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COMPONENT IMPROVEMENT PROGRAM TASK 83-01 36E133 AIR
TURBINE STARTER(U) ALLIED BENDIX AEROSPACE UTICA NY
FLUID POWER DIV L WILLIAMS FEB 86 8728-3173U

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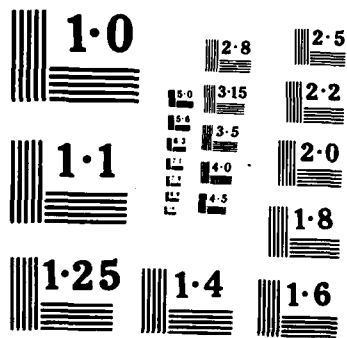
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Bendix Fluid Power Division

Report No. 8720-3173U

Component Improvement Program
Task 83-01
36E133 Air Turbine Starter

February, 1986

Contract No. N00019-80-G-0607-XU04

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 **ALLIED** Bendix
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Report No. 8720-3173U

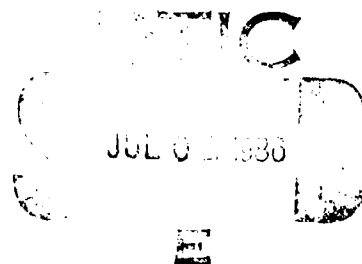
Component Improvement Program
Task 83-01
36E133 Air Turbine Starter

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Contract No. N00019-80-G-0607-XU04

Prepared for:
Department of the Navy
Naval Air Systems Command
Washington, DC

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SCOPE

This report describes the analysis and results of the first half of Task 83-01, "Solid State Electronic Cutout Switch for the 36E123 (A-29) and 36E133 (A-28) Starters", conducted in accordance with NAVAIR Contract No. N00019-80-G-0607-XU04.

All analysis and initial phase testing was performed by the Engineering Department of Allied Signal Corporation, Bendix Fluid Power Division at Utica, New York.

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1.0 INTRODUCTION

The subject air turbine starters (ATS), Bendix Type 36E133 ATS and Type 36E123 ATS were designed to comply with MIL-S-19557, 8 and 9, respectively. The automatic cutoff control for both starters, as permitted by Paragraph 3.5.7 of the aforementioned specification, was designed to sense the speed of the starter's output drive. The existing control is a fly-weight type governor which acts to open an electrical switch at the predetermined cutout speed.

While the device has some definite advantages, field service has demonstrated that they are overridden by the following:

- ° The location of the governor (buried in the front end of the starter) makes it very difficult to service in the field.
- ° The mechanical elements are negatively influenced by the vibrational environment of the starter and engine.
- ° The electrical leads, which must be snaked through "tortuous" paths and small holes from the external connector to the switch, has caused insulation to be stripped from the leads, shorting out the switch.

In the recent past, Bendix has designed and developed an electronic solid-state "cutout switch" for turbine starters. This totally electronic device, typically monitors starter turbine speed and acts to terminate the start cycle at the turbine equivalent to the specified cutout speed.

These electronic devices are potted to isolate the components from environmental affects and the devices can be mounted externally of the starter to permit easy replacement, if necessary, or to put them in an environmentally favorable location.

Field experience has demonstrated that these electronic cutout switches are far superior to the mechanical devices.

The effort described herein was performed to adapt an existing, service proven, switch to the 36E133-4A starter, S/N 1501, supplied by the NAVY. The new starter configuration is a 36E133-6A (reference Figure 3).

2.0 TASK DESCRIPTION

2.1 Objective

Replace mechanical cutout switch with a solid-state electronic cutout switch to improve accuracy and reliability of the automatic start cycle termination in the S-3A and F-14A aircraft.

2.2 Work Statement

The program consisted of the following steps:

1. Evaluate feasibility of adapting a production Bendix solid state electronic switch for this application.
2. Propose design changes necessary to adopt electronic switch.
3. Prepare detail drawings of proposed switch and modified/new parts.
4. Fabricate one set of parts for test evaluation. Would include breadboard switch assembly.
5. Run development test on breadboard system.
6. Fabricate cutout switch mockup and check installation of starter on aircraft.
7. Complete design changes/detail drawings of proposed switch.

8. Fabricate final design of switch and associated hardware. (Reference Appendix 2).
9. Perform qualification test on final design. Test would include environmental tests.
10. Prepare final reports, to include ECP submittal.

3.0 ANALYSIS

The 36E133-4A starter (see Figure 1) is the latest Bendix configuration starter being used on the F-14A aircraft. This starter has a fly weight governor-type cutout (c/o) switch. (See Figure 2).

A more recently designed Bendix starter, currently in use on the KC-135R aircraft re-engined with the CFM56-2 engine, uses an electronic cutout switch on a highly similar turbine and gear reduction system. The high degree of similarity between this starter and the subject starters (36E123 ATS and 36E133 ATS) make the electronic device a prime candidate for adapting to subject units.

3.1 The following is a list of advantages of the electronic cutout switch over the mechanical/governor type cutout switch.

3.1.1 The electronic switch selected for the 36E133 starter is the same proven circuit presently being used on the Bendix KC-135R starter. Only a minor resistor change needed to be made.

3.1.2 The electronic cutout switch is bench set and tested easily and accurately before being installed in the starter. Conversely, the mechanical switch normally requires an adjustment involving a disassembly of the starter output spline. This is an unreliable, awkward and time consuming procedure.

