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B1	3-21-83	Revised per FCR No. 81-302 "AS BUILT" See Rev. B1 Revision Record	RB	DB	PJC	RSW	NK	—
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INFORMATION ONLY

2

INSTRUCTION MANUAL

FOR AUXILIARY FEED PUMP TURBINES

7749-M-36-21

REVISION RECORD

Revision B1

REMOVE	INSERT
1. ---	pg. i B1
2. Terry Steam Turbine Dwg. No. 99606C, Rev. A	Terry Steam Turbine Dwg. No. 99606C, Rev. B1
3. Terry Steam Turbine Dwg. No. 96466B, Rev. A	Terry Steam Turbine Dwg. No. 96466B, Rev. B1

FACILITY ENGINEERING

APR 11 1983

RECEIVED

INFORMATION ONLY

THE TERRY STEAM TURBINE COMPANY
DIVISION OF TERRY CORPORATION

Auxiliary Feed Pump, P14, 1-2

THIS MANUAL HAS BEEN ASSEMBLED
FOR THE EQUIPMENT LISTED BELOW:

PURCHASER Byron Jackson Pump Div.	
ORDER NO: V-147411	*DATE:* 12/6/73
JOB NO:	
ULTIMATE USER: Cleveland Electric	
LOCATION: Davis Besse	
SERVICE: B J Pump	
ITEM NO/s	
WORKS FILE NO: 37686-A-B	

TYPE		*SERIAL NO: TURBINE*	*SERIAL NO: GEAR*	*ITEM NO:*	*BHP*	*RPM*
Turbine	*Gear*					
GS-2		37686-A			800	3600
GS-2		37686-B			800	3600

NOTICE

GITP. Rev. 0, 72

INFORMATION ONLY

CAUTION NOTICE

This turbine has been designed to provide safe and reliable service within the designed specifications. It is a pressure containing piece of rotating machinery; therefore, good judgement and proper safety practices to avoid damage to the equipment and surroundings and serious or painful injuries, must be exercised by responsible and qualified personnel.

The responsibility for correct operation, maintenance, and training of personnel is that of the owner but, the following "DO NOT" and "DO" items are given.

DO NOT! . . . .

1. Attempt to operate if installation is not correct and/or pre-operation (static) safety and control features have not been checked and verified.
2. Attempt to operate until you have a thorough knowledge of the steam supply and exhaust system, its associated valves and drain system and the correct procedure for warming through and draining the system before starting the turbine.
3. Attempt to operate until you have a thorough knowledge of the function and operation of the turbine control system, lubrication system, turbine drain and gland seal systems, safety devices and emergency operational procedures.
4. Attempt to operate, adjust, disassemble the turbine or its associated equipment until you have a thorough knowledge of the manufacturers instructions.
5. Wear neckties or loose clothing when standing near couplings or any rotating parts.
6. Remove any inspection covers or guards when the unit is in operation.
7. Open up bearings, oil reservoirs or lube system until unit is sufficiently cooled.
8. Use the turbine casing eye bolt for lifting the turbine. Rig suitable slings for lifting.

DO! . . . .

1. Consult the manufacturer should any problems arise or are foreseeable.
2. After starting, test and verify the correct function of the overspeed device (mechanical/ electrical) before putting the unit into service. Refer to the manufacturers instructions for the correct procedure.
3. After starting and verification of overspeed device, test and verify the correct function of the governor or control system through its range before putting unit into service.
4. After starting, check and verify that the lubrication system has sufficient oil and is operating satisfactorily.
5. Avoid personal contact with the turbine casing, valve bodies, drains and steam lines. Serious burns may result. Wear protective clothing.
6. Ensure that the lifting devices used have been regularly tested and have a sufficient safety factor for the weight to be lifted. Also ensure that lifting devices are properly secured before any lifting is done.
7. Ensure all steam and exhaust lines are completely drained and isolated and all turbine drains open before attempting to work on the turbine.
8. Fit spades, blinds or blank flanges of sufficient design to withstand full line steam pressure in the inlet and exhaust lines if the turbine is to be dismantled.

GICN. Rev-0,-72

THE TERRY STEAM TURBINE COMPANY
DIVISION OF TERRY CORPORATION

INTRODUCTION

This instruction manual has been prepared for the equipment described on the title page and is intended as an aid to supplement the experience and ability of qualified personnel in the installation, operation and maintenance of rotating equipment and its associated auxiliaries and controls.

These instructions do not purport to cover all details nor to provide for every possible contingency to be met in connection with installation, operation or maintenance.

Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to The Terry Steam Turbine Company.

Please address any inquiries to the attention of the Service Manager, The Terry Steam Turbine Company, P.O. Box 1200, Hartford, Connecticut 06101.

CONSULTATION: Our Engineering Department welcomes inquiries regarding any phase of steam turbine practice, installation, operation, repairs, or changes to meet unexpected conditions.

INSPECTION: Your TERRY equipment can be expected to operate successfully for years without much special attention; however, periodic inspection of vital parts can greatly help in avoiding unscheduled shutdowns.

If you will write us fully about any trouble or unusual wear, we will be pleased to offer our help in their solution.

SERVICE: We maintain a force of trained engineers and service representatives, skilled in turbine work, who are available for installation, inspection or repair of TERRY equipment. They can be secured on reasonable notice. A charge at a daily or hourly rate while away from our Works, plus expenses, with an extra charge for overtime, is made for their services. We will be glad to supply you with our current rates for service.

The proper erection and starting of any turbine or gear is highly important. The success of a unit frequently hinges on how it is installed. We strongly urge that such work be supervised by skilled personnel thoroughly familiar with steam turbine work. Unless you have men available with proper experience and ability, it would be advisable to employ our service representatives. These men can instruct the operators in the care and handling of the units.

Many companies, especially those operating several TERRY units have our service representatives make periodic inspection to forestall trouble and to insure the best possible results. Our personnel can explain how to operate TERRY equipment to secure the greatest usefulness and economy, and the longest life.

When sending for a service representative to make repairs, be sure to give us the equipment serial number with full particulars as to what is wrong and what new parts are, or may be, needed. This will enable us to instruct our personnel for the work required. If possible, have these parts on hand.

If the trouble involves apparatus other than that of Terry manufacture, such as generators, pumps, blowers, governors, etc., we recommend that any such work be done by the manufacturer of this equipment. Our personnel are instructed that they must secure authorization from our factory before undertaking work on any apparatus not manufactured by us.

SHIPMENT - After final completion of test and inspection the oil is drained from the unit and the reservoir and sumps are cleaned. All exterior machined and exposed surfaces are coated with a rust preventative. The interior of the turbine is sprayed through all available openings with a suitable rust preventative. All tapped pipe connections are plugged and flanged pipe connections are covered with wood or metal enclosures and all exterior parts of the unit coated with shop paint or such paints and procedures specified by the buyer.

Turbines and gears are shipped mounted on skids and enclosed in open frame work crating as required by the transportation company for domestic shipments. When boxed for export, the unit is packed in a totally enclosed box.

RECEIVING SHIPMENT

Immediately upon receipt of shipment, check the items received against those shown on the packing list.

Care should be used when opening up a crate for inspection and checking for damage and shortage. Check the bottom of the crate because some parts, such as loose piping, trip and throttle valve, coupling halves, coupling guards, are attached to the bottom of the crate.

Any claims for shortages or damages suffered in transit shall be submitted by the receiver directly to the carrier and a copy of the report forwarded to The Terry Steam Turbine Company within ten (10) days after receipt.

STORAGE

On completion of receiving inspection, action must be taken to protect the equipment if it is not to be installed immediately. The unit should be kept in its crate and attached to the skid until ready to install on its foundation.

The equipment should at all times be stored in a clean, non-corrosive atmosphere and protected against loss, weather, damage and foreign materials such as dust, sand, etc.

Indoor storage where constant temperature is maintained at a level which will prevent condensation is preferred. Should preparation for additional protection be required for adverse conditions or for an extended period of time it is recommended that The Terry Steam Turbine Company be consulted.

For outdoor storage or in areas with a corrosive atmosphere, additional protection is usually necessary.

The standard preservation procedure applied by Terry is for three (3) months under indoor storage conditions.

NOTE: The purchaser shall be responsible for all expenses related to returning the unit to original factory condition including the services of a Terry engineer or service representative.

WARRANTY

Our Standard Warranty Clause is as follows:

"The machinery covered hereby is warranted against defects in design, materials and workmanship, if properly erected and maintained, for a period of one year from date of initial operation or 18 months from date of shipment, whichever is less. The Company will repair or furnish without charge, F.O.B. Works where made, any part or parts of its own manufacture which, within the warranty period, are proven to have been defective when shipped, provided the Purchaser gives the Company immediate written notice of any such alleged defect or defects. No allowance will be granted for any repairs or alterations made by the Purchaser without the Company's written consent. Equipment and accessories furnished by third parties are warranted only to the extent of the original manufacturer's warranty to the Company, but in no event to a greater extent than the Company's warranty of machinery of its own manufacture. There are no warranties which extend beyond the description on the face hereof. No affirmation or representation by the Company or by its agents or employees by words or action shall constitute a warranty. The Company's liability for damages or losses arising from breach of the warranty contained herein shall be limited to the foregoing and the Purchaser shall not be entitled to recover any incidental or consequential damages therefrom. This warranty shall be construed in accordance with the laws of the State of Connecticut."

We live up to this fully. If you are obliged to replace a part within the above guarantee period and suspect it to be defective, please return it to us. If actually defective, we desire to give you proper credit.

TERRY TURBINE DATA

OPERATING CONDITIONS

	HORSEPOWER	SPEED RPM	STEAM RATE LB/HP/HR	OPERATING SPEED RANGE R.P.M.
RATED	800	3600	41	
NORMAL				
OVERLOAD				

1st CRITICAL SPEED ________ RPM *2nd CRITICAL SPEED ________ RPM. TRIP SPEED 4500 RPM

STEAM CONDITIONS

INLET STEAM NORM. 885 PSIG 590 °FTT. MAX. INIT. ____ PSIG ____ °FTT. MIN. INIT. ____ PSIG ____ °FTT

EXHAUST STEAM NORM. 3 PSIG/[redacted] ____ °FTT. MAX. 3 PSIG/[redacted] ____ °FTT. MIN. 3 PSIG/[redacted] ____ °FTT.

STEAM RATE GUARANTEE POINT, HP 800 STEAM 885 PSIG, EXH. 243 °FTT, LB/HP/HR 41

FULL LOAD EXHAUST TEMP. 243 FTT. MAX. CASING PRESS. ____ PSIG, SENTINEL RELIEF VALVE SETTING 13 PSIG

EXTRACTION [ ] ADMISSION [ ] NON RETURN VALVE [ ] EXTRACTION FLOW CONTROLLED [ ] UNCONTROLLED [ ]

	FLOW LB/HR	PSIG	FTT
NORMAL			
MINIMUM			
MAXIMUM			

FOR RELIEF VALVE SIZING
MAX. THROTTLE FLOW LB/HR ________
AT STEAM ________ PSIG EXHAUST ________ °FTT
MAX. FLOW TO CONDENSER LB/HR @ IN Hg ________

CONSTRUCTION FEATURES

FRAME DESIGNATION TYPE GS-2 HORIZONTAL [X] VERTICAL [ ] CASING SPLIT: HORIZONTAL [X] VERTICAL [ ]

STEAM FLOW: HELICAL (SOLID WHEEL) [X] AXIAL (BLADED) [ ] NUMBER OF WHEELS 2

STAGES: PRESS. COMPOUND (RATEAU) [ ] VELOCITY COMPOUND (CURTIS) [ ] BLADES: TWO ROW [ ] THREE ROW [ ]

ROTOR CONSTRUCTION: BUILT-UP [X] SOLID [ ]

STEAM CHEST [ ] STEAM RING [ ] JETS [X] NOZZLE BLOCK [ ] REV. CHAMBERS [ ] RATEAU (NO JETS OR NOZZ.) [ ]

JETS OR NOZZLE GROUP POSITIONS. 1 [X] 2 [X] 3 [X] 4 [X] 5 [X] 6 [X] 7 [X] 8 [X] 9 [X] 10 [X] 11 [ ] 12 [ ] 13 [ ] 14 [ ]

NO. JETS/[redacted]S 10 DIAMETERS .480

NO. NOZZLE GROUPS ________ NO. IN EACH GROUP ________

HAND VALVES: LOW STEAM [ ] PART LOAD (ECON) [ ] OVERLOAD [ ] AUTO. VALVES [ ] POSITION NONE

NOTE: JETS, HAND VALVES AND NOZZLE GROUPS POSITIONS ARE NUMBERED IN A CLOCKWISE DIRECTION STARTING JUST BELOW THE CASING HORIZONTAL JOINT AT THE RIGHT HAND SIDE WHEN FACING THE STEAM RING OR STEAM CHEST FROM THE TURBINE HIGH PRESS. END.

ROTATION FACING COUPLING END: CW [ ] CCW [X] CASING SUPPORT: FOOT [X] PEDISTAL [ ] CENTERLINE [ ]

BEARINGS (ROTOR): RADIAL TYPE ________ THRUST TYPE 2 BALL DUPLEX

LUBRICATION: RING OILED [X] FORCED FEED [ ] CIRCULATING [ ] FROM: TURBINE [X] GEAR [ ] BY OTHERS [ ]

OVERSPEED TRIP: MECHANICAL [X] DISC TYPE [X] PIN TYPE [ ] ELECTRICAL [ ] HYDRAULIC [ ]

TRIP VALVE BUTTERFLY [ ] BALL [ ] TRIP AND THROTTLE [X]

TRIP AND THROTTLE VALVE: NONE [ ] OPERATE: AIR [ ] MOTOR [ ] HYDRAULIC [X] MANUAL [X]

TRIP: MECHANICAL [X] HYDRAULIC [ ] SOLENOID [ ] AIR [ ] EXH. PRESS. [ ] MANUAL [X] MANUF. GIMPEL

INTERSTAGE GLAND SEALS: CARBON [ ] LABYRINTH [ ]

END GLAND SEALS: CARBON [X] LABYRINTH [ ] No. GOVERNOR END ________ No. COUPLING END ________

GLAND SEAL SYSTEM: PRESSURE LEAK-OFF [X] VACUUM CONDENSING [ ]

TURBINE CONNECTIONS	SIZE	RATING	FLANGE FACE	POSITION
INLET	4"	900# ASA	RF	RH FACING COUPLING
EXHAUST	8"	300# ASA	FF	LH FACING COUPLING
EXTRACTION				
ADMISSION				

GOVERNOR TYPE: MECHANICAL [X] HYDRAULIC [ ] ELECTRICAL [ ] AIR HEAD [ ] NEMA CLASS D

GOVERNOR VALVES: SINGLE [X] MULTI [ ] NO ________ BUTTERFLY [ ] BY OTHERS [ ]

ACTUATION: DIRECT [ ] INDIRECT [X] REMOTE SERVO [ ] OIL RELAY [ ]

GOVERNOR MANUFACTURER WOODWARD MODEL PG-PL

COUPLING SUPPLIED BY: TERRY [ ] OTHERS [X] HIGH SPEED [ ] TYPE ________ LOW SPEED [ ] TYPE ________

BASE TYPE: BOX [ ] PLATE [ ] "I" BEAM [ ] SOLEPLATES [ ] UNDER TURBINE [ ]

UNDER TURBINE AND GEAR [ ] UNDER TURBINE AND DRIVEN EQUIPMENT [ ] [X] OTHERS

WEIGHTS AND DIMENSIONS: SEE OUTLINE DRAWING

NOTE* WHEN APPLICABLE TO ORDER. TURBINE SERIAL NO. 37686AB

INFORMATION ONLY

THE TERRY STEAM TURBINE COMPANY
LAMBERTON. RD. WINDSOR. CONNECTICUT U.S.A.

DESIGN DATA

Design Data No. ____________________
SUBJECT:

Page 1
Total Pages 1

ALLOWABLE PIPING FORCES AND MOMENTS - NEMA STANDARDS

1) The total resultant force and the total resultant moment imposed on the turbine at any connection must not exceed the following:

Inlet Size 4" (a)

Exh. Size 8" (b)

$$F = \frac{A - M}{3}$$

A inlet 2000 (c)

A exh. 4000 (d)

F = resultant force in pounds including pressure forces where unrestrained expansion joints are used at the connection.

M = resultant moment in pound-feet.

2) The combined resultants of the forces and moments on the inlet and exhaust connections resolved at the centerlines of the exhaust connection must not exceed either of the following two conditions:

A) $Fc = \frac{B - Mc}{2}$

B = 2236 (e)

Fc = Combined resultant of inlet and exhaust forces in pounds.

Mc = Combined resultant of inlet and exhaust moments and moments resulting from forces in pound-feet.

B) The components of these resultants shall not exceed:

Coordinate System

x - parallel to turbine shaft

y - vertical

z - horizontal and at right angles to turbine shaft

Fx = 447 (f)
Fy = 1118 (g)
Fz = 894 (h)
Mx = 2236 (i)
My = 1118 (j)
Mz = 1118 (k)

The above is a simplified and abbreviated version of NEMA Standards SM21 1970 and 22 1970 Section 7.06.

Revision
Addition

TURBINE TYPE GS-2 TURBINE NUMBER 37686AB

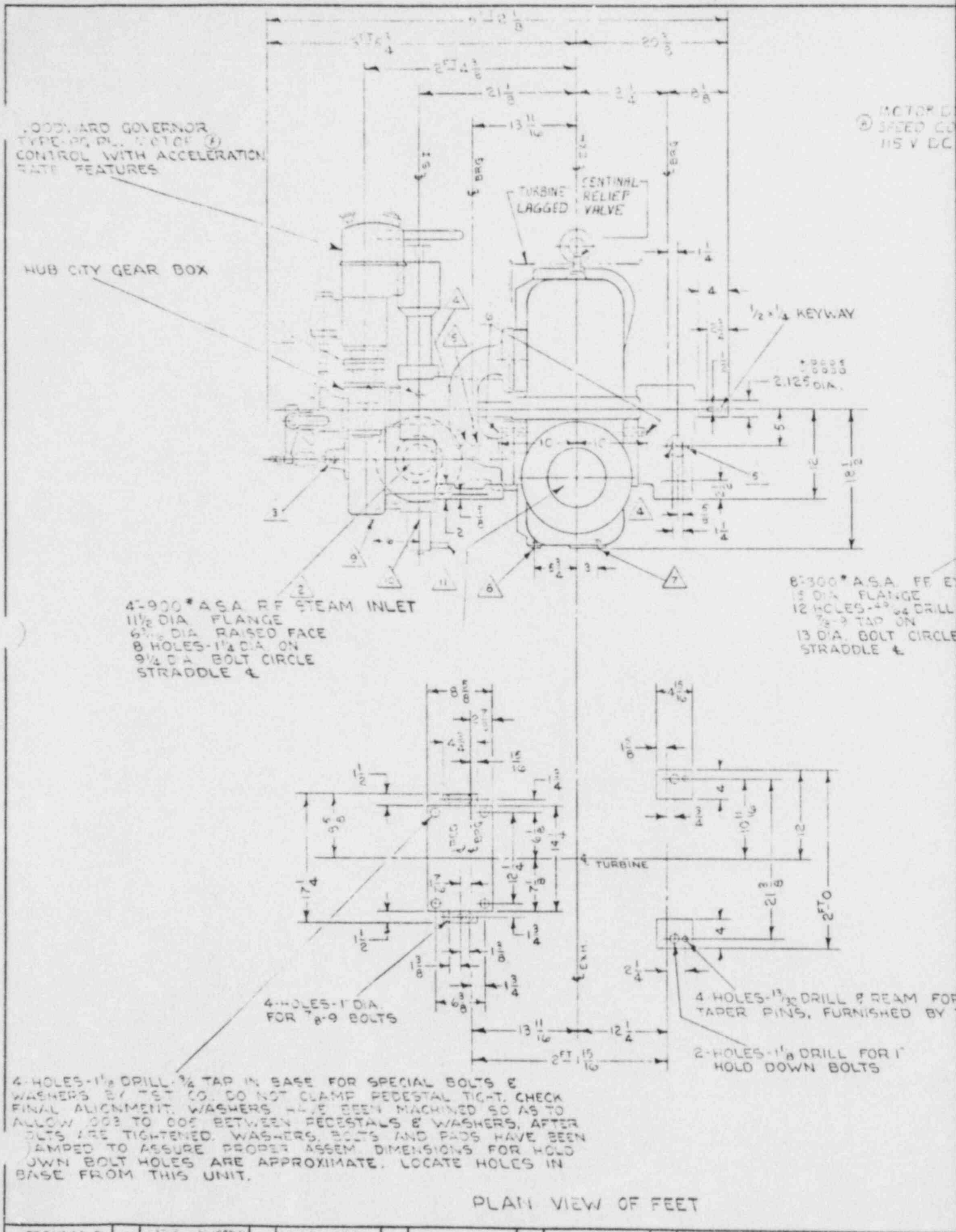
PREPARED BY R.S. Golas DATE 12/5/73

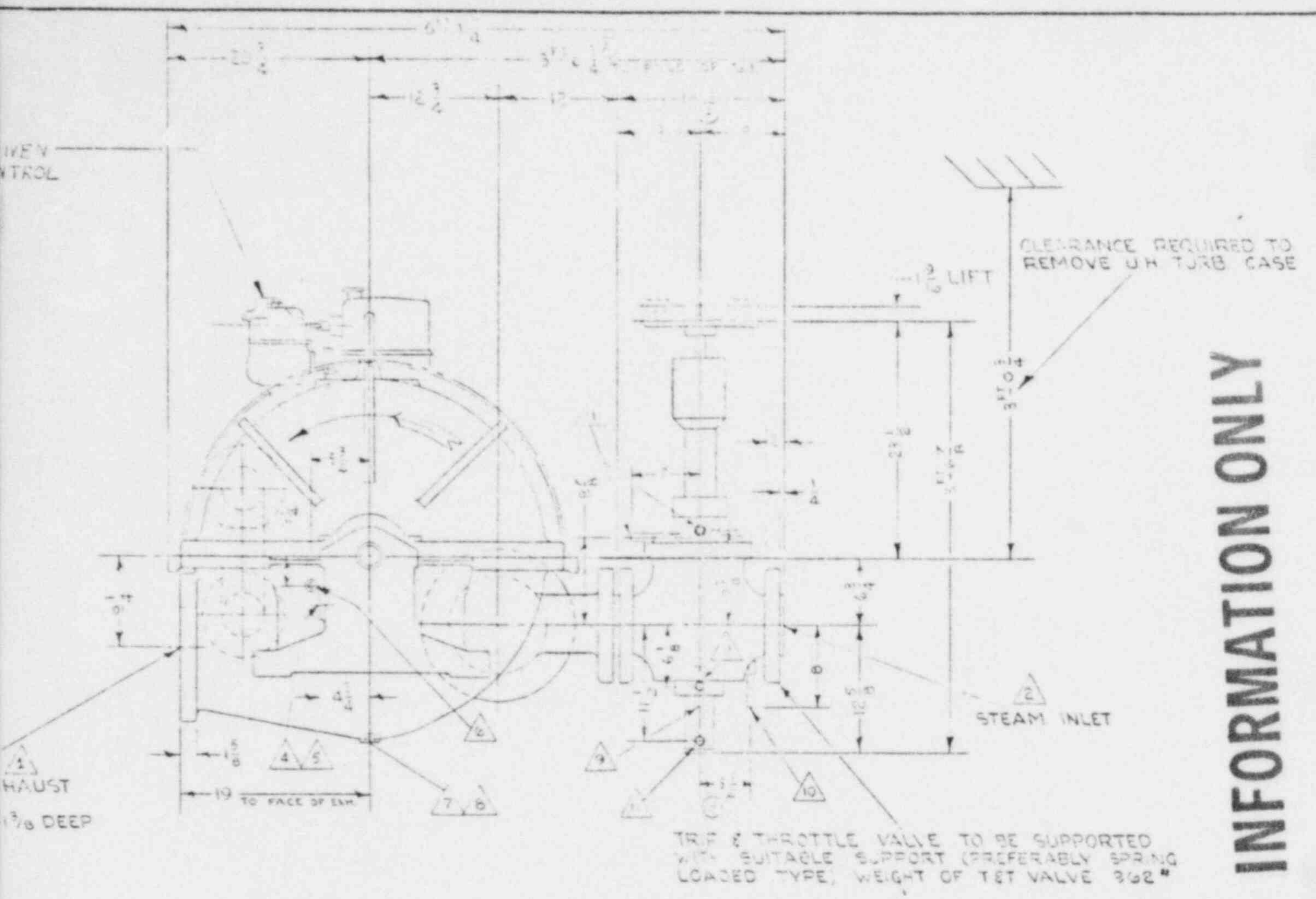
K-11954A

Prepared By: K. Wheeler	Date Issued: 5/16/72	Design Data No.
Supersedes Issue Dated: NEW		
Routing - Engin. Stds. List		Page 1 of 0

September 26, 1973 NEW PAGE SECTION 18-P-45

FORM E-162


WOODWARD GOVERNOR TYPE-PG PL. MOTOR CONTROL WITH ACCELERATION RATE FEATURES
HUB CITY GEAR BOX
TURBINE LAGGED
SENTINAL RELIEF VALVE
1/2 × 1/4 KEYWAY
2.125 DIA.
MOTOR SPEED 115 V DC
4"-900# A.S.A. R.F. STEAM INLET
11½ DIA. FLANGE
6 DIA. RAISED FACE
8 HOLES-1¼ DIA. ON
9¼ DIA. BOLT CIRCLE
STRADDLE ℄
8"-300# A.S.A. FF
15 DIA. FLANGE
12 HOLES
13 DIA. BOLT CIRCLE
STRADDLE ℄
℄ TURBINE
4-HOLES-1 DIA. FOR 7/8-9 BOLTS
4 HOLES-13/32 DRILL & REAM FOR TAPER PINS, FURNISHED BY
2-HOLES-1⅛ DRILL FOR 1" HOLD DOWN BOLTS
4-HOLES-1⅛ DRILL-¾ TAP IN BASE FOR SPECIAL BOLTS & WASHERS BY T&T CO. DO NOT CLAMP PEDESTAL TIGHT. CHECK FINAL ALIGNMENT. WASHERS HAVE BEEN MACHINED SO AS TO ALLOW .003 TO .005 BETWEEN PEDESTALS & WASHERS, AFTER BOLTS ARE TIGHTENED. WASHERS, BOLTS AND PADS HAVE BEEN STAMPED TO ASSURE PROPER ASSEM. DIMENSIONS FOR HOLD DOWN BOLT HOLES ARE APPROXIMATE. LOCATE HOLES IN BASE FROM THIS UNIT.
PLAN VIEW OF FEET
787480 A
73-789



INFORMATION ONLY

CUSTOMERS CONNECTIONS			
ITEM NO.	NO. REQ.	SIZE	DESCRIPTION
1	1	6-300# FLANGE	EXHAUST
2	1	4-300# FLANGE	STEAM INLET
3	1	½ NPT.	[illegible] LEAKOFF
4	2	½ NPT.	COOLING WATER-INLET
5	2	½ NPT.	COOLING WATER-OUTLET
6	2	½ NPT.	GLAND DRAINS TO ATMOSPHERE
7	1	¾ NPT.	TURBINE CASING DRAIN
8	1	½ NPT.	STEAM RING DRAIN
9	1	¾ SCH 80 PIPE	BELOW SEAT DRAIN
10	1	¾ SCH 80 PIPE	ABOVE SEAT DRAIN
11	4	½ SCH 80 PIPE	LEAKOFF CONN.

*BREW.
S.T. CO.

REV. A

DWG. NO. 787-8D, 87-8D

CERTIFIED CORRECT FOR—
BYRON JACKSON PUMP DIV.
FOR
CLEVELAND ELECTRIC
DAVIS BESSE

ORDER NO. V-1474

PER
DATE

FOLLOWING EXTRAS SUPPLIED BUT NOT SHOWN
2 THERMOCOUPLES [illegible]
2 VIBRATION PROBES (ONE ON EACH BRG. CAP)

PIPES OF SUFFICIENT SIZE TO INSURE RATED STEAM INLET AND EXHAUST PRESSURE AT THE TURBINE MUST BE INSTALLED.
ALL PIPING SHOULD BE ANCHORED AND SUPPORTED IN A MANNER TO PREVENT STRAINS BEING TRANSMITTED TO TURBINE. USE EXPANSION JOINT WHEN NECESSARY. IN GENERAL WE RECOMMEND USE OF EXPANSION JOINT ON EXHAUST CONNECTION FOR 8" AND LARGER.
ATMOSPHERIC RELIEF VALVES SHOULD BE PLACED BETWEEN EXHAUST OR BLEEDER OR MIXED PRESSURE TURBINE FLANGES AND ANY SHUT-OFF VALVE.
STEAM PIPE SHOULD BE LAGGED AND SEPARATOR INSTALLED CLOSE TO THE TURBINE. DRY STEAM MEANS BETTER EFFICIENCY AND LONGER LIFE.
WHEN BASE OR BED PLATE IS FURNISHED NOT LESS THAN 1" SHOULD BE ALLOWED BETWEEN THE BASE AND FOUNDATION FOR GROUTING. FOUNDATION BOLTS MUST NOT BE FIXED RIGIDLY UNTIL UNIT IS IN PLACE. DIMENSIONS ARE FROM DRAWINGS. WE ARE NOT RESPONSIBLE FOR SLIGHT VARIATIONS IN CASTINGS.

FILE

TYPE- GS-2

OUTLINE

SCALE 1"=1 FT. DATE

THE TERRY STEAM TURBINE CO.
WINDSOR, CONN. U.S.A.

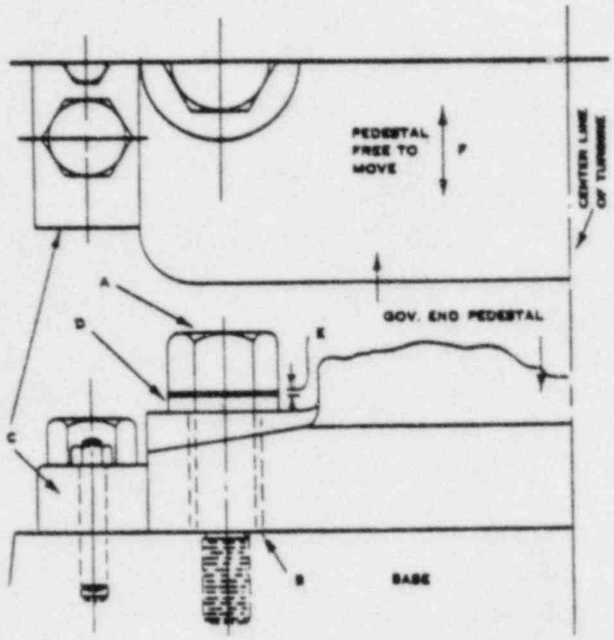
DRAWN
TRACED
CHECKED
APPROVED

787-8D

TURBINE WGT. 2800#
T&T VALVE WGT. 962#

SECTION XXII

SLIDING FOOT - GOVERNOR END PEDESTAL



To provide for axial expansion of the casing, a sliding support is used under the governor and pedestal. Two steel blocks (C) are bolted or welded to the baseplate pads, as indicated. They serve as guides for the pedestal and prevent lateral movement. The two sides of the pedestal are machined where they are in contact with the guide blocks. The pedestal is held to the baseplate by means of hold-down bolts (A) in such a manner that it is permitted to slide between the two guide blocks. The hold-down bolt (A) is tightened down until it bears up against the shoulder at (B). Washer (D) is so made that a small clearance is left at (E). The hold-down bolt is smaller in diameter than the hole in the pedestal.

The design, it will be seen, prevents the pedestal from lifting, but allows it to move axially a small amount. when the turbine casing expands or contracts, the pedestal therefore is free to move in the direction by the arrow (F).

If the pedestal were bolted down tight, heavy stresses would be set up in the turbine casing, which would result in the bearing, shaft, etc., being thrown out of alignment.

 Printed in U.S.A.

INSTALLATION

Foundation

The foundation is one of the most influential factors where overall reliability of a unit is concerned. A foundation must maintain alignment under all normal and abnormal conditions. This includes the way the foundation is supported on the soil and/or superstructure, equal deflections of all columns under load, soil settling and soil resonances, thermal distortion, piping forces, vacuum pull or pressure forces in expansion joints.

The foundation must minimize vibration by being as heavy as possible and non-resonant. It is important that the turbine be isolated from external vibration by providing an air gap filled with mastic sealer all round the slab and mat.

Provision in design must be adequate when a turbine unit is carried on steel work or other structure, as applied to foundations in soil. In the same manner, it must be so supported that alignment cannot be disturbed. Structure must be stiff enough to prevent yielding or springing. The addition of a substantial concrete mat will minimize vibration. It is essential that no part of the foundation or structure is resonant within the operating speed range of the machine.

Vibration transmissions may be from the unit to the surroundings or vice-versa, and it may be aggravated by resonance at transmission frequencies, piping, stairways and ducts may also transmit vibration, which should be prevented by proper isolation.

Certified general outline drawings are furnished with each order. These drawings include dimensions for locating anchor bolts, weight of each assembly and general information needed for determining foundation size and thickness.

A generous factor of safety should be used when determining foundation thickness. The foundation length and width should extend at least 6" (six inches) beyond the anchor bolts.

Anchor bolts must be positioned accurately and provided with sleeves (Fig. 1 and 3). The sleeve bore diameter should be approximately twice the bolt diameter, but should provide not less than ½" clearance all round the bolt.

Carefully constructed templates are required to hold bolts and sleeves in position while foundation is cast.

Templates are usually made of wood and secured to the foundation forms. Skilled craftsmen should be able to set anchor bolts to a tolerance of 1/8" by locating and drilling the holes in the templates after they have been secured to the braced forms.

The anchor bolts should be threaded at both ends and of sufficient length to extend one and a half to twice the bolt diameter above the top of the securing holes in the base of sole plate.

The lower end of each bolt passes through an anchor plate and is secured by a nut and welded (Fig. 1).

Anchor plates can be either standard cast iron, washers or flat steel plates. They should have a diameter or side dimension of approximately twice to two and a half times the outside diameter of the sleeves.

Note:

1. The templates must be rigid enough to prevent bolts from shifting while the concrete is being poured.

2. After concrete has been poured and before it has hardened, recheck the position of the anchor bolts.

3. Allow $1\frac{1}{2}$" gap above the top of the foundation surface for grouting under the edge of base or sole plates.

Leveling

Sufficient parallel machined bearing plates or chock blocks should be placed beneath soleplates or base, along the sides and ends, to distribute the load evenly.

It is essential that they are leveled before the sole plates or base are placed in position. For leveling use an optical method, or a level of very high quality with a ground calibrated dial. Obtain an accurate condition of level lengthwise and crosswise.

INSTALLATION (Continued)

Only stainless steel shims should be used to adjust height of sole plates or base to align turbine and driven equipment (Figs. 1 & 2). Allowances must be made for the turbine horizontal centerline rise due to thermal expansion relative to that of the driven equipment. (See Section 4 - Alignment.)

Note: Shims supplied under turbine feet or flexplate supports are not for initial installation alignment, but for final alignment after a "hot run" check. (See Section 4 - Alignment.)

In an installation involving a gear drive between the driver and driven unit, installation procedure should be to align the driver and driven unit to the gear to achieve minimum error. (See Section 4 - Alignment.)

Where units are attached to a common base and are so installed, wedges or jacking bolts can be used to initially adjust alignment (Fig. 2).

Grouting

The anchor bolts are used for hold down only. The grouting resists side thrust, end thrust, and compensates for the irregularities between foundation and base, thus preventing turbine and driven unit or units from shifting.

Therefore, it is absolutely essential that the top of the foundation and metal surface of the base or sole plates that are to be in contact with the grout be thoroughly clean.

All loose dirt and debris must be removed and anchor bolt sleeves cleaned out. Any oil or grease will impair the bonding of the grout and must be removed.

The foundation surfaces should be roughened by chipping and washed repeatedly with liberal quantities of clean water, so that concrete is damp when the grout is poured. Placing of the grout can be done from the sides, and through access holes in the top of base.

Note:

1. Use only "non-shrink" or "epoxy" grout.

INSTALLATION (Continued)

2. It is necessary to vent each recess in a box type base to allow air to escape. A stiff wire or suitable rod will help release entrapped air by puddling, and will also ensure that the grout is distributed thoroughly and in contact with the inside surfaces completely. Finish flush to access holes.

3. The metal parts of base which will be unavoidably in contact with the grout can be lightly covered with grease to make the clean-up job easier.

4. Allow grouting to set before tightening anchor bolts. After tightening, check alignment to make sure it has not changed.

5. Do not connect piping to turbine until alignment and grouting are completed.

Special Note: Lifting

1. Before lifting heavy equipment, be certain that weights listed on certified drawings are within the capacity of the crane or hoist. Lift smoothly and avoid twisting and shock damage. Adjust cable or chain lengths to lift squarely. Use wooden block pads, etc., to prevent cables or chains from damaging pipe work or turbine parts.

2. Where turbines are mounted on a base and are equipped with a sliding expansion foot on the bearing pedestal at the governor or high pressure end of the lower half casing, the sliding foot is secured to the base by two bolts, one on each side within the guide blocks. These bolts are not designed to take the weight of lifting the assembly from the turbine only or to stand any severe shock. Chock washers are fitted under bolt heads to secure pedestal foot from movement during shipment. Do not remove until unit is installed.

Inlet and Exhaust Piping

The piping system should be designed with sufficient inherent flexibility to take care of thermal expansion without creating excessive forces at the flanges.

On both inlet and exhaust pipes, a suitable support (adjustable spring loaded) should be installed directly under vertical risers near the turbine and above horizontal pipe runs, and then adjusted for best possible alignment of flanges when hot. This will insure that most of the forces resulting from expansion and stresses due to dead weight will not be placed on the turbine flanges.

IMPORTANT! The piping must be so arranged and so supported that no excessive stress can be transmitted to the turbine, either due to the weight of the pipe or to its expansion and contraction. All piping must be within the limits of the allowable forces and moments in accordance with the applicable NEMA standards publication. The only exception being when allowable forces and moments are included on a certified outline drawing for a particular project.

Piping Strain

The net effect of piping strain on a machine reduces reliability by:

1. Causing misalignment and consequent vibration.

2. Causing case distortion and consequent vibration, rubs, case leakage and possible cracking.

3. Causing foundation or base deflection, which may result in misalignment, case distortions and consequent vibrations or rubs.

Excessive piping strain may be the result of:

1. Thermal expansion and contraction of the pipe, boiler, and machine. This indicates faulty pipe design. Expansion joints or loops may have to be installed.

2. Improper pipe support. Frequent problems arise from indiscriminate use of rod hangers (instead of spring hangers), anchors, and other non-elastic restraints and supports. To correct this, disconnect piping at both ends and support on spring hangers, except where anchors or restraints are required by the pipe design.

Inlet Piping

Pipe sizes should be large enough to maintain rated steam pressure at the turbine inlet flange under maximum load conditions.

INSTALLATION (Continued)

In determining pipe size, proper allowance should be made for pressure drop due to long sections of pipe, elbows, valves or other fittings between the boiler and the turbine.

If wet or saturated steam is used, it is very important that the piping be arranged so that condensate cannot be carried over into the turbine. A steam separator of the proper size, with a trap of ample capacity, should be installed before the turbine inlet. If the turbine is fed from a main header under no circumstances should the pipe be taken from the side or bottom of the header. It should, in all cases, be fed from the top. All horizontal runs must be sloped in direction of steam flow, with drains at the low points.

The importance of protecting the turbine against slugs of water cannot be over-emphasized. We are not concerned with the "wetness" of the steam, but with condensate, which is separated out as water. The harmful effects of water are:

1. Rapid erosion of blading and valves.

2. In the case of wheels with inserted blades, the danger is present of the hammer-blow effect of the water tearing out the blades and wrecking the rotor.

3. Governing is adversely affected.

4. Rotor may be permanently distorted and/or turbine may be wrecked.

5. Danger of thrust bearing failure and consequent destruction of turbine.

Exhaust Piping

On each installation the length of run, elbows, valves and other fittings in the pipe must be considered and all factors which may cause excessive back pressure on non-condensing turbines or reduced vacuum on condensing turbines, and the final decision on piping size made accordingly. On non-condensing turbines, back pressure higher than that for which the turbine was designed will cause reduction of power and increase of steam consumption. It may also cause gland leakage and, in extreme cases, can rupture the turbine casing. On condensing turbines decrease of vacuum will have an even greater effect on capacity and economy.

INSTALLATION (Continued)

The exhaust pipe must be installed and anchored so that no excessive stress can be put on the turbine from either the weight of the pipe or its expansion and contraction. Where such arrangement cannot be made with certainty the provision of an expansion joint near the turbine can be useful in low pressure lines and is usually required on large pipe sizes. The use of an expansion joint does not of itself avoid undue stress. It is not as flexible as many people assume and when installed it must be properly aligned and not indiscriminately exposed to shear or torsion. In a majority of applications the axial thrust created on the cross-sectional area of the largest bellows, by internal pressure, must be restricted by the use of tie rods. They are most effective when the expansion joint is used in shear, instead of tension or compression. When used in either a vacuum or a pres sure line, the tie rods have to be arranged accordingly. They are useless where a joint moves under tension and compression as they by-pass the joint and transmit pipe forces direct to the turbine. Provision must be made to anchor the piping in such a manner that excessive forces will not be transmitted to the turbine during shutdown and operational running. (See NEMA standards in this section.) As on inlet lines, connection to a header must be made at the top--never from the bottom or the side, and great care must be taken to avoid draining water back into the turbine. All horizontal runs must be sloped.

Full-Flow Relief Valve

An atmospheric full-flow relief valve is part of the exhaust piping which is external to the turbine and it must be installed in the exhaust piping between the turbine exhaust connection and the first shutoff valve in the exhaust system to protect the turbine casing and internal parts against excessive steam pressure.

The valve must be sized to pass the maximum steam flow, to the atmosphere, that will pass through the turbine nozzles under rated initial steam conditions.

This valve is not to be confused with the sentinal relief valve installed on the turbine casing to give audible and visual warning of excessive exhaust pressure only.

The full-flow relief valve should start to open at the sentinal relief valve setting and be fully open with the additional rise in pressure not to exceed ten (10) per cent (NEMA Standards Code). The sentinal relief valve will then give a visual and audible indication when the full-flow relief valve starts to open.

Check Valve

Where a turbine exhausts or bleeds steam into another system and a check valve is installed to provide containment of reverse flow to the turbine, adequate bracing must be installed to absorb any forces created by water hammer occurring in the exhaust line downstream and acting on the check valve.

Auxiliary Piping

When indicated on the certified drawings, water cooling is required and inlet pipes must be provided with valves for regulating. Never install valves in outlet pipes! Outlet pipes must be so arranged that they cannot in any manner become obstructed. Only clean, cool water should be used. Cooling water piping should be sized to suit the connections on the cooler. The amount of cooling water will vary, depending on the temperature of the water, steam temperatures, etc. With forced feed lubrication, the flow of water should be adjusted to maintain an oil temperature leaving the bearings not to exceed 165° F., and an inlet temperature not under 100° F. When so indicated on the certified outline drawing, air coolers are provided to maintain a specified bearing oil temperature. The coolers are designed to keep the oil outlet temperature below 140° F.

Every turbine is provided with one or more drain outlets. These should be piped up with suitable open atmospheric drain lines and shutoff valves provided. These drain lines must be left open when the turbine is idle to prevent accumulation of condensate in the turbine which will result in corrosion and rapid deterioration of internal parts. Make sure that no condensate can be pulled into the turbine through drain lines under any conditions.

If subject to freezing temperatures, water must not be allowed to stand in cooling coils or pockets in the case, steam chest or valves.

Oil Piping & Gland Piping

Instructions are provided in the Lubrication, Steam Seal and Drain System sections in this manual.

INSTALLATION (Continued)

Cleaning of Steam Piping

The Terry Steam Turbine Company has found from experience over many years, with different customers, that it is very important to clean steam piping and headers, especially with new installations, before a steam turbine is put into operation.

There have been cases where steam lines have not been cleaned at all, with the idea that strict inspection for cleanliness during installation would be sufficient.

This has proven unsatisfactory since very small particles of steel, welding slag and large quantities of oxide scale have been blown into the turbine through the small strainer holes of the turbine governor or stop valve.

From experience it has been found most satisfactory to blow-down steam lines with steam, using a cycle of heating, blowing and cooling, and this method is recommended by The Terry Steam Turbine Company.

The procedure suggested by Terry Steam is not mandatory. The purchaser is at liberty to employ other accepted proven methods.

IN EITHER CASE, IT MUST BE CLEARLY UNDERSTOOD, THAT IT IS THE PURCHASER'S RESPONSIBILITY TO SUPPLY STEAM FREE OF FOREIGN MATERIAL TO THE INLET OF THE TURBINE CONNECTIONS.

Suggested Blowdown Procedure

Dur to the variations in different installations of the length, configuration, number of stop valves, and sizes of steam piping, it is not intended or possible to give a detailed procedure.

The purchaser must plan and make proper arrangements to achieve maximum cleaning of piping. The blowdown cycle consists of warming through steam lines initially then, maximum design pressure for the piping is built up in the boiler and released quickly through the stop valve to blow through the steam line. Blowing should be stopped before boiler pressure drops to 100 psig or the minimum pressure recommended by the boiler manufacturer.

Boiler pressure is then built up again, during which time the steam line should be cooled enough and the cycle can be repeated.

The cycle should be repeated from four to six times. The use of targets installed in the steam path are recommended as they give a good indication as to the cleanness of the line. Targets should have a highly polished finish and be re-polished after each blowdown check.

To achieve maximum cleaning during the blowing cycle, the blow-piping should be sized large enough to obtain the maximum mass velocity head that can be developed during full load operation of the turbine.

The blow pipe should be piped outside of the building where the blow-down steam and particles will not injure personnel or damage equipment. It should also be of the same design rating of the steam line being blown down.

The purchaser must decide as to whether the steam line should be blown down by sections, stop valve to stop valve or direct from boiler stop valve, according to the system layout and bearing in mind that the maximum velocity must be maintained to achieve maximum cleaning.

On completion of the blowdown of steam piping with steam or other methods of cleaning, it is recommended that a fine mesh screen be assembled over the permanent coarse strainer of the turbine stop valve. This is removed after initial spin testing and operational checks of turbine up to full load operation.

The fine mesh screen must be never considered as a substitute for a thorough pipe cleaning job.

NOTE: When cleaning steam piping, it must be disconnected from the inlet to the turbine or the turbine stop valve.

Suggest mesh size No. 40 (.0165") for fine mesh strainer.

Expansion Joints - IMPORTANT . . . READ CAREFULLY

WARNING - Do not permit cinders or other foreign material to become lodged between the equalizing rings and the corrugations.

Expansion joints 5" and smaller in size are shipped with two spacing blocks between the equalizing rings. These must be removed before pipe spacers between the equalizing rings. These should not be removed until joint is set in place in the line, but must be removed before the joint is permitted to function.

INSTALLATION (Continued)

Flanged expansion joints having internal sleeves require a soft gasket between the face of the joint and the back of the sleeve face as well as a gasket between the sleeve and the companion flange. Those joints should be installed so that the flow is in the inner sleeve.

The universal type of expansion joint has two or four heavy limit rods which divide the movement equally between both expansion joints. Each of these rods have four split spacing collars under the nut. Those maintain the proper overall length and should only be removed after the joint is bolted in place.

WARNING

GASKETS CONTAINING CARBON OR GRAPHITE SHOULD NOT BE USED IN CONTACT WITH STAINLESS STEEL. SEVERE CORROSION MAY RESULT. ANY DARK GASKETS MAY CONTAIN GRAPHITE; CONSULT GASKET MANUFACTURER TO BE SURE.

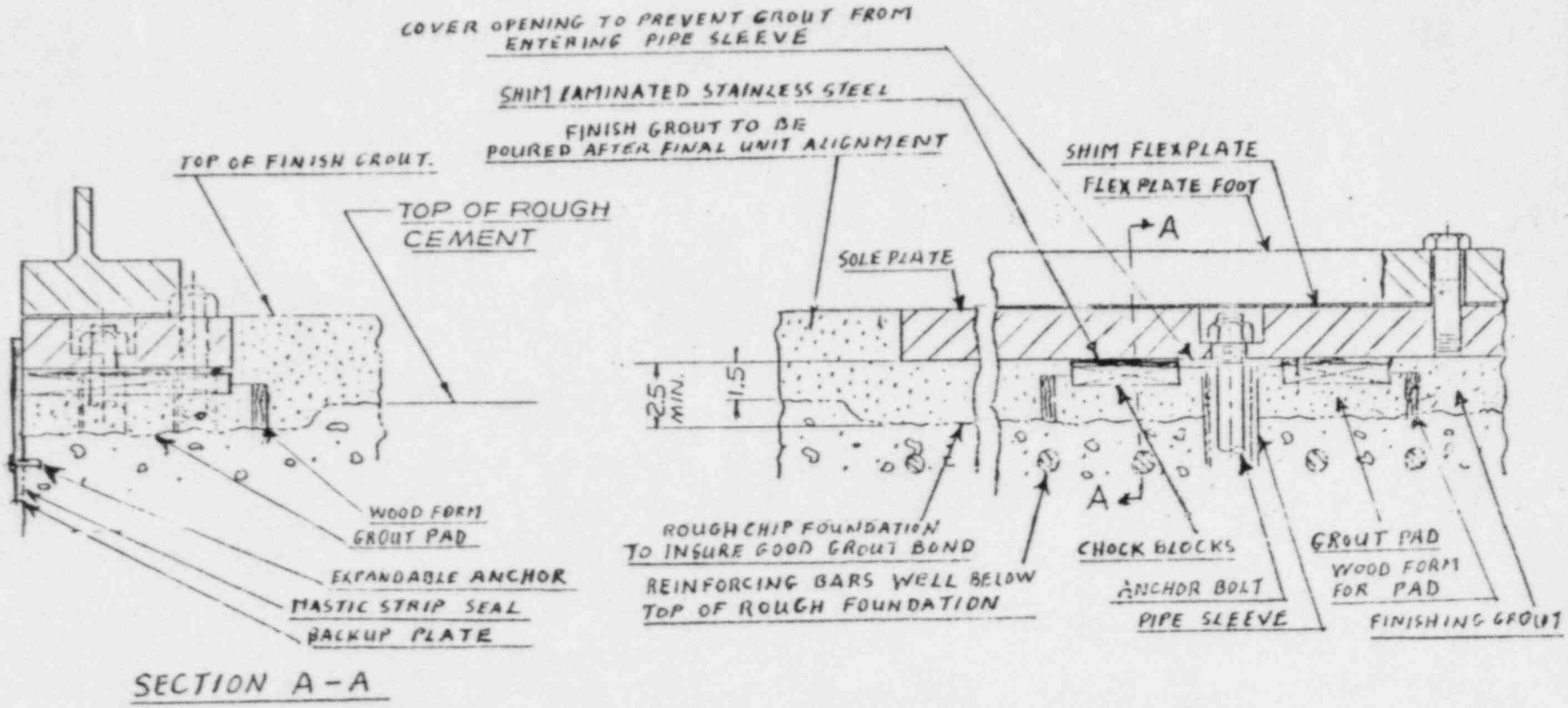


FIG. 3

SUGGESTED ARRANGEMENT OF SOLEPLATES AND GROUTING

INSTALLATION FOUNDATION

FIG. 1

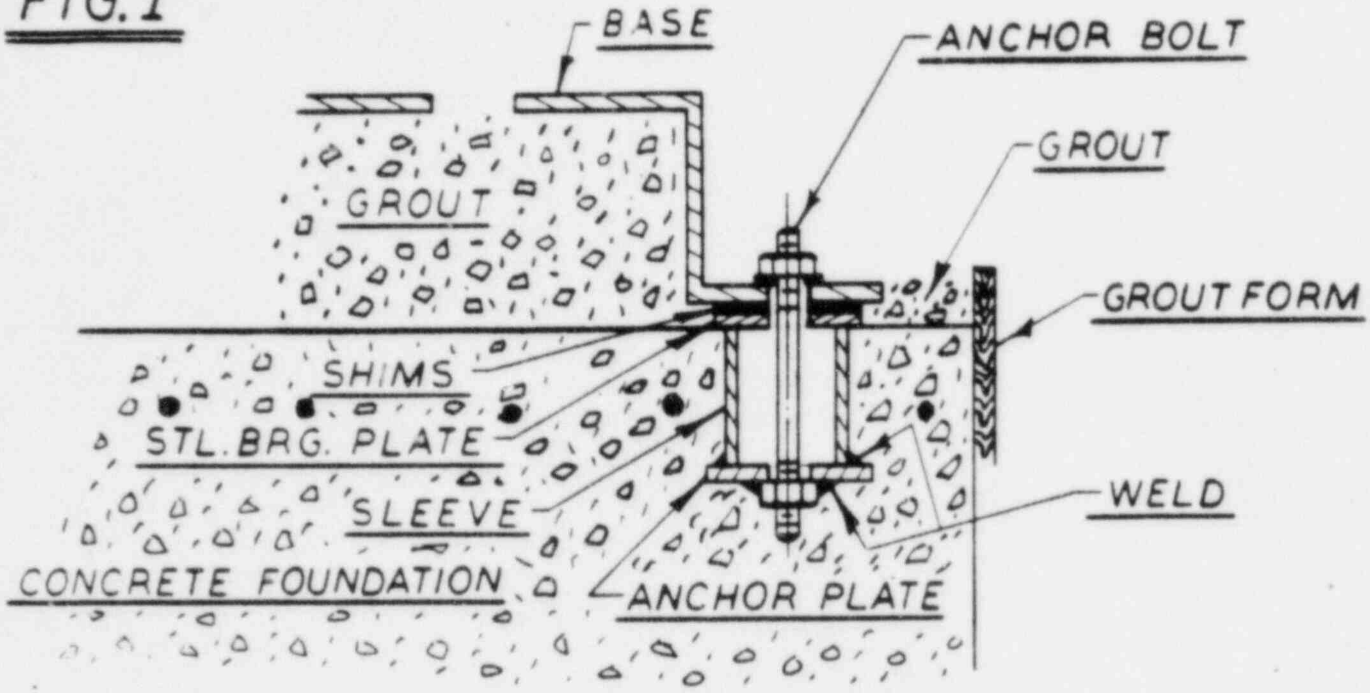
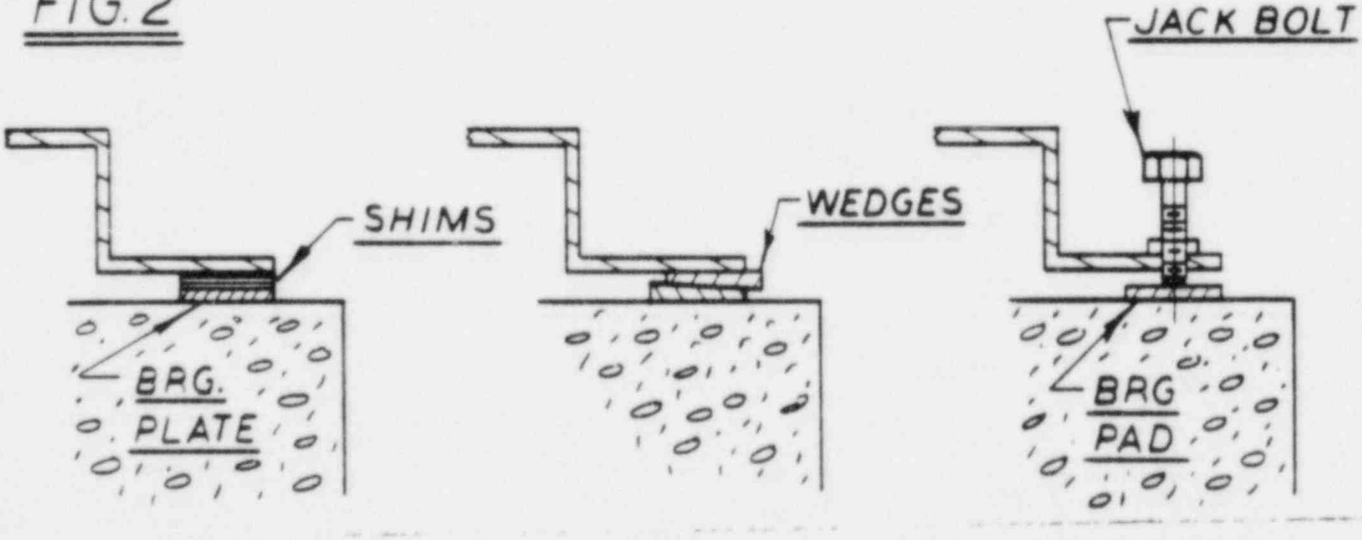


FIG. 2



NOTE: When using Jack bolts or wedges to establish alignment before grouting they should be backed off or removed after the grout has set and the anchor bolts should be tightened.

This page is included as a location reference for the following extract as taken from the National Electrical Manufacturers Association (NEMA) Standards Publication No. SM21-1970, for which due credit is acknowledged.

It is included in this Instruction Manual as a guide for the Minimum Requirements of installation, except that, where allowable forces and moments are shown on certified outline drawings, pipe loads are to be kept within those limits shown.

Part 7
STEAM PIPING SYSTEMS CONNECTED TO MECHANICAL-DRIVE STEAM TURBINES

SM 22-7.01 INTRODUCTION

The first consideration in designing any piping system is to keep the stresses in the pipe within the limits of the established rules of national codes such as the ASME "Boiler Code," the American National Standard "Code for Pressure Piping," and any local codes that may be applicable. In general, the jurisdiction of such authorities stops at the turbine inlet and exhaust connections or other openings on the machine to which external piping systems connect.

When a piping system is connected to a steam turbine, there are additional limitations, and it is the purpose here to discuss and define these limitations as an aid to the purchaser in designing such systems.

Authorized Engineering Information 11-13-1969.

SM 22-7.02 THE PIPING PROBLEM AS APPLIED TO TURBINES

Steam turbines have been very carefully designed to provide for expansion and, at the same time, maintain close alignment between the rotating and stationary parts. The provisions for expansion of the casing and maintenance of close clearances necessarily limits the forces that can be applied to the turbine by the piping connected to it. Pipe reactions, if of sufficient magnitude, will result in misalignment of the turbine sufficient to cause rough operation and serious mechanical damage.

In order to keep the strains due to forces and bending moments on the turbine connections, including the weight of the pipe, within allowable limits, the piping system design should be such that restraints and freedom of movement match the requirements of the turbine. Pipe forces which seem small may lead to large moments at the connections to the turbine and to very large forces at the turbine supports. Under some conditions, other piping connections may require checking.

The stresses in a piping system under operating conditions can be grouped into three classes; stresses due to steam pressure, stresses due to thermal expansion, and stresses due to dead weight.

Authorized Engineering Information 11-13-1969.

SM 22-7.03 FORCES DUE TO STEAM PRESSURE

These are most commonly associated with low-pressure and vacuum lines where expansion joints are often used to provide flexibility. If an expansion joint is improperly used, it may cause a pipe reaction greater than the one which it is supposed to eliminate. An expansion joint will cause an axial thrust equal to the area of the largest corrugation times the internal pressure. The force necessary to compress or elongate an expansion joint can be quite large, and either of these forces may be greater than the limits for the exhaust flange. In order to have the lowest reaction, it is best to avoid absorbing pipe-line expansion by axial compression or elongation. If it is found that expansion joints or loops, etc., are required, it is essential that they be properly located and installed.

Figure 7-1 shows an expansion joint in a pressure line. The axial thrust from the expansion joint tends to separate the turbine and the elbow. To prevent this, the elbow must have an anchor to keep it from moving. The turbine must also absorb this thrust and, in doing so, becomes an anchor. This force on the turbine case may be greater than can be allowed. In general, this method should be discouraged.

Figure 7-2 shows the same piping arrangement as Figure 7-1 except for the addition of tie rods on the expansion joint. The tie rods limit the elongation of the joint and take the axial thrust created by the internal pressure so it is not transmitted to the turbine flange. The tie rods eliminate any axial flexibility but the joint is still flexible in shear, that is, the flanges may move in parallel planes. The location of this type of joint in the piping should be such that movement of the pipe puts the expansion joint in shear instead of tension or compression.

Figure 7-3 is an arrangement frequently used, having tie rods as indicated for noncondensing operation. This arrangement will prevent any thrust due to internal pressure from being transmitted to the exhaust flange and retains the axial flexibility of the joint. It may be used for either vacuum or pressure service (by suitable arrangement of tie rods).

Figure 7-4 shows a suggested arrangement for a condensing turbine with an up exhaust. Due to the large exhaust pipe size normally encountered on condensing turbines, the exhaust piping will be relatively stiff, and an expansion joint must be used at some point to take care of thermal expansion. An unrestricted expansion joint placed at the exhaust flange of the turbine will exert an upward or lifting force on the turbine flange which in many cases is excessive. Figure 7-4 provides the necessary flexibility to take care of thermal expansion without imposing a lifting force on the turbine. The expansion joint is in shear which is the preferred use. The relatively small vertical expansion will compress one joint and elongate the other which causes a small reaction only and will be well within the turbine flange limits.

Authorized Engineering Information 11-13-1969.

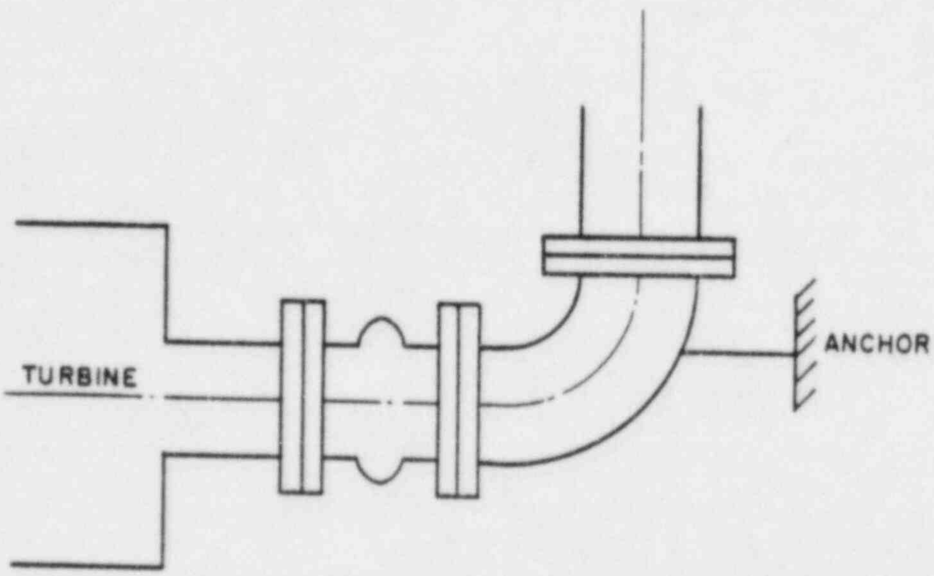


Fig. 7-1

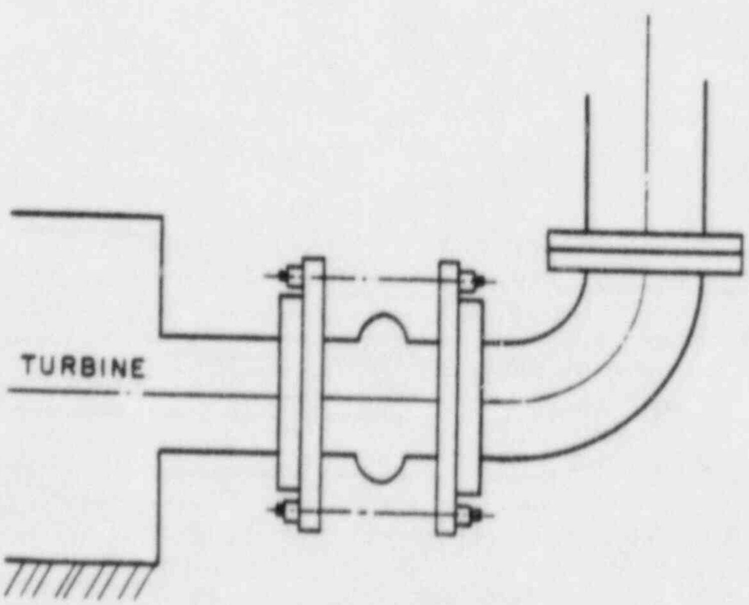


Fig. 7-2

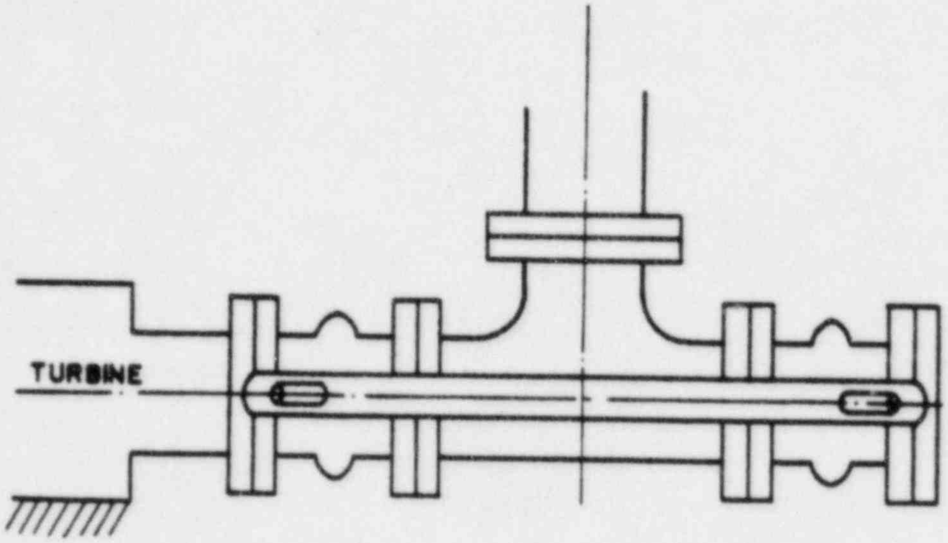


Fig. 7-3

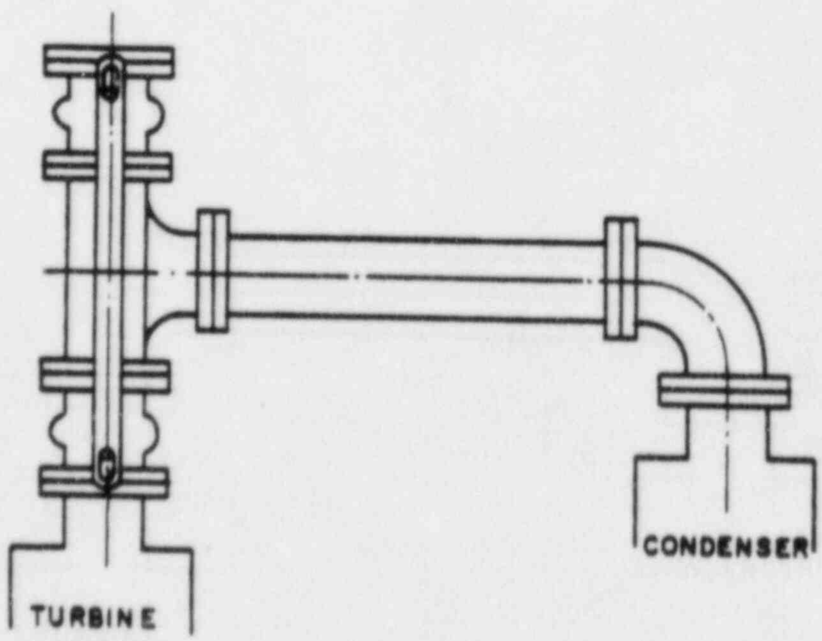


Fig. 7-4

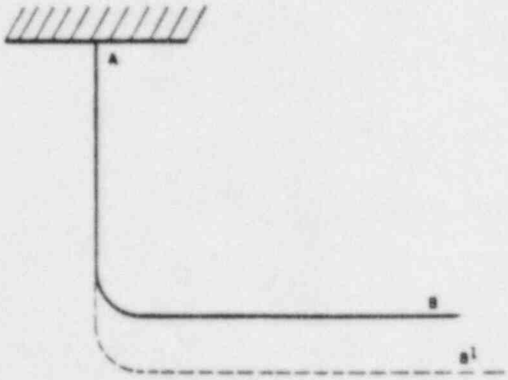


Fig. 7-5

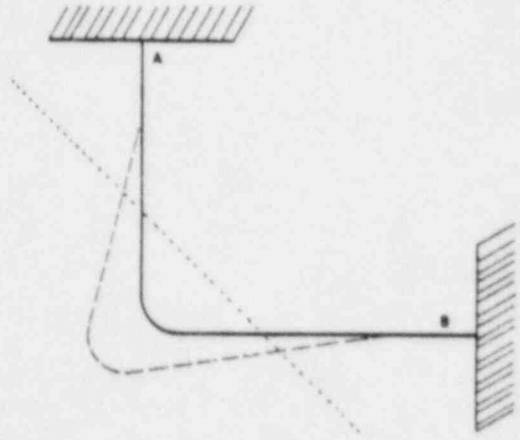


Fig. 7-6

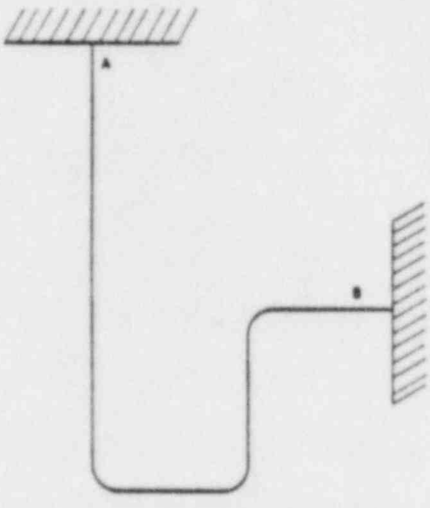


Fig. 7-7

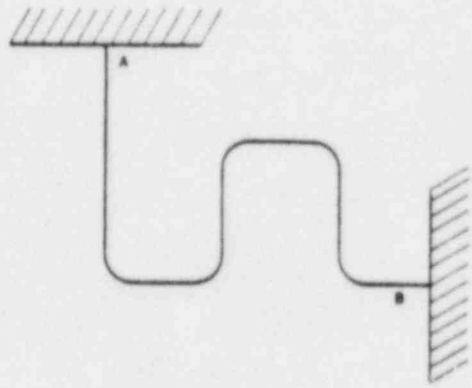


Fig. 7-8

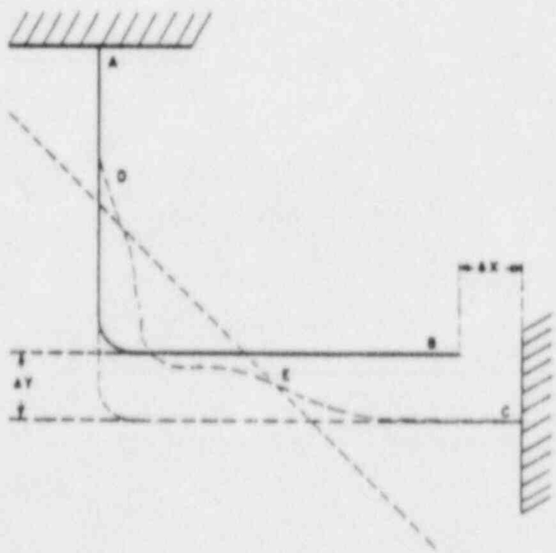


Fig. 7-9

SM 22-7.04 EFFECT OF TEMPERATURE EXPANSIONS ON PIPING SYSTEMS

If a pipe is connected to some point as A in Figure 7-5 and has the configuration shown by the solid line, it will assume the position shown by the dash line when heated to a higher temperature, providing no restraint is offered by point B.

If both points A and B are rigid points which will not move, the pipe will assume the shape shown by the dash line in Figure 7-6 when heated.

The stresses may be reduced by using expansion loops such as shown in Figures 7-7 and 7-8. When the piping does not have to be confined to one plane, torsional flexibility may be effectively used to reduce stresses. Prestressing the pipe in the cold condition or "cold springing" may also be used to reduce the stresses in operation. These principles may be used in combination to produce a design with flexibility enough to keep the stresses, forces and moments within the permissible limits in both the hot and cold conditions.

The piping system should be designed with sufficient inherent flexibility to take care of thermal expansion. The amount of piping can often be reduced by the use of "cold springing" to reduce or eliminate stresses due to thermal expansion. This is done by cutting the pipe short by a predetermined amount and then forcing it into place during installation as illustrated in Figure 7-9. Forces and moments in the hot condition are thus reduced below the values they would have if the system were not cold-sprung. Points A and C are the points to be connected by a piping system and ΔX and ΔY are the respective expansions.

In the case of welded connections, it is necessary to bend the pipe by putting a moment on it when connecting it to point C to make the weld preparations parallel, as well as just pulling B up to C. If this is not done, a moment will exist in the hot condition, and only a partial cold-springing job results. Wherever possible, it is wise to facilitate assembly by locating field welds at points of minimum moment. Points D and E are such points.

Authorized Engineering Information 11-13-1969.

SM 22-7.05 STRESSES DUE TO DEAD WEIGHT

The dead weight of the piping should be entirely supported by pipe hangers or supports. There are basically two types of supports, rigid and spring. Rigid supports are necessary when an unrestricted expansion joint is used. Rigid supports may be used to limit the movement of a line to prevent excessive deflection at any point. A rigid support is not satisfactory where thermal expansion may cause the pipe to move away from the support.

On the two types of rigid supports shown in Figure 7-10, the rise of the turbine case due to temperature would lift the base elbow from the support so the turbine would have to support the weight of the pipe. The expansion of the vertical run of pipe would relieve the pipe hanger of its load so the turbine would again have to support the weight of the pipe.

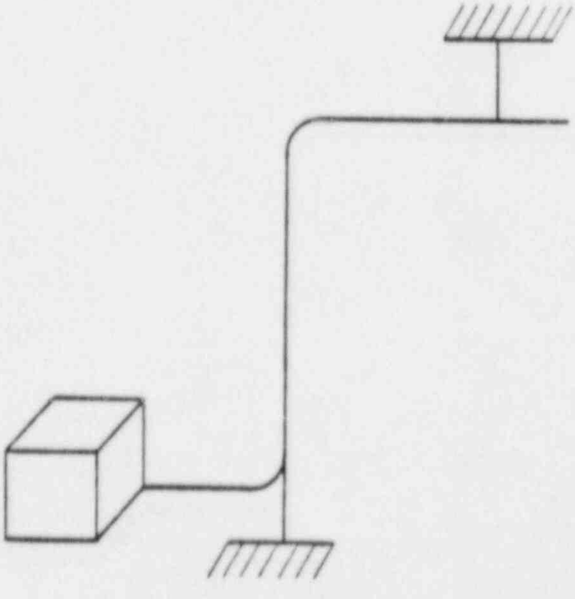


Fig. 7-10

If an expansion joint with restraining tie rods is used, either a rigid pipe hanger or a base elbow with a sliding or rolling contact surface may be used as shown in Figure 7-11.

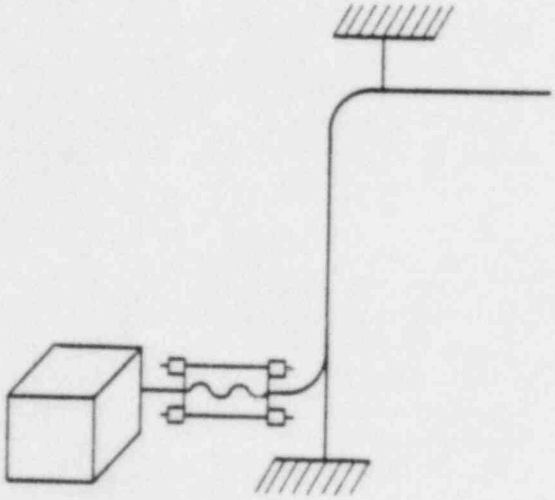


Fig. 7-11

When the thrust due to an expansion joint is less than the exhaust flange limits and no restraining tie rods are used, the pipe must have an anchor as shown in Figure 7-12. Since this condition rarely exists, it is better to use one of the preferred arrangements such as shown in Figure 7-11 and eliminate as much pipe reaction as possible rather than just stay within the limits.

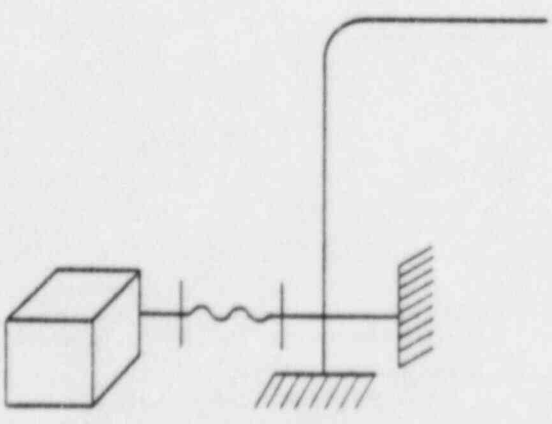


Fig. 7-12

Spring hangers or supports are best suited to carry the dead weight when there is thermal expansion to be considered. The movement of the pipe will change the spring tension or compression a small amount and the hanger loading a small amount but will not remove the load from the hanger. The published manuals on pipe design provide information on hanger spacing to give proper support. In addition to this, it may be found necessary to add additional supports or move existing supports if resonant vibration appears in the piping.

A spring support should not be used to oppose the thrust of an expansion joint as, when the pressure is removed from the line, the spring support will exert a force the same as the expansion joint only in the opposite direction.

Authorized Engineering Information 6-3-1956.

SM 22-7.06 ALLOWABLE FORCES AND MOMENTS ON MECHANICAL-DRIVE STEAM TURBINES

The forces and moments acting on mechanical-drive steam turbines due to the steam inlet, extraction and exhaust connections are limited by the following rules:

1. The total resultant force and total resultant moment imposed on the turbine at any connection must not exceed the following:

$$F = \frac{500\,D - M}{3}$$

F — Resultant force (pounds), including pressure forces where unrestrained expansion joints are used at the connection except on vertical exhausts covered under item 3.

M — Resultant moment (pound-feet).

D — Pipe size of the connection (I.P.S.) in inches up to 8 inches in diameter. For sizes greater than this, use a value of D equal to $\frac{(16 + \text{I.P.S.})}{3}$ inches.

2. The combined resultants of the forces and moments of the inlet, extraction and exhaust connections, resolved at the centerlines of the exhaust connection must not exceed the following two conditions:

a. These resultants must not exceed:

$$F_c = \frac{250\ D_c - M_c}{2}$$

F_c — Combined resultant of inlet, extraction and exhaust forces, pounds.

M_c — Combined resultant of inlet, extraction and exhaust moments and moments resulting from forces, pound-feet.

D_c — Diameter (in inches) of a circular opening equal to the total areas of the inlet, extraction and exhaust openings up to a value of 9 inches in diameter. For values beyond this, use a value of D_c equal to

$$\frac{(18 + \text{Equivalent Diameter})}{3} \text{ inches.}$$

b. The components of these resultants shall not exceed:

$F_y = 125\ D_c$ — $M_y = 125\ D_c$
$F_z = 100\ D_c$ — $M_z = 125\ D_c$
$F_x = 50\ D_c$ — $M_x = 250\ D_c$

F_y — Vertical component of F_c.

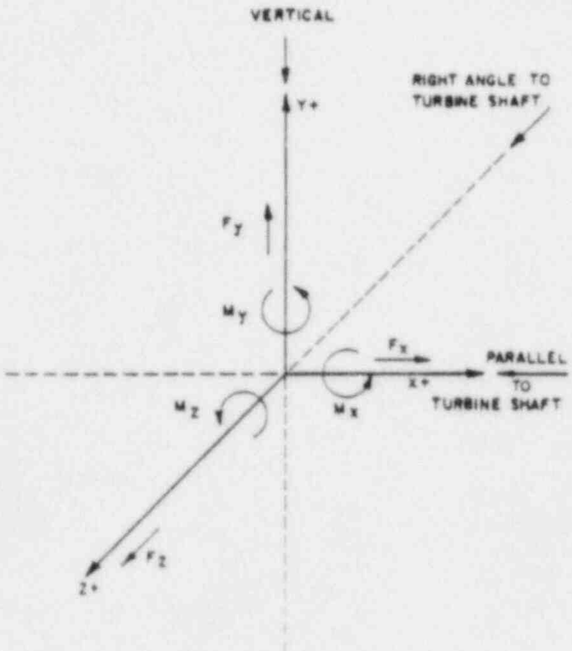
F_z — Horizontal component of F_c at right angles to turbine shaft.

F_x — Horizontal component of F_c parallel to turbine shaft.

M_x — Component of M_c in a vertical plane at right angles to turbine shaft.

M_y — Component of M_c in a horizontal plane.

M_z — Component of M_c in a vertical plane parallel to the turbine shaft.



3. For installation of turbines with a vertical exhaust and an unrestrained expansion joint at the exhaust, an additional amount of force caused by pressure loading is allowed. (The additional force referred to is perpendicular to the face of the exhaust flange and central.) For this type of application, calculate the vertical force component on the exhaust connection, excluding pressure loading, and compare with value of 1/6 the pressure loading on the exhaust. Use the larger of these two numbers for vertical force component on exhaust connection in making calculations outlined in items 1 and 2.

The force caused by the pressure loading on the exhaust is allowed in addition to the values established by the foregoing up to a maximum value of vertical force (pounds) on the exhaust connection (including pressure loading) of 15 1/2 times the exhaust area (square inches).

4. These values of allowable force and moment pertain to the turbine structure only. They do not pertain to the forces and moments in the connecting piping, flange and flange bolting which should not exceed the allowable stress as defined by applicable codes and regulatory bodies.

Authorized Engineering Information 6-3-1956.

SECTION 4

TURBINE SET UP AND ALIGNMENT

TURBINE INSTALLATION

Should be undertaken by a skilled mechanic who is thoroughly familiar with proper procedures commonly used to set up and align turbo machinery. We strongly recommend supervision by a TERRY SERVICE REPRESENTATIVE.

GENERAL

The importance of correct alignment of the turbine and driven equipment cannot be over-emphasized. Time and care devoted to ensuring the best possible installation will result in more reliable operation and reduced maintenance.

The objective is to obtain and retain the best possible alignment between the turbine and driven equipment under normal operating conditions.

Cold alignment figures are based on theoretical calculations and must be confirmed by a "HOT CHECK" carried out as quickly as possible after an operational run of sufficient length to ensure that full operational temperatures are reached throughout the unit.

FACTORS FOR CONSIDERATION

1. Installation

Accurate alignment starts here!

Foundation, grouting, hold down bolting and shimming must be properly carried out. Unit bases, however substantial may distort during transportation and handling. Whether turbine and driven unit are mounted separately or on a common base, they must be installed with sole plate level and properly aligned before grouting. Remember that shims under unit feet are intended primarily for final adjustment after "hot check" and not for initial alignment.

"Soft" legs - Turbine feet must not be stressed, particularly when integral with casing or support pedestal castings. Before starting alignment set a dial indicator at each foot vertically and loosen hold down bolts. Deflections should be only a few mils and approximately equal. (e.g., if 3 legs show 6 mils and the fourth 16 mils, add 10 mil shim to fourth leg.) Always add equal number of shims to pairs of feet after that.

Pipe Stresses - Any stresses imposed by pipework must be removed from the turbine at cold installation and are always a potential cause of misalignment when the unit is hot. Inlet and exhaust flange bolts must enter without forcing or springing of pipes. Dial indicators, to read vertical and horizontal movement, should be located at inlet and exhaust flanges and coupling when connecting pipework. At cold assembly any movement indicates pipe stress which must be corrected. If bolt hole alignment is good, look for misalignment between flange faces or uneven torque of bolting. During warm up, dial indicators will reveal stresses caused by thermal expansion of pipework, particularly if any movement is in the horizontal plane.

2. Thermal Expansion (turbine)

Thermal expansion and contraction must be considered. The turbine may rise at the horizontal centerline and axial expansion of the casing and shaft will occur. Axial clearance between the turbine and driven equipment shafts should be in accordance with the coupling manufacturer's recommendations and should be measured with both units against their active thrust faces. Allowances for any axial expansion of the shafts should be included in the gap.

3. Thermal Expansion (driven equipment)

Anticipated movement of the driven equipment should be obtained from the manufacturer and due allowances made during alignment.

4. Rise Due to Bearing Oil Film

When running the turbine shaft will rise approximately half the journal bearing diametrical clearance due to the lubricating oil film.

5. Vacuum Effect

On condensing units a vacuum "pull" of approximately .005 inches to .010 inches may be recorded at the turbine exhaust flange.

6. Couplings

Correct installation of couplings is vital to proper operation of the unit and great care must be exercised at assembly. Hubs are normally an interference fit to the turbine shaft and must be heated in an oil bath for assembly. Excessive run out or eccentricity must be avoided and may be caused by damage to journals or bore, faulty tapers, badly fitted keys, wear or poor assembly.

High speed couplings are balanced and match marked on all components for correct assembly. The coupling manufacturer's recommendation for misalignment limits and coupling gap must be followed.

Alignment of a flexible coupling should be made to the same degree of accuracy as for a rigid coupling. As coupling hubs are frequently used for checking alignment, great care should be taken to avoid bruising or distortion of the hubs which would result in erroneous readings.

ALIGNMENT CHECKING PROCEDURE

Preferred Method

The preferred method is by the use of a dial indicator securely fastened to one coupling hub and arranged to indicate on the matching hub. Measurements should be taken with the machine rotors held against their active thrust faces to prevent axial movement while recording indicator readings.

(a) To Check Hub Runout

1. Set dial indicator to read on face of one hub and rotate that hub only. Runout is the difference between the minimum and maximum indicator readings.

2. Reposition dial indicator to read on outside diameter of hub and rotate hub. Runout is half the difference between the maximum and minimum indicator reading.

3. Remove dial indicator bracket from one hub and secure to other. Repeat steps 1 and 2. Record readings.

Positions of maximum runout must be marked on coupling before alignment check and allowances made while checking.

Excessive runout should be corrected by re-installing hubs or by renewal.

(b) To Check Angular Misalignment

Set dial indicator to read on face of one hub. Rotate both hubs together noting indicator readings at vertical and horizontal positions to check for vertical and horizontal angular face alignment. The face misalignment is the actual difference between two readings taken at points 180° apart.

Notes: Face alignment may be checked using an internal micrometer where space permits.

Turbine cases which do not have centerline support tend to expand vertically slightly more at the steam inlet end than at the cooler exhaust end. For this reason coupling faces of these units are normally aligned with a gap .002 inches greater at the top than that at the bottom. For centerline supported cases coupling faces should be parallel.

(c) To Check Parallel Offset Alignment

Set dial indicator to read on the outside diameter of one hub. Rotate both hubs together to check for vertical and horizontal centerline offset. Misalignment is one half the difference of the total indicator readings taken at points 180° apart.

After consideration of all factors, if one shaft (A) is expected to rise above the other shaft (B), at normal operating temperatures, set shaft (A) lower than shaft (B) by the amount of the calculated horizontal centerline rise.

Remove dial indicator bracket from one hub and secure to the other. Repeat procedures (a) and (b).

"HOT CHECK" after operational temperatures are reached.

Note: If both couplings cannot be rotated together, rotate the coupling to which the dial indicator bracket is secured. Be certain that angular alignment is correct, before final check of parallel offset alignment, when using this method. Particular care is also necessary in making allowances for coupling run out.

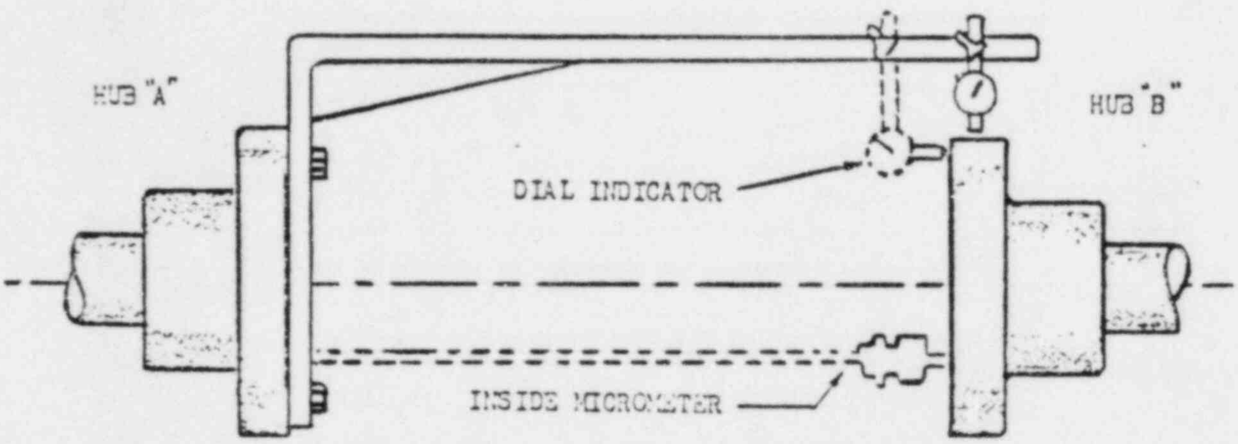
Hot Check - Make HOT CHECK when maximum operating temperatures are achieved. The purpose of a HOT CHECK is to confirm the cold alignment settings. If initial calculations, installation and alignment are properly carried out, hot check will show the units to be in proper alignment. Should the hot check reveal movement which differs largely from that anticipated, FIND THE CAUSE! Re-check calculations. Check security of units. Look for excessive pipe stresses or faulty supports. If necessary break hot pipe-work flanges and check alignment of boltholes and flange faces. If provision for casing expansion is by sliding foot, check clearances at foot guide blocks and hold down bolts. If dowels are removed to establish cold alignment, do not re-dowel until hot check is completed.

Hot check must be made quickly, before cooling causes false readings.

Once established, accurate alignment must be maintained by proper care. Record all readings, re-check periodically and immediately in the event of increased vibration, noise of bearing wear. Vibration analysis equipment is invaluable for periodic checks of the operating condition.

MEASURING ALIGNMENT

PREFERRED METHOD



Alternate Method - Alignment

For some close coupled units it may be impractical to use either a dial indicator or micrometer. In these circumstances feeler gauges or precision taper wedges may be used to measure angular misalignment. Parallel offset may be gauged by use of a straight edge and feeler gauges. (See following diagrams)

MEASURING ALIGNMENT

Alternate Method

The tools required are straight edge, a finished steel wedge and a thickness gauge. If no wedge is available, the thickness gauge may be used in a similar manner. A dial indicator can also be used to measure alignment. Remember, when using a dial indicator, that the actual misalignment is one-half of the full indicator reading.

If the couplings are perfectly true on both the face and the outside diameter, and they are of the same diameter, the measurement of alignment is very simple. When the unit is in exact alignment, the wedge will show the distance between the coupling faces to be the same at all points, and a straight edge will lie squarely across the rims of both havles in the horizontal plane. See Fig. 1 and 2. If the faces are out of parallel, the wedge will show it. If one coupling half is higher than the other, the amount may be determined by the straight edge and feelers. Allowances for heat can be made in this manner. See Fig. 3. If the couplings are not perfectly true and of the same diameter, proper allowance must be made. For example, let us try a case as follows: With the turbine standing and coupling disconnected, and both rotors against their thrust surfaces, insert the wedge between faces at the top of the coupling and scratch a line on the wedge. Without moving the coupling, insert the wedge between faces at the bottom and scratch another line. Let us suppose there is a 1/8" distance between the lines, and the wedge enters further at the top of the coupling. It would then appear as though the coupling were open at the top. See Fig. 5. Now revolve both coupling halves one-half turn and obtain two lines on the wedge as before. If these lines are 1/8" apart and indicate the coupling to be open at the bottom, the unit is in line, but the coupling halves are running out slightly at the faces, and no further alignment is necessary. See Figs. 4, 5 & 6.

