DTE Gas Company
Alpena Compressor Station

White Superior Engine
Oxidation Catalyst Control System

Startup, Shutdown, Malfunction (SSM) and Continuous Parameter Monitoring System (CPMS) Plans

TABLE OF CONTENTS

ATTACHMENTS

SECTION 1: INTRODUCTION

1.1 Purpose and Requirements

This document includes the systems and procedures for the DTE Energy (DTE) Alpena Compressor Station located at 8512 East Arnold Lake Road, Harrison, MI 48625 in Clare County, hereafter referred to as the Alpena Station (SRN N5935). The Alpena Station contains a gas fired compressor engine subject to the requirements of 40 CFR Part 63 National Emissions Standards for Hazardous Air Pollutants (NESHAP) for Source Categories. The regulations are referred to as the MACT standards and the applicable rules for the compressor engine are contained in 40 CFR Part 63, Subpart A; the General Provisions applicable to all Part 63 source categories and Subpart ZZZZ, applicable to Reciprocating Internal Combustion Engines.

The compressor engine is required to be equipped with an emission control device and associated monitoring equipment. Monitoring parameters must be implemented for the control device and must demonstrate compliance with the standards. A source that is required to use a Continuous Monitoring System (CMS) for measurement of the above mentioned operating parameters must also develop and implement a Continuous Parameter Monitoring System (CPMS) quality control program, pursuant to 40 CFR 63.6625(b)(1) and 63.8 (d).

The Alpena Station has also developed and implemented a Startup, Shutdown and Malfunction (SSM) plan in order comply with the specific startup, shutdown and malfunction requirements of 40 CFR 63 Subpart ZZZZ. The SSM plan can be found in Section 4 of this document. The SSM plan does not address the general SSM plan requirements of 40 CFR 63 Subpart A, as they are not applicable to the Alpena Station, pursuant to Table 8 of 40 CFR 63 Subpart ZZZZ.

1.2 Plan Maintenance and Updates

DTE maintains a complete copy of the CPMS and SSM Plans (the "Plan") at Kalkaska. . DTE has the overall responsibility to ensure that the Plan is maintained and updated as required by the rules. Environmental Management & Resources (EM&R) works with the Operations/Maintenance personnel to obtain the information needed to maintain and update the Plan. Specific requirements governing maintenance for the CPMS and SSM plans can be found as a subpart in their respective sections.

1.3 Site Overview

The compressor engine located at the Alpena Station is a four stroke lean burn White Superior Engine with a rating of 2000 horsepower (hp) used to push natural gas through a pipeline. There is only one compression engine at the Alpena Station.

SECTION 2: PROCESS DESCRIPTION

DTE operates the compression engine located at the Alpena Station as needed to provide additional compression pressure to the pipeline in order to move the natural gas through the pipeline. The compression engine is a stationary reciprocating internal combustion engines (“RICE”) equipped with an oxidation catalyst for the purpose of reducing carbon monoxide emissions during operation. Included with the oxidation catalyst system is a continuous parameter monitoring system (CPMS) consisting of monitoring points that record: control device inlet gas temperature, pressure drop across the catalyst bed, and date / time stamps of all records. These data points are recorded and displayed by the station HMI (human machine interface) software and also by DTE Energy’s SCADA system. The data points are monitored by the unit control panel (UCP) to ensure compliance with the Plan.

SECTION 3: CONTINUOUS PARAMETER MONITORING SYSTEM PLAN (CPMS)

3.1 Monitoring Plan

This monitoring plan addresses the monitoring system design, data collection, and the quality assurance and quality control elements outlined in the paragraphs 40 CFR 63.6625 Part (b)(1) and in § 63.8(d). Each CPMS is installed, operated, and maintained according to procedures in this monitoring plan.

3.1.1 Equipment Performance Criteria and Design Specifications

An Allen Bradley Control Logix Programmable logic controller (“PLC”) provides continuous monitoring of the catalyst inlet temperature and differential pressure which is mandated by the RICE NESHAP. The PLC also monitors and controls all other engine and compressor functions. The PLC is capable of monitoring up to 4000 analog input points – however, this particular control system only possesses approximately 50 analog points.

The PLC continuously monitors all analog inputs whether the engine is running or not. The catalyst alarms and shutdowns are only armed once the PLC control system has started the engine and put the compressor on-line. The engine speed is sensed by a magnetic pickup. The exhaust temperature sensor has an accuracy of $\pm$ 3 degrees Celsius plus 0.1 % of the input range which is -328°F to 2282°F. If an input crosses an over or under alarm threshold (**Table 3-1**), the HMI system will annunciate the condition to alert the operator of the condition. If an input crosses over or under a shutdown threshold (**Table 3-1**), the HMI system will annunciate the condition and the PLC system will shut down the engine. All annunciated events are stored in an alarm log on the station HMI. These events are maintained in the log for a minimum of 5 years from the date of the event. These events are also logged by the Station Operator (DTE employee).

The station HMI will log all catalyst data at 10 minute intervals at all times. This data is also logged by the company SCADA (Supevisory Control and Data Acquisition) system once per minute.