- 3.1.3 The electronic device provides a positive, sharp and consistent break in the electrical circuit, while that provided by the mechanical governor is highly influenced by the varying friction of it's mechanical components.
- 3.1.4 Should the electronic switch need to be replaced, that can be done easily without removing the starter from the engine.

4.0 ELECTRONIC SWITCH DESCRIPTION

The function of the cutout switch is to terminate the start cycle at a predetermined speed. An electromechanical speed sensing device is used to terminate the start cycle. The device is similar to many we have and are currently providing on other military aircraft start systems. Experience has demonstrated that the electronic devices are more reliable than the mechanical, flightweight devices.

The device consists of the following major elements:

- ° An electric relay - aircraft power is connected to the contacts only. The relay coil is powered by a small fixed stator coil generator in the starter.
- ° A single pole, magnet-fastened to the starter turbine shaft, rotated in the generator stator coil.
- ° A small electronic package - also powered by the generator, encapsulated in a potting compound and mounted in a small metal box, fastened to the starter gear housing. (See Figures 3, 4 and 5).

In operation, airframe power is applied to the starter control valve through the normally closed contacts of the relay. This arrangement permits the use of existing airframe wiring.

The small generator incorporated in the starter manifold produces an electric output in terms of power and frequency that is a direct function of turbine rotative speed and is more than ample to power the circuit and relay.

The output of the generator is directed to the electronic package through a short length of shielded cable furnished with the starter.

The output of the generator:

- ° Powers the electronic circuit in which the instantaneous turbine speed in terms of frequency is compared to a frequency equivalent to starter cutout speed.
- ° Powers the coil of the relay (normally de-energized - see Figure 6) when the electronic circuit switches it on at cutout speed.

Essentially, a part of the circuit develops a fixed pulse signal, whose frequency is equivalent to starter cutout speed relative to the starter turbine. This signal is compared to the varying frequency equivalent to the instantaneous turbine speed.

When that signal from the turbine is equal to, or less than that of the fixed pulse generator, the relay is switched on, opening the airframe circuit to the starter valve and terminating the start cycle. The relay will remain "on" with its contacts open for a short period as the starter turbine begins to coast down in speed. Latching circuits typically provided in the airframe prevent inadvertent recycling of the starter.

5.0 CONCLUSIONS

- 5.1 The existing electronic circuit can be used for the 36E133/123 with only a minor resistor change to accommodate the subject unit's cutout speed.
- 5.1 Breadboard testing was successfully completed and satisfactorily demonstrated feasibility. —
- 5.3 The suitability of the configuration selected was demonstrated by a successful mock-up on F-14A at Oceana Naval Air Station.
- 5.4 A failure, which occurred at about the eight hundredth cycle of a two thousand start cycle test, was not the fault of the cutout switch. The switch was found to be in excellent condition.
- 5.5 The electronic switch is available to complete the endurance evaluation program.

6.0 RECOMMENDATIONS

- 6.1 Accept that steps 1 through 8 of the work statement (reference para. 2.2, pg. 3) have been satisfactorily completed.
- 6.2 Complete the remaining defined test program , using the starter that will be employed in accomplishing the objectives of TASK 85-01, Bearing Improvement, as the test vehicle. .

APPENDIX 1

FIGURES 1 through 6

2497432
PART OF 248-2
LOT PART OF 306130-9A

645011H54 12 REQ

MS20825C20-12 5 REQ

2494278 *

MS20825C20-4 2 REQ

645094G41DY 4 REQ

2494422

2491818

645274-4 2 REQ

SOLDER WIRES PER PS32

USING ECL 9 GRADE 16

2 REQ

6 REQ

2 REQ

3 REQ

4 REQ

645001RR252

2494389

2487641

2487628

6455536

2487652

2487645

2487650

2487389 ⊗

MS16395-26 3 REQ
SEE NOTE "B"

