ATOMICS INTERNATIONAL
A Division of North American Aviation, Inc.

MASTER

NAA-SR-MEMO -3295

This document contains 32 pages

This is copy _____ of _____ series _____

Do not remove
this sheet

UNCLASSIFIED

Security Classification

*NAA-SR-MEMOs are working papers and may be expanded,
modified, or withdrawn at any time,
and are intended for internal use only.*

This report may not be published without the approval of the Patent Branch, AEC. - *released 10/14/61*

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

WRITTEN BY R. S. Baker <i>RSB</i>		ATOMICS INTERNATIONAL A Division of North American Aviation, Inc. TECHNICAL DATA RECORD	TDR NO.
SECTION Component Development			Rev. 3295 <i>X</i>
GROUP Mechanical Component			GO 7529
UNIT Coolant System Equipment			LEDGER ACCT. 3621
APPROVED BY: (SUPERVISOR) <i>[Signature]</i>		PROGRAM SRE	SUB-ACCT. 4370
OTHER		PROJECT Engineering Improvements in the SRE	TWR
			DATE 20 December 1958
			PAGE 1 OF 32

TO: G. E. Deegan

COPIES TO:

B. H. Colmery	R. B. Hinze	R. Cygan
R. W. Dickinson	H. W. Lohman	J. J. Droher
L. E. Glasgow	H. Pearlman	J. A. Leppard
W. J. Hallett	E. R. Smith	

SUBJECT: Design and Performance of Induction Pump for SRE Moderator System

CONTENTS:

I	STATEMENT OF PROBLEM	PAGE 1
II	SUMMARY OF RESULTS AND RECOMMENDATIONS	PAGE 1
III	METHOD USED, DESCRIPTION OF EQUIPMENT, SAMPLE CALCULATIONS . . .	PAGE 1 & 2
IV	REFERENCES AND APPENDICES	PAGE 12 & 13

I STATEMENT OF PROBLEM

Data from tests made at the SRE (Reference 1) indicated the need for a pump to control moderator temperature. An electromagnetic pump was requested on TWR 2563, G.O. 9693, sub-account 4197, to achieve this objective.

II SUMMARY OF RESULTS AND RECOMMENDATIONS

A three-phase linear induction pump was designed and built for this purpose by Group 793-33. The pump has been installed in the SRE. The procedure for designing this pump, together with test curves, is presented in this report. The pump was originally designed for pumping sodium having a temperature of 500°F at a flow rate of 100 gpm and 15 psi. Due to a change in the SRE requirements, no test runs were made at this temperature. The maximum flow rate was obtained at a temperature of 760°F; this rate was 91 gpm, at 12.4 psi and an efficiency of 1.7%.

III METHOD USED, DESCRIPTION OF EQUIPMENT, SAMPLE CALCULATIONS

The linear induction pump which was designed in accordance with the procedure outlined in this TDR was placed in a loop 8 feet square of 2 inch type 304 stainless steel pipe in the Engineering Test Building. A schematic drawing of the loop is shown on page 20 of this TDR, and a schematic diagram of the electrical connections is shown on page 19.

The throttling valve was set at its wide open position. The powerstat was set at an output voltage of 50 volts. Suction and discharge pressures were recorded, as well as flow rate and power input to the pump.

TECHNICAL DATA RECORD

PROGRAM SRE

Engineering Improve-
PROJECT ments in the SRE

TDR NO. 3295

DATE 20 December 1958

PAGE 2 OF 32

The powerstat setting was changed to raise the output of voltage to 75 volts, and the readings were repeated. This sequence of operations was repeated in increments of 25 volts output voltage, up to 200 volts.

The flow was then reduced 20% by means of the throttling valve with 200 volts pump voltage. The powerstat was set at 50 volts output, and the operations repeated. The developed fluid power, in watts, is .435 times the flow rate in gallons per minute times the difference between discharge and suction pressures.

The efficiency, expressed as a decimal, is the ratio of developed fluid power to pump input power as measured with a wattmeter.