Table 3-1: Oxidation Catalyst Alarm Thresholds

Monitored Parameter	Alarm Threshold	Shutdown Threshold
Temperature at catalyst inlet	Lower limit: 500°F Upper limit: 1300°F	Lower limit: 450°F Upper limit: 1325°F

3.1.2 Sampling Interface

The thermocouples and differential pressure sensing equipment were mounted per the manufacturer's recommendations. Catalyst bed inlet temperatures are taken via thermocouple located at the inlet to the catalyst. Pressure drop is calculated via pressure measurements at the inlet and outlet of the catalyst.

3.1.3 Equipment Performance Evaluations

The differential pressure transmitter is a Yokogawa Model EJA110E-JMS4G-U12EB/FF1/D1 calibrated 0-20" H2O. The thermocouple assemblies are Sandelius S5H-240K600-G-00-CP1A3R6B thermocouples mounted in stainless steel thermowells. The thermocouples are wired into a Weidmuller WAS5 ProThermo converter which converts the thermocouple signal to a 4-20ma signal. The 4-20 ma signal is read by the Allen Bradley UCP with a Flex IO analog input module, model 1794-IE8. The accuracy of the overall system is measured by comparing the thermocouple signal with a thermocouple calibrator value as measured by the PLC. The results should be within the standard specification limits indicated in the Thermocouple data sheets **(Appendices B, C, and D)**. The thermocouple signal will be calibrated once per calendar year.

The Alpena Station Operators will ensure that these performance evaluations are documented and supplied to EM&R.

3.1.4 Operating and Maintenance Procedures

The Alpena Station keeps spare analog input cards, WAS5 thermocouple converters, and thermocouple and differential pressure elements for routine repairs on the Catalyst Monitor system readily available in accordance with 40 CFR 63.8(c)(1)(ii). The Catalyst Monitor was installed in accordance with the Manufacturer's written recommendations for installation, operation, and calibration of the system. Information on the installation, operation, calibration, and design of the UCP (which monitors the Catalyst) can be found in the Station O & M manual or operation records available from the Alpena Station or EM&R.

3.1.5 Reporting and Recordkeeping

DTE maintains the following records for the Catalyst Monitor System to ensure compliance with 40 CFR 63.10(c) and (e):

- Catalyst inlet temperature and pressure drop;
- The date and time identifying each period during which the CMS was inoperative except for zero (low level) and high-level checks;
- The date and time identifying each period during which the CMS was out of control;
- The specific identification (i.e., the date and time of commencement and completion) of each period of excess emissions and parameter monitoring exceedances, as defined in the relevant standard(s), that occurs during startups, shutdowns, and malfunctions of the affected source;
- The specific identification (i.e., the date and time of commencement and completion) of each time period of excess emissions and parameter monitoring exceedances, as defined in the relevant standard(s), that occurs during periods other than startups, shutdowns, and malfunctions of the affected source;
- The nature and cause of any malfunction (if known);
- The corrective action taken or preventive measures adopted;
- The nature of the repairs or adjustments to the CMS that was inoperative or out of control;
- The total process operating time during the reporting period; and
- All procedures that are part of a quality control program developed and implemented for CMS under § 63.8(d).

All performance evaluations are kept on record for a minimum of five years or until the affected source no longer falls under § 63.8(d)(3). The records are available for inspections or upon request. DTE keeps previous versions of the performance evaluation plan on record for a period of 5 years after each revision of the plan.

The Alpena Station also maintains records of maintenance conducted on the stationary RICE located on-site in order to demonstrate compliance with operating procedures and the equipment maintenance plan.

SECTION 4: STARTUP, SHUTDOWN, MALFUNCTION (SSM) PROCEDURES

It is the Alpena Station's obligation to ensure that the stationary RICE, including its associated oxidation catalyst and monitoring equipment, is operated and maintained, in such a way that minimizes emissions. This Startup, Shutdown, Malfunction (SSM) plan complies with the specific startup, shutdown and malfunction requirements of 40 CFR 63 Subpart ZZZZ. This SSM plan does not address the general SSM plan requirements of 40 CFR 63 Subpart A as they are not applicable to the compressor engine at the Alpena Station pursuant to Table 8 of 40 CFR 63 Subpart ZZZZ.

4.1 Startup Procedures

A startup is defined as "the setting in operation of an affected source or portion of an affected source for any purpose." [§63.2]

This procedure has been set to minimize the engine's time spent at idle and minimize the engine's overall startup time in order to allow for the appropriate and safe loading of the engine. With the exception of engine break-in, at all times, including startup, the engine exhaust is vented through the oxidation catalyst to reduce emissions. Under EPA regulation, startup time is not to exceed 30 minutes, after which time non-startup emission regulations apply [§63.6600(d)(Table 2c and 2d)]. Additionally, excessive idling at Startup may result in a temperature or pressure error report (i.e., the temperature and pressure values violate the conditions in **Table 3-1**).

Normal Start

The startup procedure of the stationary RICE is initiated from the Control Room at the Kalkaska Compressor Station. The engine is turned on. Heaters are used to preheat the operating fluids (oil and jacket water) of the RICE and connected compressor to come up to recommended operating temperatures. Once the recommended temperatures are reached, the connected compressor is put on line to pump gas per the required flow rate.