645001RR034

2487440

645001RR032

2490518

645001RR017

2487122

6453985820
APPLY LOCTITE PR M R T
RETAINING COMPOUND #40

645536

2487438 10R 2 REQ
PER ECL C1275

645537

249437 ⊗
645001RR161

249666

2494397

2494397

2494397

645001RR000

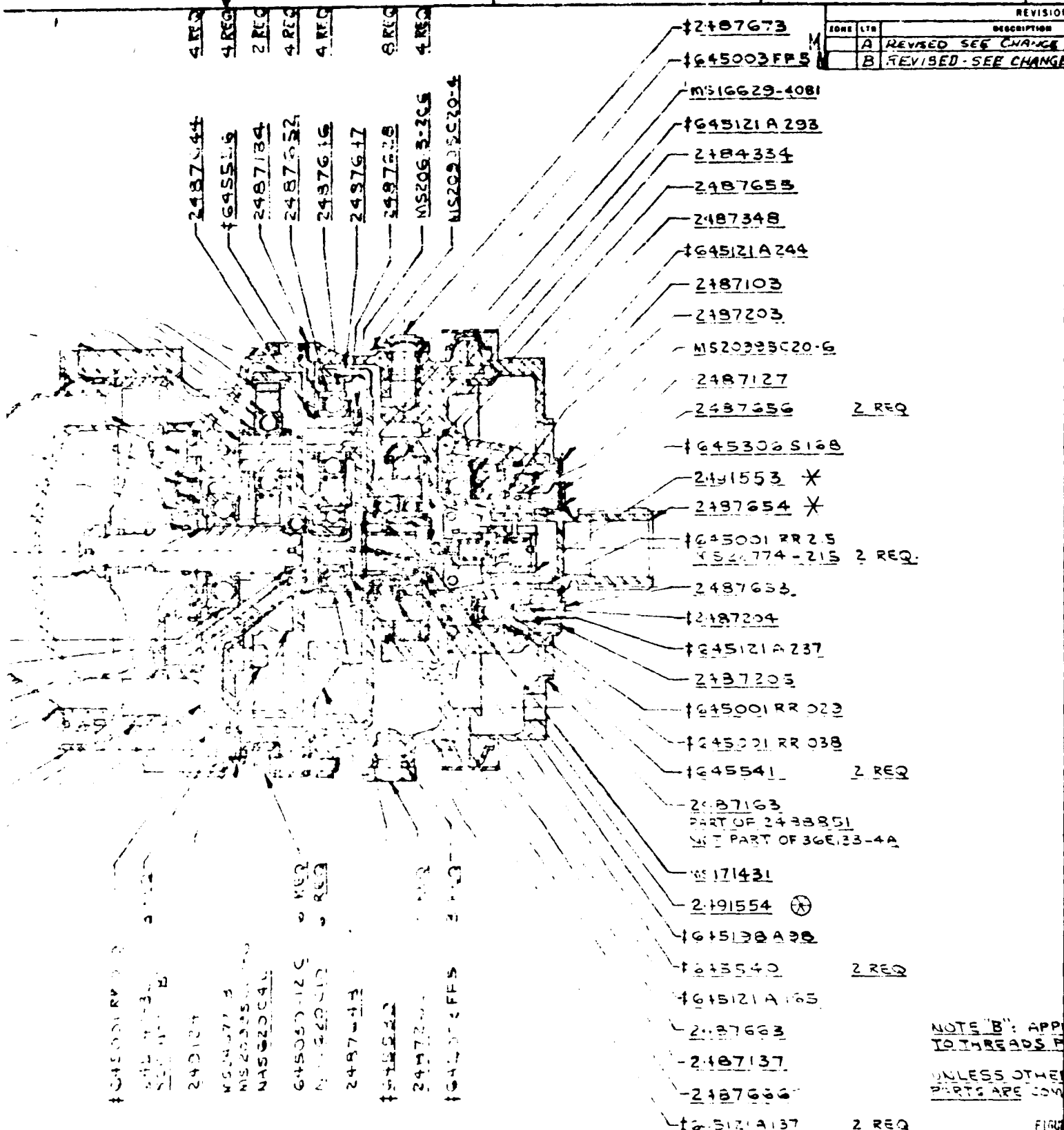
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2494397

2494397

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* INDICATES SUB-ASSEMBLY WITH
⊗ INDICATES SUB-ASSEMBLY OF
+ VENDOR ITEM; SEE SOURCE
CONTROL ENG. FOR PRODUCTION



REVISION	
EDR	DESCRIPTION
A	REVISED SEE CHANGE
B	REVISED-SEE CHANGE

SUB-ASSEMBLY WITH REPLACEABLE COMPONENTS
 SUB-ASSEMBLY OF PERMANENT CONSTRUCTION
 GIVE SEE SOURCE CONTROL OR SPECIFICATION ON
 1. FOR REQUIREMENT OR PART NUMBER

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES RELATIONSHIPS MUST BE HELD AS SHOWN STANDARDS FOR BENDIS SPEC. 18-1000 AND MIL-D-1000		CONTRACT NO. DE J. E. 5 JAN 78		The Bendix Corp. Fluid Power Div. Utica, New York	
MATERIAL SEE DETAILS		FINISH SEE DETAILS		STARTER AIR TURBINE	
HEAT TREAT SEE DETAILS		DESIGN ACTIVITY APPROVAL		SIZE CODE IDENT NO. D 99551	
APPLICATION		SCALE 1/1		REP. LD.	

2487673

1645003FP5

MS16629-4081

1645121A293

2484334

2487655

2487348

1645121A244

2487103

2487203

MS20223C20-6

2487127

2487656 2 REQ

1645300S168

2491553 *

2487654 *

1645001RR25

1645001RR25 2 REQ

2487653

2487004

1645121A237

2487205

1645001RR002

1645001RR033

1645541 2 REQ

2487163

2487163

2487163

MS171431

2491554 ①

1645300A00

1645540 2 REQ

1645121A165

2487663

2487137

2487666

1645121A137 2 REQ

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVAL
A		REVISED SEE CHANGE ORDER	11/1	10086
B		REVISED SEE CHANGE ORDER	11/1	20075

NOTE "B": APPLY ANTI SEIZE COMPOUND TO THREADS PER JAN-A-469

UNLESS OTHERWISE SPECIFIED ALL PARTS ARE COMPONENTS OF 36E133-4A

FIGURE 1

36E133-4QA

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES MUST BE HELD AS
FOLLOWS FOR SURFACE FINISH: 125-1000
0.0001-0.0005