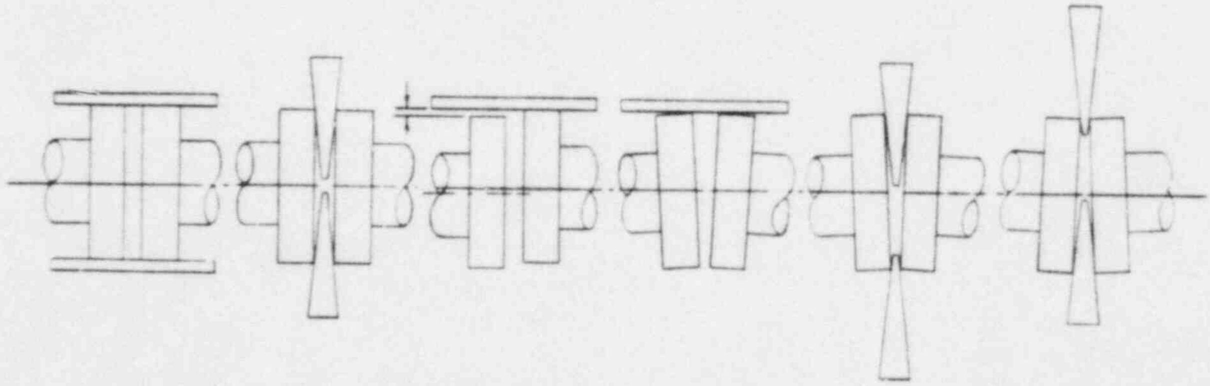


FIG. 1 FIG. 2 FIG. 3 FIG. 4 FIG. 5 FIG. 6

RESET PROCEDURE FOR PG-PL WOODWARD GOVERNOR EQUIPPED TURBINES UTILIZING DAMP BUSHING FOR QUICK START.

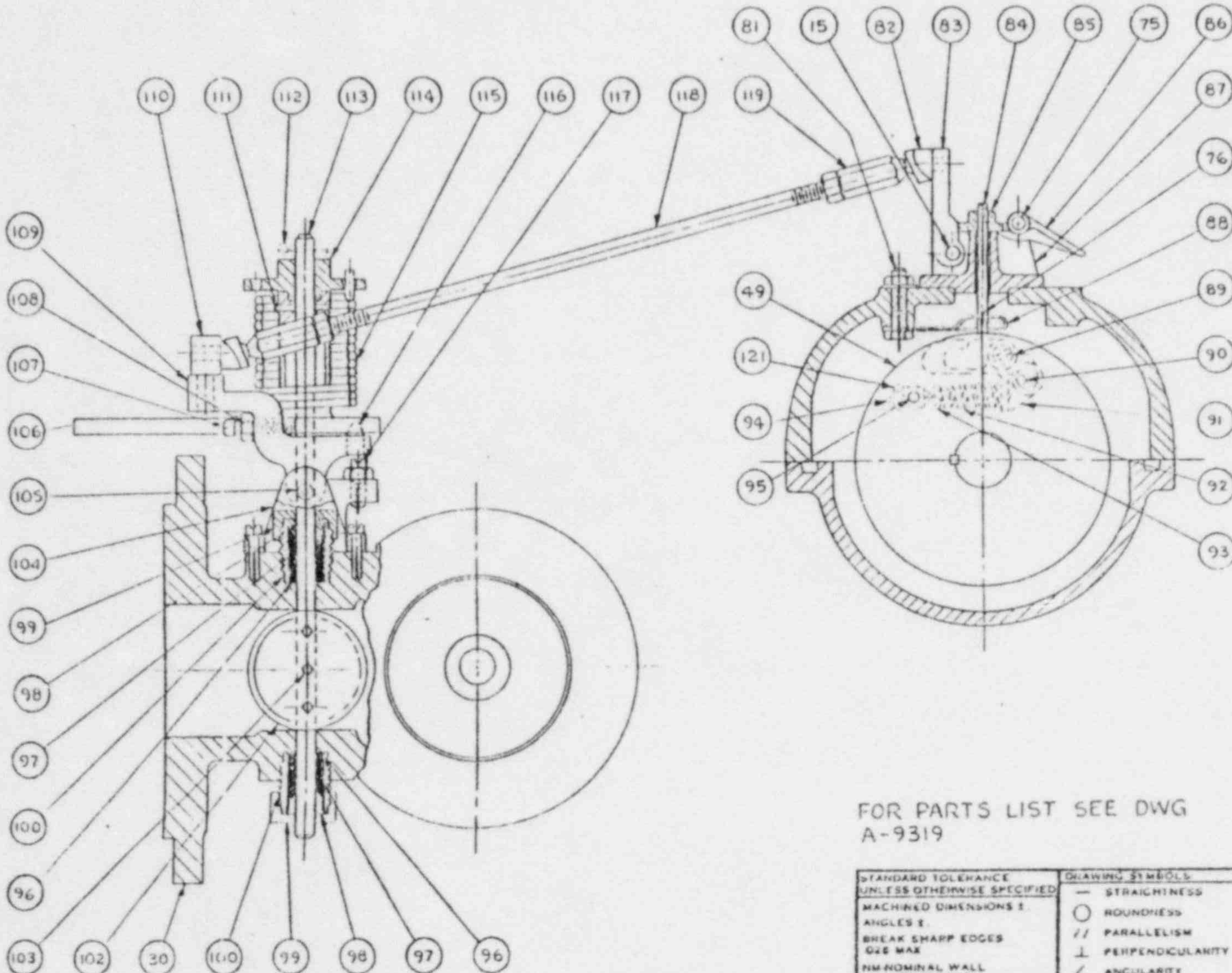
In order to "BLEED OUT" entrapped oil which may be temporarily captured under the main speed piston within the WOODWARD governor after each shut down operation, the knob on the WOODWARD governor must be exercised manually to its lowest speed setting. Then the governor must be returned to the desired speed setting.

Unless the above exercise cycle is carried out, it can take an appreciable time period (as long as thirty minutes) for entrapped oil under the WOODWARD's speed setting piston to bleed out.

Failure to perform the above operation may cause the turbine to overshoot [illegible] speed if started within less than 30 minutes of last start-up be- [illegible] entrapped oil under the WOODWARD speed setting piston.

[illegible]

SYM	ZONE	DESCRIPTION	DATE	APPROVED	ECN
A		REDRAWN - NO CHG			75-2283



FOR PARTS LIST SEE DWG A-9319

STANDARD TOLERANCE UNLESS OTHERWISE SPECIFIED	DRAWING SYMBOLS
MACHINED DIMENSIONS ±	— STRAIGHTNESS
ANGLES ±	○ ROUNDNESS
BREAK SHARP EDGES .025 MAX	// PARALLELISM
NM-NOMINAL WALL THICKNESS	⊥ PERPENDICULARITY
MWT-MINIMUM WALL THICKNESS	∠ ANGULARITY
	◎ CONCENTRICITY
	⌒ CONTOUR
FINISHES	✓ ✓

FAMILY NO.	LOCATION
TERRY WINDSOR, CONN., U.S.A.	
TITLE "E" EMERGENCY GOVERNOR SECTION	
PC NO.	MATERIAL
CASTING/FORGING NO.	
STANDARD PRACTICE	
SCALE 1:2	DATE 11-29-62
DRAWN G.F.D. CHECKED	APPROVED
ENGINEERING APPROVAL SIGNED	DATE
MANUFACTURING APPROVAL SIGNED	DATE
TYPE STD.	REF. DWG NO. E-3863
DRAWING NO. C 8680	SHEET 1 OF 1

C 8680

PARTS LIST: TYPE "E" EMERGENCY GOVERNOR

FILE ______ SECTION DRAWING NO. C-8680

SH. 1 OF 2

DWG NO. A-9319

ITEM NO.	NAME OF PART	TERRY PIECE NO.	MATERIAL TERRY SPEC	MATERIAL TYPE	MATERIAL GRADE	NO. PER UNIT
15	EMERGENCY HEAD LEVER PIN					
30	EMERG. & GOV. VALVE BODY					
49	GOVERNOR DISC					
75	PUSH TRIP LEVER PIN					
76	EMERG. TAPPET SPRING PIN					
81	EMERG. TAPPET SPRING BOLT					
82	BALL SOCKET 22 1/2°					
83	EMERGENCY HEAD LEVER					
84	EMERGENCY TAPPET					
85	EMERGENCY TAPPET NUT					
86	PUSH TRIP LEVER					
87	EMERGENCY HEAD BRACKET					
88	EMERGENCY TAPPET SPRING					
89	EMERGENCY WEIGHT SCREW					
90	EMERGENCY WEIGHT STOP PIN					
91	EMERGENCY GOVERNOR WEIGHT					
92	EMERGENCY WEIGHT SPRING					
93	EMERGENCY SPRING SEAT					
94	EMERGENCY ADJUSTING SCREW					
95	EMERGENCY SPRING ADJ. STUD					
96	PACKING FILLER PIECE					
97	EMERGENCY VALVE PACKING					
98	PACKING FOLLOWER					
99	EMERGENCY VAL. PACKING NUT					
100	EMERGENCY VAL. STUFF. BOX					

REV & ECN		REV & ECN	
	Retyped N.L. 11/13/75		

THE TERRY STEAM TURBINE CO.
WINDSOR, CONN., U.S.A.

DRAWN ....
TRACED ....
CHECKED ....
APPROVED ....

DWG NO. A-9319 SH. 1 OF 2

PARTS LIST: TYPE "E" EMERGENCY GOVERNOR

FILE ______ SECTION DRAWING NO. C-8680

DWG NO. A-9319 SH. 2 OF 2

ITEM NO.	NAME OF PART	TERRY PIECE NO.	MATERIAL TERRY SPEC	MATERIAL TYPE	MATERIAL GRADE	NO. Unit
102	BUTTERFLY VALVE					
103	1/4" x 7/8" SET SCREW					
104	EMERGENCY VALVE BRACKET					
105	RING BEARING SCREW					
106	EMERGENCY RESETTING LEVER					
107	5/16" x 1 1/4" SET SCREW					
108	5/16"-18 NUT					
109	EMERGENCY TRIP RING					
110	TRIP RING EXTENSION					
111	#2 P & W TAPER PIN					
112	1/8" x 1" COTTER PIN					
113	BUTTERFLY VALVE SPINDLE					
114	EMERGENCY SPRING ADJ. PLATE					
115	EMERGENCY VALVE SPRING					
116	EMERGENCY TRIP RING INSET					
117	5/16" x 3/4" FILL HD. MACHINE SCREW					
118	EMERGENCY CONNECTING ROD					
119	BALL ROD END					
121	EMERGENCY ADJ. SCREW NUT					

REV & ECN: Retyped N.L. 11/13/75

REV & ECN:

THE TERRY STEAM TURBINE CO.
WINDSOR, CONN., U.S.A.

DRAWN ....
TRACED ....
CHECKED ....

DWG NO. A-9319 SH. 2 OF 2

GOVERNOR VALVE

The Terry governor valve is a bushing type consisting of three units - a governor valve body, a valve cage and a valve.

There are several styles and materials used, depending on the particular installation; however, the method of installation and removal described in this Section applies to all styles.

The governor valve and cage are machined and ground as a unit and should be replaced as a unit.

The valve and cage can be removed from the valve body without disturbing the steam pipe connections. A strainer is installed on the valve cage to help prevent pieces of metal or other foreign matter from entering the turbine.

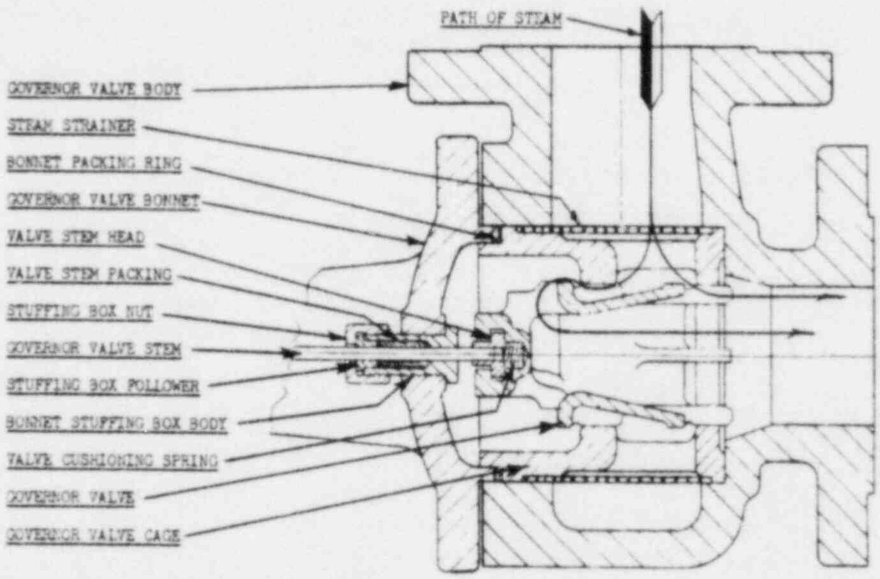


Fig. 7.

REMOVING THE GOVERNOR VALVE & CAGE Remove the governor lever and then the parts installed on the valve stem. Note the position of the valve stem seats, etc., on the stem so that the original positions may be re-established at assembly.

Loosen the valve bonnet nuts. Slide the valve bonnet off the valve body, taking care not to bend the valve stem.

Once the bonnet has been removed, the valve and stem can be removed.

A packing ring is installed in the recess at the top of the cage. The packing ring is compressed by a spigot on the valve bonnet. This serves as a seal and to hold the cage in position by compression.

Once the valve has been removed, the cage can be removed by means of a puller of some sort placed behind the upper seat.

ASSEMBLING THE GOVERNOR VALVE & CAGE From the drawing (Fig. 7) note that the valve cage seats at the bottom of a recess in the valve body. The valve body has a machined seat at this point to insure a tight joint between the valve cage and the valve body. Do not use a gasket between these faces. A coating of suitable sealing compound is sufficient to make this joint tight.

The method in which the governor valve and cage should be assembled is as follows:

1. Make certain that the cage and body faces are free from burrs and dirt, and check the seating of the cage in the body. If necessary, lap the cage into the body until a good seating surface is obtained in the valve body. Cover both faces with a coating of Copaltite or other suitable sealing compound, and install the cage in the valve body with one of the cage posts centered in the steam inlet.

2. Insert the packing ring in the recess in the valve cage.

3. Install the valve stem with T-head and cushioning spring in the valve. (On 3/4" or 1" valves, the valve stem screws into the swivel on the valve and is locked in place by a hex. nut).

4. Install the governor valve in the valve cage. Do not assemble the valve with the valve bonnet as there is danger of cramping the valve and damaging the seats.

5. Install the valve bonnet. At the same time, assemble loosely any valve stem parts which cannot be installed after the bonnet is in place. Take care not to bend the valve stem when sliding the bonnet into position. The bonnet nuts should be tightened evenly so that the spacing between the bonnet and the body is even all the way around. If the bonnet is cocked, the governor will be affected adversely. When a new packing ring has been installed, the valve bonnet nuts should be checked for tightness after the turbine has run for one hour and a further check made from time to time.

6. Re-pack the valve stem stuffing box.

7. Return all valve stem parts to their original positions, and set the governor valve travel (see below).

VALVE STEM PACKING The valve stem stuffing box should be packed with suitable packing. Too tight or hard packing may cause the valve stem to stick, resulting in a hunting or surging condition. Crane #187-I packing is installed at the factory on all steel turbines (251# - 521° F. or above).

CHECKING THE VALVE SETTING The valve setting is very important for safety. Correct valve travel is stamped on the turbine nameplate. The valve opening should not exceed the maximum travel given on this nameplate. A double seated valve should open 1/8 of its diameter. For a V-ported or piston type valve, an additional 1/8" should be allowed. On turbines with Woodward governors, refer to the Governor Log.

The valve opening is measured when the turbine is not running. First, close the valve manually until it seats and make a mark on the stem at the stuffing box nut. Then open the valve as far as the governor mechanism will allow. The distance between the mark and the stuffing box nut is the valve opening. This opening will be increased by the wear of any part of the governor mechanism and should be occasionally checked and corrected if necessary. Refer to the Section covering the governor for the proper method of adjusting valve travel for the type of governor installed.

THE GOVERNOR VALVE SPRING is for the purpose of keeping a constant load in one direction on the governor mechanism to avoid lost motion. This spring should not be used to raise the speed of the turbine.

DETECTION OF LEAK A small leak can be repaired easily, but if not properly stopped, it will get rapidly worse and become difficult to stop, and be a possible source of serious trouble. An easy way to test valve tightness is to close the valve by hand while the turbine is running. If the speed drops quickly, the valve is tight. Some indications of the valve's leaking are:

1. Speed runs up at light load with valve apparently closed.

2. Thrust bearing or ball holder heats or shows wear. This is because the governor presses very hard on the valve in effort to shut off steam.

3. Turbine is shut down by the emergency governor tripping out on light loads. This may be caused by other things, but the valve should always be checked.

If a valve leaks, the first thing to do, of course, is to stop the leak by re-grinding or re-seating the valve. If the valve has apparently not given as long service as should be expected, the cause of rapid wear should be found and removed. Some common causes are:

1. The turbine runs much of the time at light load. This will always increase the valve wear. Secure a smaller valve if your load conditions will allow. Write us fully as to the heaviest load you must carry, the ring pressure required to carry it, the actual steam pressure available at the throttle and actual exhaust pressure, and we will advise you if it is possible to use a smaller valve.

2. Wet steam is destructive to all valves which are required to throttle steam. It has been well established that there may be water even in superheated steam pipes, particularly towards the end of the lines and at times of light load. For especially severe conditions a valve of monel metal and stainless steel seats or similar material can be provided at an extra cost. While high in first

cost, valves of special metals are most economical where conditions are such as to cause rapid wear.

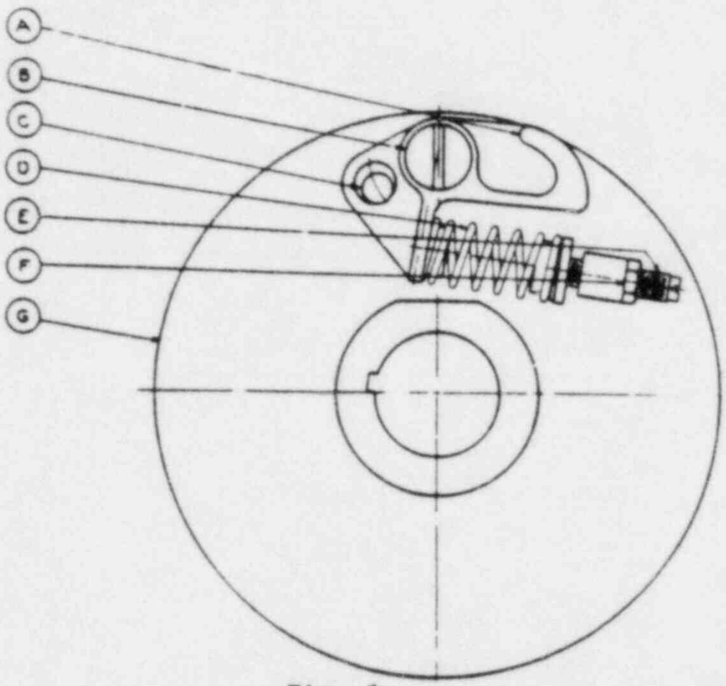
3. There are sometimes corrosive agents in the steam which will attack brass, monel metal, or machined surfaces of cast iron and steel.

If a valve is re-ground sufficiently often to keep deep scores from forming, the life of the valve will be much greater.

OVERSPEED GOVERNOR

DISC TYPE

The overspeed governor is designed so that, at a given speed, a blow is transmitted to a suitable trigger, tappet spring or tappet ball to release a spring loaded butterfly valve or some other tripping mechanism. This governor is usually set at the factory to operate at about 5 percent above the maximum no load speed.



A-Emer. Gov. Wgt.
B-Emer. Wgt. Screw
C-Emer. Wgt. Stop Pin
D-Emer. Wgt. Spring
E-Emer. Adj. Screw
F-Check Nut
G-Emer. Disc

Fig. 8

OPERATION The overspeed tripping device is mounted on the back of the main governor disc (G), Fig. 8. The weight (A) pivots about weight screw (B) and is limited in movement by stop pin (C). When the required speed is reached, centrifugal force overcomes the force of spring (D) and the weight (A) swings outward, striking a trigger, tappet spring, or ball which, in turn, trips a mechanism to close the overspeed trip valve.

The speed adjustment is made by screw (E) which controls the compression of spring (D). The screw is locked by a nut (F). Raising or lowering the trip speed is accomplished by increasing or decreasing the spring force by means of screw (E). No changes in trip speed should be attempted by changing the trigger or tappet setting.

TRIP VALVE This may be a butterfly or clapper type valve operated directly through the linkage or a trip and throttle type which would normally be actuated by means of an oil pressure trip mechanism.

For turbines having the tappet spring arrangement, refer to Fig. 10.

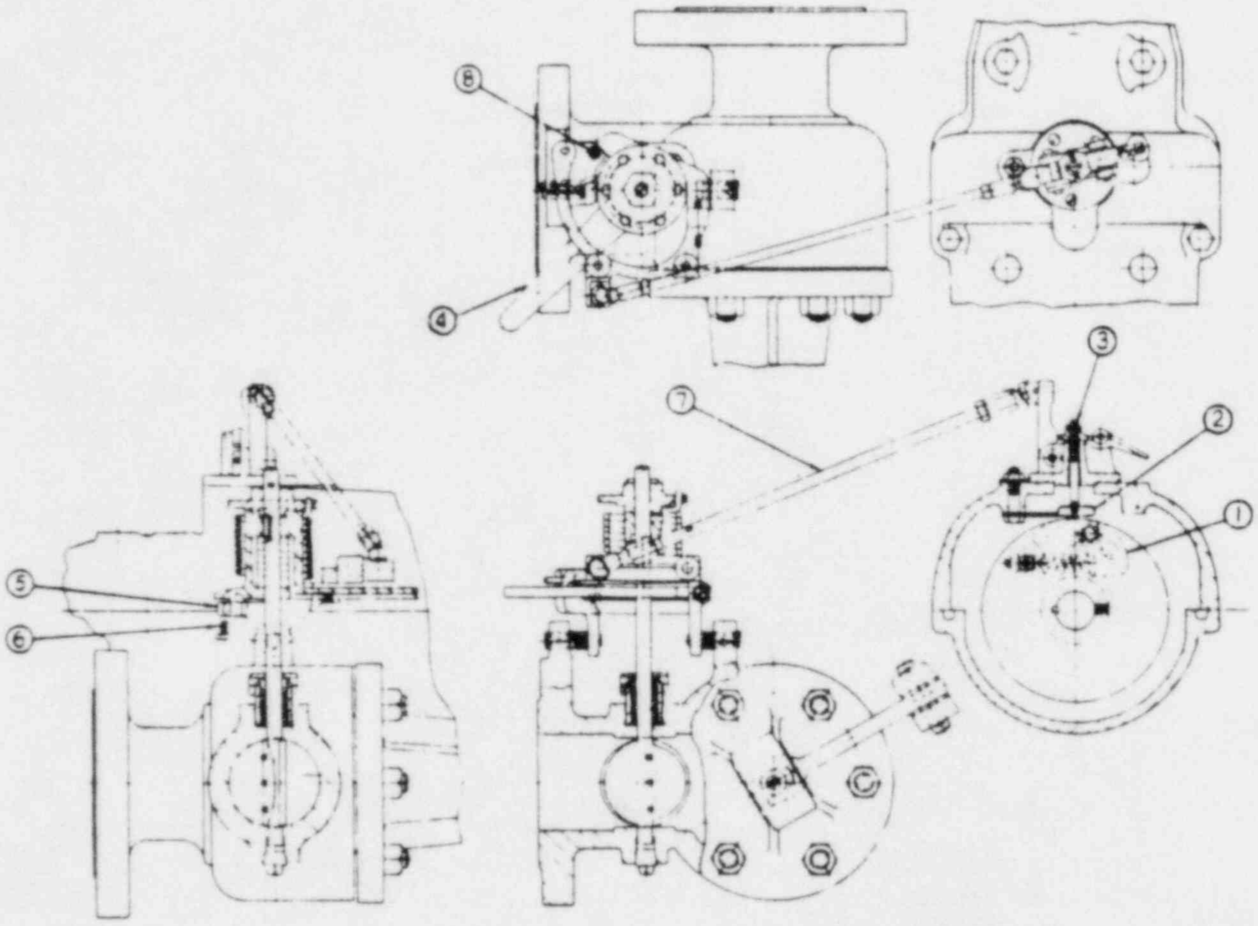


Fig. 10

OPERATION

Read instructions carefully, making sure you understand any special features and the functions of all parts.

Remove refuse, dirt and loose tools not required for operation from the turbine and its immediate vicinity.

Wipe off all slushing compound and all dust from the entire unit and make sure that all working parts are clean.

Flush out the bearings liberally with kerosene or flushing oil. Also flush any oil piping, gear cases or oil reservoirs.

If the turbine has been standing for any appreciable period or has been subjected to dirt or water, we recommend that the carbon packing rings be removed and cleaned and that the shaft and gland cases be thoroughly cleaned at the contact surfaces.

Clean the driven machine in accordance with the manufacturer's instructions.

Fill the main bearings and any other oil reservoirs, coolers, filters or gear cases. Note filling marks on the gauge glasses. The oil level should not be allowed to drop below this level. Use a good grade of turbine oil. See Section VI.

When an oil cup is provided for the governor thrust bearing, fill with the same oil as used in the main bearings. When a grease cup is provided, use a light grease.

If the coupling is of the lubricated type, fill with lubricant as per manufacturer's instructions.

Look the turbine over thoroughly before starting.

(a) Examine carefully for parts broken or bent in handling.
(b) Be sure alignment is correct (See Section III).
(c) If water cooling is supplied, check water connections.
(d) Work the governor valve by hand to be sure it works freely.

<u>STARTING</u> Having prepared the turbine for starting, open the drain valves to remove the condensate and open the exhaust valve slowly. Next, open the steam throttle valve slightly and allow the turbine to warm up. When condensate stops flowing from the drain lines, close the drain valves except for a small opening to allow condensate, which may accumulate, to escape during the starting period.

Open the throttle valve sufficiently to start the turbine rotating; then close the throttle valve enough to maintain a slow speed or a speed which will maintain some oil pressure if provided with pressure lubrication. Remove the inspection caps over the oil rings and make sure that the oil rings (when used) are turning.

On turbines where oil relay governors are provided, the oil pressure will lift the governor valve and release the starting latch at less than half speed.

Watch all bearings carefully. Undue heating on the first run may be due to dirt or faulty alignment.

If the turbine is operating condensing, do not turn on gland seal until after the unit is turning over slowly.

Open the throttle valve gradually to increase the speed, checking the speed frequently with a speed indicator; and as the turbine approaches full speed, the governor should come into action smoothly and partially close the governor valve to control the speed. When the governor apparently has control, continue to open the throttle valve slowly. This should not increase the speed. Now, fully open the throttle valve, and the turbine is ready for load.

The operation of the trip valve and the emergency governor should be tested. (See Section IX).

<u>GENERAL NOTES</u> Installations vary considerably with respect to special features; therefore, the preceeding instructions are of a general nature. If you feel that certain points are not sufficiently covered, step by step instructions for your specific unit will be furnished on request.

In an emergency, a TERRY solid wheel turbine can be brought up to speed in a few seconds. Bladed wheel turbines take longer, depending on size, speed, number of stages and the limitations of the driven machine. A quick start is made easier by keeping the turbine well drained and all parts in working condition.

Continuous, trouble-free operation with minimum attention to wearing parts is influenced by the condition of the steam and of the lubricating oil.

The ideal steam is free of moisture and other erosive and corrosive agents. Clean lubricating oil of the correct type, kept in proper condition, is essential.

Notes on the proper care of various parts will be found under suitable headings in this manual.

<u>HAND VALVES</u> For best economy, always keep as many hand valves

closed as the load conditions will allow. The hand valves are tagged to indicate their function. Hand valves should be kept fully open or fully closed.

Low steam hand valves (L.S.) should be closed when operating at normal steam conditions and should be opened only if necessary to obtain output at lower steam conditions than normal.

Overload hand valves (OL) should be closed whenever possible and opened only if load conditions require.

Partial load hand valves (P.L.) should be normally open and closed whenever load conditions permit for most economical operation.

OPERATIONAL PROBLEMS

POSSIBLE CAUSES AND REMEDIES

A steam turbine has relatively few moving parts; and, if it is properly installed and maintained, many years of dependable service with very few problems can be expected. No mechanical equipment, however, is immune to difficulty, and this Section has been prepared as a guide to the various problems which might arise as well as their possible causes and remedies.

PROBLEM	CAUSE	REMEDY
Turbine will not carry the load	* Insufficient number of hand valves open	The operator should be familiar with the proper use of hand valves and make sure the correct combinations of hand valves are open for the various loads.
* NOTE! Indicated when ring pressure equals or nearly equals inlet pressure.	* Load too great for turbine rating	If the load cannot be reduced, consult our Engineering Department - a turbine can usually be re-nozzled for a reasonable increase in power.
	* Low steam pressure at throttle, or exhaust pressure too high	Make sure the steam line is not too small, or pressure drop through the valves and fittings in the line too great. Check steam pressure at the throttle under maximum load conditions and minimum boiler pressure. Check back pressure at exhaust flange. If conditions cannot be corrected, the turbine can usually be re-nozzled to suit the actual service conditions. Consult our Engineering Department for details.
** NOTE! Indicated when ring pressure is lower than inlet pressure.	* Nozzles plugged or damaged	Open the turbine and check the nozzles. Clean or replace the nozzles as required.
	** Steam strainer is obstructed	Clean the strainer and check the source of the foreign material.
	** Governor valve does not open far enough	A double-seated governor valve should open at least 1/8 of the valve diameter when the turbine is not running. See Page VII-3.

PROBLEM	CAUSE	REMEDY
Turbine will not carry the load (Continued)	Buckets worn excessively	On TERRY solid wheels, the wheel should be replaced when the buckets show more than ¼" erosion. On bladed wheels reblade or replace the wheel when blades are worn 1/16" to 3/32".
Excessive Steam Consumption	Too many hand valves open	Too many open hand valves allow more steam than necessary to pass through the steam ring. It may cause poor governor valve control, since it forces the valve to operate too close to the seat. Check for the correct combination of hand valves.
	Nozzles and wheel worn or damaged	This affects the efficiency of the turbine adversely. The nozzles and/or turbine wheel should be replaced or repaired at the earliest possible opportunity.
	Internal steam leakage	This should be corrected promptly. Check and replace the diaphragm packing rings or repair leaking joints as soon as possible.
* Vibration *NOTE! Vibration may be transmitted from the driven machine. To localize vibration, disconnect coupling and operate turbine alone. This should help to indicate whether turbine or driven machine is causing vibration.	Misalignment with driven shaft	Check the alignment when the turbine is hot. If the turbine drives a coupled gear, and the gears run together at the top, allow for the pinion running in the top of its bearing when under load. See separate Section in this manual on alignment.
	Unbalance	Remove any foreigh matter which might have collected on the wheel. Make sure the turbine is thoroughly drained during shutdown periods in order to prevent uneven rust formations. Bad vibration might also be caused by the loss of some blades or shrouding. Replace or repair the wheel in this case.

PROBLEM	CAUSE	REMEDY
Vibration (Continued)	Rubbing	Correct the axial position of the rotor. Repair or replace the thrust bearing as required. Make sure that the driven machine cannot thrust against the turbine shaft.
	Bent shaft	The shaft should be replaced if runout at the bearing journals exceeds .0005"F.I.R. (Full Indicator Reading), and at the glands and coupling end .001" F.I.R. On single stage machines, loosen the wheel nuts to see if runout is affected. Warped wheel nuts can create runout. A bent shaft may also be caused by hot bearings (see "Bearing, Heating and Wear"), tight packing glands (see "Glands Fitted too Tightly"), or mechanical damage. Check the complete rotor. Runout at the extreme governor end of the shaft can be corrected by striking the high spot sharply with a soft hammer until runout is reduced to less than .001" F.I.R. (Insert an arbor in the end of the shaft if turbine has flyball governor).
	Loose wheels	This is extremely unusual, but may be caused by a runaway. Replace the wheel, and also the shaft if necessary.
	Worn coupling	Replace the coupling. Be sure that lubricated couplings are kept well lubricated per the manufacturer's recommendations.
	Bearings worn excessively	Replace worn bearings. Re-babbiting is NOT recommended, since possible distortion of bearing shell in rebabbiting process will prevent re-machining the bearing so that the bore and O.D. are concentric.
	Bearings loose in bridges	Uncommon, but may be caused by excessive vibration for a prolonged period. Contact the factory for recommendations on the best method of correction for the particular turbine involved.

PROBLEM	CAUSE	REMEDY
Vibration (Continued)	Glands fitted too tightly	Tight carbon rings may cause vibration and overheating. Tight labyrihth rings will damage the turbine shaft. Carbon rings should be replaced.
Excessive Gland Leakage	Broken or badly worn carbon rings	Replace with new carbon rings. The carbon rings should have a slight clearance on the turbine shaft when the unit is cold, since carbon expands much less than steel when heated.
	Carbon rings fouled by dirt, or scale carried over by steam	The carbon rings should be free to float axially, and the downstream face of the carbon rings must seat perfectly against the smooth, true and clean surface in the gland case.
	Gland drain line not freely open	Be sure that the gland leak-off line cannot trap water and cause back pressure.
	Excessive back pressure	Packing cases are designed for a predetermined back pressure. Excessive back pressure causes leakage, which is a common cause of water in the lubricating oil. Correct back pressure according to design conditions.
	Excessive compound in the carbon rings	When replacing the carbon rings, use joint seal compound carefully. Excessive compound may foul the carbon rings and the surfaces against which they float.
Bearing, Heating and Wear	Use of improper oil	Oil must be clean and of the proper viscosity. Refer to the Section on Lubrication in this manual.

PROBLEM	CAUSE	REMEDY
Bearing, Heating & Wear (Continued)	Water coolers provided not used; cooling water too hot	This may cause a breakdown of the oil. It also will cause the thrust bearing and main bearings to overheat excessively. Each unit may have different cooling water requirements. Oil should leave the cooler at not less than 110° F. in forced feed units, with the cooling water adjusted to give the proper temperature to the oil.
	Water in the oil	This may be the result of gland leakage, cooler leakage, or condensation from the atmosphere. To minimize condensation from the atmosphere, shut off water from the oil cooler after shutting the unit down. This should be done as soon as the turbine casing has cooled enough so excessive heat will not be transferred to the bearings. Occasionally check oil reservoirs for water and drain off any present.
	Misalignment	This is a common cause of excessive bearing wear. The babbitt may be cracked or broken loose as a result of pounding from a misaligned shaft. Alignment should be corrected as soon as possible. See the Section on Alignment in this manual.
	Unbalance	This is often due to deposits on buckets or wheels. In some cases, although rare, it is caused by the loss of one or more buckets or a piece of shroud. Inspect and clean the rotating element.
	Rough journal surface	Journals can be stoned if not too seriously roughened. In extreme cases the shaft should be replaced.
	Thrust from driven shaft transmitted through coupling	Proper distance must be maintained between ends of the shaft and the driven unit. Check this distance and make sure the coupling is free to move laterally. The coupling can become full of dirt or sludge and not be free to move laterally.

PROBLEM	CAUSE	REMEDY
Bearing, Heating & Wear (Continued)	Compression in valve stem spring excessive.	The compression on the valve stem spring must be sufficient to hold the governor lever firmly against the governor spindle connection under all conditions. Avoid any unnecessary loading on this spring as this would impose excessive load on the thrust bearing.
	Flyball governor trying to close leaking or stuck governor valve	Leaking or stuck governor valves should be corrected as they constitute a safety hazard, besides being detrimental to the thrust bearing. Excessive wear is also imposed on the governor ball thrust bearing.
	Heavy slugs of water in the steam	This condition can be avoided through proper boiler control. Damage to thrust bearings, diaphragms and to wheels will result from water slugs.
	Rough or untrue thrust collars	Rough or untrue thrust collars and space collars on single-stage turbines may cause rapid wear on the thrust facings of the sleeve bearings. This could eventually increase thrust clearance to a point where the turbine wheels rub. Rough or untrue collars should be replaced or repaired at the first opportunity.
Units do not stay in alignment	No provision for exhaust pipe stresses	A good expansion joint and proper pipe supports are needed. There should be no severe stresses on the exhaust casing.
	Excessive steam pipe stresses	The outline drawings and instruction manual warn against pipe stresses. These can be overcome by the use of proper pipe supports and hangers, and the use of loops or bends in the steam line. An expansion joint should be provided for the exhaust line adjacent to the turbine.

PROBLEM	CAUSE	REMEDY
Units do not stay in alignment (Continued)	Foundations of driver and driven machine move	If the turbine and the driven unit are on separate foundations, any movement will cause misalignment. If foundations are not adequate to hold both units, a concrete cap should be poured over both to assure operation on a similar plane.
	Baseplates exposed to heat from steam pipes	The distortion caused by excessive heat on the baseplate may cause misalignment. Pipes should be insulated or relocated away from baseplates.
GOVERNOR: Speed drops too much with load	(See also causes under "Turbine will not carry the load").	
	Governor valve linkage damaged or out of adjustment; valve sticking	Governor valve and linkage must be adjusted so that the valve is wide open when the governor is open. The governor must have safety travel in the closing direction to insure the valve being completely closed. Sticking of valve linkage must be eliminated to assure free movement both in opening and in closing.
Speed rises excessively with loss of load	Leaky governor valve, or leak near governor valve	This situation should be corrected by replacing or repairing the governor valve and cage; otherwise the turbine will continue to receive steam even with the governor in closed position.
	Governor responds slowly due to worn parts or sticking	Free the sticking valve and inspect all pivot points in the governor linkage for signs of sticking or binding or excessive wear.
	Governor does not fully close the governor valve	Adjust the linkage.

PROBLEM	CAUSE	REMEDY
Hunting	Sticking or excessive friction in governor, valve or valve stem	This is generally due to dirt, wear, or mechanical damage. Clean and repair or replace any parts which cause this trouble. The valve stem stuffing box may be packed too tightly.
	Lost motion so governor valve does not follow motion of the governor	This usually is the result of excessive wear at the pivot points in the linkage. Replace worn parts as might be required.
	Governor knife edges worn	These must be replaced if badly worn. There is no effective repair for these parts.
	Governor thrust bearing not accurately aligned with shaft	This situation will cause failure of the governor slide and will also damage the thrust bearing itself. The ball thrust bearing must be concentric with the bore in the turbine shaft. This can be checked by inserting a tight plug in the shaft bore and indicating the bore of the governor housing end.
Slow response	(Same causes as Hunting)	
	Turbine carrying very heavy load, little reserve power	Open the necessary hand valves to increase the horsepower. If the load is too great for the design turbine rating, consult our Engineering Department for possibly renozzling your turbine for a greater horsepower rating.
Trip valve not properly functioning	Improper adjustment or poor condition of tripping mechanism, springs or latches	The overspeed governor should be tested frequently. To test, trip the overspeed mechanism by hand or by overspeeding. Make sure the trip valve closes promptly.

PROBLEM	CAUSE	REMEDY
Trip valves (Continued)	Excessive friction in Emergency valve packing. Scaling, wear, or mechanical damages to emergency valve	These serious faults should be corrected by cleaning, repairing or replacing the parts so that this important safety device can operate effictively.
Overspeed governor not functioning properly	Governor does not trip at or near proper speed	Remove the governor housing and examine the overspeed governor. Make sure that it is clean and in good order, and that the emergency weight can be moved easily and freely by a small screw-driver or similar tool. Make sure the overspeed trip lever clears the trip lever by about .060" when the turbine shaft is rotated. Reassemble with the governor housing and all parts. Test the unit by actually overspeeding. If it still does not trip at the proper speed, adjust the setting of the emergency governor as required. If low oil pressure trips, solenoid trips, high back pressure trips, or similar devices are provided, check them at the same time.

When writing to The Terry Steam Turbine Company with regard to the power or steam consumption of the turbine, please include as much of the following information as possible.

Take readings with the turbine running under load as follows:

(a) Steam pressure in the line at the turbine inlet.
(b) Superheat or quality of the steam.
(c) Steam pressure in the steam ring, or steam chest.
(d) Number and position of hand valves opened or closed.
(e) R.P.M. of the turbine.
(f) Back pressure at the turbine exhaust.

IMPORTANT! PLEASE BE SURE TO INCLUDE THE TURBINE SERIAL NUMBER WHEN WRITING ABOUT THE TURBINE OR WHEN ORDERING PARTS!

L U B R I C A T I O N

The tabulation below indicates the recommended oil viscosities for various arrangements and operating temperatures. Oil conforming to these specifications should give satisfactory service. It should be noted, however, that the tabulation merely covers the viscosity range for a given temperature and does not specify those qualities which enable an oil to give long life and trouble-free service. Refiners have devoted years of research to the subject of turbine oils and know what qualities are necessary for best results. We therefore recommend the use of an oil backed by a reputable refiner and designed especially for turbine and gear lubrication.

Steam turbine bearings receive considerable heat from the steam in the turbine casing. Bearing temperatures run much higher than on other types of equipment where most of the heat is due to bearing friction.

In connection with turbines and gears with a common lubrication system, the oil should be selected to suit the gear.

Ring Lubrication

Operating Temperature of Oil in Bearing	Viscosity SSU at 100° F.
Up to 200° F.	225 to 300
Over 200° F.	400 to 580

Forced Feed Lubrication

Without Reduction Gear	150 to 160
With Reduction Gear	
Up to 180° F.	250 to 350
Over 180° F.	400 to 580

SECTION VII

GOVERNOR VALVE

The Terry governor valve is a bushing type consisting of three units - a governor valve body, a valve cage and a valve.

There are several styles and materials used, depending on the particular installation; however, the method of installation and removal described in this Section applies to all styles.

The governor valve and cage are machined and ground as a unit and should be replaced as a unit.

The valve and cage can be removed from the valve body without disturbing the steam pipe connections. A strainer is installed on the valve cage to help prevent pieces of metal or other foreign matter from entering the turbine.

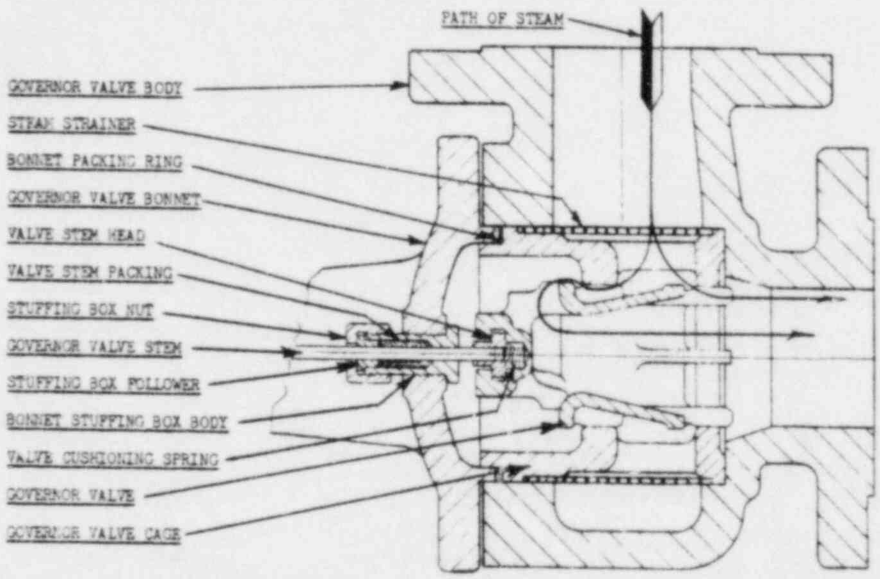


Fig. 7.

REMOVING THE GOVERNOR VALVE & CAGE Remove the governor lever and then the parts installed on the valve stem. Note the position of the valve stem seats, etc., on the stem so that the original positions may be re-established at assembly.

Loosen the valve bonnet nuts. Slide the valve bonnet off the valve body, taking care not to bend the valve stem.

Once the bonnet has been removed, the valve and stem can be removed.

A packing ring is installed in the recess at the top of the cage. The packing ring is compressed by a spigot on the valve bonnet. This serves as a seal and to hold the cage in position by compression.

Once the valve has been removed, the cage can be removed by means of a puller of some sort placed behind the upper seat.

ASSEMBLING THE GOVERNOR VALVE & CAGE From the drawing (Fig. 7) note that the valve cage seats at the bottom of a recess in the valve body. The valve body has a machined seat at this point to insure a tight joint between the valve cage and the valve body. Do not use a gasket between these faces. A coating of suitable sealing compound is sufficient to make this joint tight.

The method in which the governor valve and cage should be assembled is as follows:

1. Make certain that the cage and body faces are free from burrs and dirt, and check the seating of the cage in the body. If necessary, lap the cage into the body until a good seating surface is obtained in the valve body. Cover both faces with a coating of Copaltite or other suitable sealing compound, and install the cage in the valve body with one of the cage posts centered in the steam inlet.

2. Insert the packing ring in the recess in the valve cage.

3. Install the valve stem with T-head and cushioning spring in the valve. (On 3/4" or 1" valves, the valve stem screws into the swivel on the valve and is locked in place by a hex. nut).

4. Install the governor valve in the valve cage. Do not assemble the valve with the valve bonnet as there is danger of cramping the valve and damaging the seats.

5. Install the valve bonnet. At the same time, assemble loosely any valve stem parts which cannot be installed after the bonnet is in place. Take care not to bend the valve stem when sliding the bonnet into position. The bonnet nuts should be tightened evenly so that the spacing between the bonnet and the body is even all the way around. If the bonnet is cocked, the governor will be affected adversely. When a new packing ring has been installed, the valve bonnet nuts should be checked for tightness after the turbine has run for one hour and a further check made from time to time.

6. Re-pack the valve stem stuffing box.

7. Return all valve stem parts to their original positions, and set the governor valve travel (see below).

VALVE STEM PACKING The valve stem stuffing box should be packed with suitable packing. Too tight or hard packing may cause the valve stem to stick, resulting in a hunting or surging condition. Crane #187-I packing is installed at the factory on all steel turbines (251# - 521° F. or above).

CHECKING THE VALVE SETTING The valve setting is very important for safety. Correct valve travel is stamped on the turbine nameplate. The valve opening should not exceed the maximum travel given on this nameplate. A double seated valve should open 1/8 of its diameter. For a V-ported or piston type valve, an additional 1/8" should be allowed. On turbines with Woodward governors, refer to the Governor Log.

The valve opening is measured when the turbine is not running. First, close the valve manually until it seats and make a mark on the stem at the stuffing box nut. Then open the valve as far as the governor mechanism will allow. The distance between the mark and the stuffing box nut is the valve opening. This opening will be increased by the wear of any part of the governor mechanism and should be occasionally checked and corrected if necessary. Refer to the Section covering the governor for the proper method of adjusting valve travel for the type of governor installed.

THE GOVERNOR VALVE SPRING is for the purpose of keeping a constant load in one direction on the governor mechanism to avoid lost motion. This spring should not be used to raise the speed of the turbine.

DETECTION OF LEAK A small leak can be repaired easily, but if not properly stopped, it will get rapidly worse and become difficult to stop, and be a possible source of serious trouble. An easy way to test valve tightness is to close the valve by hand while the turbine is running. If the speed drops quickly, the valve is tight. Some indications of the valve's leaking are:

1. Speed runs up at light load with valve apparently closed.

2. Thrust bearing or ball holder heats or shows wear. This is because the governor presses very hard on the valve in effort to shut off steam.

3. Turbine is shut down by the emergency governor tripping out on light loads. This may be caused by other things, but the valve should always be checked.

If a valve leaks, the first thing to do, of course, is to stop the leak by re-grinding or re-seating the valve. If the valve has apparently not given as long service as should be expected, the cause of rapid wear should be found and removed. Some common causes are:

1. The turbine runs much of the time at light load. This will always increase the valve wear. Secure a smaller valve if your load conditions will allow. Write us fully as to the heaviest load you must carry, the ring pressure required to carry it, the actual steam pressure available at the throttle and actual exhaust pressure, and we will advise you if it is possible to use a smaller valve.

2. Wet steam is destructive to all valves which are required to throttle steam. It has been well established that there may be water even in superheated steam pipes, particularly towards the end of the lines and at times of light load. For especially severe conditions a valve of monel metal and stainless steel seats or similar material can be provided at an extra cost. While high in first

cost, valves of special metals are most economical where conditions are such as to cause rapid wear.

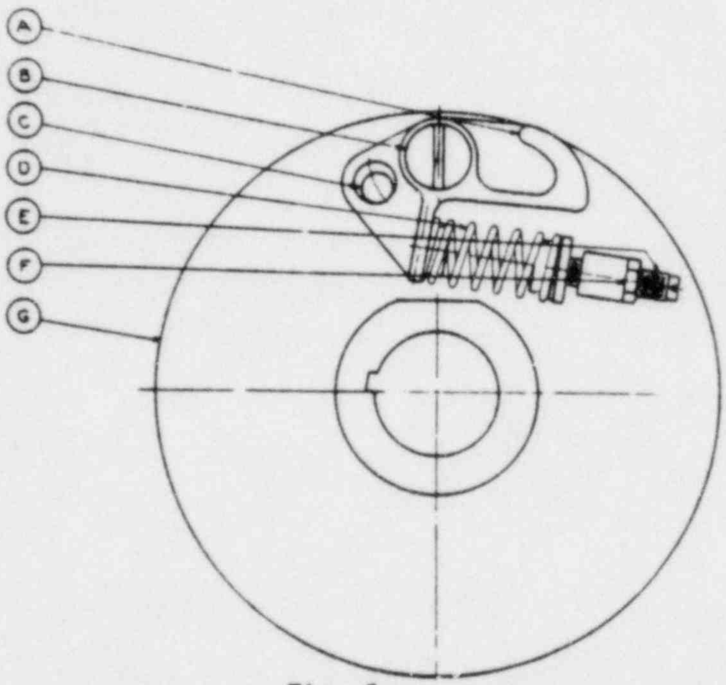
3. There are sometimes corrosive agents in the steam which will attack brass, monel metal, or machined surfaces of cast iron and steel.

If a valve is re-ground sufficiently often to keep deep scores from forming, the life of the valve will be much greater.

OVERSPEED GOVERNOR

DISC TYPE

The overspeed governor is designed so that, at a given speed, a blow is transmitted to a suitable trigger, tappet spring or tappet ball to release a spring loaded butterfly valve or some other tripping mechanism. This governor is usually set at the factory to operate at about 5 percent above the maximum no load speed.



A-Emer. Gov. Wgt.
B-Emer. Wgt. Screw
C-Emer. Wgt. Stop Pin
D-Emer. Wgt. Spring
E-Emer. Adj. Screw
F-Check Nut
G-Emer. Disc

Fig. 8

OPERATION The overspeed tripping device is mounted on the back of the main governor disc (G), Fig. 8. The weight (A) pivots about weight screw (B) and is limited in movement by stop pin (C). When the required speed is reached, centrifugal force overcomes the force of spring (D) and the weight (A) swings outward, striking a trigger, tappet spring, or ball which, in turn, trips a mechanism to close the overspeed trip valve.

The speed adjustment is made by screw (E) which controls the compression of spring (D). The screw is locked by a nut (F). Raising or lowering the trip speed is accomplished by increasing or decreasing the spring force by means of screw (E). No changes in trip speed should be attempted by changing the trigger or tappet setting.

TRIP VALVE This may be a butterfly or clapper type valve operated directly through the linkage or a trip and throttle type which would normally be actuated by means of an oil pressure trip mechanism.

For turbines having the tappet spring arrangement, refer to Fig. 10.

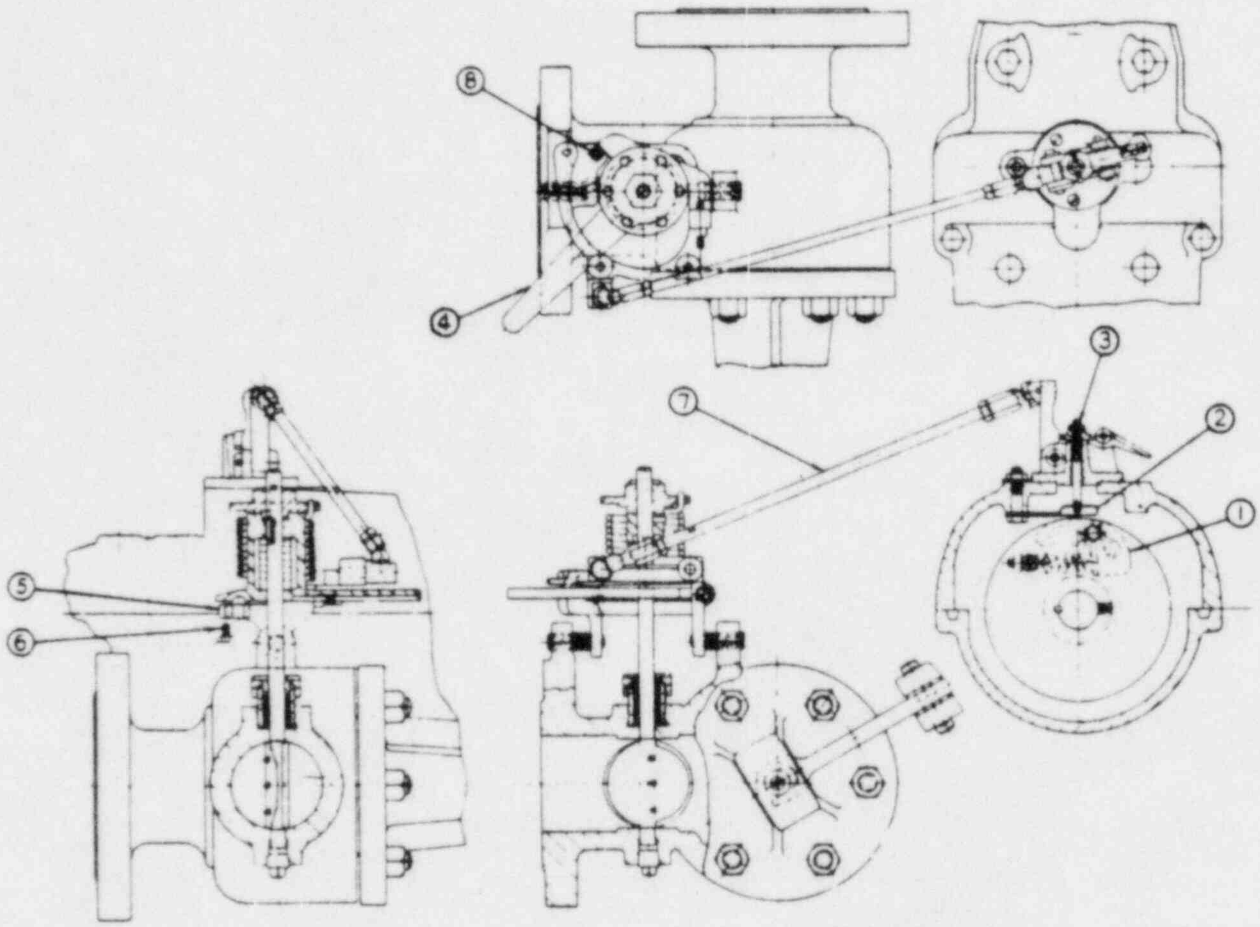


Fig. 10

The adjustment between overspeed weight (1) and tappet spring (2) is obtained as follows:

1. Rotate the turbine at a very low speed. Remove cotter pin installed ir tappet (3). Insert a screw driver in the slot at the top of tappet (3).

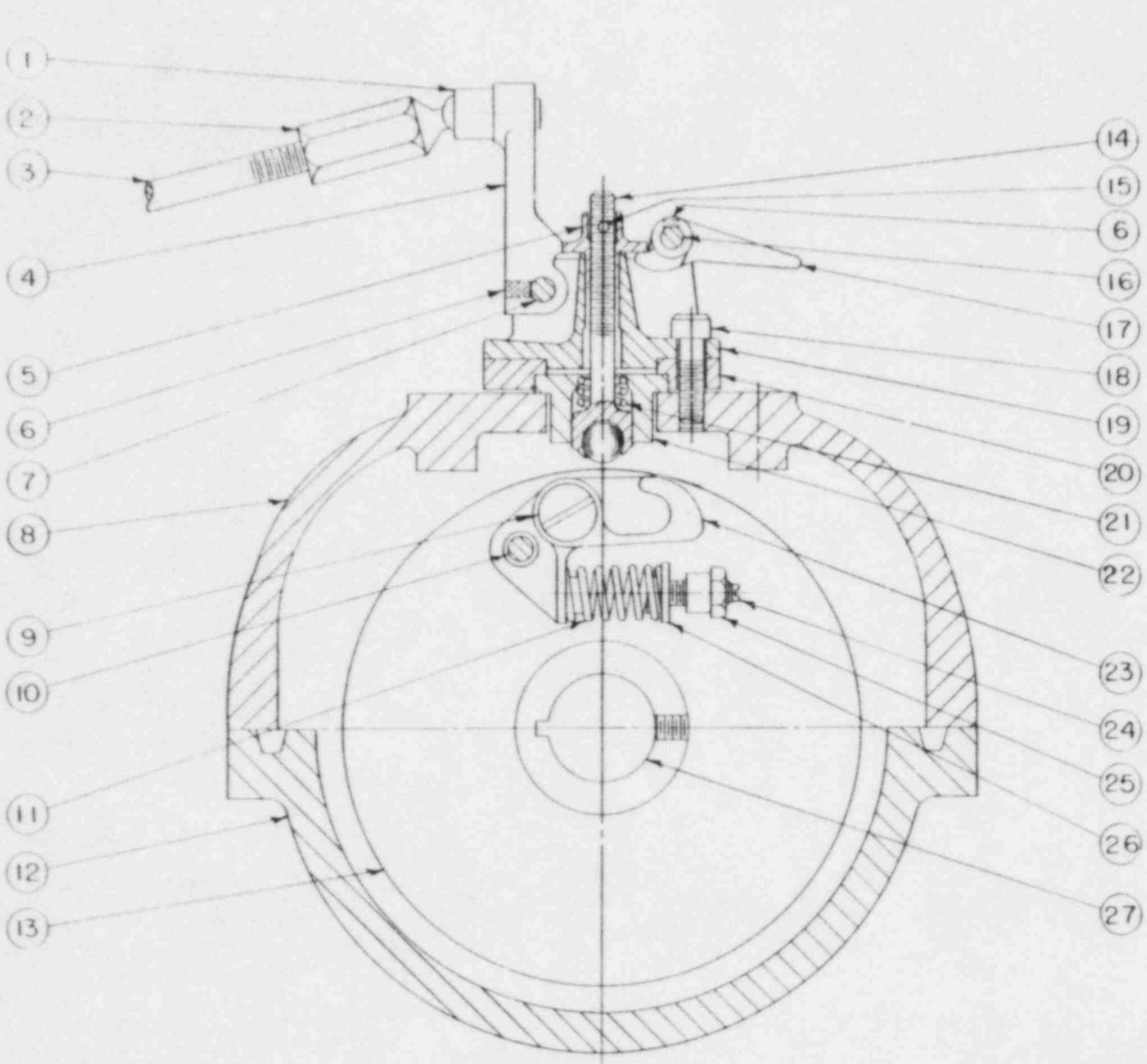
2. Screw down on tappet (3) until tappet spring (2) just contacts overspeed weight (1). Then unscrew tappet (3) one and one-half turns.

3. Insert cotter pin, and the adjustment is complete with the clearance between weight (1) and tappet spring (2) about 1/16".

CAUTION! When adjustment is made, be sure that the slot in the end of the tappet is parallel with the centerline of the turbine shaft. This aligns the tappet spring pins in the same way and prevents the pins from interfering with the operation of the tappet spring.

On turbines using the ball-type tappet, refer to separate instructions.

NOTE: When the turbine is first placed in service, check the linkage, after turbine has reached its operating temperature, to make certain that the resetting lever (4) is latched about 1/16" on insert (8) with about 1/16" between trip ring (5) and stop pin (6). If these measurements are not found to be correct, the linkage should be changed by lengthening or shortening connecting rod (7).



NO.	NAME OF PART
1	BALL SOCKET
2	BALL ROD END
3	CONNECTING ROD
4	EMERG. HEAD LEVER
5	EMERG. TAPPET NUT
6	#10-32 SET SCREW
7	HEAD LEVER PIN
8	GOVERNOR HOUSING
9	EMERG. GOV. WEIGHT SCREW
10	EMERG. GOV. WEIGHT STOP PIN
11	EMERG. WEIGHT SPRING
12	WHEEL CASE L.H.
13	EMERG. GOV. DISC
14	TAPPET & BALL
15	3/32 X 3/4 COTTER PIN
16	TRIP LEVER PIN
17	TRIP LEVER
18	5/16 X 1" CAP SCR. SOC. HEAD
19	HEAD BRACKET
20	SPACE COLLAR
21	COMP. SPRING
22	EMERG. TAPPET GUIDE
23	EMERG. GOV. WEIGHT
24	EMERG. SPRING ADJ. STUD
25	JAM NUT
26	EMERG. SPRING SEAT
27	WHEEL SHAFT

DISC TYPE EMERG. ASSEMBLY.
USING BALL TYPE TAPPET.
USED WITH BUTTERFLY VALVE
OR CLAPPER VALVE.

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
TOLERANCE ON FRACTIONS FOR MACHINED SURFACES
INSIDE MACHINED CORNERS TO HAVE A RADIUS OF 3/64
OUT OF ROUNDNESS, ECCENTRICITY OR UNINTENTIONAL TAPER TO BE WITHIN THE DIAMETRAL TOLERANCE SPECIFIED

FILE

TYPE- TYPICAL

ASSEM OF DISC TYPE EMERG

SCALE FULL SIZE DATE 9-6-62

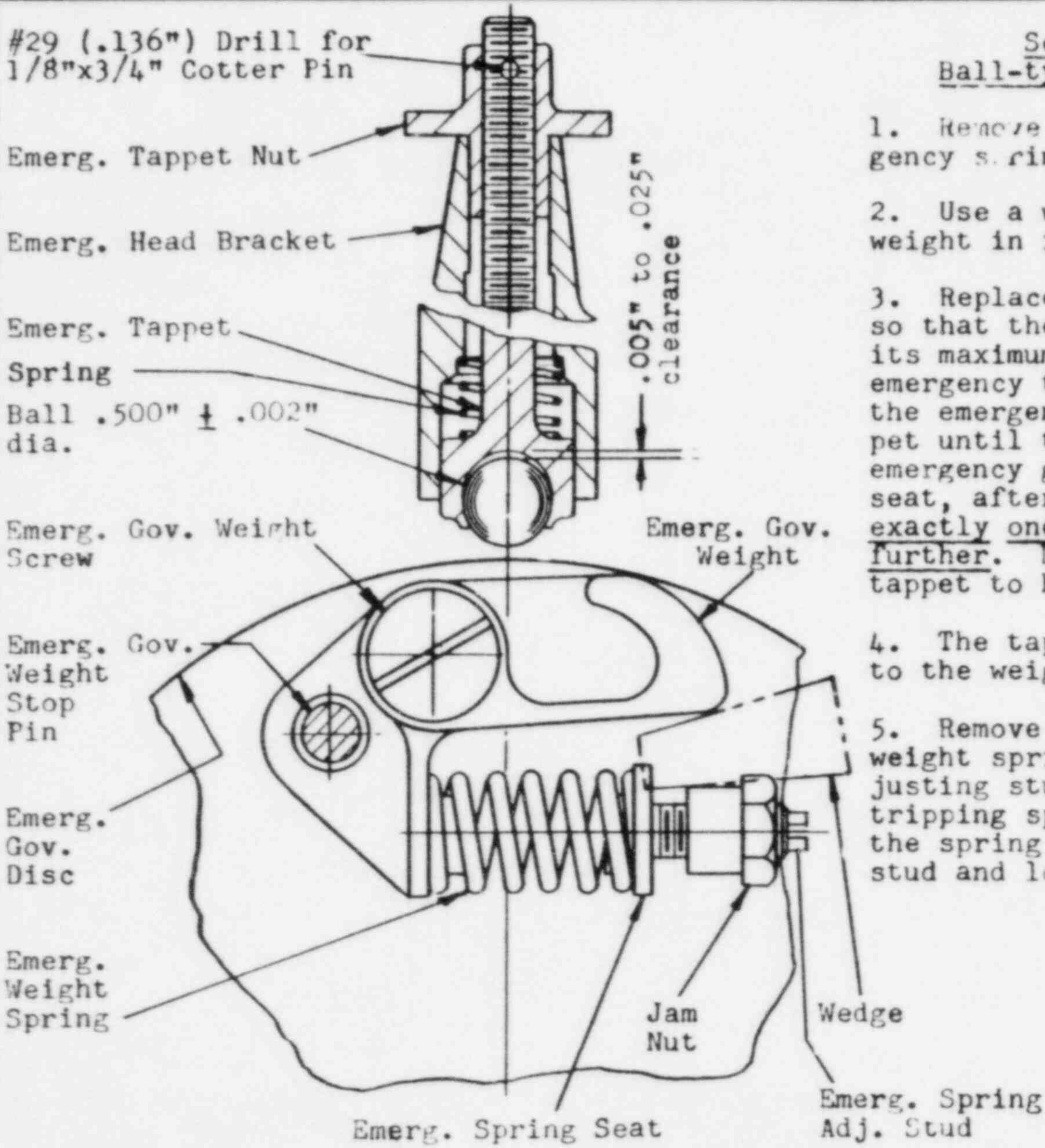
THE TERRY STEAM TURBINE CO.
HARTFORD CONN. U.S.A.

DRAWN T. BIANCHI
TRACED
CHECKED
APPROVED

C-8655

C-8655

REF DWG C-8634



Setting Disc-Type Emergency with Ball-type Tappet During Turbine Shut-down

1. Remove the emergency weight spring, emergency spring seat and jam nut.

2. Use a wedge to block the emergency governor weight in its maximum outward position.

3. Replace the bearing cap and rotate the shaft so that the emergency governor weight presents its maximum height to the ball tappet. With the emergency tappet nut held down firmly against the emergency head bracket, screw down the tappet until the ball is just held between the emergency governor weight and the top of ball seat, after which, <u>screw the ball tappet down exactly one turn</u>. <u>Do not screw tappet any further</u>. Drill and install a cotter pin in the tappet to hold this setting.

4. The tappet is now properly set with respect to the weight.

5. Remove the wedge and reinstall the emergency weight spring, spring seat, emergency spring adjusting stud and jam nut. Obtain the proper tripping speed by adjusting the compression on the spring with the emergency spring adjusting stud and lock by means of the jam nut.

FIRST USED ON FILE

TYPE- Disc-type emerg. setting for ball type emergency

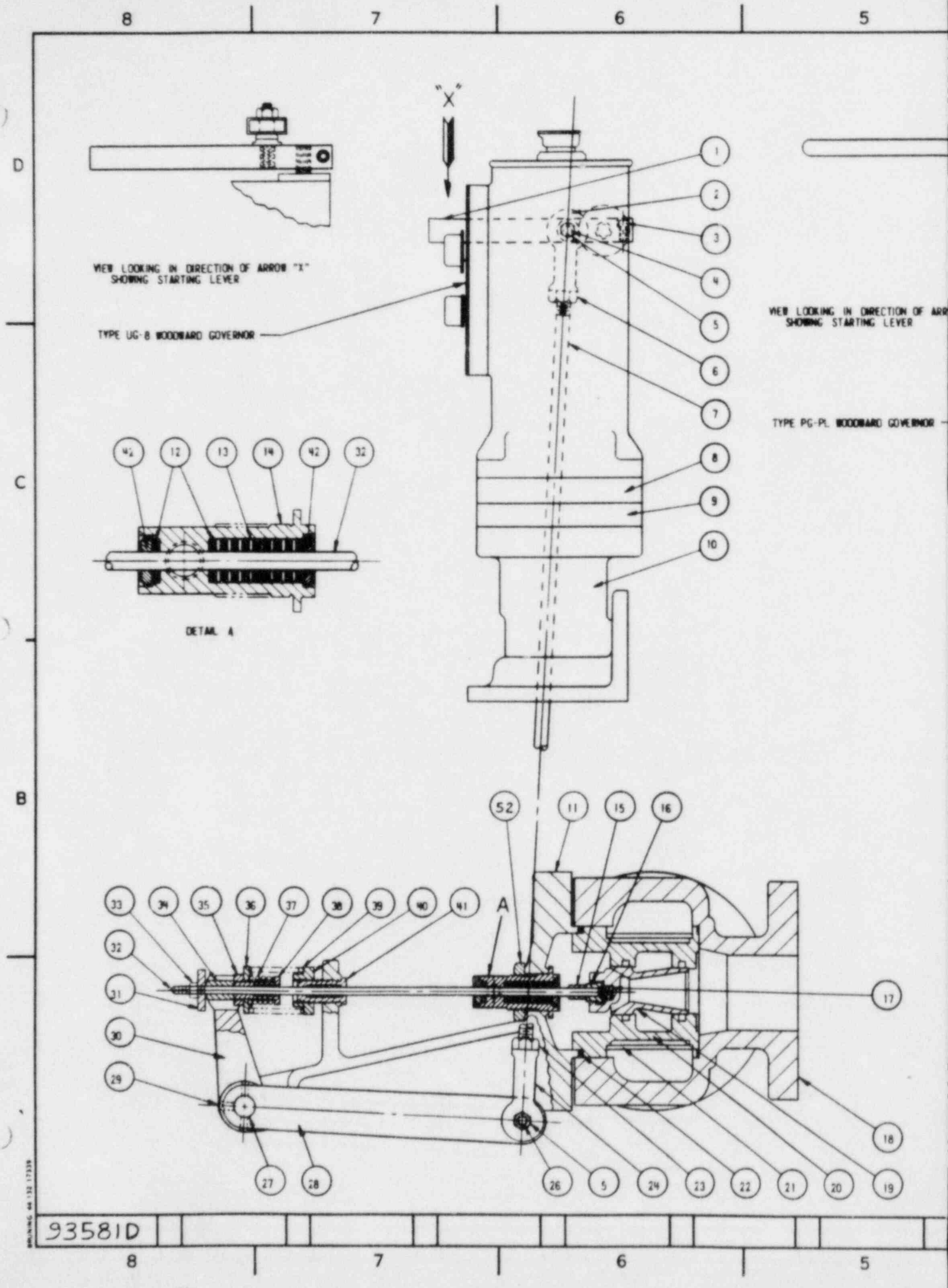
SCALE Full size DATE

THE TERRY STEAM TURBINE CO.
HARTFORD, CONN., U. S. A.

DRAWN L.A.R.
TRACED
CHECKED C.A.S.
APPROVED

A- 8348 A

A- 8348



"X"
VIEW LOOKING IN DIRECTION OF ARROW "X"
SHOWING STARTING LEVER
TYPE UG-8 WOODWARD GOVERNOR
VIEW LOOKING IN DIRECTION OF ARR
SHOWING STARTING LEVER
TYPE PG-PL WOODWARD GOVERNOR
DETAIL A
A
1
2
3
4
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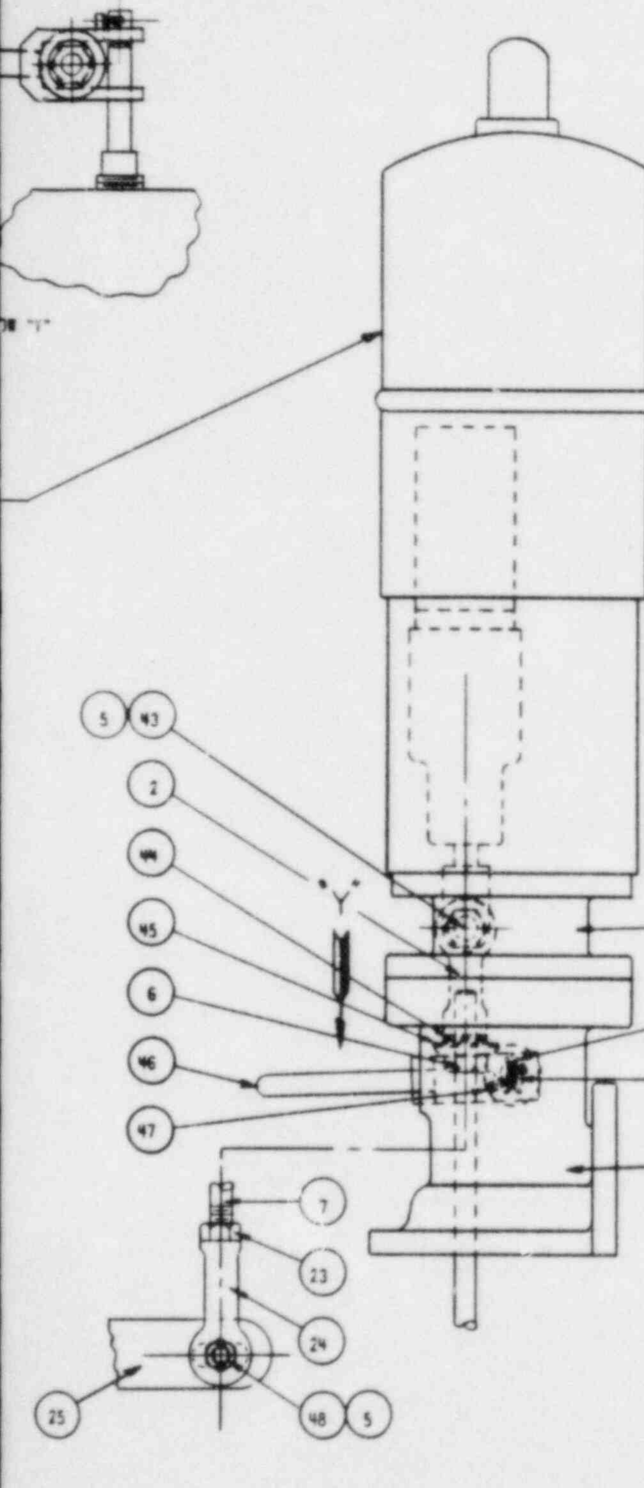
1 19 HR



PART NO		NAME OF PART
935810	1	TERMINAL SHAFT LEVER
935810	2	HEIM UNIBAL HF 8
935810	3	ALLEN CONE PT SET SCREW
935810	4	EXTENSION PIN
935810	5	#2"*A 616 FLEXLOC LOCKNUT
935810	6	HEX NUT R H
935810	7	CONNECTING ROD
935810	8	TYPE UG 8 WOODWARD GOVERNOR
935810	9	WOODWARD GOVERNOR ADAPTER
935810	10	PUMP BRACKET CAP
935810	11	GOVERNOR VALVE BONNET
935810	12	CARBON SPACER
935810	13	SPACER
935810	14	BONNET BUSHING
935810	15	VALVE STEM SPACER
935810	16	VALVE STEM HEAD
935810	17	VALVE CUSHIONING SPRING
935810	18	VALVE BODY
935810	19	GOVERNOR VALVE
935810	20	GOVERNOR VALVE CAGE
935810	21	STEAM STRAINER
935810	22	BONNET PACKING RING
935810	23	HEX NUT (L H)
935810	24	HEIM UNIBAL HFL 8
935810	25	GOVERNOR LEVER
935810	26	EXTENSI ON PIN
935810	27	PIN
935810	28	GOVERNOR LEVER
935810	29	#3 P & W TAPER PIN
935810	30	GOVERNOR VALVE LEVER
935810	31	VALVE STEM SEAT UPPER
935810	32	VALVE STEM
935810	33	5/16" 24 HEX NUT
935810	34	VALVE LEVER SPACER
935810	35	SPRI NG HOLDER NUT
935810	36	VALVE SPRING SEAT UPPER
935810	37	VALVE STEM SPRING
935810	38	VALVE STEM SPRING HOLDER
935810	39	GOVERNOR VALVE SPRING
935810	40	VALVE SPRING SEAT ADJ
935810	41	VALVE STEM GUIDE
935810	42	GUIDE BUSHING
935810	43	PIN
935810	44	WASHER (1/16"X5/8" D X 1"O/D)
935810	45	WASHER
935810	46	STARTING LEVER
935810	47	SET SCREW (¼ 20X3/4")
935810	48	PIN
935810	49	TYPE PG PL WOODWARD GOVERNOR
935810	50	COTTER PIN (3/32"X3/4")
935810	51	STARTI NG LEVER PIN
935810	52	NUT

Also Available On Aperture Card

TI APERTURE CARD

INFORMATION ONLY

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

8507300089 - 02

FILE STANDARD

TYPE- TYPICAL HOR VALVE ASSEM

USED WITH WOODWARD GOV'S

SCALE HALF SIZE DATE 6/19/73

THE TERRY STEAM TURBINE Co
WINDSOR CONN U S A

DRAWN
TRACED
CHECKED
APPROVED

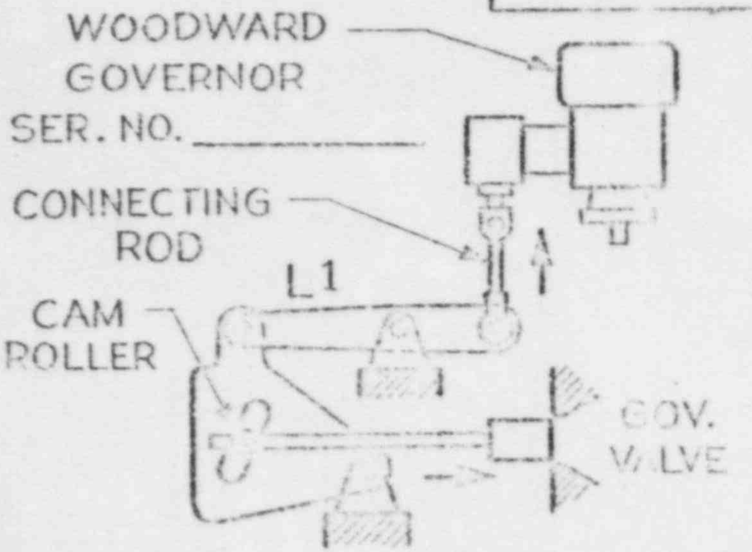
93581D

GOVERNOR SETTING WITH WOODWARD GOVERNOR - CAM OPERATED

TURBINE NO. 38686 TYPE GS FILE 38686 H.P. 800 R.P.M. 3600

VALVE SIZE 3" VENTURI | DRIVE GEAR RATIO 3:1 | EMERG. TRIP SPEED 4500

HIGH SPEED STOP SET AT 3600 TURB. RPM & 1200 GOV. RPM



	CALCULATED VALVE OPENING	TURB. R.P.M.	AIR PRESS.	WOODWARD GOV. R.P.M.
MAX. OPER.	.600	3600	—	1200
NORMAL HIGH		3600		1200
NORMAL LOW		1125	—	375

1. WITH VALVE 5/16 OPEN, SET LEVER L1 HORIZONTAL. CAM PLATE SHOULD BE IN MID-POSITION.
2. WITH VALVE CLOSED, ADJUST CAM ROLLER ON STEM SO THAT IT IS JUST 1/16" OFF OF BOTTOM STOP.
3. ADJUST CONNECTING ROD SO THAT WOODWARD SERVO IS IN MID-STROKE POSITION.

NOTES:

INFORMATION ONLY

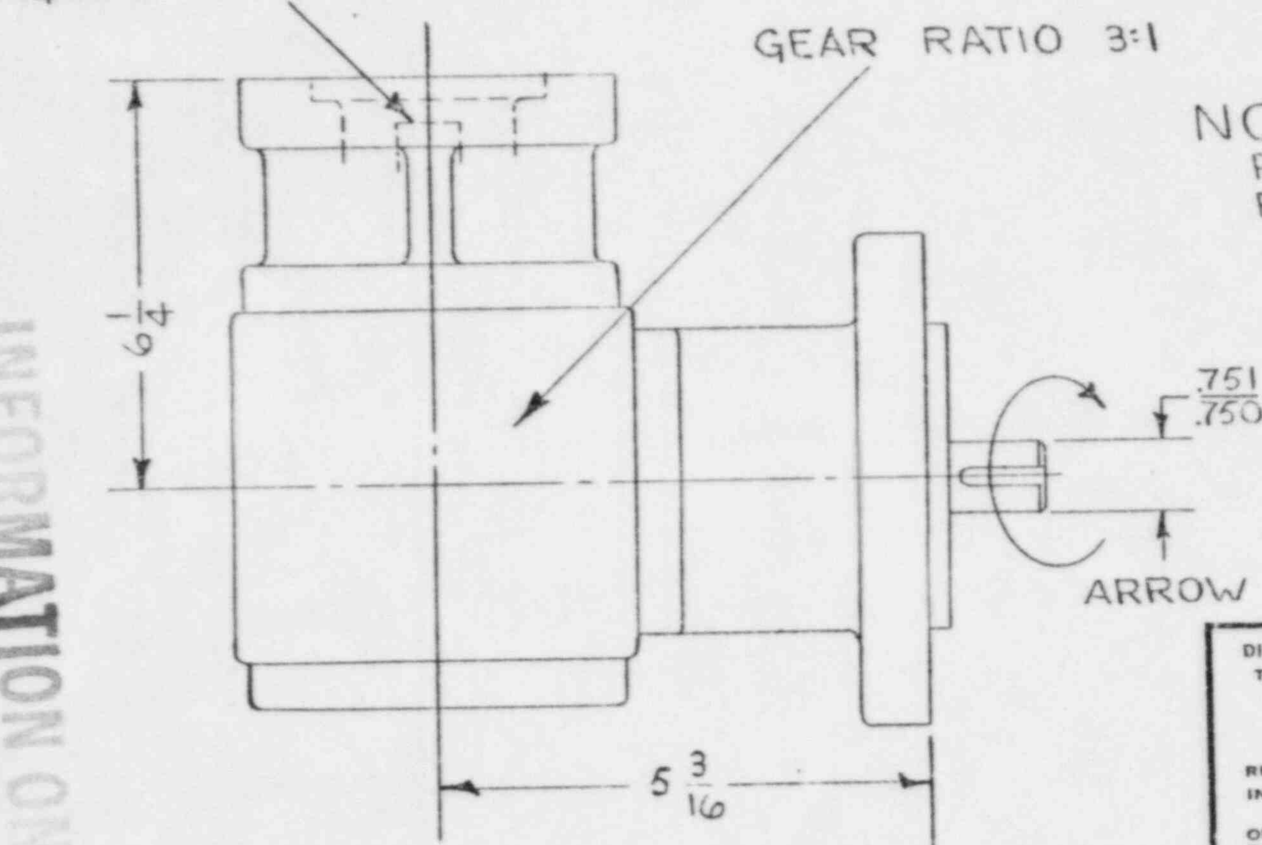
LEVER DIAGRAM

FIGURED BY CP

CHECKED BY

38686

THE TERRY STEAM TURBINE CO.



NOTE:
ROTATION VIEWED
FROM THIS END.

ARROW INDICATES CLOCK ROT.

Hub City Governor Drive Gear Box
FOR PG & UG-8 WOODWARD GOV.

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
TOLERANCE ON FRACTIONS FOR MACHINED SURFACES

0 TO 1/4	± .000
OVER 1/4 TO 24	± 1/64
OVER 24 TO 72	± 1/32
OVER 72	± 1/16

REAMED HOLE TOLERANCE IS ± .001
INSIDE MACHINED CORNERS TO HAVE A RADIUS OF 3/64 $^{+0}_{-1/32}$
OUT OF ROUNDNESS, ECCENTRICITY OR UNINTENTIONAL TAPER TO BE WITHIN THE DIAMETRAL TOLERANCE SPECIFIED.

FILE

TYPE-

SCALE NONE DATE 11-20-70

TERRY Pc. NO	ROTATION	HUB CITY NO	RATIO
68216A	CLOCK DRIVE	02-22-00046-558	3:1
68216A01	C'CLOCK	02-22-00047-558	3:1

THE TERRY STEAM TURBINE CO.
WINDSOR, CONN., U. S. A.

DRAWN
TRACED
CHECKED
APPROVED

68216A

68216A

LUBRICATION AND MAINTENANCE INSTRUCTIONS - TERRY STEAM TURBINE GOVERNOR DRIVE

#99-23-0183-558 - #99-23-00198-558

These gear reducers are splash lubricated and the quantity of lubricant may be varied depending upon the mounting position and the speed of operation. In general, the oil in the gear case for most mounting positions should fill half the cavity, for proper splash operation at input speeds between 500 and 1800 rpm. Vertical operations require slightly more oil. This level will be sufficient to place a film of oil on all moving parts, lubricate contacting areas and provide adequate heat dissipation. Input shaft speeds below 500 rpm require more oil to assure more complete circulation. Speeds greater than 1800 rpm should have somewhat less oil to reduce the heat generated from splashing. Normal operating temperature will be 140 to 160 degrees Fahrenheit. Operating temperatures as high as 200 degrees will not damage the unit provided proper lubrication is maintained. Instructions for proper lubrication are furnished with each reducer. Speed reducers are shipped from the factory without oil and must be filled before operating. Oil level recommendations are noted on the blueprints and adequate pipe plugs have been provided.

The oil in a new unit should be drained at the end of 50-100 hours of operation and the case thoroughly flushed with a light ~~cleaning~~ oil that will remove any particle accumulation. The unit should be refilled with new oil. After the break-in interval, the oil should be changed every 2500 hours of operation or every 6 months, whichever comes first, under favorable conditions. Under severe atmospheric or dusty conditions, or where rapid temperature changes cause condensation to occur, sludge can form and will make it necessary to change oil more frequently.

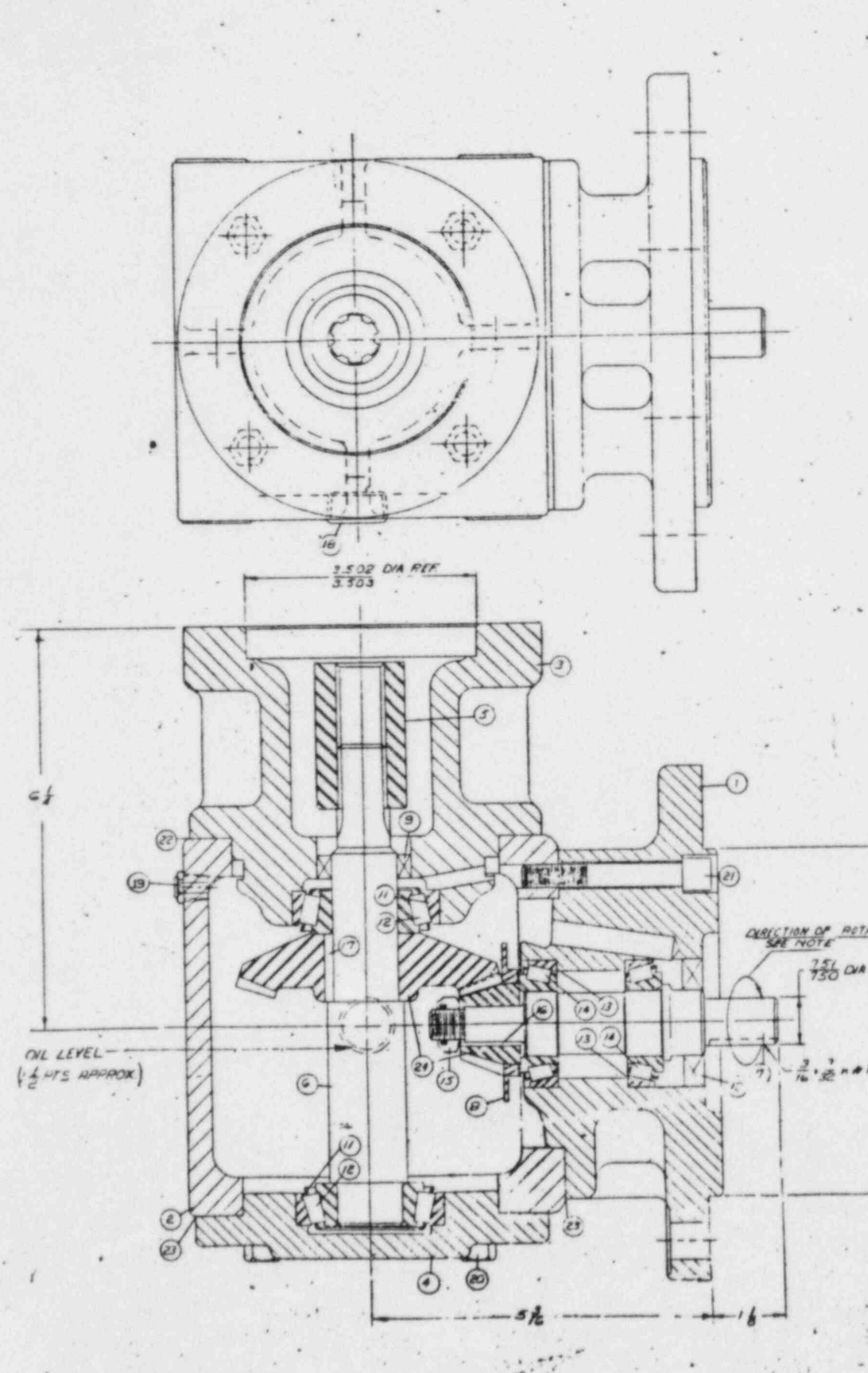
ON INSTALLATION INSURE THAT SPLINE SLEEVE IS COATED WITH MOLVE-ALLOY GREASE or EQUIVALENT.

RECOMMENDED GEAR LUBRICANTS

AMBIENT TEMPERATURE	LUBRICANT	ALTERNATE LUBRICANT
40° to 100° F.	Meropa Lubricant 1	Multigear 80
100° to 200° F.	Meropa Lubricant 3	Multigear 90
Consistently over 200° F.	Meropa Lubricant 6	Multigear 100

The factory cannot assume responsibility for damage caused by inadequate lubrication or maintenance. The design or maintenance engineer must provide adequate lubrication of any gear box installation by checking speed, operating positions and temperature rise in operation. Special provision for lubrication can be made by the factory before shipment and upon request. Factory must be advised whether special filler drain plugs are required and the intended operating speeds and mounting positions.

