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MC DONNEL AIRCRAFT CORP., ST. LOUIS, MO. (REPORT NO. 2221)

RAM JET HELICOPTER DEVELOPMENT - PROGRESS REPORT 59 -
MONTH OF JULY 1951 = MODEL XII-20

WOOD, C. R., JR. 15 AUG 51 26PP PHOTOS, GRAPHS

AF CONTR. NO. AF 33(038)-9845

HELICOPTER = ROTORS, ROTATING WING AIRCRAFT (34)
JET ENGINES, RAM JET

DRIVE SYSTEM (6)
EXTRA COPY

PROPELLER LABORATORY

MCDONNELL Aircraft Corporation

ST. LOUIS 3, MISSOURI

PROCESS REPORT 59

MONTH OF JULY 1951

RAF JET HELICOPTER DEVELOPMENT

SUBMITTED UNDER Contract AF 33 (038)-0816

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APPROVED BY R. H. Osborn

APPROVED BY A. C. Ballew

APPROVED BY C. H. Burkamp
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1. SUMMARY

Preliminary ground and flight evaluation of the first 27-foot diameter rotor were completed. The rotor was removed from the helicopter and installed on the whirling test stand for the rotor calibration and adjustment of Rm Jets No. 32 and 33. Installation of the skid type landing gear and instrumentation for measurement of control position and forces and rotor tilt was started.
2. Rotor Development

2.1 First 27-Foot Diameter Rotor

A 21-01h6 swivel was installed in the cyclic pitch actuator in place of the 21-01h6 swivel for continuation of the preliminary ground and flight evaluation, see Figure (1). Rotor operations were marginally improved. Bhartrio blade weights have been installed at the trailing edge of the root of each blade, see Fig.-ro(6). A maximum of eleven weights, totalling 8 lbs., was installed 11.19 inches aft of the blade feathering axis at each blade root. Further evaluation of the effects of Bhartrio blade weights is scheduled for the near future.

After completion of the preliminary ground and flight evaluation, the rotor was removed from the helicopter and installed on the whirl test stand.

After tests and adjustment of Sim Jato Nos. 32 and 33 for increased thrust, whirl stand torque calibration tests were conducted. The 90 hp added to the whirl stand drive permitted rotor calibration at much higher rotational speeds.
Tests were made with:

a) ram jet inlet with cowl type fairings -

fied blade tips

b) ram jet installed and open

c) ram jet exit area reduced

The reduced inlet tests were made to determine the
external shell drag. The casing attached to the ram
jet exit was designed to reduce the internal rise to
simulate actual burning external air flow conditions
with a temperature rise ratio of 6. This temperature
rise had been estimated from blower tests to be
typical of the maximum thrust burning condition.

Graph plots of these data are shown in Figures (3),
(4), and (5). The equivalent tip drag vs. pitch of the
rotor alone is shown in Figure (3) for several tip speeds.
The cold drag of the ram jets alone, was deduced from rotor
alone and the rotor plus ram jet test data in Figure (4).
The average cold ram jet drag coefficient was .16.

- Effective pitch is the average of the measured pitch
  of the outer 50% of the blade.
2.1 (cont)

Figure (3) shows the results of the reduced exit tests made to determine the external drag coefficient of the ram jet shell. An internal drag was calculated from internal pressure measurements in blower tests. This is subtracted from the reduced exit data, Figure (5), to indicate the ram jet external drag with the ram jet burning.

Figure (5). Figure (6) shows the blade twist at various blade stations.
2.2 Second 27-Foot Diameter Rotor

Engineering data re the structural analysis, methods of fabrication, and static and dynamic tests results of the first 27-foot rotor were submitted on 19 July 1951. Fabrication of the second 27-foot rotor awaits the measurement of flight stresses on the first rotor, a restudy of the stress data and WADC approval of the design.
3. RAM JET

3.1 Comparative Study of MAC Ram Jets and Afterburners

MAC has accumulated considerable experience in the design, development and production of afterburners for turbo-jet engines. MAC's Propulsion Division currently is under contract to develop and produce afterburners for several types of USAF turbo-jets.