The Engine Operating Manual contains further details on the startup procedures and is attached as **Appendix E** and can also be obtained from the Alpena Station Operators.

4.2 Shutdown Procedures

A shutdown is defined as "the cessation of operation of an affected source or portion of an affected source for any purpose." [§63.2]

During shutdown of the engine, exhaust is vented through the existing oxidation catalyst to minimize emissions.

4.3 Malfunction Procedures

A malfunction is defined as "any sudden, infrequent, and not reasonably preventable failure of air pollution control and monitoring equipment, process equipment, or a process to operate in a normal or usual manner which causes, or has the potential to cause, the emission limitations in an applicable standard to be exceeded. Failures that are caused in part by poor maintenance or careless operation are not malfunctions." [§63.2]

Upon receiving a trouble alarm, the operator will evaluate the alarm to determine whether it is a nuisance alarm or an actual malfunction/system problem. If it is a nuisance alarm, the operator will acknowledge the alarm & continue operation as normal. If the alarm is not a nuisance alarm, the operator will trouble shoot the alarm using the unit manual (**Appendix E**).

All alarms and responses will be documented. Additionally, RICE MACT testing for catalyst operation is completed every year the Alpena Station is operating.

4.4 Recordkeeping and Reporting

Records are retained for all operations for a period of five years in accordance with 40 CFR 63.10(b)(1).

If a malfunction occurs, it needs to be included in the semiannual compliance report covering the period during which the malfunction occurred. In accordance with 40 CFR 63.10(b)(2), each malfunction instance will include the following:

- ☐The date, time, duration, and description of the malfunction;
- ☐Actions taken to minimize emissions; and
- ☐Actions taken to correct the malfunction.

SECTION 5: QUALITY CONTROL PROGRAM

The owner or operator of an affected source that is required to use a CMS and is subject to the monitoring requirements of this section and a relevant standard shall develop and implement a CMS quality control program. As part of the quality control program, the owner or operator shall develop and submit to the Administrator for approval upon request a site-specific performance evaluation test plan for the CMS performance evaluation required in paragraph 40 CFR 63.8(e)(3)(i) of this section, according to the procedures specified in paragraph (e). In addition, each quality control program shall include, at a minimum, a written protocol that describes procedures for each of the following operations [40 CFR 63.8(d)(2)]:

5.1 Calibrations [40 CFR 63.8(d)(2)(i) and (ii)]

The initial calibration of the Catalyst Monitor follows the installation directions in the monitor manual. Any subsequent calibrations follow the guidelines and recommendations also mentioned in the monitor manual. Procedures in the determination and/or adjustments required during calibration in order to account for calibration drifts are contained in the catalyst monitor manual.

5.2 Preventative Maintenance [40 CFR 63.8(d)(2)(iii) and (iv)]

All maintenance conducted on the monitoring system is done in accordance with the manual. A spare thermocouple and differential pressure transmitter are maintained at the station for regular maintenance of the catalyst monitoring system. Maintenance records are available from the Alpena Station Operators.

5.3 Audit Procedures [40 CFR 63.8(d)(2)(v)]

The continuous catalyst monitor system date / time stamps all data collected and stores the data in an internal database. The catalyst monitor observes the inlet temperature and pressure, calculates the differentials, and sounds an alarm in the case that an over or under threshold has been crossed. See Section 3.1.1 for more details.

Performance evaluations, system accuracy audits and other audit procedures are conducted at least annually.

5.5 Record Keeping [40 CFR 63.8(d)(3)]

These written procedures are kept on record for the life of the affected source or until the affected source is no longer subject to the regulations.

Appendix A
Allen Bradley Analog Modules Manual

Installation Instructions

FLEX I/O Input, Output and Input/Output Analog Modules

Cat. Nos. 1794-IE8, -IE8K, -OE4, -OE4K, and -IE4XOE2 Series B

(Modules with a K in the last position of the catalog number are conformally coated to meet noxious gas requirements of ISA/ANSI-71.040 1985 Class G3 Environment.)

Important User Information

Solid state equipment has operational characteristics differing from those of electromechanical equipment. *Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls* (Publication SGI-1.1 available from your local Rockwell Automation sales office or online at http://www.ab.com/manuals/gi) describes some important differences between solid state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.

In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

No patent liability is assumed by Rockwell Automation, Inc. with respect to use of information, circuits, equipment, or software described in this manual.

Reproduction of the contents of this manual, in whole or in part, without written permission of Rockwell Automation, Inc. is prohibited.

Throughout this manual we use notes to make you aware of safety considerations.

WARNING Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.

IMPORTANT Identifies information that is critical for successful application and understanding of the product.

ATTENTION Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you:

- identify a hazard
- avoid a hazard
- recognize the consequence

WARNING When you insert or remove the module while backplane power is on, an electrical arc can occur. This could cause an explosion in hazardous location installations. Be sure that power is removed or the area is nonhazardous before proceeding.

WARNING If you connect or disconnect wiring while the field side power is on, an electrical arc can occur. This could cause an explosion in hazardous location installations. Be sure that power is removed or the area is nonhazardous before proceeding..

ATTENTION FLEX I/O is grounded through the DIN rail to chassis ground. Use zinc plated yellow-chromate steel DIN rail to assure proper grounding. The use of other DIN rail materials (e.g. aluminum, plastic, etc.) that can corrode, oxidize, or are poor conductors, can result in improper or intermittent grounding.

