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T-2 REPORT ON FRANK-1 (KI-84), T-2 SERIAL NO. 302 INTERIM REPORT NO. 3 (PROJECT NO. NAD 25)

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HEADQUARTERS AIR MATERIEL COMMAND
WRIGHT FIELD, DAYTON, OHIO

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R. J. Groseclose, Captain, Air Corps

Approved by:

for O N LeBlanc Captain

Walter F. Nyblade, Major, Air Corps
Chief, Aircraft Section
Analysis Division
Intelligence (T-2)

For the Commanding General:

for W E Gold by courier

P. F. Helmick, Colonel, Air Corps
Chief, Analysis Division
Intelligence (T-2)

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1/ See Report No. F-IM-1119B-ND, entitled "Pilot's Handbook, Frank - I (KI-84)."

INTRODUCTION

The Japanese Fighter Frank-1 (Ki-84), manufactured by Nakajima Aircraft Corporation was accepted by the Japanese Army in April 1944 and was recognized as one of Japan's best front-line fighters from then until the close of the war.

Japan's faith in this fighter is exemplified by the fact that at the close of the war they were building underground factories capable of producing 200 Frank's a month.

The Frank was used in all theaters of operation and in practically all types of combat in which a fighter can be used. In addition to high and low level interception and aerial combat, it was used for dive bombing and strafing.

T-2 REPORT ON FRANK-1 (KI-84), T-2, SERIAL NO. 302
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DESCRIPTION

The Frank-1 is radically different from earlier models in many respects. Standard Japanese practice on earlier models was to center their production on well designed airframes of relatively light construction. The Frank, however, is unusually strong. Of particular interest is the heavy main spar built up to extruded aluminum angle pieces one-half in. thick, into I-beam design. The fuel tanks are self-sealing, and armor plating and bulletproof glass windshield are provided for the pilot.

The plane is a conventional, single-seat, single-engine fighter with no outstanding recognition characteristics. The wings and fuselage are of normal design, being all-metal, flush riveted, cantilever construction. A point of additional interest is the absence of corrosion preventive finishes. Neither lacquer nor anodizing has been applied to the interior surfaces.

The control surfaces of the Frank-1 are conventional, being of metal framework covered with fabric. The horizontal stabilizer and elevators are set well ahead of the rudder hinge line. The flaps are Fowler type, actuated hydraulically.

The canopy is of the bubble type, actuated by a hand crank. There is no means of emergency release of the canopy.

The main landing gear is hydraulically operated and retracts upward and inward near the leading edge of the wing. The tail wheel is fully retractable.

The Frank-1 is powered by an Ha-45, Model 21, Nakajima engine. This is an 18-cylinder radial engine comparable to our R-2800 Pratt and Whitney engine. It differs in that it uses a carburetor bowl prime and carburetor priming system instead of priming the cylinders. This engine uses 92-octane fuel which is supplemented by injection of a solution of 50% water and 50% methanol. A four-bladed propeller similar to our Curtiss electrical propeller is used on this airplane.

The Frank-1 is fitted with four machine guns. Two fixed-type 12.7 machine guns are engine-synchronized and mounted in the fuselage on either side forward of the cockpit. Two 20-mm guns are installed, one in each wing just outboard of the landing gear assembly.

The Frank-1 has very little remote control or automatic equipment and very little effort has been made to make the pilot's job easy or safe. Armor plate and self-sealing tanks are installed but there are no fire extinguishers nor emergency escape means. (The AAF has installed a fire extinguisher in ship No. T-2, (302).