SEE DETAILS

SEE DETAILS

SEE DETAILS

CONTRACT NO.
DE J. E. 3 JAN 78

DESIGN ACTIVITY APPROVAL

DESIGN ACTIVITY APPROVAL

DESIGN ACTIVITY APPROVAL

The Bendix Corporation
Fluid Power Division
Utica, New York

STARTER ASSEMBLY,
AIR TURBINE

SIZE CODE IDENT NO

D 99551

36E133-4QA

SCALE 1/1 REF ID: A927 SHEET 1 OF 1

<u>2487107</u>	<u>16 REQ.</u>	FLYWEIGHT, GOVERNOR
<u>2491536</u>		INSULATOR & PLUNGER COMPLETE
<u>2489620</u>		SPRING, GOVERNOR
<u>2487699</u>		NUT, ADJUSTING - GOVERNOR
<u>2487701</u>		HOUSING, GOVERNOR

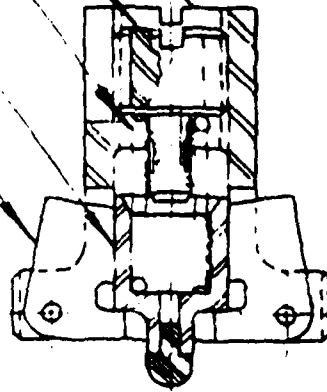
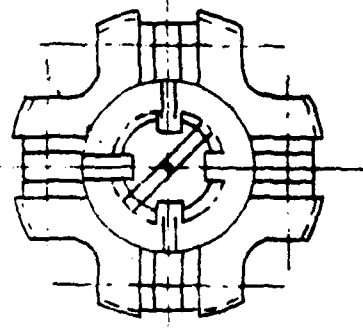
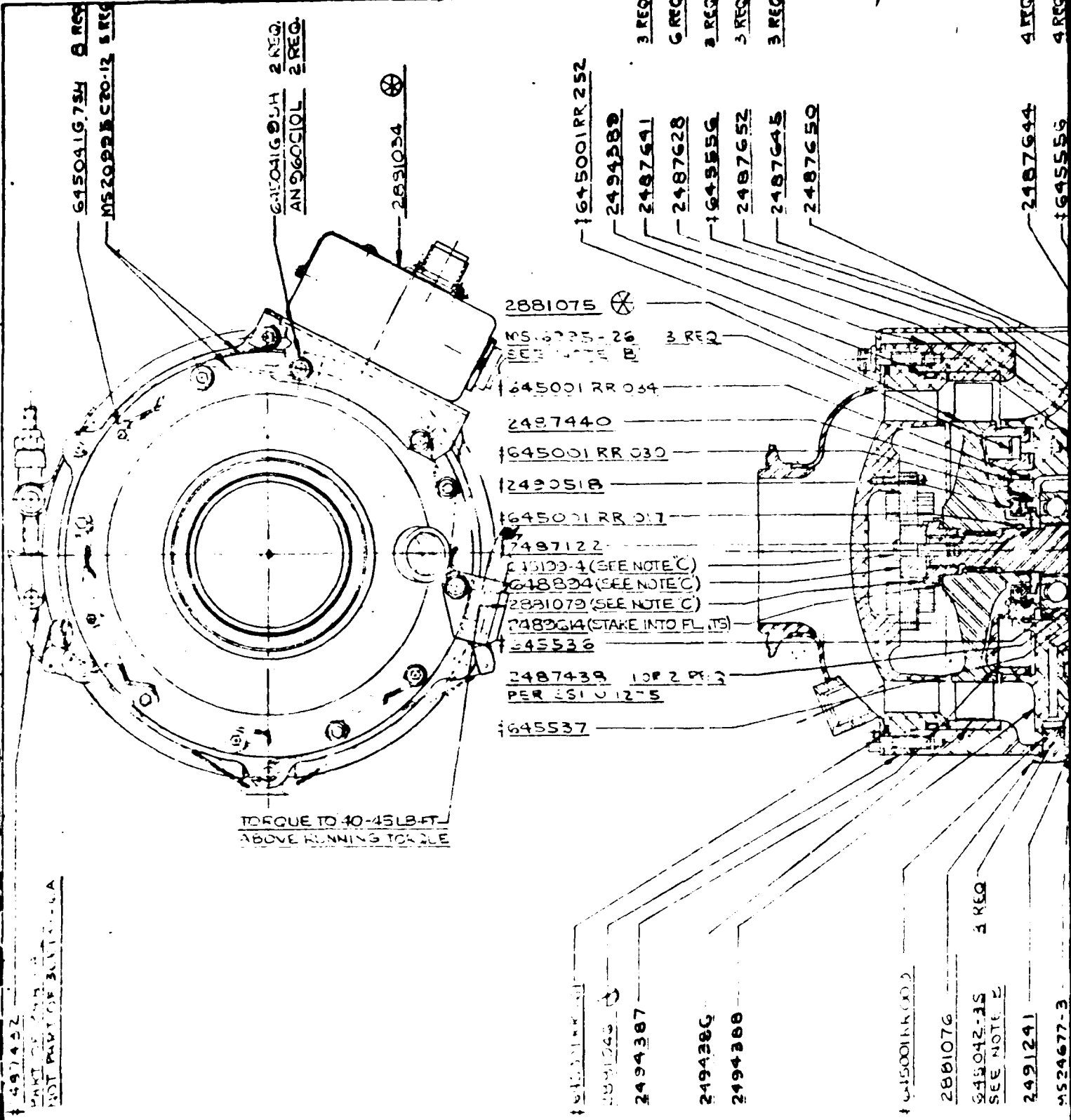