This is to acknowledge the contributions of H. W. Lohman, 793-33, and E. R. Smith, 795-53, in the preparation of this TDR.

The data used in preparation of this TDR are recorded in Laboratory Notebook number 3165.

030 002

TECHNICAL DATA RECORD

PROGRAM SRE

Engineering Improve-
PROJECT ments in the SRE

TDR NO. 3295

DATE 20 December 1958

PAGE 3 OF 32

DESIGN SHEET
FOR
LINEAR POLYPHASE INDUCTION ELECTROMAGNETIC
PUMP

Capacity in gallons per minute 100

Liquid metal to be pumped Sodium

Pressure to be developed by pump in pounds per square inch 14

Temperature of liquid metal in pump 500°F

SYMBOL	MEANING	MAGNITUDE
Q	Volumetric flow rate in gallons per minute	From Specs 100
d ₁	Liquid metal passage width in the pumping section in inches. See Section A-A of Figure 1 and reference 20. For the purposes of this TDR $d_1 = 1 - e^{-9.2 \times 10^{-3} Q}$ where e is the base of natural logarithms. A method of precise determination of d ₁ is given in reference 2.	.290 ("As-built" dimension)
d ₂	Pumping section wall thickness in inches. The value of d ₂ must be no larger than necessary to satisfy thermal stress, bursting pressure, and corrosion requirements.	.120
d ₃	Clearance between outside wall of pumping section and the stack of laminations measured in inches. See section A-A of Figure 1. $d_3 = 0.050 \pm 0.020 \text{ inches}$	
d ₄	Width of stator tooth in inches. To avoid excessive fringing of the magnetic flux in the pumping section, d ₄ should be at least equal to the air gap (d ₆ below) and preferably greater. $d_4 = d_1 + 2d_2 + 2d_3 \pm .02 \sqrt{2} \text{ inches}$ If this value of d ₄ causes Carter's coefficient, defined later in this TDR, to be greater than 1.15, the value of d ₄ must be increased. See Figure 1 and reference 3. The lamination should be die punched free from burrs (Continued)	2.22 ("As-built" dimension) 030 004

TECHNICAL DATA RECORD

Engineering Improve-

DATE 20 December 1958

PROGRAM SRE

PROJECT ments in the SRE

PAGE 4 OF 32

SYMBOL	MEANING	MAGNITUDE
	from the best motor grade silicon steel with insulating coating.	
d_5	Width of stator slot in inches; assume d_5/d_4 to be $3/4$. The value of d_5 should not be taken greater than d_4 . See Figure 1 and the reference for d_4 ; reference 3; also reference 4.	1.11 as built
d_6	Total air gap length in inches. See section A-A of Figure 1. $d_6 = d_1 + 2d_2 + 2d_3 \pm .02\sqrt{2} \text{ inches}$	$.630 \pm .028$ inches
d_7	Pole pitch in inches. For the coil connection diagram of this TDR, Figure 2, $d_7 = 3d_4 + 3d_5$	9.99
r_1	Electrical resistivity of the liquid metal in ohm-inches. For sodium see the curve of the "Electrical Resistivity of Liquid Sodium," page 25 of this TDR, also reference 5.	6.18×10^{-6}
v_1	Liquid metal velocity in the pumping section in inches per second. To reduce erosion of the pumping section by cavitation, v_1 should not exceed 120 inches per second when pumping sodium. For other liquid metals the value of v_1 should be just below the value where cavitation begins; this must be determined by hydraulic tests on scale models of the pumping sections.	120 at 10 psig cover gas pressure.
f	Line frequency in cycles per second.	60
d_8	The internal depth of each pumping section in inches. See section A-A of Figure 1. The value of d_8 is calculated as shown below to enable the pump to develop a maximum pressure at shut off, assuming that the air-gap flux wave consists only of the fundamental or line frequency component. $d_8 = \frac{d_7}{\left[\frac{20.2 f d_1 (d_7)^2}{r_1 d_6 \times 10^9} - 1 \right]^{\frac{1}{2}}}$ See references 6 and 7.	4.00 as built