FACTUAL DATA

Dimensions

Span 37.1 ft
Length 32.22 ft
Height 11.17 ft
Wing Area 226 sq ft

Weight

Condition	Weight (lb)	Fuel Load (lb)	Bombs (lb)
Normal fighter	7940	1110	
Overload fighter	9194	2088	

Speed

	Normal fighter	Overload fighter
At S.L. Military Power	350 mph	312 mph
At S.L. W.E.P.	363 mph	
At 10,000 ft Military Power	389 mph	347 mph
At 10,000 ft W.E.P.	390 mph	
At 20,000 ft Military Power	412 mph	370 mph
At 20.000 ft W.E.P.	427 mph	
At 23,000 ft Military Power	426 mph	382 mph
At 23,000 ft W.E.P.	419 mph	
At 30,000 ft Military Power	400 mph	357 mph
At 30,000 ft W.E.P.	393 mph	
At 35,000 ft Military Power	370 mph	317 mph
At 35,000 ft W.E.P.	360 mph	

Climb

	Normal fighter	Overload fighter
Time to 10,000 ft	2.6 min	3.3 min
Time to 20,000 ft	5.8 min	7.3 min
Time to 30,000 ft	10.0 min	12.7 min
Rate of Climb at S.L. Military Power	3790 ft/min	
Rate of Climb at S.L. W.E.P.	4275 ft/min	
Rate of Climb at 20,900 ft Military Power	3195 ft/min	
Rate of Climb at 17,900 ft W.E.P.	3615 ft/min	
Service Ceiling	38,800 ft	

Range

At 1500 ft

Max. Range, Max. Fuel	At 173 mph	1815 mi
	At 241 mph	1410 mi
Max. Range Normal Fuel	At 178 mph	1025 mi
	At 254 mph	780 mi

Fuel

Normal Fuel (Built-in Tanks)	185 gal
External (Drop Tanks)	174 gal
Total Capacity	359 gal

Type Fuel - 92-octane

The water and methanol tank has a capacity of 42.2 gal.

Take Off

At normal weight 7940 lb, 1460 ft of runway is required.

Engine

Ha-45 Model 21, 18 cyl, radial, manufactured by Nakajima.

Power Available.

Take Off	1970 hp at S.L.
Normal Power	1150 hp at 8,000 ft
Normal Power	1000 hp at 22,000 ft
Military Power	1875 hp at 5,900 ft
Military Power	1695 hp at 20,000 ft
War Emerg.	2050 hp at 2,500 ft
War Emerg.	1850 hp at 17,900 ft

Armament

2 - 12.7-mm synchronize guns
Ammunition - approx 350 rounds per gun
2 - 20-mm free-firing guns
Ammunition - approx 150 rounds per gun
2 - 30 kg (132 lb total) or
2 - 100 kg (440 lb total) Bombs
Bombs carried externally in place of droppable gas tanks.

Propeller

4-blade diameter 10.2 ft
Type - constant-speed, electric

CONCLUSIONS

The Frank-1 may be compared favorably to the P-51H or the P-47N. Although both of these fighters have a slightly higher top speed, the Frank-1 will climb to altitude a little more quickly. The Frank-1 is more maneuverable in turns and will turn inside of either of the AAF fighters; but both the P-51H and P-47N have a higher diving speed. The range of the Frank-1 is about the same as that of the P-51H.

The Frank-1 is not so well constructed as contemporary AAF fighters in that it will not stand up so well under continual usage and requires more maintenance and minor repairs.

PILOT'S COMMENTS ON AND HANDLING
CHARACTERISTICS OF FRANK-1

Purpose

To forward pilot's comments on cockpit layout and handling characteristics on the above aircraft.

Factual Data

1. Introduction.

The Frank-1 is a single-place, single-engine, low-wing, Japanese Army fighter with hydraulically retracted landing gear and a glass-enclosed, sliding, greenhouse-type canopy. All-metal, stressed-skin construction is used throughout, with the exception of the fabric-covered movable control surface.

Power is supplied by a Nakajima Ha-45 Homare, Model 21, twin row, radial, air-cooled, 18-cylinder engine developing 1970 brake horsepower at sea level with 3,000 rpm and 49.6 in. Hg.

The propeller is a four-bladed, constant-speed, non-feathering, automatic or manually-operated model, similar to the United States Curtiss Electric Type.

The aircraft was flown a total of 11-1/2 hours by flight test pilots in their effort to determine its handling characteristics and to obtain information on which to comment.

The program was hampered by repeated failures of the exhaust stacks due to poor material, welding, and method of suspension.