The fuel distribution characteristics, mixture conditions, etc., of the ram jet and the afterburner are similar. The afterburner can be considered as a ram jet with step-type flame holders. Comparative studies of afterburners and ram jet thrust specific fuel consumption indicate that the actual thrust specific fuel consumption (TSFC) of the MAC ram jet approaches that of the afterburner, see Figure (7). Figure (3) shows relative performance of the ram jet and afterburner. Higher afterburner pressure ratio account primarily for the lower TSFC.
3.2 New Modified Radial Fingertip Run Jets

The run jets Nos. 32 and 33 fitted to the 27-foot diameter rotor were utilized to complete the primary evaluation of control forces and control response characteristics. They were then utilized for calibration of the 27-foot diameter rotor. The run jets were to be adjusted for improved thrust subsequent to further flight tests of the 27-foot diameter rotor.
3.3 MAC Ram Jet Development

Thirty-five ram jets have been designed, developed, and tested under Contracts W33-038-co-14856, AF 33(038)-937, and AF 33(038)-9845. The first 16 ram jets were of the swirl-vane flame holder type and used propane as fuel. The ram jets were of the swirl-vane type with internal gasoline vaporizer. All subsequent ram jets have been of the liquid fuel injection type with either gatton cone flame holders or radial finger type flame holders. The maximum diameter has been varied from 7.25 to 8.7 inches; the exit diameter from 4.5 to 5.7 inches; the inlet diameter from 3 to 4.20 inches, and the length from 14 to 22 inches. Ram jets have been constructed of stainless steel, Inconel "X", and 1-635 material. The ram jet weight has varied from 9.5 lbs. to 11.3 lbs.

Test ram jets - 8.7 inches maximum diameter, 22 inches length, radial finger liquid injector type - have been fabricated and are being tested in the free air jet test stand prior to whirl testing. These larger ram jets are designed for improved rotor performance of the XR-20.
3.3 (cont)

MAC has financed development of 8 additional ram jets of maximum diameter from 7.25 to 8.7 inches; exit diameter from 5.0 to 5.7 inches; inlet diameter, 4.50 inches; length from 21.5 to 22 inches. All ram jets were of Inconel "x" material. The ram jet's weight has varied from 12.22 to 16.21 pounds.
3.4 Modified Whirl Stand

The preliminarily modified whirl stand supplemented by a 20 hp engine was utilized for the calibration of the first 27-foot diameter rotor. Marginally sufficient power was available to permit completion of cold drag test of the 27-foot diameter rotor. An improved whirl test stand is being developed, to be supplemented by a 50 hp engine, and will soon be available for tests of rotors under simulated actual operative conditions.
4. McDONNELL XE-30, USAF LD. 46-690

4.1 Preliminary Tests

Preliminary ground and flight tests of the XE-30, No. 2, fitted with the first 27-foot
rotor were completed in July. The effects
of control changes, elastomer blade weights, etc.,
were measured. Tests produced small reductions in
central forces with little improvement in control
response. Collective pitch control sensitivity
was reduced and was satisfactory with R-302h
pulley installed in place of R-0150 pulley,
see Figure (2).
4.2 Skid Gear and Extended Tail Boom

The landing gear stability of the XH-20 had been reduced by the installation of the 27-foot diameter rotor and the raising of the vertical Stol of the helicopter. Therefore, a wide skid gear was installed after completion of the preliminary tests. For improved directional control an extended tail boom with swiveling rudder was also installed.
4.3 Control System Design

Studies of the control system design have been conducted in order to reduce control forces and to improve control response. The XH-20 is being fully instrumented for the measurement of stick forces, stick position and blade root-slip motions. Test operations are scheduled for August to measure the actual forces and conditions encountered to permit study of changes necessary for satisfactory flight operations.
5. **DAILY FLIGHT SHEETS - XH-20 Helicopter Test Data**

<table>
<thead>
<tr>
<th>Part No.</th>
<th>130</th>
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<tr>
<td>Pilot:</td>
<td>C. R. Wood, Jr.</td>
</tr>
<tr>
<td>Date:</td>
<td>2 July 1951</td>
</tr>
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<td>No. 2</td>
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**Rotor:** 27-Foot Diameter 12-inch Chord Rotor Blade Powered By

Ram Jets Nos. 32 and 33

**Purpsoe:** Evaluate Control Changes of 27-Foot Rotor and Effect of C. G. Variation

**Remarks:** Rotor acceleration was sluggish; ram jet fuel pressure is inadequate for rotor acceleration; there was little stick shake during rotor run-up or in hovering. The helicopter was noisy heavy. Longitudinal stick forces were high; and lateral forces not noticeably reduced by the installation of J-1-0150 swivel in place of J-1-0159 cyclic stick attachment. The lateral displacement required was increased. The movement of the cyclic pitch stick neutral position are interfered with controllability. Collective pitch control sensitivity was reduced and was satisfactory on a result of change of J-302a for J-0150 pedal. Landing gear stability is reduced with the 27-foot rotor.