030 005

TECHNICAL DATA RECORD

PROGRAM SRE

Engineering Improve-
PROJECT ments in the SRE

TDR NO. 3295

DATE 20 December 1958

PAGE 5 OF 32

SYMBOL	MEANING	MAGNITUDE
d_8 (cont)	If the above calculated value of d_8 is greater than five inches, it is advisable to limit d_8 to five inches. The pumping section should be constructed from commercially available seamless tubing, flattened to the requisite dimensions. Fifteen per cent tolerance is allowable.	
n_1	Total number of pumping sections in parallel between headers. See section A-A of Figure 1. $n_1 = \frac{3.85 Q}{v_1 d_1 d_8}$ <p>n_1 must be an integer. If n_1 as calculated falls between two whole numbers, make n_1 the larger of the two numbers. Assume 1/16 inches between sections.</p>	4 ("As-built" dimension)
d_9	Nominal inside diameter of header pipe in inches. $d_9 = \left(\frac{4.9Q}{v_1} \right)^{1/2}$ <p>Allowable tolerance is $\pm 10\%$.</p>	2.0
d_{10}	Actual outside diameter of header pipe in inches. See reference 8.	2
n_2	Number of parallel circuits per phase. For the coil connection diagram of Figure 2, $n_2 = 2$. The minimum value of n_2 is 2; n_2 must be an even integer.	2
n_3	Number of poles produced by the connection of the pump windings. For a concise method of determining n_3 , see reference 9. The value of n_3 must be an even integer. If, after calculating the developed pressure by the method given later in this TDR for the case where $n_3 = 2$, it is found that the pressure is too low, then the length of the pump in the direction of flow must be enlarged by increasing n_3 to a greater even integer in order to produce a pressure that will meet specifications. The peak value of air-gap flux density B_1 , must be fixed in making this calculation at the value for which peak tooth flux density, B_2 , is not greater than 70,000 lines per square inch. (B_1 and B_2 are described later in this TDR.)	2

TECHNICAL DATA RECORD

PROGRAM SRE

PROJECT Engineering Improve-
ments in the SRE

TOR NO. 3295

DATE 20 December 1958

PAGE 6 OF 32

SYMBOL	MEANING	MAGNITUDE
n_4	Number of slots per pole per phase. For the coil connection diagram of Figure 2, $n_4 = 1$. The reason for using this value of n_4 is the limited space available. Normally, n_4 should be 2 or more.	1
n_5	Number of phases. Three phase power is generally used.	3
P	Pressure to be developed in the pump in pounds per square inch.	14
V_2	The velocity of the air gap field in inches per second. $V_2 = 2fd_7$	1200
B_1	Peak value in lines per square inch of the air-gap flux density wave. The magnitude of B_1 should be as large as practicable - between 15,000 and 20,000 lines per square inch. See references 10 and 11. Solving Rudenberg's equation (see reference 12) for B_1 in terms of the other parameters, $B_1 = \left[\frac{r_1 P \left[\left(\frac{1.016 \times 10^{-8} (V_2 - V_1) d_1 d_8}{r_1 d_6} \right)^2 + \left(\frac{d_7 + d_8}{d_8 d_7} \right)^2 \right]}{2.22 \times 10^{-16} (V_2 - V_1) n_3 d_8 \left(\frac{d_8}{d_7} + \frac{d_7}{d_8} \right)} \right]^{\frac{1}{2}}$	17,200
d_{11}	Total depth of the stack of laminations in inches. See Figure 1, section A-A. $d_{11} = n_1 (d_8 + 2d_2) + 1/16 (n_1 - 1)$	17
ϕ_1	Useful air gap flux per pole in Maxwells. $\phi_1 = 0.636 B_1 d_7 d_{11}$	1.86×10^6
C_1	Dimensionless constant entering into the calculation of the Carter Coefficient. See references 13, 14, and 15. $C_1 = 1 - 0.636 \arctan \frac{d_5}{2d_6} + 0.636 \frac{d_6}{d_5} \log_e \left[1 + \left(\frac{d_5}{2d_6} \right)^2 \right]$	.7453 007