In general, the pilots agree that the maneuverability of the Frank-1 is slightly inferior to that of the Zeke-52, while level flight speeds are much higher with less vibration at comparable velocities. Control forces are lighter than those of most American aircraft even though elevator forces on the Frank-1 are heavier than those of the Zeke-52.

2. Weight and C G Information.

Flights were made with a take-off gross weight of 7900 lb with CG position 84.6 in. aft of reference datum (rear of propeller spinner).

3. Flight Characteristics.

a. Cockpit Layout.

Entrance to the cockpit is from the left wing root walkway and is facilitated by presence of a retractable step and a push-in-type hand hold at the wing trailing edge and a retractable step just below the cockpit opening. The location of the steps is well planned and makes for much easier entry than that of comparable American types.

The stamped-metal pilot's seat is adjustable vertically by means of a handle on its left side. Adjustment in the lower position of its travel is poor due to the failure of the lock pin to engage, which occasionally causes annoying shifting of the seat with changes in G forces.

Present installation of American shoulder harness is unsatisfactory and affords no protection whatsoever in the event of crash landing as no stress member over which to pass the straps has been installed. In event of accident involving longitudinal deceleration, sheetmetal back of seat would fail allowing pilot's head to strike gunsight or instrument panel.

In general, the layout of the cockpit is good, using conventional methods of control installation and operation procedure. Flap and gear controls are on the left cockpit floor. Elevator trim wheel and engine control quadrant are on the left cockpit side. No flight-adjustable aileron or rudder trim is installed.

Instrument panel layout is good with logical placement of flight instruments in the upper center position and engine instruments in the lower portion.

The auxiliary electrical panel and ignition boost control containing circuit breakers are in the right forward part of the cockpit below the instrument panel.

Internal and external fuel selector valves and fuel cooler and primer controls are on the right cockpit floor.

Cowl and oil-cooler flap controls are on the upper right cockpit side with the radio equipment.

Auxiliary hydraulic pump is on the right rear cockpit side and the mechanical up-lock release is on the left side of the cockpit floor.

The original instruments function well and appear to be reliable with the exceptions listed below:

(1) The gyro turn indicator appears to be binding inasmuch as one-third needle width right or left

is the maximum indication obtainable under any attitude or rate of turn.

(2) The caging knob is missing or has been omitted from the artificial horizon making it impossible to cage the instrument for aerobatics or to erect the gyro after it has been upset. After upset, no gyro erection tendency was apparent in five minutes of level flight.

(3) The left liquidometer consistently reads lower than the right, even though the fuel tanks theoretically feed evenly.

(4) Flight controls consist of a stick and a bar-type rudder. Control friction is nominal on the ground with no binding or roughness present; however, interference is present between the automatic mixture control and the stick when attempting to apply full left aileron when the mixture control is set for "normal." The rudder bar is adjustable fore and aft, but still too close to the seat for larger-than-normal American pilots.

(5) Installation of Detrola is unsatisfactory as it blocks view of the Demand Oxygen panel, is practically impossible to tune, and leaves insufficient shoulder and arm room for operation of stick.

(6) The canopy is barely large enough and has no provisions for jettisoning.

b. Taxiing and Ground Handling.

The Frank-1 handles rather poorly in taxiing due to inadequate brake action; and the condition is aggravated by the inferior design of the rudder bar and toe brake assembly. Use of the brakes is mandatory for S - ing to obtain forward vision. At the same time, use of brakes must be limited as much as possible to prevent overheating and subsequent locking. The tailwheel lock with its slight swivel is a definite aid in cross-wind taxiing.

c. Take Off and Initial Climb.

The take-off characteristics of this aircraft are good, with a comparatively short ground run and negligible torque effect if rated power is applied gradually. If power is blasted on, full right rudder and some brake is necessary to counteract the pull to the left. Other than this, directional control is easy to maintain. Three-point take offs may be safely executed at 95 mph IAS with normal rated power or above.

Initial air acceleration is normal with rate of climb becoming very good upon retraction of landing gear. At 150 mph IAS, an estimated four seconds is required for gear retraction and causes very little flight longitudinal trim change.

d. Climbs.