ATTENTION **Environment and Enclosure**

This equipment is intended for use in a Pollution Degree 2 industrial environment, in overvoltage Category II applications (as defined in IEC publication 60664-1), at altitudes up to 2000 meters without derating.

This equipment is considered Group 1, Class A industrial equipment according to IEC/CISPR Publication 11. Without appropriate precautions, there may be potential difficulties ensuring electromagnetic compatibility in other environments due to conducted as well as radiated disturbance.

This equipment is supplied as "open type" equipment. It must be mounted within an enclosure that is suitably designed for those specific environmental conditions that will be present and appropriately designed to prevent personal injury resulting from accessibility to live parts. The interior of the enclosure must be accessible only by the use of a tool. Subsequent sections of this publication may contain additional information regarding specific enclosure type ratings that are required to comply with certain product safety certifications.

See NEMA Standards publication 250 and IEC publication 60529, as applicable, for explanations of the degrees of protection provided by different types of enclosure. Also, see the appropriate sections in this publication, as well as the Allen-Bradley publication 1770-4.1 ("Industrial Automation Wiring and Grounding Guidelines"), for additional installation requirements pertaining to this equipment.

ATTENTION **Preventing Electrostatic Discharge**

This equipment is sensitive to electrostatic discharge, which can cause internal damage and affect normal operation. Follow these guidelines when you handle this equipment:

- Touch a grounded object to discharge potential static.
- Wear an approved grounding wriststrap.
- Do not touch connectors or pins on component boards.
- Do not touch circuit components inside the equipment.
- If available, use a static-safe workstation.

European Zone 2 Hazardous Location Approval

The following analog input/output modules are European Zone 2 approved: 1794-IE8/B, 1794-IE8K/B, 1794-OE4/B, 1794-OE4K/B and 1794-IE4XOE2/B.

European Zone 2 Certification (The following applies when the product bears the EEx Marking)

This equipment is intended for use in potentially explosive atmospheres as defined by European Union Directive 94/9/EC.

The LCIE (Laboratoire Central des Industries Electriques) certifies that this equipment has been found to comply with the Essential Health and Safety Requirements relating to the design and construction of Category 3 equipment intended for use in potentially explosive atmospheres, given in Annex II to this Directive. The examination and test results are recorded in confidential report No. 28 682 010.

Compliance with the Essential Health and Safety Requirements has been assured by compliance with EN 50021.

IMPORTANT Observe the following additional Zone 2 certification requirements.

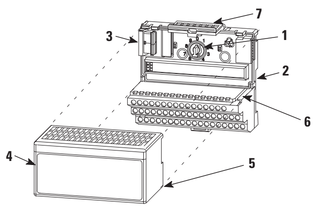
- This equipment is not resistant to sunlight or other sources of UV radiation.
- The secondary of a current transformer shall not be open-circuited when applied in Class I, Zone 2 environments.
- Equipment of lesser Enclosure Type Rating must be installed in an enclosure providing at least IP54 protection when applied in Class I, Zone 2 environments.
- This equipment shall be used within its specified ratings defined by Allen-Bradley.
- Provision shall be made to prevent the rated voltage from being exceeded by transient disturbances of more than 40% when applied in Class I, Zone 2 environments.

North American Hazardous Location Approval

The following modules are North American Hazardous Location approved: 1794-IE8/B, 1794-IE8K/B, 1794-OE4/B, 1794-OE4K/B and 1794-IE4XOE2/B.

The following information applies when operating this equipment in hazardous locations:	**Informations sur l'utilisation de cet équipement en environnements dangereux :**
Products marked "CL I, DIV 2, GP A, B, C, D" are suitable for use in Class I Division 2 Groups A, B, C, D, Hazardous Locations and nonhazardous locations only. Each product is supplied with markings on the rating nameplate indicating the hazardous location temperature code. When combining products within a system, the most adverse temperature code (lowest "T" number) may be used to help determine the overall temperature code of the system. Combinations of equipment in your system are subject to investigation by the local Authority Having Jurisdiction at the time of installation.	Les produits marqués "CL I, DIV 2, GP A, B, C, D" ne conviennent qu'à une utilisation en environnements de Classe I Division 2 Groupes A, B, C, D dangereux et non dangereux. Chaque produit est livré avec des marquages sur sa plaque d'identification qui indiquent le code de température pour les environnements dangereux. Lorsque plusieurs produits sont combinés dans un système, le code de température le plus défavorable (code de température le plus faible) peut être utilisé pour déterminer le code de température global du système. Les combinaisons d'équipements dans le système sont sujettes à inspection par les autorités locales qualifiées au moment de l'installation.
WARNING **EXPLOSION HAZARD** • Do not disconnect equipment unless power has been removed or the area is known to be nonhazardous. • Do not disconnect connections to this equipment unless power has been removed or the area is known to be nonhazardous. Secure any external connections that mate to this equipment by using screws, sliding latches, threaded connectors, or other means provided with this product. • Substitution of components may impair suitability for Class I, Division 2. • If this product contains batteries, they must only be changed in an area known to be nonhazardous.	**AVERTISSEMENT** **RISQUE D'EXPLOSION** • Couper le courant ou s'assurer que l'environnement est classé non dangereux avant de débrancher l'équipement. • Couper le courant ou s'assurer que l'environnement est classé non dangereux avant de débrancher les connecteurs. Fixer tous les connecteurs externes reliés à cet équipement à l'aide de vis, loquets coulissants, connecteurs filetés ou autres moyens fournis avec ce produit. • La substitution de composants peut rendre cet équipement inadapté à une utilisation en environnement de Classe I, Division 2. • S'assurer que l'environnement est classé non dangereux avant de changer les piles.