TECHNICAL DATA RECORD

PROGRAM SRE

Engineering Improve-
PROJECT ments in the SRE

TDR NO. 3295

DATE 20 December 1958

PAGE 7 OF 32

SYMBOL	MEANING	MAGNITUDE
C_2	<p>The Carter Coefficient</p> $C_2 = \frac{1 + \frac{d_5}{d_4}}{1 + \frac{C_1 d_5}{d_4}}$ <p>See Reference 13.</p>	1.09
$(NI)_1$	<p>Peak amp turns per pole</p> $(NI)_1 = 0.313 B_1 d_6 C_2$	3.7×10^3
ϕ_2	<p>Total flux per pole in Maxwells.</p> <p>Determine ϕ_2 by making a flux plot using electrolytic bath method or conducting paper method.</p> <p>See Reference 16.</p>	3.95×10^6
d_{12}	<p>Depth in inches of laminations behind slots. See Figure 1 and section A-A of Figure 1.</p> $d_{12} = \frac{\phi_2}{(2)(7 \times 10^4) d_{11}}$ <p>The 7×10^4 term is the peak flux density in the laminations (70,000 lines per square inch.)</p>	3.00 as built
r_2	<p>Resistivity of pumping section wall in ohm-inches. For type 304 stainless steel, r_2 may be obtained from the curve on page 26 of this TDR.</p>	35×10^{-6}
B_2	<p>Peak flux density in the teeth in lines per square inch. for the coil connection of Figure 2,</p> $B_2 = \frac{\phi_2}{3 d_4 d_{11}}$ <p>If this equation gives a value larger than 70,000 lines per square inch for B_2, the tooth width d_4 must be increased to reduce B_2.</p>	34,700

TECHNICAL DATA RECORD

PROGRAM SRE

Engineering Improve-
ments in the SRE

TOR NO. 3295

DATE 20 December 1958

PAGE 8 OF 32

SYMBOL	MEANING	MAGNITUDE
E_1	Coil voltage. For the connection of Figure 2, $E_1 = 1/2$ specified line voltage	110
N_6	Number of turns in each coil. $N_6 = \frac{10^8 E_1}{2.22 f \phi_2}$	27 as built
$(NI)_2$	Peak ampere - turns per coil. For connection of Figure 2, $(NI)_2 = \frac{(NI)_1}{2}$	1.85×10^3
I_1	Coil magnetizing current in amperes r.m.s. For the connection of Figure 2, $I_1 = \frac{(NI)_2}{N_6 \sqrt{2}}$	48.5
S_1	Slip of liquid metal in pumping section behind traveling field. $S_1 = \frac{V_2 - V_1}{V_2}$	0.90
M_1	Weight in pounds of the silicon steel laminations in the pump. Calculate M_1 from design sketches or drawings.	1500
W_1	The fluid power output expressed in watts that must be developed by the pump. $W_1 = 0.435 \text{ QP watts}$	610
W_2	Power loss in watts in pumping section walls. $W_2 = \frac{5 \times 10^{-17} v_2^2 n_1 n_3 d_2 d_8^2 \left(\frac{d_8}{d_7} + \frac{d_7}{d_8} \right) B_1^2}{r_2 \left[\left(\frac{1.02 \times 10^{-8} v_2 d_2 d_8}{r_2 d_6} \right)^2 + \left(\frac{d_7}{d_8} + \frac{d_8}{d_7} \right)^2 \right]}$	3230