It is apparent that the rate of climb of the Frank-1 is very good although no performance climbs were attempted due to flying time restrictions.

e. Handling and Control at Various Speeds.

In general, the handling and control characteristics of the aircraft are definitely superior to those of comparable American fighters, especially in the low-speed range; however, rate of roll and radius of turn are slightly inferior to those of the Zeke-52. Control-feel is good; rudder and aileron forces are light, well correlated, and produce quick, positive changes of attitude. Elevator forces, although heavier than those for the rudder and aileron, are not objectionable and progress with G forces with no apparent lightening. No flat spots or control reversal tendencies were noticed over an IAS range of from 74 to 350 mph. The rudder control is extremely sensitive at 300 mph IAS, slightly less sensitive above this speed, with little change in directional trim from 150 to 350 mph IAS.

f. Trim and Stability.

Flight-adjustable trim is provided for the elevators only. The trim control works easily but excessive play in the cockpit end of the device makes initial presetting of the tab difficult. Very little trim change is necessary throughout the level-flight speed range of the aircraft. Only slight longitudinal trim changes occur with operation of the gear and flaps. Aileron and rudder trim appear to be unnecessary after initial rigging adjustments are accomplished. As flown, the Frank-1 had too much right rudder trim and attendant right wing heaviness, which handicapped evaluation of stall and handling characteristics.

From pilot observations alone the stability of the aircraft appears to be very satisfactory. Yaw tests indicate some lateral oscillations, although not of a serious nature.

(Rudder trim would improve Frank as a gun platform.)

g. Stalls and Stall Warning.

The stalling characteristics of the Frank-1 are normal and stall warning occurs soon enough to prevent stall if recovery procedure is instituted at the time of the warning.

The following results were obtained from stalls with the configurations as shown:

Power off - wheels and flaps up, cowl flaps and canopy closed, 8,000 ft PA, 2200 rpm throttle closed, straight stall.

Stall warning consisting of shudder and elevator buffet occurs at 108 mph IAS; actual stall, at 102 mph. Stall is clean and aircraft is stable with negligible tendency to drop off on a wing. Aileron and rudder are effective well below stall speed.

Power off - wheels and flaps down, cowl flaps and canopy closed, oil cooler shutters open, 8500 ft PA, 2200 rpm, throttle closed, straight stall.

Stall warning, occasionally accompanied by severe canopy buffet, occurs at 92 mph IAS; actual stall, at 90 mph IAS. Nose drops straight through with no unstable tendencies.

Power on - wheels and flaps down, cowl flaps and canopy closed, 8000 ft PA, 2200 rpm, 20 mm Hg. Aircraft does not stall in this configuration. Rudder does not stall but becomes inadequate below 81 mph IAS. At this speed, heading may be maintained by use of full right rudder and right aileron. Aileron becomes inadequate for maintaining altitude below 74 mph IAS. Aircraft yaws left and rolls left below 74 mph IAS. Control may be regained by increasing airspeed and decreasing power slightly. With M.P. decreased to 20 mm Hg the aircraft will stall. The warning occurs at 81 mph and the actual stall, accompanied by dropping of the left wing, at 79 mph IAS.

Power on - wheels and flaps up, cowl flaps and canopy closed, 8000 ft PA, 2200 rpm, 20 mm Hg 60° bank, 3 G estimated, turning stall. Left and right turns, elevator buffet below 160 mph IAS becoming more severe as IAS is decreased. Turn discontinued at 130 mph due to severe elevator buffet and out of trim adjustment of the rudder tab.

h. Maneuverability and Aerobatics.

The aircraft was found to be quite maneuverable with rate of roll and radius of turn slightly inferior to those of the Zeke-52. Handling of aircraft in loops and slow rolls is very good, although well-coordinated maneuvers are difficult due to the lack of flight-adjustable rudder and aileron trim.

j. Changes in Trim when Operating Landing Gear, Flaps, etc.

