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SUBJECT: NAKAJIMA ENGINE Design and Development

REFERENCE Air Staff Intelligence Requirements in the Far East Section III 1 A (b)

PERSONS INTERVIEWED
Mr. HAROU NIIYAMA, Manager of OGIKUBO plant of Nakajima.
Mr. TAKIO KOTANI, CHief Designer of Nakajima Engine Company
Mr. TYOICHI NAKEJIMA, Designer of Homare engine.
Mr. SHIGEHITO UEDA, Chief of Experimental Engines.
Mr. YOSHIO INOUE, Reduction gear designer.

INTERVIEWING OFFICERS
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BRIEF OF MATERIAL DISCUSSED G eneral design and development of Nakajima Engine

The OGIKUBO plant of the NAKAJIMA ENGINE COMPANY is at present the headquarters of the engine design personnel of the company. All of the men interviewed had been with the company for at least 10 years and most of them since the beginning of the company in 1925. They are considered the best qualifed personnel available to furnish information on Nakajima engines. There was no indication of reticence or reluctance to furnish information requested and the information so furnished is believed reliable.

The Nakajima Engine Company is one of the two major engine companies of Japan. In general its organization, procedures and methods, relations with the government and with other companies very closely parallel those of the major engine companies of the United States. In general the Nakajima company tended to follow the organization and policies of the Wright Aeronautical Corporation from whom they received licenses for production in the 1930's. At the time these licenses were bought, several Nakajima personnel, including the chief designer, Mr. Kotani, spent several months in the United States under instruction at the Wright Company.

The Nakejima company undertook developments for the government by two different methods. In the first method the government set down the general design features of a desired engine, leavint the detailed design to the company engineers. In the other case the government left the entire design and development to the company. In general it was considered that the Army tended to leave more of the details to the engine manufacturer than did the Navy. The Nakajima engineers did not have a very high regard for the engineering abilities of either Army or Navy personnel. However, they were frequently required to accept service decisions in engineering matters. This situation had apparently resulted in considerable friction between the company and the Services at times.

The company engineers emphasised the difference in policy and requirements between the Army and Navy. These differences had been particularly apparent at the beginning of the war. As an example, it was stated that at the beginning of the war only 50% of the engine accessories were interchangeable between Army and Navy engines. At the end of the war some cooperation was apparent and the percentage had increased to 90%. The Army and Navy had never consolidated their inspection forces and each service had maintained a complete inspection group in each plant. Theoretically they were supposed to cooperate and unify inspection, but practically there was very little cooperation evidenced in inspection even toward the end of the war.

For specifications the company was furnished common A-N general engine and type test specifications. Detail specifications were proposed by the company after the general design of an engine had been determined. The proposed detail specification was then discussed in conference between the company and the interested service and the specification finally approved much as in American practice.

In the accessory field the government furnished some assessories and the engine manufacturer furnished others as in American practices. The manufacturer furnished carbureters, oil pumps, and gun synchronizers. The government furnished magnetoes, starters, fuel pumps, vacuum pumps, high pressure oil (hydraulic) pumps, propellers, alcohol pumps, and spark plugs.

The company retained little responsibility for the remedy of service difficulties. It appeared that the company would have preferred to engineer its own service problems, but that the services, particularly the Navy, insisted upon incorporating their own service remedies. The company did maintain a service organization of approximately sixty men who were available for assistance to the services in any theatre of operations considered necessary. Remedial parts for service defects were manufactured by the company and distributed and installed by the services unless they requested company assistance for this work.

Like all engine companies in Japan, the Nakajima company was going to fuel injection rather than carburetion. However, their fuel injection system was of the low pressure type which in effect was a variety of speed density carburetion with injection of fuel just before the impeller entrance. Operating pressures were about 14 pounds/square inch at the pump and about 80% of this value at the injection point. Several advantages were claimed for this system over carburetion. Some of these advantages were: elimination of icing hazard which had apparently been an important trouble with the previous carburetors, correct metering during maneuvers, and the use of fuels unsuited for carburetion. Apparently the company was very confident of the non icing qualities of this system although they had run no tests other than ground operation in Manchuria during cold weather. No icing tunnels were available, and no experiments had been run involving injection of moisture into the intake system. Toward the latter part of the war the Army and Navy had insisted that the company adopt fuel injection in preference to carburetion because of the rapidly deteriorating quality of fuels. A considerable amount of flight test experience had been accumulated on this system and the company was going into full production at the end of the war. Samples of this system are being returned to the United States by the Technical Air Intelligence Group.