TECHNICAL DATA RECORD

PROGRAM SRE

Engineering Improve-
PROJECT ments in the SRE

TDR NO. 3295

DATE 20 December 1958

PAGE 9 OF 32

SYMBOL	MEANING	MAGNITUDE
W_3	Power loss in watts in liquid metal. $W_3 = \frac{W_1}{1 - S_1}$	6100
W_4	Copper loss plus iron loss in watts. For purposes of estimating power requirements, assume $W_4 = 6 \text{ watts per pound times } M_1.$	9000
W_5	Total power input in watts to pump. $W_5 = W_1 + W_2 + W_3 + W_4$	18940
I_2	In phase or energy component of coil current in amperes. For the connection of Figure 2, $I_2 = \frac{W_5}{12 E_1}$	14.35
I_3	Line current in amperes $I_3 = 2 [3(I_1^2 + I_2^2)]^{1/2}$	174.7
A_1	Cross section area of copper conductor in square inches, assuming a current density of 1,500 amperes per sq. inch. $A_1 = \frac{I_3}{3,000 \sqrt{3}}$	.034
r_3	Resistivity of the copper conductor in ohm-cm at the average temperature of the coil. Experience indicates that the average temperature of the coil may be taken equal to the ambient temperature plus one-third the difference between liquid metal temperature and the ambient temperature. The value of r_3 may be obtained from reference 18, or from the curve on page 24 of this TDR.	3.3×10^{-6}
d_{13}	Diameter of bare conductor in inches. See Figure 3. $d_{13} = \left(\frac{A_1}{0.7854} \right)^{1/2}$ Because of the availability of flat strip copper conductors in small sizes, it is recommended that flat strip be used instead of round conductor if d_{13} is 0.113 inches or more.	.208 use #3 wire

TECHNICAL DATA RECORD

PROGRAM SRE

PROJECT Engineering Improve-
ments in the SRE

TDR NO. 3295

DATE 20 December 1958

PAGE 10 OF 32

SYMBOL	MEANING	MAGNITUDE
d_{14}	The following calculations are based on a line voltage of 600 volts or less. Overall diameter of round conductor in inches. (See Figure 3) Obtain from magnet wire manufacturer's catalog such as reference 18, for double glass insulation, silicone impregnated.	0.243
d_{15}	Overall coil width in inches, for round conductor. See Figure 3. $d_{15} = d_5 - 0.150$ The 0.150 term is an allowance for 1/16 inch thick asbestos board (Quinterrabord) on each side of the coil plus 0.005 inch stainless steel shim stock wrapped around the Quinterrabord. This side of the coil with the Quinterrabord and stainless steel is the side within the laminations.	0.960
d_{16}	Coil depth in inches for round conductor; see Figure 3. $d_{16} = \frac{N_6 d_{14}^2}{d_{15} - .080} + .080$	2.070
d_{17}	Width of bare rectangular (flat strip) conductor in inches. $d_{17} = d_5 - 0.150 - 2(0.040) - 2(0.020)$ $d_{17} = d_5 - 0.270$ The 2×0.020 term is allowance for conductor insulation of 0.020 inches thickness; 2×0.040 is for glass tape wrapped to a thickness of 0.040 inches; and for 0.150 see explanation under d_{15} . See Figure 4.	0.84 as built
d_{18}	Thickness of bare rectangular (flat strip) conductor in inches. $d_{18} = \frac{A_1}{d_{17}}$	0.0405 as built
d_{19}	Overall coil width in inches for rectangular conductor. See Figure 4. $d_{19} = d_{17} + 2(0.020) + 2(0.040)$ $d_{19} = d_{17} + 0.120$	0.960 as built

TECHNICAL DATA RECORD

PROGRAM SRE

Engineering Improve-
PROJECT ments in the SRE

TDR NO. 3295

DATE 20 December 1958

PAGE 11 OF 32

SYMBOL	MEANING	MAGNITUDE
d_{20}	Coil depth in inches for rectangular conductor. See Figure 4. $d_{20} = N_6 d_{18} + N_6 (2)(0.020) + 2(0.040)$ $d_{20} = N_6 (d_{18} + 0.040) + 0.080$	2.25
d_{21}	Slot depth in inches, See Figure 1 and section A-A of Figure 1. For a round conductor - $d_{21} = d_{16} + 0.300$ <p>For a rectangular conductor -</p> $d_{21} = d_{20} + 0.300$ <p>The 0.300 term in each equation is the allowance for thickness of 1/16 inch for Quinterrabond on the coil plus the clearance between coil and outer end of the slot.</p> <p>NOTE: If the value of d_{21} is greater than 3 times the value of d_5, the number of slots per pole must be increased to the next larger number, and design calculations repeated. See reference 18.</p>	2.37 2.55

