11
41	Bell gear assembly	16200	180 Z6B 402326 213 2189 21K958TT - 180N - M K GK 55967M 190N M - 118 Y 2189 116N M - T105 2189
44	Crankshaft counterweight	2725	= 0 K Z 62 v5
46	Crankshaft - front	12000	S2936S - 4923N K - M 213 Z6 2189
	- center	12000	.01 M 925 T 228T30729T - S354N Z6 K - M 213
	- rear	11250	752 E S3411S-377 K - M 213
47	Crankshaft bolts		2189 2377 24
51	Sun gear	5450	2189 M T 23 191N 1 M 23
52	Cam	2700	2189S D 7375D-6837N M - 118
55	Master rod	3175	+25 T12 2 5673G 33'13 2189S
56	Articulated rod	910	5539 3-3/4 6 2189 5 225 76560 6494 11/121
57	Impeller shaft	1460	K M 23 0

TABLE 6. (Continued)

BMI Part No.	Name	Wt. in Grams	Markings
58	Impeller drive gear assembly	4550	2189S 43 T107 745 M 6318 75
59	Crankcase - front	18000	2189S K 211-SN2125-A711N 82
	- rear	18000	2189S 711 211 - SN220S- C 4597N K
60	Piston	1830	SN37622N 2189 2 1830 G 20
61	Blower case	20200	2189S K 524 504 H 2-302N72 975N 26 87 L
62	Impeller	2590	K 2189S 2794-5496N H 20 20 2189 #2794-5937N K 1
63	Nose casting	10400	28 F 504 H 85 3192N53 820 1296NT
64	Diffuser		2189S
65	Master rod bearing	390	Y 586-7M M P L M = 1059
66	Piston pin bearing	100	
67	Rocker arm bearing	35	
68	Impeller shaft bearing	215	
69	Cam bearing	1380	
86	Propeller shaft plug	225	2189
89	Tappet assembly	385	s 7 M
93	Lifting eye	55	M

TABLE 6. (Continued)

BMI Part No.	Name	Wt. in Grams	Markings
94	Impeller cover plate	1820	2189 439 N 501 A
95	Knuckle pins	335	M K
96	Air intake section		2189S 504 H 393N50 1 -1867 89 H
97	Gear case and accessories	29000	131461515 2189 1756N 107 T 329 H F504Z 396N57 82154 211
99	Tail shaft assembly	5900	2189S 5758N 23 M T105 H M
101	Cuno oil strainer	2300	54 2189 K 21898 504 S

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