Installing Your Analog Input/Output Module



The module mounts on a 1794 terminal base.

ATTENTION During mounting of all devices, be sure that all debris (metal chips, wire strands, etc.) is kept from falling into the module. Debris that falls into the module could cause damage on power up.

1. Rotate the keyswitch (1) on the terminal base (2) clockwise to position 3 (1794-IE8), 4 (1794-OE4) or 5 (1794-IE4XOE2) as required.
2. Make certain the flexbus connector (3) is pushed all the way to the left to connect with the neighboring termbase/adapter. **You cannot install the module unless the connector is fully extended.**
3. Make sure the pins on the bottom of the module are straight so they will align properly with the connector in the terminal base.
4. Position the module (4) with its alignment bar (5) aligned with the groove (6) on the terminal base.
5. Press firmly and evenly to seat the module in the terminal base unit. The module is seated when the latching mechanism (7) is locked into the module.

Connecting Wiring for the Analog Inputs and Outputs

1. Connect individual input/output wiring to numbered terminals on the 0-15 row (A) for 1794-TB2, -TB3, -TB3S, -TB3T and -TB3TS, or on row (B) for the 1794-TBN as indicated in the following tables.

IMPORTANT Use Belden 8761 cable for signal wiring.

2. Connect channel common/return to the associated terminal on row (A) or row (B) for the 1794-TB2, -TB3, -TB3S, -TB3T and -TB3TS, or on row C for the 1794-TBN. For input devices requiring terminal base power, connect the channel power wiring to the associated terminal on row (C).
3. Connect any signal wiring shields to functional ground as near as possible to the module.

   1794-TB3T or -TB3TS only: Connect to earth ground terminals C-39 thru C-46.
4. Connect the +V dc power to terminal 34 on the 34-51 row (C) and -V common/return to terminal 16 on the B row.

ATTENTION To reduce susceptibility to noise, power analog modules and digital modules from separate power supplies. Do not exceed a length of 9.8 ft (3m) for dc power cabling.

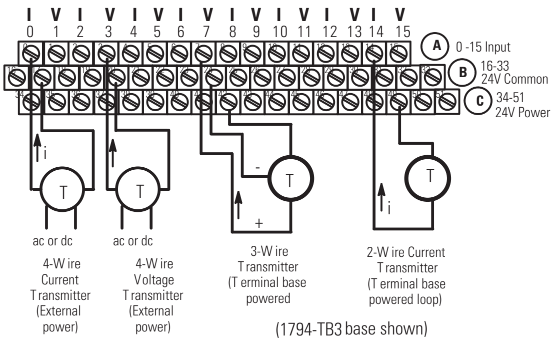
5. If daisychaining +V power to the next terminal base, connect a jumper from terminal 51 (+V dc) on this base unit to terminal 34 on the next base unit.
6. If continuing dc common (-V) to the next base unit, connect a jumper from terminal 33 (common) on this base unit to terminal 16 on the next base unit.

Wiring Connections for the 1794-IE8/B or -IE8K/B Analog Input Module

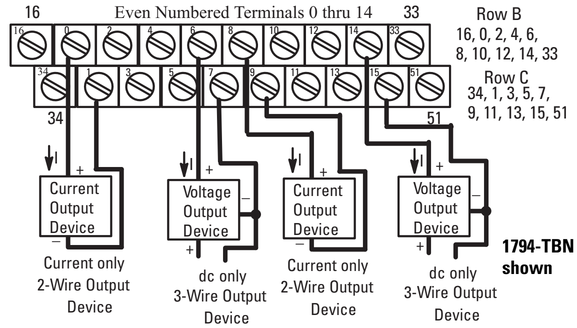
Channel	Signal Type	Label Marking	1794 -TB2, -TB3, -TB3S, -TB3T, -TB3TS,	1794 -TB3, -TB3S	1794 -TB2, TB3, -TB3S	1794-TB3T, -TB3TS	
			Input	Power[1]	Common Terminal		Shield
Input 0	Current	I0	A-0	C-35	B-17	B-17	C-39
	Voltage	V0	A-1	C-36	B-18	B-17	
Input 1	Current	I1	A-2	C-37	B-19	B-19	C-40
	Voltage	V1	A-3	C-38	B-20	B-19	
Input 2	Current	I2	A-4	C-39	B-21	B-21	C-41
	Voltage	V2	A-5	C-40	B-22	B-21	
Input 3	Current	I3	A-6	C-41	B-23	B-23	C-42
	Voltage	V3	A-7	C-42	B-24	B-23	
Input 4	Current	I4	A-8	C-43	B-25	B-25	C-43
	Voltage	V4	A-9	C-44	B-26	B-25	
Input 5	Current	I5	A-10	C-45	B-27	B-27	C-44
	Voltage	V5	A-11	C-46	B-28	B-27	
Input 6	Current	I6	A-12	C-47	B-29	B-29	C-45
	Voltage	V6	A-13	C-48	B-30	B-29	
Input 7	Current	I7	A-14	C-49	B-31	B-31	C-46
	Voltage	V7	A-15	C-50	B-32	B-31	
-V dc Common	1794-TB2, -TB3, -TB3S - Terminals 16 thru 33 are internally connected in the terminal base unit. 1794-TB3T, -TB3TS - Terminals 16, 17, 19, 21, 23, 25, 27, 29, 31 and 33 are internally connected in the terminal base unit.						
+V dc Power	1794-TB3, -TB3S - Terminals 34 thru 51 are internally connected in the terminal base unit. 1794-TB3T, -TB3TS - Terminals 34, 35, 50 and 51 are internally connected in the terminal base unit. 1794-TB2 - Terminals 34 and 51 are internally connected in the terminal base unit.						
Chassis Ground (Shield)	1794-TB3T, -TB3TS - Terminals 39 thru 46 are internally connected to chassis ground.						

