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SUBJECT: General Design and Development of Mitsubishi Aircraft Engines.

REFERENCE: Section III 1 A (b) Air Staff Intelligence Requirements.

Persons INTERVIEWED: Mr. M. INO General Manager of the Kyoto plants.
Mr. T. HORI Manager Prototype Engine Shop
Mr. I. SAKO Manager Design Department and original designer of the Kinsei series.
Mr. F. YAMAMURO, Vibration engineer.
Mr. N. Narita, Manager of Research Department

INTERVIEWING OFFICER: Commander J.H. Morse, Jr., U.S.N.

BRIEF OF MATERIAL DISCUSSED: General design and development of Mitsubishi aircraft engines.

When the main Nagoya plant of the Mitsubishi Engine Company was bombed and practically destroyed, the company removed its design engineers to Kyoto which was never bombed. The personnel interviewed as listed above represent the best of this design group and are considered excellently qualified to discuss the Mitsubishi engine. There was no evidence of reticence or reluctance to furnish any information requested and the information so furnished is considered reliable. All of the engineers interrogated have been with the company for at least 10 years and several of them for more than 20 years.

In general the Mitsubishi Engine Company in its organization, procedures and methods, relations with the government and with other companies very closely parallels the relationships and functions of the major engine companies of the United States. Apparently the Army and the Navy interfered relatively little with the design and development of engines, leaving this primarily to the company engineers. The Navy did at times tend to interfere, usually with unsuccessful results This tendency decreased toward the end of the war. It was interesting to note that the company engineers unanimously considered the engineering talent of both Army and Navy to be very poor, with the Navy having somewhat the better qualified personnel. This situation was attributed to the military system which supposedly failed to supply proper training of young engineers. It was believed that the quality of these young engineers

acquired by the services was higher than that available to the companies. Considerable ridicule was apparent whenever the question of Army or Navy engineering was brought up. Although the engineering abilities of service personnel were not respected, it appeared that whenever one of the services insisted on a given policy or change, the company was forced to do its best to comply with the request. In many cases the company had protested requirements laid down by the services, and by its opposition had persuaded the service involve to modify its demands. As an example of a service request it was stated that two years ago the Navy had demanded that Mitsubishi develo a liquid cooled engine. The company against its will undertook this development and did its best without success. Again, the Navy about one year ago designed a jet propulsion engine and requested the company to build a prototype. Before this engine was completed it was proven of no value and the Navy submitted a second design, followed in rapid succession by a third design. At this point the company informed the Navy that its production was being too seriously hampered by this jet work and the project was abandoned. The company engineers had several adverse comments to make concerning the differences in requirements between Army and Navy and the lack of cooperation between them. Some degree of cooperation in requirements was evident near the end of the war, but too late to be effective. It was stated that in some cases a design would be rejected entirely by the Navy and immediately accepted by the Army. The company very clearly regarded the Nakajima company as a competitor and there was no evidence of pooling of design information or standardizing of parts. The engineering talent of Nakajima was respected, although it was stated that Nakajima did little research or original development work. In the handling of service difficulties and changes in design there was clearly a difference in method between the two companies. Mitsubishi preferred to retain responsibility for all service changes in design and did so, accepting full responsibility for major service defects and devising and applying remedies, including corrective parts for engines already in the field. Nakajima on the oth r hand accepted no responsibility for service changes in design and left this task to the Navy or Army. In the preparation of specifications, the company designed an engine, submitted a propose specification and then in discussion with the procuring service compromised on a final specification suitable to both parties. Apparentl considerable argument developed occasionally over these specification but the services usually obtained agreement on points which they considered important.

Engine tests as such were confined to ground operations. The company had pilots and occasionally was assigned airplanes for specifi projects. There were no altitude test stands and engine calibration was accomplished at sea level conditions, except for throttling of intake to simulate altitude intake pressures. The formula for altitu correction of sea level data is enclosed with this report. The Army and Navy had common type test specifications samples of which are being furnished by the company. It was understood that the type

test required four hundred hours of operation with the company permitted to tear down and overhaul the engine at the end of 200 hours of the test. Production tests at the beginning of the war involved eight hours of engine operation with both green and final runs required. This time was successively reduced as fuels became scarce until near the end of the war the final run had been eliminated, resulting in a decided increase of engine failures.

The company was considered responsible for all of the engine except government furnished equipment such as fuel pumps, etc. Ignition systems were usually designed originally by ignition companies, but the engine company usually found it necessary to considerably modify the designs and improve them. The carburetors or fuel injection equipment were completely designed by the engine company, but manufactured by others in the case of carburetors and by the engine company in the case of fuel injection equipment.

Float type carburetion was used entirely at the beginning of the war but the trend gradually increassed toward fuel injection and at the end of the war it was expected to use fuel injection exclusively. The primary reason for this was the decreasing quality of fuels available, although the company thought that distribution was also improved by fuel injection. When questioned about fact that equal fuel distribution does not always mean equal mixture distribution because of faulty air distribution, the engineers stated that they had made no studies of that effect. They were agreed that fuel injection required very careful machine and accurate assembly, but considered that they had had no choice in its adoption. It is interesting to note that they had done extensive research on the optimum positions and directions of injection and had eventually reached the conclusion that injection from a ring just before the impellor was best. Along with this method of injection they had adopted a variation of a speed density carburetor. Previous to arriving at this system, the optimum injection point had been selected as the intake pipe just before the intake valve, with individual cylinder pumps to meter fuel. This system was used on a number of engines during the later part of the war.