ENGINEERING DEPARTMENT
HUB CITY DIVISION
SAFEGUARD INDUSTRIES



REF NO	DESC
1	PINIO
2	CASE
3	RETAI
4	CLOS
5	SPLIN
6	OUTPU
7	INPUT
8	OIL
9	SEAL
10	SEAL
11	BEAR
12	BEAR
13	BEAR
14	BEAR
15	NUT
16	WOOD
17	WOOD
18	PIPE
19	BREA
20	CAPS
21	CAPS
22	GASK
23	GASK
24	GEAR

NOTE: (REF 24)
GEAR SET
GEAR SET

All Dimensions In Inches
Tolerance Except When Given
Fractional +/− 1/64
Decimal +/− .010
Angle +/− 1°

H. C. I. PART NO ________

Mfg. Part No. ________

CL [illegible] ——— [illegible] 33-22-00018-[illegible]
COUNTER CL[illegible] [illegible] 33-22-[illegible]0019-[illegible]
H.C. PART NO 02-22-00046-558 (C.W. ROTATION)
H.C. PART NO 02-22-00047-558 (C.C.W. ROTATION)

PARTS LIST

[illegible]PTION	PART NO.	NO. REQ.	NEW NO.
[illegible] HOUSING		1	02-25-0219[illegible]-558
		1	02-25-02193-558
[illegible]NER OUTPUT BRG		1	02-25-02194-558
[illegible]D END CAP	6-278CC	1	02-21-00500-064
[illegible]D SLEEVE		1	02-25-02195-558
[illegible]T SHAFT		1	02-25-02196-558
SHAFT		1	02-25-02197-558
[illegible]INGER		1	02-25-02198-559
	6-1431	1	8-74-21-25-148
	1-1381	1	8-74-21-26-203
[illegible]NG CUP	15520	2	8-32-20-56-018
[illegible]NG CONE	15578	2	8-32-20-6A-018
[illegible]NG CUP	L44610	2	8-32-20-5?-002
[illegible]G CONE	L44643	2	8-32-20-6?-002
[illegible]/2-20UNF-38)	NTE-080-18	1	02-23-01029-141
[illegible]RUFF (1/8 × 3/4)		1	8-47-17-06-012
[illegible]RUFF (*808)	6 815	1	8-47-17-06-005
[illegible]PLUG 1/2 NPT	57-900	1 Ⓐ	8-63-12-51-004
[illegible]THER 1/8 NPT	756-5677	1	8-63-12-71-002
[illegible]REW (3/8 NC × 1)	40-922	8	8-47-14-04-023
[illegible]REW (3/8 NC × 2-1/2)		5	8-47-11-44-039 Ⓔ
[illegible]T .005	E-TLS-4062	AS REQ.	02-23-01570-067
[illegible]T .005		AS REQ.	02-25-02199-558
[illegible] SET	(SEE NOTE BELOW)		

ADJUST BRGS TO
.003/.005 END PLAY

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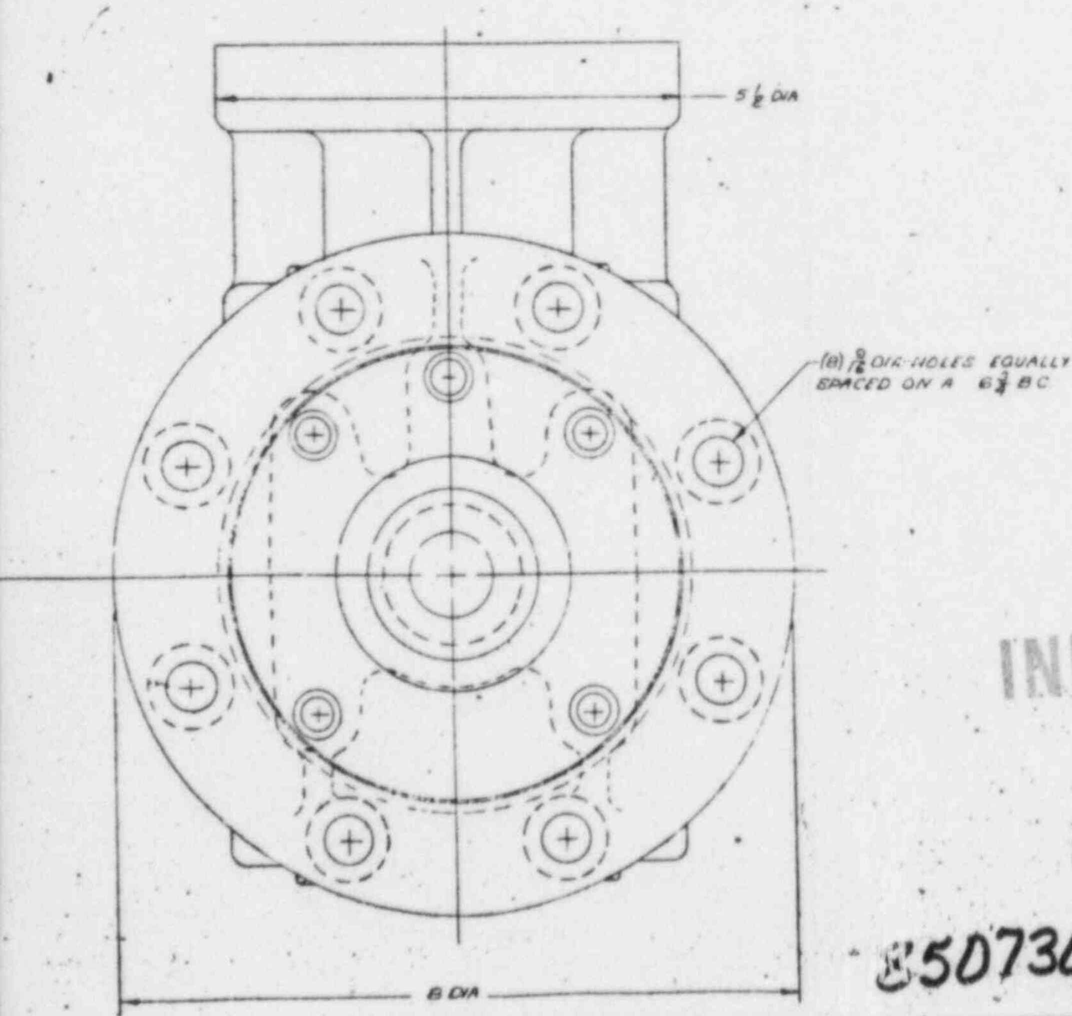
		ASSEMBLY NO.	GEAR SET NO.
RATIO 3:1	CLOCKWISE DRIVE	02-22-00046-558	02-25-02200-558
RATIO 3:1	COUNTER CLOCKWISE DRIVE	02-22-00047-558	02-25-02201-558



TERRY STEAM TURBINE CO.
HARTFORD, CONN

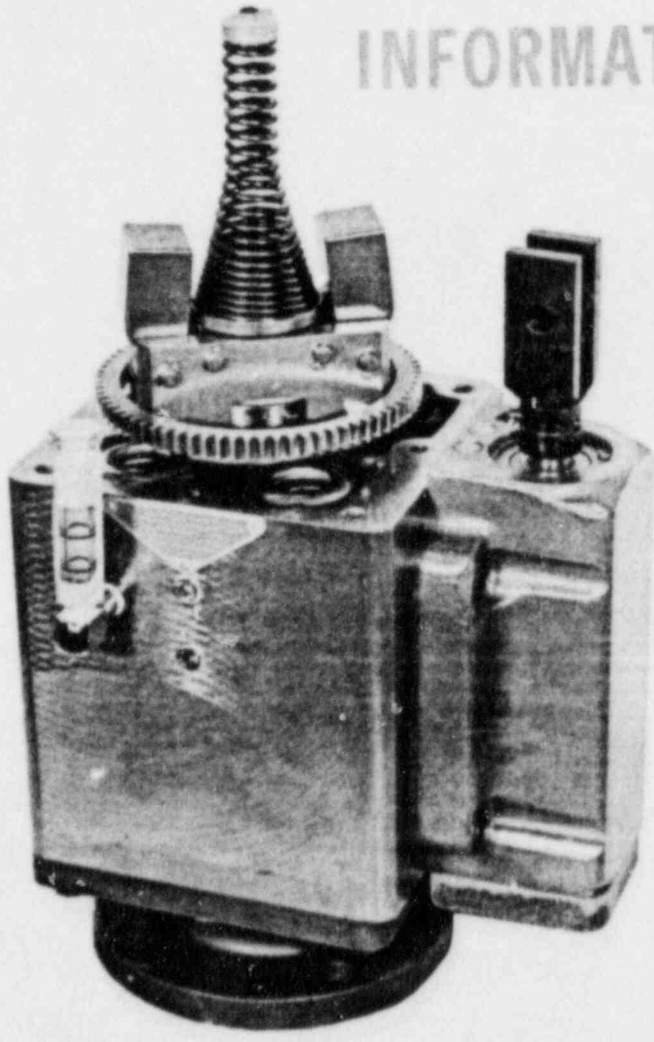
8507300089-03

3-?-29	HUB CITY IRON COMPANY
SCALE FULL	GEAR BOX
DRAWN BY NC.	

WOODWARD®

BULLETIN 36602C

BASIC ELEMENTS PG GOVERNOR WITH DIFFERENTIAL SERVOMOTOR



WOODWARD GOVERNOR COMPANY

ENGINE & TURBINE CONTROLS DIVISION

FT. COLLINS, COLORADO, U.S.A.

WOODWARD ®

BASIC ELEMENTS PG GOVERNOR WITH DIFFERENTIAL SERVOMOTOR

OPERATING AND SERVICE MANUAL

BULLETIN 36602C

WOODWARD GOVERNOR COMPANY
ENGINE & TURBINE CONTROLS DIVISION
FT. COLLINS, COLORADO, U.S.A.

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BASIC ELEMENTS

PG GOVERNOR WITH DIFFERENTIAL SERVOMOTOR

INTRODUCTION

Woodward PG governors control the speed of diesel, gas, and dual fuel engines and steam turbines used in a variety of fields. They find service on engines and turbines driving pumps, compressors, alternators, variable speed D.C. generators, marine propulsion units, and papermaking machines.

In addition to the primary function of controlling engine or turbine speed, the governor is often required to perform such auxiliary functions as limiting engine load, varying generator excitation or propeller pitch to maintain a constant engine power output for a given speed setting, shutting the engine down in the event of lubricating oil pressure failure, etc. Each governor is designed to meet the needs of the engine and the operating requirements of the installation in which it is used.

All PG governors have similar basic elements regardless of how simple or complex the complete control may be. The following elements, found in each PG governor, are sufficient to enable the governor to maintain a constant engine speed as long as the load does not exceed engine capacity:

1. an oil pump, storage area for oil under pressure, and a relief valve by which maximum oil pressure may be limited;
2. a centrifugal flyweight head-pilot valve assembly which controls flow of oil to and from the governor power cylinder assembly;
3. a power cylinder assembly—sometimes referred to as a servomotor—which repositions the fuel racks, fuel valve, or steam valve of the engine or turbine;
4. a compensating system which gives stability to the governed system;
5. a means of adjusting the governor (and thus, engine) speed setting.

Either of two kinds of power cylinder assemblies can be used: a spring-loaded assembly or a differential assembly.

This bulletin describes the operation of the basic elements of a PG governor having a differential power cylinder assembly. Another bulletin describes the arrangement having a spring-loaded power cylinder assembly.

Figures 4 and 5, found on fold-out page 6, show the schematic arrangement of these elements in the relative positions they assume when the prime mover is operating on-speed under steady-state conditions. The two schematics differ due to the two designs of differential power cylinder assemblies depicted. (Figure 4 is the schematic for the unit shown in figure 2; figure 5, the schematic for the assembly in figure 3.) The functional differences between the power cylinder assemblies are outlined in the section entitled "Compensating System". While differences exist in the actual design details of individual parts from one governor to another, the scheme of operation is the same.

GOVERNOR OIL PUMP

Each PG governor contains its own oil sump and oil pump. The governor drive shaft, driven at a speed proportional to engine speed by a mechanical connection to the engine, rotates the pump drive gear and the governor pilot valve bushing. As the rotating drive gear turns the idler gear, oil is drawn from the oil sump and is carried in the space between the gear teeth and the walls of the gear pocket to the discharge side of the pump. The oil is forced from the space between the gear teeth as the drive and idler gears mesh.

Assume that all control valves of the governor are closed. Oil deposited on the discharge side of the pump first fills the various oil passages, and then forces the accumulator pistons up against the downward force of the accumulator springs. When the piston uncovers the bypass hole, the excess oil from the governor pump returns to sump. The accumulators thus not only provide a reservoir for pressure oil but also act as a relief valve to limit maximum pressure in the hydraulic circuit.

The arrangement of the four check valves on the suction and discharge sides of the oil pump permits the governor drive shaft to be rotated in either direction without any changes being made in or to the governor. The direction of

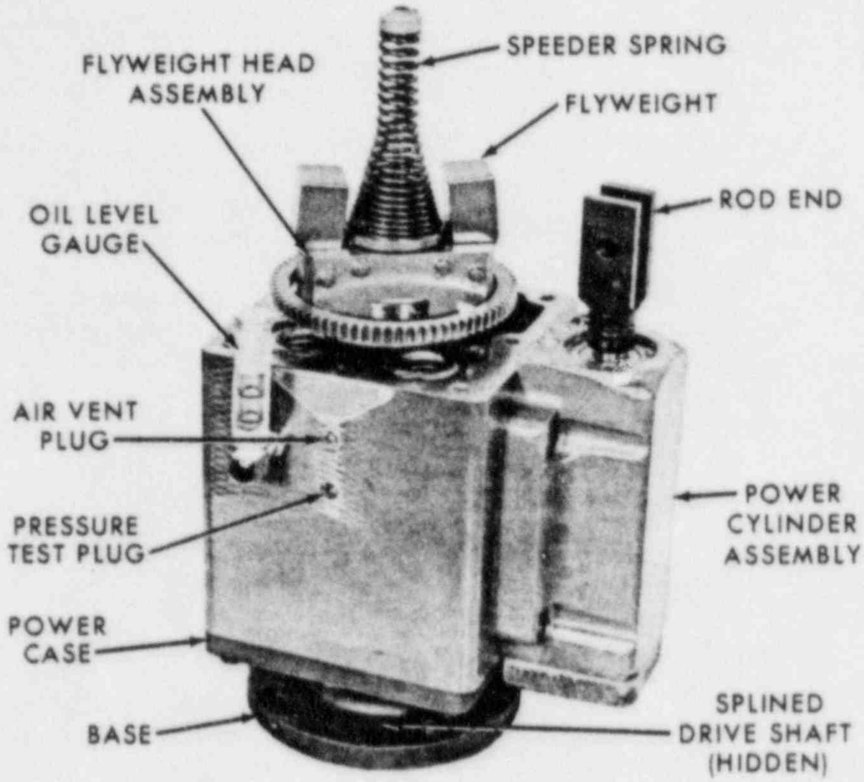


Figure 1.

pump rotation does not affect the oil pressure system or governor operation. Were the pump gears rotated in the directions opposite those shown in figure 1, the open check valves would be closed and the closed check valves opened.

Some governor models are built without check valves. In these units two plugs replace the two closed check valves so that the governor must be rotated in one direction only.

FLYWEIGHT HEAD–PILOT VALVE ASSEMBLY

The pilot valve plunger moves up and down in the rotating pilot valve bushing to control the flow of oil to or from the power cylinder assembly. When the pilot valve plunger is centered (i.e., the control land of the plunger exactly covers the control port of the bushing), no oil flows to or from the power cylinder assembly.

The greater of two forces moves the pilot valve plunger up or down. The centrifugal force developed by the rotating flyweights is translated into an upward force which tends to lift the plunger. The centrifugal force is opposed by the downward force of the speeder spring. When the opposing forces are equal, the pilot valve plunger is stationary.

With the pilot valve plunger centered and the engine running on-speed, a change in either of the two forces will move the plunger from its centered position. The plunger will be lowered (1) if the governor speed setting is unchanged but an additional load slows the engine and governor (thereby decreasing the centrifugal force developed by rotating flyweights) or (2) if the engine speed is unchanged but the speeder spring force is increased by raising the governor speed setting. Similarly, the pilot valve plunger will be raised (1) if the governor speed setting is unchanged but load is removed from the engine causing an increase in engine and governor speed (and hence, an increase in the centrifugal force developed by the rotating flyweights), or (2) if the engine speed is unchanged but the speeder spring force is reduced by lowering the governor speed setting.

The thrust bearing atop the ballarm toes permits the pilot valve bushing to rotate while the pilot valve plunger does not rotate. In this way, static friction between the bushing and plunger is minimized.

There are several styles of flyweight head assemblies available. The exact model used in any one governor depends upon the application.

A "solid" head assembly is used in governors on prime movers which afford a smooth drive to the governor.

"Spring driven" and "spring driven, oil damped" head assemblies are used to filter torsional vibrations which may be imparted to the governor by the drive from the engine. (These torsional vibrations may originate from a source other than the drive itself but reach the governor through the drive connection.) Unless minimized or eliminated, the flyweight head will sense these torsional vibrations as speed changes and continually adjust the fuel valve or racks in an attempt to maintain a constant speed.

DIFFERENTIAL POWER CYLINDER ASSEMBLY

The governor pilot valve plunger controls the movement of the power piston in the differential power cylinder assembly. The power piston, acting through the connecting linkage, controls the engine or turbine energy medium (fuel or steam).

The power piston requires pressure oil to move it either in the "increase fuel" or "decrease fuel" directions. The power piston, a differential type piston, has pressure oil continually directed to the side of the piston with the smaller area. This constant pressure continually urges the piston in the decrease fuel direction. However, the piston cannot move to decrease fuel unless oil in the passages between the opposite side of the piston (i.e., the side with the larger area) and the pilot valve plunger control land can escape to sump. This oil is connected to sump only when the pilot valve plunger is above its centered position.

If the pilot valve plunger is below its centered position, oil flows to the side of the power piston with the larger area (as well as to the side with the smaller area). Though the pressures on the two sides of the piston are approximately the same, the force resulting from the oil acting on the greater surface area is greater and moves the piston in the increase fuel direction.

Note that the power piston can move only when the pilot valve plunger is uncentered to permit the oil flow required. With the plunger centered, the power piston is, in effect, hydraulically locked.

Two different hydraulic circuits are used for the oil passages between the pilot valve plunger control land and the power piston. The scheme used in a particular model depends upon the size of the power piston. Both are discussed in the section which follows ("Compensating System").

The output of the power cylinder assembly is normally a push-pull motion. Appropriate linkage within the power cylinder assembly can change the output to a rotary motion. The power cylinder assembly can sometimes be positioned at an angle other than perpendicular to the governor base. In all such arrangements, the power piston movement is a reciprocating movement.

COMPENSATING SYSTEM

Stability of the governed system is achieved by the use of a temporary negative feedback signal which biases the speed signal to the pilot valve plunger. This temporary feedback signal is in the form of a pressure differential applied across the compensating land of the pilot valve plunger. The pressure differential is derived from the "buffer compensating system", and is dissipated as engine speed returns to the normal or set speed.

The buffer piston, buffer springs, and needle valve in the hydraulic circuit between the control land of the pilot valve plunger and the power piston comprise the "buffer compensating system" of the governor. Lowering the pilot valve plunger permits a flow of pressure oil into the buffer cylinder and power cylinder to move the power piston in a direction to increase fuel. Raising the pilot valve plunger permits oil to flow from the buffer cylinder and power cylinder to the governor sump, and the constant oil pressure moves the power piston in a decrease fuel direction.

This flow of oil in the buffer system—in either direction—carries the buffer piston in the direction of flow, compressing one of the buffer springs and releasing the other. The buffer piston movement, increasing the loading on one buffer spring while decreasing the loading on the other, creates a slight difference in the oil pressures on the two sides of the buffer piston. The higher oil pressure is on the side of the piston opposite the spring being compressed. The difference in oil pressure is proportional to the buffer piston displacement, and is dependent upon the rate of the buffer springs selected for the particular installation.

The oil pressure on one side of the buffer piston is transmitted to the lower side of the compensation land on the pilot valve plunger; the pressure on the other side of the piston is transmitted to the upper side of the compensation land. The difference in oil pressures produces a net force (often termed a "compensating force")—upward or downward, as the case may be—which assists the flyweights or speeder spring in recentering the pilot valve plunger whenever a fuel correction is made.

A relatively small power piston is used in power cylinder assemblies such as that shown in figure 2. In these assemblies, the oil displaced by the buffer piston movement is usually sufficient to move the power piston the distance necessary to correct for small load changes. This power cylinder arrangement is shown schematically in figure 4.

A larger power piston is used in the power cylinder assembly shown in figure 3. The volume of oil needed to move this piston in response to small load changes would exceed the volume resulting from the normal buffer piston displacement. For this reason, a direct passage is provided between the pilot valve plunger control land and the power piston. This arrangement is shown schematically in figure 5. The buffer piston is hydraulically connected to a smaller "compensation" area in the power cylinder assembly. The pressure differential resulting from the buffer piston displacement provides the compensating force needed to give stability to the governed system.

Operation of the buffer system can be seen by following the sequence of operations when the engine slows down because of the addition of a relatively small load. The decrease in centrifugal force developed by the rotating flyweights permits the speeder spring to push the flyweights in, lowering the pilot valve plunger and opening the control port.

As the buffer piston moves in the direction of the oil flow—from pilot valve to power cylinder—the right hand buffer spring is compressed and the left hand spring is relieved. The oil displaced by the buffer piston as it moves to the right and, in units with the large power piston, oil from the pilot valve forces the piston in a direction to increase fuel to the engine; the engine begins to accelerate. The buffer piston moves to the right until the upward force created by the pressure differential across the buffer piston and compensating land is sufficient, when added to the centrifugal force from the rotating flyweights, to recenter the pilot valve plunger. As soon as the pilot valve plunger is recentered, the power piston movement stops. When the governor is properly adjusted, this new piston position corresponds to the fuel increase needed to operate the engine at a set speed with the new load even though the engine has not yet returned to the set speed.

As the engine continues to accelerate to the set speed, the centrifugal force developed by the rotating flyweights increases. To offset this increase in centrifugal force, it is necessary to reduce the net upward force resulting from the pressure differential across the compensation land as the centrifugal force increases. (Otherwise, the pilot valve plunger would be lifted above center and the power piston would move in a direction to decrease fuel.) This is accomplished by equalizing the pressures on both sides of the compensation land at a rate proportional to the rate at which the engine speed returns to normal. As the pressure differential is decreased, the new compensating force is decreased. If the decrease in compensating force can be made at the same rate as the centrifugal force is increased, the pilot valve plunger will remain centered and the power piston will remain stationary. As the pressure differential is being dissipated, the compressed buffer spring returns the buffer piston to its normal, central position. When the pressure differential has been reduced to zero, the compensating force will be reduced to zero. At this time the engine should be back to its set speed developing the centrifugal force necessary from the flyweights to keep the pilot valve plunger centered.

The rate at which the pressure differential is reduced to zero depends upon the needle valve setting. The needle valve setting allows each governor to be "matched" to the engine on which it is used. The final setting of the needle valve cannot be made until the governor is installed on its engine.

When a relatively small load is removed from the engine while it is running on-speed under steady-state conditions, the sequence of events is similar but in the opposite directions.

The engine speed increases. The rotating flyweights develop additional centrifugal force and lift the pilot valve plunger. The oil between the buffer piston and the pilot valve plunger is connected to sump; in a power cylinder assembly with the large power piston, oil from the control area is also connected to sump. Constant pressure forces the power piston in a direction to decrease fuel, causing the buffer piston to be moved toward the pilot valve plunger. A pressure differential again exists between the oil lines to the upper and lower sides of the compensating land of the pilot valve plunger. The greater pressure is now on the upper side of the compensating land tending to push the pilot valve plunger back down to its centered position.

When the compensating force becomes sufficient to offset the increase in centrifugal force, the pilot valve plunger is returned to its centered position even though the engine speed is still greater than the set speed. As before, the compensating force is again dissipated at a rate proportional to the rate at which the engine returns to normal speed so that the pilot valve plunger remains centered.

The sequence of movements within the governor occur almost simultaneously rather than in the step-by-step manner described.

Bypass passages are provided in the buffer cylinder to facilitate large corrective movements of the power piston. A large increase or decrease in speed setting, or a large increase or decrease in load on the engine, requires a correspondingly large movement of the power piston to make the necessary fuel correction. At such times, the buffer piston moves far enough to uncover the bypass port (to pressure or drain, depending on the correcting being made).

The difference in oil pressures on the opposite sides of the buffer piston and the compensation land cannot exceed the difference which exists when the buffer piston uncovers the bypass port. With the bypass port uncovered, all oil flows directly to or from the power cylinder without further increasing the pressure differential existing on the compensation land.

The bypass ports permit the power piston to move quickly in response to large changes in load or speed setting. Since the pressure differential across the compensating land of the pilot valve plunger does not continue to increase, the speed more than returns to normal (or to the new setting). This "over-shoot" in speed is not large, and is tolerated in order to obtain the desired fast response. As soon as the speed changes beyond the desired point, normal governor action reverses the power piston movement, and stable operation is quickly established.

Surrounding the power piston and its piston rod are grooves connected to the intermediate oil pressure between the pilot valve and the buffer piston. These seal grooves have nothing to do with operation of the governor, but are used to insure that any leakage of pressure oil from the power cylinder to the sump is minimized.

"Remote" differential power cylinder assemblies (i.e., assemblies which are located away from the governor power case) have four tubes connecting the power cylinder to the power case. These tubes carry (1) constant pressure oil to the power cylinder, (2) oil to and from the buffer piston, (3) drain oil from the power cylinder, and (4) oil to the power cylinder seal grooves.

To eliminate the possibility of trapping air in the oil, the cylinder must be mounted below the governor oil level, and the connecting tubes must slope upward to the governor.

SPEED SETTING ADJUSTMENT

There are a number of speed setting arrangements available for the PG governor. The exact method used depends upon the operating scheme of the installation in which it is used.

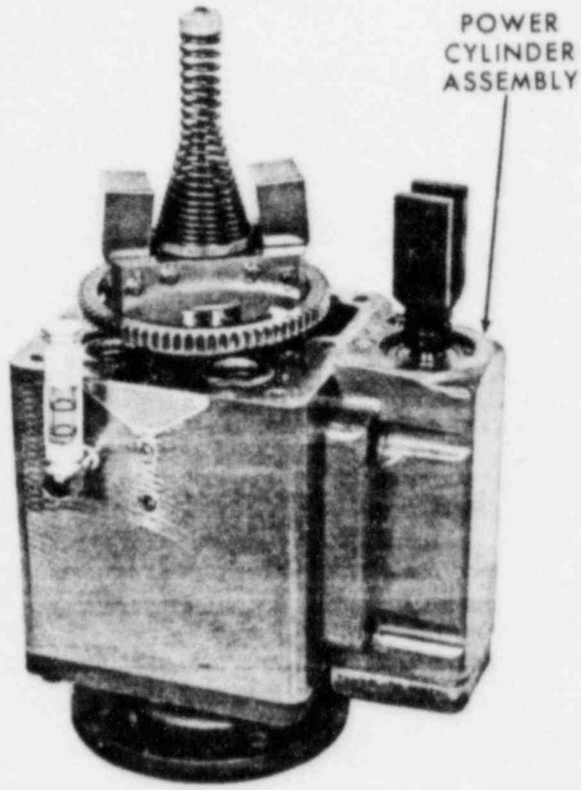


Figure 2.

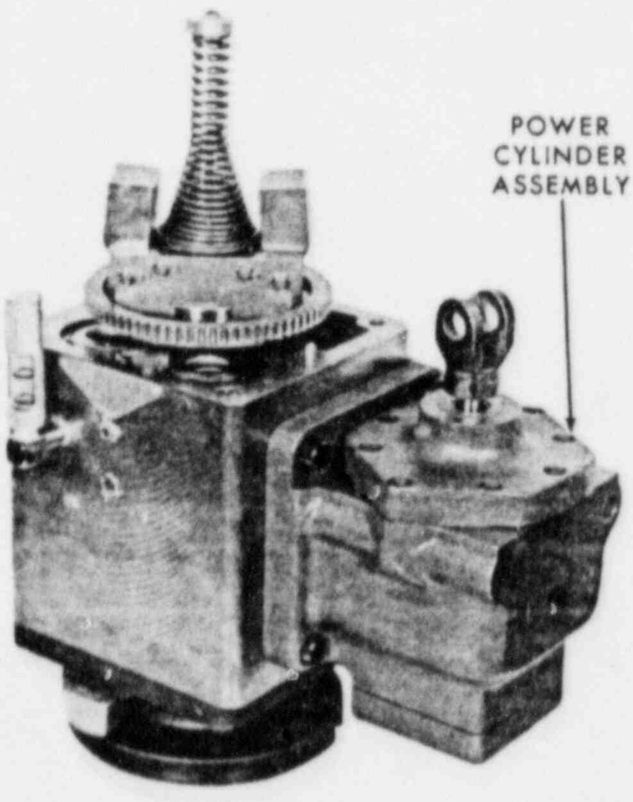
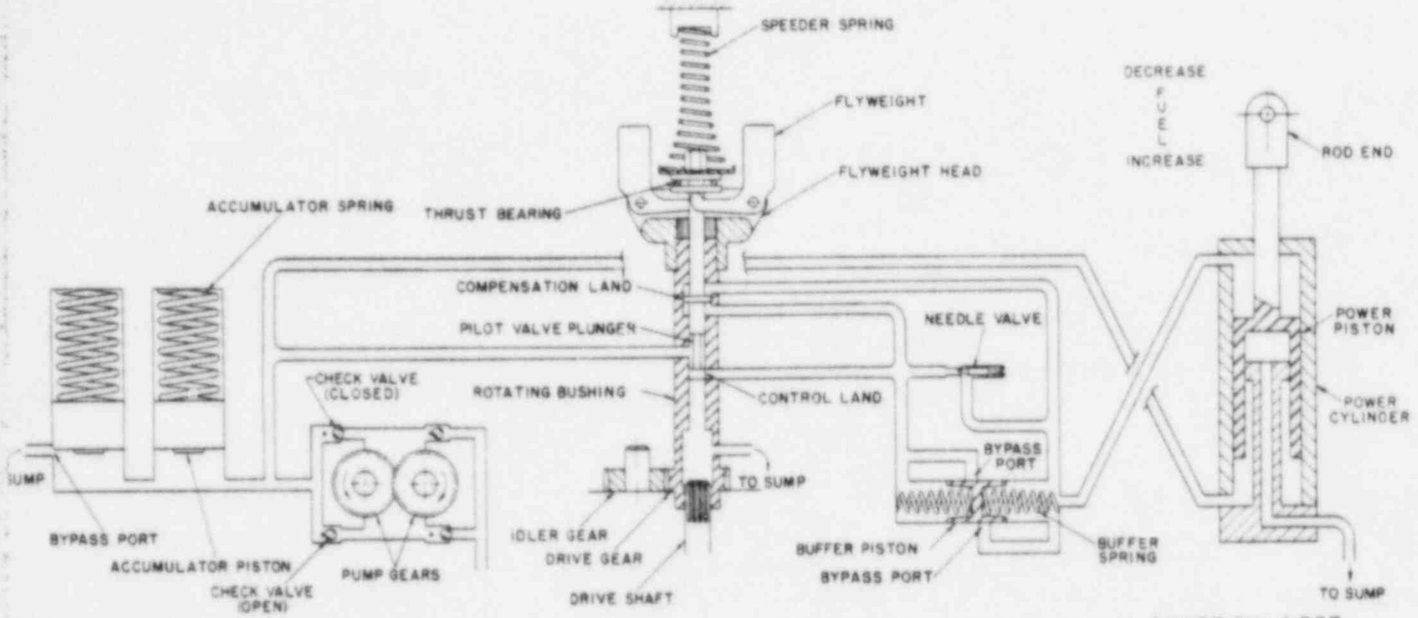


Figure 3.



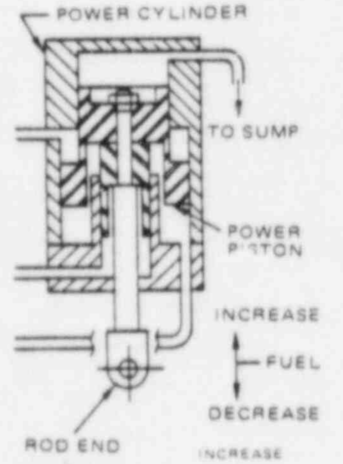


Figure 4.

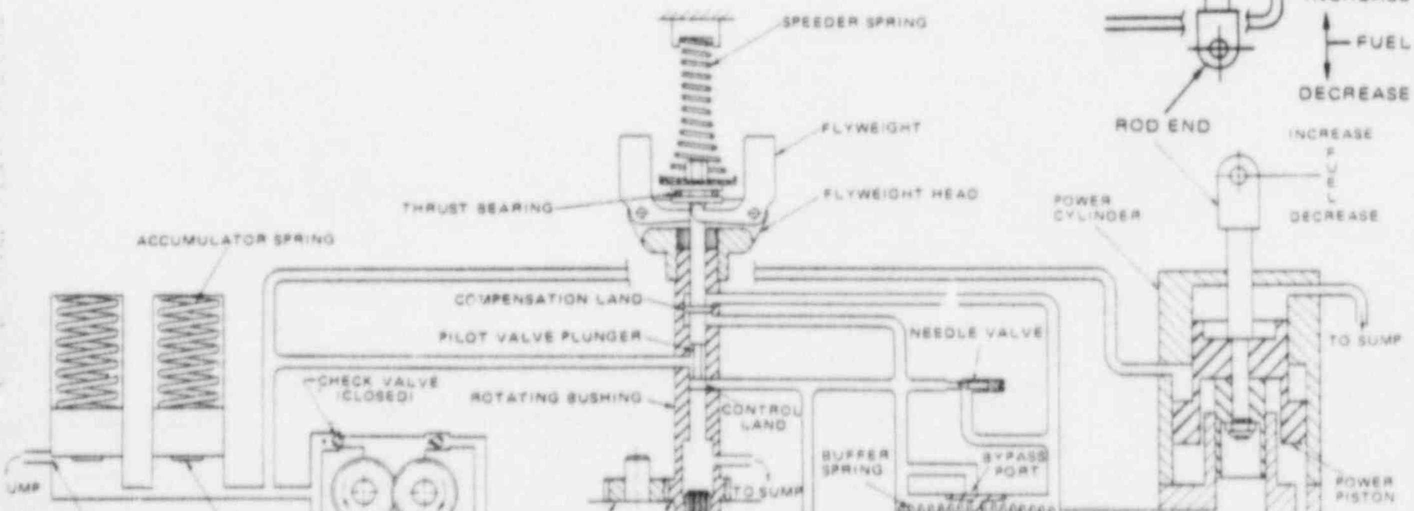


Figure 5.

FOLDOUT FOR FIGURES 4 & 5

It is enough to observe at this point that, no matter how simple or complex the means employed may be, the ultimate objective is to increase or decrease the compression of the speeder spring. An increase in the speeder spring compression requires that the engine run faster in order that the rotating flyweights will develop the additional centrifugal force needed to recenter the pilot valve plunger. Conversely, a decrease in spring compression requires a slower engine speed.

The various speed setting arrangements are described in separate bulletins.

INSTALLATION

GENERAL

At all times, use care in handling the governor; be particularly careful to avoid striking the drive shaft. Do not drop or rest the governor on its drive shaft. Such treatment could damage the governor drive components.

A gasket should be used between the mounting pad and the governor base when the governor is installed on the engine or turbine. The governor should be mounted squarely and the drive connection properly aligned. If the governor is equipped with a serrated or splined drive shaft, it should slip freely into the internal serrations or splines of the drive. If a keyed type governor drive shaft is used, the gear must slip on the shaft freely and should be checked to insure that it meshes properly with its mating gear. The gears should run freely without binding or excessive backlash. Irregularities caused by uneven gear teeth, shaft runout, etc., will result in erratic governing.

LINKAGE ADJUSTMENT

The linkage from the governor to the fuel or steam control must be properly aligned. Any friction or lost motion must be eliminated. Adjustments of fuel linkage must provide for control of fuel from "OFF" to "FULL FUEL" within the limits of the stroke of the governor output connection. For specific information on fuel linkage installation, refer to the engine instruction manual.

When the governor has been properly mounted and the linkage connections completed, make the other connections (pneumatic, electrical, etc.) to the governor.

OIL SPECIFICATIONS

The oil used in the governor should have a minimum tendency to foam, retain air, form sludge, or deposit varnish. It should protect governor parts from corrosion, but not be detrimental to seals or paint. The oil selected should have a high viscosity index; the viscosity should be within the range of 100 to 200 Saybolt Universal Seconds at normal operating temperatures. If the average operating temperature of the governor oil is below 120°F., S.A.E. 10 oil is usually satisfactory; if between 120°F. and 140°F., S.A.E. 20 oil; from 140°F. to 160°F., S.A.E. 30 oil; from 160°F. to 180°F., S.A.E. 40; and above 180°F., S.A.E. 50 oil. If the engine oil meets these requirements, it may be used in the governor as well.

Oil contamination is the major cause of governor troubles. Use only new oil or filtered oil. Containers used for governor oil must be clean, and should be rinsed with a light grade of the same oil before using.

INSTALLATION ADJUSTMENTS

Speed setting and compensating needle valve adjustments are the only external adjustments to be made. The range of speed setting adjustment is set at the factory on new or rebuilt governors and should not need changing. On initial start-up, the speed setting should be at minimum or idle speed.

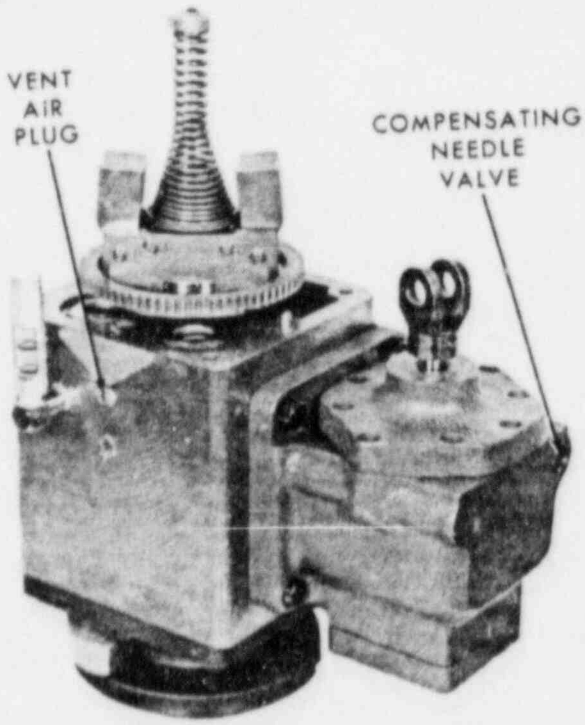


Figure 6.

PURGING AIR FROM GOVERNOR AND ADJUSTING NEEDLE VALVE

When the engine or turbine is started for the first time, or after the governor has been drained and cleaned, the governor must be filled with oil, and any air trapped in the governor removed. To bleed off the trapped air, set the governor at idle speed position. Start the engine or turbine and open the compensating needle valve (figure 6) several turns. This should cause the engine to hunt.

Loosen the air vent plug (figure 6) far enough to establish a leak, and allow the engine to hunt a sufficient length of time to permit all air trapped in the governor oil passages to escape at the vent plug. When no more air bubbles are apparent, tighten the vent plug, and if necessary add oil to the governor to restore the correct level in the gauge glass.

The compensating needle valve can now be closed gradually until hunting is just eliminated. The proper setting depends upon the characteristics of the prime mover. Keep the needle valve open as far as possible to prevent sluggishness. The needle valve setting will vary from 1/16 turn open to 2 turns open. The needle valve must never be closed tight, as the governor cannot operate satisfactorily when this condition exists.

On some installations, opening the needle valve will not cause the engine or turbine to hunt. In such cases, bleed the air from the governor by disturbing engine or turbine speed to cause the governor to move through full stroke in both directions a sufficient number of times to force out all trapped air. After the needle valve is adjusted correctly for the engine, it should not be necessary to change the setting except for a large permanent temperature change affecting the viscosity of the governor oil.

MAINTENANCE

GENERAL

When requesting information concerning governor operation and maintenance or when ordering replacement parts, it is essential that the following information be included:

(1) Governor serial number (shown on governor nameplate).

(2) Bulletin number to which reference is made.

(3) Bulletin part reference number, name of part, or description of part.

A governor should operate several years before needing replacement if it is kept clean, and if the drive from the turbine or engine is smooth and free from torsional oscillations. Governors rarely fail or break down suddenly. Instead, they wear gradually, and give an external indication of their condition in the form of slight hunting, sluggish operation, etc. Further deterioration is at a slow enough rate so an exchange governor may be ordered for installation at the next scheduled shutdown. Because there is so little chance of failure, we do not recommend keeping a complete stock of spare parts on hand. However, plants at which an unplanned shutdown would be very costly often keep a complete spare governor on hand.

It is advisable that the best mechanic available, preferably one experienced with small parts assembly, be permanently assigned to all governor repair work. Cleanliness of tools and work space is essential. A work bench, vise, arbor press, speed lathe, air supply, and containers for cleaning solvents should be provided, if possible. The usual small hand tools are required, and a few special Woodward Governor Company tools may be desirable if sub-assemblies are to be disassembled. Bulletin 36403 lists and illustrates tools available for PG governor maintenance.

GOVERNOR OIL

Contaminants and foreign matter in the governor oil are the greatest sources of governor troubles. Use only new or filtered oil. Be sure that all containers used for the governor oil are clean. The time interval between governor oil changes depends upon many factors: type of service, operating temperature, quality of oil, etc. Begin an oil maintenance program by inspecting the oil after three months service. If inspection shows the oil to be satisfactory, gradually lengthen the time between inspections. Any time the governor oil appears to be dirty or breaking down from contaminants or excessive temperatures, drain the governor while it is hot, flush with the lightest grade of the same oil, and refill with fresh oil. In any event, it is recommended that the oil be changed at least once every eighteen months.

INSPECTION AND TEST

Bulletin 36404 lists the most frequent indications of governor malfunctioning, and suggests possible causes and the corrective actions needed. A brief summary of these suggestions follows.

Governor faults are usually revealed in speed variations of the engine, but is does not necessarily follow that all such speed variations indicate governor faults. Therefore, when improper speed variations appear, make these checks:

1. Check the load to be sure that the speed changes observed are not the result of load changes.

2. Check the engine operation to be sure that all cylinders are firing properly, and that the injectors are in good operating condition.

3. See that the operating linkage between the governor and engine is free from binding or lost motion.

4. Check the setting of the compensating needle valve. It is impossible for the governor to function correctly if the needle valve is closed tight.

If neither load nor engine irregularities are found to be the cause of the speed variation and adjustments of the needle valve are unable to correct the malfunctioning, the cause may be either in the governor or the drive to the governor.

If the speed variations are erratic but small in magnitude, the fault may lie in the drive to the governor. Excessive backlash or a tight meshing of the gears driving the governor may be the cause. No amount of adjustment or other work on the governor can correct this condition.

If the speed variations of the governor are large and erratic, and unaffected (except, perhaps in magnitude) by changes of adjustment, or if the governor fails to control at all, it should be repaired or replaced.

As a last resort, to prove whether the engine or governor is at fault, another governor, known to be in good condition, should be installed on the engine. When this is done, the test governor must be of the exact same model as the one being removed.

REMOVAL OF GOVERNOR FROM ENGINE

In case of major repairs or a complete governor change, the unit may be removed from the engine as follows:

1. Remove oil drain plug. Drain oil from governor and replace the drain plug. NOTE: Governor may be equipped with drain cock for draining.

2. Disconnect linkage from the governor. If levers are removed from serrated shafts, mark their radial positions on the shafts so that they can be reinstalled in the same positions.

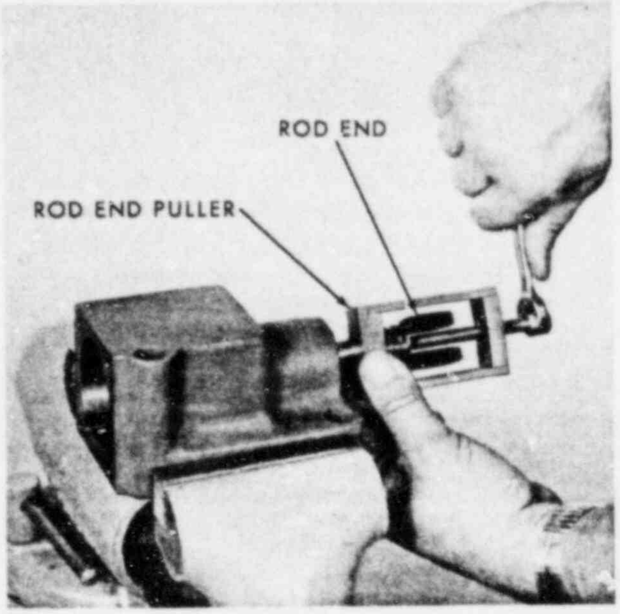


Figure 7.

3. Disconnect, at the governor, other connections (electrical, pneumatic, hydraulic, etc.) to the governor.

4. Remove the four stud nuts holding governor assembly to governor mounting pad and lift governor off the studs and away from the engine. Remove the gasket between governor and governor mounting pad.

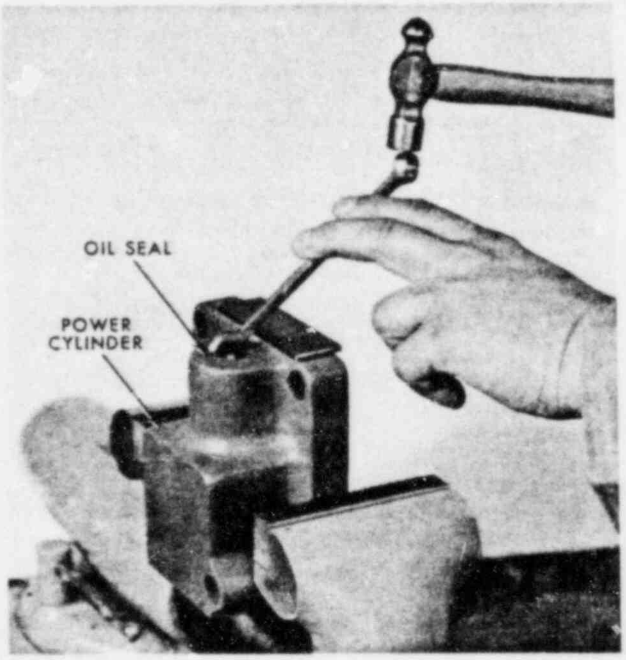


Figure 8.

NOTE

At all times use care in handling and setting the governor down; be particularly careful to avoid striking the end of the drive shaft a sharp blow. Such treatment might damage the governor drive components.

DISASSEMBLY PROCEDURES

An outline of the order of disassembly of the basic components follows. Hints for the disassembly of subassemblies are given where necessary. (The numbers in parenthesis refer to the parts shown in figure 14.)

1. Remove speeder spring (67).

2. Lift out the flyweight head-pilot valve bushing assembly. (e.g., items 68 thru 106).
   a. After detaching the flyweight head (e.g., item 98), take out snap ring (86) to permit removal of items (87) and (90).

3. Remove snap ring (65) and items (60) thru (64).

4. Remove four screws (112) and lockwashers (113) to detach the power cylinder assembly (items (1) thru (24).
   a. Use a rod end puller tool (Woodward tool 012281) to remove fuel rod end (24). See figure 7 for use of puller.
   b. Grip power cylinder (12) in a vise to remove oil seals as shown in figure 8.

5. Remove screws (58) and retainer (57). Take out drive shaft (56) and items (51) thru (55). Remove drive shaft oil seal (52) as shown in figure 9.

6. Remove screws (50) and washers (49). Lift off base (48) taking care that idler gear (45) and drive gear (43) do not fall out. Remove the idler gear and drive gear.

7. Set the power case (32), bottom end (i.e., end with idler stud 44) down, in an arbor press or small drill press. With a rod against spring seat (28), compress accumulator springs (29) and (30) to permit removal of upper snap ring (27). See figure 10. Remove spring seat (28) and springs (29) and (30).
   Invert the power case and remove snap rings (27) and accumulator pistons (42).

8. If necessary to remove check valve assemblies (33 and 34), proceed in this manner:
   a. To remove inner check valves (33), pry the

Figure 9.

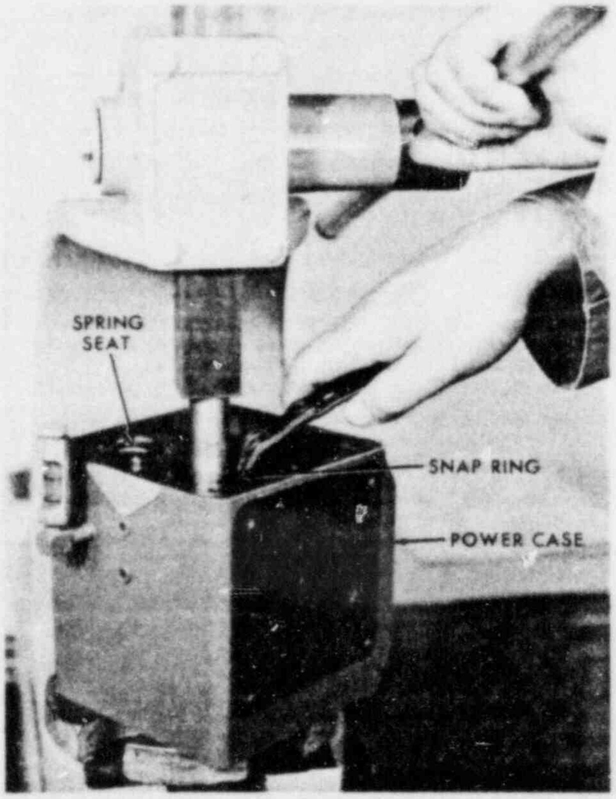


Figure 10.

Figure 11.

retainer plate from the check valve as-embly and remove springs and check balls.

b. To remove outer check valves (34), press the check valves through and out of the valve case.

c. Then tap all four check valve cases with 1/4"-28 tap. Using a 1/4"-28 bolt with a small plate as a jack, pull the four valve cases. See figure 11.

d. Remove two balls from the lower case.

INSPECTION AFTER DISASSEMBLY

After disassembling the governor, wash all parts in clean fuel oil and carefully inspect for wear. Generally, most of the repair work consists of cleaning and polishing the governor parts. All pistons, plungers, valves, and rods should move freely without binding or catching. Do not lap in parts if possible to free up by other means.

Inspect the check valves (if used) in bottom of governor power case. They must be clean, operating freely and seating properly.

The flat, joint surfaces at top and bottom of both governor case and base, must be free of burrs and high spots. Carefully avoid scratching or scoring these faces, particularly the top of the base and the bottom of the case. Avoid damage to the neoprene seal ring and the groove in the bottom face of the governor power case.

The pilot valve plunger should move freely in the pilot valve bushing assembly. If the plunger surfaces are scratched they may be dressed with a hard Arkansas stone.

CAUTION

The edges of the control land and compensating piston MUST be left sharp.

The power piston assembly should move freely in the power cylinder, and the buffer piston should move freely in the buffer cylinder.

Ballhead flyweights must work freely on the needle bearings and pivot pins.

If the toes of the flyweights have flat spots, it will be necessary to install new flyweights.

Ball races and bearing balls of the flyweight thrust bearing should be in perfect condition.

ASSEMBLY PROCEDURES

While assembling the parts into the governor, care must be taken to insure that no lint or other foreign matter is present on the parts. The governor may be assembled dry, or if preferred a small amount of clean lubricating oil can be applied to the parts as they are placed into the governor. Replace oil pipe plugs removed from the governor, using a good joint compound on the threads of the plug – NOT IN THE HOLE. When the governor is assembled, apply a liberal amount of clean lubricating oil over all the moving parts, to insure initial lubrication.

The order of assembly is, in general, the reverse of disassembly process. The following hints should aid in assembly of the basic elements. (The numbers shown in parenthesis refer to the parts shown in figure 14.)

1. Use Woodward tool 360689 to press check valve assembly (33) into power case (32). Use Woodward tool 360690 to press in check valve assembly (34).

2. After installing lower snap rings (27), accumulator pistons (42) and springs (29) and (30) use a rod and an arbor press to compress spring seats (28); install upper snap rings (27).

3. With the power case components installed and the power case resting upside-down (i.e., with idler gear stud 44 up), install idler gear (45), drive gear (43) and

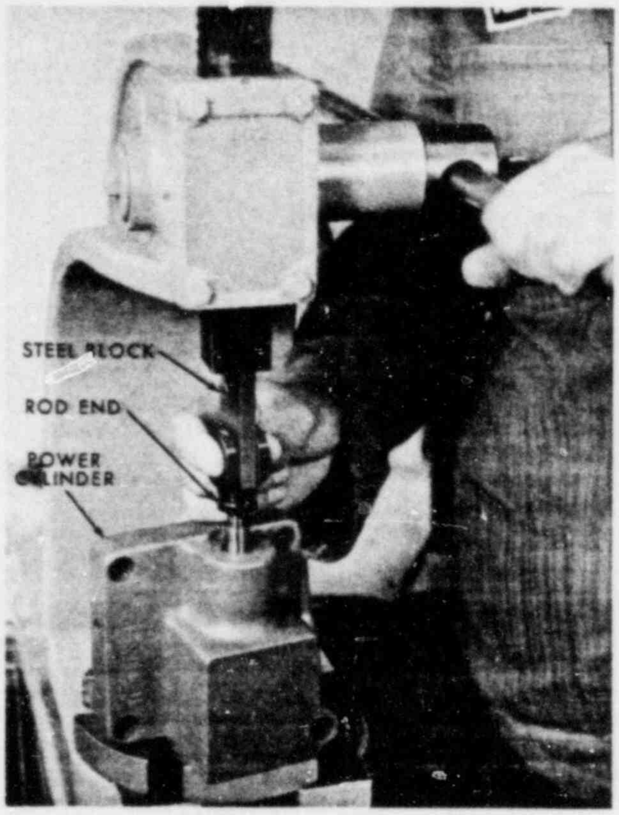


Figure 12.

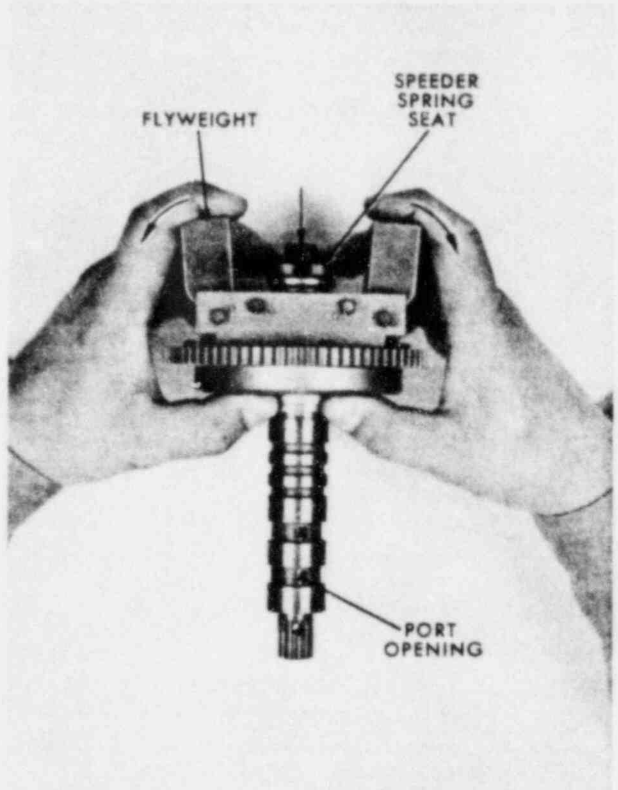


Figure 13.

oil seal ring (46). Be sure the gears turn freely.

Attach base (48) to power case with screws (50). Do not tighten screws. Insert drive shaft (56) with bearing (55) and snap ring (54) already on drive shaft into base and turn until splined end slips into splines in pump drive gear. Continue turning to check alignment and free rotation of the drive gear and idler gear while tightening screws (50).

Withdraw the drive shaft from the base.

4. Press oil seal (52) into oil seal retainer (53) flush with the end opposite the flange end of retainer.

5. Install gasket (51) and the assembly consisting of the oil seal and oil seal retainer. Install the drive shaft assembly. Attach retainer (57) with screws (58). Tighten screws evenly. Do not attempt to bring retainer into contact with base.

6. Press oil seals (21) and (22) into power cylinder (12). Seal (21) should be inserted with the part number facing out. Seal (22) should be inserted with the part number facing in and pressed in to .005" below flush.

7. Place oil seal inserter (Woodward tool 360066) on over rod of power piston assembly (18) to avoid damaging oil seals (21) and (22) when inserting the piston assembly in the power cylinder.

8. Position power cylinder in an arbor press, align taper pin holes, and press rod end (24) onto end of power piston (18). See figure 12. Place a small steel block in the rod end slot so that pressure is applied against the bottom of the slot.

9. When mounting the power cylinder assembly onto the power case, align the holes in gasket (11) with the holes in the power case (32) instead of with those in the power cylinder.

10. When assembling the flyweight head pilot valve bushing assembly, align the missing tooth in the pilot valve bushing with the corresponding missing tooth in its mating part (e.g., items 81 and 92).

11. The three-piece thrust bearing (71) fits onto the stem of the pilot valve plunger (90) with bearing race with the larger hole on the bottom (i.e., against the flyweight toes).

12. "Center" the pilot valve plunger in this manner: with slight pressure on the speeder spring seat (70), adjust the pilot plunger nut (68) until, as the flyweights (75) are moved from their extreme inward to their extreme outward position, there is the same amount of control land showing in the control port at each extreme. The control ports are the bottom row of holes in the pilot valve bushing assembly. See figure 13. (Note: Shutdown rod (77) with retaining ring (78), if used, must be inserted through nut (68) before centering adjustment is made).

INFORMATION AND PARTS REPLACEMENT

When requesting additional information concerning governor operation, or when ordering repair parts, it is very essential that the following information accompany the request.

1. Governor serial number (shown on nameplate); needed since the bulletin reference numbers do not identify the exact part number required for any one governor.
2. Bulletin number (this is bulletin 36602).
3. Part reference number, name of part, or description of part.

Parts List for Figure 14

REF. NO.	*PART NAME*	*QUANTITY*
36602- 1	Socket head cap screw (1/4-28 x 3/4)	4
36602- 2	Lockwasher (17/64 x 27/64 x 1/16)	4
36602- 3	Cylinder head (large)	1
36602- 4	Pipe plug (1/8)	AR
36602- 5	Cylinder head gasket	1
36602- 6	Retainer	1
36602- 7	Snap ring	1
36602- 8	"O" ring	1
36602- 9	Piston	1
36602- 10	Socket head screw (10-32 x 3/8)	2
36602- 11	Gasket	1
36602- 12	Power cylinder	1
36602- 13	Needle valve	1
36602- 14	"O" ring	1
36602- 15	Plug	1
36602- 16	"O" ring	2
36602- 17	Plug	1
36602- 18	Power piston	1
36602- 19	Stop collar	1
36602- 20	Cylinder head (small)	1
36602- 21	Oil seal	1
36602- 22	Oil seal	1
36602- 23	Snap ring	1
36602- 24	Rod end	1
36602- 25	Cotter pin (1/16 x 5/16)	1
36602- 26	Taper pin	1
36602- 27	Snap ring	4
36602- 28	Spring seat	2
36602- 29	Accumulator spring (large)	2
36602- 30	Accumulator spring (small)	2
36602- 31	Case-to-column dowel pin	2
36602- 32	Power case	1
36602- 33	Check valve assembly (spring loaded)	2
36602- 34	Check valve assembly (plain)	2
36602- 35	Gasket	1
36602- 36	Pipe plug (1/16)	AR
36602- 37	Instruction plate	1
36602- 38	Drive screw	3
36602- 39	Oil level gauge	1
36602- 40	Elbow	1
36602- 41	Drain cock	1
36602- 42	Accumulator piston	2
36602- 43	Drive gear	1
36602- 44	Idler gear stud	1
36602- 45	Idler gear	1
36602- 46	Oil seal ring	1
36602- 47	Case-to-base dowel pin	2
36602- 48	Base	1
36602- 49	Split lockwasher (21/64)	8
36602- 50	Hex head screw (5/16-18 x 1)	8
36602- 51	Gasket	1
36602- 52	Oil seal	1
36602- 53	Oil seal retainer	1
36602- 54	Snap ring	1
36602- 55	Bearing	1
36602- 56	Drive shaft	1

Parts List for Figure 14 (Cont'd.)

REF. NO.	PART NAME	QUANTITY
36602- 57	Bearing retainer	1
36602- 58	Hex head screw (1/4-28 x 5/8)	3
36602- 59	Lockwire	AR
36602- 60	Spring seat	1
36602- 61	Buffer spring	2
36602- 62	Buffer piston	1
36602- 63	Plug	1
36602- 64	"O" ring	1
36602- 65	Snap ring	1
36602- 66	Speeder spring check plug	1
36602- 67	Speeder spring	1
36602- 68	Pilot valve plunger nut	1
36602- 69	Cotter pin	1
36602- 70	Speeder spring seat	1
36602- 71	Thrust bearing	1
36602- 72	Adjusting spring washer	1
36602- 73	Adjusting spring	1
36602- 74	Flyweight bearing	4
36602- 75	Flyweight	2
36602- 76	Shutdown nut	2
36602- 77	Shutdown rod	1
36602- 78	Retaining ring	1

SPRING COUPLED –
UNDAMPED FLYWEIGHT HEAD ASSEMBLY

REF. NO.	PART NAME	QUANTITY
36602- 79	Round head screw (6-32 x 5/16)	1
36602- 80	Split lockwasher (#6)	1
36602- 81	Spring coupling assembly	1
36602- 82	Splined nut (10-32)	1
36602- 83	Flyweight head	1
36602- 84	Special washer	1
36602- 85	Round head screw (10-32 x 3/4)	1
36602- 86	Snap ring	1
36602- 87	Compensating bushing	1
36602- 88	Cotter pin	8
36602- 89	Flyweight pin—limit pin	4
36602- 90	Pilot valve plunger	1
36602- 91	Centering bearing	1
36602- 92	Flyweight head gear-pilot valve bushing assembly	1

SPRING COUPLED –
OIL DAMPED FLYWEIGHT HEAD ASSEMBLY

REF. NO.	PART NAME	QU
36602- 93	Round head screw (8-32 x 5/16)	
36602- 94	Split lockwasher (#8)	
36602- 95	Spring coupling assembly	
36602- 96	Fillister head screw (5-40 x 9/32)	
36602- 97	Lockwasher (#5)	
36602- 98	Flyweight head	
36602- 99	Centering bearing	
36602-100	Oil seal ring	
36602-101	Flyweight head gear-pilot valve bushing assembly	
36602-102	Flyweight head cup-pilot valve bushing assembly	

PARTS FOR SPECIAL LOW SPEED GOVERNOR OPERATION

REF. NO.	PART NAME	QU
36602-103	Spring	
36602-104	Spring seat	
36602-105	Plug	
36602-106	Snap ring	

RUBBER DAMPED FLYWEIGHT HEAD ASSEMBLY

REF. NO.	PART NAME	QU
36602-107	Rubber coupling assembly	
36602-108	Flyweight head	
36602-109	Flyweight head cup-pilot valve bushing assembly	

SOLID FLYWEIGHT HEAD ASSEMBLY

REF. NO.	PART NAME	QU
36602-110	Flyweight head	
36602-111	Pilot valve bushing assembly	
36602-112	Socket head screw (3/8-16 x 1 1/4)	
36602-113	Split lockwasher (3/8)	

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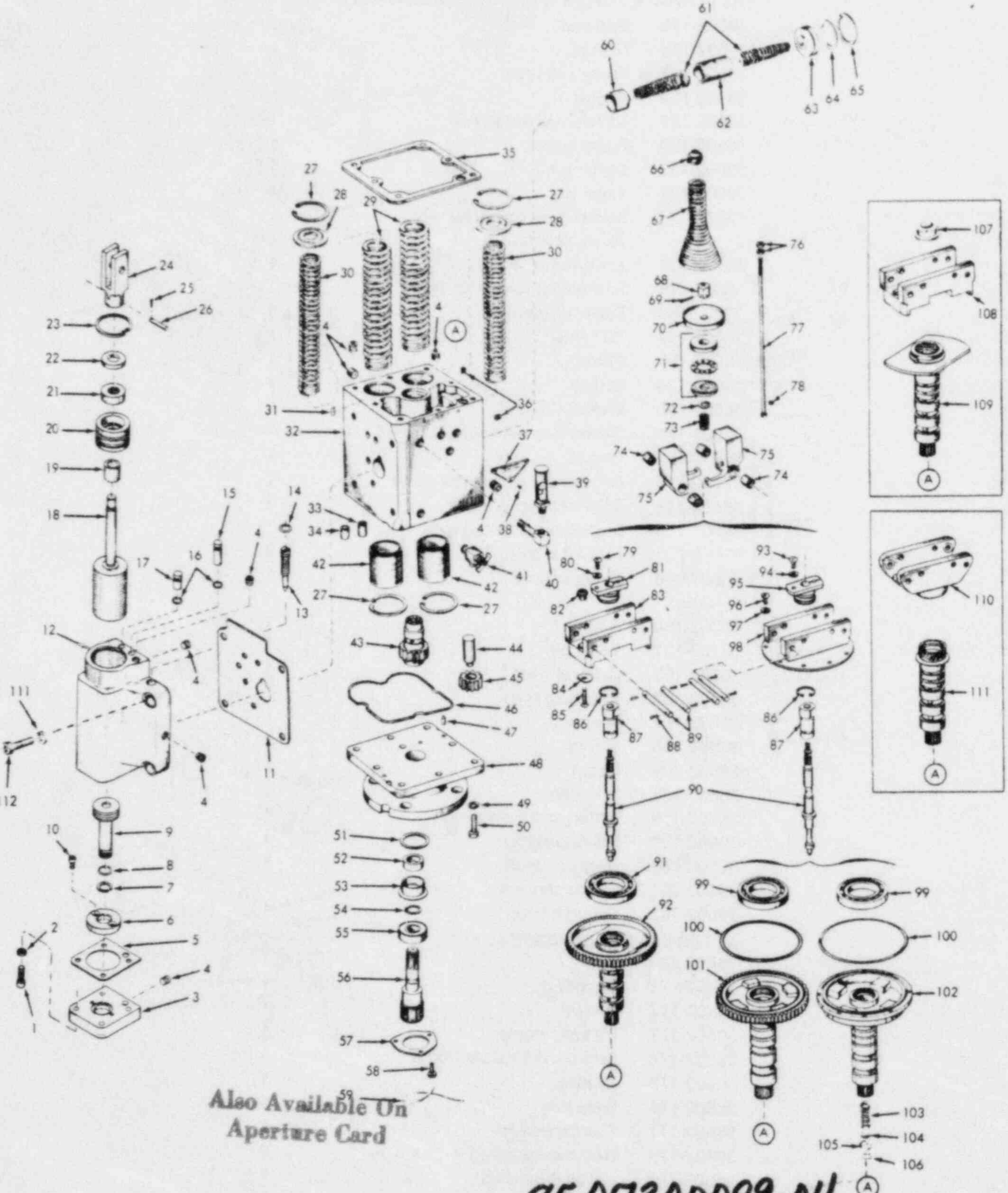

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Figure 14.

Parts List for Figure 15

REF. NO.	PART NAME	QUANTITY
ALTERNATE POWER CYLINDER ASSEMBLIES		
36602-125	Rod end	1
36602-126	Gasket	1
36602-127	Power cylinder	1
36602-128	Gasket	1
36602-129	Differential piston rod	1
36602-130	Power piston	1
36602-131	Cotter pin (1/16 x 1/4)	1
36602-132	Taper pin	1
36602-133	Socket head cap screw (5/16-18 x 1)	4
36602-134	Lockwasher (5/16)	4
36602-135	Shakeproof washer (1/2)	1
36602-136	Power piston nut	1
36602-137	"O" ring	1
36602-138	Piston	1
36602-139	Spring	1
36602-140	Washer (25/64)	1
36602-141	Elastic stop nut (3/8-24)	1
36602-142	Gasket	1
36602-143	Differential servomotor cover	1
36602-144	Split lockwasher (1/4)	8
36602-145	Socket head cap screw (1/4-20 x 3/4)	8
36602-146	Cylinder head	1
36602-150	Rod end	1
36602-151	Taper pin	1
36602-152	Cylinder head	1
36602-153	Retaining ring	1
36602-154	Washer	1
36602-155	Spring	1
36602-156	Piston	1
36602-157	"O" ring	1
36602-158	Differential piston rod	1
36602-159	Power piston	1
36602-160	Power cylinder	1
36602-161	Elastic stop nut	1
36602-162	Cylinder head	1
ALTERNATE BASE ASSEMBLY		
36602-170	Base	1
36602-171	Gasket	1
36602-172	Oil seal	1
36602-173	Oil seal retainer	1
36602-174	Serrated drive shaft (long)	1
36602-175	Bearing	1
36602-176	Snap ring	1
36602-177	Bearing retainer	1
36602-178	Hex. head screw (1-4-28 x 5/8)	3
36602-179	Keyed drive shaft	1
36602-180	Straight key	1
36602-181	Spacer sleeve	1
36602-182	Castle nut (5/8-18)	1
36602-183	Lockwire	AR

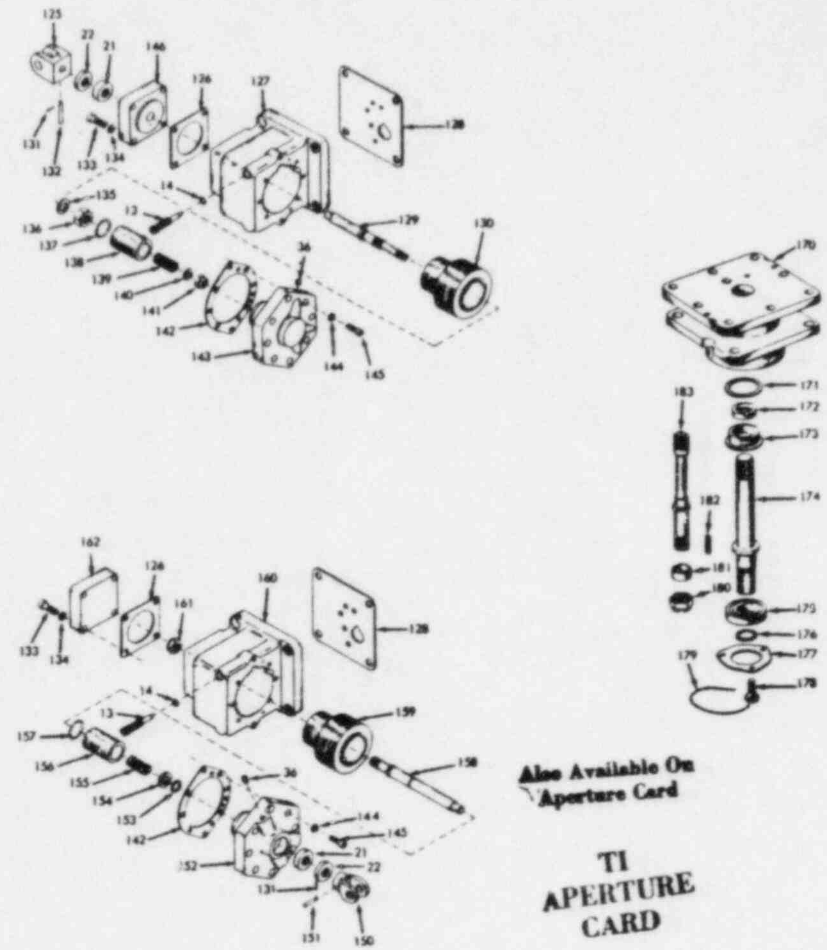

Figure 15

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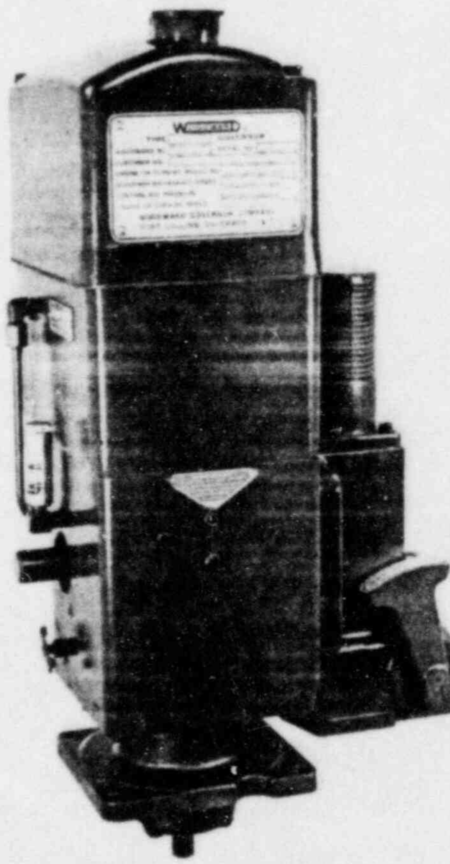
WOODWARD ®

BULLETIN 36694B

PG-PL GOVERNORS

(REPLACES BULLETIN 36012)



WOODWARD GOVERNOR COMPANY
ENGINE & TURBINE CONTROLS DIVISION
FT. COLLINS, COLORADO, U.S.A.

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PG-PL GOVERNORS

SECTION I/GENERAL INFORMATION

INTRODUCTION

This bulletin provides description, operation, installation, adjustment, maintenance, and replacement parts information for the PG-PL governor.

The basic PG governor (pressure compensated governor) with a pneumatic speed setting mechanism (direct or reverse) and a short column that is used primarily for controlling engine or turbine speed has been assigned the designation PG-PL governor. This PG governor was first used on pipe lines, hence the PL, but has since found wide acceptance on all types of diesel engines, gas engines, steam turbines driving pumps and compressors, and many special applications. The PG-PL governor includes a pneumatic speed setting mechanism, standard short column, standard base assembly, and 12 foot-pound power cylinder assembly. The repair manual for the PG-A governor (similar to the PG-PL in speed setting but with a long column to house various options for load control) is bulletin 36699.

All PG governors have the same basic components regardless of how simple or complex the complete control may be. The following components, found in each PG-PL governor, are sufficient to enable the governor to maintain a constant engine speed as long as the load does not exceed engine capacity:

1. an oil pump, storage area for oil under pressure, and a relief valve by which maximum oil pressure may be limited;
2. a centrifugal flyweight head-pilot valve assembly which controls flow of oil to and from the governor cylinder assembly;
3. a power cylinder assembly--sometimes referred to as a servomotor--which positions the fuel racks, fuel valve, or steam valve of the engine or turbine;
4. a compensating system for stability of the governed system;
5. a pneumatic speed setting mechanism for adjusting the governor speed setting.

A cutaway view of the PG-PL governor is shown in figure 1.

DESCRIPTION

The governor controls engine or turbine speed by controlling the amount of fuel or steam supplied to the engine or turbine. Speed control is isochronous, i.e., the governor will maintain constant engine or turbine steady state speed, within the capacity of the unit, regardless of load.

The standard operating oil pressure for PG governors is 100 psi. However, with appropriate modifications the oil pressure may be increased, thus increasing the work capacity of the power cylinder assembly. Table 1 lists typical governor oil pressures versus power cylinder work capacities.

Table 1. Governor Oil Pressure Versus Power Cylinder Work Capacities (Typical)

Governor Operating Oil Pressure (PSI)	Power Cyl. Work Capacities in Ft-Lb		
	12	17	29
100 (std.)	12	17	29
130	16	22	38
200	24	34	58

An air pressure signal from a pneumatic air transmitter or controller supplies air to the governor speed setting mechanism. The governor will control the engine at a definite speed for each air pressure. The most common air pressure range for the governor is from 3-15 psi. Normal minimum control air pressure is 3 psi; however, a minimum of 1 psi and a maximum of 100 psi can be accommodated. The governor speed range normally falls between 250-1000 rpm, but a low speed of 200 rpm or a high speed of 1600 rpm can be obtained. Contact Woodward Governor Company for recommended control air pressure to governor speed setting relationship to meet the requirements of the particular installation.

The pneumatic speed setting mechanism (direct or reverse) is a bellows type mechanism and is standard equipment on all PG-PL governors now manufactured by Woodward. The speed setting unit is an accurate durable mechanism which

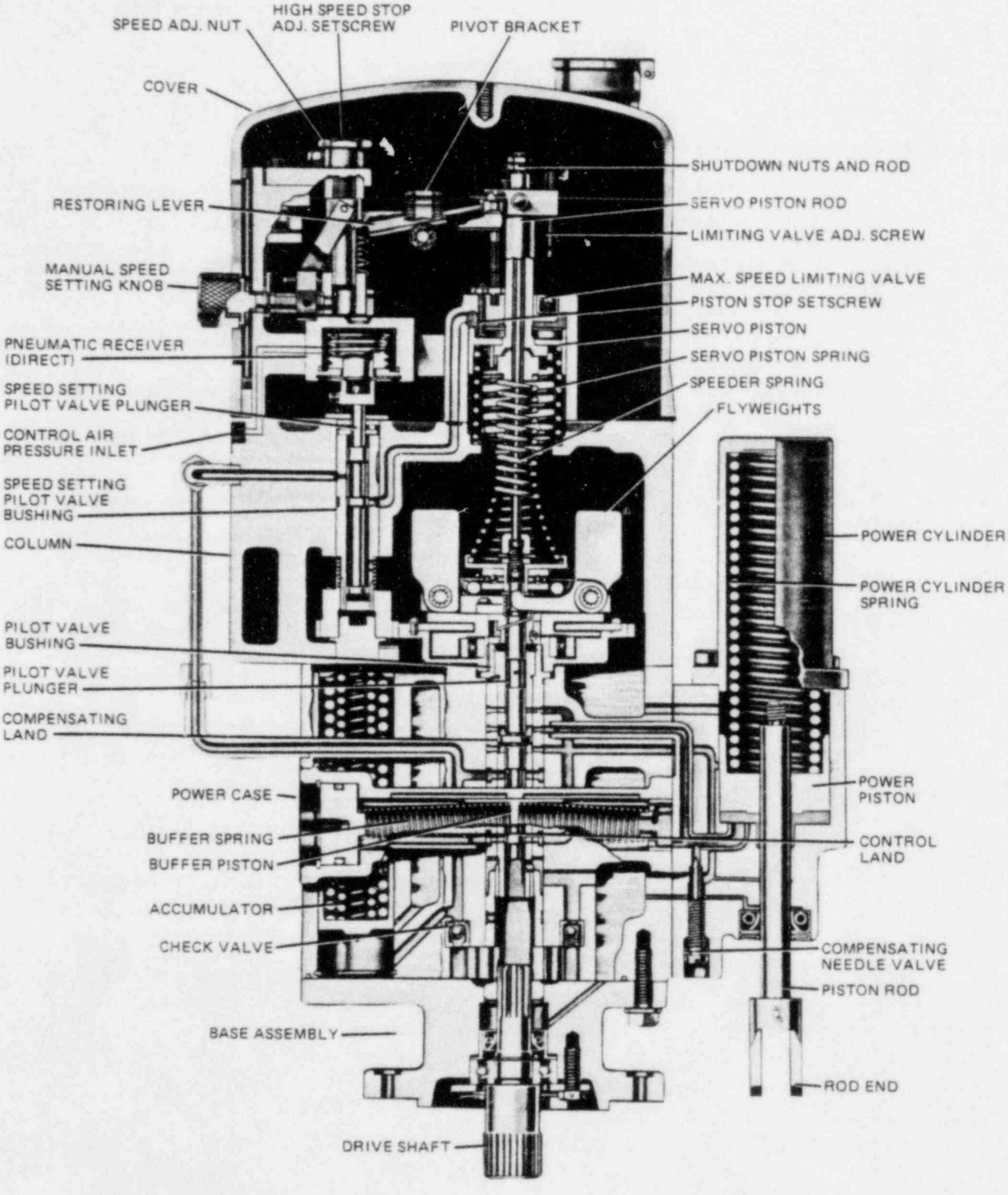


Figure 1. Cutaway View PG-PL

virtually eliminates the hysteresis loops encountered with less sensitive pneumatic speed setting elements. (A hysteresis loop is a plot of the speeds obtained at various control signal pressures; one portion is recorded as speed setting signals are being increased, the other portion as the signals are being decreased.) Bellows type speed setting provides a definite, accurate relationship between speed and speed signal.

The speed setting mechanism is available for use with air input signals of varying range and magnitude (e.g. 3 to 15 psi, 20 to 70 psi, etc.). Depending upon the exact configuration installed in the governor, speeds may be adjusted up to a 5 to 1 range. The speed setting mechanism can be furnished to increase governor speed setting for an increase in control air pressure (direct type) or to increase governor speed setting for a decrease in control air pressure (reverse type).

The manual speed setting knob permits manual operation when the air pressure signal is not available.

Diaphragm receiver models of the governors are obsolete and no longer manufactured as a complete unit. However, replacement parts for these units are available and detail information on the units is found at the end of this manual.

As is the case with any governor of any type, it is essential that the engine or turbine be equipped with a separate overspeed shutdown device to prevent runaway in the event of failure of the governor, the mechanism which drives it, or the control it operates.

AUXILIARY FEATURES (OPTIONAL)

Many auxiliary devices are available for use, either singly or in combination, on the PG governor to meet the numerous control requirements of the installation requiring precise speed setting. Each governor is designed to meet the needs of the engine or turbine and the operating requirements of the installation.

Auxiliary equipment may be supplied as original equipment in the governor or it may be installed in the field; it is recommended that the customer contact Woodward Governor Company on field installations.

The following paragraphs give a brief description of some of the auxiliary equipment available from Woodward Governor Company and list the bulletins where detail information may be obtained.

Bulletin No.	Title
36034	PG Governor Heater
36611	Current Controlled Speed Setting Mechanism
36641	Governor Heat Exchanger
36650	Solenoid Operated Shutdown Assembly
36651	Pressure Actuated Shutdown Assembly
36680	Preloaded Buffer Springs
36684	Booster Servomotor
36692	PG Power Cylinder Assemblies
36693	PG Base Assemblies

PG GOVERNOR HEATER

An electric heater is available for PG governors used on engines which are shut down for lengthy periods in cold climates. By applying heat to the governor power case during shutdown periods--or for a time before start-up--the governor oil viscosity is maintained at a point which enables the oil to flow freely through passages of the governor. This allows normal governor operation as soon as the engine is started.

CURRENT CONTROLLED SPEED SETTING MECHANISM

The current controlled speed setting mechanism provides continuous precise speed setting of a governor in response to electric signals from commercial sensing and transmitting equipment. A transducer within the unit converts the electric input signals into governor speed setting changes. The governor speed setting is proportional to the electric input signal, and can be arranged to give maximum governor speed for either the maximum input signal or the minimum input signal. Contact Woodward Governor Company on applications of this unit to PG-PL governors.

GOVERNOR OIL COOLER

A governor oil cooler is required when governor drive shaft speed exceeds 1200 RPM on an engine application, or 1100 RPM on a steam turbine. It also may be necessary to use an oil cooler at lower governor drive shaft speeds if the governor is mounted close to valves or steam lines which result in high ambient temperatures.

Water (or some other liquid coolant) from an external supply enters the oil cooler cover and passes through a tube to the oil cooler body. The water circulates through the body cavity to the discharge.

A special governor case may be required to mount the oil cooler or to connect to the external heat exchanger. Where it might be desirable to add an oil cooler to a governor already in service, the governor should be returned to the factory for conversion.

SHUTDOWN DEVICES

A shutdown device can be incorporated in the PG governor to stop fuel to the engine or turbine if equipment fails. These assemblies are used in a variety of applications including plants where automatic safety devices are a necessity. Shutdown devices can be supplied in the following arrangements to suit the particular operating conditions:

1. Shutdown assemblies which will operate from air, oil, or water pressure. These assemblies are generally supplied where electrical devices cannot be used. The air, oil, or water shutdown device can be arranged to shut down the engine or turbine on either high or low signal pressure.

2. A solenoid shutdown device which can be arranged to energize or de-energize to shut down. Solenoid coils are available to accommodate most common DC voltages. Power required is 6 watts. For AC operation, a separately mounted transformer or rectifier assembly converts AC voltage to the required DC voltage.

PRELOADED BUFFER SPRINGS

Preloaded buffer springs are often installed in PG governors used on two-cycle spark ignition engines and on some engines driving reciprocating pumps. As a result of preloading, the governor minimizes fuel linkage movements resulting from changes in speed due to misfiring or pump strokes. The use of preloaded buffer springs does not affect the capability of the governor to recognize and respond to speed changes. Preloaded buffer springs do retard the rate at which the governor output piston (or shaft) moves when responding to small or momentary offspeeds. The output piston (or shaft) moves at the normal rate for large speed changes.

BOOSTER SERVOMOTOR

The booster servomotor is used in conjunction with the PG governor to assist the engine in starting quickly. The function of this device is to supply oil under pressure to the governor at the instant starting air is supplied to the engine this enables the governor to move the engine linkage to the fuel-on position immediately.

PG BASES AND POWER CYLINDER ASSEMBLIES

A number of different base and power cylinder arrangements are available to conform to engine or turbine manufacturer's specifications.

The base assembly can be furnished with either a serrated or keyed drive shaft. Refer to bulletin 36693.

The work capacity of the power cylinder assembly normally furnished with the governor is 12 foot-pounds. A maximum of 8 foot-pounds can be used to move the fuel or steam control linkage over the full range of governor travel. Power cylinders with work capacity up to 58 foot-pounds are available. Refer to bulletin 36692.

SECTION II/INSTALLATION AND ADJUSTMENT

INSTALLATION

Refer to figure 8 for complete physical dimensions of the governor. Adequate clearance must be provided for installation, removal, and servicing. At all times, use care in handling the governor; be particularly careful to avoid striking the drive shaft. Do not drop or rest the governor on its drive shaft. Such treatment could damage the governor drive shaft, drive shaft bearing, or governor oil pump gears.

When the governor is installed on the engine or turbine, a gasket should be used between the mounting pad and the governor base. The governor should be mounted squarely and the drive connection properly aligned.

If the governor is equipped with a serrated or splined drive shaft, it should slip into the internal serrations or splines of the drive freely. If a keyed type governor drive shaft is used, the gear must slip on the shaft freely and should be checked to insure that it meshes properly. The gears should run freely without binding or excessive backlash. Irregularities caused by uneven gear teeth, shaft runout, etc., will result in erratic governing and shorten governor life.

LINKAGE ADJUSTMENT

The linkage from the governor to the fuel or steam control should be properly aligned. Any friction or lost motion should be eliminated. Unless the engine or turbine manufacturer has given special instructions, the linkage should be adjusted so that when the governor power piston is at the end of its stroke in the "OFF" direction, the gas or steam valve, or diesel fuel pumps will just be closed.

When the governor has been properly mounted and the linkage connections completed, make the air connections to the manual or automatic air controller.

OIL SPECIFICATIONS

Information on oils for use in hydraulic governors is available in bulletin 25007. Use SAE 20 or 30 oil for ordinary temperature conditions. If governor operating temperatures are extremely hot, use SAE 40 to 50; if extremely cold, use SAE 10. In most cases, the same oil that is used in the engine or turbine may be used in the governor.

Keep the governor oil level between the lines on the glass of the oil level gauge when the engine or turbine is running. The oil should never be above the line where the case and column castings meet. Oil above this level will be churned into foam by rotation of the flyweight head. The governor can run safely with the oil level quite low in the gauge glass.

PURGING AIR FROM GOVERNOR AND NEEDLE VALVE ADJUSTMENT

When the engine or turbine is started for the first time, or after the governor has been drained and cleaned, the governor must be filled with oil, and any air trapped in the governor removed. To bleed off the trapped air, set the governor at idle speed position by means of the air controller or the manual speed adjustment. Start the engine or turbine and open the compensating needle valve (figure 1) several turns. This should cause the engine to hunt.

Loosen the air vent plug (figure 8) far enough to establish a leak, and allow the engine to hunt a sufficient length of time to permit all air trapped in the governor oil passages to escape at the vent plug. When no more air bubbles are apparent, tighten the vent plug, and if necessary add oil to the governor to restore the correct level in the gauge glass.

Close the compensating needle valve gradually until hunting is just eliminated. The proper setting depends upon the characteristics of the engine. Keep the needle valve open as far as possible to prevent sluggishness. The needle valve setting will vary from 1/16-turn open to 2 turns open. With preloaded buffer springs (optional equipment), the needle valve should not be more than 1/16-turn open for smooth operation. The needle valve must never be closed tight, as the governor cannot operate satisfactorily when this condition exists.

On some installations, opening the needle valve will not cause the engine or turbine to hunt. In such cases, bleed the air from the governor by disturbing engine or turbine speed to cause the governor to move through full stroke in both directions a sufficient number of times to force out all trapped air.

After the needle valve is adjusted correctly for the engine, it should not be necessary to change the setting except for a large permanent temperature change affecting the viscosity of the governor oil.

SPEED ADJUSTMENTS

The pneumatic speed setting mechanism furnished with the governor is either (1) a direct type which increases the governor speed setting as the control air pressure signal increases or (2) a reverse type which increases governor speed setting as the control air pressure signal decreases. Perform the following procedures as applicable to set the maximum and minimum operating speed of the governor. See figures 1 and 2.

DIRECT SPEED SETTING MECHANISM

1. Set the manual speed adjusting knob to the minimum speed position (fully counterclockwise until clutch slips).

2. Adjust the high speed adjusting setscrew as required until upper end of screw is flush with top of speed setting screw.

3. Apply specified minimum control air pressure signal to the unit; adjust the speed adjusting nut as required to obtain corresponding specified minimum speed (clockwise to decrease); be sure the pneumatic low speed adjusting screw does not touch the restoring lever at this time.

4. Adjust limiting valve adjusting screw as required so that it does not unseat the maximum speed limiting valve as speed is increased. Set governor speed range to control air pressure range as follows:

   a. Slowly increase control air pressure signal to maximum. Be sure engine does not exceed specified maximum speed.

   b. If specified maximum speed is obtained before control air pressure signal is increased to maximum, adjust the pivot bracket to move the ball bearing pivot toward the speed setting servo.

   c. If specified maximum speed is not obtained with maximum control air pressure signal, adjust the pivot bracket to move the ball bearing pivot away from the speed setting servo.

   d. Adjust the pivot bracket as follows: Loosen the socket head screw in top of the pivot bracket; loosen knurled nut on appropriate side of bracket and turn opposite knurled nut to move bracket; tighten screw and knurled nuts.

5. Repeat steps 3 and 4 above until specified minimum speed is obtained with minimum control air pressure and specified maximum speed is obtained with maximum control air pressure. Speed should begin to increase as the control air pressure begins to increase from minimum.

6. Apply maximum control air pressure for maximum speed. Adjust the limiting valve adjusting screw so that it just contacts the ball in the maximum speed limiting valve. Increase control air pressure slightly above specified maximum; the maximum speed limiting valve should open prior to engine reaching [illegible] rpm above specified maximum speed. Readjust screw as necessary.

7. Apply minimum control air pressure signal for minimum engine speed. Perform step a or b as applicable.

   a. If engine is to go to low speed upon loss of control air pressure signal to the governor, set the pneumatic low speed adjusting screw to just contact the stop pin in the restoring lever with the engine running at low speed. Shutdown nuts are usually omitted on governors which are arranged to go to low speed upon loss of control air pressure. If nuts are included but not used, lower nut should be a minimum of 1/32-inch above the speed setting piston rod with engine running at low speed.

   b. If engine is to shut down upon loss of control air pressure signal to the governor:

      (1) Lift up on the shutdown rod to take out any slack or lost motion; do not lift the rod so far as to cause the engine speed to drop. While holding the rod up, position the lower shutdown nut 1/32-inch above the top of the speed setting servo piston rod and lock in position with upper nut.

      (2) Turn the piston stop setscrew down until it touches the speed setting piston then turn the screw counterclockwise 2 turns and lock in position with nut. This adjustment limits the upper movement of the piston when the engine is shut down, and it minimizes the cranking required when the engine is restarted.