Figure 2 - 36E133-4A Governor
Type.Cutout Switch
P/N 2491553 Assembly

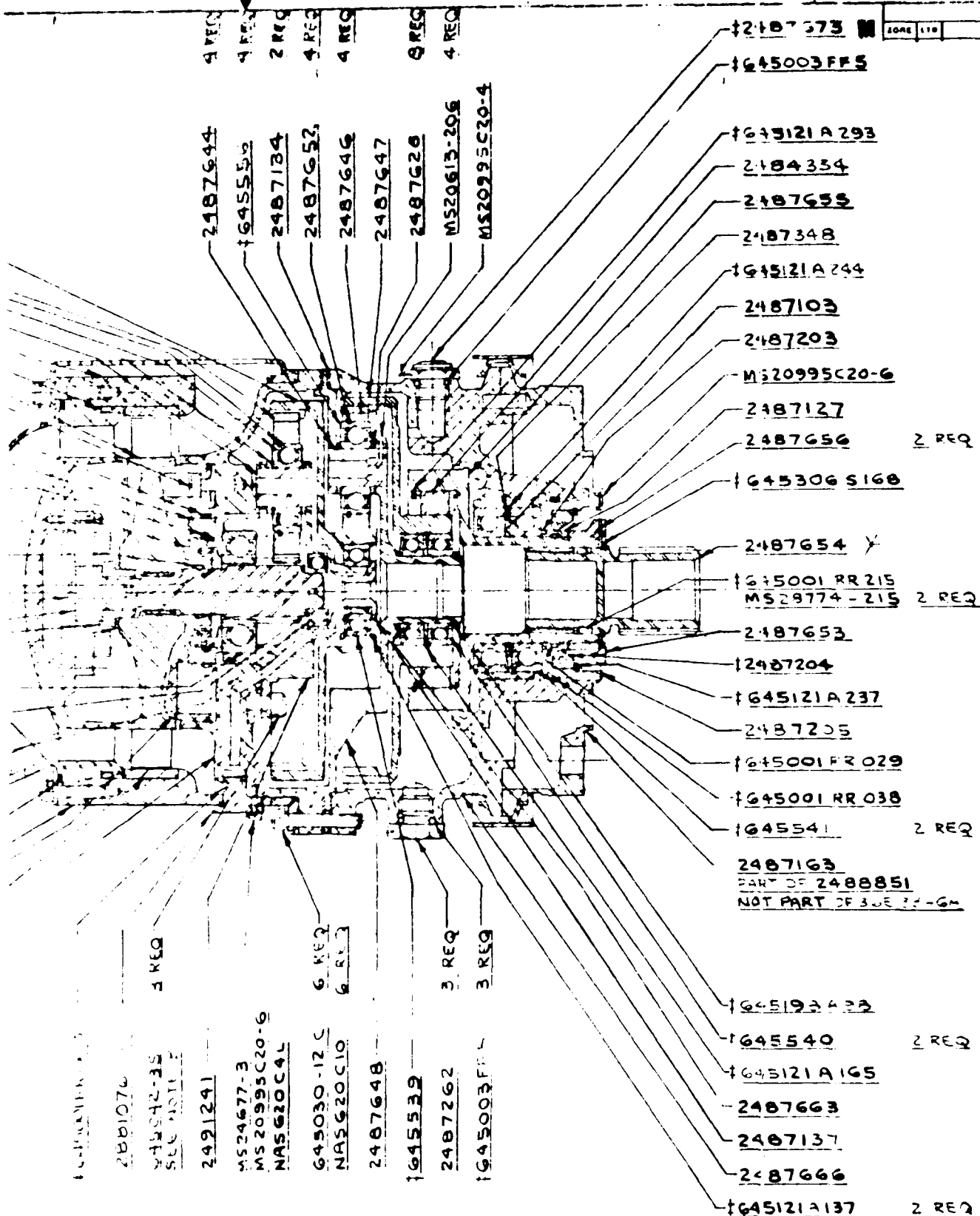


TORQUE TO 40-45 LB-FT
ABOVE RUNNING TORQUE

2494387
PART OF 2494387
NOT PART OF 2494387

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X INDICATES SUB-ASSEMBLY WITH PER
X INDICATES SUB-ASSEMBLY OF PER
+ VENDOR ITEM; SEE SOURCE CONTROL
CONTROL DWG. FOR PROCUREMENT



NOTE 'C'
 CLEAN PARTS THO
 PRIMER T. TO M
 TO DRY 3 TO 5 M
 TO DRY 242 TO
 REVEICLE NAME
 REQUIRED. CLEA
 FROM PARTS A
 AMBIENT TEMPE
 100RS MIN. BE

NOTE 'B': APPL
 TO THREADS P

SUB-ASSEMBLY WITH REPLACABLE COMPONENTS
 SUB-ASSEMBLY OF PERMANENT CONSTRUCTION
 IM. SEE SOURCE CONTROL OR SPECIFICATION
 G. FOR PROCUREMENT OF PART NUMBER

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UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES RELATIONSHIPS MUST BE HELD AS SHOWN TOLERANCES PER BENDIS SPEC IN UN93 AND MIL D 100B		CONTRACT NO.		The Bendis Corp. Plant - New York Office - New York	
MATERIAL SEE DETAILS		DR. C.W. 10 JAN 55		STARTER AIR TURB	
FINISH SEE DETAILS		CR 2.5mm 85415			
HEAT TREAT SEE DETAILS		NET 5.2G 1245.6			
APPLICATION		DESIGN ACTIVITY APPROVAL		SIZE CODE BODY 08	
NEXT ASSY USED ON		OTHER ACTIVITY APPROVAL		D. 99551	
				SCALE 1/1	