While carburetion engines were used, little difficulty was experienced with carburetor production quality control or with maintaining adjustments in the field. Original setting limits were broader than those of the American Navy, being plus or minus 3½ percent as contrasted with the American limit of plus or minus 2 percent. They had no outstanding service difficulties with carburetion.

Carburetor settings were established by dynamometer only, with no attempt to utilize flight tests for settings. There was no special ground equipment suitable for simulating flight conditions or scoop effect. Considerable difficulty was encountered because of this limitation and there had even been instances when engines would not run when installed in the airplane because of the variation in metering caused by the installation.

Great difficulty was encountered with ignition systems. Almost all features of the system gave trouble and apparently the company had little success in remedying the troubles. For altitude work pressurization of the system had been tried, using a bleed from the supercharger case. This, however, resulted in oil contamination with consequent difficulties. Finally the company adopted a low tension system which was just going into service at the end of the war. This system utilized a fixed gap plug, samples of which have been requested.

In superchargers the company had developed and installed turbo superchargers in three high altitude reconnaisance planes, Ki 46 type IV, (Dinah) which were used and lost over Okinawa. These planes had fuel injection Kensei engines. The company claimed that these superchargers had proven satisfactory and had increased the performance of the engine. Little information was available on this subject because the installations had been lost and the bombings at Nagoya had destroyed much of the information. Drawings have been requested. Primary emphasis was still being placed by the company on gear driven superchargers. The latest model of this type was the Ha42, model 31 which was a two stage supercharger with hydraulic couplings of the German Vulcan design. It is interesting to note that the arrangement of this supercharger was very similar to the new Pratt & Whitney 2800 E engine with two side mounted impellors. The performance expected from this model is illustrated in the enclosed blueprint of new engine specifications. The mechanical clutches used by the Mitsubishi company were the standard centrifugal type used for several years. They were generally satisfactory until toward the end of the war when the use of subsitute materials caused some cases of slippage. The general trend of supercharger impellor size and tip speeds was upward at a relatively slow rate. A three speed supercharger had been developed and was just going into production at the time of the heaviest bombings in Nagoya which practically wiped out the plant and all three speed production. Drawings of this three speed design have been requested.

The company felt that cooling had been a relatively simple problem and no special difficulties had been encountered with it. Cooling pressure drop was moderate and in general the cooling design seemed good. A sample curve of cooling pressure drop is enclosed. Cooling fans geared about 1.5 times crankshaft speed were used on some installations such as Ki 67 or Raiden (Peggy)

The company was working on two speed noses and had built one experimental model which had undergone 200 cycles of gear changes when the bombing or Nagoya destroyed the set up. The incorporation of this two speed nose extended the nose length about four inches.

Propellor design was left almost entirely to the propellor manufacturers of whom Sumitomo was by far the most important.

Compression ratios were limited at about 7.0 because of fuel quality. Higher ratios would have been used had the proper fuel been available.

Bearings had given a great deal of difficulty during the course of engine development. It had finally been decided to use almost exclusively the Kelmit bearing with a dendritic structure, containing about 30% lead and treated with a thin lead flash. No silver or silver, lead, indium had been used although studies were just being made of these types. The company was particularly proud of having eliminated ball bearings from the rocker arms of their engines and stated that they had never had any difficulty from their standard floating bushings.

Valve overlaps were in general about 50 degrees. They had run some engines experimentally with overlaps as high as 100 degrees. They had become aware of the advantages of constant length push rods and had experimented with the hydraulic type as early as three years ago. However they experienced damaged cams and valve pounding and abandoned the project. The vibration expert, Mr. Yamamuro, felt that this had been a mistake and that the constant length rod could have been successfully developed with considerable inprovements resulting from its use.

Exhaust systems were generally the responsibility of the airplan manufacturer, although occasionally Mistubishi Engine Company designe the exhaust system for its engine. The engineers were not aware of any particular difficulties, nor of any serious shortage of supply of proper materials for exhaust systems. They had designed systems to make use of the jet effect in one or two model airplanes, but apparently did not give this feature much emphasis.

Heat rejection to the oil and oil flow were both guaranteed by the manufacturer and were measured in a manner similar to American practice. It is interesting to note that when the hydraulic coupling for superchangers was adopted, it was necessary to install an additional oil cooler to care for the heat so rejected.

The only jet, turbine, or rocket work being undertaken by the company at the end of the war was the power plant for Shusui which was being developed at Matsumoto and the NE 330 also being developed at Matsumoto. It was considered that Shusui power plant was ready for flight operation and that the power plant failure terminating the first and only flight had been the result of a readily correctible defect. Further investigation of this development will be reported in the future. As stated previously, the company had some time ago undertaken to manufacture a jet propulsion engine to Navy design, but had abandoned it when no successful design appeared imminent.

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SUMMARY: The Mitsubishi Engine Company organization, policies, procedures, and relations with the government and other engine companies were remarkably similar to those of equivalent companies in the United States. Methods of engine development and test, both experimental and production were also quite similar to American practice. The problems encountered, and in the majority of cases satisfactorily solved, were very similar to those encountered in American engineering. While previous to the war the company had relied heavily on literature published by the Allied nations for its general guidance, it displayed a surprising degree of initiative and ingenuity in meeting problems developing after this supply of information was cut off. The company displayed a dignity and a pride it its organization, its product, and its reputation and made no apologies even while admitting freely that American engines were superior. The personnel interrogated are considered well qualified to discuss all aspects of the Mitsubishi engine development. It is considered that all possible information was furnished as requested and that no reticence or attempt to withhold information were apparent. It appears that in most aspects of engine development the company was several years behind the Allied nations, but that with its capable and aggressive engineering staff it would have continued to produce creditable engines had the war continued.

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