      (3) Adjust the pneumatic low speed adjusting screw so that it is 0.040-0.050 inch below

the stop pin in the restoring lever. Turn off control air pressure signal to the governor (engine will shut down). Adjust the adjusting screw so that it is from 0.002 to 0.005 inch below the stop pin in the restoring lever.

8. With control air pressure signal removed (engine does not go to shutdown with loss of control air pressure signal), turn the manual speed adjusting knob clockwise to increase engine speed to maximum. Turn the high speed adjusting setscrew in until it just touches the high speed stop pin (this adjustment stops the downward movement of the speed adjusting nut at high speed).

REVERSE SPEED SETTING MECHANISM

1. Set the manual speed adjusting knob to the minimum speed position (fully counterclockwise until clutch slips).

2. Adjust the speed adjusting nut so that the speed setting screw protrudes approximately 1/4-inch above the nut.

3. Adjust the high speed adjusting setscrew as required until screw is flush with the top of speed setting screw.

4. Adjust the limiting valve adjusting screw as required so that it does not unseat the maximum speed limiting valve as speed is increased. Apply minimum control air pressure signal to the governor (pressure at which specified maximum engine speed is to be obtained). Be careful that engine does not exceed specified maximum speed.

5. Turn the manual speed adjusting knob clockwise to increase engine speed to specified maximum. Turn the high speed adjusting setscrew in until it just touches the high speed stop pin. If screw is turned down too far, speed will decrease.

If the specified maximum speed is not obtained with the manual speed adjusting knob fully clockwise, turn the knob approximately 2 turns counterclockwise, back out high speed stop adjusting setscrew a few turns, then turn speed adjusting nut counterclockwise until specified maximum speed is obtained. Turn high speed adjusting setscrew down until it just touches the high speed stop pin (if the screw is turned down too far, speed will decrease). Turning the speed adjusting knob fully clockwise should not increase speed beyond the specified maximum.

6. Slowly increase control air pressure signal until specified minimum speed is obtained. The pneumatic low speed adjusting screw should not touch the stop pin in the restoring lever and the piston stop setscrew should not stop the speed setting piston as it moves up to decrease speed.

If specified minimum speed is obtained before the control air pressure signal is increased to specified maximum, adjust the pivot bracket to move the ball bearing pivot toward the speed setting cylinder.

Adjust the adjustable pivot bracket as follows: Loosen the socket head screw in top of pivot bracket; loosen knurled nut on appropriate side of pivot bracket and turn opposite knurled nut to move the pivot bracket; tighten screw and knurled nuts.

7. Repeat steps 4, 5, and 6 above until specified minimum speed is obtained with maximum control air pressure signal and specified maximum speed is obtained with specified minimum control air pressure signal. Insure engine speed begins to increase as the control air pressure signal begins to decrease from maximum.

8. After setting speeds pneumatically, apply minimum control air pressure signal (governor will go to maximum speed setting). Turn manual speed adjusting knob counterclockwise until specified minimum speed is obtained. Alternately turn speed adjusting nut 1/2 turn counterclockwise (increasing speed) and adjusting knob counterclockwise (decreasing speed) until adjusting knob is fully counterclockwise. Turn off control air supply (speed will rise slightly). Adjust speed adjusting nut to obtain specified minimum speed.

If adjusting nut is turned fully counterclockwise without reaching the specified minimum speed, turn off control air supply (speed will rise slightly). Adjust speed adjusting nut to obtain specified minimum speed.

9. With the engine operating at specified minimum speed, turn the piston stop setscrew down until it just touches the top of the speed setting piston; then turn the screw 2 turns counterclockwise; lock in position with locknut. This adjustment limits the upward movement of the piston when the engine is shut down, and it minimizes the cranking required when engine is restarted.

10. If shutdown nuts are used, lift up on the shutdown rod to take out any slack or lost motion; do not lift the rod so far as to cause the engine speed to drop. While holding the rod up, position the lower shutdown nut 1/32-inch above the top of the speed setting servo piston rod and lock in position with upper nut.

11. With the control air pressure signal turned off, turn the manual speed adjusting knob clockwise to increase engine speed to maximum. Adjust the limiting valve adjusting screw so that it just contacts the ball in the maximum speed limiting valve. Increase engine speed slightly above the specified maximum; the maximum speed limiting valve should open prior to engine reaching 5 rpm above maximum speed. Readjust screw as necessary.

12. Turn the manual speed adjusting knob fully counterclockwise and apply maximum control air pressure to the governor. Adjust the pneumatic low speed adjusting screw to just contact the stop pin in the restoring lever with the engine running at low speed.

SECTION III/PRINCIPLES OF OPERATION

INTRODUCTION

The sectional view of the PG-PL governor (see figure 1) serves to indicate the relative position of the various governor components in the complete assembly. The connecting oil passages between parts are not necessarily in their correct location, but are simplified to facilitate their location. The lower part of the governor consists of the base and power case and the basic components of the hydraulic PG isochronous governor, which functions to maintain a constant engine speed by controlling the fuel supplied to the engine. The upper part of the governor consists of the column, cover, and related parts; it also consists of the pneumatic speed setting mechanism, and optional shutdown and protective devices where applicable.

DESCRIPTION OF OPERATION

The schematic diagram (figure 2) illustrates the essential parts of the governor and speed setting mechanism which are required to regulate fuel and control engine speed.

Speed adjusting in the governor is effected by controlling the position of the speed setting servo piston. Movement of the servo piston to a higher or lower speed setting is obtained by admitting or draining pressure oil to or from the area above the servo piston.

The flow of governor oil to or from the area above the servo piston is controlled by the speed setting pilot valve plunger - contained in a rotating bushing - which is actuated by a controlled air pressure signal or by a manual control knob.

After each speed setting change, a restoring lever connected between the servo piston rod and speed setting pilot valve plunger returns the plunger to the closed port position, stopping the flow of oil to or from the area above the servo piston, thus holding the piston at the position for the particular speed setting of the governor.

The governor drive shaft passes through the governor base into the pump drive gear, which is direct connected to the rotating pilot valve bushing. The flyweight head is secured to the upper end of the pilot valve bushing, thus providing a direct drive from the engine to the flyweights. At any speed setting of the governor, when the engine is on speed, the centrifugal force of the flyweights will balance the opposing force of the speeder spring with the flyweights in the vertical position, and the control land of the pilot valve plunger will be covering the regulating ports in the rotating pilot valve bushing.

Pressure seal grooves are supplied with pressure oil through the regulating port to prevent the oil trapped between the power piston and the buffer piston from leaking past the power piston, power piston rod and pilot valve stem. To make up leakage of the seal oil and hold the power piston in a steady state position against the power spring -- when the engine is on speed with a steady load -- the pilot valve plunger will be below center enough to supply the required amount of oil through the regulating port.

The governor oil pump supplies pressure oil to the rotating pilot valve bushing, speed setting pilot valve bushing, pressure seal grooves, and to the accumulators, with excess oil (at maximum pressure) bypassing from the accumulators to the governor sump. Duplicate suction and discharge ball check valves at the pump permit rotation of the governor in either direction.

The pilot valve plunger moves up and down in the rotating pilot valve bushing to control the flow of oil to or from the power cylinder assembly. When the pilot valve plunger is centered (i.e., the control land of the plunger exactly covers the control port of the bushing), no oil flows to or from the power cylinder assembly.

The greater of two forces moves the pilot valve plunger up or down. The centrifugal force developed by the rotating flyweights is translated into an upward force which tends to

lift the plunger. The centrifugal force is opposed by the downward force of the speeder spring. When the opposing forces are equal, the pilot valve plunger is stationary.

With the pilot valve plunger centered and the engine running on-speed, a change in either of the two forces will move the plunger from its centered position. The plunger will be lowered (1) if the governor speed setting is unchanged but an additional load slows the engine and governor (thereby decreasing the centrifugal force developed by rotating flyweights) or (2) if the engine speed is unchanged but the speeder spring force is increased to raise the governor speed setting. Similarly, the pilot valve plunger will be raised (1) if the governor speed setting is unchanged but load is removed from the engine causing an increase in engine and governor speed (and hence, an increase in the centrifugal force developed by the rotating flyweights), or (2) if the engine speed is unchanged but the speeder spring force is reduced to lower the governor speed setting.

The thrust bearing atop the ballarm toes permits the pilot valve bushing to rotate while the pilot valve plunger does not rotate. In this way, static friction between the bushing and plunger is minimized.

There are several styles of flyweight head assemblies available. The exact model used in any one governor depends upon the application.

A "solid" head assembly is used in governors on prime movers which afford a smooth drive to the governor.

"Spring driven" and "spring driven, oil damped" head assemblies are used to filter torsional vibrations which may be imparted to the governor by the drive from the engine. (These torsional vibrations may originate from a source other than the drive itself but reach the governor through the drive connection). Unless minimized or eliminated, the flyweight head will sense these torsional vibrations as speed changes and continually adjust the fuel valve or racks in an attempt to maintain a constant speed.

Movements of the power piston are transmitted by the piston rod to the engine fuel linkage. Regulated oil pressure under the power piston is used to raise the power piston -- to increase fuel -- and the power spring above the power piston is used to lower the power piston to decrease fuel.

Located between the pilot valve bushing and the power piston is the buffer compensating system, consisting of the buffer cylinder and piston, the buffer springs, and the compensating needle valve. Lowering the pilot valve plunger permits a flow of pressure oil from the pilot valve bushing into the buffer system and power cylinder to raise the power piston and increase fuel. Raising the pilot valve results in a flow of oil from the power cylinder and buffer system to the governor sump, and the power spring moves the power piston down to decrease fuel to the engine.

This flow of oil in the buffer system -- in either direction -- carries the buffer piston in the direction of flow, compressing one of the buffer springs and releasing the other. This action creates a slight differential in the pressures of the oil on opposite sides of the buffer piston, with the higher pressure on the side opposite the spring which is compressed. These differential oil pressures are transmitted to the areas above and below the compensating land on the pilot valve plunger, producing an upward or downward force on the compensating land which assists in re-centering the pilot valve plunger whenever a fuel correction is made.

The vertical position of the flyweights with the control land of the pilot valve covering the regulating port indicates that the engine is on-speed.

THEORY OF OPERATION

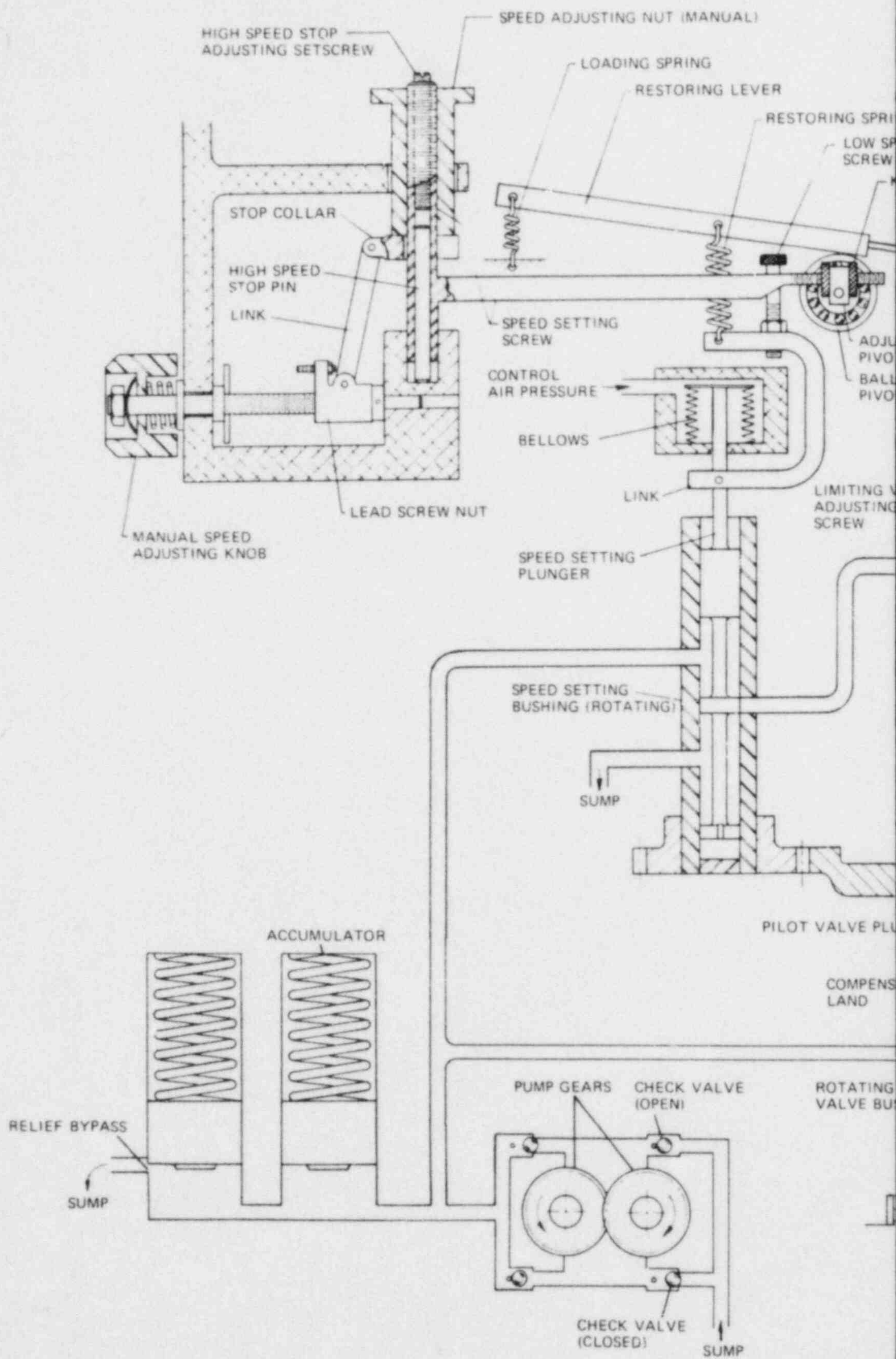
See figure 2 for the schematic diagram of the essential components of the basic governor and speed setting mechanism and the relative positions they assume when the engine is operating on-speed under steady-state conditions. Differences may exist in the actual design details of these components from one governor to another, but the scheme of operation is the same in each.

The schematic arrangement of the "direct" speed setting mechanism (governor speed increases as the control air pressure signal increases) is incorporated into the diagram of figure 2. The inset shown on figure 2 shows the "reverse" speed setting (governor speed decreases as the control air pressure signal increases) version.

The following theory of operation describes the direct speed setting mechanism. The sequence of events occurring in the governor take place more or less in a simultaneous manner, rather than step by step as described in the following paragraphs.

SPEED INCREASE

An increase in the control air pressure signal to the pneumatic receiver assembly is sensed by a bellows. Through a mechanical connection to the speed setting pilot valve plunger, the bellows movement -- caused by changes



HIGH SPEED STOP ADJUSTING SETSCREW
SPEED ADJUSTING NUT (MANUAL)
LOADING SPRING
RESTORING LEVER
STOP COLLAR
HIGH SPEED STOP PIN
LINK
SPEED SETTING SCREW
CONTROL AIR PRESSURE
BELLOWS
LINK
LEAD SCREW NUT
MANUAL SPEED ADJUSTING KNOB
SPEED SETTING PLUNGER
SPEED SETTING BUSHING (ROTATING)
SUMP
ACCUMULATOR
RELIEF BYPASS
SUMP
PUMP GEARS
CHECK VALVE (OPEN)
CHECK VALVE (CLOSED)
SUMP

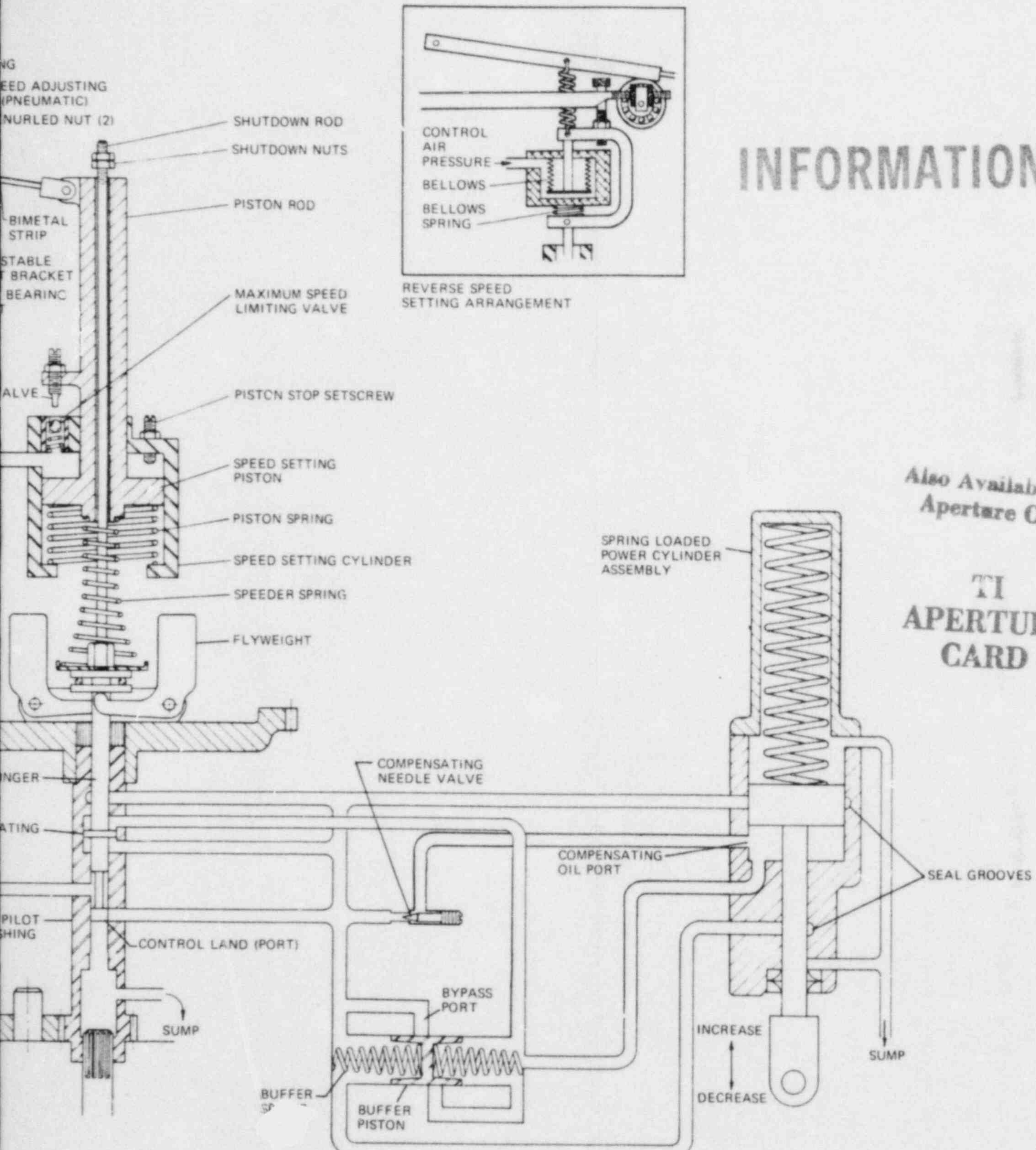


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Figure 2. Schematic Diagram of PG-PL Governor

in the input signal pressure -- displaces the speed setting pilot valve plunger to change the governor speed setting. The increased pressure compresses the bellows to lower the speed setting pilot valve plunger. Pressure oil flows to the area above the speed setting servo piston to force the piston down, and thus increase the governor speed setting.

As the servo piston moves down, a restoring lever -- connected between the servo piston rod and speed setting pilot valve plunger on a ball bearing pivot -- increases the lifting force on a restoring spring attached to the restoring lever. When the lifting force of the restoring spring is equal to the downward force resulting from the increased pressure signal, the speed setting pilot valve plunger will be returned to its centered position.

Increasing the speed setting of the governor increases the downward pressure of the speeder spring on the toes of the flyweights and the flyweights move in, lowering the pilot valve plunger and opening the control port.

Opening the port in this direction admits pressure oil into the buffer system, causing the buffer piston to move to the right and transfer an equal volume of oil to the power cylinder, forcing the power piston up in the direction to increase fuel.

As the buffer piston moves in the direction of the oil flow -- from pilot valve to power cylinder -- the right buffer spring is compressed and the left spring is relieved. This produces an intermediate oil pressure on the left side of the buffer piston which is higher than the pressure of the trapped oil on the right side of the buffer piston and spring displacement.

Simultaneously with the movement of the power piston and buffer piston, the differential oil pressures on opposite sides of the buffer piston are transmitted to the upper and lower sides of the compensating land, with the higher pressure on the lower side causing an upward force on the compensating land which will increase until (added to the upward force of the flyweights) it will balance the speeder spring force, raise the pilot valve plunger enough to cover the control port, and return the flyweights to the vertical position. As soon as the control port is covered the power piston will be stopped at a new position corresponding to the increased amount of fuel needed to operate the engine at the desired higher speed. The engine is still accelerating toward the new speed setting.

As the centrifugal force of the flyweights increases to a higher value with engine acceleration, the upward oil force at the compensating land is reduced to zero by the equalization of the oil pressures in the buffer system through the compensating needle valve. If the needle valve is correctly adjusted the oil pressures will equalize at the same rate as the increase in the centrifugal force of the flyweights, and the flyweights will remain in the vertical position, keeping the control port covered by the control land of the pilot valve, and holding the power piston stationary at the new position. Equalizing the oil pressures in the buffer system allows the buffer springs to return the buffer piston to center in the buffer cylinder.

The engine will now be running at a higher speed with an increased fuel setting.

SPEED DECREASE

A decrease in the control air pressure signal to the bellows of pneumatic receiver assembly allows the restoring spring -- attached to restoring lever -- to lift the speed setting pilot valve plunger. Oil drains from the area above the servo piston, the servo piston spring forces the piston to rise and thus decrease the speeder spring compression and lower the governor speed setting.

The restoring lever follows the movement of the servo piston, moves up and, in so doing, decreases the lifting force on the restoring spring. When the servo piston and right end of the restoring lever has moved up sufficiently to balance the upward force of the restoring spring to equal the decrease in downward force resulting from the decrease in control air pressure signal, the speed setting pilot valve plunger will have returned to its centered position.

Lowering the speed setting of the governor decreases the downward pressure of the speeder spring on the toes of the flyweights and the flyweights move out, raising the pilot valve plunger and opening the control port.

Opening the port in this direction permits oil to flow from the buffer system to the governor sump. This will lower the oil pressure in the buffer system and the power spring will force the power piston down in the direction to decrease fuel. As the buffer piston moves in the direction of the oil flow -- from power cylinder to pilot valve -- the left buffer spring is compressed and the right spring is relieved. This produces a pressure in the trapped oil, on the right side of the buffer piston which is higher than the intermediate oil pressure on the left side of the buffer piston, by an amount proportional to the displacement of the buffer piston and spring.

Simultaneously with the power piston and buffer piston

movement, these pressures will be transmitted to the compensating land, with the higher pressure now on the upper side of the land, causing a downward force which will increase until (added to the downward force of the speeder spring) it will balance the flyweight force, lower the pilot valve plunger enough to cover the control port, and return the flyweights to the vertical position. As the control port is covered the power piston will stop at a new position to correspond to the reduced amount of fuel required to operate the engine at the desired lower speed. The engine will be still decelerating toward the new speed setting.

As the centrifugal force of the flyweights decreases with engine deceleration, the downward oil force at the compensating land will again be reduced to zero by the equalization of the oil pressures in the buffer system through the compensating needle valve. With the needle valve correctly adjusted the oil pressures will equalize at the same rate as the decrease of centrifugal force in the flyweights, and the flyweights will remain in the vertical position, keeping the control port covered by the control land of the pilot valve, and holding the power piston stationary at the new position. Again, the buffer piston will be returned to center by the action of the buffer springs. The engine will now be running at a lower speed with a reduced fuel setting.

Bypass ports are provided in the buffer cylinder to facilitate large corrective movements of the power piston. A large increase or decrease in the speed setting of the governor, or a large increase or decrease of load on the engine, will require a correspondingly large movement of the power piston to make the necessary correction to the fuel setting. Under such conditions, the buffer piston will move only far enough to the left or right to effect an opening at the bypass port (pressure or drain). Oil will then flow directly to or from the power cylinder through the bypass port without further increasing the differential oil pressure force existing on the compensating land.

As soon as sufficient governor movement and fuel correction has occurred to effect a correction of engine speed toward the speed at which the governor is set, the differential oil pressures -- still present -- will act on the compensating land to re-center the pilot valve plunger, as described in the previous paragraphs.

With a large decrease in load the power piston assembly moves to the "no fuel" position, closing the compensating oil passage from the power cylinder to the compensating needle valve and blocking passage of oil from the right end to the left end of the buffer cylinder, so that the needle valve cannot equalize buffer oil pressures in the usual manner. The buffer piston will have moved off center to the left and will be held there by the oil now trapped between the power piston and the buffer piston.

The higher pressure of the oil on the right side of the buffer piston -- produced by the compression of the left buffer spring -- will act on the receiving compensating land to add to the effect of the speeder spring setting and provide a temporary higher speed setting of the governor.

As the engine decelerates to a speed slightly below this higher speed setting, the governor will respond to raise the power piston (and restore fuel supply) in the normal manner, uncovering the port to permit passage of oil through the compensating needle valve so that the governor and engine will stabilize at the speed corresponding to the actual speed setting of the governor. This minimizes possible under-speeding of the engine when a large load decrease occurs.

MANUAL SPEED SETTING

The manual speed setting mechanism can be used to adjust the speed setting of the governor to any point within the normal speed range when the control air pressure signal is not available.

With no air signal, the restoring spring holds the pneumatic low speed stop screw in contact with the restoring lever. The speed setting pilot valve plunger is thus mechanically connected to the movement of the restoring lever. The grounded loading spring which keeps the restoring lever against the ball bearing pivot continually urges the bearing and speed setting screw in the downward direction. Turning the manual speed adjusting knob clockwise (to increase the governor speed setting) lowers the stop collar under the base speed adjusting nut. The speed setting screw with the ball bearing pivot will move down with the stop collar until the high speed stop adjusting setscrew hits the high speed stop pin; further clockwise turning of the manual knob will have no effect on the speed screw position.

As the speed setting screw and the ball bearing pivot are lowered, the left end of the restoring lever pushes the pneumatic low speed adjusting screw down and, in so doing, lowers the speed setting pilot valve plunger. Oil flows to the speed setting cylinder to push the speed setting piston down and raise the governor speed setting. The downward movement of the piston raises the left end of the restoring lever to "lift" the pilot valve plunger back to center.

Turning the manual speed adjusting knob counterclockwise will raise the speed setting screw and ball bearing pivot, raise the left end of the restoring lever, and thereby lift the speed setting pilot valve plunger. As the piston moves up to decrease the governor speed setting, the restoring lever movement recenters the pilot valve plunger.

TEMPERATURE COMPENSATION

Temperature compensation on older governors is incorporated in the speed setting mechanism through a bimetal strip in the restoring lever. The temperature compensation in later governors is in the speeder spring and there is no bimetal strip.

LOSS OF PNEUMATIC SIGNAL

"DIRECT" TYPE BELLOWS. The pneumatic low adjusting screw is adjusted to contact the restoring lever when the control air signal and governor speed are at their normal minimum. Thus, should the air signal be interrupted -- either accidentally or intentionally -- or be reduced below the pressure required for minimum speed, the restoring spring will lift the speed setting pilot valve plunger until the adjusting screw contacts the restoring lever. With the pilot valve plunger raised, the speed setting piston will move up to the low speed position. At this position, the restoring lever, turning about the ball bearing pivot and pushing down on the adjusting screw, will have recentered the pilot valve plunger. The governor will, therefore, go to minimum speed setting if the air signal is lost.

"REVERSE" TYPE BELLOWS. The pneumatic low speed adjusting screw is adjusted to just clear the restoring lever when the control air signal is at its normal maximum setting. Thus, should the air signal be interrupted -- either accidentally or intentionally -- the spring under the bellows will act to lower the speed setting pilot valve plunger and allow the governor to go to maximum speed setting.

SECTION IV/MAINTENANCE

TROUBLESHOOTING

Governor faults are usually revealed in speed variations of the engine or turbine, but it does not necessarily follow that such speed variations indicate governor faults. Therefore, when improper speed variations appear, the following procedure should be performed:

1. Check the load to be sure that the speed changes observed are not the result of load changes beyond the capacity of the engine or turbine.

2. If the governor is on an engine, check the operation to be sure that all cylinders are firing properly and that the injectors are in good operating condition. If the governor is on a turbine, check the steam valves for proper operation.

3. Check the operating linkage between the governor and the engine or turbine to make certain there is no binding or lost motion.

4. Check for steam or fuel gas pressure changes.

5. Check the setting of the compensating needle valve.

6. Check air transmitter for specified output pressure. If neither load nor engine or turbine irregularities are found to be the cause of the speed variation, the cause may be either in the governor or in the engine or turbine drive to the governor.

7. Check governor for specified operating oil pressure. Normal oil pressure for PG governors is 100 psi. However, this value may vary between governors, depending upon the required output work capacity of the power cylinder (refer to table). With engine shut down, remove plug from pressure port on governor power case and install a pressure gauge rated above specified operating oil pressure.

The source of most troubles in any governor stems from dirty oil. Grit and other impurities can be introduced into the governor with the oil, or foam when the oil begins to break down (oxidize) or become sludgy. The moving parts within the governor are continually lubricated by the oil within the governor. Thus, grit and other impurities will cause excessive wear of valves, pistons, and plungers, and can cause these parts to stick and even "freeze" in their bores.

In many instances erratic operation and poor readability can be corrected by flushing the unit with fuel oil or kerosene while cycling the governor. The use of commercial solvents is not recommended as they may damage seals or gaskets.

If the speed variations of the governor are erratic but small, excessive backlash or a tight meshing of the gears driving the governor may be the cause. If the speed variation is erratic and large and cannot be corrected by adjustments the governor should be repaired and/or replaced.

LUBRICATION

The oil used in the governor should be clean and free of foreign particles to obtain maximum performance from the governor. Under favorable conditions, the oil may be used for six months or longer without changing. Change oil immediately when it starts to break down or darken.

DISASSEMBLY

Disassemble the governor following the sequence of index numbers assigned to figures 6 and 7, giving special attention to the following. Circled index numbers do not require further disassembly unless replacement parts are required.

Refer to the applicable modular bulletin (refer to section I) for parts information and disassembly procedures on auxiliary equipment.

1. Clean exterior surfaces of governor with clean cloth moistened with cleaning solvent.

2. Discard all gaskets, o-rings, seals, retaining rings, cotter pins, clips, etc., removed in the process of disassembly.

3. Do not remove press fit components unless replacement is required.

4. Disassemble power cylinder assembly as applicable per instructions contained in bulletin 36692.

5. Disassemble base assembly as applicable per instructions contained in bulletin 36693.

6. To remove accumulator springs and pistons from the power case, place the power case (260, figure 7) in an arbor or drill press with the bottom down. With a rod against the spring seat (246), compress accumulator springs (247 and 248) to permit removal of upper retaining ring (245). Remove spring seat and springs. (see Figure 3)

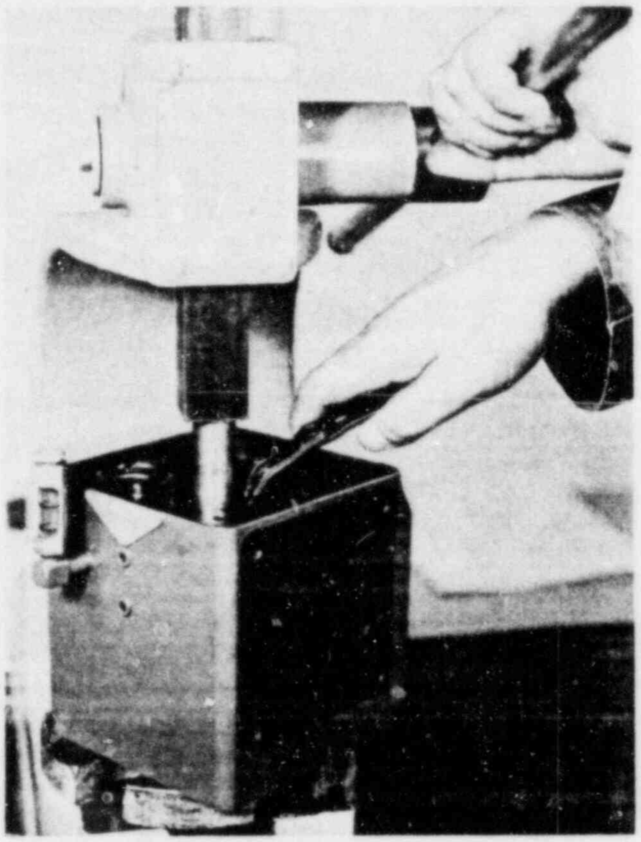


Fig. 3 Removing Accumulator Retaining Ring

Invert the power case and remove lower retaining ring and accumulator piston (249).

7. If necessary to remove check valve assemblies (250 and 251), proceed as follows:

a. To remove inner check valves (250), pry the retainer plate from the check valve assembly and remove springs and check balls.

b. To remove outer check valves (251), press the check valves through and out of the valve case.

c. Then tap all four check valve cases with 1/4"-28 tap. Using a 1/4"-28 bolt with a small plate as a jack, pull the four valve cases.

d. Remove two balls from the lower case.

CLEANING

1. Wash all parts ultrasonically or by agitation while immersed in cleaning solvent (Federal Specification P-D-680 or similar).

2. Use a non-metallic brush or jet of compressed air to clean slots, holes, or apertures.

3. Dry all parts after cleaning with a jet of clean, dry compressed air.

Fig. 4 Removal of Check Valves

INSPECTION

1. Visually inspect all parts for wear and damage.

2. Inspect bearings in accordance with standard shop practice. Replace bearings when there is any detectable roughness.

3. All pistons, valves, plungers, rods, and gears should move freely without excessive play. Do not lap in parts if possible to free by other means.

4. Mating surfaces must be free of nicks, burrs, cracks or other damage.

5. Inspect flyweight toes for wear. Replace flyweights if any detectable wear or doubtful areas are found.

6. It is recommended that speeder spring be replaced at time of overhaul.

REPAIR OR REPLACEMENT

1. Repair of small parts of the governor is impractical and shall generally be limited to removal of nicks and burrs from mating flanges and light burnishing of mating parts.

2. Replace damaged thread inserts in accordance with standard shop practice.

3. Polish slightly corroded areas with fine grit (600 grit) abrasive cloth or paper and oil.

ASSEMBLY

Assemble governor assembly in reverse order of index numbers assigned to figures 6 and 7, following the special instructions given below.

NOTE

A dust free area is recommended for assembly if acceptable results are to be obtained.

During assembly insure no lint or other foreign matter is present on the parts. The governor may be assembled dry or a small amount of clean lubricating oil may be applied to the parts as they are assembled into the governor. When the governor is assembled, apply a liberal amount of clean lubricating oil over all moving parts to insure initial lubrication. Apply a small amount of joint compound to pipe plug threads as plugs are installed. Insure compound does not enter cavity.

Obtain new gaskets, o-rings, seals, retaining rings, cotter pins, etc., to replace those discarded during disassembly.

1. Press spring loaded check valve (250, figure 7) into power case (260) using Woodward tool 360689. Press plain check valve into power case using Woodward tool 360690.

2. Install accumulator piston (249) and lower retaining ring (245) into power case. Place power case in an arbor or drill press with bottom down, (see figure 3) install springs (247 and 248) and spring seat (246); compress springs, using a rod on spring seat, and install upper retaining ring.

3. Attach base assembly (207) to power case loosely, rotate drive shaft until splined end engages with splines in pump drive gear. Continue turning drive shaft to check for alignment and free rotation of the drive gear and idler gear while tightening base screws.

4. Attach power cylinder assembly (203) to power case in the proper plan and quadrant; insure holes in gasket (204) are aligned with holes in power case.

5. When assembling the flyweight head pilot valve bushing assembly (238), align the missing tooth in the bushing with the corresponding missing tooth in the spring coupling assembly (229).

6. Install three piece thrust bearing (218) onto stem of pilot valve plunger (235) (bearing race with the larger hole must be against the flyweight toes).

7. When items 216 through 238 have been assembled, center pilot valve plunger as follows: (see figure 5) apply a slight pressure to speeder spring seat (217), adjust pilot valve plunger nut (216) until flyweights (225) move from their extreme inward to their extreme outward position and there is the same amount of control land showing in the control port at each extreme. The control ports are the bottom holes in the pilot valve bushing.

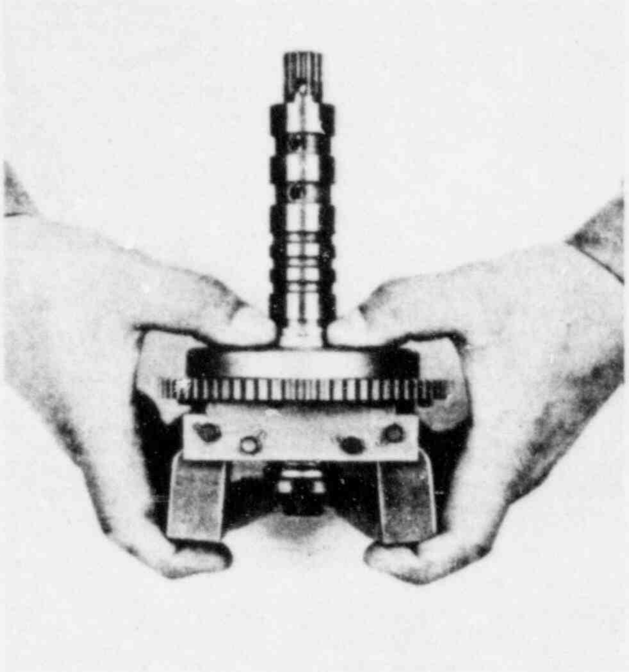


Fig. 5 Centering Pilot Valve Plunger

8. When assembling speed setting mechanism, insure retaining ring (30, figure 6), is positioned with opening in line with setscrew (33).

9. Assemble manual speed setting shaft assembly 43 through 47), tighten nut (43) approximately seven turns; insert roll pin (39) to protrude through shaft (43) approximately 0.090-inch.

TESTING

The PG governor has been manufactured in such a wide variety of arrangements that it would be impractical to cover specifications and testing procedures for each model.

It is recommended the customer contact Woodward Governor Company, Engine and Turbine Controls Division, Fort Collins, Colorado, for detail specifications and testing instructions for the particular models at the installation. When ordering information it is essential to supply the governor serial number (as shown on nameplate).

SECTION V/PARTS INFORMATION

PARTS REPLACEMENT

When ordering replacement parts it is essential that the following information be given:

1. Governor serial number and part number (as shown on nameplate).
2. Bulletin number (this is bulletin 36694).
3. Part reference number in parts list and description of part or part name.

ILLUSTRATED PARTS BREAKDOWN

The illustrated parts breakdown (figures 6 and 7) illustrates and lists all parts of the basic PG governor. Index numbers are assigned in disassembly sequence. Circled index numbers indicate items which do not require further disassembly unless repair or replacement of the part is required.

PARTS LIST FOR FIGURE 6

REF. NO.	PART NAME	NO. REQ'D.
36694- 1	Screw, hex hd., 5/16-24 x 5-13/32	2
36694- 2	Washer, lock, 5/16 (MS35338-45)	2
36694- 3	Washer, plain, 5/16 (MS27183-12)	2
36694- 4	Screw, drive, #2 x 3/16 (AN535-2-3)	4
36694- 5	Nameplate	1
36694- 6	Oil filler cap	1
36694- 7	Cover	1
36694- 8	Cover gasket	1
36694- 9	Loading spring	1
36694- 10	Restoring spring	1
36694- 11	Cotter pin, 1/16 x 3/8 (MS24665-130)	3
36694- 12	Pivot pin (Restoring lever)	1
36694- 13	Restoring lever	1
36694- 14	Pin (loading spring)	1
36694- 15	Stop pin (low speed-pneumatic)	1
36694- 16	Screw, soc. hd., 5-40 x 1/2	1
36694- 17	Washer, lock, #5 (AN935-5)	1
36694- 18	Screw, soc. hd., 1/4-28 x 1-1/4 (MS16998-46)	1
36694- 19	Screw, soc. hd., 1/4-28 x 2 (MS16998-49)	1
36694- 20	Washer, lock, 1/4 (MS35338-44)	2
36694- 21	Pilot valve link	1
36694- 22	Stop screw (low speed-pneumatic)	1
36694- 23	Nut, hex., 10-32 (MS35650-302)	1
36694- 24	Bellows spring	1
36694- 25	Bellows coupling	1
36694- 26	Setscrew, soc. hd., cone pt., 8-32 x 5/16 (MS51973-30)	1
36694- 27	Passage screw	
36694- 28	Washer, soft copper	1
36694- 29	Receiver cap gasket	1
36694- 30	Retaining ring, int., 1.660 OD	1
36694- 31	Bellows	1
36694- 32	Packing, preformed, 1-1/2 OD (NAS1593-028)	1
36694- 33	Setscrew, soc. hd., cone pt., 5-40 x 1/4	1
36694- 34	Pneumatic receiver cup	1
36694- 35	Screw, Phillips, rd. hd., 6-32 x 3/8 (MS35206-25)	4
36694- 36	Dial plate	1
36694- 37	Spacer	4
36694- 38	Friction spring	1
36694- 39	Roll pin, 3/32 x 5/8 (MS9048-071)	1
36694- 40	Stop washer	1
36694- 41	Spring washer, 1/4	1
36694- 42	Washer, plain, 25/64 ID x 5/8 OD	1
36694- 43	Nut, hex., slflkg, 1/4-28 (MS21083N4)	1
36694- 44	Belleville washer, 1/4	1
36694- 45	Knob (Manual speed adjusting)	1
36694- 46	Clutch spring	1
36694- 47	Shaft (head screw)	1
36694- 48	Receiver bracket gasket	1
36694- 49	Screw, soc. hd., 10-24 x 1/2 (MS1699[illegible]4)	2
36694- 50	Washer, lock, #10 (MS35338-43)	2
36694- 51	Stop pin (High speed)	1
36694- 52	Collar	1
36694- 53	Pivot pin	4
36694- 54	Link	1
36694- 55	Setscrew, soc. hd., dog pt., 8-32 x 3/8 (MS51977-31)	1
36694- 56	Thread insert, scr. lkg., 8-32 x 1/4 (MS21209C0815)	1
36694- 57	Nut (Lead screw)	1
36694- 58	Thread insert, 7/16-20 x 7/16	1
36694- 59	Speed adjusting nut (Low speed-manual)	1
36694- 60	Guide	1
36694- 61	Setscrew, soc. hd., oval pt., 10-32 x 1 (MS51982)	1
36694- 62	Nut, knurled	2
36694- 63	Screw, soc. hd., 10-32 x 1-1/8	1
36694- 64	Washer, lock, hi-collar, #10 (MS51848)	2
36694- 65	Screw, soc. button hd., 10-32 x 1	1
36694- 66	Spacer	1
36694- 67	Ball bearing	1
36694- 68	Pivot bracket	1
36694- 69	Thread insert, scr. lkg., 10-32 x 3/8 (MS21209F120)	1
36694- 70	Speed setting screw	1
36694- 71	Pin (Loading spring anchor)	1
36694- 72	Friction spring seat	1
36694- 73	Dowel pin	2
36694- 74	Thread insert, scr. lkg., 8-32 x 1/4 (MS21209C0815)	1
36694- 75	Receiver bracket	1
36694- 76	Packing, preformed, 3/8 OD (NAS1593-010)	2
36694- 77	Nut, hex., 8-32 (MS35649-282)	2
36694- 78	Screw, hex. hd., 1/4-28 x 1-3/16 (MS90726-9)	2
36694- 79	Washer, plain, 1/4 (AN960-4166)	2

PARTS LIST FOR FIGURE 6 (CONT.)

REF. NO.	PART NAME	NO. REQ'D.
36694- 80	Speed setting piston spring	1
36694- 81	Nut, hex., 10-32 (MS35650-302)	2
36694- 82	Guide pin	1
36694- 83	Setscrew, soc. hd., oval pt., 10-32 x 7/8 (MS51982)	1
36694- 84	Screw, soc. hd., 10-32 x 3/8 (MS16998-26)	1
36694- 85	Adjusting screw (Max. speed)	1
36694- 86	Thread insert, scr. lkg., 10-32 x 9/32 (MS21209F1-15)	1
36694- 87	Adjusting screw bracket	1
36694- 88	Fulcrum	1
36694- 89	Speed setting piston	1
36694- 90	Check valve assembly (Max. speed)	1
36694- 91	Speed setting cylinder	1
36694- 92	Screw, hex. hd., 5/16-24 x 5 (MS90726-52)	4
36694- 93	Washer, lock, int. tooth, 5/16 (MS35333-41)	4
36694- 94	Screw, Phillips, rd. hd., 10-32 x 3/8 (MS35207-53)	2

REF. NO.	PART NAME	NO. REQ'D
36694- 95	Washer, lock, #10 (MS35338-43)	2
36694- 96	Retainer	1
36694- 97	Washer, plain, 3/8 ID x 3/4 OD	1
36694- 98	Thrust bearing	1
36694- 99	Speed setting plunger	1
36694-100	Plug	1
36694-101	Speed setting plunger	1
36694-102	Bushing loading spring	1
36694-103	Bushing gear	1
36694-104	Bearing stud	1
36694-105	Elbow, 90°	3
36694-106	Tubing, 1/4-inch	1
36694-107	Dowel pin	2
36694-108	Cover dowel	2
36694-109	Dowel bushing	2
36694-110	Thread insert, 5/16-24	2
36694-111	Pipe plug, soc. hd., 1/16-27 NPTF (AN932S1)	5
36694-112	Taper screw (Not used with solenoid or pressure actuated shutdown option)	1
36694-113	Column	1

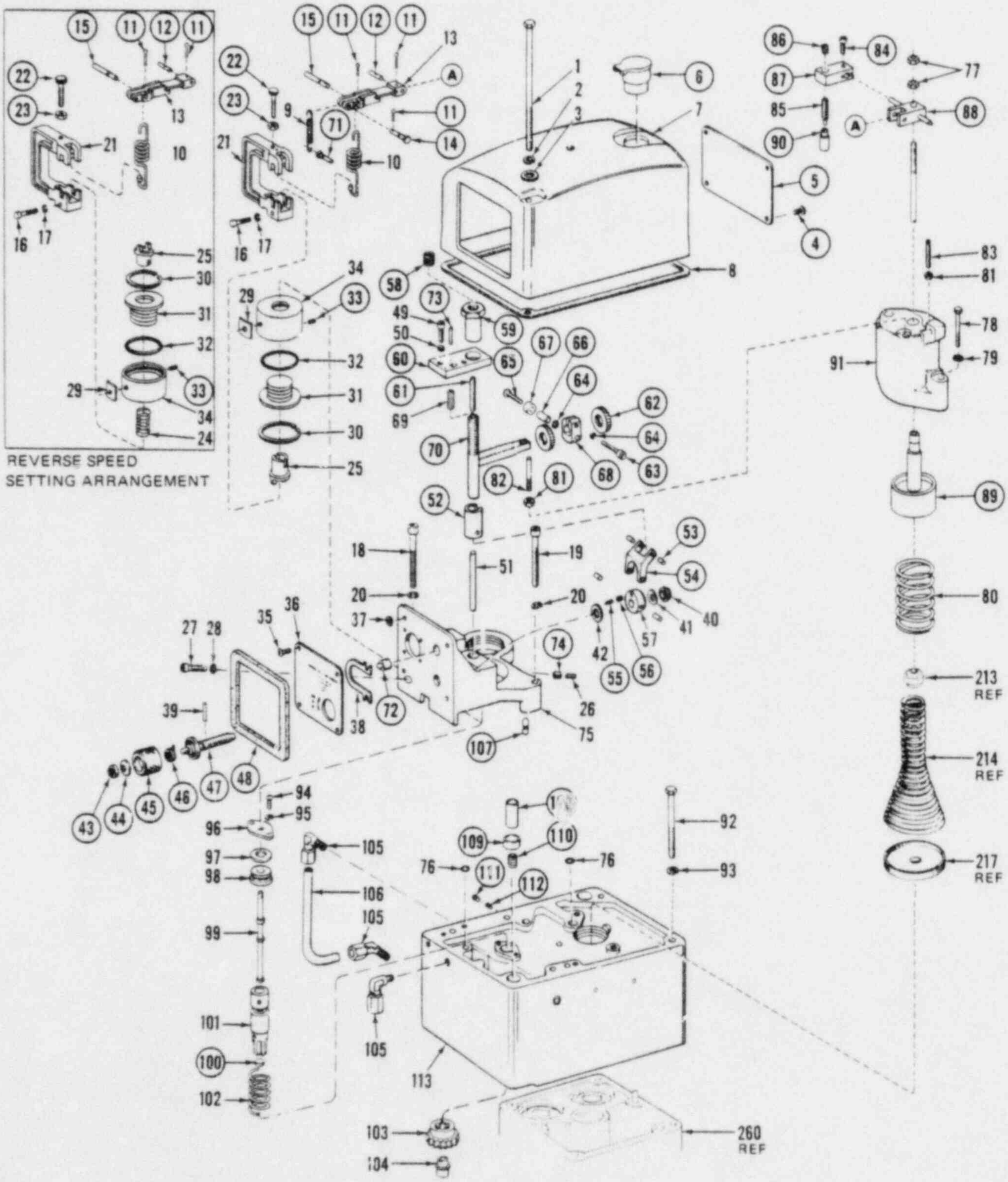
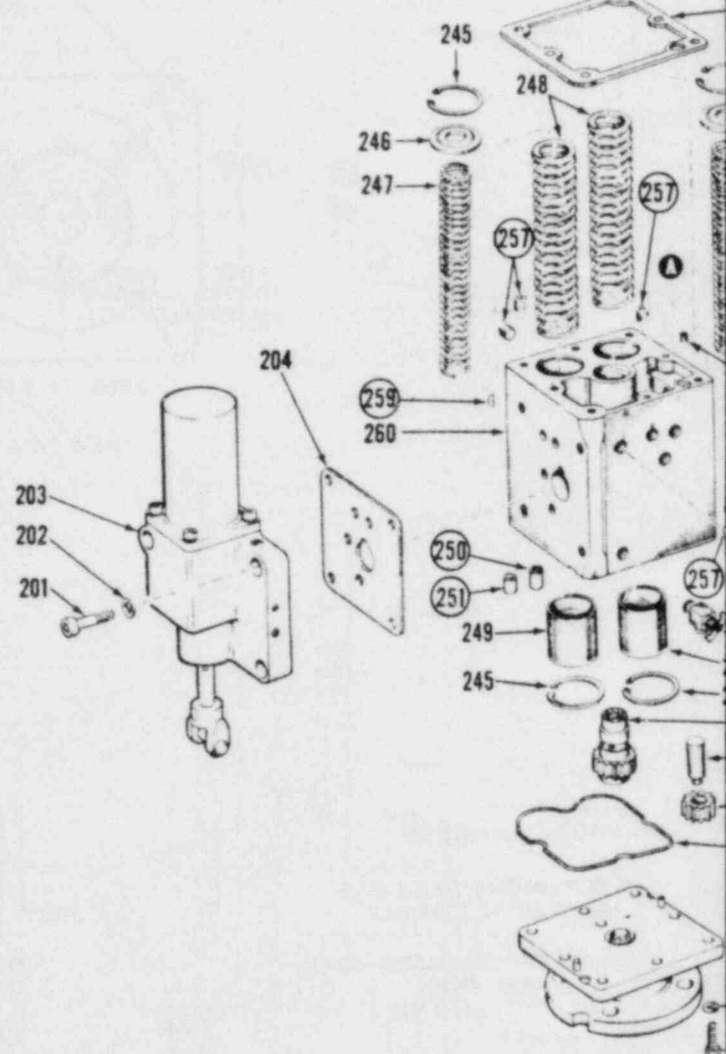


Figure 6. Exploded View of Column

PARTS LIST FOR FIGURE 7

REF. NO.	PART NAME	NO. REQ'D	REF. NO.	PART NAME	NO. REQ'D.
36694-201	Screw, soc. hd., 3/8-16 x 1 1/4	4	36694-232	Flyweight head sub-assembly	1
36694-202	Washer, lock, 3/8	4	36694-233	Retaining ring	1
36694-203	Power cylinder assembly (refer to bulletin 36692)	1	36694-234	Compensating bushing	1
			36694-235	Pilot valve plunger	1
36694-204	Gasket, power cylinder case	1	36694-236	Bearing	1
36694-205	Screw, hex hd., 5/16-18 x 1	8	36694-237	Oil seal ring	1
36694-206	Washer, lock, 21/64	8	36694-238	Flyweight head-bushing assembly	1
36694-207	Base assembly (refer to bulletin 36693)	1	36694-239	Retaining ring	1
36694-208	Power case-base oil seal ring	1	36694-240	O-ring	1
36694-209	Idler gear	1	36694-241	Plug	1
36694-210	Idler stud	1	36694-242	Buffer spring	2
36694-211	Drive gear	1	36694-243	Buffer piston	1
36694-212	Gasket	1	36694-244	Buffer seat	1
36694-213	Speeder spring check plug	1	36694-245	Retaining ring	4
36694-214	Speeder spring	1	36694-246	Spring seat	2
36694-215	Cotter pin, 1/16 x 5/8	1	36694-247	Small accumulator spring	2
36694-216	Pilot valve plunger nut	1	36694-248	Large accumulator spring	2
36694-217	Speeder spring seat	1	36694-249	Accumulator piston	2
36694-218	Thrust bearing	1	36694-250	Spring loaded check valve	2
36694-219	Washer, adjusting spring	1	36694-251	Plain check valve	2
36694-220	Adjusting spring	1	36694-252	Drain cock	1
36694-221	Retaining ring	1	36694-253	Elbow	1
36694-222	Shutdown rod	1	36694-254	Oil gage	1
36694-223	Cotter pin, 1/16 x 1	8	36694-255	Screw, rd. hd. dr.	3
36694-224	Flyweight pin-limit pin	4	36694-256	Instruction plate	1
36694-225	Flyweight	2	36694-257	Pipe plug, 1/8	AR
36694-226	Flyweight bearing	4	36694-258	Pipe plug, 1/16	AR
36694-227	Screw, rd. hd., 8-32 x 5/16	1	36694-259	Dowel pin	2
36694-228	Washer, lock, #8	1	36694-260	Power case	1
36694-229	Spring coupling assembly	1			
36694-230	Screw, fil. hd., 5-40 x 9/32	8			
36694-231	Washer, lock, #5	8			



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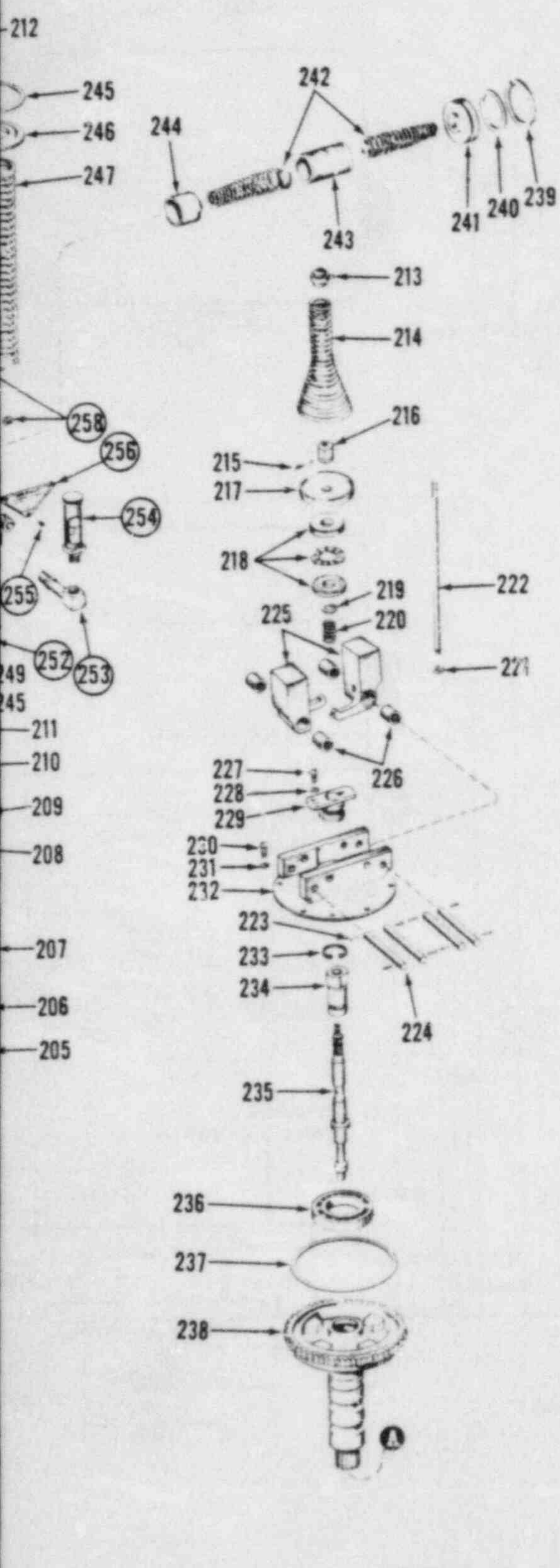

Figure 7. Exploded View of Case

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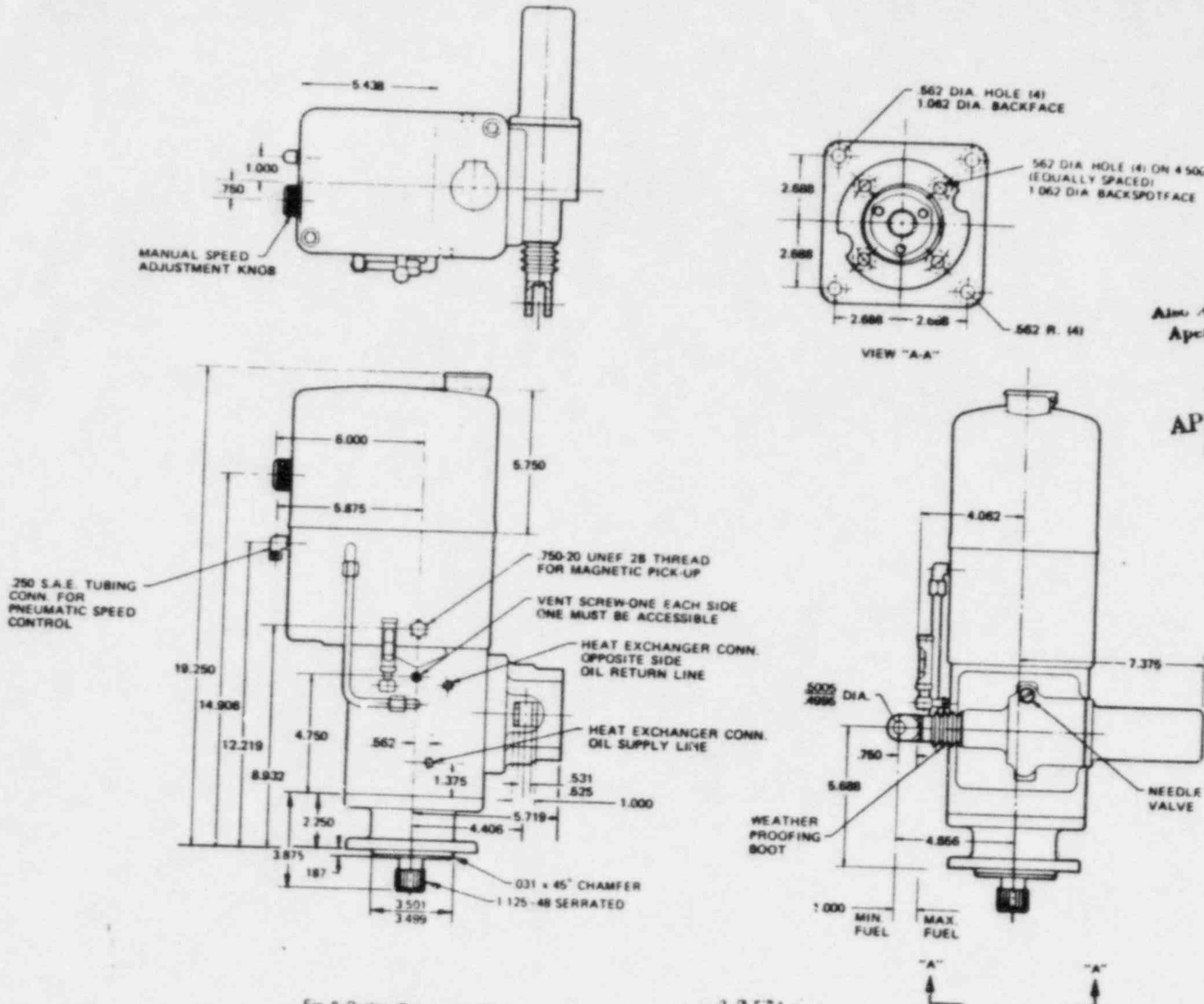

Fig. 8. Outline Drawing of PG-PL

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in the input signal pressure – displaces the speed setting pilot valve plunger to change the governor speed setting. The increased pressure compresses the bellows to lower the speed setting pilot valve plunger. Pressure oil flows to the area above the speed setting servo piston to force the piston down, and thus increase the governor speed setting.

As the servo piston moves down, a restoring lever – connected between the servo piston rod and speed setting pilot valve plunger on a ball bearing pivot – increases the lifting force on a restoring spring attached to the restoring lever. When the lifting force of the restoring spring is equal to the downward force resulting from the increased pressure signal, the speed setting pilot valve plunger will be returned to its centered position.

Increasing the speed setting of the governor increases the downward pressure of the speeder spring on the toes of the flyweights and the flyweights move in, lowering the pilot valve plunger and opening the control port.

Opening the port in this direction admits pressure oil into the buffer system, causing the buffer piston to move to the right and transfer an equal volume of oil to the power cylinder, forcing the power piston up in the direction to increase fuel.

As the buffer piston moves in the direction of the oil flow – from pilot valve to power cylinder – the right buffer spring is compressed and the left spring is relieved. This produces an intermediate oil pressure on the left side of the buffer piston which is higher than the pressure of the trapped oil on the right side of the buffer piston and spring displacement.

Simultaneously with the movement of the power piston and buffer piston, the differential oil pressures on opposite sides of the buffer piston are transmitted to the upper and lower sides of the compensating land, with the higher pressure on the lower side causing an upward force on the compensating land which will increase until (added to the upward force of the flyweights) it will balance the speeder spring force, raise the pilot valve plunger enough to cover the control port, and return the flyweights to the vertical position. As soon as the control port is covered the power piston will be stopped at a new position corresponding to the increased amount of fuel needed to operate the engine at the desired higher speed. The engine is still accelerating toward the new speed setting.

As the centrifugal force of the flyweights increases to a higher value with engine acceleration, the upward oil force at the compensating land is reduced to zero by the equalization of the oil pressures in the buffer system through the compensating needle valve. If the needle valve is correctly adjusted the oil pressures will equalize at the same rate as the increase in the centrifugal force of the flyweights, and the flyweights will remain in the vertical position, keeping the control port covered by the control land of the pilot valve, and holding the power piston stationary at the new position. Equalizing the oil pressures in the buffer system allows the buffer springs to return the buffer piston to center in the buffer cylinder.

The engine will now be running at a higher speed with an increased fuel setting.

SPEED DECREASE

A decrease in the control air pressure signal to the bellows of pneumatic receiver assembly allows the restoring spring – attached to restoring lever – to lift the speed setting pilot valve plunger. Oil drains from the area above the servo piston, the servo piston spring forces the piston to rise and thus decrease the speeder spring compression and lower the governor speed setting.

The restoring lever follows the movement of the servo piston, moves up and, in so doing, decreases the lifting force on the restoring spring. When the servo piston and right end of the restoring lever has moved up sufficiently to balance the upward force of the restoring spring to equal the decrease in downward force resulting from the decrease in control air pressure signal, the speed setting pilot valve plunger will have returned to its centered position.

Lowering the speed setting of the governor decreases the downward pressure of the speeder spring on the toes of the flyweights and the flyweights move out, raising the pilot valve plunger and opening the control port.

Opening the port in this direction permits oil to flow from the buffer system to the governor sump. This will lower the oil pressure in the buffer system and the power spring will force the power piston down in the direction to decrease fuel. As the buffer piston moves in the direction of the oil flow– from power cylinder to pilot valve – the left buffer spring is compressed and the right spring is relieved. This produces a pressure in the trapped oil, on the right side of the buffer piston which is higher than the intermediate oil pressure on the left side of the buffer piston, by an amount proportional to the displacement of the buffer piston and spring.

Simultaneously with the power piston and buffer piston

movement, these pressures will be transmitted to the compensating land, with the higher pressure now on the upper side of the land, causing a downward force which will increase until (added to the downward force of the speeder spring) it will balance the flyweight force, lower the pilot valve plunger enough to cover the control port, and return the flyweights to the vertical position. As the control port is covered the power piston will stop at a new position to correspond to the reduced amount of fuel required to operate the engine at the desired lower speed. The engine will be still decelerating toward the new speed setting.

As the centrifugal force of the flyweights decreases with engine deceleration, the downward oil force at the compensating land will again be reduced to zero by the equalization of the oil pressures in the buffer system through the compensating needle valve. With the needle valve correctly adjusted the oil pressures will equalize at the same rate as the decrease of centrifugal force in the flyweights, and the flyweights will remain in the vertical position, keeping the control port covered by the control land of the pilot valve, and holding the power piston stationary at the new position. Again, the buffer piston will be returned to center by the action of the buffer springs. The engine will now be running at a lower speed with a reduced fuel setting.

Bypass ports are provided in the buffer cylinder to facilitate large corrective movements of the power piston. A large increase or decrease in the speed setting of the governor, or a large increase or decrease of load on the engine, will require a correspondingly large movement of the power piston to make the necessary correction to the fuel setting. Under such conditions, the buffer piston will move only far enough to the left or right to effect an opening at the bypass port (pressure or drain). Oil will then flow directly to or from the power cylinder through the bypass port without further increasing the differential oil pressure force existing on the compensating land.

As soon as sufficient governor movement and fuel correction has occurred to effect a correction of engine speed toward the speed at which the governor is set, the differential oil pressures -- still present -- will act on the compensating land to re-center the pilot valve plunger, as described in the previous paragraphs.

With a large decrease in load the power piston assembly moves to the "no fuel" position, closing the compensating oil passage from the power cylinder to the compensating needle valve and blocking passage of oil from the right end to the left end of the buffer cylinder, so that the needle valve cannot equalize buffer oil pressures in the usual manner. The buffer piston will have moved off center to the left and will be held there by the oil now trapped between the power piston and the buffer piston.

The higher pressure of the oil on the right side of the buffer piston -- produced by the compression of the left buffer spring -- will act on the receiving compensating land to add to the effect of the speeder spring setting and provide a temporary higher speed setting of the governor.

As the engine decelerates to a speed slightly below this higher speed setting, the governor will respond to raise the power piston (and restore fuel supply) in the normal manner, uncovering the port to permit passage of oil through the compensating needle valve so that the governor and engine will stabilize at the speed corresponding to the actual speed setting of the governor. This minimizes possible under-speeding of the engine when a large load decrease occurs.

MANUAL SPEED SETTING

The manual speed setting mechanism can be used to adjust the speed setting of the governor to any point within the normal speed range when the control air pressure signal is not available.

With no air signal, the restoring spring holds the pneumatic low speed stop screw in contact with the restoring lever. The speed setting pilot valve plunger is thus mechanically connected to the movement of the restoring lever. The grounded loading spring which keeps the restoring lever against the ball bearing pivot continually urges the bearing and speed setting screw in the downward direction. Turning the manual speed adjusting knob clockwise (to increase the governor speed setting) lowers the stop collar under the base speed adjusting nut. The speed setting screw with the ball bearing pivot will move down with the stop collar until the high speed stop adjusting setscrew hits the high speed stop pin; further clockwise turning of the manual knob will have no effect on the speed screw position.

As the speed setting screw and the ball bearing pivot are lowered, the left end of the restoring lever pushes the pneumatic low speed adjusting screw down and, in so doing, lowers the speed setting pilot valve plunger. Oil flows to the speed setting cylinder to push the speed setting piston down and raise the governor speed setting. The downward movement of the piston raises the left end of the restoring lever to "lift" the pilot valve plunger back to center.

Turning the manual speed adjusting knob counterclockwise will raise the speed setting screw and ball bearing pivot, raise the left end of the restoring lever, and thereby lift the speed setting pilot valve plunger. As the piston moves up to decrease the governor speed setting, the restoring lever movement recenters the pilot valve plunger.

TEMPERATURE COMPENSATION

Temperature compensation on older governors is incorporated in the speed setting mechanism through a bimetal strip in the restoring lever. The temperature compensation in later governors is in the speeder spring and there is no bimetal strip.

LOSS OF PNEUMATIC SIGNAL

"DIRECT" TYPE BELLOWS. The pneumatic low adjusting screw is adjusted to contact the restoring lever when the control air signal and governor speed are at their normal minimum. Thus, should the air signal be interrupted -- either accidentally or intentionally -- or be reduced below the pressure required for minimum speed, the restoring spring will lift the speed setting pilot valve plunger until the adjusting screw contacts the restoring lever. With the pilot valve plunger raised, the speed setting piston will move up to the low speed position. At this position, the restoring lever, turning about the ball bearing pivot and pushing down on the adjusting screw, will have recentered the pilot valve plunger. The governor will, therefore, go to minimum speed setting if the air signal is lost.

"REVERSE" TYPE BELLOWS. The pneumatic low speed adjusting screw is adjusted to just clear the restoring lever when the control air signal is at its normal maximum setting. Thus, should the air signal be interrupted -- either accidentally or intentionally -- the spring under the bellows will act to lower the speed setting pilot valve plunger and allow the governor to go to maximum speed setting.

SECTION IV/MAINTENANCE

TROUBLESHOOTING

Governor faults are usually revealed in speed variations of the engine or turbine, but it does not necessarily follow that such speed variations indicate governor faults. Therefore, when improper speed variations appear, the following procedure should be performed:

1. Check the load to be sure that the speed changes observed are not the result of load changes beyond the capacity of the engine or turbine.

2. If the governor is on an engine, check the operation to be sure that all cylinders are firing properly and that the injectors are in good operating condition. If the governor is on a turbine, check the steam valves for proper operation.

3. Check the operating linkage between the governor and the engine or turbine to make certain there is no binding or lost motion.

4. Check for steam or fuel gas pressure changes.

5. Check the setting of the compensating needle valve.

6. Check air transmitter for specified output pressure. If neither load nor engine or turbine irregularities are found to be the cause of the speed variation, the cause may be either in the governor or in the engine or turbine drive to the governor.

7. Check governor for specified operating oil pressure. Normal oil pressure for PG governors is 100 psi. However, this value may vary between governors, depending upon the required output work capacity of the power cylinder (refer to table). With engine shut down, remove plug from pressure port on governor power case and install a pressure gauge rated above specified operating oil pressure.

The source of most troubles in any governor stems from dirty oil. Grit and other impurities can be introduced into the governor with the oil, or foam when the oil begins to break down (oxidize) or become sludgy. The moving parts within the governor are continually lubricated by the oil within the governor. Thus, grit and other impurities will cause excessive wear of valves, pistons, and plungers, and can cause these parts to stick and even "freeze" in their bores.

In many instances erratic operation and poor readability can be corrected by flushing the unit with fuel oil or kerosene while cycling the governor. The use of commercial solvents is not recommended as they may damage seals or gaskets.

If the speed variations of the governor are erratic but small, excessive backlash or a tight meshing of the gears driving the governor may be the cause. If the speed variation is erratic and large and cannot be corrected by adjustments the governor should be repaired and/or replaced.

LUBRICATION

The oil used in the governor should be clean and free of foreign particles to obtain maximum performance from the governor. Under favorable conditions, the oil may be used for six months or longer without changing. Change oil immediately when it starts to break down or darken.

DISASSEMBLY

Disassemble the governor following the sequence of index numbers assigned to figures 6 and 7, giving special attention to the following. Circled index numbers do not require further disassembly unless replacement parts are required.

Refer to the applicable modular bulletin (refer to section I) for parts information and disassembly procedures on auxiliary equipment.

1. Clean exterior surfaces of governor with clean cloth moistened with cleaning solvent.

2. Discard all gaskets, o-rings, seals, retaining rings, cotter pins, clips, etc., removed in the process of disassembly.

3. Do not remove press fit components unless replacement is required.

4. Disassemble power cylinder assembly as applicable per instructions contained in bulletin 36692.

5. Disassemble base assembly as applicable per instructions contained in bulletin 36693.

6. To remove accumulator springs and pistons from the power case, place the power case (260, figure 7) in an arbor or drill press with the bottom down. With a rod against the spring seat (246), compress accumulator springs (247 and 248) to permit removal of upper retaining ring (245). Remove spring seat and springs. (see Figure 3)

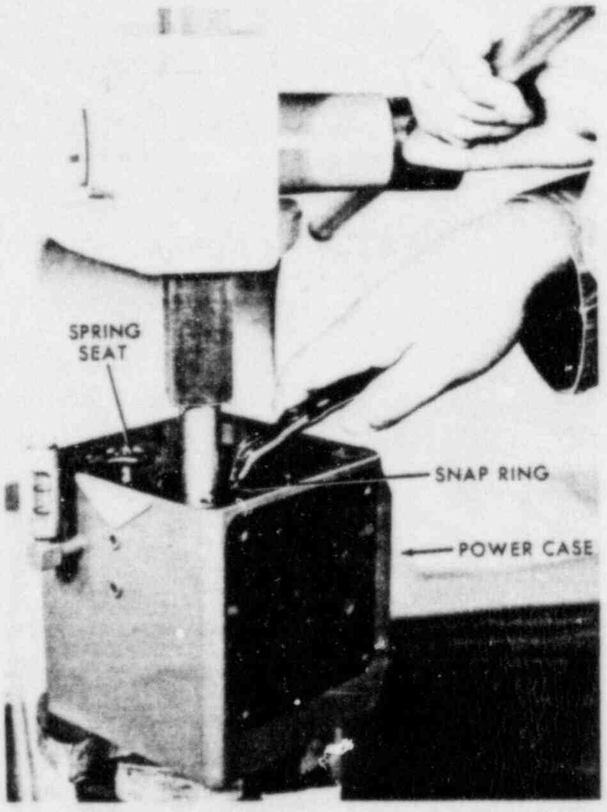


Figure 3. Removing Accumulator Retaining Ring

Invert the power case and remove lower retaining ring and accumulator piston (249).

7. If necessary to remove check valve assemblies (250 and 251), proceed as follows:

a. To remove inner check valves (250), pry the retainer plate from the check valve assembly and remove springs and check balls.

b. To remove outer check valves (251), press the check valves through and out of the valve case.

c. Then tap all four check valve cases with 1/4"-28 tap. Using a 1/4"-28 bolt with a small plate as a jack, pull the four valve cases.

d. Remove two balls from the lower case.

CLEANING

1. Wash all parts ultrasonically or by agitation while immersed in cleaning solvent (Federal Specification P-D-680 or similar).

2. Use a non-metallic brush or jet of compressed air to clean slots, holes, or apertures.

3. Dry all parts after cleaning with a jet of clean, dry compressed air.

Figure 4. Removal of Check Valves

INSPECTION

1. Visually inspect all parts for wear and damage.

2. Inspect bearings in accordance with standard shop practice. Replace bearings when there is any detectable roughness.

3. All pistons, valves, plungers, rods, and gears should move freely without excessive play. Do not lap in parts if possible to free by other means.

4. Mating surfaces must be free of nicks, burrs, cracks or other damage.

5. Inspect flyweight toes for wear. Replace flyweights if any detectable wear or doubtful areas are found.

6. It is recommended that speeder spring be replaced at time of overhaul.

REPAIR OR REPLACEMENT

1. Repair of small parts of the governor is impractical and shall generally be limited to removal of nicks and burrs from mating flanges and light burnishing of mating parts.

2. Replace damaged thread inserts in accordance with standard shop practice.

3. Polish slightly corroded areas with fine grit (600 grit) abrasive cloth or paper and oil.

ASSEMBLY

Assemble governor assembly in reverse order of index numbers assigned to figures 6 and 7, following the special instructions given below.

NOTE

A dust free area is recommended for assembly if acceptable results are to be obtained.

During assembly insure no lint or other foreign matter is present on the parts. The governor may be assembled dry or a small amount of clean lubricating oil may be applied to the parts as they are assembled into the governor. When the governor is assembled, apply a liberal amount of clean lubricating oil over all moving parts to insure initial lubrication. Apply a small amount of joint compound to pipe plug threads as plugs are installed. Insure compound does not enter cavity.

Obtain new gaskets, o-rings, seals, retaining rings, cotter pins, etc., to replace those discarded during disassembly.

1. Press spring loaded check valve (250, figure 7) into power case (260) using Woodward tool 360689. Press plain check valve into power case using Woodward tool 360690.

2. Install accumulator piston (249) and lower retaining ring (245) into power case. Place power case in an arbor or drill press with bottom down, (see figure 3) install springs (247 and 248) and spring seat (246); compress springs, using a rod on spring seat, and install upper retaining ring.

3. Attach base assembly (207) to power case loosely, rotate drive shaft until splined end engages with splines in pump drive gear. Continue turning drive shaft to check for alignment and free rotation of the drive gear and idler gear while tightening base screws.

4. Attach power cylinder assembly (203) to power case in the proper plan and quadrant; insure holes in gasket (204) are aligned with holes in power case.

5. When assembling the flyweight head pilot valve bushing assembly (238), align the missing tooth in the bushing with the corresponding missing tooth in the spring coupling assembly (229).

6. Install three piece thrust bearing (218) onto stem of pilot valve plunger (235) (bearing race with the larger hole must be against the flyweight toes).

7. When items 216 through 238 have been assembled, center pilot valve plunger as follows: (see figure 5) apply a slight pressure to speeder spring seat (217), adjust pilot valve plunger nut (216) until flyweights (225) move from their extreme inward to their extreme outward position and there is the same amount of control land showing in the control port at each extreme. The control ports are the bottom holes in the pilot valve bushing.

8. When assembling speed setting mechanism, insure retaining ring (30, figure 6), is positioned with opening in line with setscrew (33).

9. Assemble manual speed setting shaft assembly 43 through 47), tighten nut (43) approximately seven turns; insert roll pin (39) to protrude through shaft (43) approximately 0.090-inch.

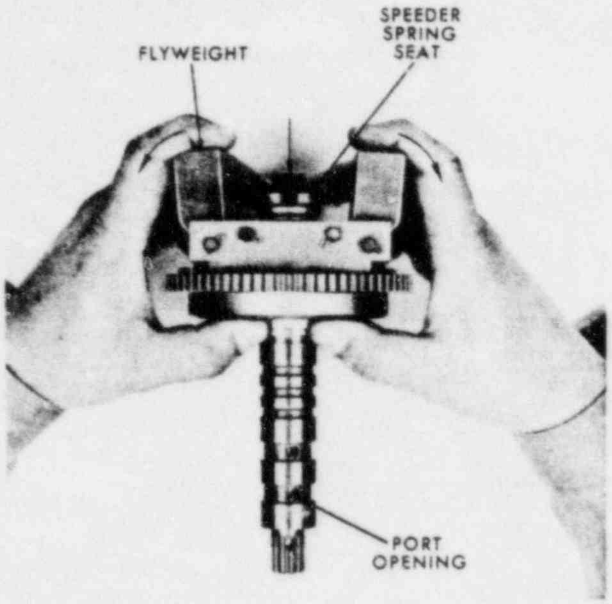


Figure 5. Centering Pilot Valve Plunger

TESTING

The PG governor has been manufactured in such a wide variety of arrangements that it would be impractical to cover specifications and testing procedures for each model.

It is recommended the customer contact Woodward Governor Company, Engine and Turbine Controls Division, Fort Collins, Colorado, for detail specifications and testing instructions for the particular models at the installation. When ordering information it is essential to supply the governor serial number (as shown on nameplate).

SECTION V/PARTS INFORMATION

PARTS REPLACEMENT

When ordering replacement parts it is essential that the following information be given:

1. Governor serial number and part number (as shown on nameplate).
2. Bulletin number (this is bulletin 36694).
3. Part reference number in parts list and description of part or part name.

ILLUSTRATED PARTS BREAKDOWN

The illustrated parts breakdown (figures 6 and 7) illustrates and lists all parts of the basic PG governor. Index numbers are assigned in disassembly sequence. Circled index numbers indicate items which do not require further disassembly unless repair or replacement of the part is required.

PARTS LIST F[illegible]R FIGURE 6

REF. NO.	PART NAME	NO. REQ'D.
36694- 1	Screw, hex hd., 5/16-24 x 5-13/32	2
36694- 2	Washer, lock, 5/16 (MS35338-45)	2
36694- 3	Washer, plain, 5/16 (MS27183-12)	2
36694- 4	S[illegible]w, drive, #2 x 3/16 ([illegible]535-2-3)	4
36694- 5	Nameplate	1
36694- 6	Oil filler cap	1
36694- 7	Cover	1
36694- 8	Cover gasket	1
36694- 9	Loading spring	1
36694- 10	Restoring spring	1
36694- 11	Cotter pin, 1/16 x 3/8 (MS24665-130)	3
36694- 12	Pivot pin (Restoring lever)	1
36694- 13	Restoring lever	1
36694- 14	Pin (loading spring)	1
36694- 15	Stop pin (low speed-pneumatic)	1
36694- 16	Screw, soc. hd., 5-40 x 1/2	1
36694- 17	Washer, lock, #5 (AN935-5)	1
36694- 18	Screw, soc. hd., 1/4-28 x 1-1/4 (MS16998-46)	1
36694- 19	Screw, soc. hd., 1/4-28 x 2 (MS16998-49)	1
36694- 20	Washer, lock, 1/4 (MS35338-44)	2
36694- 21	Pilot valve link	1
36694- 22	Stop screw (low speed-pneumatic)	1
36694- 23	Nut, hex., 10-32 (MS35650-302)	1
36694- 24	Bellows spring	1
36694- 25	Bellows coupling	1
36694- 26	Setscrew, soc. hd., cone pt., 8-32 x 5/16 (MS51973-30)	1
36694- 27	Passage screw	1
36694- 28	Washer, soft copper	1
36694- 29	Receiver cap gasket	1
36694- 30	Retaining ring, int., 1.660 OD	1
36694- 31	Bellows	1
36694- 32	Packing, preformed, 1-1/2 OD (NAS1593-028)	1
36694- 33	Setscrew, soc. hd., cone pt., 5-40 x 1/4	1
36694- 34	Pneumatic receiver cup	1
36694- 35	Screw, Phillips, rd. hd., 6-32 x 3/8 (MS35206-25)	4
36694- 36	Dial plate	1
36694- 37	Spacer	4
36694- 38	Friction spring	1
36694- 39	Roll pin, 3/32 x 5/8 (MS9048-071)	1
36694- 40	Stop washer	1
36694- 41	Spring washer, 1/4	1
36694- 42	Washer, plain, 25/64 ID x 5/8 OD	1
36694- 43	Nut, hex., slflkg, 1/4-28 (MS21083N4)	1
36694- 44	Belleville washer, 1/4	1
36694- 45	Knob (Manual speed adjusting)	1
36694- 46	Clutch spring	1
36694- 47	Shaft (head screw)	1
36694- 48	Receiver bracket gasket	1
36694- 49	Screw, soc. hd., 10-24 x 1/2 (MS16997-44)	2
36694- 50	Washer, lock, #10 (MS35338-43)	2
36694- 51	Stop pin (High speed)	1
36694- 52	Collar	1

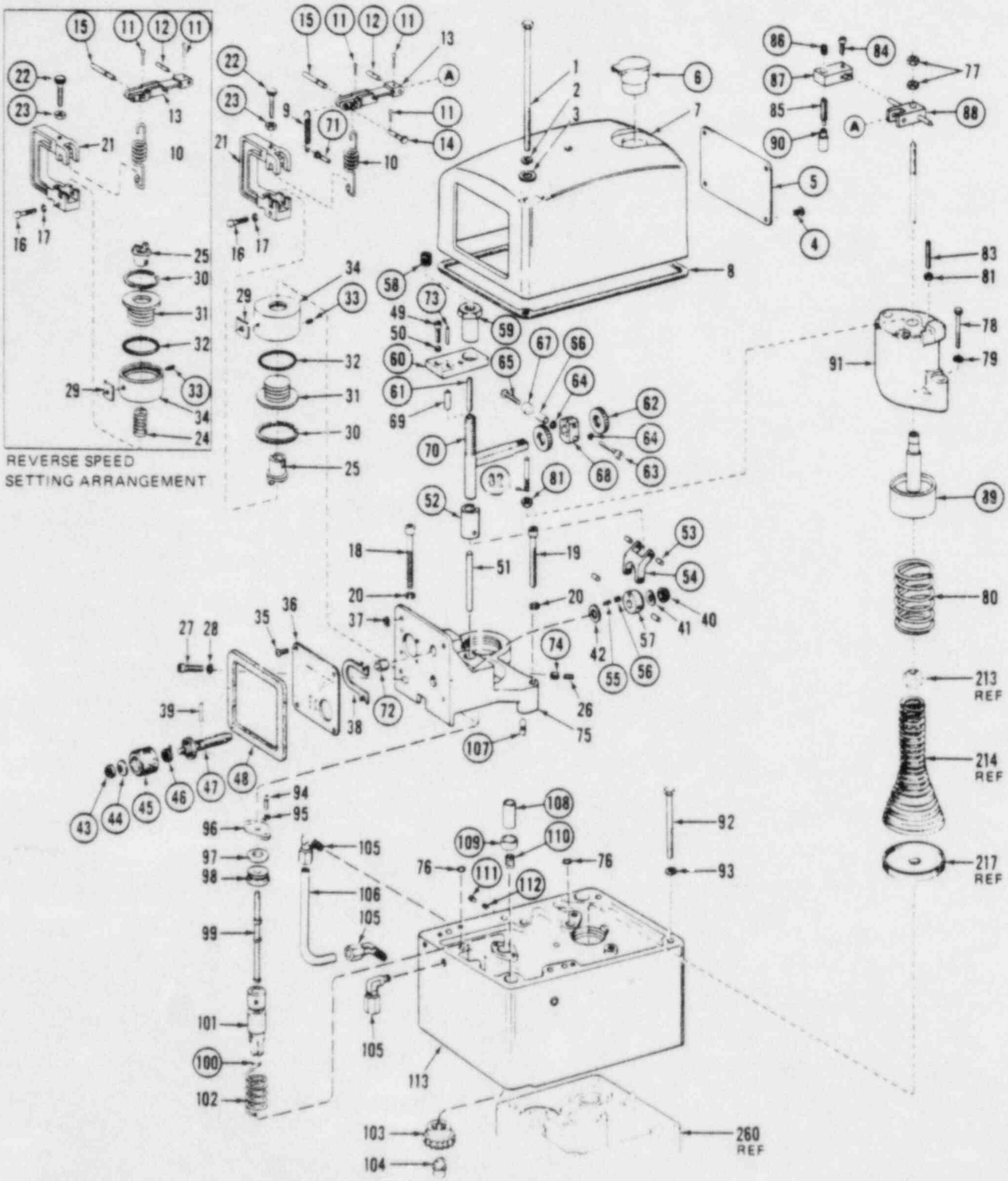


Figure 6. Exploded View of Column

PARTS LIST FOR FIGURE 6 (CONT.)