REVISIONS

2487673

DATE LTR

DESCRIPTION

DATE

APPROVAL

645003FF5

645121A293

2484334

2487655

2487348

645121A244

2487103

2487203

MS20995C20-6

2487127

2487656 2 REQ

645306S168

2487654 X

645001RR215

MS29774-215 2 REQ

2487653

2487204

645121A237

2487205

645001RR029

645001RR038

645541 2 REQ

2487163

PART OF 2488851

NOT PART OF 30E 17-6H

NOTE C

CLEAN PARTS THOROUGHLY. APPLY LOCTITE PRIMER TO MATING SURFACES ALLOW TO DRY 3 TO 5 MINUTES. APPLY LOCTITE TO MATING SURFACES. ASSEMBLE IMMEDIATELY. Wipe off EXCESS LOCTITE FROM PARTS ALLOW TO DRY FROM AMBIENT TEMPERATURE FOR FOUR (4) HOURS MIN. BEFORE USE.

645192A22

645540 2 REQ

645121A165

2487663

2487137

2487666

645121A137 2 REQ

NOTE B: APPLY ANTI SEIZE COMPOUND TO THREADS PER JAN-A-663

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES MUST BE HELD AS
SHOWN
ANALYZED PER BENDIS SPEC. ON JUNE
13 1968

SEE DETAILS

SEE DETAILS

SEE DETAILS

CONTRACT NO.
BY CW. 10 JAN 68
TE
CA 2 04m 02.15
DET 326 10.5 h
FANC 20 5 22.15
ENG 214 22.20 15
DESIGN ACTIVITY APPROVAL

OTHER ACTIVITY APPROVAL

The Bendix Corporation
Fluid Power Division
Utica, New York

STARTER ASSEMBLY,
AIR TURBINE

FIGURE 3

SIZE 1/1

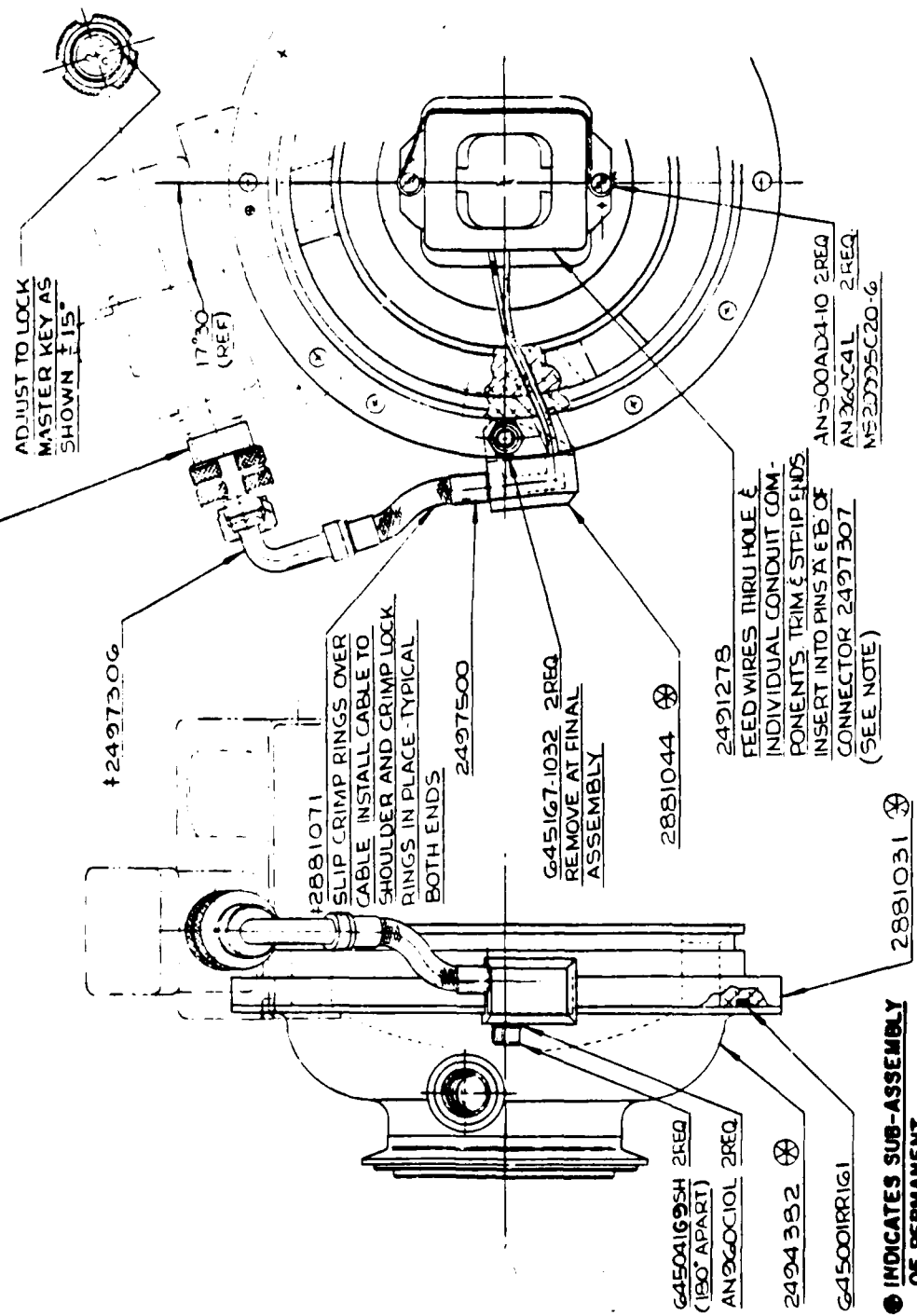
D 99551

36E133-6QA

SCALE 1/1

SHEET

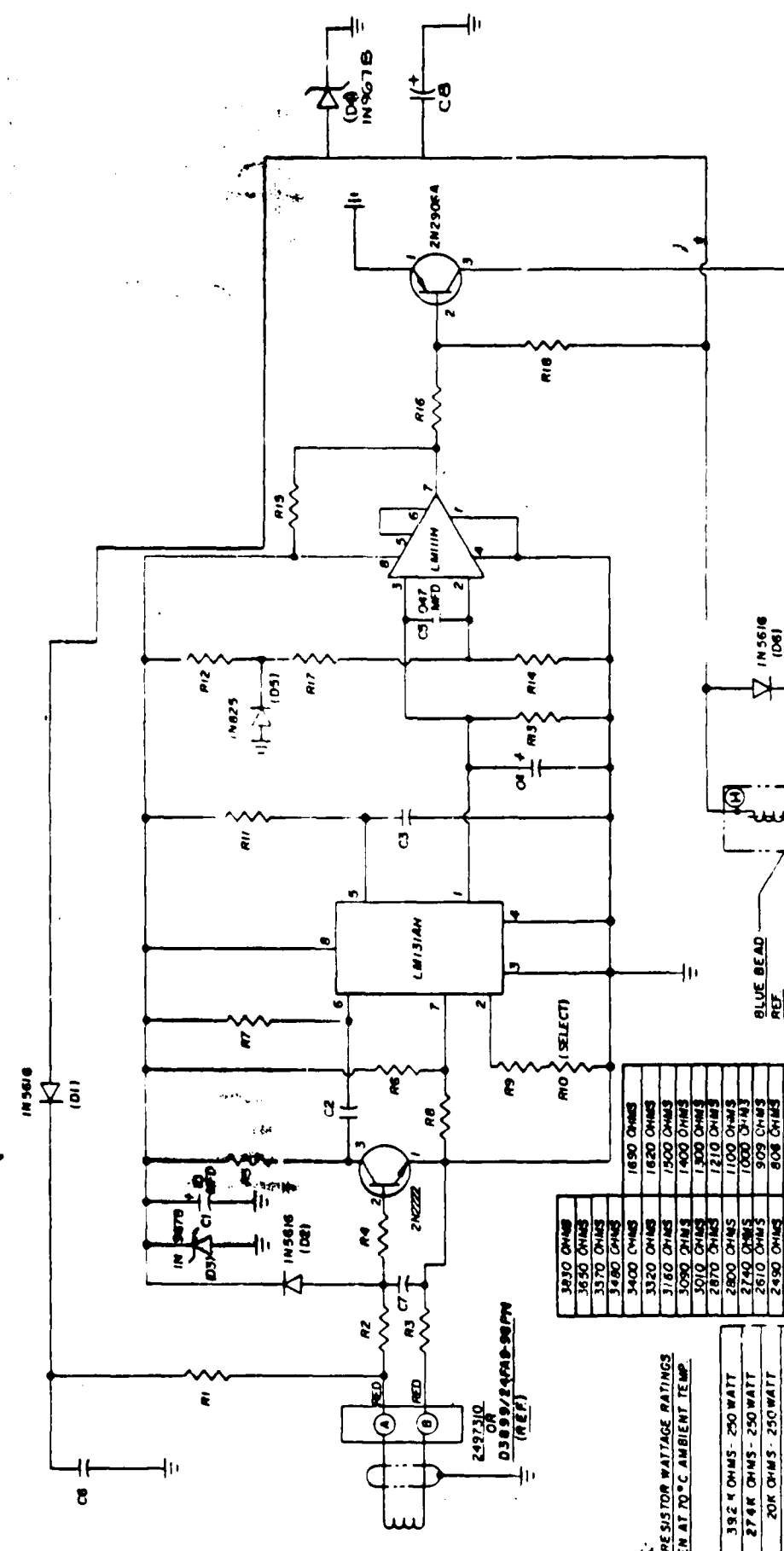
FORM	LTB	DESCRIPTION	DATE	APPROVAL
A	64504	64504H9SH	1 MAY 64	10753404



NOTE.
PERFORM CONTINUITY CHECK
ACROSS PINS 'A' & 'B' AND EACH
PIN TO GROUND TO INSURE
AGAINST FRAY WIRES OR INCORRECT
WIRING.

GENERATOR WIRES TO BE TWISTED
APPROX. 190° PER INCH. INSTALLED.

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THIS IS A HARDNESS CRITICAL PART. ALL CHANGES ANNOTATED OR NOT ON THE DRAWING OR PARTS LIST MUST BE EVALUATED FOR HARDNESS IMPACT.