C30 C12

IV REFERENCES AND APPENDICES

1. IOL from R. D. Welsh to R. S. Baker, "Requirements for E.M. Pump for Moderator Coolant," 7 November 1957.
2. D. A. Watt "A Study in Design of Travelling Field Electromagnetic Pumps for Liquid Metal," AERE ED/R 1696, 12 June 1955, Page 11, paragraph 5.
3. J. F. Asti "Development of Electromagnetic Pumps for Liquid Metals," Final report, Report number 43-109, Allis-Chalmers Mfg. Co., 30 June 1952, Appendix "F," page 54, Eq. 17.
4. R. M. Baker "Transverse Flux Induction Heating," AIEE Transactions, 1950, Vol. 69, part 2, page 716, eq. 37.
5. Liquid Metals Handbook, U. S. Government Printing Office 1952 and 1955 editions.
6. R. S. Baker "Design of Two Permanent Magnet Rotor Pumps for Liquid Metal" AI TDR Number 2368, 27 December 1957, page 5, eq. 2-b.
7. R. S. Baker "Calculation of Developed Pressure and Fluid Power in Linear Polyphase Induction Liquid Metal Pumps," Mine Safety Appliances Company, Technical Report Number 48, 24 March 1956, page 39, eq. 97.
8. Pipe and Fittings, catalog of the Ladish Co., Cudahy, Wisconsin (or a similar publication of standard stainless steel pipe).
9. A. M. Dudley, Connecting Induction Motors (3rd edition, McGraw-Hill Book Co., 1936) pp 11-21.
10. D. A. Watt "A Study in Design of Travelling Field Electromagnetic Pumps for Liquid Metals," AERE ED/R 1696, 12 June 1955, page 10.
11. D. A. Watt "Design of Travelling Field Induction Pumps for Liquid Metals" AERE R/M 144, September 1957, page 1.
12. R. S. Baker, "Calculation of Development Pressure and Fluid Power in Linear Polyphase Induction Liquid Metal Pumps," Technical Report number 48, MSA, 24 March 1956.
13. J. F. Asti "Development of Electromagnetic Pumps for Liquid Metals," Final report number 43-109 Allis-Chalmers Mfg. CO., 30 June 1952, Appendix F, page 40.
14. MIT Electrical Engineering Dept. Staff, Magnetic Circuits and Transformers. (John Wiley and Sons, 1943) page 90, eq. 39.
15. F. W. Carter "Air Gap Induction," Electrical World & Engineer, 38 pages 884-888 (1901)
16. Instruction Manual IM24, "Instructions-Analog Field Plotter", published by Sunshine Scientific Instrument, 1810 Grant Avenue, Philadelphia 15, Pa. (Atomics International Manual SGR 90242).

TECHNICAL DATA RECORD

PROGRAM SRE

Engineering Improve-
PROJECT ments in the SRE

TDR NO. 3295

DATE 20 December 1958

PAGE 13 OF 32

17. Magnet Wire - Publication number C-79-12 A, (Anaconda Wire & Cable Co. 25 Broadway, New York, New York).
18. R. M. Baker "Transverse Flux Induction Heating," AIEE Transactions, 1950, Vol. 69, eq. (37).
19. Atomics International Drawing 9693-41977.
20. Atomics International Drawing 9693-41973.

FIGURE 1

TECHNICAL DATA RECORD

Engineering Improve-
ments in the SRE

PROGRAM SRE

PROJECT

SECTION A-A
FIGURE 1

030 016

ERS

COILS IN PLACE IN LAMINATIONS

COIL CONNECTION DIAGRAM

FIGURE 2

SECTION A-A OF FIGURE 2

SECTION OF
A COIL WOUND
WITH ROUND
CONDUCTORS.