REF. NO.	PART NAME	NO. REQ'D.
36694- 53	Pivot pin	4
36694- 54	Link	1
36694- 55	Setscrew, soc. hd., dog pt., 8-32 x 3/8 (MS51977-31)	1
36694- 56	Thread insert, scr. lkg., 8-32 x 1/4 (MS21209C0815)	1
36694- 57	Nut (Lead screw)	1
36694- 58	Thread insert, 7/16-20 x 7/16	1
36694- 59	Speed adjusting nut (Low speed-manual)	1
36694- 60	Guide	1
36694- 61	Setscrew, soc. hd., oval pt., 10-32 x 1 (MS51982)	1
36694- 62	Nut, knurled	2
36694- 63	Screw, soc. hd., 10-32 x 1-1/8	1
36694- 64	Washer, lock, hi-collar, #10 (MS51848)	2
36694- 65	Screw, soc. button hd., 10-32 x 1	1
36694- 66	Spacer	1
36694- 67	Ball bearing	1
36694- 68	Pivot bracket	1
36694- 69	Thread insert, scr. lkg., 10-32 x 3/8 (MS21209F120)	1
36694- 70	Speed setting screw	1
36694- 71	Pin (Loading spring anchor)	1
36694- 72	Friction spring seat	1
36694- 73	Dowel pin	2
36694- 74	Thread insert, scr. lkg., 8-32 x 1/4 (MS21209C0815)	1
36694- 75	Receiver bracket	1
36694- 76	Packing, preformed, 3/8 OD (NAS1593-010)	2
36694- 77	Nut, hex., 8-32 (MS35649-282)	2
36694- 78	Screw, hex. hd., 1/4-28 x 1-3/16 (MS90726-9)	2
36694- 79	Washer, plain, 1/4 (AN960-4166)	2
36694- 80	Speed setting piston spring	1
36694- 81	Nut, hex., 10-32 (MS35650-302)	2
36694- 82	Guide pin	1
36694- 83	Setscrew, soc. hd., oval pt. 10-32 x 7/8 (MS51982)	1

REF. NO.	PART NAME	NO. REQ'D
36694- 84	Screw, soc. hd., 10-32 x 3/8 (MS16998-26)	1
36694- 85	Adjusting screw (Max. speed)	1
36694- 86	Thread insert, scr. lkg., 10-32 x 9/32 (MS21209F1-15)	1
36694- 87	Adjusting screw bracket	1
36694- 88	Fulcrum	1
36694- 89	Speed setting piston	1
36694- 90	Check valve assembly (Max.speed)	1
36694- 91	Speed setting cylinder	1
36694- 92	Screw, hex. hd., 5/16-24 x 5 (MS90726-52)	4
36694- 93	Washer, lock, int. tooth, 5/16 (MS35333-41)	4
36694- 94	Screw, Phillips, rd. hd., 10-32 x 3/8 (MS35207-53)	2
36694- 95	Washer, lock, #10 (MS35338-43)	2
36694- 96	Retainer	1
36694- 97	Washer, plain, 3/8 ID x 3/4 OD	1
36694- 98	Thrust bearing	1
36694- 99	Speed setting plunger	1
36694-100	Plug	1
36694-101	Speed setting plunger	1
36694-102	Bushing loading spring	1
36694-103	Bushing gear	1
36694-104	Bearing stud	1
36694-105	Elbow, 90°	3
36694-106	Tubing, 1/4-inch	1
36694-107	Dowel pin	2
36694-108	Cover dowel	2
36694-109	Dowel bushing	2
36694-110	Thread insert, 5/16-24	2
36694-111	Pipe plug, soc. hd., 1/16-27 NPTF (AN932S1)	5
36694-112	Taper screw (Not used with solenoid or pressure actuated shutdown option)	1
36694-113	Column	1

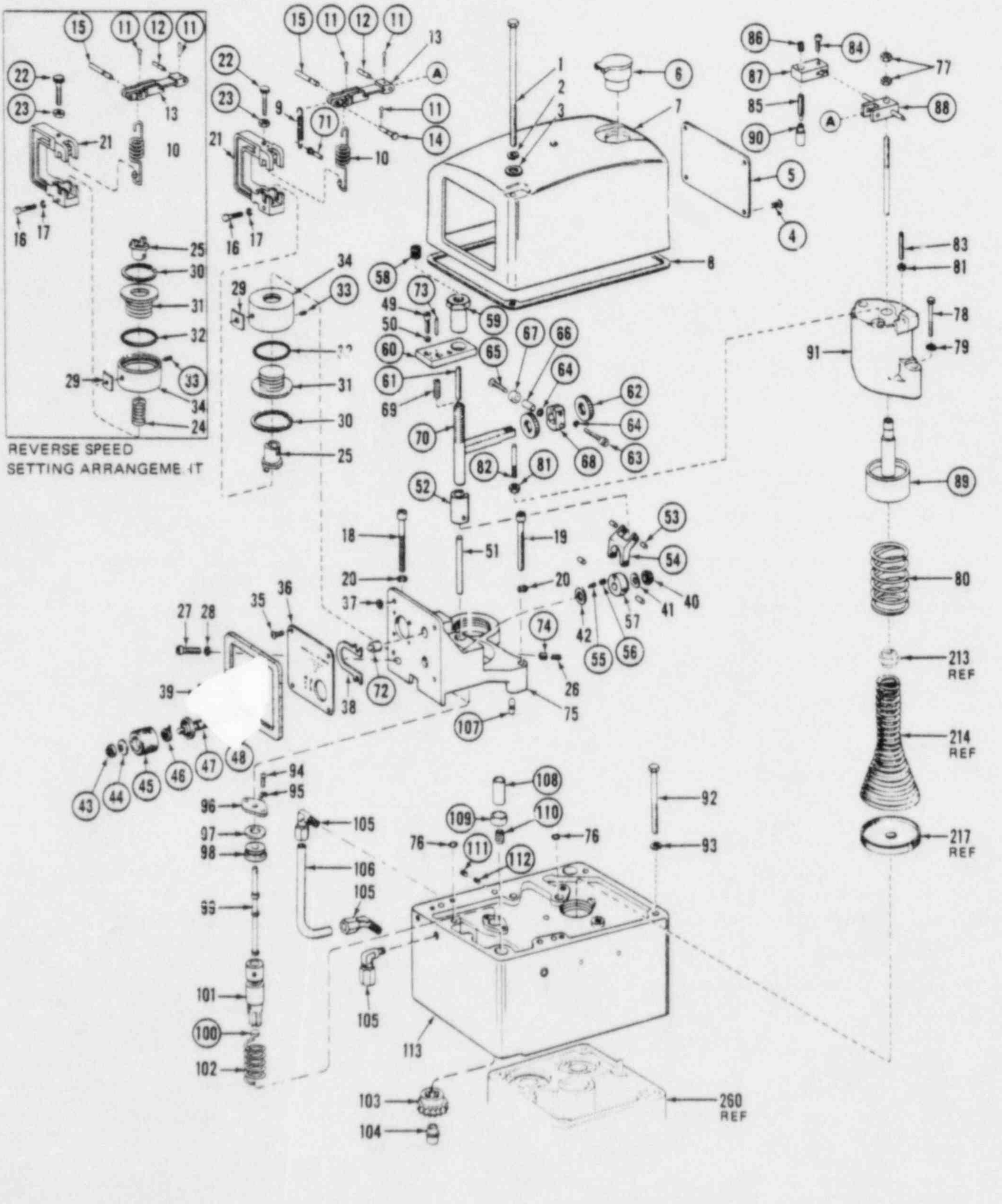


Figure 6. Exploded View of Column

PARTS LIST FOR FIGURE 7

REF. NO.	PART NAME	NO. REQ'D
36694-201	Screw, soc. hd., 3/8-16 x 1 1/4	4
36694-202	Washer, lock, 3/8	4
36694-203	Power cylinder assembly (refer to bulletin 36692)	1
36694-204	Gasket, power cylinder case	1
36694-205	Screw, hex hd., 5/16-18 x 1	8
36694-206	Washer, lock, 21/64	8
36694-207	Base assembly (refer to bulletin 36693)	1
36694-208	Power case-base oil seal ring	1
36694-209	Idler gear	1
36694-210	Idler stud	1
36694-211	Drive gear	1
36694-212	Gasket	1
36694-213	Speeder spring check plug	1
36694-214	Speeder spring	1
36694-215	Cotter pin, 1/16 x 5/8	1
36694-216	Pilot valve plunger nut	1
36694-217	Speeder spring seat	1
36694-218	Thrust bearing	1
36694-219	Washer, adjusting spring	1
36694-220	Adjusting spring	1
36694-221	Retaining ring	1
36694-222	Shutdown rod	1
36694-223	Cotter pin, 1/16 x 1	8
36694-224	Flyweight pin-limit pin	4
36694-225	Flyweight	2
36694-226	Flyweight bearing	4
36694-227	Screw, rd. hd., 8-32 x 5/16	1
36694-228	Washer, lock, #8	1
36694-229	Spring coupling assembly	1
36694-230	Screw, fil. hd., 5-40 x 9/32	8
36694-231	Washer, lock, #5	8
36694-232	Flyweight head sub-assembly	1
36694-233	Retaining ring	1
36694-234	Compensating bushing	1
36694-235	Pilot valve plunger	1
36694-236	Bearing	1
36694-237	Oil seal ring	1
36694-238	Flyweight head-bushing assembly	1
36694-239	Retaining ring	1
36694-240	O-ring	1
36694-241	Plug	1
36694-242	Buffer spring	2
36694-243	Buffer piston	1
36694-244	Buffer seat	1
36694-245	Retaining ring	4
36694-246	Spring seat	2
36694-247	Small accumulator spring	2
36694-248	Large accumulator spring	2
36694-249	Accumulator piston	2
36694-250	Spring loaded check valve	2
36694-251	Plain check valve	2
36694-252	Drain cock	1
36694-253	Elbow	1
36694-254	Oil gage	1
36694-255	Screw, rd. hd. dr.	3
36694-256	Instruction plate	1
36694-257	Pipe plug, 1/8	AR
36694-258	Pipe plug, 1/16	AR
36694-259	Dowel pin	2
36694-260	Power case	1

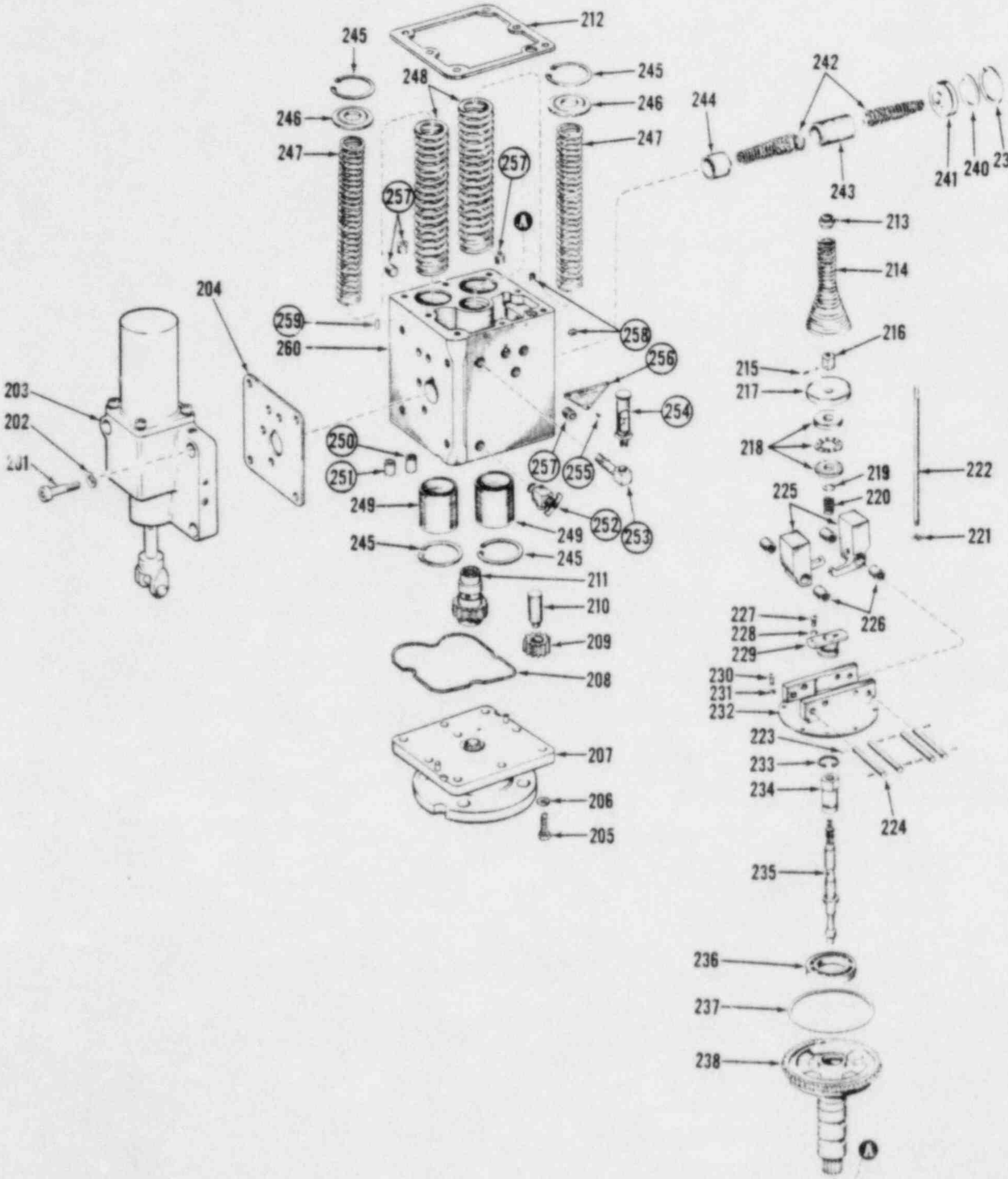


Figure 7. Exploded View of Case

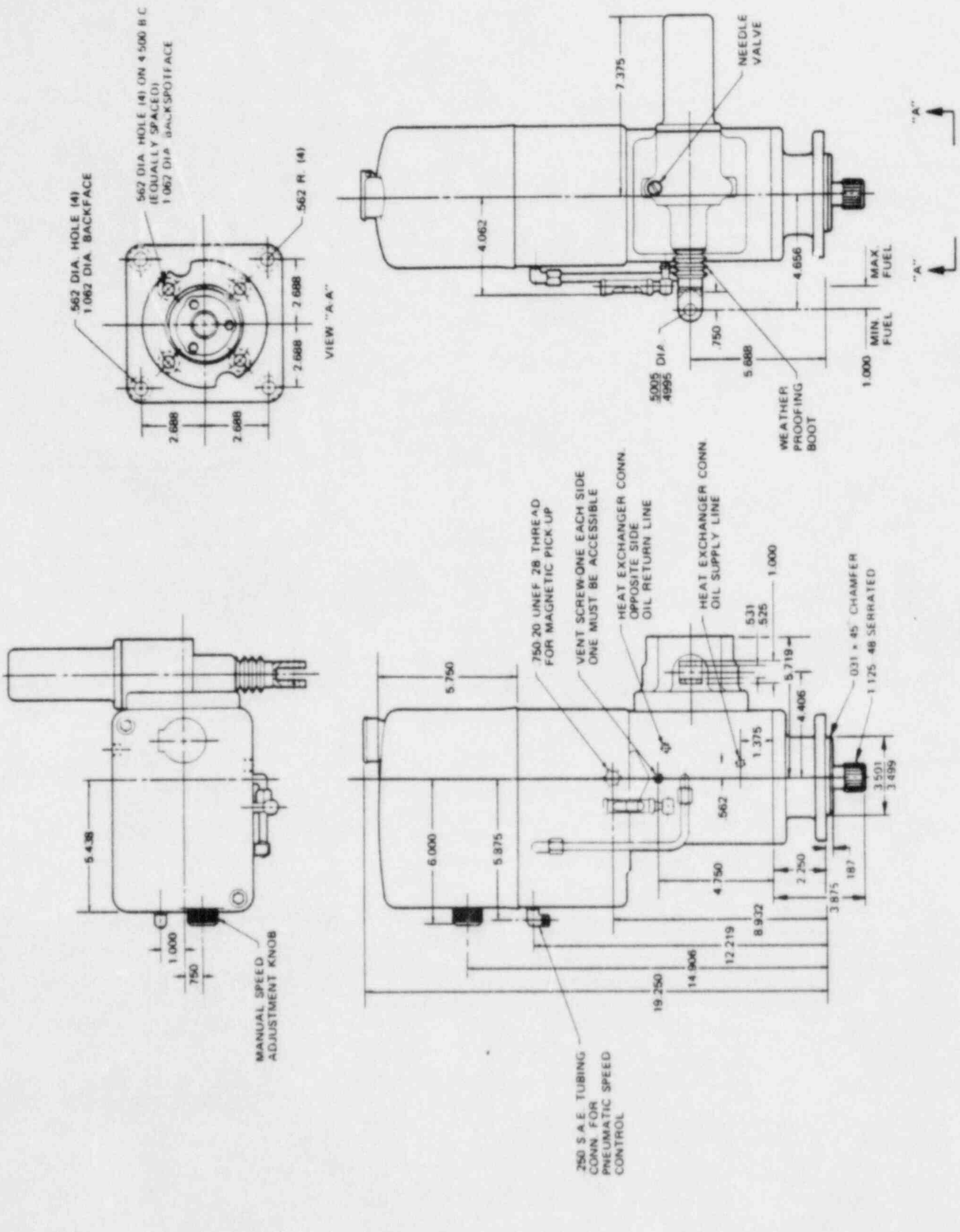


Figure 8. Outline Drawing of PG-PL Governor

SECTION VI/AUXILIARY FEATURES

AUXILIARY FEATURES (OPTIONAL)

Many auxiliary devices are available for use, either singly or in combination, on the PG governor to meet the numerous control requirements of the installation requiring precise speed setting. Each governor is designed to meet the needs of the engine or turbine and the operating requirements of the installation.

Auxiliary equipment may be supplied as original equipment in the governor or it may be installed in the field; it is recommended that the customer contact Woodward Governor Company on field installations.

The following paragraphs give a brief description of some of the auxiliary equipment available from Woodward Governor Company and list the bulletins where detail information may be obtained.

Bulletin No.	Title
36034	PG Governor Heater
36611	Current Controlled Speed Setting Mechanism
36641	Governor Heat Exchanger
36650	Solenoid Operated Shutdown Assembly
36651	Pressure Actuated Shutdown Assembly
36680	Preloaded Buffer Springs
36684	Booster Servomotor
36692	PG Power Cylinder Assemblies
36693	PG Base Assemblies

PG GOVERNOR HEATER

An electric heater is available for PG governors used on engines which are shut down for lengthy periods in cold climates. By applying heat to the governor power case during shutdown periods--or for a time before start-up--the governor oil viscosity is maintained at a point which enables the oil to flow freely through passages of the governor. This allows normal governor operation as soon as the engine is started.

GOVERNOR OIL COOLER

A governor oil cooler is required when governor drive shaft speed exceeds 1200 RPM on an engine application, or 1100 RPM on a steam turbine. It also may be necessary to use an oil cooler at lower governor drive shaft speeds if the governor is mounted close to valves or steam lines which result in high ambient temperatures.

Water (or some other liquid coolant) from an external supply enters the oil cooler cover and passes through a tube to the oil cooler body. The water circulates through the body cavity to the discharge.

A special governor case may be required to mount the oil cooler or to connect to the external heat exchanger. Where it might be desirable to add an oil cooler to a governor already in service, the governor should be returned to the factory for conversion.

CURRENT CONTROLLED SPEED SETTING MECHANISM

The current controlled speed setting mechanism provides continuous precise speed setting of a governor in response to electric signals from commercial sensing and transmitting equipment. A transducer within the unit converts the electric input signals into governor speed setting changes. The governor speed setting is proportional to the electric input signal, and can be arranged to give maximum governor speed for either the maximum input signal or the minimum input signal. Contact Woodward Governor Company on applications of this unit to PG-PL governors.

SHUTDOWN DEVICES

A shutdown device can be incorporated in the PG governor to stop fuel to the engine or turbine if equipment fails. These assemblies are used in a variety of applications including plants where automatic safety devices are a necessity. Shutdown devices can be supplied in the following arrangements to suit the particular operating conditions:

1. Shutdown assemblies which will operate from air, oil, or water pressure. These assemblies are generally supplied where electrical devices cannot be used. The air, oil, or water shutdown device can be arranged to shut down the engine or turbine on either high or low signal pressure.

2. A solenoid shutdown device which can be arranged to energize or de-energize to shut

down. Solenoid coils are available to accommodate most common DC voltages. Power required is 6 watts. For AC operation, a separately mounted transformer or rectifier assembly converts AC voltage to the required DC voltage.

PRELOADED BUFFER SPRINGS

Preloaded buffer springs are often installed in PG governors used on two-cycle spark ignition engines and on some engines driving reciprocating pumps. As a result of preloading, the governor minimizes fuel linkage movements resulting from changes in speed due to misfiring or pump strokes. The use of preloaded buffer springs does not affect the capability of the governor to recognize and respond to speed changes. Preloaded buffer springs do retard the rate at which the governor output piston (or shaft) moves when responding to small or momentary offspeeds. The output piston (or shaft) moves at the normal rate for large speed changes.

BOOSTER SERVOMOTOR

The booster servomotor is used in conjunction with the PG governor to assist the engine in starting quickly. The function of this device is to supply oil under pressure to the governor at the instant starting air is supplied to the engine; this enables the governor to move the engine linkage to the fuel-on position immediately.

PG BASES AND POWER CYLINDER ASSEMBLIES

A number of different base and power cylinder arrangements are available to conform to engine or turbine manufacturer's specifications.

The base assembly can be furnished with either a serrated or keyed drive shaft. Refer to bulletin 36693.

The work capacity of the power cylinder assembly normally furnished with the governor is 12 foot-pounds. A maximum of 8 foot-pounds can be used to move the fuel or steam control linkage over the full range of governor travel. Power cylinders with work capacity up to 58 foot-pounds are available. Refer to bulletin 36692.

SECTION VII/DIAPHRAGM SPEED SETTING

INTRODUCTION

Many of the earlier PG-PL governors are still in operation. These governors are of a type that uses an air receiver diaphragm instead of a bellows. The linkage for speed setting is also different and requires other instructions for adjustment. Both direct and reverse mechanisms are available in the diaphragm PG-PL governor. This section deals with the description, setting, and parts lists for the diaphragm type speed setting.

DESCRIPTION OF OPERATION

The following is a description of how the diaphragm direct speed setting mechanism operates. See figures 9 and 10. When a higher air pressure is sent under the pneumatic receiver diaphragm, the diaphragm rises against atmospheric and spring pressure on the opposite side. This movement, carried by the diaphragm link, pivots the speed control lever and pushes the speed setting pilot valve down through the action of the connecting link and the lower floating lever. The displacement of the speed setting pilot valve allows pressure oil to be admitted above the speed setting piston. The piston moves downward until the upper floating lever, floating lever link, and lower floating lever restore the pilot valve to its steady-state position.

With a lower air pressure signal, the receiver diaphragm would lower because of the receiver spring pressure atop it. Through the linkage previously described the speed setting pilot valve is raised, opening the port to sump and allowing the piston return spring to raise the piston. The linkage attached to the speed setting servo shaft closes the pilot valve again.

The diaphragm reverse mechanism runs the engine or turbine at high speed for minimum control air pressure, and low speed for maximum control air pressure. The special linkage arrangement is shown in figure 11. Note that the base speed setting nut pivot and upper end of the floating lever link have exchanged places from the arrangement shown in figure 10. A special speed setting pilot valve plunger is used. It must now move upward to admit oil to the speed setting servomotor. Converting a governor from direct operation to reverse speed setting involves changing a few parts so it is preferable, though not absolutely necessary, to specify the correct arrangement when a governor is ordered. See description of operation, page 9, for information on the rest of the governor.

ADJUSTMENT AND PARTS LIST

Air pressure versus engine or turbine speed relationships are set at the factory with more precise measuring instruments

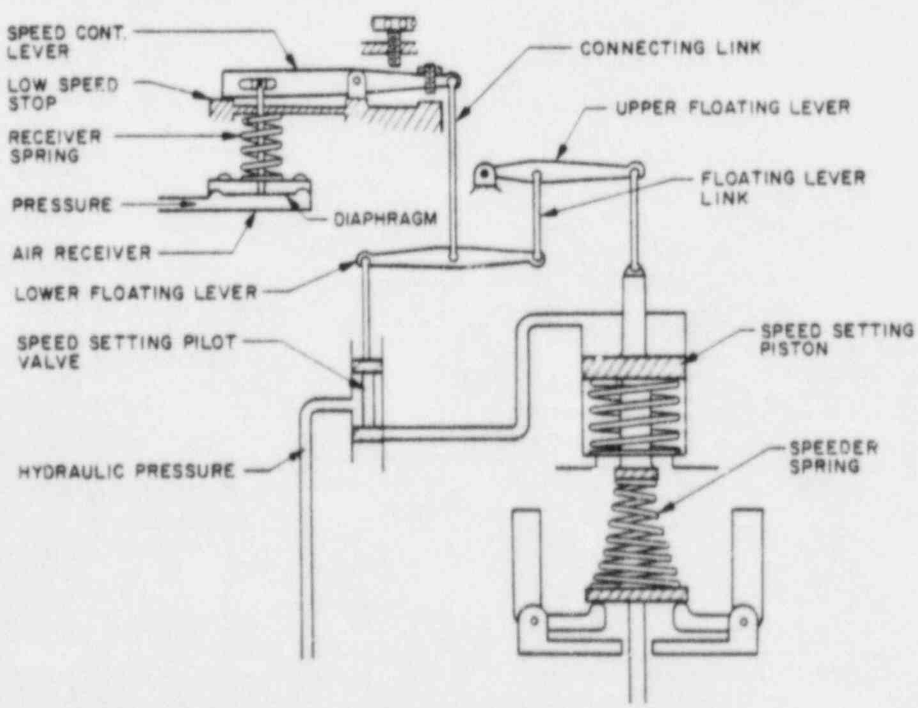


Figure 9. Schematic of Diaphragm Direct Speed Setting

than are available in the field. The governor speed settings normally will never need to be readjusted, and under no circumstances should they be altered without thorough knowledge of the procedure. If it is necessary to change or reset the governor speed settings, first determine the pressure range of the associated air pressure instrument, and the engine or turbine speed range corresponding to this pressure range.

Back off the high speed stop screw, shown in figure 10. Loosen the idle speed screw locknut and the sliding block lockscrew and nut. The sliding block can now be moved freely to either end of the slot. Set it at approximately the mid-point in its travel and lock it with the lockscrew and nut. Start the engine or turbine and apply the specified low air pressure (generally three psi). Adjust the idle speed screw up or down, as required, until the left end of the speed control lever just touches or is a few thousandths (roughly the thickness of tissue paper) short of touching the pneumatic receiver casting which serves as the low speed stop.

Adjust the base speed setting nut to obtain the specified engine speed corresponding to minimum air pressure. Screw down to decrease speed, or up to increase speed. Slowly raise control air pressure to the specified maximum value, making sure the engine does not overspeed. The speed obtained will probably be either higher or lower than the desired maximum. Check to be sure the high speed stop screw is not limiting speed by touching the screw head below it.

If the maximum speed obtained is too low, loosen the sliding block lockscrew and nut and the idle speed screw locknut. Move the sliding block a short distance to the right. Moving the sliding block to the right (toward the pivot) increases the amount of RPM change that results from a specified air pressure change. Moving the sliding block to the left (away from the pivot) reduces the amount of RPM change obtained for a given air pressure change.

It is now necessary to start over again with the specified air pressure at minimum and adjust and lock the idle speed screw so the left end of the speed control lever just touches, or as explained previously, almost contacts the casting. Set the base speed setting nut as before to obtain the specified minimum speed corresponding to minimum air pressure. Again apply maximum specified air pressure and check the speed. Repeat this process until the desired high and low speeds are obtained.

When desired speeds have been obtained for the specified air pressures, adjust the high speed stop screw so it just contacts the screw head below it at maximum specified air pressure. Tighten the locknut.

Make sure the diaphragm link between the diaphragm and the idle speed screw does not rub on the edge of the hole where it passes through the pneumatic receiver casting. This could happen if the sliding block were either too far from or too near the pivot. Such interference indicates that it is necessary to use the next heavier or lighter air receiver spring.

On PG-PL governors equipped with reverse speed setting (minimum control air pressure produces maximum speed), the procedure for setting speeds is basically the same; however, the left end of the speed control lever rests on the

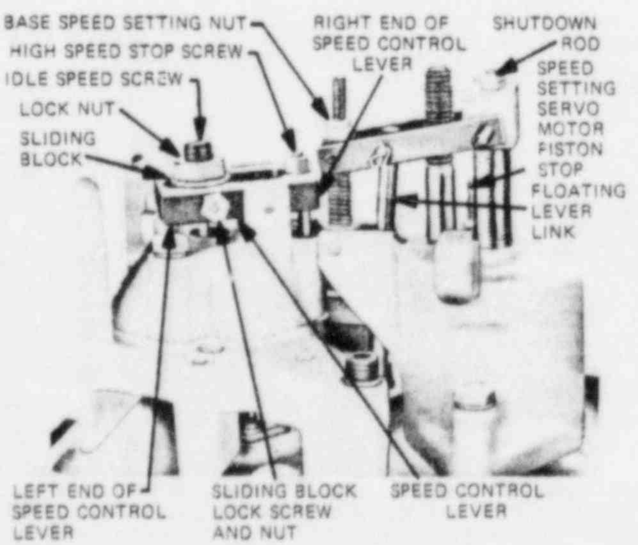


Figure 10. Adjustment Points of Diaphragm Direct Air Receiver

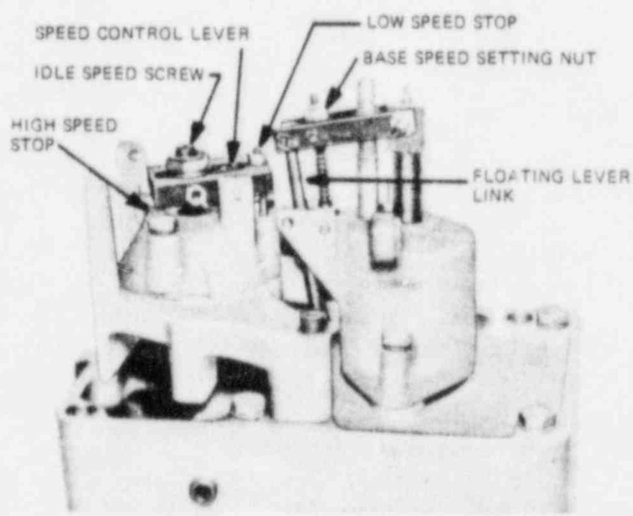


Figure 11. Reverse Diaphragm Linkage Arrangement

housing casting at maximum engine speed, and the high speed stop screw now serves as the low speed stop.

SPEED SETTING SERVOMOTOR PISTON STOP SCREW ADJUSTMENT

Set the governor for the minimum speed position. Turn the speed setting servomotor piston stop screw down until it contacts the top of the piston, then back it off 1-1/2 turns and tighten the locknut.

INFORMATION AND PARTS REPLACEMENT

When requesting additional information concerning governor operation, or when ordering repair parts, it is essential that the following information accompany the request.

1. Governor serial number shown on the nameplate.
2. Bulletin number. (This is bulletin 36694).
3. Part reference number, name of part, or description of part.

PARTS LIST FOR FIGURE 12.

REF. NO.	PART NAME	QUANTITY
36694-301	5/16-24 x 5-15/32 hex head screw	2
36694-302	5/16 shakeproof washer	6
36694-303	Oil filler cup	1
36694-304	Set screw (knob)	1
36694-305	Control knob	1
36694-306	Taper pin	1
36694-307	Drive screw	AR
36694-308	Manual speed adjustment plate	1
36694-309	Friction plunger	1
36694-310	Friction spring	1
36694-311	5/16 lockwasher	AR
36694-312	Gasket	1
36694-313	Bushing-dowel	2
36694-314	Bushing	2
36694-315	5/16-24 x 5/8 threaded insert	2
36694-316	Stud	1
36694-317	Power piston stop screw	1
36694-318	#10-32 hex nut	1
36694-319	Adjustable fulcrum screw	1
36694-320	13/64 x 7/16 x 1/32 washer	1
36694-321	Link adjusting spring	1
36694-322	Adjustable fulcrum pin	1
36694-323	#10-32 stop nut	1
36694-324	Fulcrum link	2
36694-325	Link spacer	2
36694-326	Piston fulcrum assembly	1
36694-327	Floating lever link	1
36694-328	Floating lever link spring	1
36694-329	1/8 straight pin	1
36694-330	1/16 x 3/8 cotter pin	6
36694-331	Lower floating lever assembly	1
36694-332	1/8 x 47/64 drilled pin	2
36694-333	.186 x 3/4 pin	1
36694-334	Speeder spring power cylinder	1
36694-335	1/4-28 x 1 3/8 hex head cap screw	5
36694-336	17/64 x 1/2 x 1/32 washer	2
36694-337	Speeder spring power piston assembly	1
36694-338	Speeder spring servo spring	1
36694-339	Speed setting pilot valve plunger	1
36694-340	Pilot valve plunger spring	1
36694-341	Speed setting pilot valve bushing	1
36694-342	Pilot valve bushing spring	1
36694-343	Column assembly	1
36694-344	Gear	1
36694-345	Bearing stud	1
36694-346	Thrust bearing	1
36694-347	Bushing retainer	1
36694-348	#10-32 x 3/8 round head phillips screw	2
36694-349	#10 lockwasher	2
36694-350	1/4 x 9/16 dowel pin	4
36694-351	1/4-28 socket head screw	1
36694-352	Speed control bracket	1
36694-353	17/64 x 27/64 x 1/16 lockwasher	AR
36694-354	1/4-28 x 1 1/4 socket head cap screw	1
36694-355	1/4-28 x 1 3/4 socket head cap screw	1
36694-356	Diaphragm nut	1
36694-357	Retaining washer	1
36694-358	Diaphragm washer	1
36694-359	Diaphragm	1
36694-360	Spring seat	1
36694-361	Diaphragm spring	1
36694-362	Pivot pin	1
36694-363	Floating lever link assembly	1
36694-364	Diaphragm link assembly	1
36694-365	Speed control bracket cap	1
36694-366	Control lever slide	1
36694-367	Idle speed setting screw	1
36694-368	Needle bearing	2
36694-369	Speed control lever	1
36694-370	3/8 washer	1
36694-371	3/8-32 hex jam nut	1
36694-372	#10-32 x 3/4 socket set screw	1
36694-373	#10-32 hex nut	2
36694-374	#10-32 x 1/2 socket set screw	1
36694-375	Speed adjusting screw	1

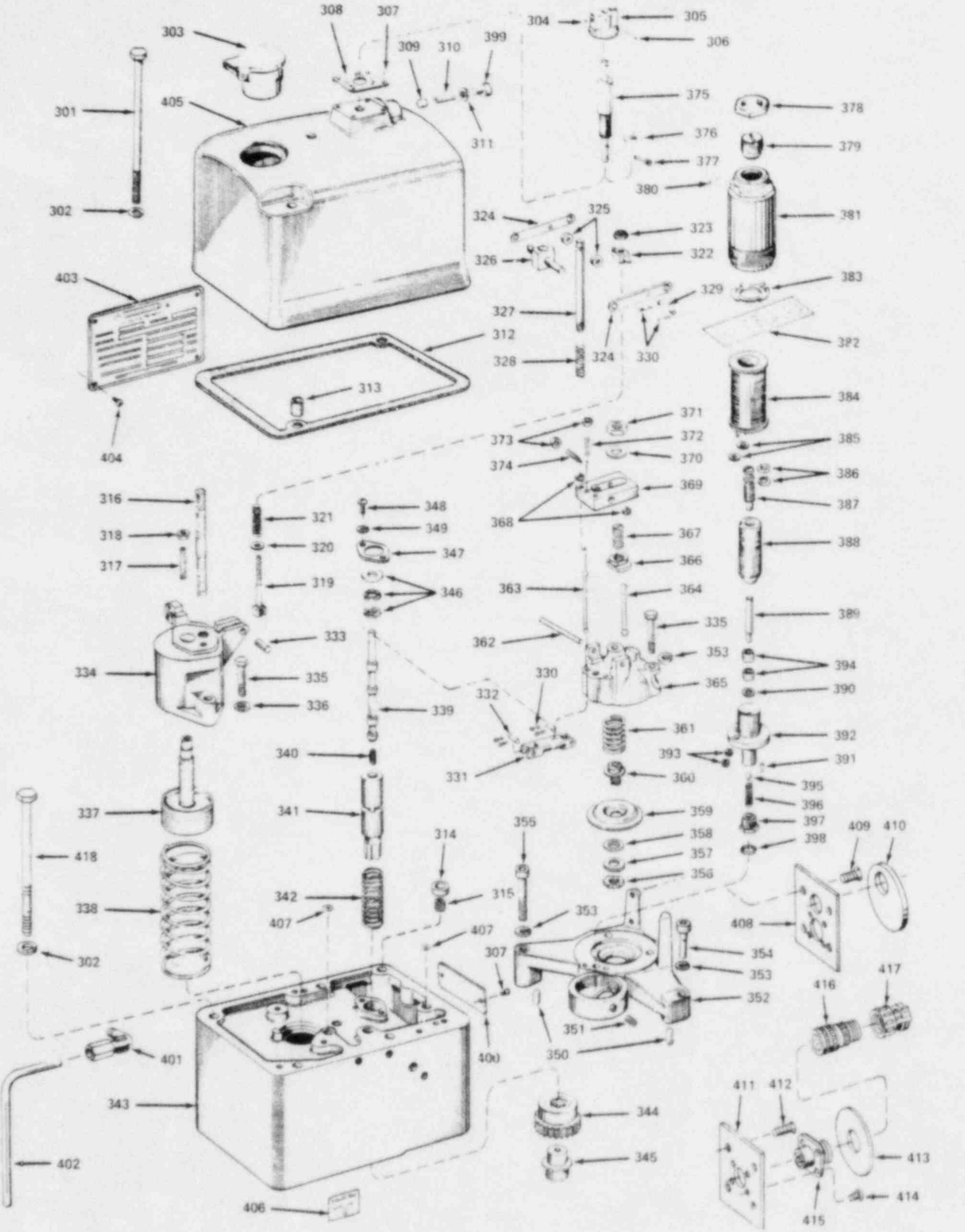


Figure 12. Exploded View of Diaphragm Column Parts

PARTS LIST FOR FIGURE 12 (CONT.)

REF. NO.	PART NAME	QUANTITY
36694-376	9/16 x 21/64 x 1/16 washer	1
36694-377	3/32 x 1/2 cotter pin	1
36694-378	Solenoid locknut	1
36694-379	Plunger stop plug	1
36694-380	Solenoid plunger lock pin	1
36694-381	Solenoid case	1
36694-382	Insulating paper	1
36694-383	Load spring	1
36694-384	Solenoid coil	1
36694-385	Soldering shield washer	2
36694-386	"O" ring	2
36694-387	Adjusting screw	1
36694-388	Solenoid plunger assembly	1
36694-389	Solenoid plunger rod	1
36694-390	Solenoid plunger washer	1
36694-391	Plunger guide locating pin	1
36694-392	Shutdown valve body	1
36694-393	Varnished tubing	2
36694-394	Solenoid plunger bushing	2
36694-395	1/4 steel ball	1
36694-396	Unloading spring	1
36694-397	Shutdown valve seat	1
36694-398	"O" ring	1
36694-399	Friction plunger retaining screw	1
36694-400	Nameplate (column)	1
36694-401	Elbow	2
36694-402	Tubing	1
36694-403	Nameplate (cover)	1
36694-404	Drive screw	4
36694-405	Cover	1
36694-406	Oil level decal	1
36694-407	"O" ring	2
36694-408	Plate	1
36694-409	#10-32 x 3/8 screw	1
36694-410	Gasket	1
36694-411	Plate	1
36694-412	#10-32 x 1/2 screw	4
36694-413	Gasket	1
36694-414	#6-32 x 3/8 screw	4
36694-415	Receptacle	1
36694-416	Plug	1
36694-417	Cable clamp	1
36694-418	5/16-24 x 4-31/32 hex head screw	4

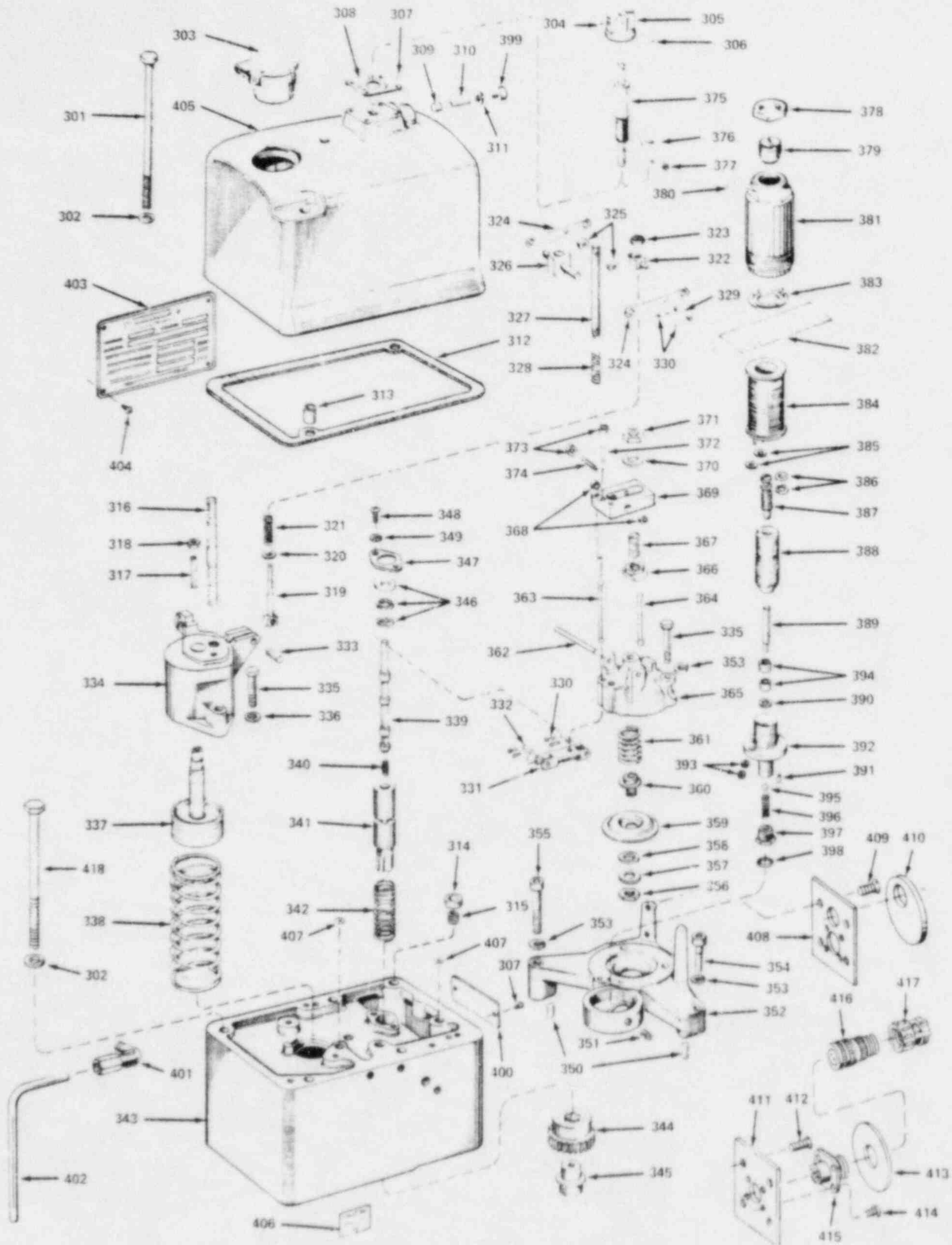


Figure 12. Exploded View of Diaphragm Column Parts

WOODWARD GOVERNOR COMPANY
MAIN OFFICE: Rockford, Illinois, U.S.A.
Fort Collins, Colorado, U.S.A. – Tokyo, Japan
Sydney, Australia
WOODWARD GOVERNOR NEDERLAND N.V.
Hoofddorp, The Netherlands
WOODWARD GOVERNOR (U.K.) LTD.
Slough, Bucks., England

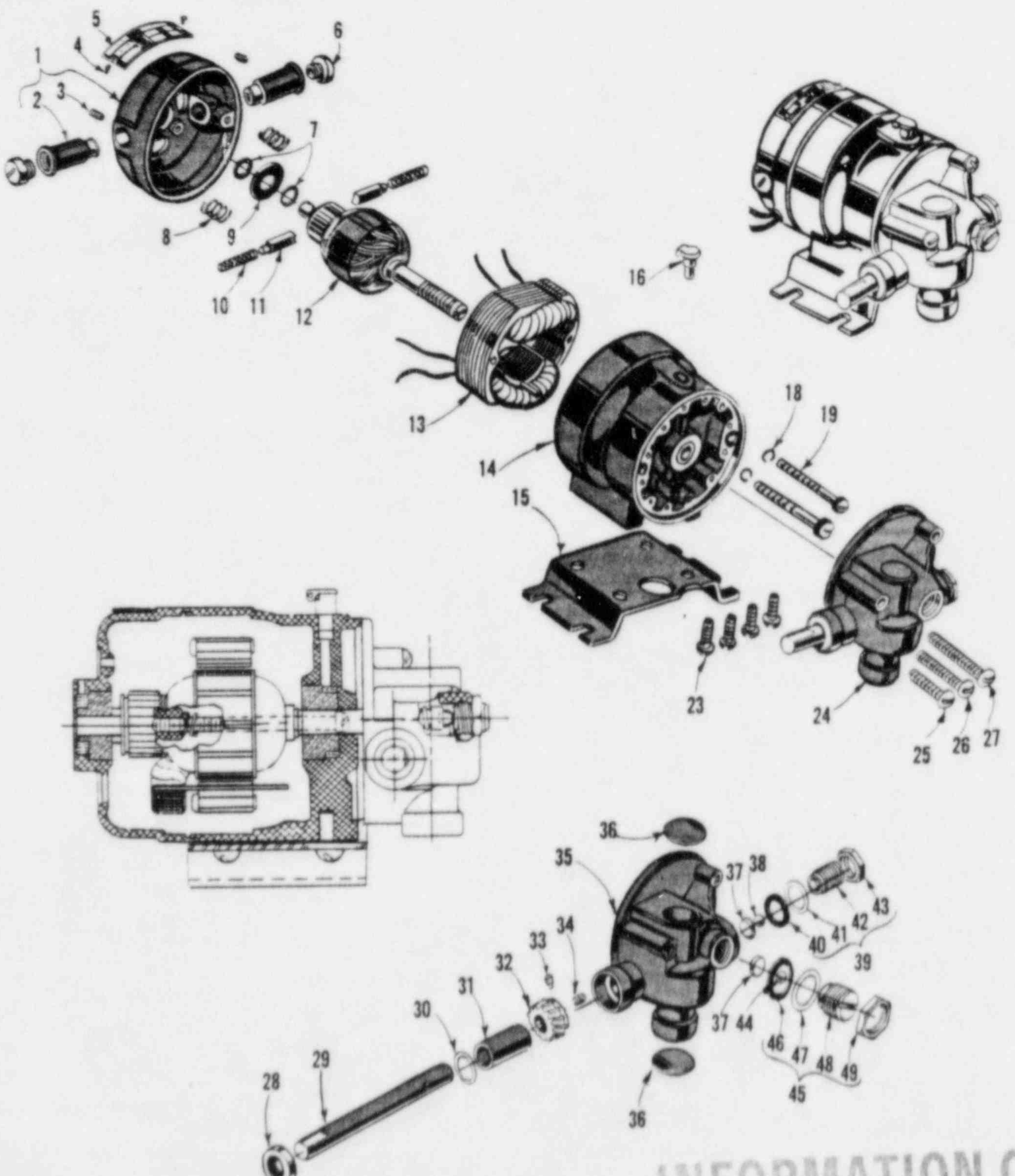
REPLACEMENT PARTS

BODINE

V-IOR FRAME
SLEEVE BEARING SERIES WOUND
SINGLE REDUCTION

SECTION 3035
PAGE 5

567 FORM-1623-26



Replacement Parts

Bodine Electric Co.
Chicago 18, Ill.

Item No.	Description Of Part		Qty. Req'd.	Part No.	Price
1	HOUSING,	FRONT ASSEMBLY	1	V-274	
2	BRUSHHOLDER		2	C-450	
3	SCREW,	BRUSHHOLDER SET	2	N-1598	
4	PIN,	NAMEPLATE	2	K-290	
5	NAMEPLATE		1	V-280	
6	CAP,	BRUSHHOLDER SCREW	2	N-2813	
7	WASHER,	SPACING (1/64" THICK)	As Req'd	V-331	
7	WASHER,	SPACING (1/32" THICK)	As Req'd	V-332	
8	SPRING,	FIELD CORE HOLDING	2	V-189	
9	SLINGER,	OIL	1	V-36	
10	SPRING,	BRUSH	2	~~See Note (1) Below~~	N-1812
11	BRUSH		2	~~See Note (1) Below~~	V-360
12	ARMATURE	(WOUND COMPLETE)	1	See Note (1) Below	
13	CORE,	FIELD & COIL ASSEMBLY	1	See Note (1) Below	
14	HOUSING,	REAR ASSEMBLY	1	V-353	
15	BASE		1	V-96	
16	OILER		1	N-776	
			1*		
18	WASHER,	LOCK	2	3098-7-7	
19	SCREW,	SHIELD	2	K-78	
23	SCREW,	BASE	4	S-243	
24	GEAR HOUSING ASSEMBLY		1	~~See Note (1) Below~~	N-3900-2H
25	SCREW,	GEAR HOUSING	1	S-212 1/2	
26	SCREW,	GEAR HOUSING	1	S-215 1/2	
27	SCREW,	GEAR HOUSING	1	S-216 3/4	
28	SEAL,	DRIVE SHAFT	1	N-2449	
29	SHAFT,	DRIVE	1	C-208	
30	WASHER		1	N-2497	
31	SLEEVE,	SPACING	1	C-213	
32	GEAR		1	~~See Note (1) Below~~	N-2083
33	SCREW,	GEAR SET	1	C-460	
34	SCREW,	GEAR SET	1	C-199	
35	HOUSING,	GEAR	1	N-2436	
36	DISC,	GEAR HOUSING	2	N-2460	
37	DISC,	THRUST	2	C-220	
38	BALL,	THRUST	1	N-2515	
39	ADJUSTING SCREW ASSEMBLY		1	N-2454	
40	WASHER,	NEOPRENE	1	N-2526	
41	WASHER,	FIBER	1	N-2453	
42	SCREW,	ADJUSTING	1	N-2450	
43	NUT,	ADJUSTING SCREW LOCK	1	N-2451	
44	BALL,	THRUST	1	C-186	
45	ADJUSTING SCREW ASSEMBLY		1	C-397	
46	WASHER,	FELT	1	3096-4	
47	WASHER,	FIBER	1	D-138	
48	SCREW,	ADJUSTING	1	C-197	
49	NUT,	ADJUSTING SCREW LOCK	1	C-198	

FOR PRICES, SEE SECTION 5000

IMPORTANT: PLEASE GIVE MOTOR SERIAL NUMBER ON ALL ORDERS FOR PARTS.

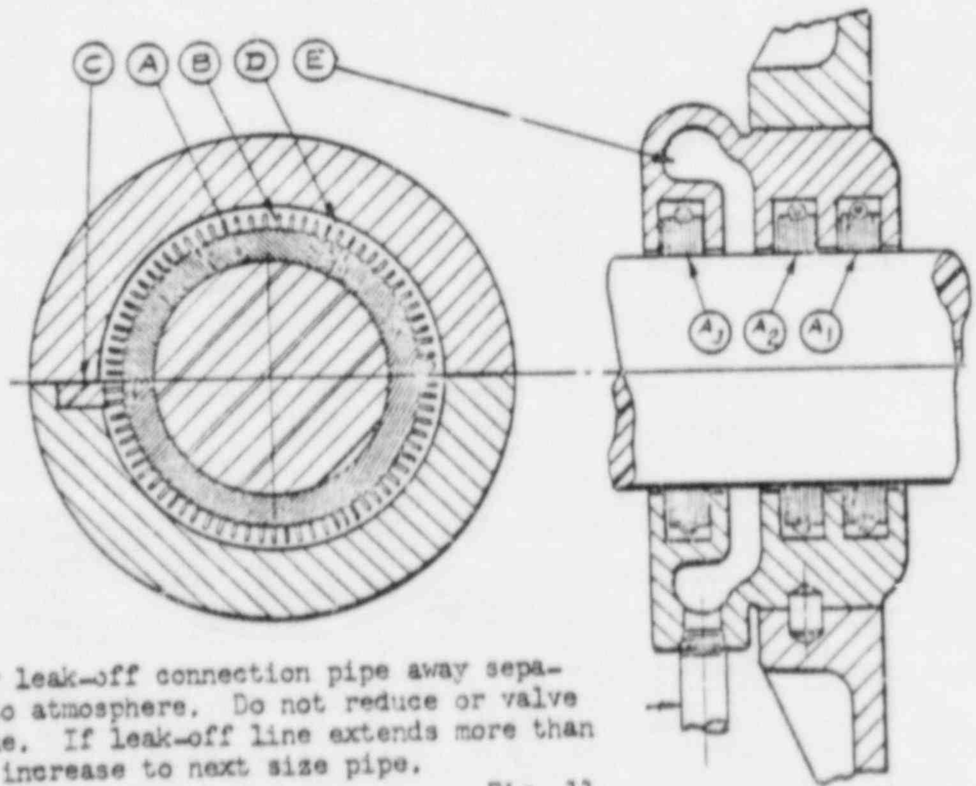
NOTE:
(1) THESE PARTS VARY WITH VOLTAGE, H.P. AND SPEED, THEREFORE, PLEASE GIVE FULL NAMEPLATE DATA, INCLUDING SERIAL NUMBER. WOUND ARMATURES AND FIELD WINDING ASSEMBLIES ARE NOT NORMALLY CARRIED IN STOCK.

C A R B O N   R I N G   G L A N D S

Carbon rings (A) generally consist of three segments bound together by a garter spring (B) (In some cases, a four segment ring with two springs is used). They are prevented from rotating by stop piece (C). They fit the shaft closely but do not grip it. They are free in the slots (D) and are held against one side of the slot by difference of steam pressure on the two sides of the ring. This type of gland requires no water or lubricant. The number of rings in a gland case may vary depending on steam conditions.

When packing against back pressure, a small quantity of steam will leak past rings A-1 and A-2. This steam is caught in a leak-off space (E) from which it may be piped to atmosphere or to a gland condenser when provided. If pressure is held in the leak-off space, it may also leak past ring A-3 with the possibility of getting into the bearings.

On high back pressure units, an intermediate leak-off connection is provided. See separate page covering piping and adjustments on this feature when provided.



Drain or leak-off connection pipe away separately to atmosphere. Do not reduce or valve this line. If leak-off line extends more than 6 feet, increase to next size pipe.

Fig. 11

When packing against vacuum, steam at a pressure slightly above atmospheric is connected to space (D) as a steam seal to prevent air from being drawn through the gland. The quantity of steam admitted to the steam seal must be carefully regulated so that the pressure in the sealing space is above atmospheric pressure but not great enough to blow out of the end of the gland. This may be done either by a small reducing valve or by a hand-operated valve. If the latter is used, a relief valve should be installed as well to guard against excessive pressure.

A gland is sometimes called on to pack against either Back Pressure or Vacuum. In this case provision must be made for both, and considerably more care is required in handling the glands. Adjustments must be made whenever the conditions are changed unless automatic devices are provided.

When changes are not frequent, Hand Control is satisfactory. See separate instructions on following page showing piping and operation of steam seal when provided.

To dismantle, remove top halves of gland housing and remove carbon rings and springs, keeping each gland ring separate so that they can be reinstalled in their same position. The carbon ring consists of three or four segments. Each segment is marked so that when the ring is reinstalled the mark on each segment should match. Trouble will be experienced if the segments become mixed with other rings.

The gland journals or sleeves are sized to produce correct clearances with standard rings, at rated conditions; therefore, if the gland journals are in good condition, it is not normally necessary to hand fit new carbon rings and they may be installed as received. Sometimes because operating conditions differ slightly from design, it is necessary to alter the carbon ring diameter to obtain best results.

Generally, if the glands have been blowing excessively and the ID of the rings has a dull appearance, indicating poor contact, better results will be obtained if the ID is reduced. To do this, it is necessary to remove material from the butt end of the segments.

If leakage is excessive and the ID of the ring is glazed, the rings are too tight and the ID should be increased slightly.

TAKING APART AND RE-ASSEMBLING

It is seldom necessary to dismantle a Terry turbine entirely, but when it is necessary to do so it is quite simple, because of the accessibility of the interior parts.

BEFORE STARTING TO TAKE APART Note carefully the setting of all adjustable parts such as governor valve, governor, etc., so that they can be restored easily to their original adjustment.

HANDLE ALL PARTS CAREFULLY Avoid bruises which might cause steam leakage or misalignment.

CAREFULLY CLEAN AND EXAMINE This applies to all parts removed or made accessible. Repair or replace any which show injurious wear or damage. When reassembling be sure all parts are clean and free from bruises.

The action of the steam in the wheel and reversing chamber is shown in Figure 1. When re-assembling the rotor must be so adjusted that the relation between the moving and fixed buckets is correct, as described below, after making any necessary adjustments to eliminate excessive end play.

Fig. 1. Action of Steam in Terry Turbine

Action is such that steam is returned to the wheel again and again until all available energy is utilized

The important point is the "lap" or the amount by which the wheel buckets and the stationary reversing chambers lap over each other. Adjustment should be made by means of the wheel nuts which are indicated in Figure 3. The lap measurement should be made at the point shown at the toe of the reversing chamber. The amount of lap is given in the table in Figure 2, and should be kept correct within 1/64".

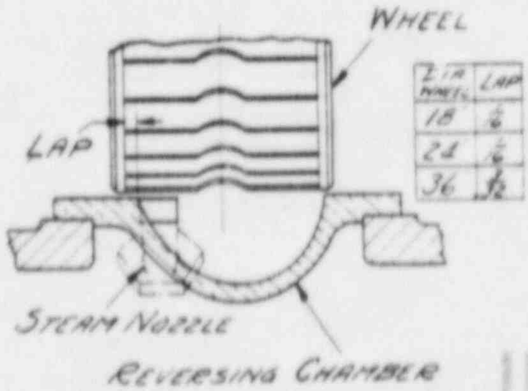


Figure 2.

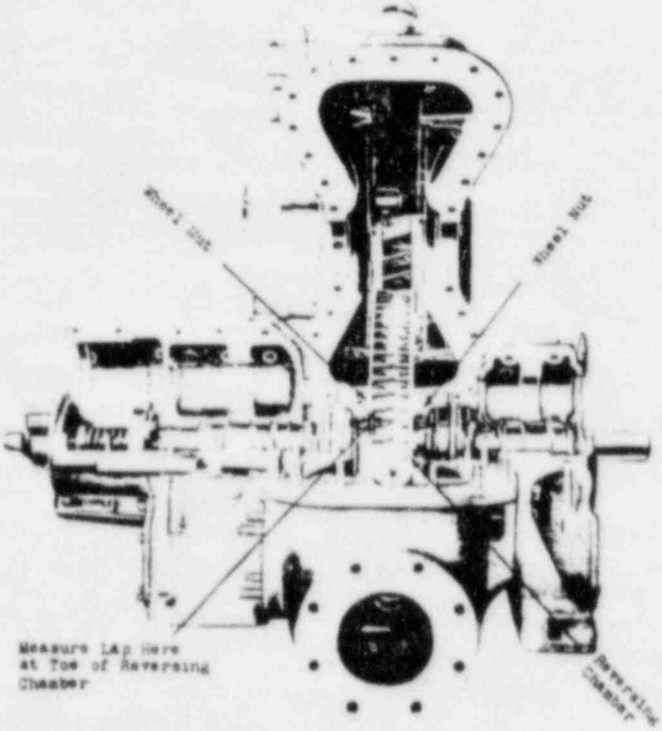


Figure 3

To make the horizontal joint steam tight, first make sure that it is clean and free from bruises. Then coat with cement form Copaltite* and lay one or two threads of shoemaker's twine or other thread (not string) carefully around the joint. Never use a gasket in the horizontal casing joint.

* Copaltite may be purchased from The Terry Steam Turbine Company, P.O. Box 1200, Hartford, Connecticut, or from The National Engineering Products, Inc., 15th & New York Avenues, N.W., Washington, D.C.

Parts List 67327A

Reference Dwg. 67062E

Type GS-2 Longitudinal Section

Part No.	Name of Parts	Piece No.=	Dwg. No.
1	Case - U.H.-T.S.T.Co.Spec 01-69	59917	E-4941
2	Shaft Nut	4318	A-811
3	Packing Ring - carbon	6894	A-1618
4	Packing Ring Spring - inconel	26838	A-966X
5	Electromagnetic Pick Up Airpax #11-0003	-	std.
6	Bearing Pedestal Cap	57872	B-12313
7	Inspection Plug	22185	A-8022
8	Hex Nut - 3/8"	-	std.
9	Studs Bolts	7018	A-1644
10	Packing Ring Stop	12887	F-1881
11	Gland Case - upper half	28701	C-3245
12	Gland Case - lower half	28702	C-3245
13	Shaft - alloy steel T.S.T. Spec15-69	65678C	65678C
14	Oil Deflector	10618	F-903
15	Dust Collar	46337	A-8692
16	Oil Ring	56394	A-10489
17	Oil Well Cover	11679	A-2528
18	Bearing Pedestal-cast iron ASTM-A-48, Class 30	33911	D-3326
19	Bearing-cast iron & babbitt ASTM-A-48 babbitt-ASTM-B-23-46T,grade 15	47551,47552	C-8212
20	Pick-Up Gear	46927	A-8807
21	Thrust Collar	46372	A-8703
22	Oil Deflector	46344	A-8694
23	Pin	3834	F-240
24	Wheel-SAE-alloy st. T.S.T. Spec 17-69	65680B	65680B
25	Steam Jet	49737	A-9369
26	Steam Jet Body	57862	B-12310
27	Rev. Chamber	56578	A-6070
28	Jet Body Holder	57865	A-10745
29	Case-L.H.-T.S.T. CO.Spec 01-69	67594	E-4956
30	Jet Plug	57864	A-10744
31	Thrust Collar	46372	A-8703
32	Bearing Pedestal-Gov.End-C.I. ASTM-A-48, Class #30	56422	D-5946
33	Governor Bearing-cast iron & babbitt ASTM-A-48 Babbitt ASTM-B-23-46T,grade15	31204,31205	C-4782
34	N.D. Bearing -Q 30208 DFL#3666	-	std.
35	Lockwasher W-08	-	std.

INFORMATION ONLY

TERRY

Parts List - continued

Part No.	Name of Parts	Piece No.	Dwg. No.
36	Locknut N-08	-	std.
37	Emerg. Governor Disc.	29592	B-6102
38	Pump Bracket	53143	C-10718
39	Gear Space Collar	43193	A-7983
40	Pump Driving Gear - driver	46471	A-8717
41	Gear Nut	4339	A-822
42	Oil Pump Cover	46738	B-10037
43	Tuthill Pump Model GRFD-1	-	std.
44	Lower Shaft Bushing	16064	E-3088
45	1" Pipe Plug	-	std.
46			
47			
48	Upper Shaft Bushing	17569	F-3692
49	Lower Thrust Washer Dowel	10386	F-813
50	N26-51 Truarc Retainer Ring	-	std.
51	Lower Thrust Washer	41601	A-7705
52	Pump Driving Gear- driven	46472	A-8717
53	Upper Thrust Washer	38909	A-7259
54	Upper Thrust Washer Dowel	16632	F-3223
55	Oil Pump Shaft-driving	57851	B-12308
56	Coupling Pin 18 X 1½"	-	-
57=	Coupling	51353	A-9636
58	Pump Bracket Cap	46757	C-8014
59	Woodward Adapter	57860	B-12309
60	Woodward Governor - Type EGR	-	std.
61	Governor End-Bearing Pedestal Cap	16086	D-5946
62	By-Pass ASTM:A216,WCB	66494B	66494B
63	Stud	30319	A-891X
64	Nut 7/8-9	-	std.
65	Blank Flange - Ladish #64	-	std.
66	Eye Bolt	21662	A-942X
67	Body Gasket R 4 - 9F	-	std.
68	Jet Plug Gasket - stn. stl.	67974	A-933X
69	Flexitallic Gasket # RI - 9J	-	
70	Flexitallic Gasket # CG - 6K	—	Std.
71			Std.
72	Jet Dummy(not shown)	67889B	67889B
73	DUST COLLAR	3322	A-577
74	ELECTROMAGNETIC PICKUP WOODWARD #1680-822 NOT SHOWN ON CROSS-SECTION DRAWING LOCATION IS IN SAME PLANE AS PART NO 5		

lift the plunger. The centrifugal force is opposed by the downward force of the speeder spring. When the opposing forces are equal, the pilot valve plunger is stationary.

With the pilot valve plunger centered and the engine running on-speed, a change in either of the two forces will move the plunger from its centered position. The plunger will be lowered (1) if the governor speed setting is unchanged but an additional load slows the engine and governor (thereby decreasing the centrifugal force developed by rotating flyweights) or (2) if the engine speed is unchanged but the speeder spring force is increased to raise the governor speed setting. Similarly, the pilot valve plunger will be raised (1) if the governor speed setting is unchanged but load is removed from the engine causing an increase in engine and governor speed (and hence, an increase in the centrifugal force developed by the rotating flyweights), or (2) if the engine speed is unchanged but the speeder spring force is reduced to lower the governor speed setting.

The thrust bearing atop the ballarm toes permits the pilot valve bushing to rotate while the pilot valve plunger does not rotate. In this way, static friction between the bushing and plunger is minimized.

There are several styles of flyweight head assemblies available. The exact model used in any one governor depends upon the application.

A "solid" head assembly is used in governors on prime movers which afford a smooth drive to the governor.

"Spring driven" and "spring driven, oil damped" head assemblies are used to filter torsional vibrations which may be imparted to the governor by the drive from the engine. (These torsional vibrations may originate from a source other than the drive itself but reach the governor through the drive connection). Unless minimized or eliminated, the flyweight head will sense these torsional vibrations as speed changes and continually adjust the fuel valve or racks in an attempt to maintain a constant speed.

Movements of the power piston are transmitted by the piston rod to the engine fuel linkage. Regulated oil pressure under the power piston is used to raise the power piston – to increase fuel – and the power spring above the power piston is used to lower the power piston to decrease fuel.

Located between the pilot valve bushing and the power piston is the buffer compensating system, consisting of the buffer cylinder and piston, the buffer springs, and the compensating needle valve. Lowering the pilot valve plunger

permits a flow of pressure oi
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results in a flow of oil from
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the power piston down to de

This flow of oil in the buffe
carries the buffer piston
compressing one of the bu
other. This action creates
pressures of the oil on oppo
with the higher pressure or
which is compressed. These
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downward force on the com
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The vertical position of the f
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THEORY OF OPERATI

See figure 2 for the schem
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Differences may exist in th
components from one gover
of operation is the same in e

The schematic arrangement
mechanism (governor spee
pressure signal increases) is
of figure 2. The inset sh
"reverse" speed setting (go
control air pressure signal in

The following theory of
speed setting mechanism. T
in the governor take place
manner, rather than step
following paragraphs.

SPEED INCREASE

An increase in the contr
pneumatic receiver assem
Through a mechanical conn
valve plunger, the bellows

from the pilot valve bushing
power cylinder to raise the
fuel. Raising the pilot valve
he power cylinder and buffer
, and the power spring moves
rease fuel to the engine.

system -- in either direction --
in the direction of flow,
fer springs and releasing the
a slight differential in the
ite sides of the buffer piston,
the side opposite the spring
differential oil pressures are
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pensating land which assists in
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ON

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governor and speed setting
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increases as the control air
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movement -- caused by changes

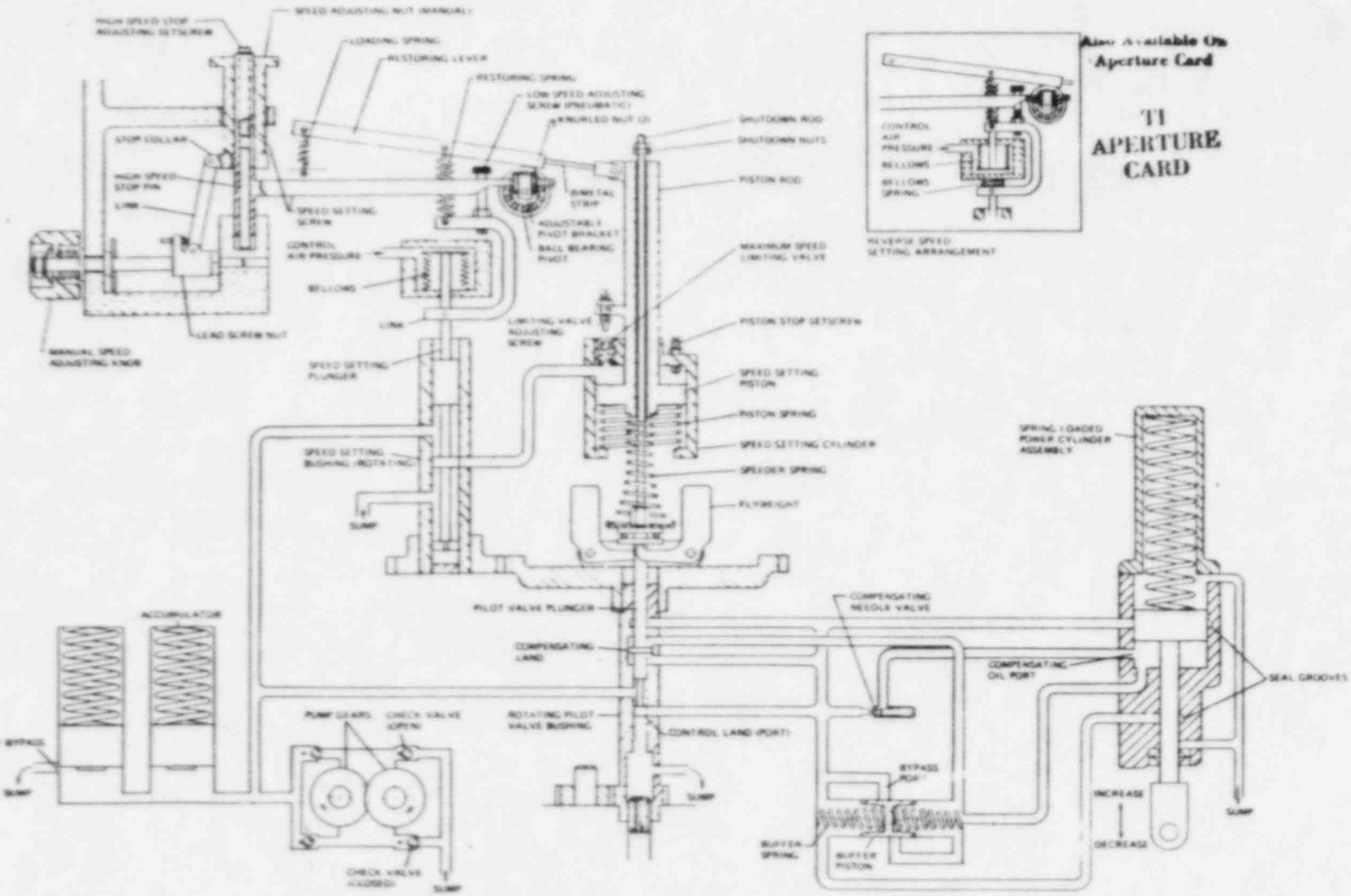

Figure 2. Schematic Diagram of PG-PL Governor

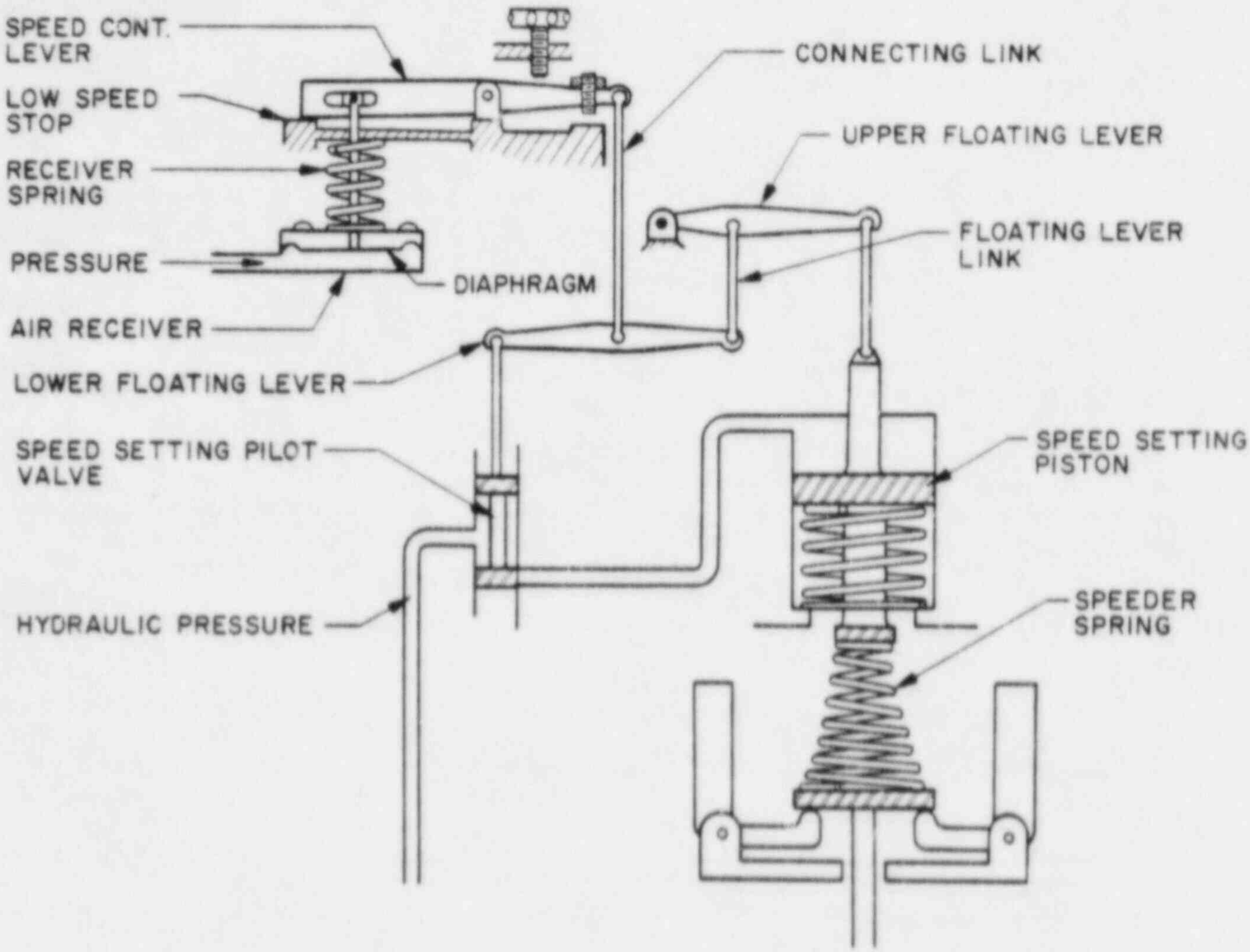

Fig. 9. Schematic of Diaphragm Direct Speed Setting

SECTION VI/DIAPHRAGM SPEED SETTING

INTRODUCTION

Many of the earlier PG-PL governors are still in operation. These governors are of a type that uses an air receiver diaphragm instead of a bellows. The linkage for speed setting is also different and requires other instructions for adjustment. Both direct and reverse mechanisms are available in the diaphragm PG-PL governor. This section deals with the description, setting, and parts lists for the diaphragm type speed setting.

DESCRIPTION OF OPERATION

The following is a description of how the diaphragm direct speed setting mechanism operates. See figures 9 and 10. When a higher air pressure is sent under the pneumatic receiver diaphragm, the diaphragm rises against atmospheric and spring pressure on the opposite side. This movement, carried by the diaphragm link, pivots the speed control lever and pushes the speed setting pilot valve down through the action of the connecting link and the lower floating lever. The displacement of the speed setting pilot valve allows pressure oil to be admitted above the speed setting piston. The piston moves downward until the upper floating lever, floating lever link, and lower floating lever restore the pilot valve to its steady-state position.

With a lower air pressure signal, the receiver diaphragm would lower because of the receiver spring pressure atop it. Through the linkage previously described the speed setting pilot valve is raised, opening the port to sump and allowing the piston return spring to raise the piston. The linkage attached to the speed setting servo shaft closes the pilot valve again.

The diaphragm reverse mechanism runs the engine or turbine at high speed for minimum control air pressure, and low speed for maximum control air pressure. The special linkage arrangement is shown in figure 11. Note that the base speed setting nut pivot and upper end of the floating lever link have exchanged places from the arrangement shown in figure 10. A special speed setting pilot valve plunger is used. It must now move upward to admit oil to the speed setting servomotor. Converting a governor from direct operation to reverse speed setting involves changing a few parts so it is preferable, though not absolutely necessary, to specify the correct arrangement when a governor is ordered. See description of operation, page 9, for information on the rest of the governor.

ADJUSTMENT AND PARTS LIST

Air pressure versus engine or turbine speed relationships are set at the factory with more precise measuring instruments than are available in the field. The governor speed settings normally will never need to be readjusted, and under no circumstances should they be altered without thorough knowledge of the procedure. If it is necessary to change or reset the governor speed settings, first determine the pressure range of the associated air pressure instrument, and the engine or turbine speed range corresponding to this pressure range.

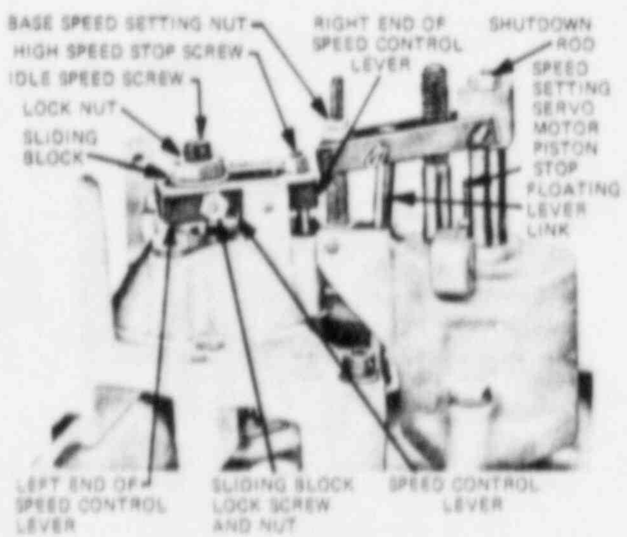

Fig. 10 Adjustment Points of Diaphragm Direct Air Receiver

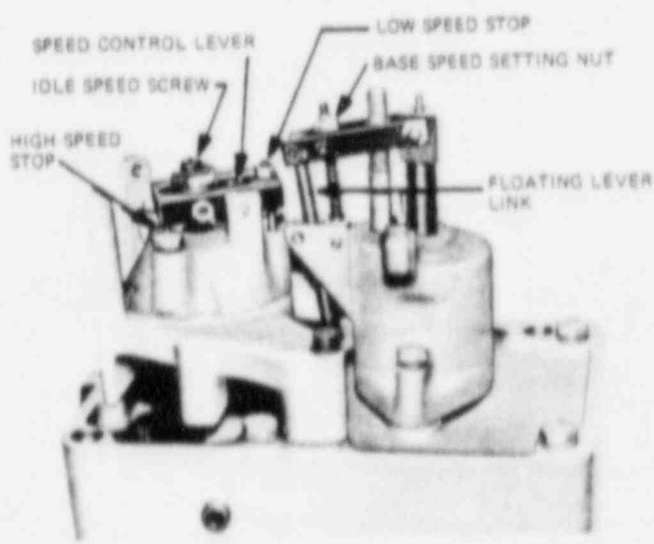

Fig. 11 Reverse Diaphragm Linkage Arrangement

Back off the high speed stop screw, shown in figure 10. Loosen the idle speed screw locknut and the sliding block lockscrew and nut. The sliding block can now be moved freely to either end of the slot. Set it at approximately the mid-point in its travel and lock it with the lockscrew and nut. Start the engine or turbine and apply the specified low air pressure (generally three psi). Adjust the idle speed screw up or down, as required, until the left end of the speed control lever just touches or is a few thousandths (roughly the thickness of tissue paper) short of touching the pneumatic receiver casting which serves as the low speed stop.

Adjust the base speed setting nut to obtain the specified engine speed corresponding to minimum air pressure. Screw down to decrease speed, or up to increase speed. Slowly raise control air pressure to the specified maximum value, making sure the engine does not overspeed. The speed obtained will probably be either higher or lower than the desired maximum. Check to be sure the high speed stop screw is not limiting speed by touching the screw head below it.

If the maximum speed obtained is too low, loosen the sliding block lockscrew and nut and the idle speed screw locknut. Move the sliding block a short distance to the right. Moving the sliding block to the right (toward the pivot) increases the amount of RPM change that results from a specified air pressure change. Moving the sliding block to the left (away from the pivot) reduces the amount of RPM change obtained for a given air pressure change.

It is now necessary to start over again with the specified air pressure at minimum and adjust and lock the idle speed screw so the left end of the speed control lever just touches, or as explained previously, almost contacts the casting. Set the base speed setting nut as before to obtain the specified minimum speed corresponding to minimum air pressure. Again apply maximum specified air pressure and check the speed. Repeat this process until the desired high and low speeds are obtained.

When desired speeds have been obtained for the specified air pressures, adjust the high speed stop screw so it just contacts the screw head below it at maximum specified air pressure. Tighten the locknut.

Make sure the diaphragm link between the diaphragm and the idle speed screw does not rub on the edge of the hole where it passes through the pneumatic receiver casting. This could happen if the sliding block were either too far from or too near the pivot. Such interference indicates that it is necessary to use the next heavier or lighter air receiver spring.

On PG-PL governors equipped with reverse speed setting (minimum control air pressure produces maximum speed), the procedure for setting speeds is basically the same; however, the left end of the speed control lever rests on the housing casting at maximum engine speed, and the high speed stop screw now serves as the low speed stop.

SPEED SETTING SERVOMOTOR PISTON STOP SCREW ADJUSTMENT

Set the governor for the minimum speed position. Turn the speed setting servomotor piston stop screw down until it contacts the top of the piston, then back it off 1-1/2 turns and tighten the locknut.

INFORMATION AND PARTS REPLACEMENT

When requesting additional information concerning governor operation, or when ordering repair parts, it is essential that the following information accompany the request.

1. Governor serial number shown on the nameplate.
2. Bulletin number. (This is bulletin 36694).
3. Part reference number, name of part, or description of part.

PARTS LIST FOR FIGURE 12.

REF. NO.	*PART NAME*	*QUANTITY*
36694-301	5/16-24 x 5-15/32 hex head screw	2
36694-302	5/16 shakeproof washer	6
36694-303	Oil filler cup	1
36694-304	Set screw (knob)	1
36694-305	Control knob	1
36694-306	Taper pin	1
36694-307	Drive screw	AR
36694-308	Manual speed adjustment plate	1
36694-309	Friction plunger	1
36694-310	Friction spring	1
36694-311	5/16 lockwasher	AR
36694-312	Gasket	1
36694-313	Bushing-dowel	2
36694-314	Bushing	2
36694-315	5/16-24 x 5/8 threaded insert	2
36694-316	Stud	1
36694-317	Power piston stop screw	1
36694-318	#10-32 hex nut	1

PARTS LIST FOR FIGURE 12 (CONT.)

REF. NO.	PART NAME	QUANTITY
36694-319	Adjustable fulcrum screw	1
36694-320	13/64 x 7/16 x 1/32 washer	1
36694-321	Link adjusting spring	1
36694-322	Adjustable fulcrum pin	1
36694-323	#10-32 stop nut	1
36694-324	Fulcrum link	2
36694-325	Link spacer	2
36694-326	Piston fulcrum assembly	1
36694-327	Floating lever link	1
36694-328	Floating lever link spring	1
36694-329	1/8 straight pin	1
36694-330	1/16 x 3/8 cotter pin	6
36694-331	Lower floating lever assembly	1
36694-332	1/8 x 47/64 drilled pin	2
36694-333	.186 x 3/4 pin	1
36694-334	Speeder spring power cylinder	1
36694-335	1/4-28 x 1 3/8 hex head cap screw	5
36694-336	17/64 x 1/2 x 1/32 washer	2
36694-337	Speeder spring power piston assembly	1
36694-338	Speeder spring servo spring	1
36694-339	Speed setting pilot valve plunger	1
36694-340	Pilot valve plunger spring	1
36694-341	Speed setting pilot valve bushing	1
36694-342	Pilot valve bushing spring	1
36694-343	Column assembly	1
36694-344	Gear	1
36694-345	Bearing stud	1
36394-346	Thrust bearing	1
36694-347	Bushing retainer	1
36694-348	#10-32 x 3/8 round head phillips screw	2
36694-349	#10 lockwasher	2
36694-350	1/4 x 9/16 dowel pin	4
36694-351	1/4-28 socket head screw	1
36694-352	Speed control bracket	1
36694-353	17/64 x 27/64 x 1/16 lockwasher	AR
36694-354	1/4-28 x 1 1/4 socket head cap screw	1
36694-355	1/4-28 x 1 3/4 socket head cap screw	1
36694-356	Diaphragm nut	1
36694-357	Retaining washer	1
36694-358	Diaphragm washer	1
36694-359	Diaphragm	1
36694-360	Spring seat	1
36694-361	Diaphragm spring	1
36694-362	Pivot pin	1
36694-363	Floating lever link assembly	1
36694-364	Diaphragm link assembly	1
36694-365	Speed control bracket cap	1
36694-366	Control lever slide	1
36694-367	Idle speed setting screw	1
36694-368	Needle bearing	2
36694-369	Speed control lever	1
36694-370	3/8 washer	1
36694-371	3/8-32 hex jam nut	1
36694-372	#10-32 x 3/4 socket set screw	1
36694-373	#10-32 hex nut	2
36694-374	#10-32 x 1/2 socket set screw	1
36694-375	Speed adjusting screw	1
36694-376	9/16 x 21/64 x 1/16 washer	1
36694-377	3/32 x 1/2 cotter pin	1
36694-378	Solenoid locknut	1
36694-379	Plunger stop plug	1
36694-380	Solenoid plunger lock pin	1
36694-381	Solenoid case	1
36694-382	Insulating paper	1
36694-383	Load spring	1
36694-384	Solenoid coil	1
36694-385	Soldering shield washer	2
36694-386	"O" ring	2
36694-387	Adjusting screw	1
36694-388	Solenoid plunger assembly	1
36694-389	Solenoid plunger rod	1
36694-390	Solenoid plunger washer	1
36694-391	Plunger guide locating pin	1
36694-392	Shutdown valve body	[illegible]
36694-393	Varnished tubing	2
36694-394	Solenoid plunger bushing	2
36694-395	1/4 steel ball	1
36694-396	Unloading spring	1
36694-397	Shutdown valve seat	1
36694-398	"O" ring	1
36694-399	Friction plunger retaining screw	1
36694-400	Nameplate (column)	1
36694-401	Elbow	2
36694-402	Tubing	1
36694-403	Nameplate (cover)	1
36694-404	Drive screw	4
36694-405	Cover	1
36694-406	Oil level decal	1
36694-407	"O" ring	2
36694-408	Plate	1
36694-409	#10-32 x 3/8 screw	1
36694-410	Gasket	1
36694-411	Plate	1
36694-412	#10-32 x 1/2 screw	4
36694-413	Gasket	1
36694-414	#6-32 x 3/8 screw	4
36694-415	Receptacle	1
36694-416	Plug	1
36694-417	Cable clamp	1
36694-418	5/16-24 x 4-31/32 hex head screw	[illegible]

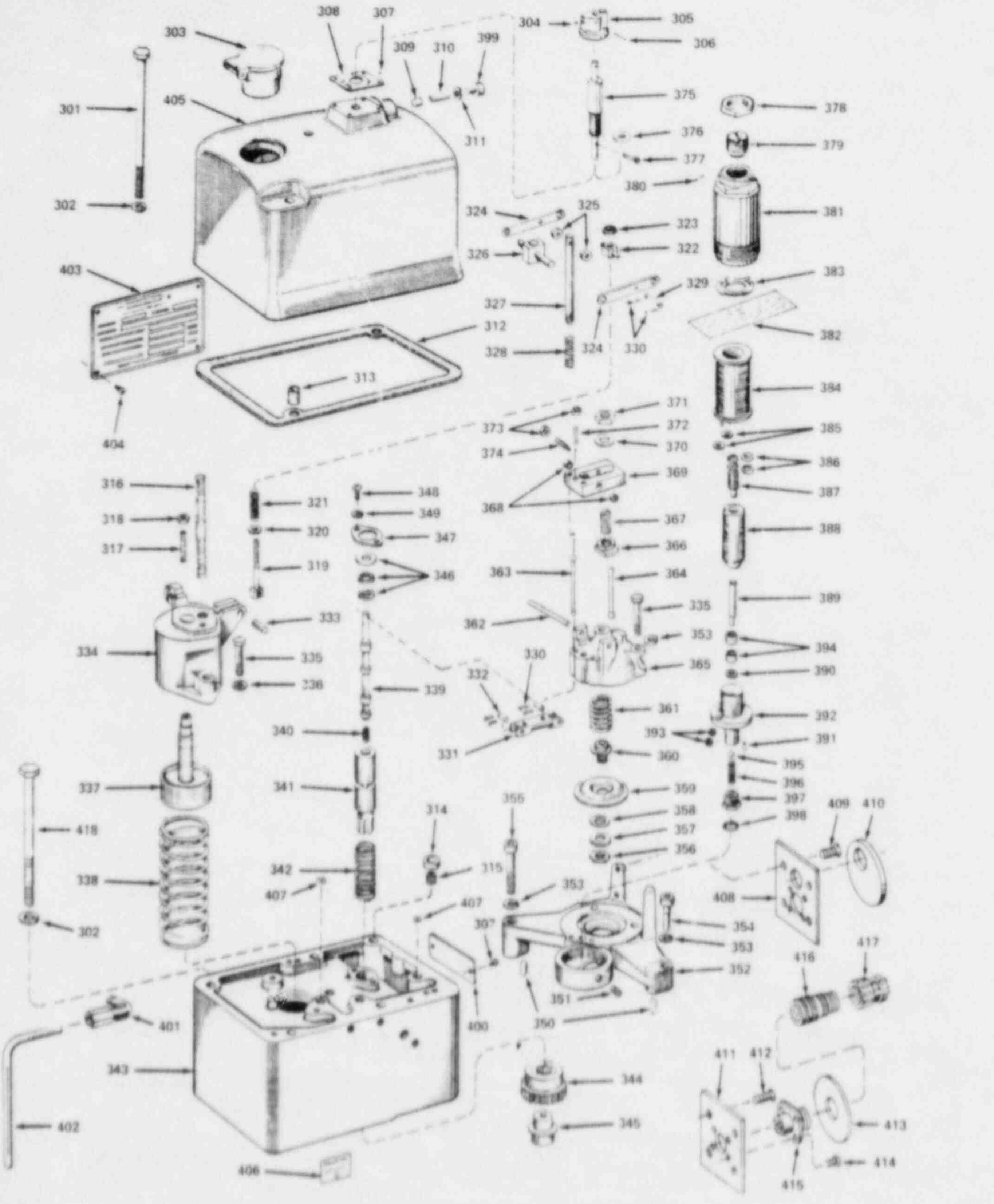

Fig. 12. Exploded View of Diaphragm Column Parts

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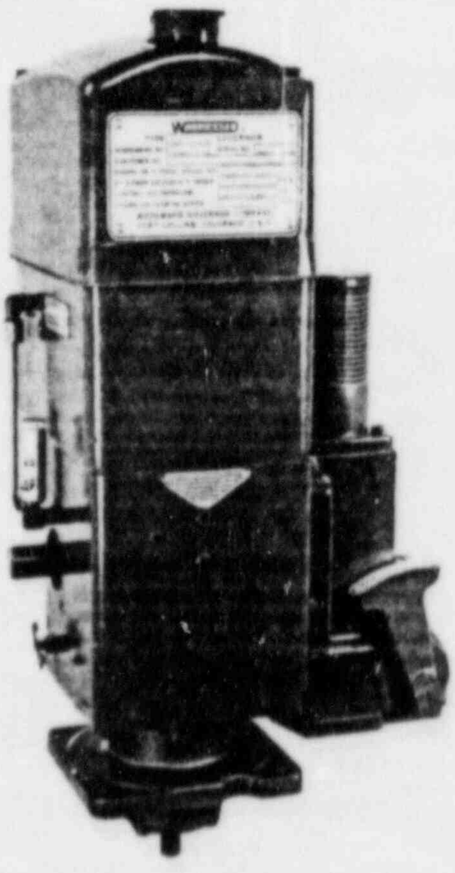
PG–PL GOVERNORS

(REPLACES BULLETIN 36012)



WOODWARD GOVERNOR COMPANY

ENGINE & TURBINE CONTROLS DIVISION

FT. COLLINS, COLORADO, U.S.A.

WOODWARD ®

PG—PL GOVERNOR

OPERATING & SERVICE MANUAL

BULLETIN 36694C

WOODWARD GOVERNOR COMPANY
ENGINE & TURBINE CONTROLS DIVISION
FT. COLLINS, COLORADO, U.S.A.

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PG-PL GOVERNOR

SECTION I/GENERAL INFORMATION

INTRODUCTION

This bulletin provides description, operation, installation, adjustment, maintenance, and replacement parts information for the PG-PL governor.

The basic PG governor (pressure compensated governor) with a pneumatic speed setting mechanism (direct or reverse) and a short column that is used primarily for controlling engine or turbine speed has been assigned the designation PG-PL governor. This PG governor was first used on pipe lines, hence the PL, but has since found wide acceptance on all types of diesel engines, gas engines, steam turbines driving pumps and compressors, and many special applications. The PG-PL governor includes a pneumatic speed setting mechanism, standard short column, standard base assembly, and 12 foot-pound power cylinder assembly. The repair manual for the PG-A governor (similar to the PG-PL in speed setting, but with a long column to house various options for load control) is bulletin 36699.

All PG governors have the same basic components regardless of how simple or complex the complete control may be. The following components, found in each PG-PL governor, are sufficient to enable the governor to maintain a constant engine speed as long as the load does not exceed engine capacity:

1. an oil pump, storage area for oil under pressure, and a relief valve by which maximum oil pressure may be limited;
2. a centrifugal flyweight head-pilot valve assembly which controls flow of oil to and from the governor cylinder assembly;
3. a power cylinder assembly--sometimes referred to as a servomotor--which positions the fuel racks, fuel valve, or steam valve of the engine or turbine;
4. a compensating system for stability of the governed system;
5. a pneumatic speed setting mechanism for adjusting the governor speed setting.