While carburetion was in effect, only float carburetors were used. It was claimed that there was little difficulty in adjusting carburetors or in holding metering within required limits. The Nakajima carburetor was designed to permit adjustment of the main metering valve from outside which enabled adjustments to be made relatively easily with the carburetor installed. The nozzles of this type were arranged around the barrel and surrounded by hot oil circulated from the engine. It was claimed that the Bendix float carburetor would not work on Japanese airplanes because of icing

It was claimed that ice was encountered in all parts of Japan in winter months with float type carburetors. Although the icing problem was general no large scale studies had been made of this problem, and it was concluded that the statements relative to icing were the result of long experience of the company plus the usual amount of hearsay associated with the icing problem. Other than the use of spinner injection and hot oil heating of float type carburetors the only means of combatting carburetor ice was preheat. The heat rise on most airplanes was between 15 and 40 degrees C. with a 30 degree rise as average.

The company stated that the corrosion problem was always present with water injection systems or tanks, although not serious. Injection was automatically used above 80% normal rated power because of the low grade fuel used. Fluid was injected into the impeller channels from an annular groove in the back of the impeller. The injection rate was controlled by boost pressure. The tanks and systems were kept filled with water injection fluid (50% alcohol for cold weather and 30% alcohol for warm weather). Keeping the system wet helped prevent corrosion. Chrome plating was tried as a corrosion preventative but was unsuccessful, Bakelite vanes were tried experimentally but were also abandoned. Ordinary fuel pumps were used as water pumps and it was found that thdy did not corrode if kept filled. Whenever the pumps were not filled they were immersed in a mineral oil. These pumps were a copy of the Pasco G 6 or G 9 and were furnished by four different Japanese manufacturers.

Ignition systems were considered one of the weakest points of the engines. Difficulty was encountered with almost all phases of the equipment, particularly the spark plugs. No satisfactory spark plug was ever available. Plugs which did not foul at low powers were too hot for high powers and caused preignition. Plugs which did not cause preignition fouled easily. High oil consumption which was another difficulty of Nakajima engines, contributed to the plug fouling troubles. There was no design for detachable ignition leads although the idea had been considered. Magnetoes and distributors had been pressurized experimentally by utilizing the discharge from the vacuum pump and passing the air through a two stage oil separator. It was claimed that oil was completely eliminated from the pressurizing air in this manner. A low tension ignition system was in the design stage, but had not yet been built. It was considered that the standard ignition system was satisf ctory up to 10,000 meters (32,800 feet) and the above that altitude low tension ignition would be necessary.

The Nakajima company designed and built two turbo superchargers about five years ago, but at that time the services were not interested and the project was dropped. When interest was again aroused in turbo supercharging the majority of the work was done by the Hitachi and Ishikawajima Companies, As a result the interviewed engineers were not very familiar with the latest status of turbo superchargers. However, it was known that Nakajima had made 5 four engine long range bombers, KI 87, SAIUN, equipped with Hitachi superchargers on the Ha 45-24 engines. These planes had made several flights but no supercharger data was available because they had been unable to obtain satisfactory operation of the regulator.

The Company was applying most of its experimental effort near the end of the war to the development of a three speed two stage engine, the Ha 45-44. Parts for two of these engines had been built and one engine assembled. This assembled engine had been motored over and binding of the supercharger parts had been detected. It had been torn down for inspection when peace was declared. Since no models of this engine had been run it is impossible to check the Nakajima estimates of 1910 take off HP and 1530 HP at 26,300 feet. Since the displacement of the engine is only 2185 cubic inches, this estimate rating is probably very optomistic.

In general the company experienced the same difficulties with its supercharger clutches as are encountered in America.

Sludging was prevalent. A creeper type of sludge eliminator very similar th the Pratt & Whitney design was adopted to help the situation. All clutches were of conventional plate design. The Vulcan hydraulic drive was tried but eliminated when the additional heat rejection to the oil was considered excessive.

The cooling drop required for most engines was 150mm. of H_2O (6 inches), but this drop was not always provided by airplane manufacturers. As a result the engine and airplane company were frequently arguing over cooling problems. The rear spark plug gasket limiting temperature was set as 230 degrees C. for continuous operation. Cooling fans were to be used with all Ha 44 model engines. All troubles with cooling were attributed by the engineers to the failure of airplane manufacturers to incorporate the required cooling drop. The company had reluctantly dropped its process of casting sheet aluminum cooling fins into the cylinder heads. This decision was made because of production difficulties. The process was slow and required expensive steel molds which were easily damaged. To maintain production it had been necessary in practice to use approximately 50% cylinder heads with fins cast in the usual manner. The cast sheet aluminum fins had been in production for approximately the past three years. It was claimed that the sheet aluminum fins had resulted in rear spark plug gasket temperatures 15 degrees C lower than with conventional heads under the same operating conditions.