1 Use when transmitter requires terminal base power.

Terminal Base Wiring for the 1794-IE8/B and -IE8K/B



Terminal Base Wiring for the 1794-OE4/B and -OE4K/B



Wiring Connections for the 1794-OE4/B and -OE4K/B Output Module

Channel	Signal Type	Label Marking	1794-TB2, -TB3, -TB3S, -TB3T, -TB3TS Output Terminal[1]	Shield (1794-TB3T, -TB3TS	1794-TBN Output Terminal[2]
Output 0	Current	I0	A-0	C-39	B-0
	Current	I0 Ret	A-1		C-1
	Voltage	V0	A-2	C-40	B-2
	Voltage	V0 Ret	A-3		C-3
Output 1	Current	I1	A-4	C-41	B-4
	Current	I1 Ret	A-5		C-5
	Voltage	V1	A-6	C-42	B-6
	Voltage	V1 Ret	A-7		C-7
Output 2	Current	I2	A-8	C-43	B-8
	Current	I2 Ret	A-9		C-9
	Voltage	V2	A-10	C-44	B-10
	Voltage	V2 Ret	A-11		C-11
Output 3	Current	I3	A-12	C-45	B-12
	Current	I3 Ret	A-13		C-13
	Voltage	V3	A-14	C-46	B-14
	Voltage	V3 Ret	A-15		C-15
-V dc Common	1794-TB3, -TB3S - Terminals 16 thru 33 are internally connected in the terminal base unit. 1794-TB3T, -TB3TS - Terminals 16, 17, 19, 21, 23, 25, 27, 29, 31 and 33 are internally connected in the terminal base unit. 1794-TB2 - Terminals 16 and 33 are internally connected in the terminal base unit				
+V dc Power	1794-TB3, -TB3S - Terminals 34 thru 51 are internally connected in the terminal base unit. 1794-TB3T, -TB3TS - Terminals 34, 35, 50 and 51 are internally connected in the terminal base unit. 1794-TB2 - Terminals 34 and 51 are internally connected in the terminal base unit.				
Chassis Ground (Shield)	1794-TB3T, -TB3TS - Terminals 39 thru 46 are internally connected to chassis ground.				

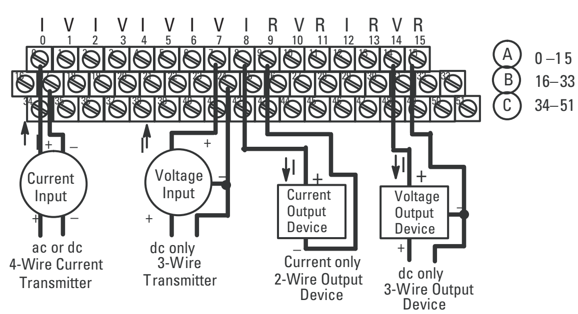
1 A-1, 3, 5, 7, 9, 11, 13 and 15 are internally connected in the module to 24V dc common.
2 C-1, 3, 5, 7, 9, 11, 13 and 15 are internally connected in the module to 24V dc common