A cutaway view of the PG-PL governor is shown in figure 1.

DESCRIPTION

The governor controls engine or turbine speed by controlling the amount of fuel or steam supplied to the engine or turbine. Speed control is isochronous, i.e., the governor will maintain constant engine or turbine steady state speed, within the capacity of the unit, regardless of load.

The standard operating oil pressure for PG governors is 100 psi. However, with appropriate modifications the oil pressure may be increased, thus increasing the work capacity of the power cylinder assembly. Table 1 lists typical governor oil pressures versus power cylinder work capacities.

Table 1. Governor Oil Pressure Versus Power Cylinder Work Capacities (Typical)

Governor Operating Oil Pressure (PSI)	Power Cyl. Work Capacities in Ft-Lb 12	17	29
100 (std.)	12	17	29
130	16	22	38
200	24	34	58

An air pressure signal from a pneumatic air transmitter or controller supplies air to the governor speed setting mechanism. The governor will control the engine at a definite speed for each air pressure. The most common air pressure range for the governor is from 3-15 psi. Normal minimum control air pressure is 3 psi; however, a minimum of 1 psi and a maximum of 100 psi can be accommodated. The governor speed range normally falls between 250-1000 rpm, but a low speed of 200 rpm or a high speed of 1600 rpm can be obtained. Contact Woodward Governor Company for recommended control air pressure to governor speed setting relationship to meet the requirements of the particular installation.

The pneumatic speed setting mechanism (direct or reverse) is a bellows type mechanism and is standard equipment on all PG-PL governors now manufactured by Woodward. The speed setting unit is an accurate durable mechanism which

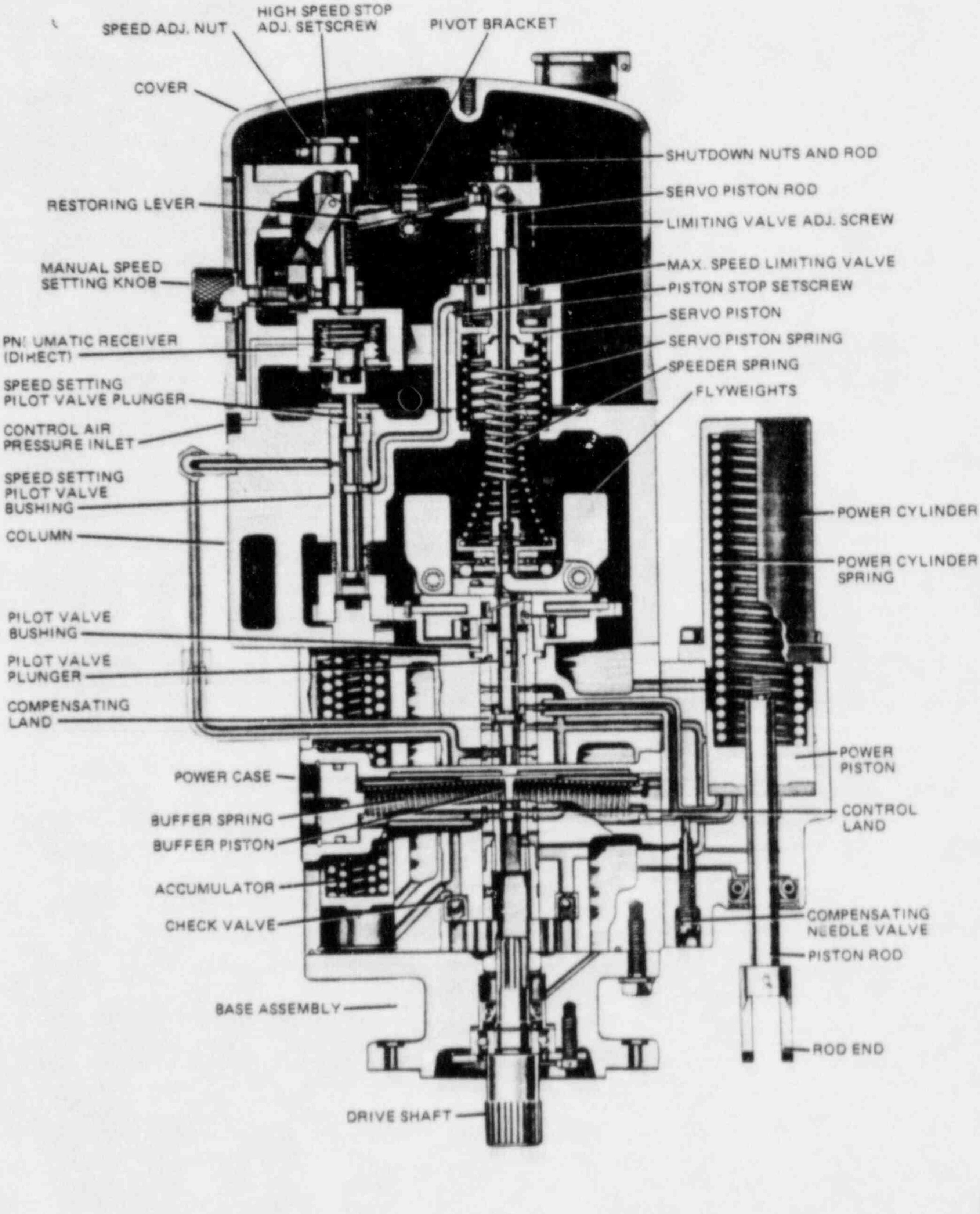


Figure 1. Cutaway View PG-PL Governor

virtually eliminates the hysteresis loops encountered with less sensitive pneumatic speed setting elements. (A hysteresis loop is a plot of the speeds obtained at various control signal pressures; one portion is recorded as speed setting signals are being increased, the other portion as the signals are being decreased.) Bellows type speed setting provides a definite, accurate relationship between speed and speed signal.

The speed setting mechanism is available for use with air input signals of varying range and magnitude (e.g. 3 to 15 psi, 20 to 70 psi, etc.). Depending upon the exact configuration installed in the governor, speeds may be adjusted up to a 5 to 1 range. The speed setting mechanism can be furnished to increase governor speed setting for an increase in control air pressure (direct type) or to increase governor speed setting for a decrease in control air pressure (reverse type).

The manual speed setting knob permits manual operation when the air pressure signal is not available.

Diaphragm receiver models of the governors are obsolete and no longer manufactured as a complete unit. However, replacement parts for these units are available and detail information on the units is found at the end of this manual.

As is the case with any governor of any type, it is essential that the engine or turbine be equipped with a separate overspeed shutdown device to prevent runaway in the event of failure of the governor, the mechanism which drives it, or the control it operates.

SECTION II/INSTALLATION AND ADJUSTMENT

INSTALLATION

Refer to figure 8 for complete physical dimensions of the governor. Adequate clearance must be provided for installation, removal, and servicing. At all times, use care in handling the governor; be particularly careful to avoid striking the drive shaft. Do not drop or rest the governor on its drive shaft. Such treatment could damage the governor drive shaft, drive shaft bearing, or governor oil pump gears.

When the governor is installed on the engine or turbine, a gasket should be used between the mounting pad and the governor base. The governor should be mounted squarely and the drive connection properly aligned.

If the governor is equipped with a serrated or splined drive shaft, it should slip into the internal serrations or splines of the drive freely. If a keyed type governor drive shaft is used, the gear must slip on the shaft freely and should be checked to insure that it meshes properly. The gears should run freely without binding or excessive backlash. Irregularities caused by uneven gear teeth, shaft runout, etc., will result in erratic governing and shorten governor life.

LINKAGE ADJUSTMENT

The linkage from the governor to the fuel or steam control should be properly aligned. Any friction or lost motion should be eliminated. Unless the engine or turbine manufacturer has given special instructions, the linkage should be adjusted so that when the governor power piston is at the end of its stroke in the "OFF" direction, the gas or steam valve, or diesel fuel pumps will just be closed.

When the governor has been properly mounted and the linkage connections completed, make the air connections to the manual or automatic air controller.

OIL SPECIFICATIONS

Information on oils for use in hydraulic governors is available in bulletin 25007. Use SAE 20 or 30 oil for ordinary temperature conditions. If governor operating temperatures are extremely hot, use SAE 40 to 50; if extremely cold, use SAE 10. In most cases, the same oil that is used in the engine or turbine may be used in the governor.

Keep the governor oil level between the lines on the glass of the oil level gauge when the engine or turbine is running. The oil should never be above the line where the case and column castings meet. Oil above this level will be churned into foam by rotation of the flyweight head. The governor can run safely with the oil level quite low in the gauge glass.

PURGING AIR FROM GOVERNOR AND NEEDLE VALVE ADJUSTMENT

When the engine or turbine is started for the first time, or after the governor has been drained and cleaned, the governor must be filled with oil, and any air trapped in the governor removed. To bleed off the trapped air, set the governor at idle speed position by means of the air controller or the manual speed adjustment. Start the engine or turbine and open the compensating needle valve (figure 1) several turns. This should cause the engine to hunt.

Loosen the air vent plug (figure 8) far enough to establish a leak, and allow the engine to hunt a sufficient length of time to permit all air trapped in the governor oil passages to escape at the vent plug. When no more air bubbles are apparent, tighten the vent plug, and if necessary add oil to the governor to restore the correct level in the gauge glass.

Close the compensating needle valve gradually until hunting is just eliminated. The proper setting depends upon the characteristics of the engine. Keep the needle valve open as far as possible to prevent sluggishness. The needle valve setting will vary from 1/16-turn open to 2 turns open. With preloaded buffer springs (optional equipment), the needle valve should not be more than 1/16-turn open for smooth operation. The needle valve must never be closed tight, as the governor cannot operate satisfactorily when this condition exists.

On some installations, opening the needle valve will not cause the engine or turbine to hunt. In such cases, bleed the air from the governor by disturbing engine or turbine speed to cause the governor to move through full stroke in both directions a sufficient number of times to force out all trapped air.

After the needle valve is adjusted correctly for the engine, it should not be necessary to change the setting except for a large permanent temperature change affecting the viscosity of the governor oil.

SPEED ADJUSTMENT

The pneumatic speed setting mechanism furnished with the governor is either (1) a direct type which increases the governor speed setting as the control air pressure signal increases or (2) a reverse type which increases governor speed setting as the control air pressure signal decreases. Perform the following procedures as applicable to set the maximum and minimum operating speed of the governor. See figures 1 and 2.

DIRECT SPEED SETTING MECHANISM

1. Set the manual speed adjusting knob to the minimum speed position (fully counterclockwise until clutch slips).

2. Adjust the high speed adjusting setscrew as required until upper end of screw is flush with top of speed setting screw.

3. Apply specified minimum control air pressure signal to the unit; adjust the speed adjusting nut as required to obtain corresponding specified minimum speed (clockwise to decrease); be sure the pneumatic low speed adjusting screw does not touch the restoring lever at this time.

4. Adjust limiting valve adjusting screw as required so that it does not unseat the maximum speed limiting valve as speed is increased. Set governor speed range to control air pressure range as follows:

   a. Slowly increase control air pressure signal to maximum. Be sure engine does not exceed specified maximum speed.

   b. If specified maximum speed is obtained before control air pressure signal is increased to maximum, adjust the pivot bracket to move the ball bearing pivot toward the speed setting servo.

   c. If specified maximum speed is not obtained with maximum control air pressure signal, adjust the pivot bracket to move the ball bearing pivot away from the speed setting servo.

   d. Adjust the pivot bracket as follows: Loosen the socket head screw in top of the pivot bracket; loosen knurled nut on appropriate side of bracket and turn opposite knurled nut to move bracket; tighten screw and knurled nuts.

5. Repeat steps 3 and 4 above until specified minimum speed is obtained with minimum control air pressure and specified maximum speed is obtained with maximum control air pressure. Speed should begin to increase as the control air pressure begins to increase from minimum.

6. Apply maximum control air pressure for maximum speed. Adjust the limiting valve adjusting screw so that it just contacts the ball in the maximum speed limiting valve. Increase control air pressure slightly above specified maximum; the maximum speed limiting valve should open prior to engine reaching 5 rpm above specified maximum speed. Readjust screw as necessary.

7. Apply minimum control air pressure signal for minimum engine speed. Perform step a or b as applicable.

   a. If engine is to go to low speed upon loss of control air pressure signal to the governor, set the pneumatic low speed adjusting screw to just contact the stop pin in the restoring lever with the engine running at low speed. Shutdown nuts are usually omitted on governors which are arranged to go to low speed upon loss of control air pressure. If nuts are included but not used, lower nut should be a minimum of 1/32-inch above the speed setting piston rod with engine running at low speed.

   b. If engine is to shut down upon loss of control air pressure signal to the governor:

      (1) Lift up on the shutdown rod to take out any slack or lost motion; do not lift the rod so far as to cause the engine speed to drop. While holding the rod up, position the lower shutdown nut 1/32-inch above the top of the speed setting servo piston rod and lock in position with upper nut.

      (2) Turn the piston stop setscrew down until it touches the speed setting piston then turn the screw counterclockwise 2 turns and lock in position with nut. This adjustment limits the upper movement of the piston when the engine is shut down, and it minimizes the cranking required when the engine is restarted.

      (3) Adjust the pneumatic low speed adjusting screw so that it is 0.040-0.050 inch below

the stop pin in the restoring lever. Turn off control air pressure signal to the governor (engine will shut down). Adjust the adjusting screw so that it is from 0.002 to 0.005 inch below the stop pin in the restoring lever.

8. With control air pressure signal removed (engine does not go to shutdown with loss of control air pressure signal), turn the manual speed adjusting knob clockwise to increase engine speed to maximum. Turn the high speed adjusting setscrew in until it just touches the high speed stop pin (this adjustment stops the downward movement of the speed adjusting nut at high speed).

REVERSE SPEED SETTING MECHANISM

1. Set the manual speed adjusting knob to the minimum speed position (fully counterclockwise until clutch slips).

2. Adjust the speed adjusting nut so that the speed setting screw protrudes approximately 1/4-inch above the nut.

3. Adjust the high speed adjusting setscrew as required until screw is flush with the top of speed setting screw.

4. Adjust the limiting valve adjusting screw as required so that it does not unseat the maximum speed limiting valve as speed is increased. Apply minimum control air pressure signal to the governor (pressure at which specified maximum engine speed is to be obtained). Be careful that engine does not exceed specified maximum speed.

5. Turn the manual speed adjusting knob clockwise to increase engine speed to specified maximum. Turn the high speed adjusting setscrew in until it just touches the high speed stop pin. If screw is turned down too far, speed will decrease.

If the specified maximum speed is not obtained with the manual speed adjusting knob fully clockwise, turn the knob approximately 2 turns counterclockwise, back out high speed stop adjusting setscrew a few turns, then turn speed adjusting nut counterclockwise until specified maximum speed is obtained. Turn high speed adjusting setscrew down until it just touches the high speed stop pin (if the screw is turned down too far, speed will decrease). Turning the speed adjusting knob fully clockwise should not increase speed beyond the specified maximum.

6. Slowly increase control air pressure signal until specified minimum speed is obtained. The pneumatic low speed adjusting screw should not touch the stop pin in the restoring lever and the piston stop setscrew should not stop the speed setting piston as it moves up to decrease speed.

If specified minimum speed is obtained before the control air pressure signal is increased to specified maximum, adjust the pivot bracket to move the ball bearing pivot toward the speed setting cylinder.

Adjust the adjustable pivot bracket as follows: Loosen the socket head screw in top of pivot bracket; loosen knurled nut on appropriate side of pivot bracket and turn opposite knurled nut to move the pivot bracket; tighten screw and knurled nuts.

7. Repeat steps 4, 5, and 6 above until specified minimum speed is obtained with maximum control air pressure signal and specified maximum speed is obtained with specified minimum control air pressure signal. Insure engine speed begins to increase as the control air pressure signal begins to decrease from maximum.

8. After setting speeds pneumatically, apply minimum control air pressure signal (governor will go to maximum speed setting). Turn manual speed adjusting knob counterclockwise until specified minimum speed is obtained. Alternately turn speed adjusting nut 1/2 turn counterclockwise (increasing speed) and adjusting knob counterclockwise (decreasing speed) until adjusting knob is fully counterclockwise. Turn off control air supply (speed will rise slightly). Adjust speed adjusting nut to obtain specified minimum speed.

If adjusting nut is turned fully counterclockwise without reaching the specified minimum speed, turn off control air supply (speed will rise slightly). Adjust speed adjusting nut to obtain specified minimum speed.

9. With the engine operating at specified minimum speed, turn the piston stop setscrew down until it just touches the top of the speed setting piston; then turn the screw 2 turns counterclockwise; lock in position with locknut. This adjustment limits the upward movement of the piston when the engine is shut down, and it minimizes the cranking required when engine is restarted.

10. If shutdown nuts are used, lift up on the shutdown rod to take out any slack or lost motion; do not lift the rod so far as to cause the engine speed to drop. While holding the rod up, position the lower shutdown nut 1/32-inch above the top of the speed setting servo piston rod and lock in position with upper nut.

11. With the control air pressure signal turned off, turn the manual speed adjusting knob clockwise to increase engine speed to maximum. Adjust the limiting valve adjusting screw so that it just contacts the ball in the maximum speed limiting valve. Increase engine speed slightly above the specified maximum; the maximum speed limiting valve should open prior to engine reaching 5 rpm above maximum speed. Readjust screw as necessary.

12. Turn the manual speed adjusting knob fully counterclockwise and apply maximum control air pressure to the governor. Adjust the pneumatic low speed adjusting screw to just contact the stop pin in the restoring lever with the engine running at low speed.

SECTION III/PRINCIPLES OF OPERATION

INTRODUCTION

The sectional view of the PG-PL governor (see figure 1) serves to indicate the relative position of the various governor components in the complete assembly. The connecting oil passages between parts are not necessarily in their correct location, but are simplified to facilitate their location. The lower part of the governor consists of the base and power case and the basic components of the hydraulic PG isochronous governor, which functions to maintain a constant engine speed by controlling the fuel supplied to the engine. The upper part of the governor consists of the column, cover, and related parts; it also consists of the pneumatic speed setting mechanism, and optional shutdown and protective devices where applicable.

DESCRIPTION OF OPERATION

The schematic diagram (figure 2) illustrates the essential parts of the governor and speed setting mechanism which are required to regulate fuel and control engine speed.

Speed adjusting in the governor is effected by controlling the position of the speed setting servo piston. Movement of the servo piston to a higher or lower speed setting is obtained by admitting or draining pressure oil to or from the area above the servo piston.

The flow of governor oil to or from the area above the servo piston is controlled by the speed setting pilot valve plunger - contained in a rotating bushing - which is actuated by a controlled air pressure signal or by a manual control knob.

After each speed setting change, a restoring lever connected between the servo piston rod and speed setting pilot valve plunger returns the plunger to the closed port position, stopping the flow of oil to or from the area above the servo piston, thus holding the piston at the position for the particular speed setting of the governor.

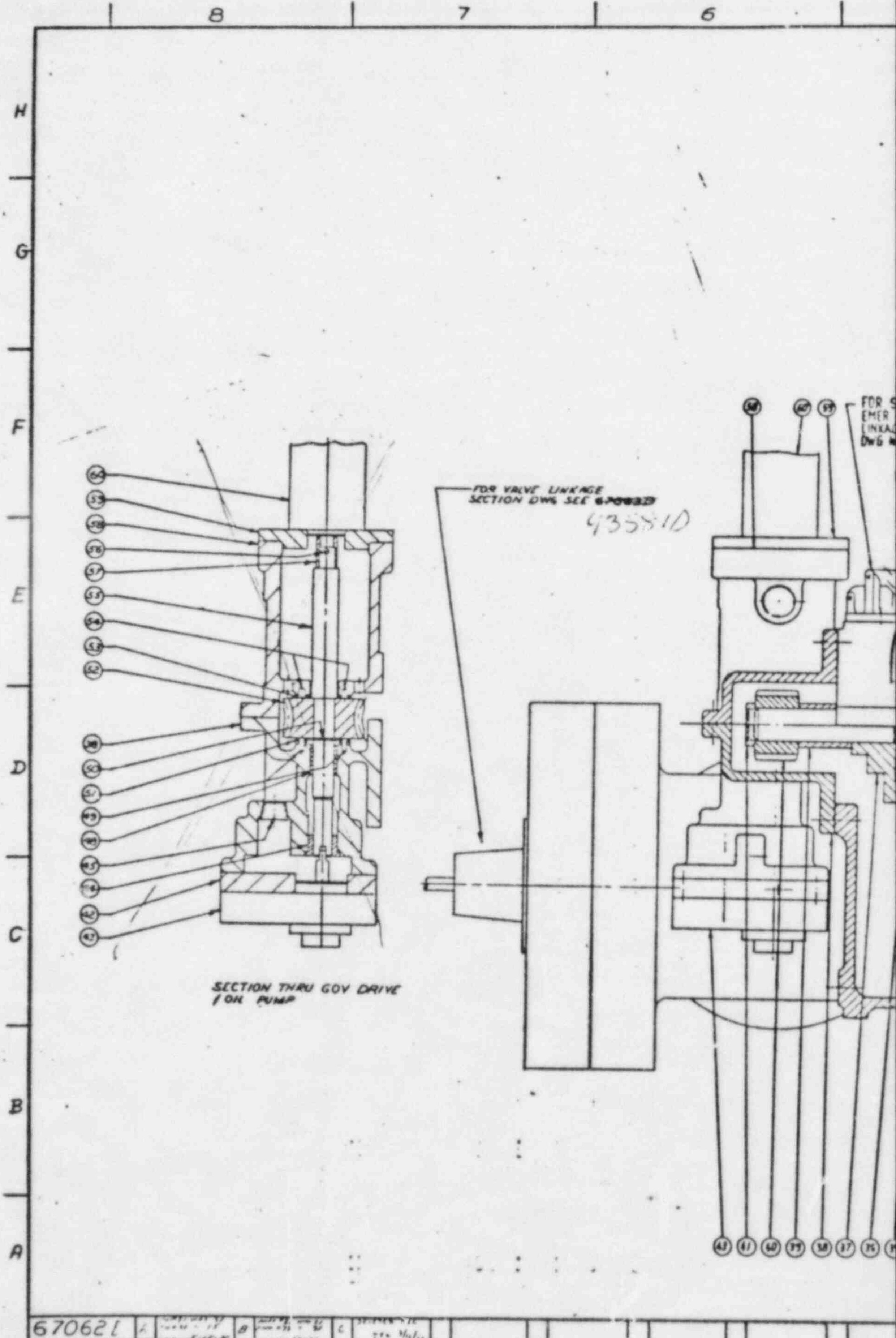
The governor drive shaft passes through the governor base into the pump drive gear, which is direct connected to the rotating pilot valve bushing. The flyweight head is secured to the upper end of the pilot valve bushing, thus providing a direct drive from the engine to the flyweights. At any speed setting of the governor, when the engine is on speed, the centrifugal force of the flyweights will balance the opposing force of the speeder spring with the flyweights in the vertical position, and the control land of the pilot valve plunger will be covering the regulating ports in the rotating pilot valve bushing.

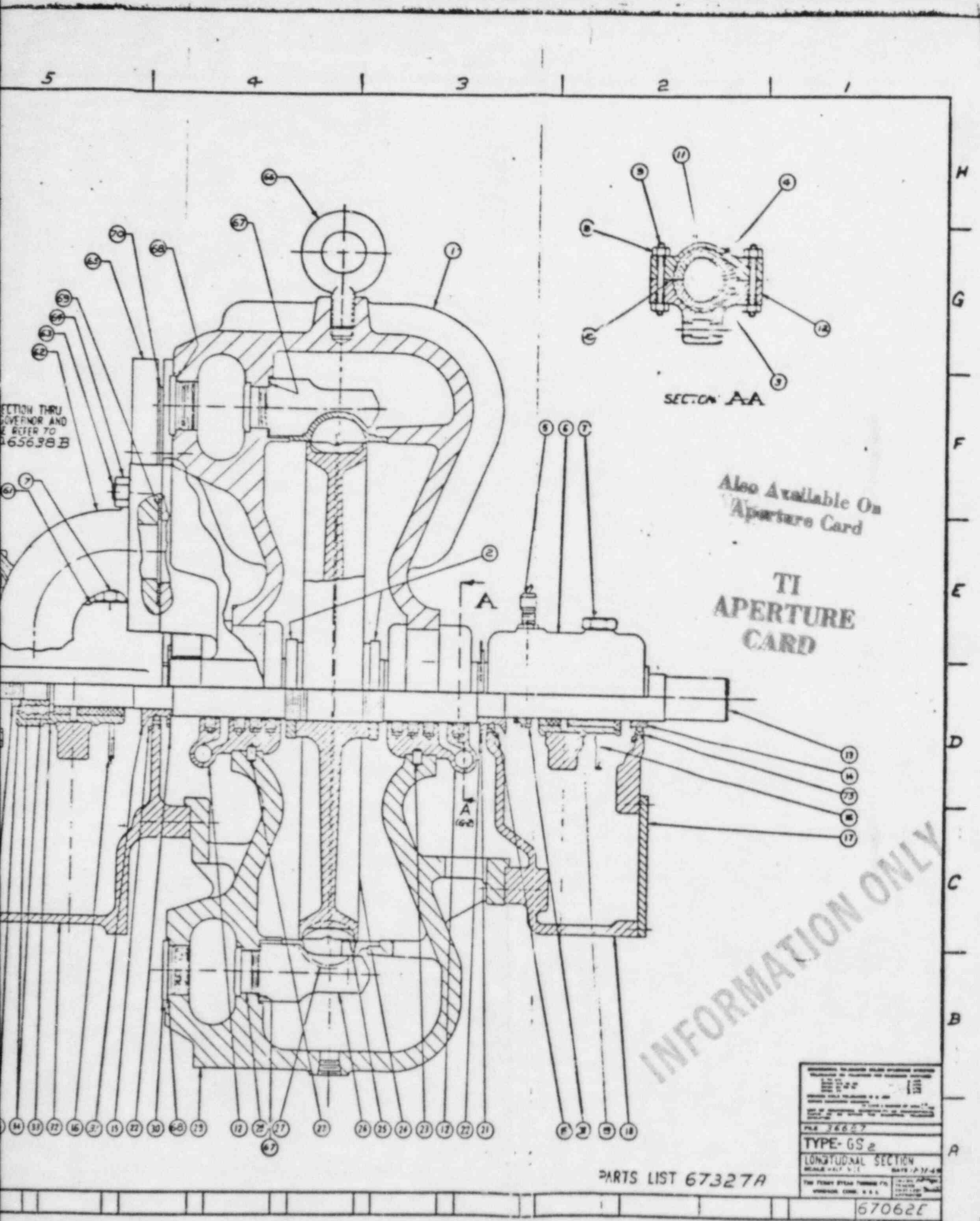
Pressure seal grooves are supplied with pressure oil through the regulating port to prevent the oil trapped between the power piston and the buffer piston from leaking past the power piston, power piston rod and pilot valve stem. To make up leakage of the seal oil and hold the power piston in a steady state position against the power spring -- when the engine is on speed with a steady load -- the pilot valve plunger will be below center enough to supply the required amount of oil through the regulating port.

The governor oil pump supplies pressure oil to the rotating pilot valve bushing, speed setting pilot valve bushing, pressure seal grooves, and to the accumulators, with excess oil (at maximum pressure) bypassing from the accumulators to the governor sump. Duplicate suction and discharge ball check valves at the pump permit rotation of the governor in either direction.

The pilot valve plunger moves up and down in the rotating pilot valve bushing to control the flow of oil to or from the power cylinder assembly. When the pilot valve plunger is centered (i.e., the control land of the plunger exactly covers the control port of the bushing), no oil flows to or from the power cylinder assembly.

The greater of two forces moves the pilot valve plunger up or down. The centrifugal force developed by the rotating flyweights is translated into an upward force which tends to


8
7
6
H
G
F
E
D
C
B
A
FOR VALVE LINKAGE
SECTION DWG SEE
43581D
SECTION THRU GOV DRIVE
FOR PUMP
670621



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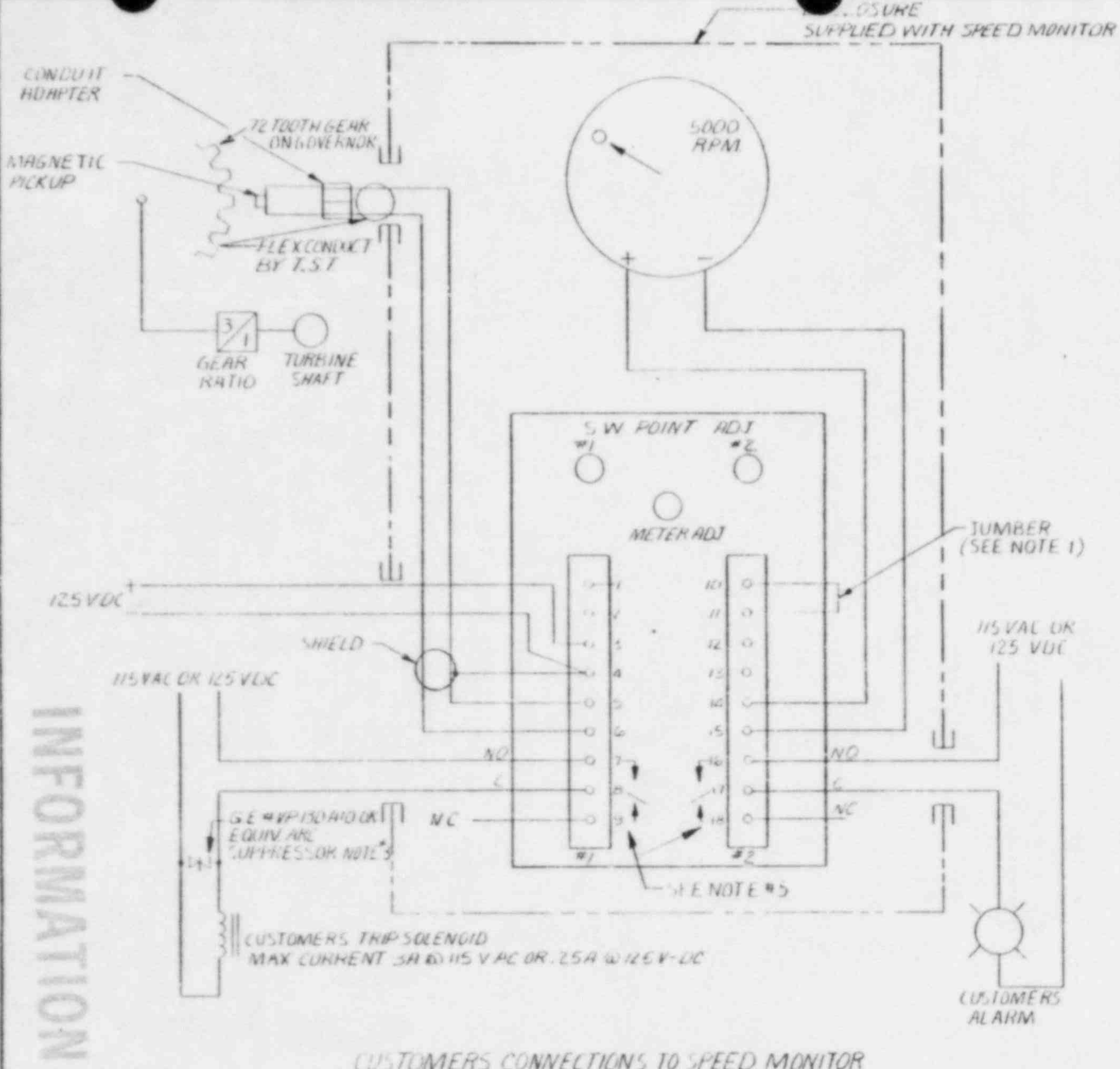


NOTE

1. JUMPER PROVIDES AUTO RESET OR SWITCH POINT #1. IF MANUAL RESET IS DESIRED CUSTOMER TO PROVIDE N.C. SWITCH (OPEN TO RESET).
2. SYSTEM IS FAIL SAFE. THUS POWER MUST BE PROVIDED TO SPEED MONITOR FIRST OR CUSTOMERS TRIP VALVE WILL REMAIN IN TRIP CONDITION. LOSS OF POWER TO MONITOR WILL ACTIVATE CUSTOMERS TRIP PROVIDED POWER IS AVAILABLE FOR TRIP SOLENOID.
3. CUSTOMER SHOULD PROVIDE ARC SUPPRESSION AT HIS TRIP SOLENOID.
4. ALL WIRING BY CUSTOMER EXCEPT PICKUP CABLE AND JUMBER.
5. RELAY CONTACTS SHOWN IN NORMAL OPERATING CONDITION WITH POWER ON AND FREQUENCY BELOW TRIP POINT.

FILE [illegible]

TYPE- GS-2

WIRING DIAGRAM

SCALE NONE DATE 4/1973

THE TERRY STEAM TURBINE CO.
WINDSOR, CONN. U.S.A.

91819 C

91819 C

OPERATING INSTRUCTIONS EASY FLOW BODY COMBINED TRIP THROTTLE VALVE

Application

This valve is used as a hand throttle valve for admitting steam to the turbine when bringing it up to speed. Another function of this valve is to act as an emergency closing valve, tripping shut in less than 0.3 seconds upon turbine overspeed, loss of oil pressure, power, etc.

Construction:

There are two types of assemblies of valves, top mechanism and inverted. The drawing accompanying these Instructions indicates the type. The drawing is typical and is not intended to show actual physical assembly.

Valves are designed for maximum operating pressures and temperatures specified. The steam is admitted to the above seat side of the valve. The forces for closing the valve consist of spring pressure, weight of moving parts and steam pressure above the valve disc. The valve is cushioned in closing by the dash pot action of the disc piston in the cylinder. The body opening is closed by a bolted on yoke (cover inverted valve) with a gasket at the joint.

The stuffing boxes are supplied with extra long hardened bushings with either single or double leak-off connections. Soft asbestos packing with gland is furnished only when specified.

The valve cover is equipped with a throttle screw. This screw regulates the amount of steam admitted from the inlet side of the valve to the chamber above the main disc. To eliminate the chattering of main disc, if any, it is necessary to increase the leakage to the chamber by turning the throttle screw outward. If the handwheel effort appears excessive, it can be reduced slightly by turning the throttle screw inward.

A pipe tap is provided in the cover to be used for a pressure gauge in starting up the unit to check the pressure in the chamber after the pilot valve has been opened. This pressure should be not less than 10% of the line operating pressure. After an adjustment has been made, close this opening with a steel pipe plug.

The tripping medium of the valve varies with the type of turbine overspeed mechanism provided with the turbine.

1. Mechanical Trip Gear
   The trip crank is attached to the trip hook shaft. Operation of turbine overspeed governor unlatches hook faces.

2. Oil Trip Cylinder
   This trips valve upon loss or reduction of oil pressure.

3. Solenoid Trip
   This trips valve either upon opening or closing of an electric circuit.

4. Steam, Air or Vacuum Trip
   These either in form of diaphragm mechanism or piston activated by either a rise or fall in pressure.

In many cases a switch is applied to the valve and actuated by the spindle coupling. This switch can be made to either open or close a circuit at either end of the valve stroke (valve shut or open position).

Operation:

After valve has been tripped shut, turn the handwheel clockwise. The rotation of the screw will raise the sliding nut and latch lever where it will engage with the trip hook.

With the latch lever and trip hook engaged, turn the handwheel clockwise to close and counter clockwise to open the valve.

With the first movement of the screw in the opening direction the pilot valve will be lifted off its seat. Before the valve disc is unseated the steam from the chamber above the disc will be discharged through the pilot valve to the outlet side of the valve. This reduces the pressure above the valve disc since the steam is discharged from the chamber faster than same can be admitted through the clearances and throttle screw port. The reduction of pressure above the valve disc reduces the unseating effort on the handwheel rim and approximates the balanced valve condition. After the pilot valve is unseated, continued turning of the handwheel in the opening direction will lift the valve disc from its seat.

When the valve comes to the wide open position the spindle coupling (screw spindle collar on inverted valve) contacts the bottom of the sliding nut. There is no danger of jamming these parts to impede free closing of the valve since both move together in the closing direction when the valve is tripped.

After the valve has been opened wide the handwheel should be turned at least one quarter of a turn in the closing direction. This will prevent locking the valve in the open position from expansion of the valve parts.

The valve should be tripped each time the turbine is shut down and it should be left in the tripped position until the next turbine operation.

The valve should be exercised at least once per week by turning the handwheel in closing direction through the distance equal to 1/4 of the total lift of the valve.

Lubrication and Maintenance:

Alemite fittings are provided on the outside moving parts of the valve. The trip gear, sliding nut, screw spindle and other external guides should be inspected and lubricated periodically so as to insure cleanliness and prevent any possibility of sticking. When valves are operating under a high degree of super heat, the aforementioned parts become farily hot and for this reason it is recommended that a high grade of oil be used.

All valves are tested in the factory under operating pressure and temperatures. This is to insure proper alignment and working clearances. If the valve should fail to close instantaneously, it is recommended that valve be opened up for inspection. It is further recommended that a steam strainer be installed on the inlet side of the valve, perforations on the screen not more than 1/8". Some valves are provided with steam strainer basket installed inside the valve body around the valve disc.

To dis-assemble top mechanism valve remove nuts which hold cover to top of valve body, and lift up the entire yoke mechanism. Pilot valves, stem, and valve disc will come out at the same time.

For the inverted valve remove nuts which hold cover and remove cover, remove spindle coupling, insert eye bolt in tapped hole furnished in disc or pilot valve, lifting the eye-bolt in this position will remove the pilot valve, stem and valve disc as a unit.

In reassembling valve, reverse the procedure described above. It is very important that all disc flange bolts be inserted and properly locked with plates provided for this purpose.

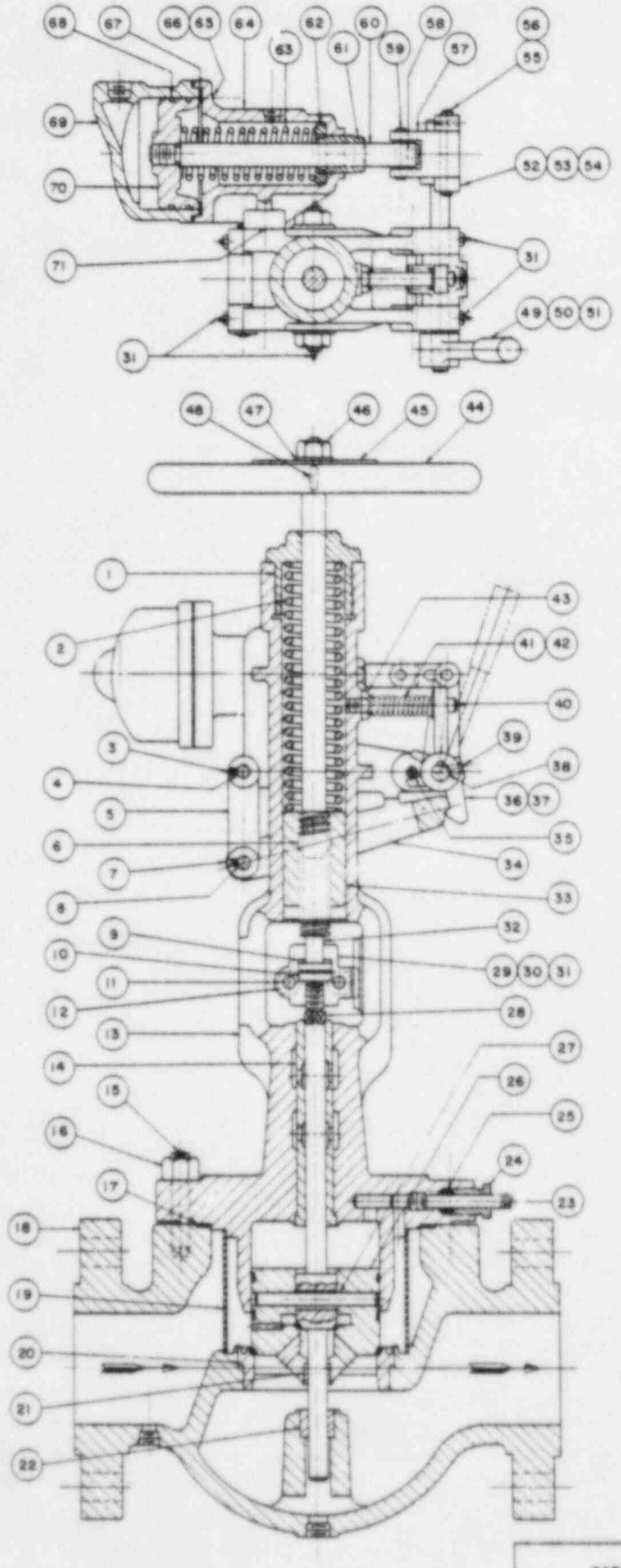
After gland has been tightened, same should be calibrated so as to insure even adjustment of packing. If no self sealing packing is available at the time of overhaul, then insert mica impregnated asbestos packing with inhibitor. Positively do not use a packing with even a small percentage of rubber.

There are drains provided for above and below seat sides of the valve. These should be connected.

Pilot valve lift varies from 1/8" to 1/2" depending upon the size of the valve.

An approximate total stroke of valve includes pilot. Lift should be in excess of 0.25% of pipe size. Free passages are provided in the valve body to provide uninterrupted flow.

When ordering replacement parts refer to the order numbers stamped on the name plate located on the handwheel.



PC. NO.	DESCRIPTION	PC. NO.	DESCRIPTION
1	YOKE CAP	31	GREASE FITTING
2	SPRING	32	SCREW SPINDLE
3	SET SCREW	33	SLIDING NUT
4	PIN, LINK	34	LATCH UP LEVER
5	LINK	35	PIN, STOP
6	TRUNNION SCREW	36	TRIP HOOK
7	SET SCREW	37	KEY
8	PIN, LINK	38	SHAFT, TRIP HOOK
9	SPLIT RING	39	SET SCREW
10	THRUST WASHER	40	STUD, SPRING
11	BOLT, HEX	41	SPRING
12	NUT, HEX	42	WASHER
13	YOKE	43	NUT, HEX
14	BUSHING	44	HAND WHEEL
15	STUD	45	NAME PLATE
16	NUT, HEX	46	NUT, HEX
17	GASKET	47	WASHER
18	BODY	48	KEY
19	STRAINER	49	HAND TRIP
20	SEAT	50	SET SCREW
21	BUSHING	51	KEY
22	BUSHING	52	TRIP CRANK
23	THROTTLE SCREW	53	SET SCREW
24	GLAND	54	KEY
25	PACKING	55	PIN, STRAIGHT
26	DISC	56	PIN, TAPER
27	PIN, DISC	57	LINK, CONNECTING
28	PILOT VALVE & STEM	58	SET SCREW
29	COUPLING	59	PIN
30	SET SCREW	60	STEM, PISTON
		61	NUT, TENSION
		62	WASHER
		63	SPRING
		64	CASING, SPRING
		65	STUD
		66	NUT, HEX
		67	GASKET
		68	RING, PISTON
		69	OIL CYLINDER
		70	PISTON
		71	BOLT
		72	
		73	
		74	
		75	
		76	
		77	
		78	
		79	
		80	

NOTE:

1. WHEN ORDERING SPARE PARTS REFER TO ORDER NUMBERS STAMPED ON NAME PLATE PC. 45
2. THE FOLLOWING ARE FURNISHED ONLY WHEN SPECIFIED: STRAINER PC 19, BUSHING PC21, HANDTRIP PC. 49.

PARTS LIST
TOP MECHANISM
TRIP THROTTLE VALVE
WITH HARD PACKING

GIMPEL MACHINE WORKS, INC.
MANUFACTURING ENGINEERS
LANGHORNE PENNA.

DRAWN BY: F.W.	DATE: 9-11-66
CHECKED BY: JW	FIRST J.O.
DRAWING NUMBER: P-2989	REV

STYLE 100-S

Size	Body (1) Mtl.	A.P. Pyrex Disc (2)	Ret. Rings (2) Mtl.	NEOPRENE Gask. (2) Fibre Gask. (2)	Flap (1) Mtl.	Flap Rod Mtl.
1/8"-3/8"	S-102	1-1/4" X 3/16"	1-3/8" - 12	1-1/4" X	102	
1/2" 3/4"	S-104 STEEL	1-3/4" X 1/4"	1-7/8" - 12 BRONZE	1-3/4" X 1 5/16"	106 STAINLESS STEEL	STAINLESS STEEL
1"	S-108	2" X 3/8"	2-1/8" - 12	2" X	903B	
1-1/4" 1-1/2"	S-112	3" X 1/2"	3-1/8" - 12	3" X	112	
2"	S-116	3-5/8" X 5/8"	705DX	3-5/8" X	116	

NOTE: Steel Bolts (4) only on 2" Unit
Size 1/2" X 6"

Tag:

CERTIFIED Bluj

INFORMATION ONLY

J.T. # 7491

JACOBY-TARBOX CORP.
808 NEPPERHAN AVE.
YONKERS, N. Y.

DRAW. BY	DATE	DRAWING NO.
JJW	12/24/69	FG429A

CUST. & P.O. # Terry Steam Turbine Co. #67694 T-37686-A-B

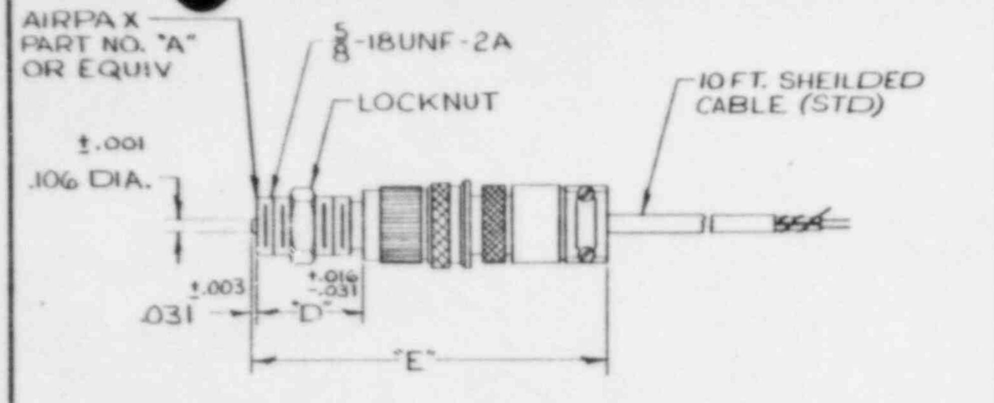


FIG. 1 GENERAL PURPOSE ~ CABLE CLAMP TERMINATION

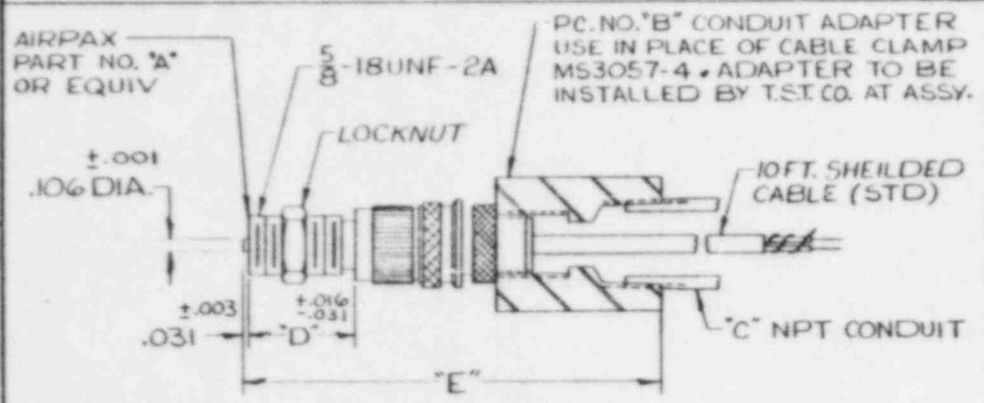


FIG. 2 GENERAL PURPOSE ~ CONDUIT TERMINATION

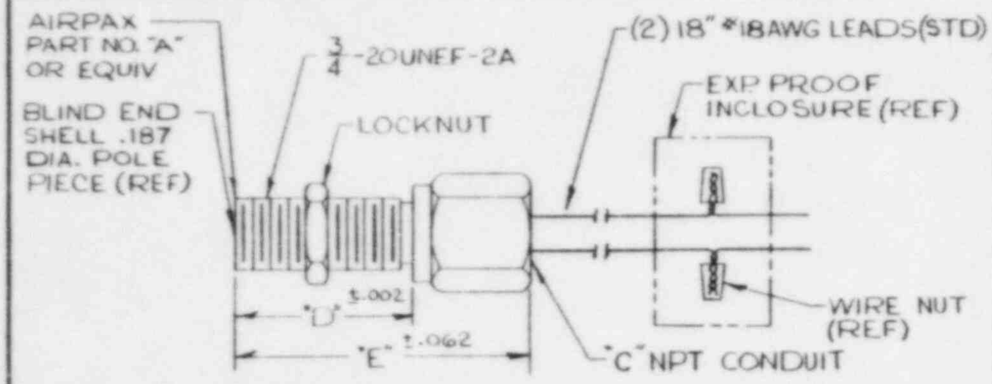


FIG. 3 EXPLOSION PROOF, CL 1 GR D, UL LISTED

SELECTION GUIDE

FIG. NO.	AIRPAX PT. NO. "A"	CONDUIT ADPTR "B"	"C" NPT	"D"	"E"	SELECTION GUIDE
1	11-0001	CABLE CLAMP TERMINATION		1.125	4"	GENERAL PURPOSE STD. LENGTH CABLE CLAMP TERMINATION
1	11-0003	CABLE CLAMP TERMINATION		2.625	5 1/2	GENERAL PURPOSE LONG REACH CABLE CLAMP TERMINATION
2	11-0001	59656	1/2	1.125	4 1/2	GENERAL PURPOSE STD. LENGTH 1/2 CONDUIT TERMINATION
2	11-0001	76651	3/4	1.125	4 1/2	GENERAL PURPOSE STD. LENGTH 3/4 CONDUIT TERMINATION
2	11-0003	59656	1/2	2.625	6"	GENERAL PURPOSE LONG REACH 1/2 CONDUIT TERMINATION
2	11-0003	76651	3/4	2.625	6"	GENERAL PURPOSE LONG REACH 3/4 CONDUIT TERMINATION
3	1-0005	(NOT REQD.) INTEGRAL CONDUIT THREAD	1/2	1.875	3.125	EXPLOSION PROOF CL 1, GR D UL LISTED 1/2 CONDUIT TERMINATION

AIRPAX SPECIFICATIONS (REF)

AIRPAX PART NO.	OUTPUT VOLTAGE	DC RESISTANCE	TYPICAL INDUCTANCE	OUTPUT POLARITY	OPERATING TEMPERATURE
11-0001	30-70V(P-P)	100-130 OHMS	32-46 mH	RED LEAD POSITIVE	-100 TO +225°F
11-0003	30-70V(P-P)	100-130 OHMS	32-46 mH	RED LEAD POSITIVE	-100 TO +225°F
1-0005	57-107V(P-P)	185-225 OHMS	63-91 MH	WHITE LEAD POSITIVE	-100 TO +225°F

NOTES-
1- THIS DRAWING IS FOR REFERANCE ONLY
2- ORDER PICKUP ASSEMBLY "A" AND ADAPTER "B" ON MISC. OR TACHOMETER BM FOR NEXT ASSEMBLY. SEE ADAPTER DRAWING A-10978 BEFORE ORDERING.

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

FILE

TYPE- STD

MAGNETIC PICK-UP

SCALE NONE DATE 2-5-72

THE TERRY STEAM TURBINE CO. WINDSOR CONN. U.S.A.

DRAWN / TRACED / CHECKED / APPROVED

77739C | A | DELETED PC. NO. ADDED NOTES 1&2 | 8-25-72

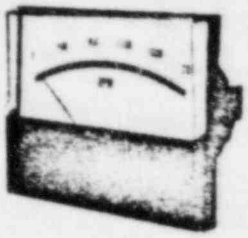
72-1701

77739C

AIRPAX
DATA SHEET
F-4

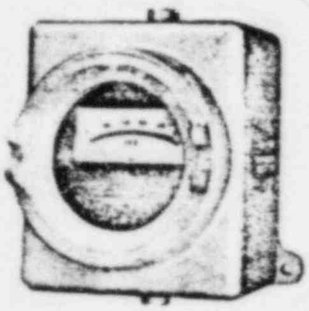
1 December 1972

Models 210 and 310 Tachometer Meters



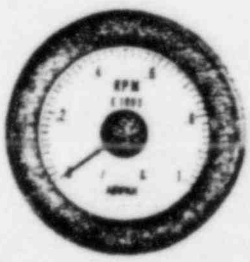
Model 210 Meter

The Model 210 Meter is a highly precise monitoring instrument with an accuracy of ±1% or better. It has a mirror-backed scale-plate for parallax correction. The standard meter movement is 0-1 mA dc full-scale. Meter resistance is 60 ohms ±10%.



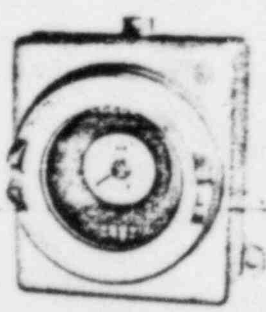
Model 210E Meter

The Model 210E Meter is enclosed in a cast iron, explosion-proof housing for applications where dust, fumes or other hazards may be encountered. The housing meets the requirements of a Class 1, Group D enclosure.



Model 310 Meter

The rugged Model 310 Model offers a 250° arc scale having a length 2-1/2 times that of standard 90° meters. The meter movement is 0-1 mA dc full-scale. Accuracy is 2%. Meter resistance is 200 ohms ±10%. Scale diameter is 2.75 inches.



Model 310E Meter

The Model 310E Meter is enclosed in a cast iron, explosion-proof housing for applications where dust, fumes or other hazards may be encountered. The housing meets the requirements for a Class 1, Group D enclosure.

AIRPAX

AIRPAX ELECTRONICS
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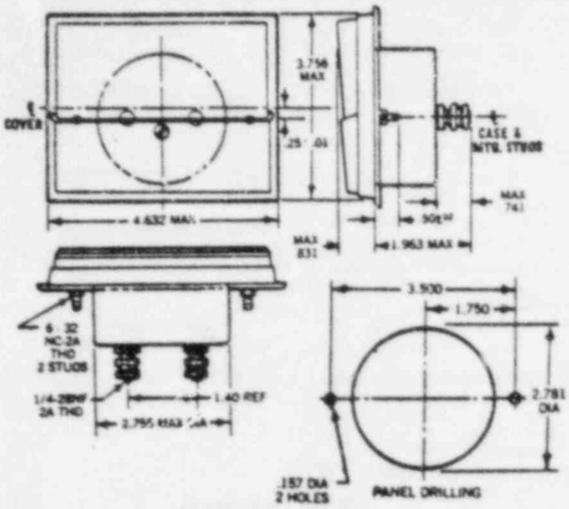
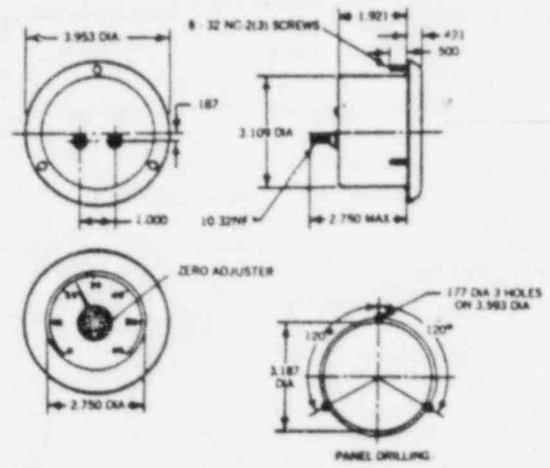
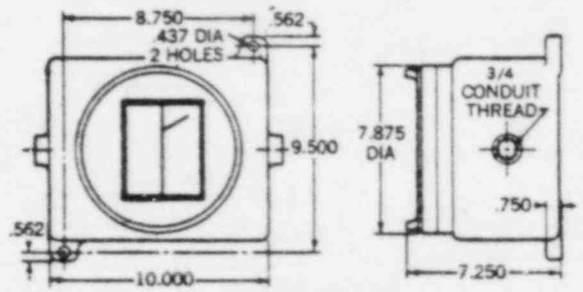


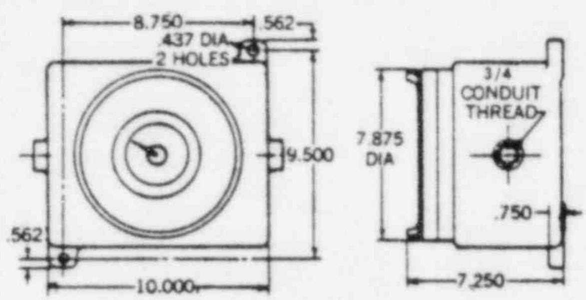
210 METER



310 METER



210E METER



310E METER

The following standard scale ranges are available at no extra cost. Each scale range shown can be marked in RPM, FPM, CPS, MPH, etc. Special scales are available.

MODELS 210 AND 210E							
0-3	0-16	0-60	0-300	0-1500	0-7000	0-10x1000	0-40x1000
0-4	0-18	0-70	0-400	0-2000	0-7500	0-12.5x1000	0-50x1000
0-5	0-20	0-75	0-500	0-2400	0-8000	0-14x1000	0-55x1000
0-6	0-25	0-100	0-600	0-3000	0-9000	0-15x1000	0-60x1000
0-10	0-26	0-120	0-700	0-4000	0-10,000	0-16x1000	0-75x1000
0-12	0-30	0-125	0-750	0-4500	0-12,000	0-18x1000	0-100x100
0-12.5	0-35	0-180	0-800	0-5000	0-13,000	0-20x1000	
0-14	0-40	0-200	0-1000	0-6000	0-15,000	0-30x1000	
0-15	0-50	0-250	0-1200	0-6500	0-20,000	0-35x1000	

MODELS 310 AND 310E							
0-1	0-5.0	0-20	0-80	0-300	0-900	0-4,000	0-5x1000
0-1.5	0-6.0	0-25	0-90	0-400	0-1,000	0-5,000	0-10x1000
0-2.0	0-8.0	0-30	0-100	0-500	0-1,500	0-6,000	0-12x1000
0-2.5	0-9.0	0-40	0-150	0-600	0-2,000	0-7,000	0-15x1000
0-3.0	0-10	0-50	0-200	0-750	0-2,500	0-8,000	0-20x1000
0-4.0	0-15	0-60	0-250	0-800	0-3,000	0-9000	0-50x1000
						0-10,000	

AIRPAX ELECTRONICS FORT LAUDERDALE, FLORIDA 33310

ADDENDUM TO THE OVERSPEED MONITOR INSTRUCTION MANUAL NO. 3201382

PART NUMBER FSS-1090 RANGE 0 - 2000 Hz

☐ SINGLE SET POINT ☒ DUAL SET POINT

THE FOLLOWING CHARACTERISTICS DIFFER FROM THOSE OF THE STANDARD OVERSPEED MONITOR AS DESCRIBED IN INSTRUCTION MANUAL NO. 3201382.

☐ High Sensitivity Input Signal: .050 to 5.0V RMS, with the "Loss of Signal" dropout feature.

☐ High Sensitivity Input Signal: .050 to 5.0V RMS, with the "Loss of Signal" dropout feature disabled.

☐ Input signal conditioning for pulse input signals. ______________

____

☐ Set Point #1 adjustable from ______________ to ______________

☐ Set Point #2 adjustable from ______________ to ______________

☐ Set Point #1 has a ______________ % hysteresis.

☐ Set Point #2 has a ______________ % hysteresis.

☐ "Verify" test is set to lower the switch point #1 to ______________ and switch point #2 to ______________ .

☒ Set Point #1 is factory adjusted to switch at 1728 Hz .

☒ Set Point #2 is factory adjusted to switch at 1584 Hz .

☒ Other: SET POINT #1, 1728 Hz, IS WIRED AS AN OVERSPEED POINT (NORMAL RELAY LOGIC). SET POINT #2, 1584 Hz, IS WIRED AS AN UNDERSPEED POINT (REVERSE RELAY LOGIC). 125V DC POWER INPUT (+) 3 & 4.

FORM NO. 2212

INFORMATION ONLY

AIRPAX

INSTRUCTION MANUAL NO. 3201382

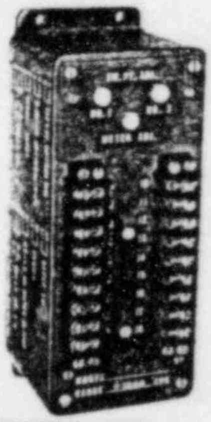
SINGLE & DUAL SETPOINT

OVER/UNDER SPEED MONITORS

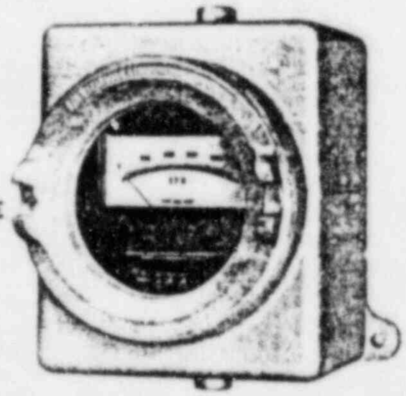
Units with special calibration or modifications are designated with special part numbers. Refer to the attached addendum sheet for description of units not included in the table below. This instruction manual is for the following units:

Frequency Range	B Style P/N		E Style P/N	
	Single Set-Point	Dual Set-Point	Single Set-Point	Dual Set-Point
0 - 50 cps	FSS21	FSS41	FSS71	FSS91
0 - 100 cps	FSS22	FSS42	FSS72	FSS92
0 - 200 cps	FSS23	FSS43	FSS73	FSS93
0 - 500 cps	FSS24	FSS44	FSS74	FSS94
0 - 1,000 cps	FSS25	FSS45	FSS75	FSS95
0 - 2,000 cps	FSS26	FSS46	FSS76	FSS96
0 - 5,000 cps	FSS27	FSS47	FSS77	FSS97
0 - 10,000 cps	FSS28	FSS48	FSS78	FSS98
0 - 20,000 cps	FSS29	FSS49	FSS79	FSS99

B STYLE



E STYLE



AIRPAX ELECTRONICS

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SPECIFICATIONS

SINGLE & DUAL OVER/UNDER SPEED MONITORS

INPUT: 0.5 to 25 VRMS, variable frequency. High sensitivity overspeed monitors are available for input signal ranges from as low as 0.025 to 25 VRMS.

INPUT IMPEDANCE: 800 ohms nominal.

TEMPERATURE: -20°F to +120°F operating; -40°F to +165°F storage. Typical temp.coeff.±0.01%/°F.

RELAY CONTACT RATINGS: 5 amperes at 28VDC, 3 amperes at 117VAC, resistive load; SPDT action. Relays de-energize at and above the switchpoints.

TRIGGER LEVEL ACCURACY: ±1% under power line and temperature ranges listed.

POWER REQUIREMENT: 117VRMS, ±10%, 50-400 CPS or 22-30VDC; 8 watts maximum.

SWITCHPOINTS: Adjustable 20-100% of full scale with resolution of the set-point adjustment of 0.2%.

METER OUTPUT: 0 to 1 ma proportional to the signal frequency, 0.25% linearity. The meter output is normally calibrated for the 60 ohm resistance of the Model 210 meter, but can be adjusted for up to a 1,000 ohm meter load. Output current is adjustable ±10% of full scale when using the Model 210 meter.

MISSING SIGNAL PROVISION: Output relay of set-point #1 de-energizes for signal amplitudes below 0.5VRMS unless over-ridden by jumpering reset terminals.

RESPONSE TIME: 50 milliseconds nominal.

SPECIAL FEATURES: Custom made units may contain any of the following features. Custom units are furnished with an instruction manual containing an addendum sheet that tabulates these features. Optional features are:

(1) High sensitivity input circuitry, for very low level input signal amplitudes of .050 to 25 V RMS, with "loss of signal" dropout feature.

(2) High sensitivity input circuitry, for very low level input signal amplitudes of .025 to 5.0V RMS (very low speeds), with the "loss of signal" dropout feature disabled.

(3) Pulse shaping input circuitry, for use with very widely separated slots, projections or gear teeth.

(4) Narrow set-point adjustment range for safety requirement or improved resolution.

(5) Wide switchpoint hysteresis, relay on and off points separated by prescribed hysteresis expressed in RPM or CPS.

(6) Factory adjustment of the "verify" test to lower the switchpoint to a predetermined value when the "verify" test is performed.

(7) Operation from a 220V AC 50-400 CPS power source.

PART I
GENERAL DESCRIPTION

1.1 INSTRUMENT FUNCTION

The Over/Under Speed Monitor is an electronic solid-state module that deenergizes an internal relay(s) when a preset speed (frequency) is exceeded. If the power input is interrupted, the internal relays also de-energize. The module also generates a DC output current proportional to speed (frequency).

1.2 ADJUSTMENTS

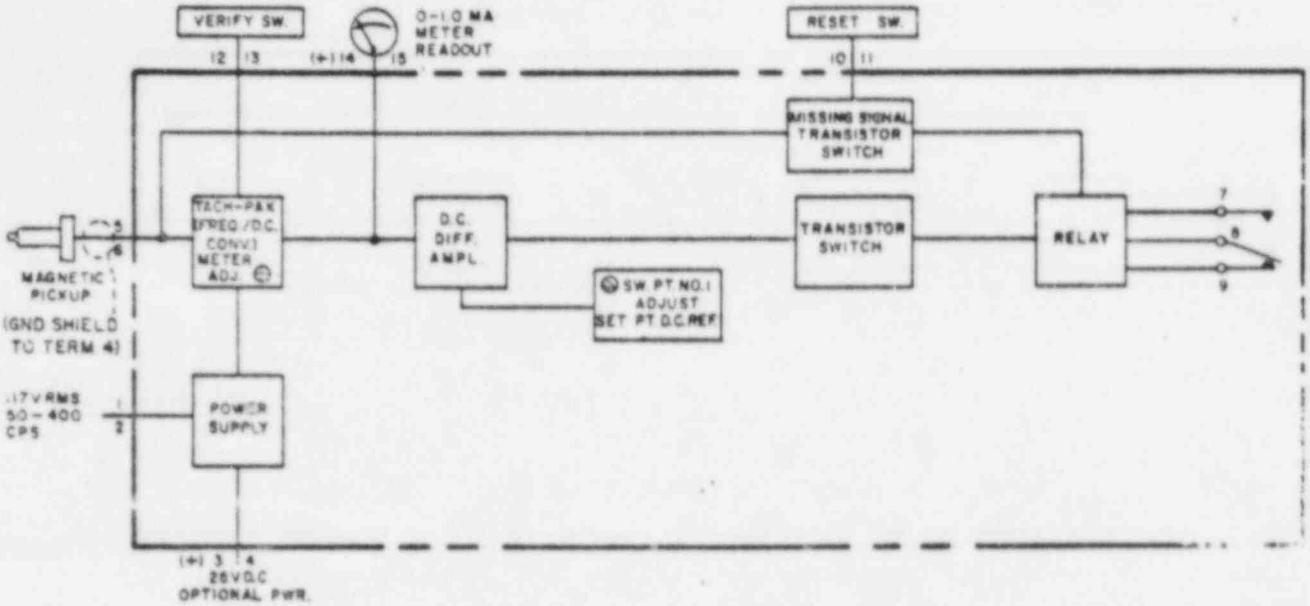
Located on the top of the single set-point unit are the METER ADJ. and SW. PT. ADJ. The potentiometers are accessible by removing the snap button plugs and can be adjusted with a screwdriver.

Located on the top of the dual set-point unit are the SW. PT. ADJ. No. 1 and No. 2, and METER ADJ. The potentiometers are accessible by removing the snap button plug and can be adjusted with a screwdriver.

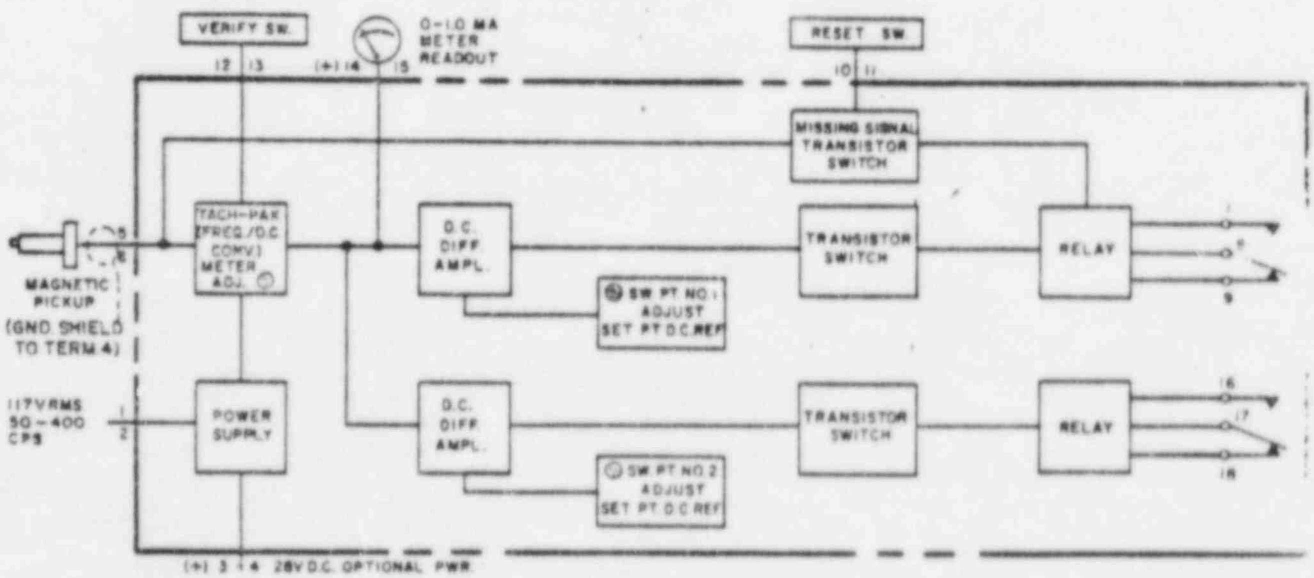
The potentiometers are normally set at the factory to specific customer's requirements and should not be readjusted except to change the calibration of the unit.

APPLICATIONS

- FREQUENCY SENSITIVE SWITCHING
- TURBINE OVERSPEED ALARM AND CONTROL
- RPM MEASUREMENT, WARNING, ALARM AND CONTROL
- CONTROL OR MONITORING OF GENERATOR FREQUENCY
- GO/NO-GO TESTING OF TONES, OSCILLATORS, HORNS AND VIBRATORS
- MACHINE SLOW DOWN DETECTOR



BLOCK DIAGRAM A



BLOCK DIAGRAM B

PART II

OPERATION

2.1 SINGLE SET-POINT CIRCUITRY

The set-point of the single set-point unit is adjustable from 20% to 100% of full scale. The output relay of a single set-point unit, being used as an overspeed monitor, has electronic latching action. After the set-point has been exceeded, the relay remains de-energized(even if the signal frequency returns below the set-point) unless the automatic reset terminals 10 and 11 are jumpered or closed with a push-button. With terminals 10 and 11 jumpered, the output relay automatically re-energizes when the signal input returns to a value below the set-point. If the reset terminals are closed, the missing signal provision is also overridden. The missing signal transistor switch de-energizes the output relay if the signal input to the monitor is interrupted or is less than 0.5V RMS when the reset terminals are open.

2.2 DUAL SET-POINT CIRCUITRY

Block diagram "B" shows the circuit for a dual set-point unit. A dual set-point monitor provides a second 20% to 100% adjustable switch-point. In such a monitor, the output relay of the No. 2 set-point also de-energizes at, and remains de-energized above the switch-point and on loss of power, however, no missing signal or remote reset is provided. The No. 2 set-point relay re-energizes automatically when the signal returns below the switch-point whether reset terminals 10 and 11 are jumpered or not, as long as power is applied.

2.3 METER OUTPUT

In both block diagrams, terminals 14 and 15 are brought out so that a meter may be used to monitor the RPM or frequency. These terminals deliver 0-1 MA DC to a meter such as the Airpax Model 210. The Model 210 meter and magnetic pickups often used, are supplied by Airpax if specified. The Model 210 meter has a resistance of 50 ohms nominal. The meter adjust potentiometer on the frequency monitor is normally set for a load of 50 ohms which is typical of commonly used 1 MA panel meters. If a meter other than Airpax Model 210 is used, this adjustment potentiometer may be adjusted to compensate for the resistance of the meter specified.

2.4 STANDARD FREQUENCY RANGES

Input signal levels for all frequency sensitive switches may be from 0.5 to 25V RMS over frequency ranges up to 0-100KC. This frequency range capability makes possible the measurement and control of any practical RPM range. For instance, a 0-20,000 CPS range would be specified if the RPM range is 0-20,000, and if the signal is derived from a 60 tooth gear. The frequency to RPM relationship is shown by the formula:

$$\text{Frequency (CPS)} = \frac{\text{RPM} \times \text{Number of Gear Teeth}}{60}$$

2.5 RESET OPERATION

After the unit is installed and connected with the power on and the signal input applied (machinery running), it is necessary to reset the No. 1 set-point by shorting terminals 10 and 11. This must be done every time the No. 1 set-point threshold is exceeded (or if the power or signal inputs are interrupted and if the signal input amplitude falls below approximately 0.5V RMS). If desired, automatic resetting may be obtained simply by installing a jumper across terminals 10 and 11.

NOTE: No. 2 set-point has automatic resetting.

2.6 VERIFY CIRCUIT

Both single and dual units have the "Verify" provision, which is particularly useful in overspeed monitoring applications. Shorting terminals 12 and 13 effectively shifts the switch-point to approximately one-half of the RPM value for which it is set. Closing these verify terminals permits the operator to simulate an alarm condition by bringing the switch-point into the normal operating speed. This procedure tests the monitor and associate alarm circuits without having to enter an actual alarm or overspeed condition.

2.7 FAIL-SAFE FUNCTION

Should power be removed or lost on the single or dual unit, the No. 1 relay will deenergize and will not re-energize until the reset terminals are shorted and power is applied. This provides a fail-safe function against power failure.

The No. 2 relay of the dual unit will also de-energize, but will automatically re-energize when power is restored.

PART III

INSTALLATION & CONNECTIONS

3.1 INSTALLATION

Refer to outline drawing Part VI. The unit can be securely mounted in any convenient location and in any position. It is not affected by normal temperature changes or shock. Due to solid state construction, it is maintenance free. Relay contacts are shown in normal operating position--relay energized.

Note: To minimize any noise pickup, connect the input signal using a twisted pair of shielded cable and connect the shield to terminal 4 of the unit <u>only</u>. Do not make any connection to the shield at the other end of the cable.

3.2 CONNECTIONS

<u>SINGLE SET-POINT</u>

1, 2	117V AC, 50-400 CPS
3+, 4-	28V DC, OPERATIONAL POWER
5, 6	SIGNAL INPUT
7 N.O., 8 COMMON, 9 N.C.	RELAY NO. 1
10, 11	RESET SWITCH
12, 13	VERIFY
14+, 15-	0-1.0 MA METER OUTPUT

<u>DUAL SET-POINT</u>

1, 2	117V AC, 50-400 CPS
3+, 4-	28V DC, OPTIONAL POWER
5, 6	SIGNAL INPUT
7 N.O., 8 COMMON, 9 N.C.	RELAY NO. 1
10, 11	RESET SWITCH
12, 13	VERIFY
14+, 15-	0-1.0 MA METER OUTPUT
16 N.O., 17 COMMON, 18 N.C.	RELAY NO. 2

PART IV

CALIBRATION

4.1 CALIBRATION

Monitors are fully calibrated at the factory and normally do not require any field recalibration.

For periodic checkout procedures, the following sections (4.2 and 4.3) provide an operation test.

4.2 SINGLE SET-POINT

A. Connect unit as shown in Figure 1.

B. Set oscillator at 2V AC initially.

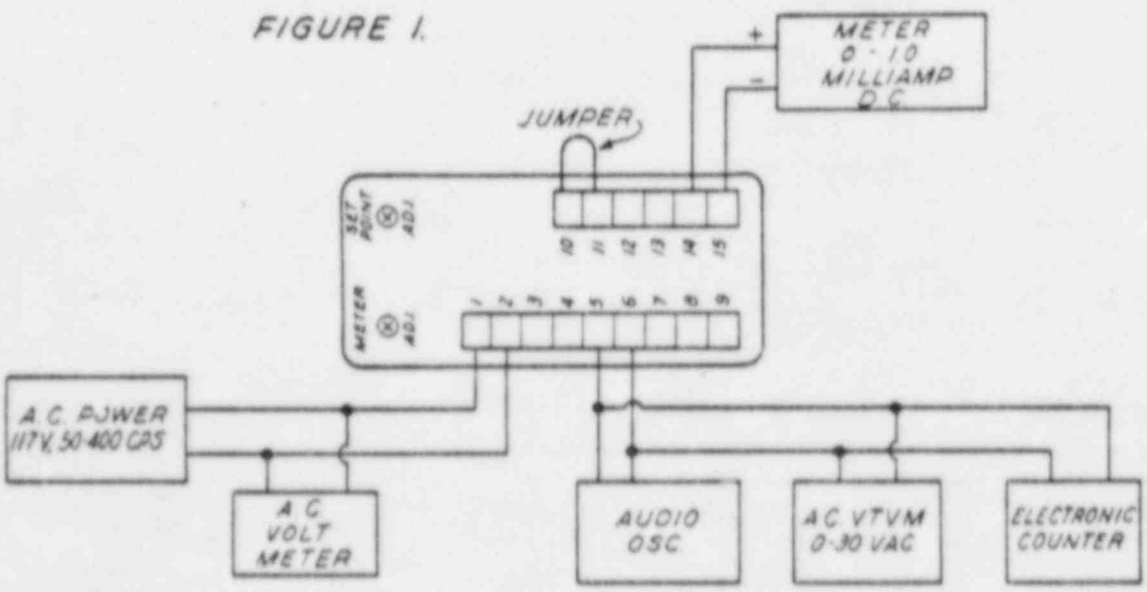
C. Center the METER ADJ. potentiometer and turn the set-point adjust potentiometer fully clockwise.

D. Set the signal input frequency to 50% of full scale and adjust the METER ADJ. potentiometer for .50 MA output. Vary the input frequency to 100% of full scale and check that the meter output is 1.0 MA within .25% of full scale. Reduce the signal frequency to 10% of full scale and check that the meter output is .10 MA within ±.25% of full scale.

E. With the set-point adjust potentiometer fully counter-clockwise, check for a switching point less than 20% of full scale. Turn the set-point adjust potentiometer fully clockwise and check that the switching point is more than 100% of full scale.

F. With the relay energized (frequency below the set-point), check for continuity between terminals 8 and 9 and with the relay de-energized (above the set-point), check frequency below set-point for continuity between terminals 7 and 8.

FIGURE 1.



4.3 DUAL SET-POINT

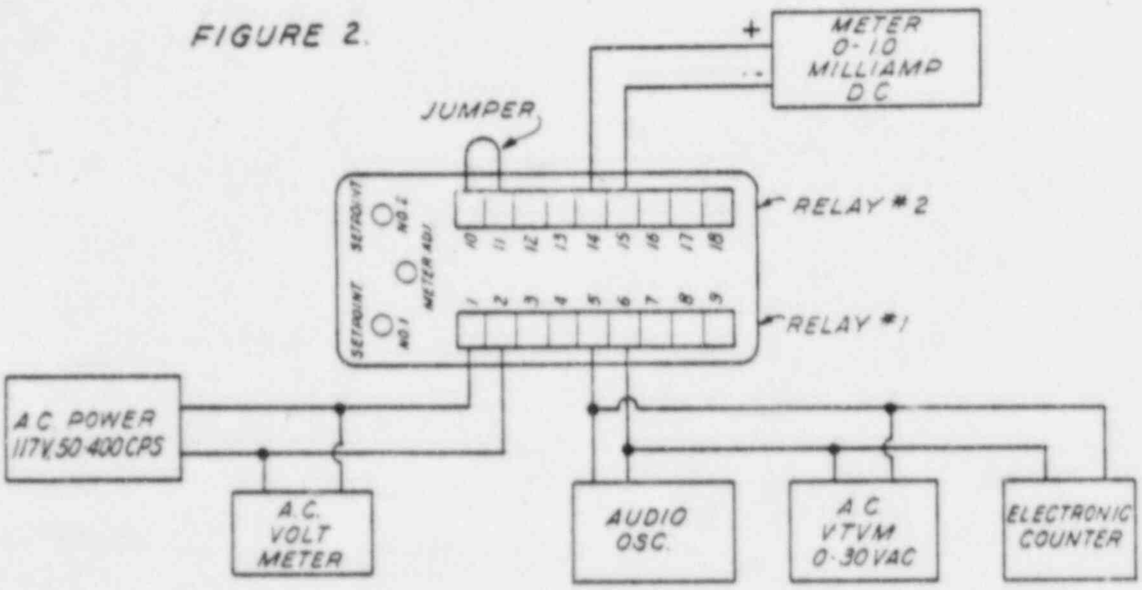
A. Connect unit as shown in Figure 2.

B. Set the signal input frequency to 50% of full scale and adjust the METER ADJ. potentiometer for .50 MA output. Vary the input frequency to 100% of full scale and check that the meter output is 1.0 MA ±.25% of full scale. Reduce the signal frequency to 10% of full scale and check that the meter output is .10 MA ±.25% of full scale.

C. With both set-point adjust potentiometers fully counterclockwise, check that the switching point is less than 20% of full scale. Turn both set-point adjust potentiometers fully clockwise and check that the switching point is more than 100% of full scale.

D. With both relays energized (frequency below the set-points), check for continuity between terminals 8 and 9 (Relay No. 1) and 17 and 18 (Relay No. 2). With both relays de-energized (frequency above the set-points), check for continuity between terminals 7 and 8 (Relay No. 1) and 16 and 17 (Relay No. 2).

FIGURE 2.



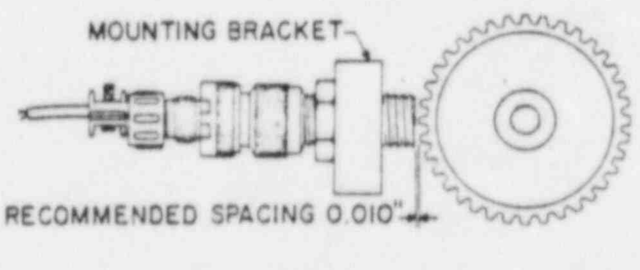
MAGNETIC PICKUP MOUNTING

The mounting for the pickup should be provided with a threaded hole. The standard (#700-0941 pickup assembly) has a 5/8" 18 U.N.F. 2A thread. Model 725-0002 is a hazardous location, Class 1, Group D pickup, having a 3/4" - 20 U.N.E.F. 2A thread. The mounting should be of sufficiently heavy metal to accommodate several complete threads in the threaded hole and should be attached to a frame free from excessive vibration. Normal vibration attendant with machine operation will not affect the accuracy of the readings obtained.

Spacing dimensions are shown in the mounting figure. Screw the pickup into the mounting and adjust for a clearance of approximately 0.005" to 0.010" between the pole piece and the gear. Make sure there is sufficient clearance between the pickup and gear to prevent damaging the pickup. Lock the pickup securely in position with the locknut.

Spacing can be checked by backing off the pickup about a quarter turn. The #700-0941 pickup will move 0.056" per turn and the #725-0002 pickup will move 0.050" per turn. Any decrease in meter indication should be, at most, barely perceptible. Any sharp decrease denotes excessive spacing. The diametral pitch (the number of teeth to each inch of pitch diameter) of the recommended gear should be 16 or less for lower speeds. This is to ensure high surface speeds when maintaining the same number of gear teeth and, therefore, more pickup output. The dimensions of the gear teeth are dictated by the diameter of the pickup pole piece which is .106". The space between tooth surfaces should be approximately two or three times .106". When the gear teeth become small with respect to size of the pickup pole piece, the pickup output decreases. This happens because maximum output is obtained (for a given speed and gap) when the region in front of the pole piece changes from "full" mass at one instant to complete absence of material the next. When a very fine tooth gear is used, the magnetic field fringes into the next tooth and never becomes fully interrupted.

Lead length from pickup to the Monitor is not critical. A twisted pair of No. 18 AWG wire will suffice. Model #725-0002 hazardous location pickup is normally furnished with two 18 inch #18 AWG leads. All #700-0941 pickup assemblies are supplied with ten feet of shielded lead for interconnection between pickup and Monitor. Connect the shield to terminal 4 of the Monitor to minimize the pickup of spurious AC signals. The shield should not be connected to the pickup housing, and should be entirely insulated. Airpax cables are supplied with an insulated shield.



Mounting of Pickup Assembly (700-0941)

PART VI
PARTS LIST

SINGLE SET-POINT OVERSPEED MONITOR

The only recommended spare part field replacement is Relay K1.

DESIGNATION	DESCRIPTION	MANUFACTURER
R1	Resistor, 1W, ±5%	A-B
R2	Resistor, 1W, ±5%	A-B
R3	Resistor, 2.2K ohms, 1/2 W, ±5%	A-B
R4	Resistor, 680 ohms, 1/2 W, ±5%	A-B
R5	Resistor, 680 ohms, 1/2 W, ±5%	A-B
R6	Resistor, 82 ohms, 1/2 W, ±5%	A-B
R7	Resistor, 680 ohms, 3W, Wirewound	SPRAGUE
R8	Resistor, Factory Trim, 1/8 W, ±1%	RN6OD
R9	Resistor, 1.21K, 1/8 W, ±1%	RN6OD
R10	Potentiometer, 5K, ±10%, Type 117	CTS
R11	Resistor, Factory Trim, 1/8 W, ±1%	RN6OD
R12	Resistor, 4.53K, 1/8 W, ±1%	RN6OD
R13	Resistor, 2K Wirewound BALCO	Kelvin
R14	Resistor, 422 ohms, 1/8 W, ±1%	RN6OD
R15	Resistor, 15.4K, 1/8 W, ±1%	RN6OD
R16	Resistor, 4.7K, 1/2 W, ±5%	A-B
R17	Resistor, 1.5K, 1/8 W, ±1%	RN6OD
R18	Resistor, 2.2K, 1/2 W, ±5%	A-B
R19	Potentiometer, 5K, ±10%, Type 117	CTS
R21	Resistor, 1K, 1/8 W, ±1%	RN6OD
R22	Resistor, 1.54K, 1/8 W, ±1%	RN6OD
R23	Resistor, 7.5K, 1/8 W, ±1%	RN6OD
R24	Resistor, 2.2K, 1/2 W, ±5%	A-B
R25	Resistor, 820K, 1/2 W, ±5%	A-B
R26	Resistor, 470 ohms, 1/2 W, ±5%	A-B
R27	Resistor, 47 ohms, 1/2 W, ±5%	A-B
C1	Capacitor, .47 ufd, 100V (mylar)	Goodall
C2	Capacitor, 100 ufd, 50V Type PSD	Callins
C3	Capacitor, Selected at time of manufacture	
C4	Capacitor, 2.2 ufd, 50V, 76F02LC2R2	G. E.
CR1	Diode, 1N277	G. E.
CR2	Diode, 1N277	G. E.
CR3	Diode, SCE2	Semtech
CR4	Diode, SCE2	Semtech
CR5	Diode, SCE2	Semtech
CR6	Diode, SCE2	Semtech
CR7	Diode, SCE2	Semtech
CR8	Diode, SCE2	Semtech
CR9	Diode, SCE2	Semtech
CR10	Diode, SCE2	Semtech

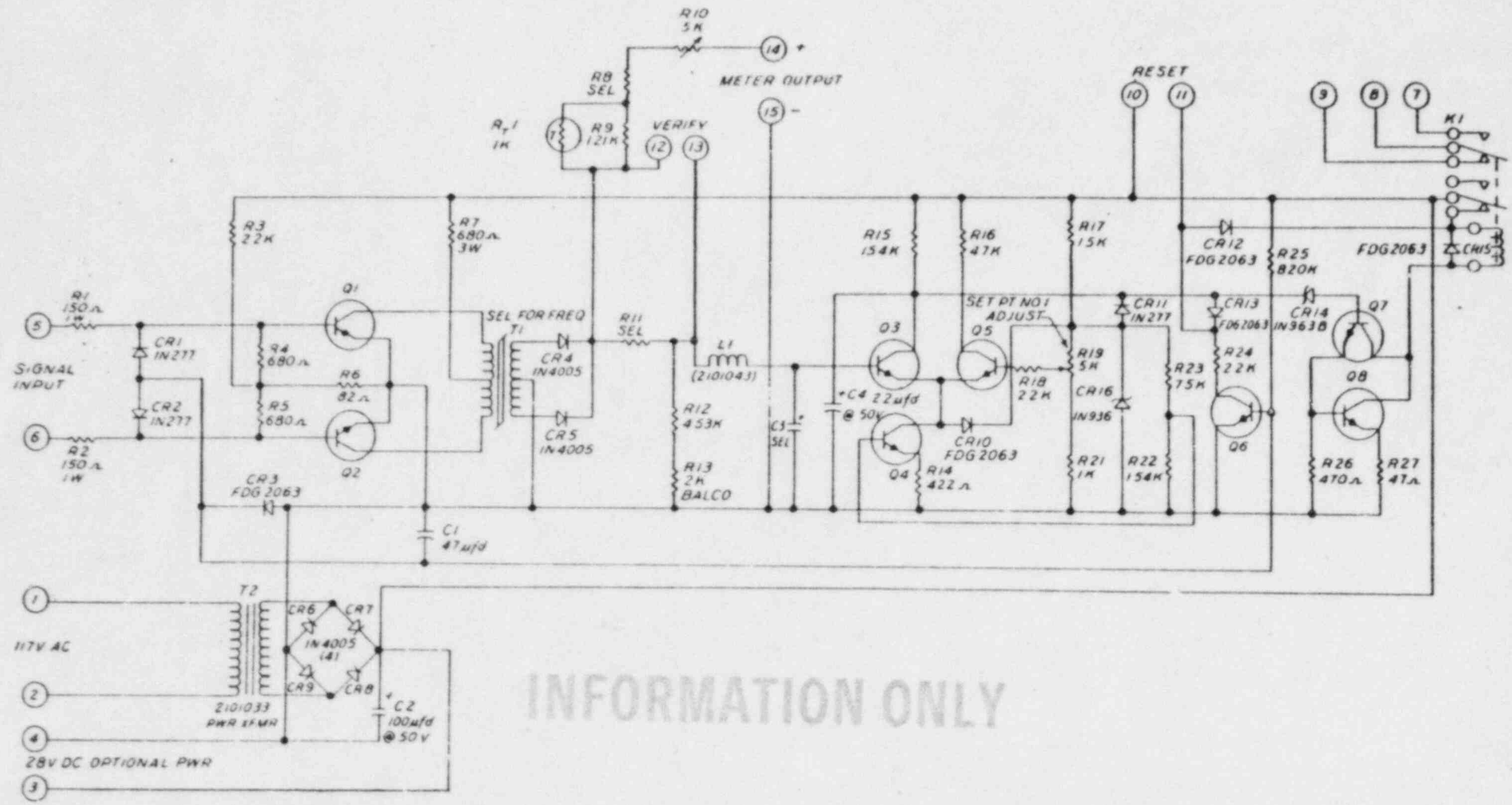
CR11	Diode, 1N277	G. E.
CR12	Diode, SCE2	Semtech
CR13	Diode, SCE2	Semtech
CR14	Diode, Zener, 1N963B	I. R.
CR15	Diode, SCE2	Semtech
CR16	Diode, Zener, 1N936	Dickson
RT1	Thermistor, 1K ohm, 31D34	VECO
L1	Choke Filter, 210143	Airpax
K1	Relay, 24V, TF154CC	Allied
T1	Magmeter, Transformer	Airpax
T2	Transformer, Power	Airpax
Q1-Q8	Transistor, 2N697	G. E.