A two speed nose design was under test just before the end of the war, but had failed after 20 hours of operation. No further tests had been undertaken before the end of the war.

Compression ratios had been reduced during the last three years from 8.0 to 7.0 and in some cases 6.7 because of the decreasing quality of fuels.

Nakajima had a great deal of bearing trouble. Like the other engine companies they had settled on the Kelmet type, 30% lead construction, for the major part of their bearings. Ball bearings were used in superchargers because of space limitations only. Experiments had been made with silver bearings, but these had been unsuccessful. A thin lead flash had been applied to a lot of 500 engines, but the process had been eliminated on the basis of results with these engines. When the supply of bronze became critical, attempts were made to use aluminum alloy bearings, but experience soon indicated that for highly loaded bearings the Kelmet type was essential. Material shortages apparently dictated few design changes, the usual procedure being to abandon a design rather than modify it to incorporate substitute materials extensively.

Valve overlaps were low, about 38 degrees. Experiments with hydraulic valve tappets had been conducted about 5 years ago but abandoned when results were not successful. Few experiments with overlaps of more than 38 degrees had been conducted.

Piston rings were a continous source of trouble, primarily from broken oil rings and high oil consumption. The piston ring difficulties had not been eliminated at the war's end, although piston scuffing encountered during the first part of the war had been cured by modification of the piston. Some trouble had been experienced with compression ring breakage, particularly at high speeds. Chrome plated cast iron compression rings were used. No difficulty was admitted from feathered rings, although it is not clear that this question was thoroughly understood in translation.

Vibration damping was in accordance with the usual Wright Aeronautical practice with a 9th order torsional damper on the front throw and a 4½ order damper on the rear. Second order dampers were designed, but never installed. A form of rubber vibration damping engine mount was used, but the exact type or form could not be determined. Vibration mounts were a responsibility of the airplane manufacturer and the interviewed engineers knew little about them.

For engine tests the only equipment available was the simple electric dynamometer with no provision for altitude simulation of carburetor air temperature or exhaust pressure. Sea level power calibrations were run and altitude ratings determined from standard correction formulaes furnished by the Army and Navy. The Nakajima company apparently attempted to give most of their new engines a flight test that was more extensive that that of the other engine companies. This was particularly true for carburetor settings where dynamometer results were checked by flight test and the final setting determined from a combination of dynamometer and flight results. Relatively simple instrumentation was used in these flight tests, including a form of Bendix flowmeter. Carburetor adjustments which flight tests showed to be necessary were made directly on the installed carbureters.

No torquemeters had been designed or built, although the company had tentative plans for such a design.

The largest fuel pump used on Nakajima engines was the type 26 rated at approximately 900 gph at 24 psi. The standard hydraulic gear pump type 15 with minor modifications was used as a fuel pump on the Nakanima jet engine. This pump had a discharge pressure of approximately 759 pounds per square inch.

The Nakajima company was working on two jet projects at the end of the war, the TR 12, and the NE 220. The TR 10 project had been assigned the company as a Navy designed turbo jet about two years ago. The final version contained a compressor of four axial stages followed by a single centrifugal stage. A single stage turbine furnished the power for driving the compressor. The NE 220 was the Nakajima version of the German BMW axial flow turbo jet engine, These engines will be described in more detail in a future report.

Toward the end of the war frantic pressure for production had become so great that all design engineers were diverted to production problems and new design and development were almost abandoned.

In the opinion of the design engineers one of the best Nakajima engines used in service was the Homare 21 (Ha 45-21) of 2180 cu.in. This engine was rated at 2000 HP take off, and 1650 HP at 18,700 feet altitude. The most promising engine among the experimental group which might have been in production within six months was considered the Ha 44-13. This engine (2940 cu.in.) was rated at 2500 HP take off and 2100 HP at 19,600 feet.

SUMMARY: The Nakajima company as one of the two large Japanese aircraft engine manufacturers corresponded very closely in policy, procedures, and methods with the Wright Aeronautical Corporation of the United States. The general pattern of the company followed that of the Wright Aeronautical Corporation from whom the company had purchased production licenses during the early 1930's. When contact with foreign publications and information permitted, the design of Nakajima engines followed in general the leads provided by foreign development, but the company indicated a considerable degree of initiative and capability of independent thought when access to foreign information was cut off. In most respects the design of Nakajima engines was several years behind that of American engines. Although excellent performance was claimed for some of the latest experimental engines, no data was available to substantiate these claims, nor was test equipment available of sufficient accuracy to determine true altitude ratings. Several engines of each model available are being forwarded to T.A.I.C. Anacostia.

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