Wiring Connections for the 1794-IE4XOE2/B 4 Analog Input/2 Output Module

Channel	Signal Type	Label Marking	1794-TB2, -TB3,-TB3S, -TB3T, -TB3TS	1794 -TB3, -TB3S	1794 -TB2, -TB3, -TB3S	1794-TB3T, -TB3TS	
			Input/Output Terminal[1]	Power Terminal[2]	Common Terminal		Shield
Input 0	Current	I0	A-0	C-35	B-17	B-17	C-39
	Voltage	V0	A-1	C-36	B-18	B-17	
Input 1	Current	I1	A-2	C-37	B-19	B-19	C-40
	Voltage	V1	A-3	C-38	B-20	B-19	
Input 2	Current	I2	A-4	C-39	B-21	B-21	C-41
	Voltage	V2	A-5	C-40	B-22	B-21	
Input 3	Current	I3	A-6	C-41	B-23	B-23	C-42
	Voltage	V3	A-7	C-42	B-24	B-23	
Output 0	Current	I0	A-8				C-43
	Current	RET	A-9				
	Voltage	V0	A-10				C-44
	Voltage	RET	A-11				
Output 1	Current	I1	A-12				C-45
	Current	RET	A-13				
	Voltage	V1	A-14				C-46
	Voltage	RET	A-15				
-V dc Common	1794-TB2, -TB3, -TB3S - Terminals 16 thru 33 are internally connected in the terminal base unit. 1794-TB3T, -TB3TS - Terminals 16, 17, 19, 21, 23, 25, 27, 29, 31 and 33 are internally connected in the terminal base unit.						
+V dc Power	1794-TB3, -TB3S - Terminals 34 thru 51 are internally connected in the terminal base unit. 1794-TB3T, -TB3TS - Terminals 34, 35, 50 and 51 are internally connected in the terminal base unit. 1794-TB2 - Terminals 34 and 51 are internally connected in the terminal base unit.						
Chassis Ground (Shield)	1794-TB3T, -TB3TS - Terminals 39 thru 46 are internally connected to chassis ground.						

1 A-9, 11, 13 and 15 are internally connected in the module to 24V dc common.
2 Use when transmitter requires terminal base power.

Terminal Base Wiring for the 1794-IE4XOE2/B (1794-TB3 Terminal Base shown)



Input Map (Read) - 1794-IE8, -IE8K

Dec.	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Oct.	17	16	15	14	13	12	11	10	7	6	5	4	3	2	1	0
Word 0	S	Analog Input Value for Channel 0														
Word 1	S	Analog Input Value for Channel 1														
Word 2	S	Analog Input Value for Channel 2														
Word 3	S	Analog Input Value for Channel 3														
Word 4	S	Analog Input Value for Channel 4														
Word 5	S	Analog Input Value for Channel 5														
Word 6	S	Analog Input Value for Channel 6														
Word 7	S	Analog Input Value for Channel 7														
Word 8	PU	Not used - set to zero							U7	U6	U5	U4	U3	U2	U1	U0

Where :PU = Power up inconfigured
S = Sign bit (in 2's complement)
U = Underrange for specified channel

Output Map (Write) - 1794-IE8, -IE8K

Dec.	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Oct.	17	16	15	14	13	12	11	10	7	6	5	4	3	2	1	0
Word 3	C7	C6	C5	C4	C3	C2	C1	C0	F7	F6	F5	F4	F3	F2	F1	F0

Where :
C = Configure select bit
F = Full range bit

Input Map (Read) - 1794-IE4XOE2

Dec.	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Oct.	17	16	15	14	13	12	11	10	7	6	5	4	3	2	1	0
Word 0	S	Analog Input Value for Channel 0														
Word 1	S	Analog Input Value for Channel 1														
Word 2	S	Analog Input Value for Channel 2														
Word 3	S	Analog Input Value for Channel 3														
Word 4	PU	Not used - set to zero									W1	W0	U3	U2	U1	U0

Where :PU = Power up inconfigured
S = Sign bit (in 2's complement)
W1 and W0 = Diagnostic bits for current output. Wire off current loop status for output channels 0 and 1
U = Underrange for specified channel

Output Map (Write) - 1794-IE4XOE2

Dec.	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Oct.	17	16	15	14	13	12	11	10	7	6	5	4	3	2	1	0
Word 0	S	Analog Output Data - Channel 0														
Word 1	S	Analog Output Data - Channel 1														
Word 2	Not used - set to 0														M1	M0
Word 3	0	0	C5	C4	C3	C2	C1	C0	0	0	F5	F4	F3	F2	F1	F0
Words 4 and 5	Not used - set to 0															
Word 6		Safe State Value for Channel 0														
Word 7		Safe State Value for Channel 1														

Where :
PU = Power up inconfigured
CF = In configuration mode
DN = Calibration accepted
U = Underrange for specified channel
P0 and P1 = Outputs holding in response to Q0 and Q1
FP = Field power off
BD = Bad calibration
W1 and W0 = Wire off current loop status for output channels 0 and 1
V = Overrange for specified channel

Range Selection Bits - 1794-IE8, -IE8K and -IE4XOE2

1794-IE8	In Ch. 0		In Ch. 1		In Ch. 2		In Ch. 3		In Ch. 4		In Ch. 5		In Ch. 6		In Ch. 7	
1794-IE4XOE2	In Ch. 0		In Ch.1		In Ch. 2		In Ch. 3		Out Ch. 0		Out Ch. 1					
	F0	C0	F1	C1	F2	C2	F3	C3	F4	C4	F5	C5	F6	C6	F7	C7
Dec. Bits	00	08	01	09	02	10	03	11	04	12	05	13	06	14	07	15
0-10V dc/ 0-20mA	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4-20mA	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
-10 to +10V dc	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
OFF[1]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Where: C = Configure Select Bit F = Full range
1 When configured to Off, individual input channels will return 0000H; output channels will drive 0V/0mA.