DUAL SET-POINT OVERSPEED MONITOR

The only recommended spare part field replacement is Relay K1 and Relay K2.

DESIGNATION	DESCRIPTION	MANUFACTURER
R1	Resistor, 150 ohms, 1W, ±5%	A-B
R2	Resistor, 150 ohms, 1W, ±5%	A-B
R3	Resistor, 2.2K, 1/2 W, ±5%	A-B
R4	Resistor, 680 ohms, 1/2 W, ±5%	A-B
R5	Resistor, 680 ohms, 1/2 W, ±5%	A-B
R6	Resistor, 82 ohms, 1/2 W, ±5%	A-B
R7	Resistor, 680 ohms, 3W, Wirewound	SPRAGUE
R8	Resistor, Factory Trim, 1/8 W, ±1%	RN6OD
R9	Resistor, 1.21K, 1/8 W, ±1%	RN6OD
R10	Potentiometer, 5K, ±10%, Type 117	CTS
R11	Resistor, Factory Trim, 1/8 W, ±1%	RN6OD
R12	Resistor, 4.53K, 1/8 W, ±1%	RN6OD
R13	Resistor, 2K	IRC
R14	Resistor, 422 ohms, 1/8 W, ±1%	RN6OD
R15	Resistor, 15.4K, 1/8 W, ±1%	RN6OD
R16	Resistor, 4.7K, 1/2 W, ±5%	A-B
R17	Resistor, 1.5K, 1/8 W, ±1%	RN6OD
R18	Resistor, 2.2K, 1/2 W, ±5%	A-B
R19	Potentiometer, 5K, ±10%, Type 117	CTS
R20	Potentiometer, 5K, ±10%, Type 117	CTS
R21	Resistor, 1K, 1/8 W, ±1%	RN6OD
R22	Resistor, 1.54K, 1/8 W, ±1%	RN6OD
R23	Resistor, 7.5K, 1/8 W, ±1%	RN6OD
R24	Resistor, 2.2K, 1/2 W, ±5%	A-B
R25	Resistor, 820K, 1/2 W, ±5%	A-B
R26	Resistor, 470 ohms, 1/2 W, ±5%	A-B
R27	Resistor, 47 ohms, 1/2 W, ±5%	A-B
R28	Resistor, 1K, 1/8 W, ±1%	RN6OD
R29	Resistor, 15.4K, 1/8 W, ±1%	RN6OD
R30	Resistor, 4.7K, 1/2 W, ±5%	A-B

DESIGNATION	DESCRIPTION	MANUFACTURER
R31	Resistor, 422 ohms, 1/8 W, ±1%	RN6OD
R32	Resistor, 2.2K, 1/2 W, ±5%	A-B
R33	Resistor, 470 ohms, 1/2 W, ±5%	A-B
R34	Resistor, 47 ohms, 1/2 W, ±5%	A-B
C1	Capacitor, .47 ufd 100V, Mylar	Goodall
C2	Capacitor, 100 ufd, 50V, Type PSD	Callins
C3	Capacitor, Selected at time of manufacture	
C4	Capacitor, 2.2 ufd, 50V, 76F02LC2R2	G. E.
C5	Capacitor, 2.2 ufd, 50V, 76F02LC2R2	G. E.
CR1	Diode, 1N277	G. E.
CR2	Diode, 1N277	G. E.
CR3	Diode, SCE2	Semtech
CR4	Diode, SCE2	Semtech
CR5	Diode, SCE2	Semtech
CR6	Diode, SCE2	Semtech
CR7	Diode, SCE2	Semtech
CR8	Diode, SCE2	Semtech
CR9	Diode, SCE2	Semtech
CR10	Diode, SCE2	Semtech
CR11	Diode, 1N277	G. E.
CR12	Diode, SCE2	Semtech
CR13	Diode, SCE2	Semtech
CR14	Diode, Zener, 1N963B	I. R.
CR15	Diode, SCE2	Semtech
CR16	Diode, Zener, 1N936	Dickson
CR17	Diode, SCE2	Semtech
CR18	Diode, 1N277	G. E.
CR19	Diode, Zener, 1N963B	I. R.
CR20	Diode, SCE2	Semtech
Q1-Q13	Transistor, 2N697	G. E.
RT1	Thermistor, 1K ohm, 31D34	VECO
L1	Choke, filter, 2101043	Airpax
T1	Magmeter, transformer	Airpax
T2	Transformer, power, 2101033	Airpax
K1	Relay, 24V, TF154CC	Allied
K2	Relay, 24V, TF154CC	Allied



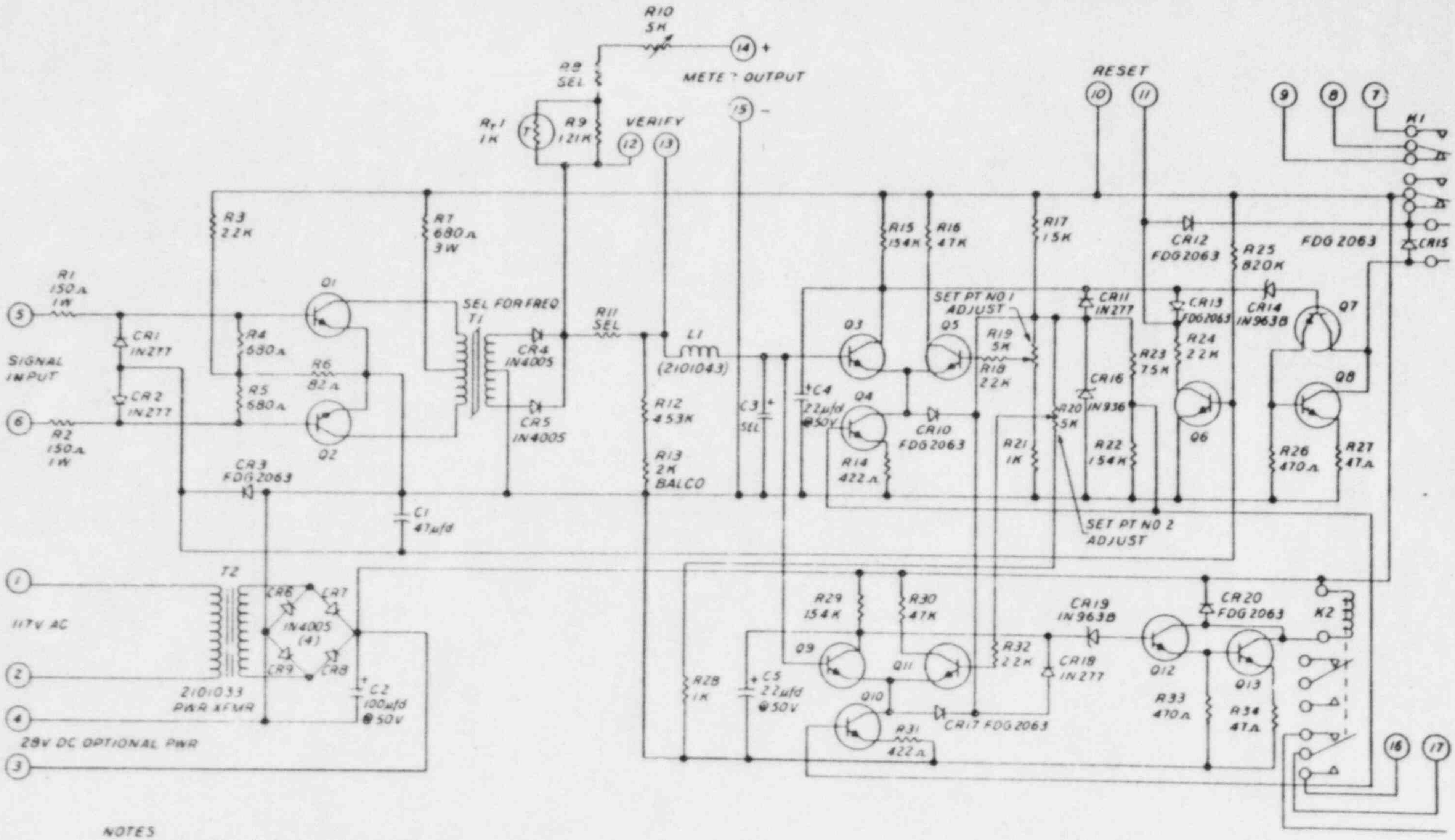
NOTES

1. ALL TRANSISTORS ARE 2N697 S

2. RELAY IS SHOWN IN NORMAL OPERATING POSITION, ENERGIZED

SCHEMATIC

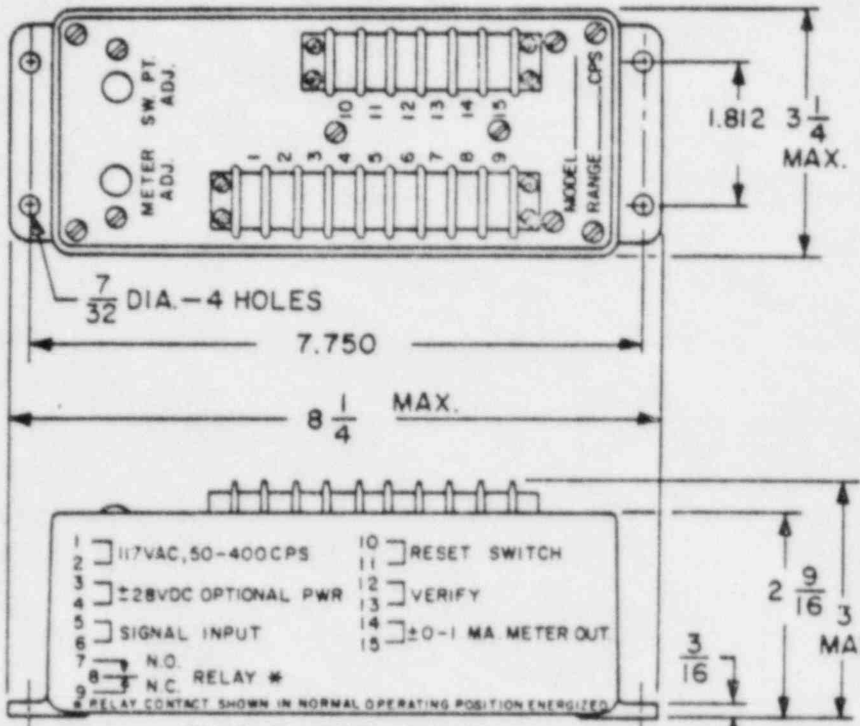
(SINGLE SETPOINT OVERSPEED SWITCH)



NOTES
1 ALL TRANSISTORS ARE 2N6975
2 RELAYS ARE SHOWN IN NORMAL OPERATING POSITION ENERGIZED

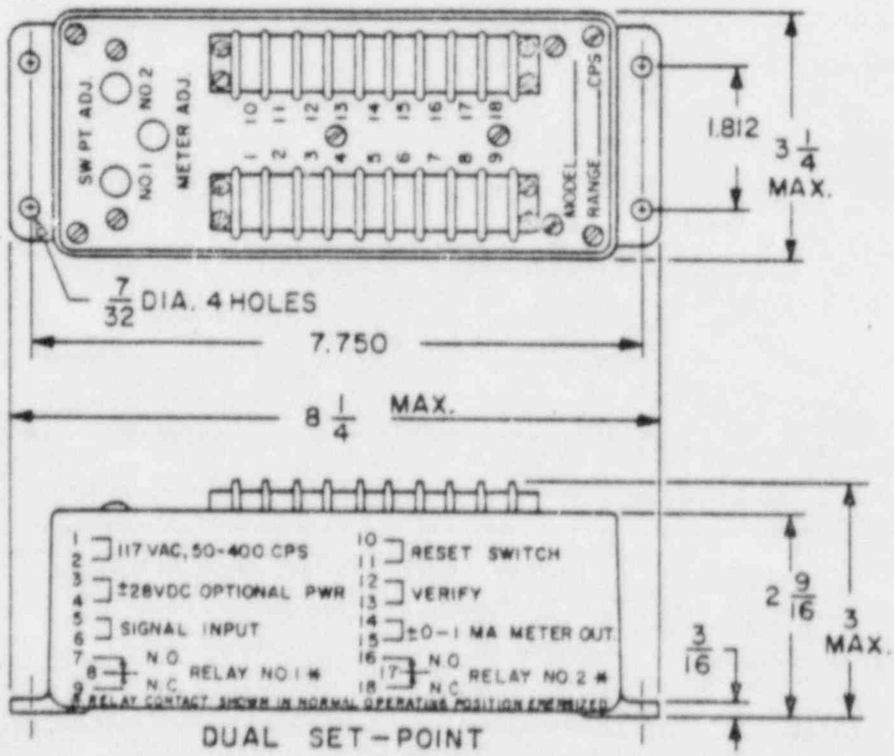
SCHEMATIC
(DUAL SETPOINT OVERSPEED SWITCH)

PART VI

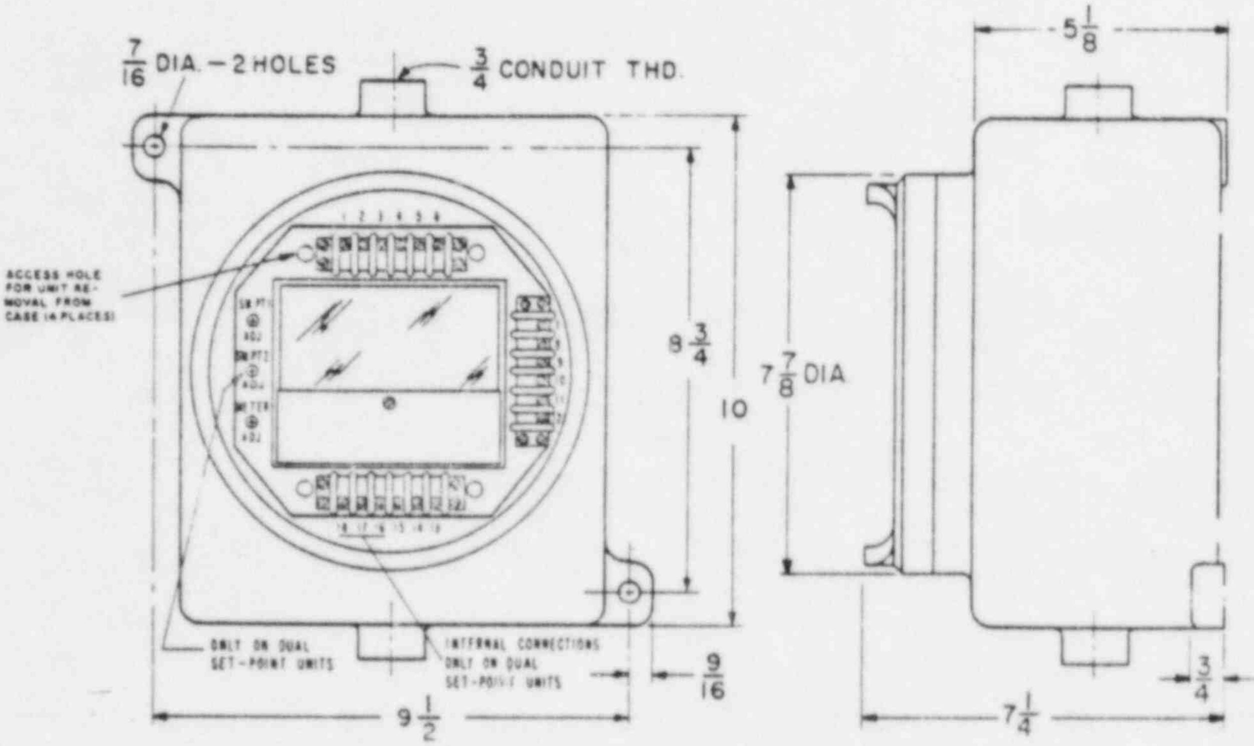


SINGLE SET—POINT

B STYLE



DUAL SET—POINT



E STYLE

TERMINALS:

1 & 2: 117 VAC, 50-400 CPS
3 & 4: 28 VDC Opt. Pwr., #3 Pos.
5 & 6: Signal Input
7 & 8: N. O. Relay No. 1 Contacts
8 & 9: N. C. Relay No. 1 Contacts
10 & 11: Reset Switch
12 & 13: Verify
14 & 15: 0-1.0 MA Ext. Meter Output #14 Pos.**
*16 & 17: N. O. Relay No. 2 Contacts
*17 & 18: N. C. Relay No. 2 Contacts

*Applies to dual set-point units.

**Normally jumpered. Remove jumper when using the Ext. Meter Output.

AIRPAX™

AIRPAX ELECTRONICS
CONTROLS DIVISION

P. O. BOX 8488 Fort Lauderdale, Florida 33310
Phone: (305) 587-1100 TWX: 510-955-9866 Telex: 51-4448

WARRANTY AND RETURN SHIPMENTS STATEMENT

The materials ordered and agreed to be furnished by Seller are warranted against defect of material or workmanship for a period of one (1) year from the date of shipment, or for their rated life (whichever period ends first). Seller's obligation under the warranty is limited to repair or replacement in Seller's option of the defective material at Seller's factory (point of shipment) and does not extend to equipment other than of Seller's manufacture. The warranty shall not apply to any product or part which has been subject to misuse, negligence, accident or attempted or unauthorized repair or modification. All return shipments must be factory authorized prior to shipment and shipment will be at Buyer's expense. The only statutory warranties applicable to the materials are warranties of title and that the materials will be merchantable and, if manufactured to Buyer's specifications, that the said items conform to such specifications. UNLESS EXPRESSLY STATED ON THE FACE HEREOF, NO WARRANTY OF FITNESS FOR ANY PARTICULAR PURPOSE IS TO BE IMPLIED, NOR ARE ANY OTHER WARRANTIES TO BE IMPLIED FROM COURSE OF DEALING OR USAGE OF TRADE. THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THOSE STATED HEREIN. SELLER'S SOLE LIABILITY FOR DEFECTS OR BREACH OF WARRANTY SHALL BE REPLACEMENT OF THE MATERIALS INVOLVED, AND IN NO EVENT WILL THE SELLER BE LIABLE FOR SPECIAL OR CONSEQUENTIAL DAMAGES. FAILURE TO TEST, INSPECT AND MAKE CLAIMS FOR BREACH OF WARRANTY WITHIN REASONABLE PERIODS SHALL BE CONCLUSIVE EVIDENCE THAT THE MERCHANDISE SHIPPED IS SATISFACTORY IN ALL RESPECTS AND SUPPLIED IN ACCORDANCE WITH ORDERED SPECIFICATIONS.

NOTICE REGARDING DAMAGE

These units were carefully packed in compliance with carrier regulations and thoroughly inspected before leaving our plant. Responsibility for their safe delivery was assumed by the carrier upon acceptance of the shipment. Claims for loss or damage sustained in transit must, therefore, be made upon the carrier.

CONCEALED LOSS OR DAMAGE

Concealed loss or damage means loss or damage which does not become apparent until the merchandise has been unpacked. The contents may be damaged in transit due to rough handling even though the package may not show external damage. When damage is discovered upon unpacking, make a request for inspection by the carrier's agent. Then file a claim with the carrier since such damage is the carrier's responsibility.

VISIBLE LOSS OR DAMAGE

Any external evidence of loss or damage must be noted on the freight bill or express receipt and signed by the carrier's agent. Failure to properly describe evidence of loss or damage may result in the carrier refusing to honor a claim.

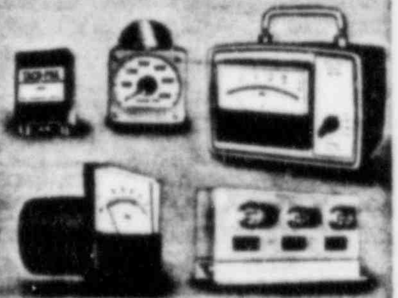
We definitely are not responsible for any damage incurred while merchandise is in transit. The transportation company will settle promptly all claims as they are insured and their rates cover this cost. Any correspondence in regard to loss or damage must be accompanied by a copy of the carrier's report.

***

INDICATING TACHOMETRY

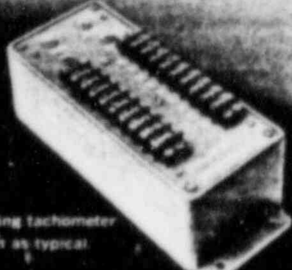
Precision Tachometers
Series 600 — Solid-state Tach-Paks* designed for continuous duty, high reliability and flexibility with ±0.25% typical accuracy which interface with meters, recorders or computers.

Complete Tachometer Systems
Series 211/311 Tach-Pak* Systems (not illustrated) provide a low-cost method of measuring speed of rotating shafts. Each system comprises a panel-mount Tach-Pak* and meter assembly, magnetic pickup and gear.



Special Purpose Tachometers
Five styles to choose from:
(a) "H" Style — Miniature Hermetically Sealed
(b) "J" Style — Switchboard
(c) "G" Style — Portable
(d) "L" Style — Panel Mount
(e) "M" Style — Military
Designed for those special applications.

CONTROL TACHOMETRY



Switching tachometer shown as typical

Precision Switching Tachometers
Tachometers to monitor the RPM of rotating equipment providing single or multiple (adjustable) switchpoints at which predetermined action (alarm, programming or verification) can take place.

Over/Under Speed Switches
Switches to measure the RPM of rotating equipment as a function of frequency providing 1 or 2 adjustable set-points for control. Trip-speed verification and fail-safe features standard.

Zero-Speed Switches
Series 130 — Switches used whenever an alarm switching or equipment shutdown function is required as the speed of a rotating shaft approaches zero.

AIRPAX EVENT CONTROLS

high-speed
low-speed
zero-speed
. . . any speed

For over 20 years, Airpax has controlled events . . . the mechanical motions found in industry. Precise monitoring and controlling of these events in terms of velocities or rates and converting them into "Events-Per-Unit-Time" or "Time-Per-Unit-Events" is a job for Airpax event controls.

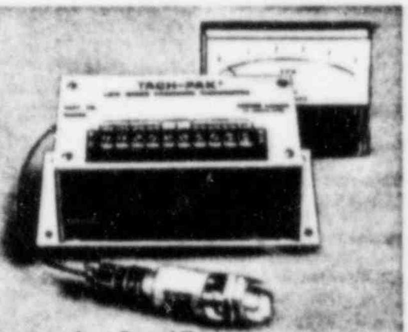
The accurate accumulation or rate of events, or even the net accumulative number of events . . . all are possible with Airpax equipment. Low-speed events down to almost zero with a full-scale meter of 5 RPM is entirely practical . . . with set-point switching down to 5% or 10% of full scale. Events can be counted digitally down to zero speed . . . we do mean out to infinitely slow . . . and up to as fast as you can move a mechanical device!

Airpax specializes in adapting stock modules to your application. We expect you to ask for the unusual, and we look forward to meeting your needs.

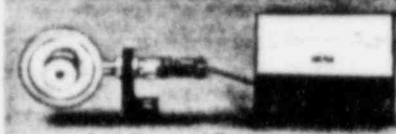
Frequency-to-DC-Converters
Series 200 — Tach-Trol* converters provide 1-5 mA, 4-20 mA and 10-50 mA standard outputs. Accurately converting frequencies into high-level output currents or voltages that are linearly proportional to the input signal.

For complete specifications, call or write . . .

AIRPAX™



Low-Speed Tachometers
Series 400 — Solid-State tachometers for low-speed measurement and control with meter readout that is steady and useful for the observer. Designed for use with Airpax Zero Velocity Pickups providing frequency ranges from 0-3 Hz to 0-15 kHz.



Self-Powered Tachometers
Series 350 — Tachometers that require neither bulky shaft-coupled tach generators, nor ac or dc power source. Utilizing only the signal from an Airpax Magnetic Pickup, they install anywhere. Intrinsically-safe design optional.

MAGNETIC PICKUPS FOR SPFED SENSING
Input signals to operate event control equipment — best derived from Airpax Magnetic Pickups (transducers) located in proximity to the teeth of a gear mounted on a rotating shaft. Airpax pickups convert motion to an ac voltage without mechanical linkage and are available in a vast selection of standard and special types for any application.

Digital Process Monitors
Series 76 — Monitors for precise digital readout and control of process machinery. Designed to be used as a digital tachometer, percent elongation, stretch or draw monitor, production rate or output monitor, cut-length controller, and control sequencer or speed switch. Selectable time base, normalization to significant engineering units and selection of rate count, ratio or accumulator modes are but a few of the many features available.

AIRPAX ELECTRONICS
CONTROLS DIVISION
6801 W. Sunrise Blvd.
Fort Lauderdale, Florida 33313
Phone: (305) 587-1100

INSTRUCTION MANUAL

BENTLY PROBES AND PROXIMITORS

FOR GENERAL USE

NOTE: See Part F for Special Notes Regarding MACHINE PROTECTION APPLICATIONS.

Unpacking and Inspection

Bently Nevada 3000 Series Probes and Proximitors have been carefully inspected and tested prior to being shipped. Although adequate packing material has been used, a thorough inspection of the equipment should be made for possible damage during shipment. Should any damage be found, it should be reported to the factory.

A. General Description

Bently Probe and Proximitor systems operate on inductive principles and therefore do not touch the object to be observed. They can be used to observe any material that is electrically conductive and conversely, are completely unaffected by any material in the Probe gap that is not electrically conductive. Therefore, oil, air, gas, etc., between the Probe and the observed surface has no effect on the system.

The Probes are manufactured from materials inert to most chemicals and environments. The Probe coils are sealed in epoxy resin to prevent most corrosive elements from attacking the wire. The Probes are mounted in epoxy, steel, or other type cases depending upon model and customer specifications.

The Bently Proximitor is contained in an aluminum extrusion that measures 1" X 1-3/8" X 3-1/8". Mounting flanges run the length of the housing and may be used to mount the Proximitor to a variety of surfaces.

The Proximitor is designed to operate a Bently Probe with a negative 18 volt at 25 ma power supply, such as the Bently S-18-4. The Proximitor supplies electrical energy from the power supply to the Probe and adjusts the signal returned from the Probe to provide a voltage signal that is proportional to the distance change detected by the Probe.

B. Installation

1. Probes

The Probes are usually installed by means of a small mounting bracket or threaded into an existing part. In any case, the mount must be rigid enough to prevent its vibrating. Such vibration will create false reading and impair the system accuracy. The Probe must be solidly locked into its mount by a lock nut or clamp.

When installing a Probe that has a lead directly attached, rather than the "Q" type which has a cable disconnect attached directly to the Probe, care must be taken to rotate the cable with the Probe when threading the Probe into the mount. Do not allow high twist loads to occur at the Probe-Cable joint as cable damage or a broken connection may result.

In the complete installation there should be no metal within 0.150 inch of the Probe face except the observed surface. Counterboring, chamfering or other relieving may be necessary to achieve this. Operation is possible without this precaution, but difficulties achieving linearity, range and calibration may be experienced.

2. Proximitors

All standard Proximitor models are stabilized for environmental temperatures over a range of about 18° to 65° C (0° - 150° F). If the Proximitor is to be operated in varying temperatures above or below this region, consult the factory for a modified model to fit the environment. The Proximitor is not affected by vibration, dust, or humidity.

Different Proximitor models are available for work with various ranges of cable lengths. Standard models are the 3106, 3109, 3115, 3120 with adjustable gain controls. For longer cable usage the 3140, plus other special Proximitors, are available. See Catalog for details.

Whenever cable length between the Probe and Proximitor is changed the Proximitor must be recalibrated. The cable may be cut and a wide variety of connectors may be used to reconnect it without impairing accuracy. Cable length between Proximitor and readout instrumentation is non-critical except where very high motion frequencies are being observed, in which case the capacitance to common from output should be kept as small as possible. See special section on Proximitor to Probe connecting cable.

3. Probe to Proximitor Connecting Cable

The Proximitors are designed to operate with a specific length of 95 ohm coaxial cable. The proper length is noted in the last two numbers of the Proximitor model number i.e. 3106, 3109, 3115, 3120. However, for mechanical reasons, a smaller 50 ohm cable is used for pig-tail leads on standard Probes. When a 95 ohm extension cable is used in conjunction with a 50 ohm Probe lead, an adjustment in total length must be made in accordance with the following:

> One foot of 50 ohm lead is the equivalent of 2 feet of 95 ohm lead.
>
> For instance, with a 3115 Proximitor and 2-1/2 feet of 50 ohm Probe lead, use a 10 foot 95 ohm extension cable. Physical length equals 12-1/2 feet, electrical length equals 2 X 2-1/2 feet plus 10 feet for 15 feet total.

C. Power Requirements

The Bently Probe and Proximitor require a regulated Power Supply that will deliver negative 18 volts d.c. at 25 ma. The Bently Nevada S-18 Power Supply is ideally suited for this purpose although other power supplies of similar quality may be used. "P" type Proximitors require both positive and negative output Power Supplies. Supply voltage may be any level from 6 to 25 volts, but unless the Power Supply is well regulated, errors in output signals can occur. Output scale factor is always directly proportional to supply voltage.

If a battery is desired as the source of primary power, very good performance may be obtained by using a 22.5 volt battery with a series resistor and a silicon voltage reference diode, in shunt with the Proximitor as a voltage regulator. Recommended components would include a Burgess No. 4156 battery, a Motorola IN 1525 reference diode and a 390 ohm, 1 watt resistor.

D. Proximitor Output

1. General

The output of the Proximitor is a voltage that varies between 0 to 16 volts d.c. at approximately 2500 ohms impedance. The output voltage varies proportionally as the distance between the Probe and the measured surface varies.

The output voltage may be used to drive numerous devices including the Bently 5000 Series Machine Protection Systems, pulse counters, oscilloscopes, oscillographs, DC voltmeters, strip chart recorders, x-y plotters, digital voltmeters, variable trip point relays, AC voltmeters, tape recorders, and other readout instruments.

2. Output biasing

When it is requred to have the output signal operate both sides of zero, such as when recording on a galvanometer or magnetic tape, it may be accomplished by using a bias battery with a shunt resistance, or, for more precise bias, a DC Coupled Differentiated Amplifier may be used. This Amplifier will shift the "Zero Voltage Output", point to any place on the output curve and may be used to either increase or decrease scale factor simultaneously. Band Pass limiting may also be incorporated in this Amplifier.

3. Observation of High Speed Motion

All Standard Probe and Proximitor combinations accurately follow at least twenty five thousand cycles per second sinusoidal motion. Model 3500 Proximitors will observe up to one hundred thousand cycles per second.

E. Calibration and Operation

1. Observed Surface

Any surface that is electrically conductive may be observed by the Probe. When it is desired to observe a non-conductive surface, it is often possible to attach a small conducting surface to the material. A thickness of 10 mils or greater is desireable.

For maximum range and linearity, the fixed conductive surface, usually formed by the Probe mounting or housing, should be chamfered or counterbored from the face of the Probe to a distance at least equal to the range to be observed. It will give reliable measurements when encased, but with shortened range and reduced linearity.

2. Calibration

Calibration of the Probe and Proximitor system is best accomplished by using a spindle micrometer such as the Bently Model SM-100. For dynamic calibration of read-out units we recommend the

Bently TK-3 "wobulator" which also contains the SM-100 micrometer. The following procedure is based upon using a SM-100 but any method that will allow precise setting of the gap between the Probe and the observed surface is satisfactory. Feeler gages may also be used to set the gap.

a. Lock the Probe to be calibrated into the spindle micrometer unit so that the observed sample lightly contacts the Probe face when the micrometer setting is at ZERO. The observed material must be the same as will be observed when in service.

b. Connect the Probe to the Proximitor using the connectors provided on the Probe cable and Proximitor. Be sure to use the proper Proximitor model to match the Probe lead length.

c. Connect the Proximitor to a regulated -18 volts d.c. supply.

d. Connect the output terminal of the Proximitor to a Simpson Model 260 Multimeter, or equivalent. Set the Multimeter to read DC volts.

e. Turn the Micrometer unit to 10 mils, giving a 10 mils gap between the Probe and the observed surface, continuing in 10 mil increments and recording, on graph paper, a record of the voltage reading vs gap distance. A graph paper graduated in 0.10 inches with a vertical scale of 2 volts per inch and a horizontal scale of 10 mils per inch is recommended.

It is normal to obtain no voltage reading for the first 20 mils gap from zero. Depending upon the type of Probe and Proximitor, and particularly upon the type of material being observed, a steep response to approximately 2-1/2 volts will occur somewhere between 20 and 30 mils Probe gap. As the Probe gap continues to increase the response will become linear at approximately 30 mils and remain so through a range of 50 to 100 mils, depending again, upon the particular Probe, Proximitor, and the observed material.

f. Most Probes and Proximitors are factory calibrated to a scale factor of .200 volts per mil when observing 4140 type steel. Most of the 4000 and 1000 type steels have very similar electrical characteristics and it is not necessary to recalibrate when changing between these steels.

For other, unusual types of material, the Proximitors may be factory calibrated to gain factors other than .200 volts per mil

g. The scale factor of the volts vs distance response may be adjusted on all but 2620 and 2800 type Proximitors by simply turning the adjustable gain potentiometer located on the end of the Proximitor near the Probe connector. This is a 15 - turn potentiometer and a light clicking will be heard when it is turned to either extreme. By adjusting this potentiometer and re-running the volts vs distance response graph a different scale factor will be obtained. Generally, the range can be greatly extended by reducing scale factor at some sacrifice in linearity.

On 2620 or 2800 type Proximitors it is necessary to adjust the fixed resistors located on the tip of the Proximitor to adjust the scale factor.

3. Probe Gap

Probe Gap to be used in service is determined by consulting the graph supplied with the Probe or as determined in preceding sections. Operation should be in the middle range of the Probe as indicated by the graph. Once determined, this gap can be set by a feeler gage plastic shim, or by observing the voltage output from the Proximitor. This last method is particularly helpful in blind hole locations. Be especially careful in blind holes to assure that the Probe is observing the required surface and not the sides of the hole.

F. Special Notes for Use of Bently Probes in MACHINE PROTECTION SERVICE

Standard Probes for relative motion measurement may be mounted at any location on or in the machine with the end of the Probe facing the machine shaft. The machine shaft surface should be bearing type finish, if at all possible, in order to minimize mechanical runout "noise". The serial number and location of each Probe should be recorded for your future reference.

The Probes observed gap distance from the Probe face to the running shaft. Therefore it is necessary for accurate measurement of vibration, that the holding structures of the Probes do not vibrate at amplitudes or frequencies of interest for the measurement to be made. If a Probe cannot be mounted in a solid location on the machine, such as the bearing structure, be certain the beam itself cannot vibrate appreciably in a plane that will change the gap distance. The resonant frequency of any such mounting structure should be field checked by tapping lightly and observing the Proximitor output on an oscilloscope. Such data should be incorporated in your permanent installation data for that point.

When installing a Probe that has a lead attached, rather than the "Q" type which has a cable disconnect attached directly to the Probe, care must be taken to rotate the cable with the Probe when threading the Probe into the mount. Do not allow high twist loads to occur at the Probe-Cable joint as cable damage or a broken connection may result. The Probe must be solidly locked into its mount by a locknut, clamp, or other vibration secure device.

When installing a Probe be certain that the mounting hole is clear of obstructions. Do not jam the Probe against the observed surface with more than finger tight twist. If the observed surface is moving, take care to prevent the Probe face from sever rubbing.

Initial gap is determined by consulting the Probe Calibration graph. In open installations the gap can be set by a feeler gage or plastic shim. The gap may also be set by observing the Proximitor output and adjusting the Probe gap until the Proximitor voltage output corresponds to the equivalent voltage output for the recommended gap indicated by the Probe Calibration Graph. This last method is particularly helpful in blind installations or with running shafts in which feeler gages or shims cannot be used. In blind holes be certain that Probe is observing the shaft by moving the Probe to increase and decrease gap while observing the output voltage.

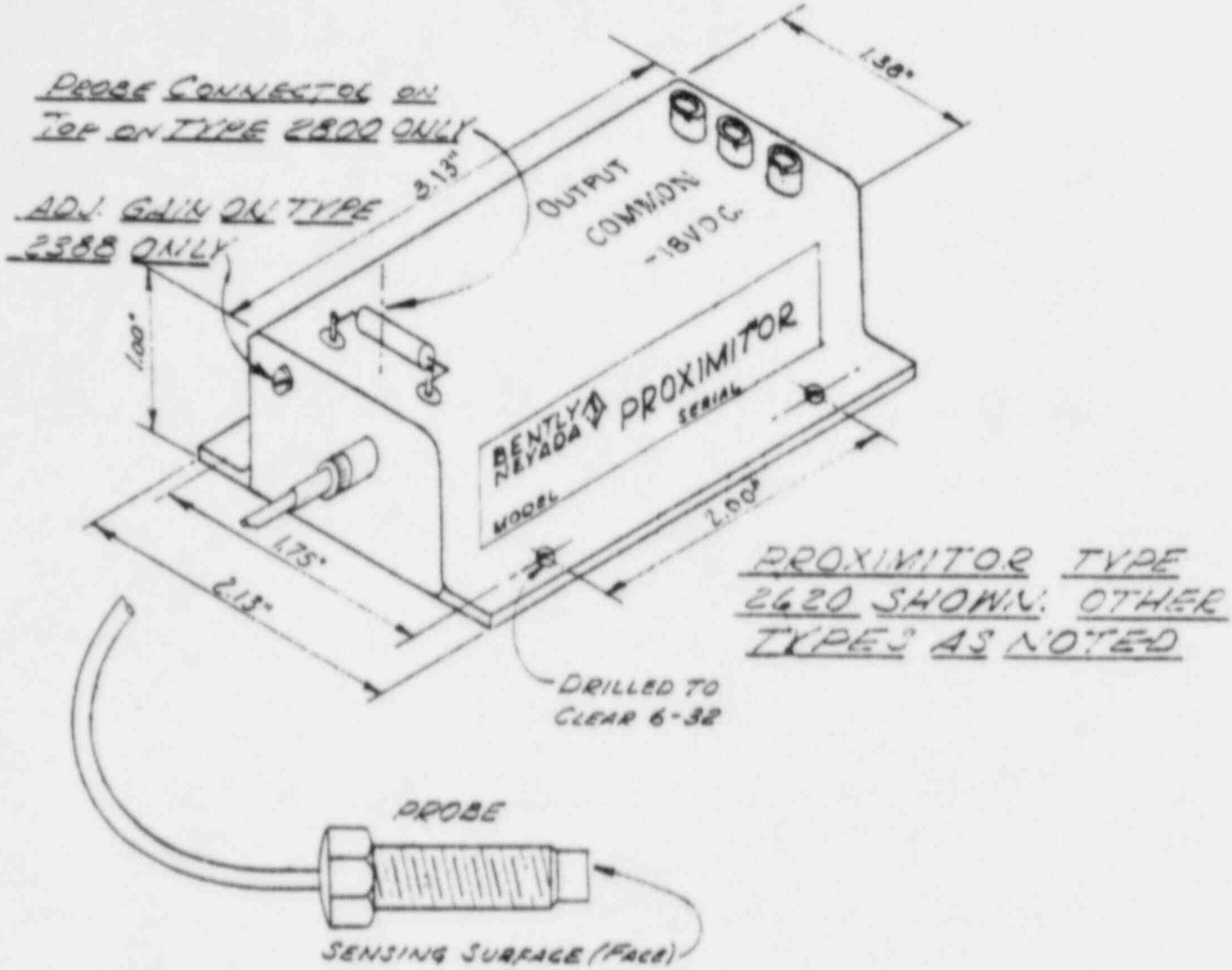
With factory calibrated Proximitors, and if the shaft is a 4000 or 1000 Series steel, or similar, and it is not practical to run a gap vs distance calibration graph, satisfactory operation may be obtained by setting Probe gap to give an output voltage of approximately 8 volts for 302 or 304 type Probes and approximately 6 volts for 306 type Probes. These gap voltages will set the gap at the approximate middle range for the Probes.

In the complete installation there should be no metal within 0.150 inch of the Probe face except the observed surface. Counter boring, chamfering, or other relieving may be necessary to achieve this clearance.

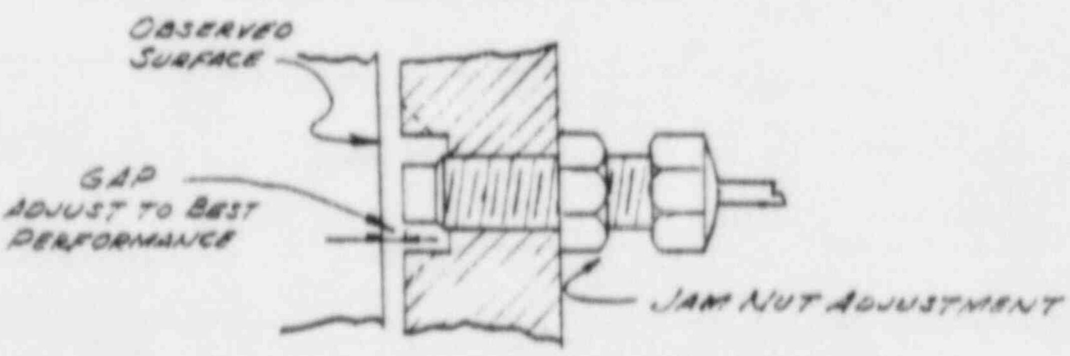
The Probe cable may be permanently attached when the Probe has been installed. Use teflon tape to cover all cable junctions. Solid or flexible conduit should be employed to mechanically protect the Probe cable from mechanical damage.

Care should be taken to cover the end of the connector to keep them clean and prevent damage.

Proper installation of Probes for Machine Protection Service is very important. Please consult a Bently Instruction Manual for Series 5000 Machine Protection Monitors and general manual entitled "OR BITS" for further discussion. Both of these publications are available upon request from the factory.



TYPICAL PROBE INSTALLATION



COUNTER BORE OR CHAMFER FOR HEADSPACE — PREFERABLY TO A DISTANCE GREATER THAN TO BE MEASURED.

DRAWING NO. 85022A

SHEET 1 of 3

ASSEMBLY PROCEDURE
PG-PL GOVERNOR & SYNCHRONIZING MOTOR

The synchronizer gear motor is mounted to the PG-PL governor housing via a bracket, a coupling and misc. hardware refer to assembly dwg. 99606-C.

Refer to Woodward Governor Co. bulletin No. 36694-B for particular gov. item numbers referenced herein.

Refer to Terry Bill of Material 9-99470 for Terry supplied items.

NOTE: Care must be taken to insure that parts are not lost or damaged during this adaptation of motor to governor.

Read entire procedure and be familiar with Woodward Bulletin noted above.

PROCEDURE

1. Assemble connector on bracket per dwg. 99606-C.

2. Hand assemble bracket, motor & coupling to governor. Locate & mark (4) holes in bracket from motor mounting flange and (4) holes in gov. case from bracket.

3. Drill & tap bracket (4) 1/4-20 holes in bracket.

4. Remove governor cover item 7 by removing 2 attaching bolts item 2.

5. Inspect unit and identify location of major components mentioned below from Woodward bulletin's illustrated exploded views.

6. Remove only items mentioned below. Keep parts covered in a clean place when removed from governor.

7. Remove receiver bracket item 75 and speed setting cylinder item 91 as an assembly with all parts attached as follows:
   (a) Locate item 77 shutdown nuts. Notice and record no. of threads exposed beyond nuts for re-assembly purposes. Remove item 77 nuts (2).
   (b) Remove items 16 and 17 screw & lock washer which connects speed setting plunger assembly item 99 to pilot valve link item 21.
   (c) Remove item 18, 19 & 20 bolts & washers holding down item 75 bracket.
   (d) Remove item 78 and 79 bolts & washers holding down item 91 cylinder.

FILE	
TYPE- STANDARD	
ASSEMBLY PROCEDURE	
SCALE	DATE 9/6/74
THE TERRY STEAM TURBINE CO. WINDSOR CONN. U.S.A.	DRAWN CWS TRACED CHECKED APPROVED
DRAWING NO. 85022A	SHEET 1 of 3

LTR	DESCRIPTION	DATE	APPROVED
REVISIONS			

7. (Continued)

(e) Lift assembly off column item 113 set aside complete assembly.
(f) Lift of 2 packing rings items 76 notice & mark location.
(g) Lift of spring item 80.

8. Remove speed setting plunger assembly and attached parts (consisting of items 97, 98, 99, 100 and 101) from column item 113 as follows:
(a) Remove (2) screws & washers items 94 & 95.
(b) Remove retainer item 96.
(c) Lift out plunger assembly.
(d) Remove spring item 102.

9. Remove column item 113 from power case item 260 by removing (4) bolts & washers item 92 and 93. Disconnect tube item 106 at elbow item 105.

10. Remove bushing gear item 103 from column.

11. Insert clean rag into gov. column pocket to collect chips. Drill and tap (4) 1/4-20 holes located in gov. column(marked in step 2 above).

12. Clean all chips from gov. column. Inspect to insure; all chips. rag and any foreign particles have been removed.

13. Assemble motor bracket to column item 113 using (4) 1/4-20 x 7/8 Allen screws lock washers, loctite and/or RTV in accordance with assembly dwg. 99606-C.

14. Reassemble governor. Follow steps 7 thru 10 in reverse order. Operate knob item 45 to insure free motion of parts.

15. Remove head screw assembly as follows:
(a) Remove item 43 nut, item 44 washer, item 45 knob, item 46 spring (discard spring).
(b) Remove item 36 dial plate and 38 spring.
(c) Position head screw item 47 so pin 39 is vertical and press out roll pin item 39 with a drift pin or punch.
(d) Unscrew "head screw" item 47 from lead screw nut item 57. (Caution - Do not loose item 40 and 41 washers). Remove item 47 head screw from governor.

16. Rework "head screw" item 47 per TST dwg. 96292-B.

FILE	
TYPE- STANDARD	
ASSEMBLY PROCEDURE	
SCALE	DATE 9/6/74
THE TERRY STEAM TURBINE CO. WINDSOR CONN. U.S.A.	DRAWN [signature] TRACED ____ CHECKED [signature] APPROVED ____
DRAWING NO. 85022A	SHEET 2 of 3

LTR	DESCRIPTION	DATE	APPROVED
REVISIONS			

17. Reassemble head screw assembly in reverse order (see step 15). Note - discard item 46 spring.

18. Insert new 3/32 x 5/8 roll pin in new hold in head screw (step 16).

19. Set screw item 55 must be replaced by new 8-32 x 1/2 flat point set screw and screwed into (item 57) nut, so that an equal amount of the screw is protruding thru each side of nut. This screw provides for anti-binding when the head screw is rotated full CW & CCW position. The two 3/32 roll pins should strike this screw at right angles providing positive end stops as the lead screw nut (item 57) travels to each of its extreme positions.

20. Adjust self-locking nut item 43 so that knob slips when end stops (step 19) are reached and does not slip while knob is rotated from full CW to CCW positions.

21. Assemble coupling to knob and motor shaft. Assemble & tighten motor to motor bracket using (4) 1/4-20 x 3/4 hex head bolts & lock washers.

22. Wire motor to power source see applicable wiring diagram 75755A01 (115 VDC) or 75755A02 (115 VAC).

23. Operate motor and verify "slip clutch" at full CW & CCW ends of head screw travel.

24. Connect wiring to connector per applicable wiring diagram (see 22 above).

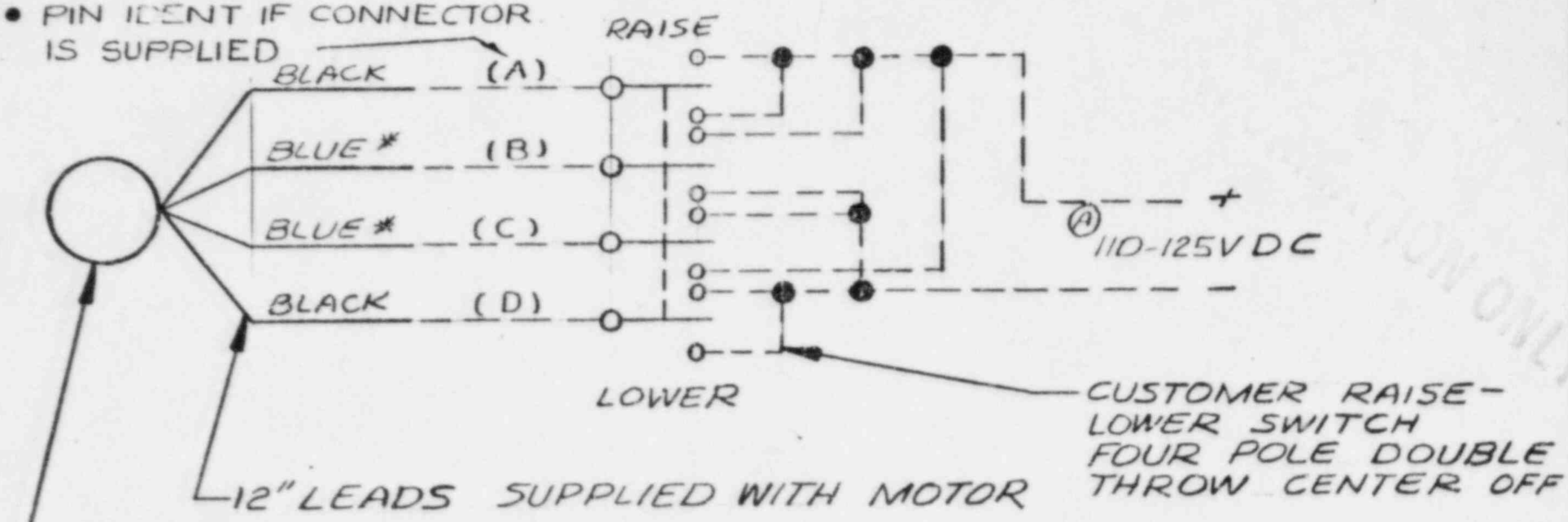
25. Assemble conduit adaptor to plug for customer use or for wiring in conduit system.

26. Any further governor adjustments are to be per Woodward bulletin referenced above.

				FILE
				TYPE- STANDARD
				ASSEMBLY PROCEDURE
				SCALE DATE 9/6/74
				THE TERRY STEAM TURBINE CO. WINDSOR CONN. U.S.A. — DRAWN CWS, TRACED, CHECKED CWS, APPROVED
LTR	DESCRIPTION	DATE	APPROVED	DRAWING NO. 85022A SHEET 3 of 3
REVISIONS				

75755A01

75755A01



(A)
110-125V DC SHUNTWOUND MOTOR BODINE MODEL 439 FRAME (A) NSH-12RH REVERSIBLE 110-125 V DC) .65A START .18 RUN * TO REVERSE DIRECTION OF MOTOR REVERSE BLUE LEADS. • IF CONNECTOR IS SUPPLIED; CONNECTOR IS MS 3100A-18-11P MATING PLUG IS MS 3106A-18-11S

ALL WIRING BY CUSTOMER

NOTE FOR MOTOR MOUNT & COUPLING SEE 91997B & 919606A

WHEN WIRED AS SHOWN; MOTOR SHAFT IS TO CAUSE GOV. KNOB TO ROTATE CW (RAISE SPEED) WHEN SWITCH IS IN "RAISE POSITION.

SYNCRONIZING MOTOR WIRING USED WITH WOODWARD PGPL GOVERNOR

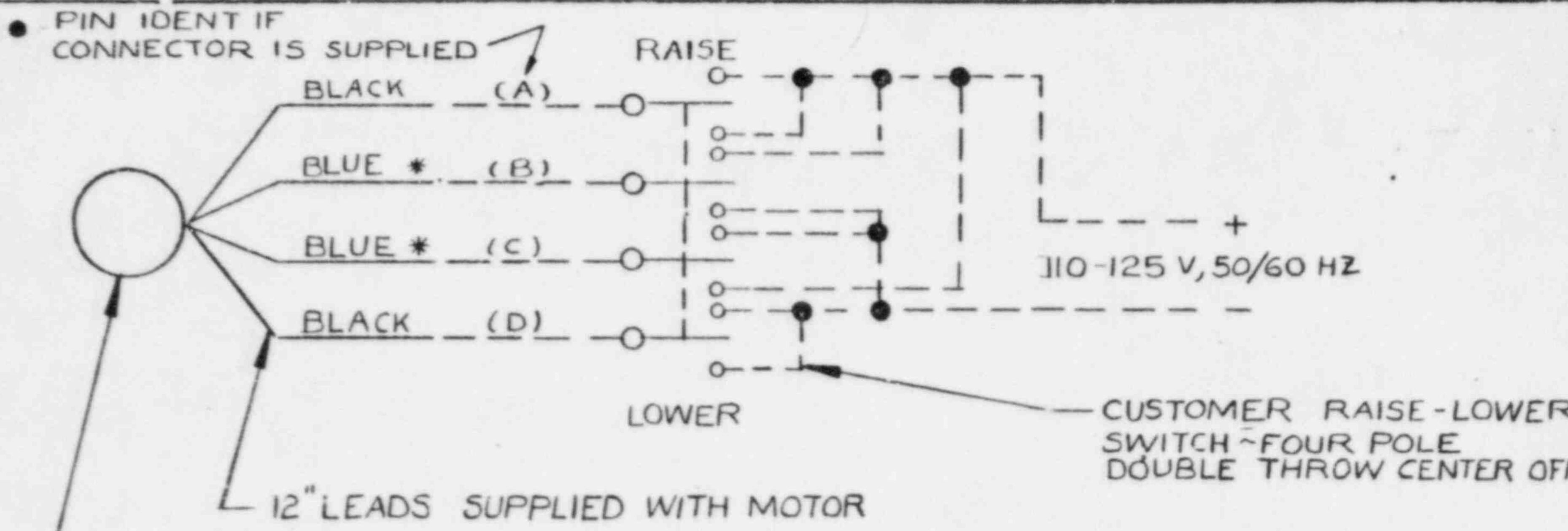
DC APPLICATIONS

THE TERRY STEAM TURBINE CO
WINDSOR, CONN. U.S.A.

DRAWN PSD
TRACED
CHECKED CWS
APPROVED E.H.

73-7144 Chg No 74-5204

75755A01	A	CHG'D 115 V TO 110-125 V DC. T.G.R. 11-19-73	B	ADDED CONNECTOR INFO. SIP 9-4-74		75755A01



110-125 VAC MOTOR
BODINE MODEL 353 FRAME NSI-12 RH
REVERSIBLE APPROX. .65 A START
& APPROX .18 RUN * TO REVERSE
DIRECTION OF MOTOR REVER BLUE
LEADS.

ALL WIRING BY
CUSTOMER

NOTE FOR MOTOR MOUNT &
COUPLING SEE 91997B & 99606 C

- IF SUPPLIED; CONNECTOR IS MS 3100-18-11P

IF SUPPLIED; MATING PLUG IS MS 3106-18-11S
WHEN WIRED AS SHOWN MOTOR SHAFT IS TO
CAUSE GOV. KNOB TO ROTATE CW (RAISE SPEED)
WHEN SWITCH IS IN "RAISE" POSITION

INFORMATION ONLY

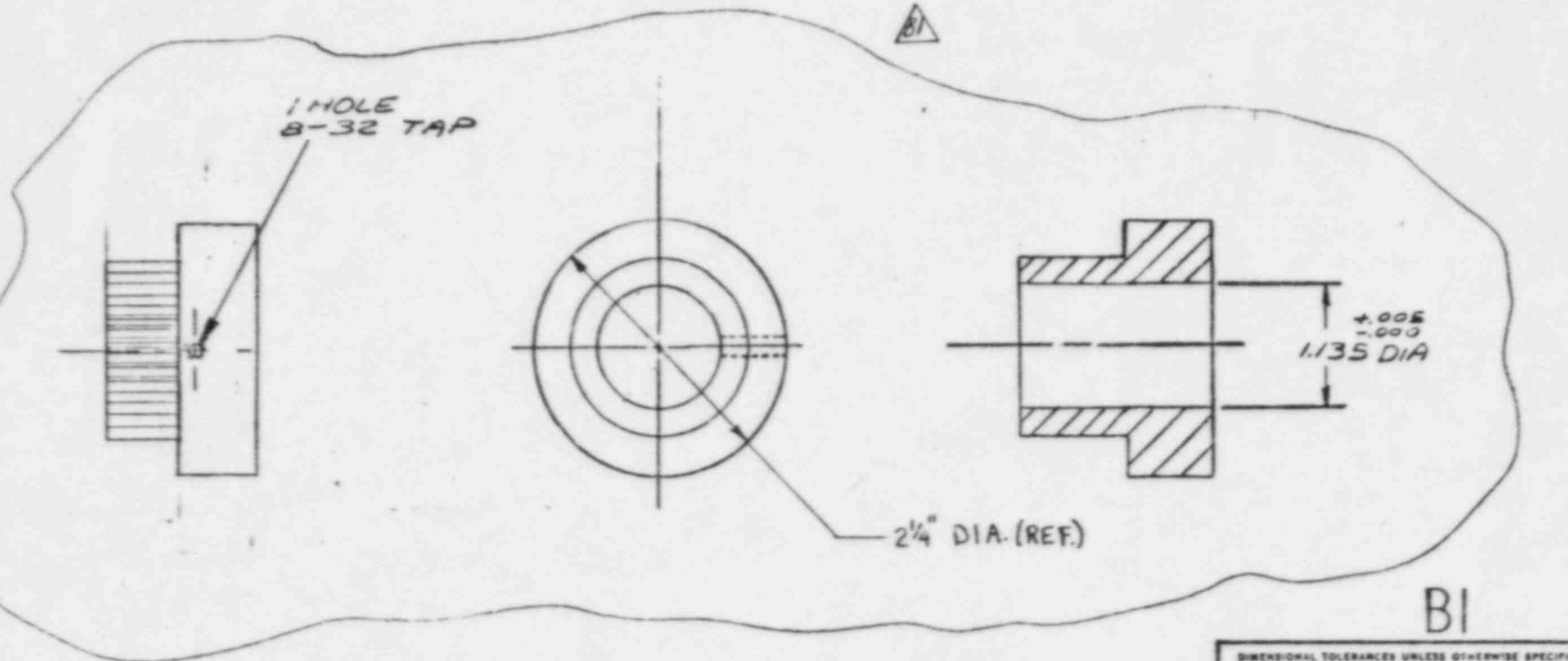
SYNCRONIZING MOTOR WIRING

USED WITH WOODWARD PGPL GOVERNOR
AC (50/60 HZ) APPLICATIONS

THE TERRY STEAM TURBINE CO WINDSOR, CONN. USA	DRAWN SID TRACED CHECKED CWS APPROVED

964668

964668



B1

SEAT, COUPLING HUB

PC# 96466 MAT'L ALUM
MAKE FROM WALDRON NYLON
COUPLING HUB TYPE 7
BORE .501 THRU .876

FACILITY ENGINEERING

APR 11 1983

RECEIVED

INFORMATION ONLY

NO	DATE	REVISION	BY	CHK	D SUP	P.E.	P.ENG	CHAR.
B1	3-21-83	REVISED AS NOTED FOR PCR 81-302 "AS BUILT"	RWB	DTS	PJC	NSW	MF	—

Chg No. 74-5211

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

FILE 37656

TYPE-GSA

COUPLING HALF

SCALE NTS DATE 1-15-74

THE TERRY STEAM TURBINE CO.
WINDSOR CONN. U.S.A.

964668 A

964668

DRA.W.O. 41 S

The Terry Steam Turbine Co.

BILL OF MATERIAL

ITEM NO.	PIECE NO.	PATT. OR FORGING NO.	PART	DWG. NO.	MATERIAL	NO. PER TURB.
1	91997B		MOTOR MOUNT	91997B	EM-102	1
2			WALDRON NYLIGN COUPLING TYPE 4			
			WITH 1.135 BORE ONE END .501 BORE			
			OTHER END. COMPLETE WITH 2 #8-32			
			FLAT POINT SET SCREWS (OPTIONAL)			
			ITEM 2 CAN BE FABRICATED BY			
			REWORK OF STOCK WALDRON TYPE			
			4 COUPLING PER TST DWG 96466B			
			AND 96286B			1
3			MOTOR-BODINE #NSH-12RH MODEL 439			
			125 VDC			1
4			ALLEN CAP SCREW 1/4-20 X 7/8	STD	STL	4
5			HEX HD BOLT	STD	STL	4
6			SPLIT LOCKWASHER 1/4	STD	STL	8
7			SET SCREW FLT. PT 8/32 X 1/4	STD	STL	1
8			SET SCREW FLT PT 8-32 X 1/2	STD	STL	2
9			ROLL PIN 3/32 X 5/8 (MS9048-071)		STL	2
10			ALLEN CAP SCREW 4-40 X 3/8	STD	STL	4
11			SPLIT LOCKWASHER #4	STD	STL	4
12			CONNECTOR MS 3100A-18-11P			1
13			PLUG MS3106A-11S			1
[illegible]	95047A05		CONDUIT ADAPTER	95047A		1

TITLE
REQUIRED PARTS TO ADD MOTOR SYNCHRONIZER TO WOODWARD PG-PL GOVERNOR ASSEMBLE PER 99606C AND 85022A

REV. AND CHG. NO.

BM NO. 9-86321 | BY R.P. | DATE 12/13/74 | TYPE GS | FILE 38587 MF

W.O. 41 5

The Terry Steam Turbine Co.

BILL OF MATERIAL

ITEM NO.	PIECE NO.	PATT. OR FORGING NO.	PART	DWG. NO.	MATERIAL	NO. PER TURB.
1	91997B		MOTOR MOUNT	91997B	EM-102	1
2			WALDRON NYLIGN COUPLING TYPE 4			
			WITH 1.135 BORE ONE END .501 BORE			
			OTHER END. COMPLETE WITH 2			
			#8-32 FLAT POINT SET SCREWS			
			(OPTIONAL) ITEM 2 CAN BE FABRICATED			
			BY REWORK OF STOCK WALDRON TYPE			
			4 COUPLING PER TST DWG 96466B AND			
			96286B			1
3			MOTOR-BODINE #NS1-12RH MODEL			
			353 (115 VAC)			1
4			ALLEN CAP SCREW 1/4-20 X 7/8	STD	STEEL	4
5			HEX HD BOLT 1/4-20 X 3/4	STD	STEEL	4
6			SPLIT LOCKWASHER 1/4	STD	STEEL	8
7			SET SCREW FLT. PT. 8-32 X 1/4	STD	STEEL	1
8			SET SCREW FLT. PT. 8-32 X 1/2	STD	STEEL	2
			ROLL PIN 3/32 X 5/8 (MS9048-071)		STEEL	2

TITLE: PAGE 1 OF 2

REV. AND CHG. NO.: 74-578

BM NO. 9-99470-1 | BY CWS | DATE 9/30/74 | TYPE GS | FILE 38587

M

FORM W.O. 41 S

The Terry Steam Turbine Co.

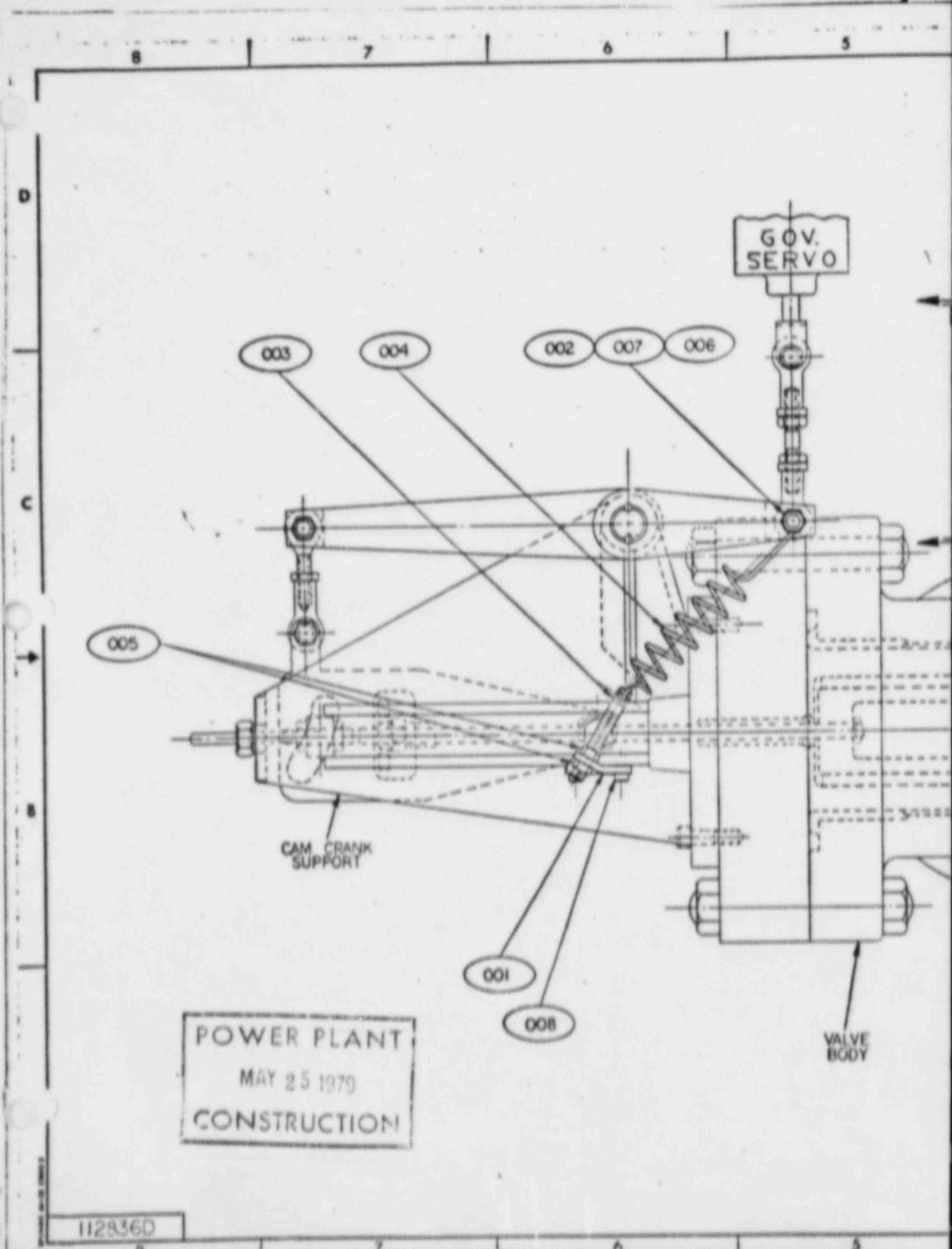
BILL OF MATERIAL

ITEM NO.	PIECE NO.	PATT. OR FORGING NO.	PART	DWG. NO.	MATERIAL	NO. PER TURB.
10			ALLEN CAP SCREW 4-40 X 3/8	STD	STEEL	4
11			SPLIT LOCKWASHER #4	STD	STEEL	4
12			CONNECTOR MS 3100A-18-11P			1
13			PLUG MS3106A-18-11S			1
14	95047A05		CONDUIT ADAPTER	95047A		1

TITLE
REQUIRED PARTS TO ADD MOTOR SYNCHRONIZER TO WOODWARD PG-PL GOVERNOR ASSEMBLE PER 99606C AND 85022A
PAGE 2 OF 2

REV. AND CHG. NO.

BM NO. 9-99470-2 | BY CWS | DATE 9/30/74 | TYPE GS | FILE 38587

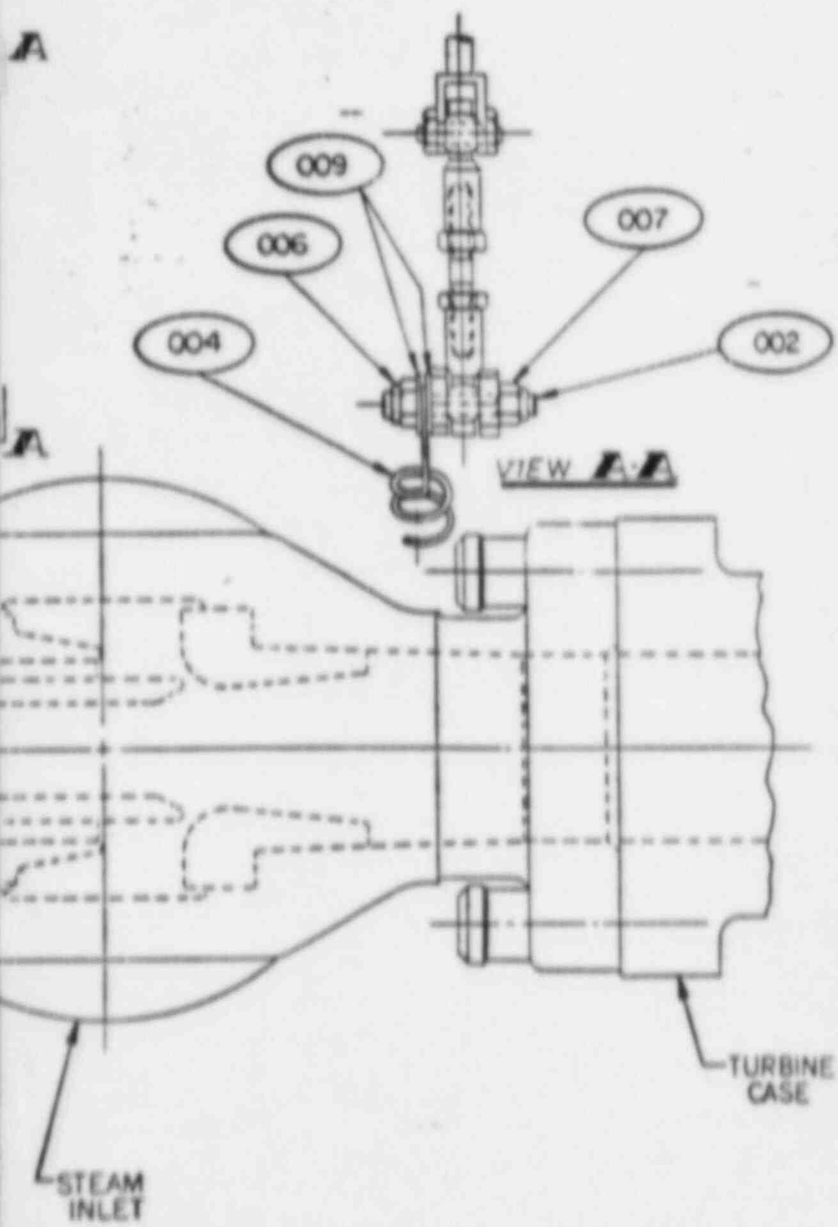


POWER PLANT
MAY 25 1979
CONSTRUCTION

1128360

REVISIONS

SYM	ZONE	DESCRIPTION	DATE	APPROVED	ECN



ITEM	ECE NO.	PART	QTY
009	75344A09	WASHER, 1/2 PLAIN	2
008	75362A08	SCREW, SOC. HD. 5/16-18	2
007	75233A06	NUT, FLEXLOC 3/8	1
006	75233A07	NUT, FLEXLOC 1/2	1
005	75266A05	NUT, JAM 1/2	2
004	32128	SPRING	1
003	33308	STUD, SPRING	1
002	132980	PIN	1
001	112823C	BRACKET, SPRING HOLDER	1

FAMILY NO. 107 LOCATION K52

TERRY CORPORATION

TITLE: ASSY. GOV. LEVER SPRING

STANDARD PRACTICE

SCALE HALF DATE 11/3/77

DRAWN SE. CHECKED APPROVED

ENGINEERING APPROVAL

SIGNED [signature] DATE 1/3/77

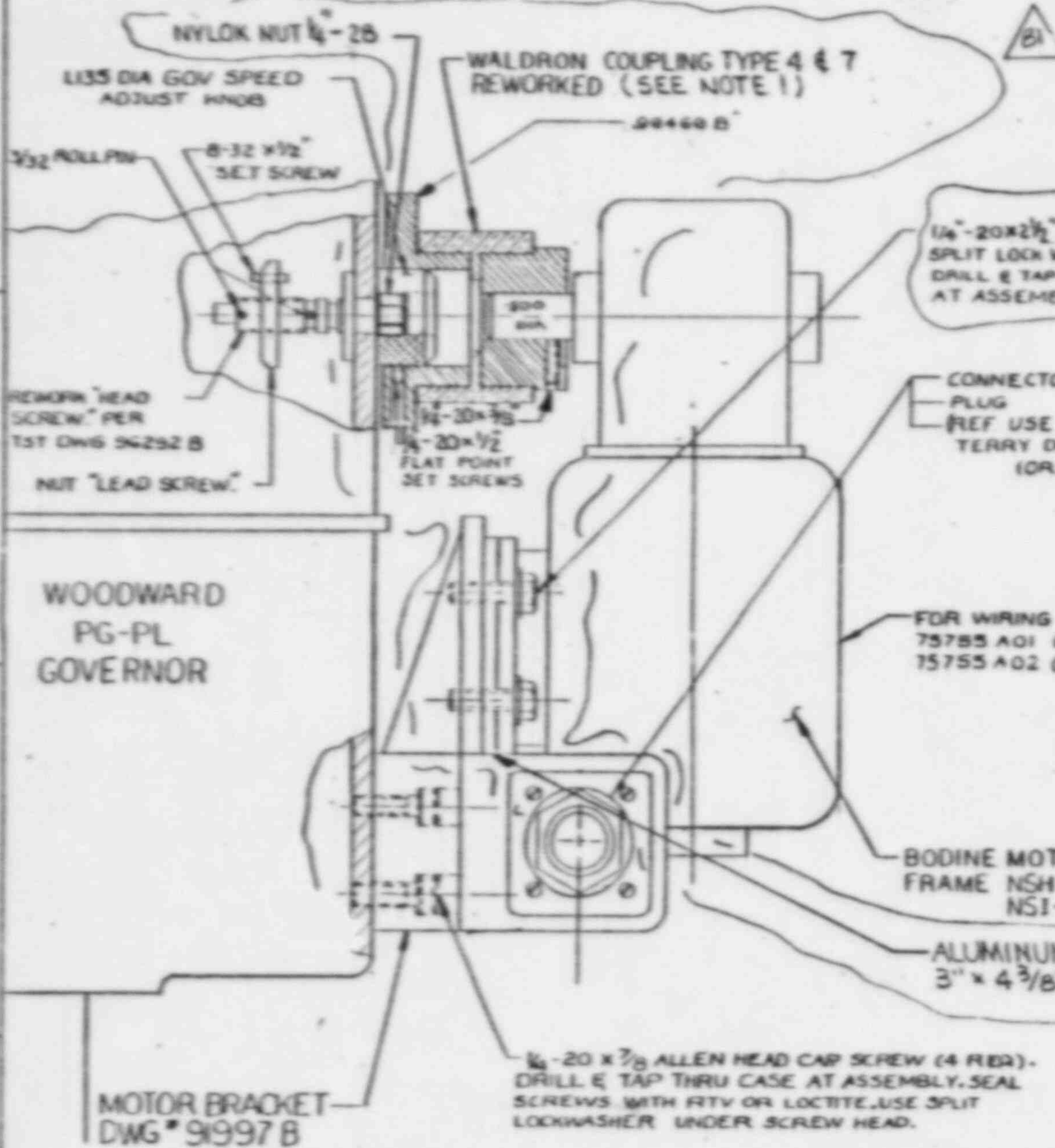
TYPE GS, N REF. DWG. NO.

DRAWING NO. 1128360 SHEET 1 OF 1

8507300089-12

USE WITH HUB CITY

SYM	ZONE	DESCRIPTION	DATE	APPROVED
A		ADDED MODEL NO AND PC NO TO MOTOR CALLOUT		



NOTES-

1. STOCK WALDRON COUPLING SHOULD BE REWORKED PER 96466 B.
2. REWORK PG-PL GOVERNOR PER TST INSTRUCTIONS DWG NO 85022A
3. GOVERNOR SPEED CAN BE CHANGED FROM MIN. TO MAX. SETTING IN APPROX. 14 SECONDS USING SYNC. MOTOR.

B1

B1	3-2-83	REVISED AS NOTED FOR FCR 81-302 "AS BUILT"	RHB	DCS	PJC	MSW	
	DATE	REVISION	BY	CHK			

TYPE- STANDARD

GOVERNOR & SYNC MOTOR ASSEMBLY

SCALE NONE DATE 7-17-74

THE TERRY STEAM TURBINE CO
WINDSOR, CONN. U.S.A.

99606 C

99606 C

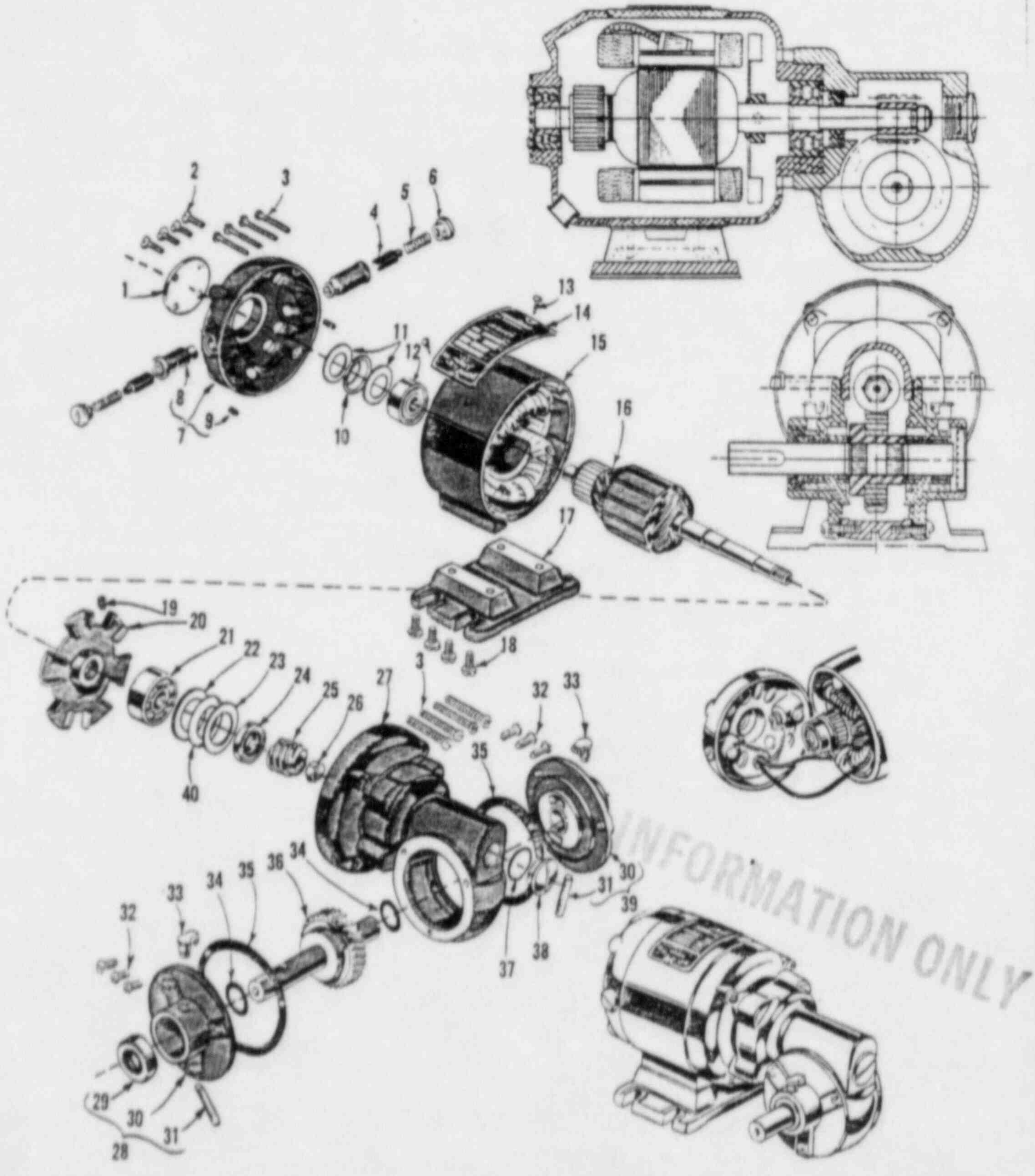
BODINE

REPLACEMENT PARTS

N-IRH FRAMES
BALL BEARING DIRECT CURRENT
TYPE-NSH-SHUNT
NCO-COMPOUND

SECTION	3010 B
PAGE	9

862 FORM-1623-44



Replacement Parts

Bodine Electric Co.
Chicago 18, Ill.

Item No.	Description Of Part	Qty. Req'd.	Part No.	Price
1	PLATE, BALL BEARING END (CLOSED)	1	N-163	FOR PRICES, SEE SECTION 5000
2	SCREW, BALL BEARING END PLATE	4	N-198	
3	SCREW, SHIELD	8	S-364	
4	BRUSH	2	See Note (1) Below	
5	SPRING, BRUSH	2	See Note (1) Below	
6	SCREW, BRUSHHOLDER CAP	2	N-2813	
7	SHIELD, FRONT ASSEMBLY (VENTILATED)	1	N-2888	
7	SHIELD, FRONT ASSEMBLY (ENCLOSED)	1	N-2889	
8	BRUSHHOLDER	2	N-2874	
9	SCREW, BRUSHHOLDER SET	2	N-1598	
10	WASHER, SPRING	1	N-2966	
11	WASHER, SPACING	As Req'd.	N-162	
12	BEARING, BALL	1	N-2207LG-2	
13	PIN, NAMEPLATE	2	SA-319	
14	NAMEPLATE	1	N-1170	
15	RING & FIELD ASSEMBLY (WOUND COMPLETE)	1	See Note (1) Below	
16	ARMATURE, WOUND COMPLETE	1	See Note (1) Below	
17	BASE	1	N-467	
18	SCREW, BASE	4	S-246-1/2	
19	SCREW, FAN SET	1	N-1364	
20	FAN (VENTILATED MOTOR ONLY)	1	N-813	
21	BEARING, BALL	1	N-2208LG-2	
22	WASHER, SPACING (.010" THICK)	As Req'd.	N-403	
23	WASHER, SPACING (.032" THICK)	As Req'd.	N-903	
24	SEAL, OIL (WHEN REQUIRED)	1	N-964	
25	WORM	1	See Note (1) Below	
26	NUT, WORM LOCK	1	N-2700	
27	HOUSING, GEAR & REAR SHIELD ASSEMBLY (VENTILATED)	1	N-797	
27	HOUSING, GEAR & REAR SHIELD ASSEMBLY (ENCLOSED)	1	N-796	
28	ENDSHIELD ASSEMBLY, GEAR HOUSING (EXTENSION END)	1	N-2594	
29	SEAL, GEAR HOUSING ENDSHIELD	1	N-2691	
30	ENDSHIELD, GEAR HOUSING	2	N-2690	
31	WICK, FELT	2	N-2693	
32	SCREW, GEAR HOUSING ENDSHIELD	6	S-210	
33	OILER, GEAR HOUSING ENDSHIELD	2	N-776	
34	WASHER, SPACING	As Req'd.	SA-321	
35	GASKET, GEAR HOUSING ENDSHIELD	2	N-2771	
36	GEAR & DRIVE SHAFT	1	See Note (1) Below	
37	GASKET, GEAR HOUSING PLUG	1	N-1006	
38	PLUG, GEAR HOUSING	1	N-167	
39	ENDSHIELD ASSEMBLY, GEAR HOUSING (NON-EXTENSION END)	1	N-2695	
40	WASHER, SPRING	1	N-2967	

IMPORTANT: PLEASE GIVE MOTOR SERIAL NUMBER ON ALL ORDERS FOR PARTS.

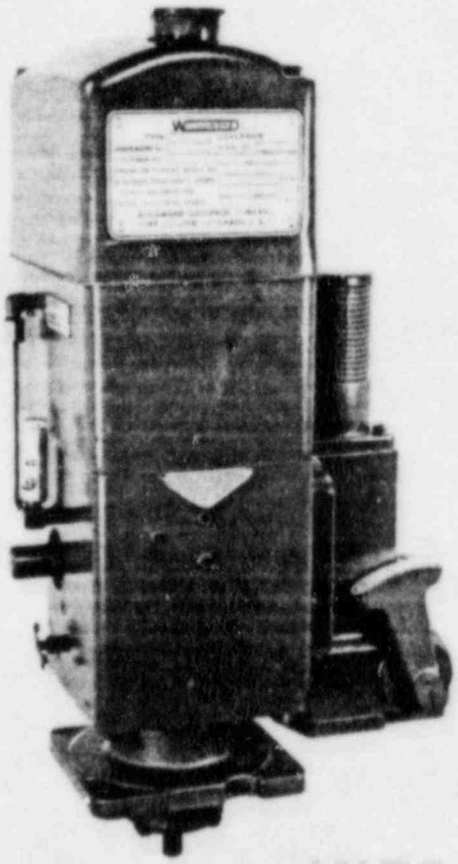
NOTE:
(1) THESE PARTS VARY WITH VOLTAGE, H. P. AND SPEED, THEREFORE, PLEASE GIVE FULL NAMEPLATE DATA, INCLUDING SERIAL NUMBER. WOUND ARMATURES AND FIELD WINDING ASSEMBLIES ARE NOT NORMALLY CARRIED IN STOCK.

WOODWARD®

BULLETIN 36694D

PG—PL GOVERNORS

(REPLACES BULLETIN 36012)



WOODWARD GOVERNOR COMPANY

ENGINE & TURBINE CONTROLS DIVISION

FT. COLLINS, COLORADO, U. S. A.

WOODWARD ®

PG—PL GOVERNOR

OPERATING & SERVICE MANUAL

BULLETIN 36694D

WOODWARD GOVERNOR COMPANY
ENGINE & TURBINE CONTROLS DIVISION
FT. COLLINS, COLORADO, U. S. A.

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PG-PL GOVERNOR

SECTION I/GENERAL INFORMATION

INTRODUCTION

This bulletin provides description, operation, installation, adjustment, maintenance, and replacement parts information for the PG-PL governor.

The basic PG governor (pressure compensated governor) with a pneumatic speed setting mechanism (direct or reverse) and a short column that is used primarily for controlling engine or turbine speed has been assigned the designation PG-PL governor. This PG governor was first used on pipe lines, hence the PL, but has since found wide acceptance on all types of diesel engines, gas engines, steam turbines driving pumps and compressors, and many special applications. The PG-PL governor includes a pneumatic speed setting mechanism, standard short column, standard base assembly, and 12 foot-pound power cylinder assembly. The repair manual for the PG-A governor (similar to the PG-PL in speed setting, but with a long column to house various options for load control) is bulletin 36699.

All PG governors have the same basic components regardless of how simple or complex the complete control may be. The following components, found in each PG-PL governor, are sufficient to enable the governor to maintain a constant engine speed as long as the load does not exceed engine capacity:

1. an oil pump, storage area for oil under pressure, and a relief valve by which maximum oil pressure may be limited;
2. a centrifugal flyweight head-pilot valve assembly which controls flow of oil to and from the governor cylinder assembly;
3. a power cylinder assembly--sometimes referred to as a servomotor--which positions the fuel racks, fuel valve, or steam valve of the engine or turbine;
4. a compensating system for stability of the governed system;
5. a pneumatic speed setting mechanism for adjusting the governor speed setting.

A cutaway view of the PG-PL governor is shown in figure 1.

DESCRIPTION

The governor controls engine or turbine speed by controlling the amount of fuel or steam supplied to the engine or turbine. Speed control is isochronous, i.e., the governor will maintain constant engine or turbine steady state speed, within the capacity of the unit, regardless of load.

The standard operating oil pressure for PG governors is 100 psi. However, with appropriate modifications the oil pressure may be increased, thus increasing the work capacity of the power cylinder assembly. Table 1 lists typical governor oil pressures versus power cylinder work capacities.

Table 1. Governor Oil Pressure Versus Power Cylinder Work Capacities (Typical)

Governor Operating Oil Pressure (PSI)	Power Cyl. Work Capacities in Ft-Lb		
	12	17	29
100 (std.)	12	17	29
130		22	38
200		34	58

An air pressure signal from a pneumatic air transmitter or controller supplies air to the governor speed setting mechanism. The governor will control the engine at a definite speed for each air pressure. The most common air pressure range for the governor is from 3-15 psi. Normal minimum control air pressure is 3 psi; however, a minimum of 1 psi and a maximum of 100 psi can be accommodated. The governor speed range normally falls between 250-1000 rpm, but a low speed of 200 rpm or a high speed of 1600 rpm can be obtained. Contact Woodward Governor Company for recommended control air pressure to governor speed setting relationship to meet the requirements of the particular installation.

The pneumatic speed setting mechanism (direct or reverse) is a bellows type mechanism and is standard equipment on all PG-PL governors now manufactured by Woodward. The speed setting unit is an accurate durable mechanism which

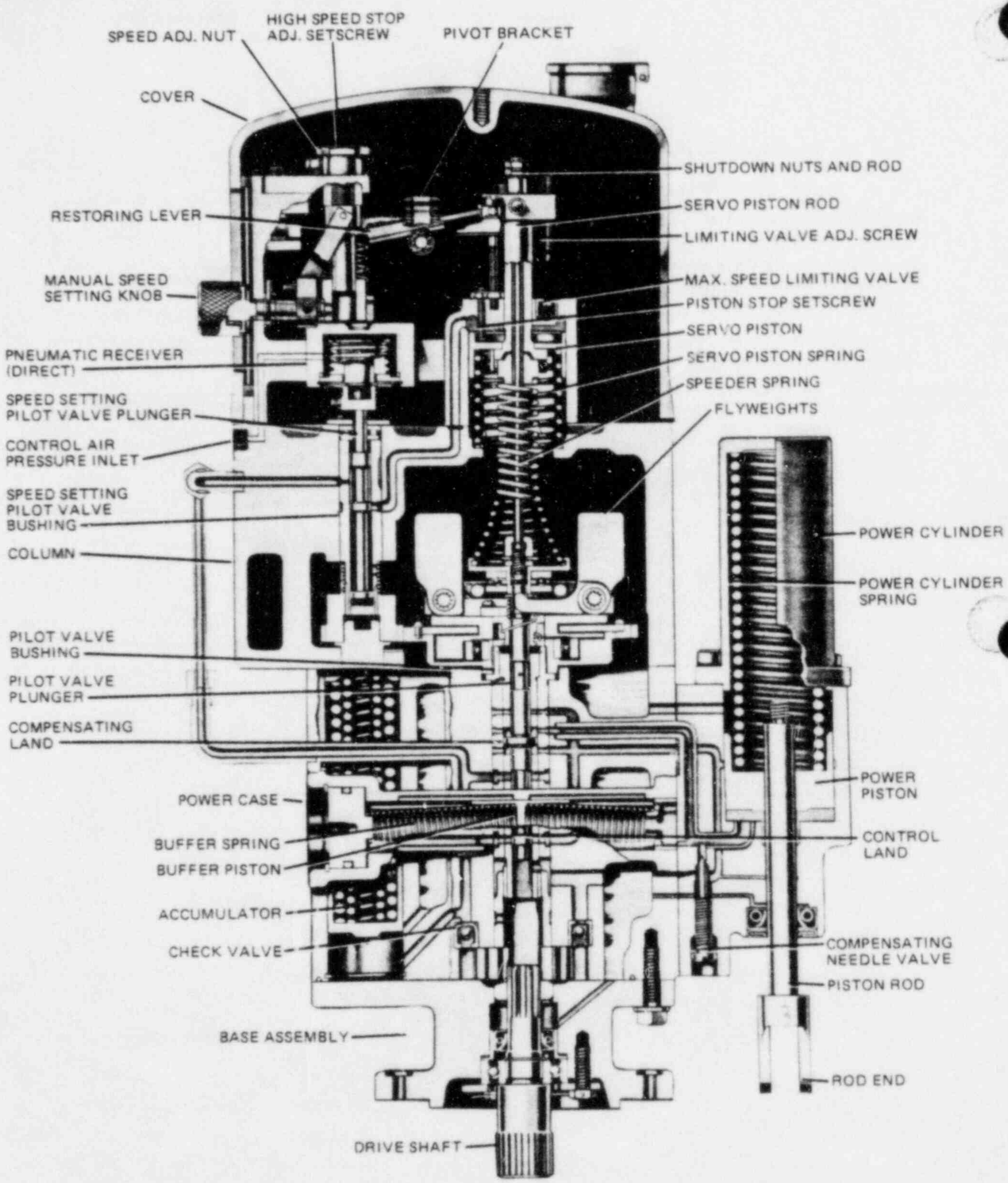

Figure 1. Cutaway View PG-PL Governor

virtually eliminates the hysteresis loops encountered with less sensitive pneumatic speed setting elements. (A hysteresis loop is a plot of the speeds obtained at various control signal pressures; one portion is recorded as speed setting signals are being increased, the other portion as the signals are being decreased.) Bellows type speed setting provides a definite, accurate relationship between speed and speed signal.