FIGURE 3

SECTION OF
A COIL WOUND
WITH A RECTAN-
GULAR CONDUCTOR.

FIGURE 4 030 019

SCHEMATIC DIAGRAM
ELECTRICAL WIRING

030 020

ERS

TEST LOOP
SCHEMATIC DRAWING

030 021

ERS

PREPARED BY: B.W.A.	NORTH AMERICAN AVIATION, INC. PRESSURE vs. FLOW PUMP VOLTAGE = 200 V.	PAGE NO. 21 OF 32
CHECKED BY: <i>SB</i>		REPORT NO. 3295
DATE: 20 November 1958		MODEL NO.

VARIATION OF PRESSURE & FLOW
OBTAINED BY THROTTLING
AT FIXED PUMP VOLTAGE

PREPARED BY: B.W.A.	NORTH AMERICAN AVIATION, INC. POWER INPUT vs. PUMP VOLTS VALVE WIDE OPEN	PAGE NO. 22 OF 32
CHECKED BY: RSB		REPORT NO. 3295
DATE: 20 November 1958		MODEL NO.

PREPARED BY: ERS	PUMP CURRENT VS. PUMP VOLTS VALVE WIDE OPEN	PAGE NO. 23 OF 32
CHECKED BY: RSB		REPORT NO. 3295
DATE: 20 NOV. 1953		MODEL NO.

PAGE NO. 24 OF 32

REPORT NO. 3295

NOBEL NO.

PREPARED BY: HWL	ELECTRICAL RESISTIVITY OF LIQUID SODIUM	PAGE NO. 25 OF 32
CHECKED BY: R.S.B.		REPORT NO. 3295
DATE: 12-31-58	Ref: Liquid Metals Handbook 1 July 1955 Pages 28 & 29	MODEL NO.

PREPARED BY: B.W.A.

NORTH AMERICAN AVIATION, INC.

PAGE NO 27 OF 32

CHECKED BY: RJB

POWERSTAT CURRENT vs.
PUMP VOLTS

REPORT NO. 3295

DATE: 20 November 1958

MODEL NO.

VALVE WIDE OPEN

030 028

PREPARED BY: <i>B.W.A.</i>	NORTH AMERICAN AVIATION, INC. PRESSURE VS. PUMP VOLTS	PAGE NO. 28 OF 32
CHECKED BY: <i>R.S.B.</i>		REPORT NO. 3295
DATE: 20 November 1958		MODEL NO.

PREPARED BY: B.W.A.

NORTH AMERICAN AVIATION, INC.

PAGE NO 29 OF 32

CHECKED BY: RJB

FLOW VS. PUMP VOLTS

REPORT NO 3295

DATE: 20 November 1958

MODEL NO.

PREPARED BY: B.W.A.

NORTH AMERICAN AVIATION, INC.

PAGE NO 30 OF 32

CHECKED BY: R.S.B.

NO LOAD LOSSES VS.
PUMP VOLTS

REPORT NO. 3295

DATE: 20 November 1958

MODEL NO.

PREPARED BY: B.W.A.

1 ~~1~~ *R 80*

CHECKED BY:

DATE: 20 November 1958

NORTH AMERICAN AVIATION, INC.

AIR GAP FLUX (GAUSSMETER)
VS. PUMP VOLTS

PAGE NO 31 OF 32

REPORT NO. 3295

MODEL NO

PREPARED BY: B.W.A.	NORTH AMERICAN AVIATION, INC. AIR GAP FLUX PER POLE (PICKUP COIL) VS. PUMP VOLTS	PAGE NO. 32 OF 32
CHECKED BY: RSB		REPORT NO. 3295
DATE: 20 November 1958		MODEL NO.

AIR-GAP FLUX PER POLE
FROM PICKUP COIL VOLTAGE
(WATTS $\times 10^5$)

650 033