RELAY SHOWN IN UNENERGIZED STATE (LETTERS IN CIRCLES FOR REFERENCE TO PIN 2497524)

The Bendix Corporation Fluid Power Division Utica, New York		FIGURE 6	
DR	C.W.	12 DEC 64	34
RE	CE	5047	514425
REV	SCG	303.85	5
DATE	28 JAN 65	28 JAN 65	55
DESIGN ACTIVITY APPROVAL		OTHER ACTIVITY APPROVAL	
SCALE		C 99551	
SHEET		2881044	
2881044		REF 2497520	

RESISTANCE		CAPACITANCE	
NO.	RESISTANCE	NO.	CAPACITANCE
18	39.2 K OHMS - 250 WATT	8	3.0 MFD
17	27.4 K OHMS - 250 WATT	7	1500 PFD
16	20 K OHMS - 250 WATT	6	1500 PFD
15	10 K OHMS - 250 WATT	5	0.47 MFD
14	27.4 K OHMS - 250 WATT	4	1.0 MFD
13	100 K OHMS - 250 WATT	3	0.1 MFD
12	10 K OHMS - 250 WATT	2	330 PFD
11	39.2 K OHMS - 250 WATT	1	10.0 MFD
10	SELECT - SEE TABLE		
9	28.7 K OHMS - 250 WATT		
8	20 K OHMS - 250 WATT		
7	10 K OHMS - 250 WATT		
6	10 K OHMS - 250 WATT		
5	10 K OHMS - 250 WATT		
4	20 K OHMS - 250 WATT		
3	400 OHMS - 2.5 WATT		
2	400 OHMS - 1.2 WATT		
1	400 OHMS - 2.5 WATT		

NOTE:
ALL RESISTOR WATTAGE RATINGS
TAKEN AT 70°C AMBIENT TEMP.

NO.	RESISTANCE	NO.	CAPACITANCE
18	39.2 K OHMS - 250 WATT	8	3.0 MFD
17	27.4 K OHMS - 250 WATT	7	1500 PFD
16	20 K OHMS - 250 WATT	6	1500 PFD
15	10 K OHMS - 250 WATT	5	0.47 MFD
14	27.4 K OHMS - 250 WATT	4	1.0 MFD
13	100 K OHMS - 250 WATT	3	0.1 MFD
12	10 K OHMS - 250 WATT	2	330 PFD
11	39.2 K OHMS - 250 WATT	1	10.0 MFD
10	SELECT - SEE TABLE		
9	28.7 K OHMS - 250 WATT		
8	20 K OHMS - 250 WATT		
7	10 K OHMS - 250 WATT		
6	10 K OHMS - 250 WATT		
5	10 K OHMS - 250 WATT		
4	20 K OHMS - 250 WATT		
3	400 OHMS - 2.5 WATT		
2	400 OHMS - 1.2 WATT		
1	400 OHMS - 2.5 WATT		

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APPENDIX 2

PARTS LISTS

Reworked Parts for 36E133-6A ATS

<u>Qty.</u>	<u>P/N</u>	<u>Description</u>
1	2881074	Shaft, Rotor (reworked from 2487094)
1	2881073	Rotor, Turbine (reworked from 2487588)
1	2881045	Board Ass'y., Cutoff Switch (reworked from 36E153, P/N 2497332 Board)
1	2496167	Flange, Stator (changed for -6A)

New Parts for 36E133-6A ATS

1	2881079	Nut, Rotor
1	648894	Rotor, Generator (used on 36E153 ATS)
1	645199-4	Screw, Button HD (used on 36E153 ATS)
1	2881030	Stator, Air Turbine
1	2491278	Generator, Cutoff Switch (used on 36E153 ATS)
2	AN500 AD4-10	Screw, Fill HD
2	AN960C4L	Washer, Flat
1	MS20995C20-6	Wire, Tie
1	2881044	Adapter, Conduit
1	2881071	Shield, Braided Wire
1	2497500	Ring, Crimp
1	2497306	Elbow, Connector
1	2497307	Plug, Electrical Connector
2	645041H9SH	Screw, Soc. HD. CAP
2	AN960C10L	Washer, Flat
2	645167-1032	Nut, Hex
1	2881076	Plug, Housing
8	645041H7SH	Screw
2	645041H9SH	Screw, Soc. HD. CAP
2	MS20995C20-12	Wire, Tie
1	2881034	Box Ass'y. Speed Control
1	2881084	Data, Ident.

36E133-4A ATS Parts Replaced by New 36E133-6A

ATS Parts

<u>Qty.</u>	<u>P/N</u>	<u>Description</u>
1	2487123	Bushing, Pilot
1	645398S820	Nut, Lock, Thin
1	2491554	Contact Ass'y. Governor Type
1	2491553	Housing, Assembly, Governor
1	2496169	Stator, Air Turbine
1	MS16555-627	Pin, Dowel
1	645001RR252	Gasket, "O" Ring
1	2494378	Conduit Ass'y., Electrical Connector
1	2491818	Gasket, Electrical Connector
2	645274-4	Tubing, Shrinkable
1	2494422	Connector, Electrical
4	645094G41DY	Screw, Socket, HD. CAP
2	MS20995C20-4	Wire, Tie
1	NAS620C4L	Washer, Flat
1	MS24677-3	Screw, Socket HD. CAP
1	MS20995C20-6	Wire, Tie
1	2494477	Data, Ident. Plate (MIL Type)

END

DT/C

8-86