The speed setting mechanism is available for use with air input signals of varying range and magnitude (e.g. 3 to 15 psi, 20 to 70 psi, etc.). Depending upon the exact configuration installed in the governor, speeds may be adjusted up to a 5 to 1 range. The speed setting mechanism can be furnished to increase governor speed setting for an increase in control air pressure (direct type) or to increase governor speed setting for a decrease in control air pressure (reverse type).

The manual speed setting knob permits manual operation when the air pressure signal is not available.

Diaphragm receiver models of the governors are obsolete and no longer manufactured as a complete unit. However, replacement parts for these units are available and detail information on the units is found at the end of this manual.

As is the case with any governor of any type, it is essential that the engine or turbine be equipped with a separate overspeed shutdown device to prevent runaway in the event of failure of the governor, the mechanism which drives it, or the control it operates.

SECTION II/INSTALLATION AND ADJUSTMENT

INSTALLATION

Refer to figure 8 for complete physical dimensions of the governor. Adequate clearance must be provided for installation, removal, and servicing. At all times, use care in handling the governor; be particularly careful to avoid striking the drive shaft. Do not drop or rest the governor on its drive shaft. Such treatment could damage the governor drive shaft, drive shaft bearing, or governor oil pump gears.

When the governor is installed on the engine or turbine, a gasket should be used between the mounting pad and the governor base. The governor should be mounted squarely and the drive connection properly aligned.

If the governor is equipped with a serrated or splined drive shaft, it should slip into the internal serrations or splines of the drive freely. If a keyed type governor drive shaft is used, the gear must slip on the shaft freely and should be checked to insure that it meshes properly. The gears should run freely without binding or excessive backlash. Irregularities caused by uneven gear teeth, shaft runout, etc., will result in erratic governing and shorten governor life.

LINKAGE ADJUSTMENT

The linkage from the governor to the fuel or steam control should be properly aligned. Any friction or lost motion should be eliminated. Unless the engine or turbine manufacturer has given special instructions, the linkage should be adjusted so that when the governor power piston is at the end of its stroke in the "OFF" direction, the gas or steam valve, or diesel fuel pumps will just be closed.

When the governor has been properly mounted and the linkage connections completed, make the air connections to the manual or automatic air controller.

OIL SPECIFICATIONS

Information on oils for use in hydraulic governors is available in bulletin 25007. Use SAE 20 or 30 oil for ordinary temperature conditions. If governor operating temperatures are extremely hot, use SAE 40 to 50; if extremely cold, use SAE 10. In most cases, the same oil that is used in the engine or turbine may be used in the governor.

Keep the governor oil level between the lines on the glass of the oil level gauge when the engine or turbine is running. The oil should never be above the line where the case and column castings meet. Oil above this level will be churned into foam by rotation of the flyweight head. The governor can run safely with the oil level quite low in the gauge glass.

PURGING AIR FROM GOVERNOR AND NEEDLE VALVE ADJUSTMENT

When the engine or turbine is started for the first time, or after the governor has been drained of oil, cleaned and refilled with oil, any trapped air in the governor must be removed. Use the following steps to remove any trapped air.

1. Start the engine or turbine and run it at idle for at least 15 minutes to allow the governor and engine to warm up.

2. Add oil to the governor to maintain the oil level between oil level lines on the gauge.

3. Back off needle valve (ccw) several turns to allow the governor to hunt. Close the needle valve (cw) until hunting just stops. If the needle valve closes completely before hunting stops proceed with the next step.

   The final needle valve setting should be between 1/16 to 2 turns open. Check this once stability is established.

4. If hunting has not stopped open the needle valve several turns to allow the governor to hunt for about 5 minutes using as much terminal shaft travel as possible.

5. Repeat step 3. If the governor continues to hunt proceed with the following.

CAUTION

The vent screw is under pressure. Do not remove while operating the governor.

6. Loosen the vent screw (refer to figure 8), on the side of the governor case, enough to establish an oil leak Bleed until the air bubbles stop, about 1/2 cup of o

7. Tighten the vent screw and refill the governor with oil. If the vent screw leaks after tightening, shut down the engine and remove the plug. Coat the plug with a good grade of pipe sealant, replace the plug and tighten it.

8. Repeat step 3.

9. Run at normal maximum operating speed and check governor stability. The needle valve may have to be closed slightly to achieve stability.

With preloaded buffer springs (optional equipment), the needle valve should not be more than 1/16 turn open for smooth operation. The needle valve must never be closed tight, as the governor cannot operate satisfactorily when this condition exists.

On some installations, opening the needle valve will not cause the engine or turbine to hunt. In such cases, bleed the air from the governor by disturbing engine or turbine speed to cause the governor to move through full stroke in both directions a sufficient number of times to force out all trapped air.

After the needle valve is adjusted correctly for the engine, it should not be necessary to change the setting except for a large permanent temperature change affecting the viscosity of the governor oil.

SPEED ADJUSTMENT

The pneumatic speed setting mechanism furnished with the governor is either (1) a direct type which increases the governor speed setting as the control air pressure signal increases or (2) a reverse type which increases governor speed setting as the control air pressure signal decreases. Perform the following procedures as applicable to set the maximum and minimum operating speed of the governor. See figures 1 and 2.

DIRECT SPEED SETTING MECHANISM

1. Set the manual speed adjusting knob to the minimum speed position (fully counterclockwise until clutch slips).

2. Adjust the high speed adjusting setscrew as required until upper end of screw is flush with top of speed setting screw.

3. Apply specified minimum control air pressure signal to the unit; adjust the speed adjusting nut as required to obtain corresponding specified minimum speed (clockwise to decrease); be sure the pneumatic low speed adjusting screw does not touch the restoring lever at this time.

4. Adjust limiting valve adjusting screw as required so that it does not unseat the maximum speed limiting valve as speed is increased. Set governor speed range to control air pressure range as follows:

a. Slowly increase control air pressure signal to maximum. Be sure engine does not exceed specified maximum speed.

b. If specified maximum speed is obtained before control air pressure signal is increased to maximum, adjust the pivot bracket to move the ball bearing pivot toward the speed setting servo.

c. If specified maximum speed is not obtained with maximum control air pressure signal, adjust the pivot bracket to move the ball bearing pivot away from the speed setting servo.

d. Adjust the pivot bracket as follows: Loosen the socket head screw in top of the pivot bracket; loosen knurled nut on appropriate side of bracket and turn opposite knurled nut to move bracket; tighten screw and knurled nuts.

5. Repeat steps 3 and 4 above until specified minimum speed is obtained with minimum control air pressure and specified maximum speed is obtained with maximum control air pressure. Speed should begin to increase as the control air pressure begins to increase from minimum.

6. Apply maximum control air pressure for maximum speed. Adjust the limiting valve adjusting screw so that it just contacts the ball in the maximum speed limiting valve. Increase control air pressure slightly above specified maximum; the maximum speed limiting valve should open prior to engine reaching 5 rpm above specified maximum speed. Readjust screw as necessary.

7. Apply minimum control air pressure signal for minimum engine speed. Perform step a or b as applicable.

a. If engine is to go to low speed upon loss of control air pressure signal to the governor, set the pneumatic low speed adjusting screw to just contact the stop pin in the restoring lever with the engine running at low speed. Shutdown nuts are usually omitted on governors which are arranged to go to low speed upon loss of control air pressure. If nuts are included but not used, lower nut should be a minimum of 1/32-inch above the speed setting piston rod with engine running at low speed.

b. If engine is to shut down upon loss of control air pressure signal to the governor:

(1) Lift up on the shutdown rod to take out any slack or lost motion; do not lift the rod so far as to cause the engine speed to drop. While holding the rod up, position the lower shutdown nut 1/32-inch above the top of the speed setting servo piston rod and lock in position with upper nut.

(2) Turn the piston stop setscrew down until it touches the speed setting piston then turn the screw counterclockwise 2 turns and lock in position with nut. This adjustment limits the upper movement of the piston when the engine is shut down, and it minimizes the cranking required when the engine is restarted.

(3) Adjust the pneumatic low speed adjusting screw so that it is 0.040-0.050 inch below the stop pin in the restoring lever. Turn off control air pressure signal to the governor (engine will shut down). Adjust the adjusting screw so that it is from 0.002 to 0.005 inch below the stop pin in the restoring lever.

8. With control air pressure signal removed (engine does not go to shutdown with loss of control air pressure signal), turn the manual speed adjusting knob clockwise to increase engine speed to maximum. Turn the high speed adjusting setscrew in until it just touches the high speed stop pin (this adjustment stops the downward movement of the speed adjusting nut at high speed).

REVERSE SPEED SETTING MECHANISM

1. Set the manual speed adjusting knob to the minimum speed position (fully counterclockwise until clutch slips).

2. Adjust the speed adjusting nut so that the speed setting screw protrudes approximately 1/4-inch above the nut.

3. Adjust the high speed adjusting setscrew as required until screw is flush with the top of speed setting screw.

4. Adjust the limiting valve adjusting screw as required so that it does not unseat the maximum speed limiting valve as speed is increased. Apply minimum control air pressure signal to the governor (pressure at which specified maximum engine speed is to be obtained). Be careful that engine does not exceed specified maximum speed.

5. Turn the manual speed adjusting knob clockwise to increase engine speed to specified maximum. Turn the high speed adjusting setscrew in until it just touches the high speed stop pin. If screw is turned down too far, speed will decrease.

If the specified maximum speed is not obtained with the manual speed adjusting knob fully clockwise, turn the knob approximately 2 turns counterclockwise, back out high speed stop adjusting setscrew a few turns, then turn speed adjusting nut counterclockwise until specified maximum speed is obtained. Turn high speed adjusting setscrew down until it just touches the high speed stop pin (if the screw is turned down too far, speed will decrease). Turning the speed adjusting knob fully clockwise should not increase speed beyond the specified maximum.

6. Slowly increase control air pressure signal until specified minimum speed is obtained. The pneumatic low speed adjusting screw should not touch the stop pin in the restoring lever and the piston stop setscrew should not stop the speed setting piston as it moves up to decrease speed.

If specified minimum speed is obtained before the control air pressure signal is increased to specified maximum, adjust the pivot bracket to move the ball bearing pivot toward the speed setting cylinder.

Adjust the adjustable pivot bracket as follows: Loosen the socket head screw in top of pivot bracket; loosen knurled nut on appropriate side of pivot bracket and turn opposite knurled nut to move the pivot bracket; tighten screw and knurled nuts.

7. Repeat steps 4, 5, and 6 above until specified minimum speed is obtained with maximum control air pressure signal and specified maximum speed is obtained with specified minimum control air pressure signal. Insure engine speed begins to increase as the control air pressure signal begins to decrease from maximum.

8. After setting speeds pneumatically, apply minimum control air pressure signal (governor will go to maximum speed setting). Turn manual speed adjusting knob counterclockwise until specified minimum speed is obtained. Alternately turn speed adjusting nut 1/2 turn counterclockwise (increasing speed) and adjusting knob

counterclockwise (decreasing speed) until adjusting knob is fully counterclockwise. Turn off control air supply (speed will rise slightly). Adjust speed adjusting nut to obtain specified minimum speed.

If adjusting nut is turned fully counterclockwise without reaching the specified minimum speed, turn off control air supply (speed will rise slightly). Adjust speed adjusting nut to obtain specified minimum speed.

9. With the engine operating at specified minimum speed, turn the piston stop setscrew down until it just touches the top of the speed setting piston; then turn the screw 2 turns counterclockwise; lock in position with locknut. This adjustment limits the upward movement of the piston when the engine is shut down, and it minimizes the cranking required when engine is restarted.

10. If shutdown nuts are used, lift up on the shutdown rod to take out any slack or lost motion; do not lift the rod so far as to cause the engine speed to drop. While holding the rod up, position the lower shutdown nut 1/32-inch above the top of the speed setting servo piston rod and lock in position with upper nut.

11. With the control air pressure signal turned off, turn the manual speed adjusting knob clockwise to increase engine speed to maximum. Adjust the limiting valve adjusting screw so that it just contacts the ball in the maximum speed limiting valve. Increase engine speed slightly above the specified maximum; the maximum speed limiting valve should open prior to engine reaching 5 rpm above maximum speed. Readjust screw as necessary.

12. Turn the manual speed adjusting knob fully counterclockwise and apply maximum control air pressure to the governor. Adjust the pneumatic low speed adjusting screw to just contact the stop pin in the restoring lever with the engine running at low speed.

SECTION III/PRINCIPLES OF OPERATION

INTRODUCTION

The sectional view of the PG-PL governor (see figure 1) serves to indicate the relative position of the various governor components in the complete assembly. The connecting oil passages between parts are not necessarily in their correct location, but are simplified to facilitate their location. The lower part of the governor consists of the base and power case and the basic components of the hydraulic PG isochronous governor, which functions to maintain a constant engine speed by controlling the fuel supplied to the engine. The upper part of the governor consists of the column, cover, and related parts; it also consists of the pneumatic speed setting mechanism, and optional shutdown and protective devices where applicable.

DESCRIPTION OF OPERATION

The schematic diagram (figure 2) illustrates the essential parts of the governor and speed setting mechanism which are required to regulate fuel and control engine speed.

Speed adjusting in the governor is effected by controlling the position of the speed setting servo piston. Movement of the servo piston to a higher or lower speed setting is obtained by admitting or draining pressure oil to or from the area above the servo piston.

The flow of governor oil to or from the area above the servo piston is controlled by the speed setting pilot valve plunger - contained in a rotating bushing - which is actuated by a controlled air pressure signal or by a manual control knob.

After each speed setting change, a restoring lever connected between the servo piston rod and speed setting pilot valve plunger returns the plunger to the closed port position, stopping the flow of oil to or from the area above the servo piston, thus holding the piston at the position for the particular speed setting of the governor.

The governor drive shaft passes through the governor base into the pump drive gear, which is direct connected to the rotating pilot valve bushing. The flyweight head is secured to the upper end of the pilot valve bushing, thus providing a direct drive from the engine to the flyweights. At any speed setting of the governor, when the engine is on speed, the centrifugal force of the flyweights will balance the opposing force of the speeder spring with the flyweights in the vertical position, and the control land of the pilot valve plunger will be covering the regulating ports in the rotating pilot valve bushing.

Pressure seal grooves are supplied with pressure oil through the regulating port to prevent the oil trapped between the power piston and the buffer piston from leaking past the power piston, power piston rod and pilot valve stem. To make up leakage of the seal oil and hold the power piston in a steady state position against the power spring - when the engine is on speed with a steady load - the pilot valve plunger will be below center enough to supply the required amount of oil through the regulating port.

The governor oil pump supplies pressure oil to the rotating pilot valve bushing, speed setting pilot valve bushing, pressure seal grooves, and to the accumulators, with excess oil (at maximum pressure) bypassing from the accumulators to the governor sump. Duplicate suction and discharge ball check valves at the pump permit rotation of the governor in either direction.

The pilot valve plunger moves up and down in the rotating pilot valve bushing to control the flow of oil to or from the power cylinder assembly. When the pilot valve plunger is centered (i.e., the control land of the plunger exactly covers the control port of the bushing), no oil flows to or from the power cylinder assembly.

The greater of two forces moves the pilot valve plunger up or down. The centrifugal force developed by the rotating flyweights is translated into an upward force which tends to

the plunger. The centrifugal force is opposed by the nward force of the speeder spring. When the opposing ces are equal, the pilot valve plunger is stationary.

With the pilot valve plunger centered and the engine running on-speed, a change in either of the two forces will move the plunger from its centered position. The plunger will be lowered (1) if the governor speed setting is unchanged but an additional load slows the engine and governor (thereby decreasing the centrifugal force developed by rotating flyweights) or (2) if the engine speed is unchanged but the speeder spring force is increased to raise the governor speed setting. Similarly, the pilot valve plunger will be raised (1) if the governor spee setting is unchanged but load is removed from the engine causing an increase in engine and governor speed (and ence, an increase in the centrifugal force developed by t e rotating flyweights), or (2) if the engine speed is unchanged but the speeder spring force is reduced to lower the governor speed setting.

The thrust bearing atop the ballarm toes permits the pilot valve bushing to rotate while the pilot valve plunger does not rotate. In this way, static friction between the bushing and plunger is minimized.

are several styles of flyweight head assemblies ble. The exact model used in any one governor depends upon the application.

A "solid" head assembly is used in governors on prime movers which afford a smooth drive to the governor.

"Spring driven" and "spring driven, oil damped" head assemblies are used to filter torsional vibrations which may be imparted to the governor by the drive from the engine. (These torsional vibrations may originate from a source other than the drive itself but reach the governor through the drive connection). Unless minimized or eliminated, the flyweight head will sense these torsional vibrations as speed changes and continually adjust the fuel valve or racks in an attempt to maintain a constant speed.

Movements of the power piston are transmitted by the piston rod to the engine fuel linkage. Regulated oil pressure under the power piston is used to raise the power piston -- to increase fuel -- and the power spring above the power piston is used to lower the power piston to decrease fuel.

Located between the pilot valve bushing and the power piston is the buffer compensating system, consisting of the r cylinder and piston, the buffer springs, and the ensating needle valve. Lowering the pilot valve plunger permits a flow of pressure oil from the pilo into the buffer system and power cylind power piston and increase fuel. Raising results in a flow of oil from the power cyli system to the governor sump, and the pow the power piston down to decrease fuel to th

This flow of oil in the buffer system -- in e carries the buffer piston in the dire compressing one of the buffer springs an other. This action creates a slight diff pressures of the oil on opposite sides of th with the higher pressure on the side opp which is compressed. These differential o transmitted to the areas above and below th land on the pilot valve plunger, producin downward force on the compensating land re-centering the pilot valve plunger wh correction is made.

The vertical position of the flyweights with of the pilot valve covering the regulating po the engine is on-speed.

THEORY OF OPERATION

See figure 2 for the schematic diagram components of the basic governor and mechanism and the relative positions they engine is operating on-speed under steady- Differences may exist in the actual design components from one governor to another, of operation is the same in each.

The schematic arrangement of the "direc mechanism (governor speed increases as pressure signal increases) is incorporated of figure 2. The inset shown on figu "reverse" speed setting (governor speed control air pressure signal increases) version

The following theory of operation desc speed setting mechanism. The sequence of in the governor take place more or less i manner, rather than step by step as following paragraphs.

SPEED INCREASE

An increase in the control air pressu pneumatic receiver assembly is sensed Through a mechanical connection to the s valve plunger, the bellows movement -- c

t valve bushing
er to raise the
the pilot valve
nder and buffer
r spring moves
e engine.

her direction --
tion of flow,
d releasing the
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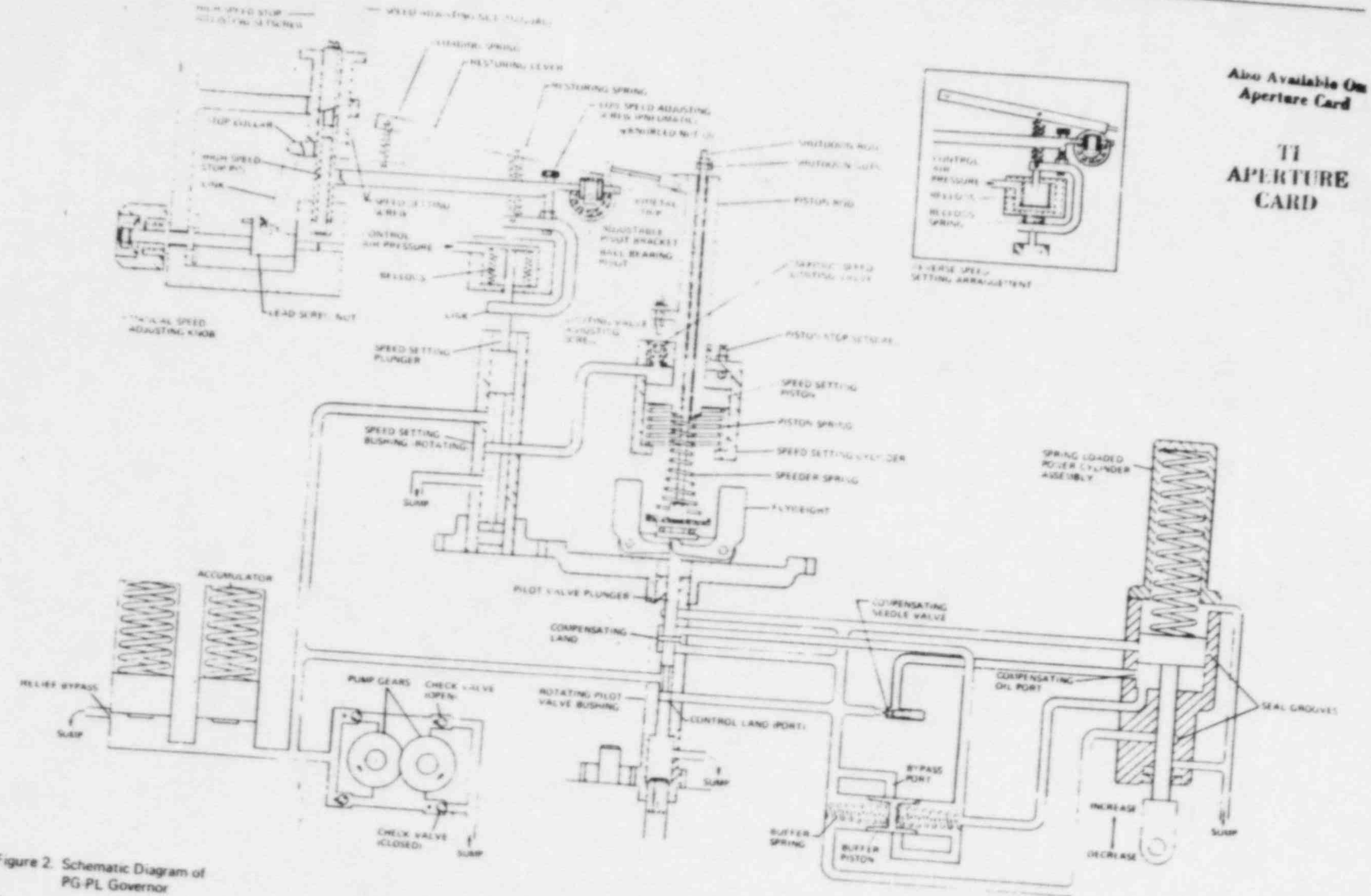

Figure 2. Schematic Diagram of PG-PL Governor

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in the input signal pressure -- displaces the speed setting pilot valve plunger to change the governor speed setting. The increased pressure compresses the bellows to lower the speed setting pilot valve plunger. Pressure oil flows to the area above the speed setting servo piston to force the piston down, and thus increase the governor speed setting.

As the servo piston moves down, a restoring lever -- connected between the servo piston rod and speed setting pilot valve plunger on a ball bearing pivot -- increases the lifting force on a restoring spring attached to the restoring lever. When the lifting force of the restoring spring is equal to the downward force resulting from the increased pressure signal, the speed setting pilot valve plunger will be returned to its centered position.

Increasing the speed setting of the governor increases the downward pressure of the speeder spring on the toes of the flyweights and the flyweights move in, lowering the pilot valve plunger and opening the control port.

Opening the port in this direction admits pressure oil into the buffer system, causing the buffer piston to move to the right and transfer an equal volume of oil to the power cylinder, forcing the power piston up in the direction to increase fuel.

As the buffer piston moves in the direction of the oil flow -- from pilot valve to power cylinder -- the right buffer spring is compressed and the left spring is relieved. This produces an intermediate oil pressure on the left side of the buffer piston which is higher than the pressure of the trapped oil on the right side of the buffer piston and spring displacement.

Simultaneously with the movement of the power piston and buffer piston, the differential oil pressures on opposite sides of the buffer piston are transmitted to the upper and lower sides of the compensating land, with the higher pressure on the lower side causing an upward force on the compensating land which will increase until (added to the upward force of the flyweights) it will balance the speeder spring force, raise the pilot valve plunger enough to cover the control port, and return the flyweights to the vertical position. As soon as the control port is covered the power piston will be stopped at a new position corresponding to the increased amount of fuel needed to operate the engine at the desired higher speed. The engine is still accelerating toward the new speed setting.

As the centrifugal force of the flyweights increases to a higher value with engine acceleration, the upward oil force at the compensating land is reduced to zero by the equalization of the oil pressures in the buffer system through the compensating needle valve. If the needle valve is correctly adjusted the oil pressures will equalize at the same rate as the increase in the centrifugal force of the flyweights, and the flyweights will remain in the vertical position, keeping the control port covered by the control land of the pilot valve, and holding the power piston stationary at the new position. Equalizing the oil pressures in the buffer system allows the buffer springs to return the buffer piston to center in the buffer cylinder.

The engine will now be running at a higher speed with an increased fuel setting.

SPEED DECREASE

A decrease in the control air pressure signal to the bellows of pneumatic receiver assembly allows the restoring spring -- attached to restoring lever -- to lift the speed setting pilot valve plunger. Oil drains from the area above the servo piston, the servo piston spring forces the piston to rise and thus decrease the speeder spring compression and lower the governor speed setting.

The restoring lever follows the movement of the servo piston, moves up and, in so doing, decreases the lifting force on the restoring spring. When the servo piston and right end of the restoring lever has moved up sufficiently to balance the upward force of the restoring spring to equal the decrease in downward force resulting from the decrease in control air pressure signal, the speed setting pilot valve plunger will have returned to its centered position.

Lowering the speed setting of the governor decreases the downward pressure of the speeder spring on the toes of the flyweights and the flyweights move out, raising the pilot valve plunger and opening the control port.

Opening the port in this direction permits oil to flow from the buffer system to the governor sump. This will lower the oil pressure in the buffer system and the power spring will force the power piston down in the direction to decrease fuel. As the buffer piston moves in the direction of the oil flow -- from power cylinder to pilot valve -- the left buffer spring is compressed and the right spring is relieved. This produces a pressure in the trapped oil, on the right side of the buffer piston which is higher than the intermediate oil pressure on the left side of the buffer piston, by an amount proportional to the displacement of the buffer piston and spring.

Simultaneously with the power piston and buffer piston

movement, these pressures will be transmitted to the compensating land, with the higher pressure now on the upper side of the land, causing a downward force which will increase until (added to the downward force of the speeder spring) it will balance the flyweight force, lower the pilot valve plunger enough to cover the control port, and return the flyweights to the vertical position. As the control port is covered the power piston will stop at a new position to correspond to the reduced amount of fuel required to operate the engine at the desired lower speed. The engine will be still decelerating toward the new speed setting.

As the centrifugal force of the flyweights decreases with engine deceleration, the downward oil force at the compensating land will again be reduced to zero by the equalization of the oil pressures in the buffer system through the compensating needle valve. With the needle valve correctly adjusted the oil pressures will equalize at the same rate as the decrease of centrifugal force in the flyweights, and the flyweights will remain in the vertical position, keeping the control port covered by the control land of the pilot valve, and holding the power piston stationary at the new position. Again, the buffer piston will be returned to center by the action of the buffer springs. The engine will now be running at a lower speed with a reduced fuel setting.

Bypass ports are provided in the buffer cylinder to facilitate large corrective movements of the power piston. A large increase or decrease in the speed setting of the governor, or a large increase or decrease of load on the engine, will require a correspondingly large movement of the power piston to make the necessary correction to the fuel setting. Under such conditions, the buffer piston will move only far enough to the left or right to effect an opening at the bypass port (pressure or drain). Oil will then flow directly to or from the power cylinder through the bypass port without further increasing the differential oil pressure force existing on the compensating land.

As soon as sufficient governor movement and fuel correction has occurred to effect a correction of engine speed toward the speed at which the governor is set, the differential oil pressures -- still present -- will act on the compensating land to re-center the pilot valve plunger, as described in the previous paragraphs.

With a large decrease in load the power piston assembly moves to the "no fuel" position, closing the compensating oil passage from the power cylinder to the compensating needle valve and blocking passage of oil from the right end to the left end of the buffer cylinder, so that the needle valve cannot equalize buffer oil pressures in the usual manner. The buffer piston will have moved off center to the left and will be held there by the oil now trapped between the power piston and the buffer piston.

The higher pressure of the oil on the right side of the buffer piston -- produced by the compression of the left buffer spring -- will act on the receiving compensating land to add to the effect of the speeder spring setting and provide a temporary higher speed setting of the governor.

As the engine decelerates to a speed slightly below this higher speed setting, the governor will respond to raise the power piston (and restore fuel supply) in the normal manner, uncovering the port to permit passage of oil through the compensating needle valve so that the governor and engine will stabilize at the speed corresponding to the actual speed setting of the governor. This minimizes possible under-speeding of the engine when a large load decrease occurs.

MANUAL SPEED SETTING

The manual speed setting mechanism can be used to adjust the speed setting of the governor to any point within the normal speed range when the control air pressure signal is not available.

With no air signal, the restoring spring holds the pneumatic low speed stop screw in contact with the restoring lever. The speed setting pilot valve plunger is thus mechanically connected to the movement of the restoring lever. The grounded loading spring which keeps the restoring lever against the ball bearing pivot continually urges the bearing and speed setting screw in the downward direction. Turning the manual speed adjusting knob clockwise (to increase the governor speed setting) lowers the stop collar under the base speed adjusting nut. The speed setting screw with the ball bearing pivot will move down with the stop collar until the high speed stop adjusting setscrew hits the high speed stop pin; further clockwise turning of the manual knob will have no effect on the speed screw position.

As the speed setting screw and the ball bearing pivot are lowered, the left end of the restoring lever pushes the pneumatic low speed adjusting screw down and, in so doing, lowers the speed setting pilot valve plunger. Oil flows to the speed setting cylinder to push the speed setting piston down and raise the governor speed setting. The downward movement of the piston raises the left end of the restoring lever to "lift" the pilot valve plunger back to center.

Turning the manual speed adjusting knob counterclockwise will raise the speed setting screw and ball bearing pivot, raise the left end of the restoring lever, and thereby lift the speed setting pilot valve plunger. As the piston moves up to decrease the governor speed setting, the restoring lever movement recenters the pilot valve plunger.

TEMPERATURE COMPENSATION

Temperature compensation on older governors is incorporated in the speed setting mechanism through a bimetal strip in the restoring lever. The temperature compensation in later governors is in the speeder spring and there is no bimetal strip.

LOSS OF PNEUMATIC SIGNAL

"DIRECT" TYPE BELLOWS. The pneumatic low adjusting screw is adjusted to contact the restoring lever when the control air signal and governor speed are at their normal minimum. Thus, should the air signal be interrupted -- either accidentally or intentionally -- or be reduced below the pressure required for minimum speed, the restoring spring will lift the speed setting pilot valve plunger until the adjusting screw contacts the restoring lever. With the pilot valve plunger raised, the speed setting piston will move up to the low speed position. At this position, the restoring lever, turning about the ball bearing pivot and pushing down on the adjusting screw, will have recentered the pilot valve plunger. The governor will, therefore, go to minimum speed setting if the air signal is lost.

"REVERSE" TYPE BELLOWS. The pneumatic low speed adjusting screw is adjusted to just clear the restoring lever when the control air signal is at its normal maximum setting. Thus, should the air signal be interrupted -- either accidentally or intentionally -- the spring under the bellows will act to lower the speed setting pilot valve plunger and allow the governor to go to maximum speed setting.

SECTION IV/MAINTENANCE

TROUBLESHOOTING

Governor faults are usually revealed in speed variations of the engine or turbine, but it does not necessarily follow that such speed variations indicate governor faults. Therefore, when improper speed variations appear, the following procedure should be performed:

1. Check the load to be sure that the speed changes observed are not the result of load changes beyond the capacity of the engine or turbine.

2. If the governor is on an engine, check the operation to be sure that all cylinders are firing properly and that the injectors are in good operating condition. If the governor is on a turbine, check the steam valves for proper operation.

3. Check the operating linkage between the governor and the engine or turbine to make certain there is no binding or lost motion.

4. Check for steam or fuel gas pressure changes.

5. Check the setting of the compensating needle valve.

6. Check air transmitter for specified output pressure. If neither load nor engine or turbine irregularities are found to be the cause of the speed variation, the cause may be either in the governor or in the engine or turbine drive to the governor.

7. Check governor for specified operating oil pressure. Normal oil pressure for PG governors is 100 psi. However, this value may vary between governors, depending upon the required output work capacity of the power cylinder (refer to table). With engine shut down, remove plug from pressure port on governor power case and install a pressure gauge rated above specified operating oil pressure.

The source of most troubles in any governor stems from dirty oil. Grit and other impurities can be introduced into the governor with the oil, or foam when the oil begins to break down (oxidize) or become sludgy. The moving parts within the governor are continually lubricated by the oil within the governor. Thus, grit and other impurities will cause excessive wear of valves, pistons, and plungers, and can cause these parts to stick and even "freeze" in their bores.

In many instances erratic operation and poor readability can be corrected by flushing the unit with fuel oil or kerosene while cycling the governor. The use of commercial solvents is not recommended as they may damage seals or gaskets.

If the speed variations of the governor are erratic but small, excessive backlash or a tight meshing of the gears driving the governor may be the cause. If the speed variation is erratic and large and cannot be corrected by adjustments the governor should be repaired and/or replaced.

LUBRICATION

The oil used in the governor should be clean and free of foreign particles to obtain maximum performance from the governor. Under favorable conditions, the oil may be used for six months or longer without changing. Change oil immediately when it starts to break down or darken.

DISASSEMBLY

Disassemble the governor following the sequence of index numbers assigned to figures 6 and 7, giving special attention to the following. Circled index numbers do not require further disassembly unless replacement parts are required.

Refer to the applicable modular bulletin (refer to section I) for parts information and disassembly procedures on auxiliary equipment.

1. Clean exterior surfaces of governor with clean cloth moistened with cleaning solvent.

2. Discard all gaskets, o-rings, seals, retaining rings, cotter pins, clips, etc., removed in the process of disassembly.

3. Do not remove press fit components unless replacement is required.

4. Disassemble power cylinder assembly as applicable per instructions contained in bulletin 36692.

5. Disassemble base assembly as applicable per instructions contained in bulletin 36693.

6. To remove accumulator springs and pistons from the power case, place the power case (260, figure 7) in an arbor or drill press with the bottom down. With a rod against the spring seat (246), compress accumulator springs (247 and 248) to permit removal of upper retaining ring (245). Remove spring seat and springs. (see Figure 3)

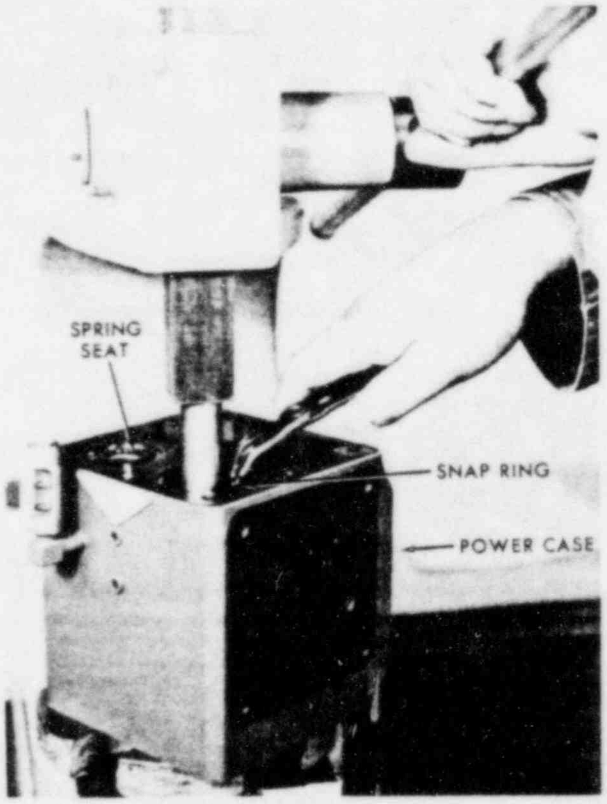

Figure 3. Removing Accumulator Retaining Ring

Invert the power case and remove lower retaining ring and accumulator piston (249).

7. If necessary to remove check valve assemblies (250 and 251), proceed as follows:

a. To remove inner check valves (250), pry the retainer plate from the check valve assembly and remove springs and check balls.

b. To remove outer check valves (251), press the check valves through and out of the valve case.

c. Then tap all four check valve cases with 1/4"-28 tap. Using a 1/4"-28 bolt with a small plate as a jack, pull the four valve cases.

d. Remove two balls from the lower case.

CLEANING

1. Wash all parts ultrasonically or by agitation while immersed in cleaning solvent (Federal Specification P-D-680 or similar).

2. Use a non-metallic brush or jet of compressed air to clean slots, holes, or apertures.

3. Dry all parts after cleaning with a jet of clean, dry compressed air.

Figure 4. Removal of Check Valves

INSPECTION

1. Visually inspect all parts for wear and damage.

2. Inspect bearings in accordance with standard shop practice. Replace bearings when there is any detectable roughness.

3. All pistons, valves, plungers, rods, and gears should move freely without excessive play. Do not lap in parts if possible to free by other means.

4. Mating surfaces must be free of nicks, burrs, cracks or other damage.

5. Inspect flyweight toes for wear. Replace flyweights if any detectable wear or doubtful areas are found.

6. It is recommended that speeder spring be replaced at time of overhaul.

REPAIR OR REPLACEMENT

1. Repair of small parts of the governor is impractical and shall generally be limited to removal of nicks and burrs from mating flanges and light burnishing of mating parts.

2. Replace damaged thread inserts in accordance with standard shop practice.

3. Polish slightly corroded areas with fine grit (600 grit) abrasive cloth or paper and oil.

ASSEMBLY

Assemble governor assembly in reverse order of index numbers assigned to figures 6 and 7, following the special instructions given below.

NOTE

A dust free area is recommended for assembly if acceptable results are to be obtained.

During assembly insure no lint or other foreign matter is present on the parts. The governor may be assembled dry or a small amount of clean lubricating oil may be applied to the parts as they are assembled into the governor. When the governor is assembled, apply a liberal amount of clean lubricating oil over all moving parts to insure initial lubrication. Apply a small amount of joint compound to pipe plug threads as plugs are installed. Insure compound does not enter cavity.

Obtain new gaskets, o-rings, seals, retaining rings, cotter pins, etc., to replace those discarded during disassembly.

1. Press spring loaded check valve (250, figure 7) into power case (260) using Woodward tool 360689. Press plain check valve into power case using Woodward tool 360690.

2. Install accumulator piston (249) and lower retaining ring (245) into power case. Place power case in an arbor or drill press with bottom down, (see figure 3) install springs (247 and 248) and spring seat (246); compress springs, using a rod on spring seat, and install upper retaining ring.

3. Attach base assembly (207) to power case loosely, rotate drive shaft until splined end engages with splines in pump drive gear. Continue turning drive shaft to check for alignment and free rotation of the drive gear and idler gear while tightening base screws.

4. Attach power cylinder assembly (203) to power case in the proper plan and quadrant; insure holes in gasket (204) are aligned with holes in power case.

5. When assembling the flyweight head pilot valve bushing assembly (238), align the missing tooth in the bushing with the corresponding missing tooth in the spring coupling assembly (229).

6. Install three piece thrust bearing (218) onto stem of pilot valve plunger (235) (bearing race with the larger hole must be against the flyweight toes).

7. When items 216 through 238 have been assembled, center pilot valve plunger as follows: (see figure 5) apply a slight pressure to speeder spring seat (217), adjust pilot valve plunger nut (216) until flyweights (225) move from their extreme inward to their extreme outward position and there is the same amount of control land showing in the control port at each extreme. The control ports are the bottom holes in the pilot valve bushing.

8. When assembling speed setting mechanism, insure retaining ring (30, figure 6), is positioned with opening in line with setscrew (33).

9. Assemble manual speed setting shaft assembly 43 through 47), tighten nut (43) approximately seven turns; insert roll pin (39) to protrude through shaft (43) approximately 0.090-inch.

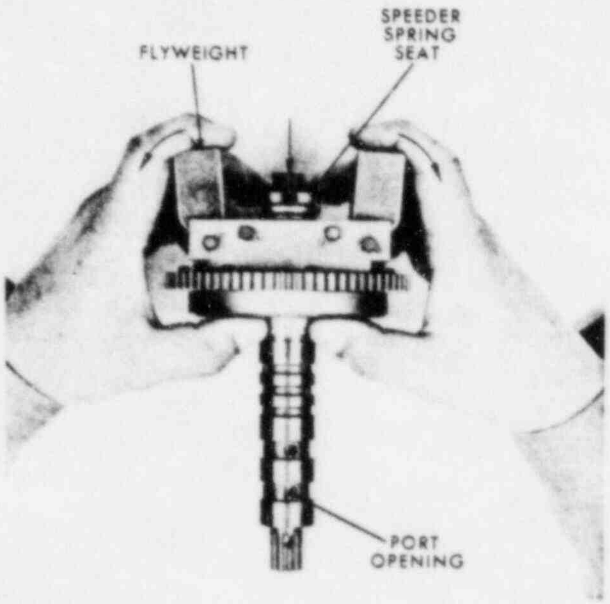

Figure 5. Centering Pilot Valve Plunger

TESTING

The PG governor has been manufactured in such a wide variety of arrangements that it would be impractical to cover specifications and testing procedures for each model.

It is recommended the customer contact Woodward Governor Company, Engine and Turbine Controls Division, Fort Collins, Colorado, for detail specifications and testing instructions for the particular models at the installation. When ordering information it is essential to supply the governor serial number (as shown on nameplate).

SECTION V/PARTS INFORMATION

PARTS REPLACEMENT

When ordering replacement parts it is essential that the following information be given:

1. Governor serial number and part number (as shown on nameplate).

2. Bulletin number (this is bulletin 36694).

3. Part reference number in parts list and description of part or part name.

ILLUSTRATED PARTS BREAKDOWN

The illustrated parts breakdown (figures 6 and 7) illustrates and lists all parts of the basic PG governor. Index numbers are assigned in disassembly sequence. Circled index numbers indicate items which do not require further disassembly unless repair or replacement of the part is required.

PARTS LIST FOR FIGURE 6

REF. NO.	PART NAME	NO. REQ'D.
36694- 1	Screw, hex hd., 5/16-24 x 5-13/32	2
36694- 2	Washer, lock, 5/16 (MS35338-45)	2
36694- 3	Washer, plain, 5/16 (MS27183-12)	2
36694- 4	Screw, drive, #2 x 3/16 (AN535-2-3)	4
36694- 5	Nameplate	1
36694- 6	Oil filler cap	1
36694- 7	Cover	1
36694- 8	Cover gasket	1
36694- 9	Loading spring	1
36694- 10	Restoring spring	1
36694- 11	Cotter pin, 1/16 x 3/8 (MS24665-130)	3
36694- 12	Pivot pin (Restoring lever)	1
36694- 13	Restoring lever	1
36694- 14	Pin (loading spring	1
36694- 15	Stop pin (low speed-pneumatic)	1
36694- 16	Screw, soc. hd., 5-40 x 1/2	1
36694- 17	Washer, lock, #5 (AN935-5)	1
36694- 18	Screw, soc. hd., 1/4-28 x 1-1/4 (MS16998-46)	1
36694- 19	Screw, soc. hd., 1/4-28 x 2 (MS16998-49)	1
36694- 20	Washer, lock, 1/4 (MS35338-44)	2
36694- 21	Pilot valve link	1
36694- 22	Stop screw (low speed-pneumatic)	1
36694- 23	Nut, hex., 10-32 (MS35650-302)	1
36694- 24	Bellows spring	1
36694- 25	Bellows coupling	1
36694- 26	Setscrew, soc. hd., cone pt., 8-32 x 5/16 (MS51973-30)	1
36694- 27	Passage screw	1
36694- 28	Washer, soft copper	1
36694- 29	Receiver cap gasket	1
36694- 30	Retaining ring, int., 1.660 OD	1
36694- 31	Bellows	1
36694- 32	Packing, preformed, 1-1/2 OD (NAS1593-028)	1
36694- 33	Setscrew, soc. hd., cone pt., 5-40 x 1/4	1
36694- 34	Pneumatic receiver cup	1
36694- 35	Screw, Phillips, rd. hd., 6-32 x 3/8 (MS35206-25)	4
36694- 36	Dial plate	1
36694- 37	Spacer	4
36694- 38	Friction spring	1
36694- 39	Roll pin, 3/32 x 5/8 (MS9048-071)	1
36694- 40	Stop washer	1
36694- 41	Spring washer, 1/4	1
36694- 42	Washer, plain, 25/64 ID x 5/8 OD	1
36694- 43	Nut, hex., slflkg, 1/4-28 (MS21083N4)	1
36694- 44	Belleville washer, 1/4	
36694- 45	Knob (Manual speed adjusting)	1
36694- 46	Clutch spring	1
36694- 47	Shaft (head screw)	1
36694- 48	Receiver bracket gasket	1
36694- 49	Screw, soc. hd., 10-24 x 1/2 (MS16997-44)	2
36694- 50	Washer, lock, #10 (MS35338-43)	2
36694- 51	Stop pin (High speed)	1
36694- 52	Collar	1

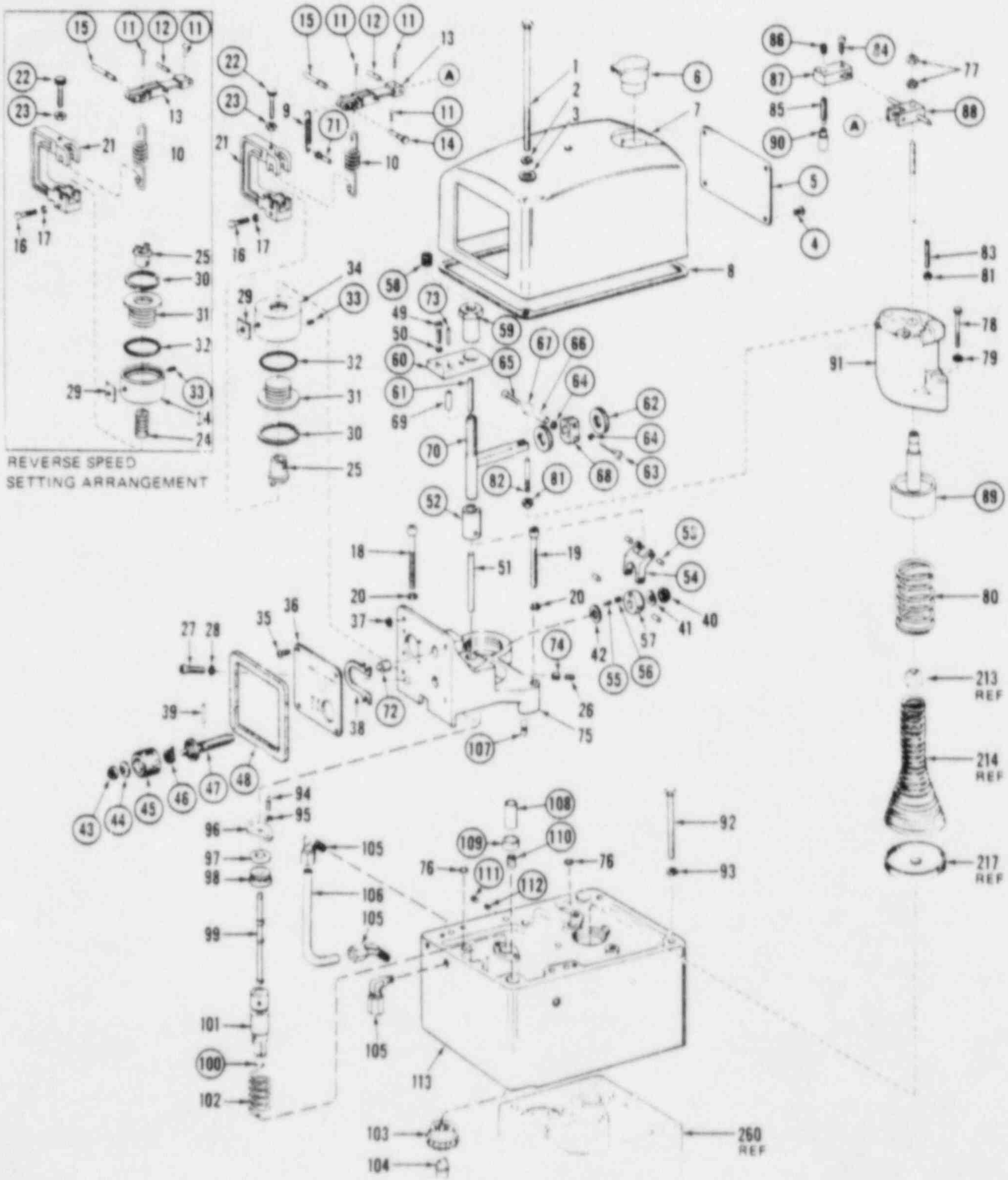

Figure 6. Exploded View of Column

PARTS LIST FOR FIGURE 6 (CONT.)

REF. NO.	PART NAME	NO. REQ'D.
36694- 53	Pivot pin	4
36694- 54	Link	1
36694- 55	Setscrew, soc. hd., dog pt., 8-32 x 3/8 (MS51977-31)	1
36694- 56	Thread insert, scr. lkg., 8-32 x 1/4 (MS21209C0815)	1
36694- 57	Nut (Lead screw)	1
36694- 58	Thread insert, 7/16-20 x 7/16	1
36694- 59	Speed adjusting nut (Low speed-manual)	1
36694- 60	Guide	1
36694- 61	Setscrew, soc. hd., oval pt., 10-32 x 1 (MS51982)	1
36694- 62	Nut, knurled	2
36694- 63	Screw, soc. hd., 10-32 x 1-1/8	1
36694- 64	Washer, lock, hi-collar, # 10 (MS51848)	2
36694- 65	Screw, soc. button hd., 10-32 x 1	1
36694- 66	Spacer	1
36694- 67	Ball bearing	1
36694- 68	Pivot bracket	1
36694- 69	Thread insert, scr. lkg., 10-32 x 3/8 (MS21209F120)	1
36694- 70	Speed setting screw	1
36694- 71	Pin (Loading spring anchor)	1
36694- 72	Friction spring seat	1
36694- 73	Dowel pin	2
36694- 74	Thread insert, scr. lkg., 8-32 x 1/4 (MS21209C0815)	1
36694- 75	Receiver bracket	1
36694- 76	Packing, preformed, 3/8 OD (NAS1593-010)	2
36694- 77	Nut, hex., 8-32 (MS35649-282)	2
36694- 78	Screw, hex. hd., 1/4-28 x 1-3/16 (MS90726-9)	2
36694- 79	Washer, plain, 1/4 (AN960-4166)	2
36694- 80	Speed setting piston spring	1
36694- 81	Nut, hex., 10-32 (MS35650-302)	2
36694- 82	Guide pin	1
36694- 83	Setscrew, soc. hd., oval pt., 10-32 x 7/8 (MS51982)	1
36694- 84	Screw, soc. hd., 10-32 x 3/8 (MS16998-26)	1
36694- 85	Adjusting screw (Max. speed)	1
36694- 86	Thread insert, scr. lkg., 10-32 x 9/32 (MS21209F1-15)	1
36694- 87	Adjusting screw bracket	1
36694- 88	Fulcrum	1
36694- 89	Speed setting piston	1
36694- 90	Check valve assembly (Max. speed)	1
36694- 91	Speed setting cylinder	1
36694- 92	Screw, hex. hd., 5/16-24 x 5 (MS90726-52)	4
36694- 93	Washer, lock, int. tooth, 5/16 (MS35333-41)	4
36694- 94	Screw, Phillips, rd. hd., 10-32 x 3/8 (MS35207-53)	2
36694- 95	Washer, lock, #10 (MS35338-43)	2
36694- 96	Retainer	1
36694- 97	Washer, plain, 3/8 ID x 3/4 OD	1
36694- 98	Thrust bearing	1
36694- 99	Speed setting plunger	1
36694-100	Plug	1
36694-101	Speed setting plunger	1
36694-102	Bushing loading spring	1
36694-103	Bushing gear	1
36694-104	Bearing stud	1
36694-105	Elbow, 90°	3
36694-106	Tubing, 1/4-inch	1
36694-107	Dowel pin	2
36694-108	Cover dowel	2
36694-109	Dowel bushing	2
36694-110	Thread insert, 5/16-24	2
36694-111	Pipe plug, soc. hd., 1/16-27 NPTF (AN932S1)	5
36694-112	Taper screw (Not used with solenoid or pressure actuated shutdown option)	1
36694-113	Column	1

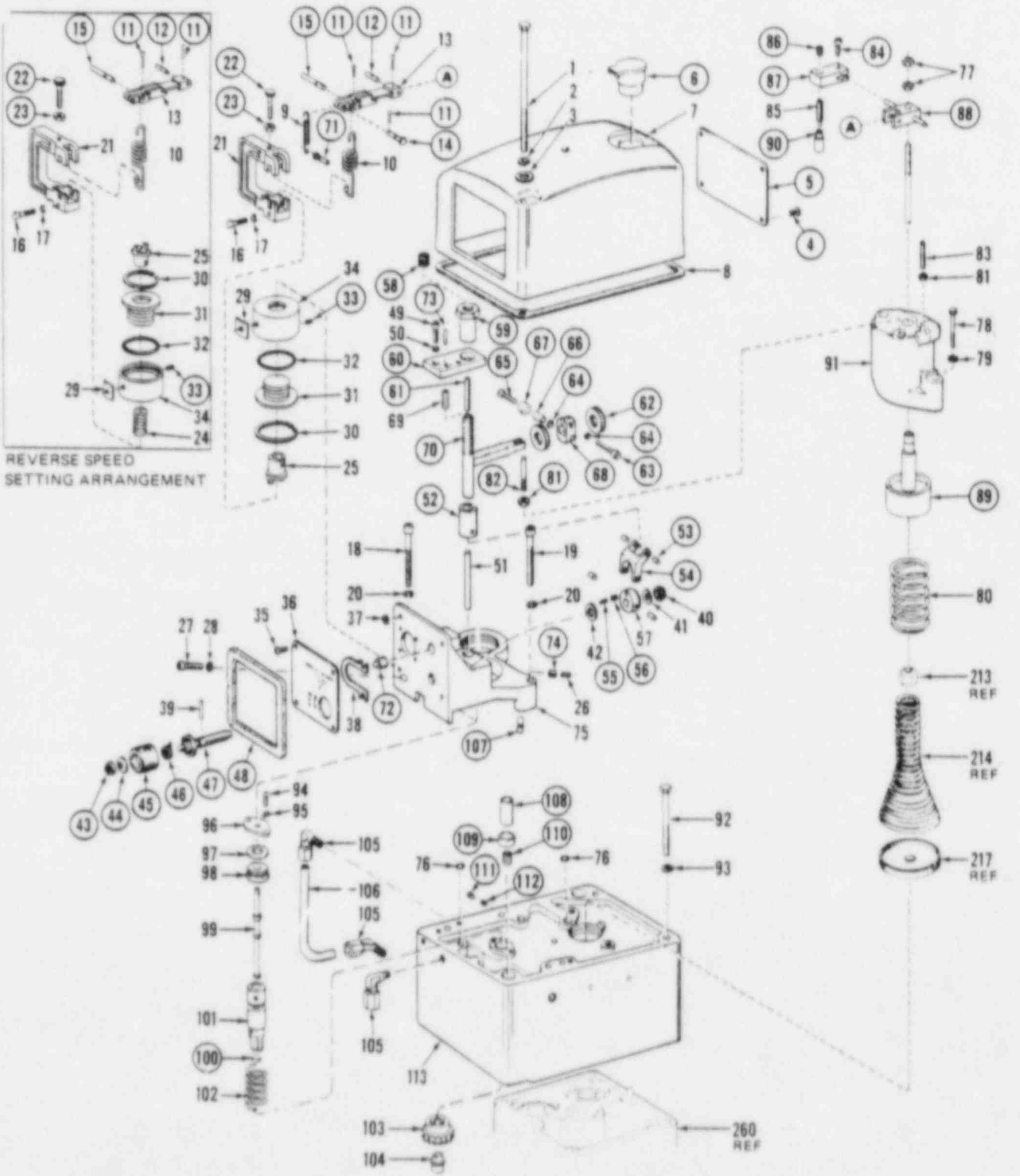

Figure 6. Exploded View of Column

PARTS LIST FOR FIGURE 7

REF. NO.	PART NAME	NO. REQ'D
36694-201	Screw, soc. hd., 3/8-16 x 1 1/4	4
36694-202	Washer, lock, 3/8	4
36694-203	Power cylinder assembly (refer to bulletin 36692)	1
36694-204	Gasket, power cylinder case	1
36694-205	Screw, hex hd., 5/16-18 x 1	8
36694-206	Washer, lock, 21/64	8
36694-207	Base assembly (refer to bulletin 36693)	1
36694-208	Power case-base oil seal ring	1
36694-209	Idler gear	1
36694-210	Idler stud	1
36694-211	Drive gear	1
36694-212	Gasket	1
36694-213	Speeder spring check plug	1
36694-214	Speeder spring	1
36694-215	Cotter pin, 1/16 x 5/8	1
36694-216	Pilot valve plunger nut	1
36694-217	Speeder spring seat	1
36694-218	Thrust bearing	1
36694-219	Washer, adjusting spring	1
36694-220	Adjusting spring	1
36694-221	Retaining ring	1
36694-222	Shutdown rod	1
36694-223	Cotter pin, 1/16 x 1	8
36694-224	Flyweight pin-limit pin	4
36694-225	Flyweight	2
36694-226	Flyweight bearing	4
36694-227	Screw, rd. hd., 8-32 x 5/16	1
36694-228	Washer, lock, #8	1
36694-229	Spring coupling assembly	1
36694-230	Screw, fil. hd., 5-40 x 9/32	8
36694-231	Washer, lock, #5	8
36694-232	Flyweight head sub-assembly	1
36694-233	Retaining ring	1
36694-234	Compensating bushing	1
36694-235	Pilot valve plunger	1
36694-236	Bearing	1
36694-237	Oil seal ring	1
36694-238	Flyweight head-bushing assembly	1
36694-239	Retaining ring	1
36694-240	O-ring	1
36694-241	Plug	1
36694-242	Buffer spring	2
36694-243	Buffer piston	1
36694-244	Buffer seat	1
36694-245	Retaining ring	4
36694-246	Spring seat	2
36694-247	Small accumulator spring	2
36694-248	Large accumulator spring	2
36694-249	Accumulator piston	2
36694-250	Spring loaded check valve	2
36694-251	Plain check valve	2
36694-252	Drain cock	1
36694-253	Elbow	1
36694-254	Oil gage	1
36694-255	Screw, rd. hd. dr.	3
36694-256	Instruction plate	1
36694-257	Pipe plug, 1/8	AR
36694-258	Pipe plug, 1/16	AR
36694-259	Dowel pin	2
36694-260	Power case	1

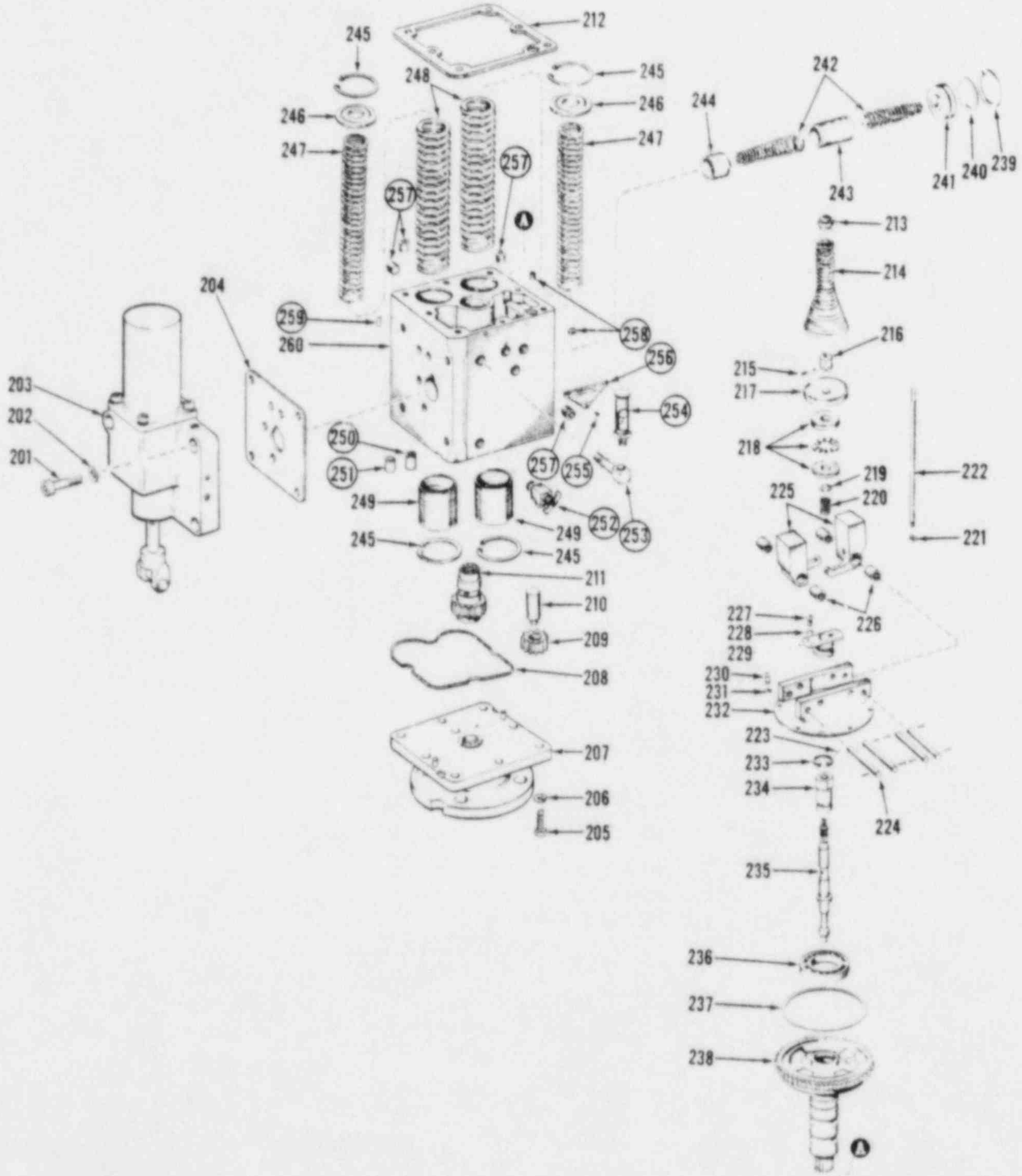

Figure 7. Exploded View of Case

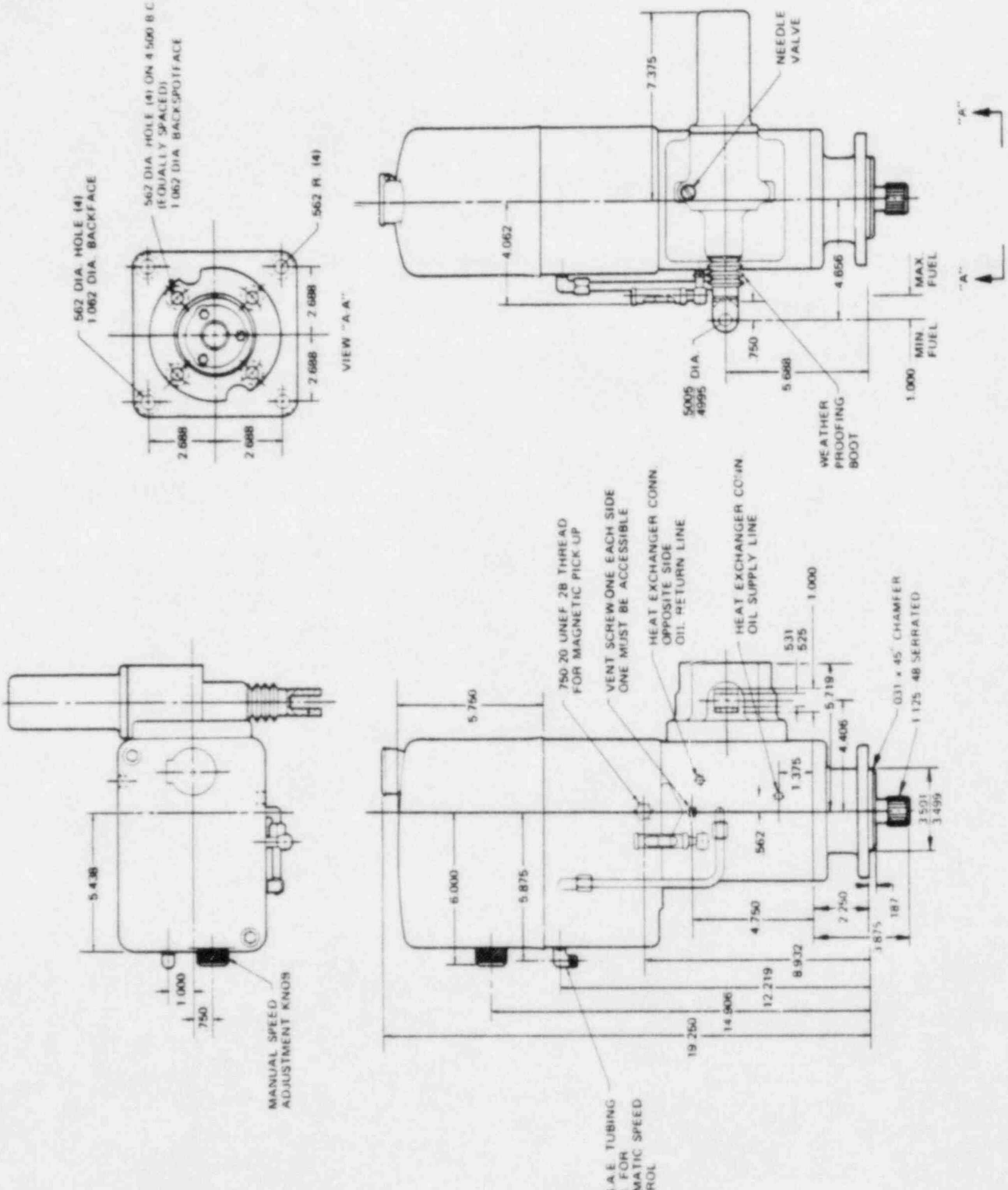

Figure 8. Outline Drawing of PG-PL Governor

SECTION VI/AUXILIARY FEATURES

AUXILIARY FEATURES (OPTIONAL)

Many auxiliary devices are available for use, either singly or in combination, on the PG governor to meet the numerous control requirements of the installation requiring precise speed setting. Each governor is designed to meet the needs of the engine or turbine and the operating requirements of the installation.

Auxiliary equipment may be supplied as original equipment in the governor or it may be installed in the field; it is recommended that the customer contact Woodward Governor Company on field installations.

The following paragraphs give a brief description of some of the auxiliary equipment available from Woodward Governor Company and list the bulletins where detail information may be obtained.

Bulletin No.	Title
36034	PG Governor Heater
36641	Governor Heat Exchanger
36650	Solenoid Operated Shutdown Assembly
36651	Pressure Actuated Shutdown Assembly
36680	Preloaded Buffer Springs
36684	Booster Servomotor
36692	PG Power Cylinder Assemblies
36693	PG Base Assemblies

PG GOVERNOR HEATER

An electric heater is available for PG governors used on engines which are shut down for lengthy periods in cold climates. By applying heat to the governor power case during shutdown periods--or for a time before start-up--the governor oil viscosity is maintained at a point which enables the oil to flow freely through passages of the governor. This allows normal governor operation as soon as the engine is started.

GOVERNOR OIL COOLER

A governor oil cooler is required when governor drive shaft speed exceeds 1200 RPM on an engine application, or 1100 RPM on a steam turbine. It also may be necessary to use an oil cooler at lower governor drive shaft speeds if the governor is mounted close to valves or steam lines which result in high ambient temperatures.

Water (or some other liquid coolant) from an external supply enters the oil cooler cover and passes through a tube to the oil cooler body. The water circulates through the body cavity to the discharge.

A special governor case may be required to mount the oil cooler or to connect to the external heat exchanger. Where it might be desirable to add an oil cooler to a governor already in service, the governor should be returned to the factory for conversion.

SHUTDOWN DEVICES

A shutdown device can be incorporated in the PG governor to stop fuel to the engine or turbine if equipment fails. These assemblies are used in a variety of applications including plants where automatic safety devices are a necessity. Shutdown devices can be supplied in the following arrangements to suit the particular operating conditions:

1. Shutdown assemblies which will operate from air, oil, or water pressure. These assemblies are generally supplied where electrical devices cannot be used. The air, oil, or water shutdown device can be arranged to shut down the engine or turbine on either high or low signal pressure.

2. A solenoid shutdown device which can be arranged to energize or de-energize to shut down. Solenoid coils are available to accommodate most common DC voltages. Power required is 6 watts. For AC operation, a separately mounted transformer or rectifier assembly converts AC voltage to the required DC voltage.

PRELOADED BUFFER SPRINGS

Preloaded buffer springs are often installed in PG governors used on two-cycle spark ignition engines and on some engines driving reciprocating pumps. As a result of preloading, the governor minimizes fuel linkage movements resulting from changes in speed due to misfiring or pump strokes. The use of preloaded buffer springs does not affect the capability of the governor to recognize and respond to speed changes. Preloaded buffer springs do retard the rate at which the governor output piston (or shaft) moves when responding to small or momentary offspeeds. The output piston (or shaft) moves at the normal rate for large speed changes.

BOOSTER SERVOMOTOR

The booster servomotor is used in conjunction with the PG governor to assist the engine in starting quickly. The function of this device is to supply oil under pressure to the governor at the instant starting air is supplied to the engine; this enables the governor to move the engine linkage to the fuel-on position immediately.

PG BASES AND POWER CYLINDER ASSEMBLIES

A number of different base and power cylinder arrangements are available to conform to engine or turbine manufacturer's specifications.

The base assembly can be furnished with either a serrated or keyed drive shaft. Refer to bulletin 36693.

The work capacity of the power cylinder assembly normally furnished with the governor is 12 foot-pounds. A maximum of 8 foot-pounds can be used to move the fuel or steam control linkage over the full range of governor travel. Power cylinders with work capacity up to 58 foot-pounds are available. Refer to bulletin 36692.

SECTION VII/DIAPHRAGM SPEED SETTING

INTRODUCTION

Many of the earlier PG-PL governors are still in operation. These governors are of a type that uses an air receiver diaphragm instead of a bellows. The linkage for speed setting is also different and requires other instructions for adjustment. Both direct and reverse mechanisms are available in the diaphragm PG-PL governor. This section deals with the description, setting, and parts lists for the diaphragm type speed setting.

DESCRIPTION OF OPERATION

The following is a description of how the diaphragm direct speed setting mechanism operates. See figures 9 and 10. When a higher air pressure is sent under the pneumatic receiver diaphragm, the diaphragm rises against atmospheric and spring pressure on the opposite side. This movement, carried by the diaphragm link, pivots the speed control lever and pushes the speed setting pilot valve down through the action of the connecting link and the lower floating lever. The displacement of the speed setting pilot valve allows pressure oil to be admitted above the speed setting piston. The piston moves downward until the upper floating lever, floating lever link, and lower floating lever restore the pilot valve to its steady-state position.

With a lower air pressure signal, the receiver diaphragm would lower because of the receiver spring pressure atop it. Through the linkage previously described the speed setting pilot valve is raised, opening the port to sump and allowing the piston return spring to raise the piston. The linkage attached to the speed setting servo shaft closes the pilot valve again.

The diaphragm reverse mechanism runs the engine or turbine at high speed for minimum control air pressure, and low speed for maximum control air pressure. The special linkage arrangement is shown in figure 11. Note that the base speed setting nut pivot and upper end of the floating lever link have exchanged places from the arrangement shown in figure 10. A special speed setting pilot valve plunger is used. It must now move upward to admit oil to the speed setting servomotor. Converting a governor from direct operation to reverse speed setting involves changing a few parts so it is preferable, though not absolutely necessary, to specify the correct arrangement when a governor is ordered. See description of operation, page 9, for information on the rest of the governor.

ADJUSTMENT AND PARTS LIST

Air pressure versus engine or turbine speed relationships are set at the factory with more precise measuring instruments

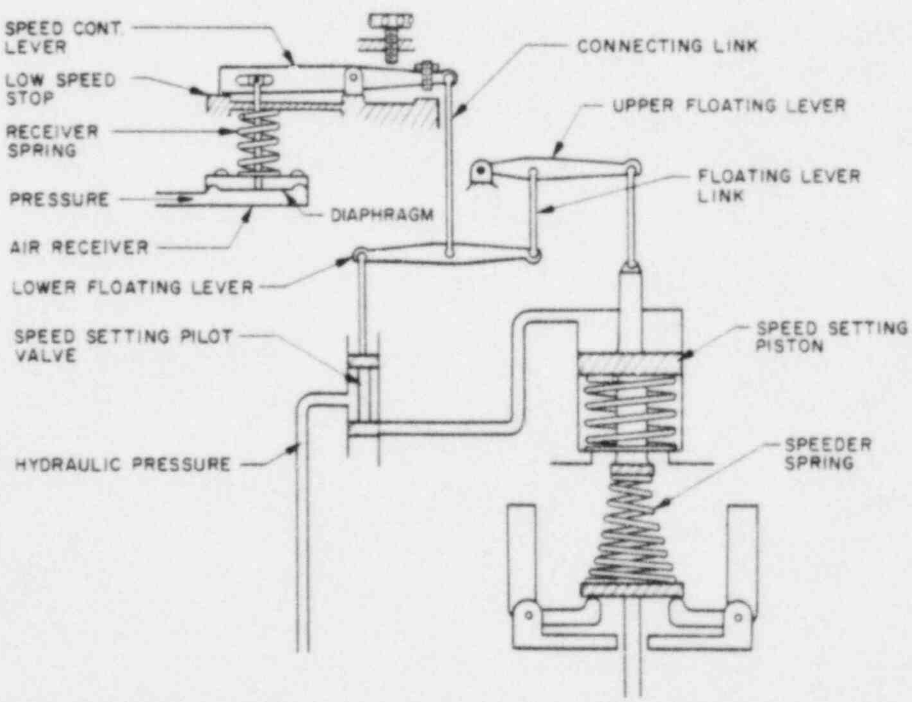

Figure 9. Schematic of Diaphragm Direct Speed Setting

than are available in the field. The governor speed settings normally will never need to be readjusted, and under no circumstances should they be altered without thorough knowledge of the procedure. If it is necessary to change or reset the governor speed settings, first determine the pressure range of the associated air pressure instrument, and the engine or turbine speed range corresponding to this pressure range.

Back off the high speed stop screw, shown in figure 10. Loosen the idle speed screw locknut and the sliding block lockscrew and nut. The sliding block can now be moved freely to either end of the slot. Set it at approximately the mid-point in its travel and lock it with the lockscrew and nut. Start the engine or turbine and apply the specified low air pressure (generally three psi). Adjust the idle speed screw up or down, as required, until the left end of the speed control lever just touches or is a few thousandths (roughly the thickness of tissue paper) short of touching the pneumatic receiver casting which serves as the low speed stop.

Adjust the base speed setting nut to obtain the specified engine speed corresponding to minimum air pressure. Screw down to decrease speed, or up to increase speed. Slowly raise control air pressure to the specified maximum value, making sure the engine does not overspeed. The speed obtained will probably be either higher or lower than the desired maximum. Check to be sure the high speed stop screw is not limiting speed by touching the screw head below it.

If the maximum speed obtained is too low, loosen the sliding block lockscrew and nut and the idle speed screw locknut. Move the sliding block a short distance to the right. Moving the sliding block to the right (toward the pivot) increases the amount of RPM change that results from a specified air pressure change. Moving the sliding block to the left (away from the pivot) reduces the amount of RPM change obtained for a given air pressure change.

It is now necessary to start over again with the specified air pressure at minimum and adjust and lock the idle speed screw so the left end of the speed control lever just touches, or as explained previously, almost contacts the casting. Set the base speed setting nut as before to obtain the specified minimum speed corresponding to minimum air pressure. Again apply maximum specified air pressure and check the speed. Repeat this process until the desired high and low speeds are obtained.

When desired speeds have been obtained for the specified air pressures, adjust the high speed stop screw so it just contacts the screw head below it at maximum specified air pressure. Tighten the locknut.

Make sure the diaphragm link between the diaphragm and the idle speed screw does not rub on the edge of the hole where it passes through the pneumatic receiver casting. This could happen if the sliding block were either too far from or too near the pivot. Such interference indicates that it is necessary to use the next heavier or lighter air receiver spring.

On PG-PL governors equipped with reverse speed setting (minimum control air pressure produces maximum speed), the procedure for setting speeds is basically the same; however, the left end of the speed control lever rests on the

Figure 10. Adjustment Points of Diaphragm Direct Air Receiver

Figure 11. Reverse Diaphragm Linkage Arrangement

housing casting at maximum engine speed, and the high speed stop screw now serves as the low speed stop.

SPEED SETTING SERVOMOTOR PISTON STOP SCREW ADJUSTMENT

Set the governor for the minimum speed position. Turn the speed setting servomotor piston stop screw down until it contacts the top of the piston, then back it off 1-1/2 turns and tighten the locknut.

INFORMATION AND PARTS REPLACEMENT

When requesting additional information concerning governor operation, or when ordering repair parts, it is essential that the following information accompany the request.

1. Governor serial number shown on the nameplate.
2. Bulletin number. (This is bulletin 36694).
3. Part reference number, name of part, or description of part.

PARTS LIST FOR FIGURE 12.

REF. NO.	PART NAME	QUANTITY
36694-301	5/16-24 x 5-15/32 hex head screw	2
36694-302	5/16 shakeproof washer	6
36694-303	Oil filler cup	1
36694-304	Set screw (knob)	1
36694-305	Control knob	1
36694-306	Taper pin	1
36694-307	Drive screw	AR
36694-308	Manual speed adjustment plate	1
36694-309	Friction plunger	1
36694-310	Friction spring	1
36694-311	5/16 lockwasher	AR
36694-312	Gasket	1
36694-313	Bushing-dowel	2
36694-314	Bushing	2
36694-315	5/16-24 x 5/8 threaded insert	2
36694-316	Stud	1
36694-317	Power piston stop screw	1
36694-318	#10-32 hex nut	1
36694-319	Adjustable fulcrum screw	1
36694-320	13/64 x 7/16 x 1/32 washer	1
36694-321	Link adjusting spring	1
36694-322	Adjustable fulcrum pin	1
36694-323	#10-32 stop nut	1
36694-324	Fulcrum link	2
36694-325	Link spacer	2
36694-326	Piston fulcrum assembly	1
36694-327	Floating lever link	1
36694-328	Floating lever link spring	1
36694-329	1/8 straight pin	1
36694-330	1/16 x 3/8 cotter pin	6
36694-331	Lower floating lever assembly	1
36694-332	1/8 x 47/64 drilled pin	2
36694-333	.186 x 3/4 pin	1
36694-334	Speeder spring power cylinder	1
36694-335	1/4-28 x 1 3/8 hex head cap screw	5
36694-336	17/64 x 1/2 x 1/32 washer	2
36694-337	Speeder spring power piston assembly	1
36694-338	Speeder spring servo spring	1
36694-339	Speed setting pilot valve plunger	1
36694-340	Pilot valve plunger spring	1
36694-341	Speed setting pilot valve bushing	1
36694-342	Pilot valve bushing spring	1
36694-343	Column assembly	1
36694-344	Gear	1
36694-345	Bearing stud	1
36694-346	Thrust bearing	1
36694-347	Bushing retainer	1
36694-348	#10-32 x 3/8 round head phillips screw	2
36694-349	#10 lockwasher	2
36694-350	1/4 x 9/16 dowel pin	4
36694-351	1/4-28 socket head screw	1
36694-352	Speed control bracket	1
36694-353	17/64 x 27/64 x 1/16 lockwasher	AR
36694-354	1/4-28 x 1 1/4 socket head cap screw	1
36694-355	1/4-28 x 1 3/4 socket head cap screw	1
36694-356	Diaphragm nut	1
36694-357	Retaining washer	1
36694-358	Diaphragm washer	1
36694-359	Diaphragm	1
36694-360	Spring seat	1
36694-361	Diaphragm spring	1
36694-362	Pivot pin	1
36694-363	Floating lever link assembly	1
36694-364	Diaphragm link assembly	1
36694-365	Speed control bracket cap	1
36694-366	Control lever slide	1
36694-367	Idle speed setting screw	1
36694-368	Needle bearing	2
36694-369	Speed control lever	1
36694-370	3/8 washer	1
36694-371	3/8-32 hex jam nut	1
36694-372	#10-32 x 3/4 socket set screw	1
36694-373	#10-32 hex nut	2
36694-374	#10-32 x 1/2 socket set screw	1
36694-375	Speed adjusting screw	1

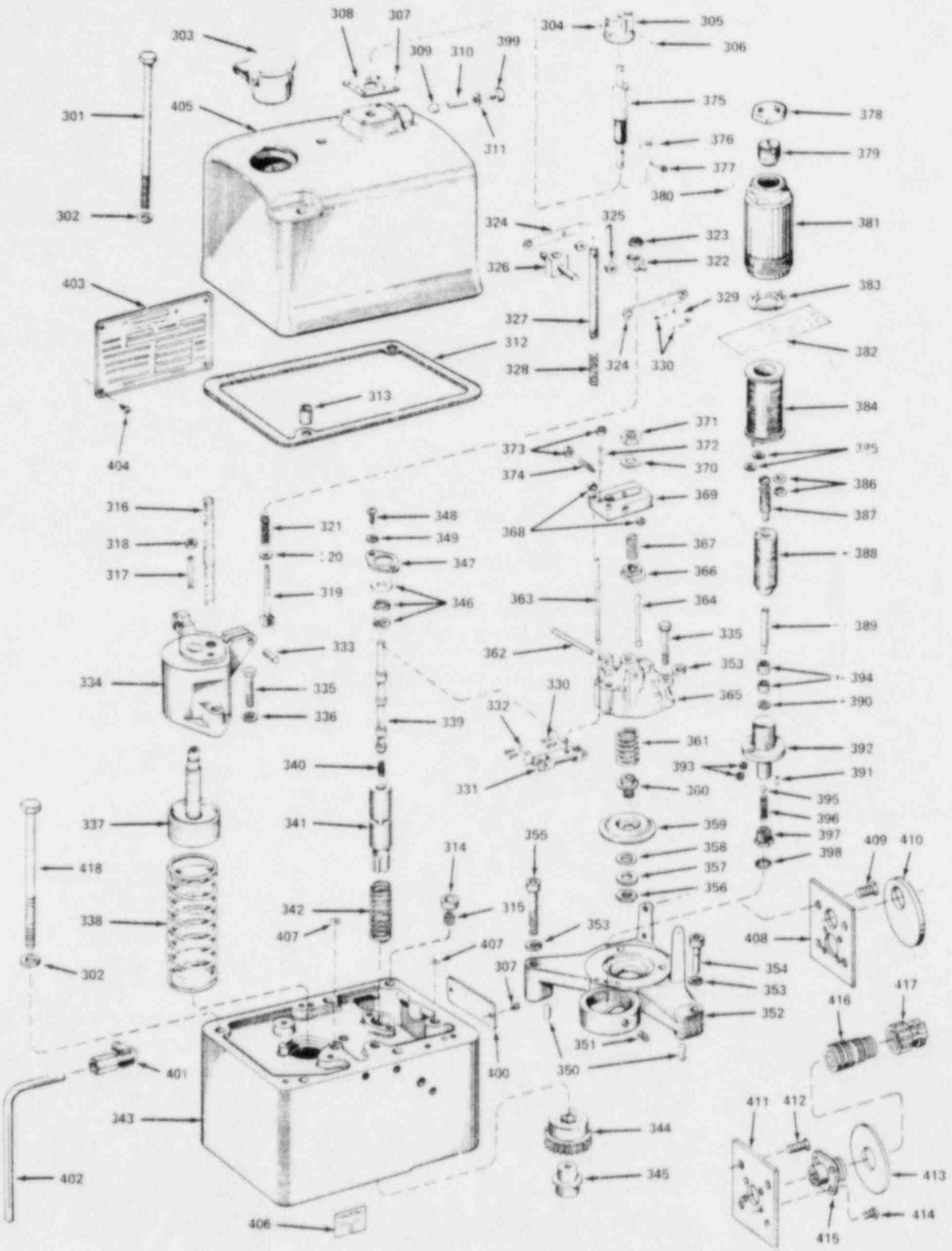

Figure 12. Exploded View of Diaphragm Column Parts

PARTS LIST FOR FIGURE 12 (CONT.)

REF. NO.	*PART NAME*	*QUANTITY*
36694-376	9/16 x 21/64 x 1/16 washer	1
36694-377	3/32 x 1/2 cotter pin	1
36694-378	Solenoid locknut	1
36694-379	Plunger stop plug	1
36694-380	Solenoid plunger lock pin	1
36694-381	Solenoid case	1
36694-382	Insulating paper	1
36694-383	Load spring	1
36694-384	Solenoid coil	1
36694-385	Soldering shield washer	2
36694-386	"O" ring	2
36694-387	Adjusting screw	1
36694-388	Solenoid plunger assembly	1
36694-389	Solenoid plunger rod	1
36694-390	Solenoid plunger washer	1
36694-391	Plunger guide locating pin	1
36694-392	Shutdown valve body	1
36694-393	Varnished tubing	2
36694-394	Solenoid plunger bushing	2
36694-395	1/4 steel ball	1
36694-396	Unloading spring	1
36694-397	Shutdown valve seat	1
36694-398	"O" ring	1
36694-399	Friction plunger retaining screw	1
36694-400	Nameplate (column)	1
36694-401	Elbow	2
36694-402	Tubing	1
36694-403	Nameplate (cover)	1
36694-404	Drive screw	4
36694-405	Cover	1
36694-406	Oil level decal	1
36694-407	"O" ring	2
36694-408	Plate	1
36694-409	#10-32 x 3/8 screw	1
36694-410	Gasket	1
36694-411	Plate	1
36694-412	#10-32 x 1/2 screw	4
36694-413	Gasket	1
36694-414	#6-32 x 3/8 screw	4
36694-415	Receptacle	1
36694-416	Plug	1
36694-417	Cable clamp	1
36694-418	5/16-24 x 4-31/32 hex head screw	4

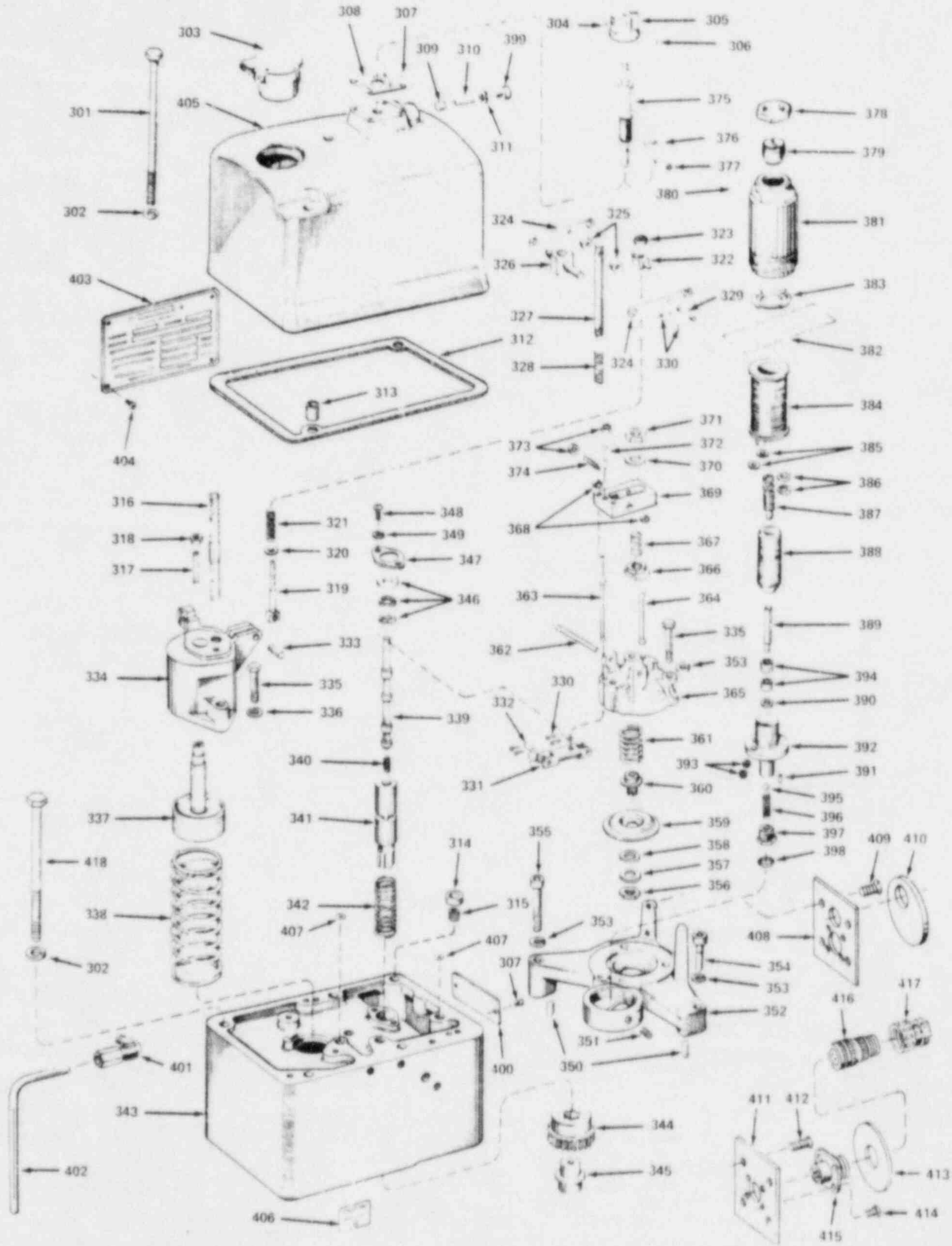

Figure 12. Exploded View of Diaphragm Column Parts

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