Normal changes are apparent, i.e., nose down when lowering gear and flaps, nose up when retracting. Right rudder required in power-

on climb, left rudder, in dive. Considerable travel in control position is required for various configurations with little change in control pressure.

k. Noise and Vibration.

The noise level is normal for propeller-driven types with radial engines without exhaust collector rings. The vibration level is definitely lower than that of the Zeke 52, especially at high speed, and is nearly comparable to that of American types. Flight check disclosed high-frequency vibration of engine transmitted to aircraft from 2000 to 3000 rpm and the level is nearly constant over this range.

l. Comfort.

The cockpit is comfortable on the ground during warm weather operation only if the canopy is fully open. Cockpit heat level and ventilation volume are good for warm weather operation at low and medium altitudes. Cold weather operation is expected to be very uncomfortable due to the lack of cockpit heat.

The seat is comfortable enough for flights of the duration for which the aircraft was designed. Design of the seat and lack of rudder pedal adjustment would cause discomfort during extended operations.

m. Vision.

Combat vision is excellent for greenhouse-type canopies except where blocked by the nose forward and the wings and fuselage below. This arrangement necessitates "S" - ing on the ground, gentle turns while climbing, and formation flying in a slightly stacked-down position with cross coverage for the blind spots below.

n. Approach and Landing.

The aircraft handles very well on approach and landing. No undesirable air characteristics or ground looping tendencies were disclosed. After extension of the gear at a speed below 160 mph and full flaps at 130 mph, the 3-point landing can be satisfactorily executed (with elevator trim tab set for 0# stick force) using speeds of 120 mph over the fence and 110 mph just off the runway, touching-down at 92 mph. The ground roll is short and 3-point forward vision is poor.

4. General Functioning.

a. Power Plant and Associated Equipment.

The operation of the power plant was satisfactory throughout the series of flights. No lack of confidence in the HA-45 Homare engine was expressed by the pilots.

The externally energized inertia starter appears to be of insufficient torque rating to insure consistent starts even in warm weather. Normal procedure in starting was to operate the 110-v Jack and Heintz external energizer at 150 v, which caused severe overheating of field coils.

The operation of the electrically controlled propeller was good. Engine speed was held satisfactorily except in the application of power after a prolonged dive, in which case the propeller would overspeed excessively unless great care was taken.

All flight and engine controls are smooth in operation with positive response and no binding or roughness throughout the permissible range.

The engine control quadrant friction locks cannot be made to hold the component controls in fixed position. As a result the propeller control tends to vibrate to low rpm position; the automatic mixture control, to cruising position; and the supercharger control, to high position.

b. Hydraulic, Pneumatic, and Electrical Systems.

Some difficulty was experienced with the hydraulically operated landing gear. On one occasion the gear retracted only part of the way and on another, the gear retracted but the up locks would not engage. On both occasions an additional cycle of operation appeared to clear the trouble. The auxiliary hand pump is connected to the reserve portion of the main hydraulic tank and works well. Its capacity is such that approximately 100 strokes of the pump are required to retract or extend the flaps. Auxiliary operation of the landing gear was not checked.

The electrical system functioned well with the exception of one instance of generator failure before take-off.

c. Emergency Systems.

No emergency canopy jettisoning or fire-fighting apparatus is included in the original installation of the Frank-I. In cases of complete hydraulic fluid failure, the gear may be unlocked manually and allowed to fall into place aided by yawing of the aircraft until the indicator lights show the down locks have engaged.

5. Performance

None obtained.

Conclusions

It is believed that the Frank-1 is a fighter aircraft with excellent

maneuverability and handling qualities and good rate of climb for its type. The light power loading and control forces are admirable, although its lack of pilot protection and short range leave much to be desired in the light of present fighter standards.

Recommendations

1. No recommendations are submitted on the Frank-1.

2. Before the testing of additional Japanese aircraft, the following suggestions are advanced:

a. That shoulder harness which would actually be of value in a crash landing be installed, in contrast to the useless arrangement on Frank-1, No. 302.

b. That an effort be made to obtain a more efficient energizer unit, possible one of higher rating which would directly engage the dog projecting from the propeller spinner.