**Flight Time:** 00:06

**Running Time:** 00:36

**Total Flight Time to Date:** 32:03

**Total Running Time to Date:** 125:45c

*Total for Nos. 1 and 2, XH-20*
Test No.: 131

Pilot: C. R. Voda, Jr.

Date: 5 July 1951

Helicopter: No. 2.


Rotor: 27-Foot Diameter 12-inch Chord Rotor Blade Powered by

Two Jet No. 12 and 33

Purpose: Evaluate Changes in Blade Chord to G. O. Final Data

and in Elevation

Remarks: Ground idle damp tests indicated that although cyclic

control forces were high, they were controllable; the

tie down was removed. With eleven weights, totalling

6 pounds per blade, the helicopter was uncontrollable

on lift-off from the ground. Conditions were only

marginally improved by removal of five, 3.5 pounds,

of the weights from each blade.

Flight Time: 03:01

Running Time: 05:25

Total Flight Time to Date: 32:05

Total Running Time to Date: 126:10

Total for Nos. 1 and 2, IH-20
Test No.: 132  
Date: 6 July 1951  
Helicopter: No. 2

Rotor: 27-Foot Diameter 12-inch Chord Rotor Blade Powered By
Rpm Joto Nos. 32 and 33

Purpose: Further Evaluation of Chordwise Blade Weights

Remarks: Covering evaluation tests were conducted with three
weights per blade; the helicopter became uncontrollable
on lifting-off the ramp. All weights were removed and
spacers and wood blocks installed in the brackets.
Momentary flight characteristics without weights were
improved; the over-balancing forces were reduced, but
the steady stick forces were increased.

Flight Time: 00:02  
Running Time: 00:16

Total Flight Time to Date: 32:06#  
Total Running Time to Date: 126:26#

#Total for Nos. 1 and 2, XH-20
6. WORK PROGRAM FOR LAST OF AUGUST

6.1 Redized XH-20, No. 2

The installation of the tail-type landing gear, extended tail boom, and swiveling rudder will be completed. Instrumentation for measurement of control position and forces and rotor tilt will be installed.

Ground and flight tests are scheduled for measurement of stick forces, stick positions, and blade see-saw motions in order to determine necessary information to permit modifications for satisfactory ground and flight evaluation of the 27-foot diameter rotor.

6.2 Run Jobs Nos. 32 and 33

Run Jobs Nos. 32 and 33 are to be modified for increased thrust and improved rotor performance. Development of improved run jobs has been accelerated.
FIG 4.
RAM JET COLD DRAG
DETERMINED BY WHIRL STAND TESTS

TIP SPEED: 200 FT/SEC
27 FT ROTOR WITH RAM JETS 32 / 33
TEST DATE: 7-11-51
DATA CORRECTED TO 13.5" RADIUS & TO STD SI. COND.
FIG. 5
RAM JET EXTERNAL DRAG
Determined by wind tunnel tests with reduced exit
TIP SPEED: 600 F.P.S.
22 FT. ROTOR WITH RAM JETS 32 FT.
TEST DATE: 1-12-51
DATA CORR. TO 14.7 FT. RADIUS
ESTD. S.L. COND.

EFFECTIVE BLADE PITCH DEG.
**Blade Angles - 27 Rotor (Paired Tips)**

0° Indicated R.Z. (Measured at Blade Root)

Blade #1

Blade #2

\( M = \text{Moment} \)

\( A = \text{Moment} \)

\( B = \text{Moment} \)

\( C = \text{Moment} \)

\( D = \text{Moment} \)

**Note:**

Positive and negative pitching moments were applied at the blade roots during the readings to take up the backlash in the whirl stand pitch mechanism.
Figure 7

RAM JET AND AFTERBURNER
THrust SPECIFIC FUEL CONSUMPTION

- Wright Field 24 in dia.
- Free air jet
- Mac 4 in dia, Free air jet
- Dangerfield 18 in dia
- Free air jet

THrust SPECIFIC FUEL CONSUMPTION - LBS. FUEL/LB. THRUST

V_{...} = FT./SEC.

RWF
6-23-57
RAM JET AND AFTERBURNER

COMBUSTION AIR PROPERTIES

$P_0 = 14.7$ psia

$T_0 = 520^\circ F$

$T_i$: INLET TOTAL TEMPERATURE

$P_i$: INLET TOTAL PRESSURE

Figure 8