Input Map (Read) - 1794-OE4, -OE4K

Dec.	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Oct.	17	16	15	14	13	12	11	10	7	6	5	4	3	2	1	0
Word 0	PU	Not used - set to 0											W3	W2	W1	W0

Where : PU = Power up bit
W thru W3 = Wire off current loop status for output channels

Output Map (Write) - 1794-OE4, -OE4K

Dec.	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Oct.	17	16	15	14	13	12	11	10	7	6	5	4	3	2	1	0
Word 0	S	Output Data Channel 0														
Word 1	S	Output Data Channel 1														
Word 2	S	Output Data Channel 2														
Word 3	S	Output Data Channel 3														
Word 4		Not used - set to 0											M3	M2	M1	M0
Word 5	Not used - set to 0				C3	C2	C1	C0	Not used - set to 0				F3	F2	F1	F0
Word 6-9	Not used - set to 0															
Word 10	S	Safe state value for Channel 0														
Word 11	S	Safe state value for Channel 1														
Word 12	S	Safe state value for Channel 2														
Word 13	S	Safe state value for Channel 3														

Where :
S = Sign bit (in 2's complement)
M = Multiplex control bit
C = Configure select bit
F = Full range bit

Range Selection Bits - 1794-OE4, -OE4K

Channel No.	In Ch. 0		In Ch.1		In Ch. 2		In Ch. 3	
	F0	C0	F1	C1	F2	C2	F3	C3
Dec. Bits	00	08	01	09	02	10	03	11
0-10V dc/ 0-20mA	1	0	1	0	1	0	1	0
4-20mA	0	1	0	1	0	1	0	1
-10 to +10V dc	1	1	1	1	1	1	1	1
OFF[1]	0	0	0	0	0	0	0	0

Where: C = Configure Select Bit F = Full range
1 When configured to Off, individual output channels will drive 0V/0mA.

Specifications

Input Specifications	
Number of Inputs	**1794-IE8, -IE8K -** 8 single-ended, nonisolated **1794-IE4XOE2 -** 4 single-ended nonisolated
Resolution Voltage Current	12 bits unipolar; 11 bits plus sign bipolar 2.56mV/cnt unipolar; 5.13mV/cnt bipolar 5.13µA/cnt
Data Format	left justified, 16 bit 2s complement
Conversion Type	successive approximation
Conversion Rate	256µs all channels
Input Current Terminal	4-20mA (user configurable 0-20mA (user configurable
Input Voltage Terminal	±10V (user configurable) 0-10V (user configurable)
Normal Mode Rejection Ratio - Voltage Terminal Current Terminal	3dB @ 17Hz; -20db/decade -10db @ 50Hz;-11.4db @ 60Hz -3dB @ 9Hz; -20db/decade -15.3db @ 50Hz;-16.8db @ 60Hz
Step Response to 63% -	Voltage Terminal - 9.4ms Current Terminal - 18.2ms
Input Impedance	Voltage Terminal - 100k ohms Current Terminal - 238 ohms
Input Resistance Voltage	Voltage Terminal - 200k ohms Current Terminal - 238 ohms
Absolute Accuracy[1]	0.20% Full Scale @ 25°C
Accuracy Drift with Temperature	Voltage Terminal - 0.00428% Full Scale/°C Current Terminal - 0.00407% Full Scale/°C
Calibration Required	None required
Maximum Overload	30V continuous or 32mA continuous, one channel at a time.
Indicators	1 green power indicator

Output Specifications

Number of Outputs	**1794-OE4, -OE4K -** 4 single-ended, nonisolated **1794-IE4XOE2 -** 2 single-ended, nonisolated
Resolution Voltage Current	12 bits plus sign 0.156mV/cnt 0.320µA/cnt
Data Format	left justified, 16 bit 2's complement
Conversion Type	Pulse width modulation
Output Current Terminal	0mA output until module is configured 4-20mA (user configurable 0-20mA (user configurable
Output Voltage Terminal	0V output until module is configured ±10V (user configurable) 0-10V user configurable)
Step Response to 63% - Voltage or Current Terminal	24ms
Current Load on voltage output	3mA maximum
Absolute Accuracy[1] Voltage Terminal Current Terminal	 0.133% Full Scale @ 25°C 0.425% Full Scale @ 25°C
Accuracy Drift with Temperature Voltage Terminal Current Terminal	 0.0045% Full Scale/°C 0.0069% Full Scale/°C
Resistive Load on mA Output	15-750 ohm @ 24V dc

General Specifications for 1794-IE8, -IE8K, -OE4, -OE4K, and -IE4XOE2

Module Location	**Cat. No. 1794-IE8, -IE8K, -IE4XOE2 -** 1794-TB2, -TB3, -TB3S, -TB3T, -TB3TS Terminal Base Unit **Cat. No. 1794-OE4, -OE4K -** 1794-TB2, -TB3, -TB3S, -TB3T, -TB3TS, and -TBN Terminal Base Unit
Terminal Base Screw Torque	7 pound-inches (0.8Nm) 9 pound-inches (1.0Nm) for 1794-TBN
Isolation Voltage	Tested at 850V dc for 1s between user power to system No isolation between individual channels
External dc Power Supply Voltage Range Supply Current	 24V dc nominal 10.5 to 31.2V dc (includes 5% ac ripple) 1794-IE8, -IB8K - 60mA @ 24V dc; 150mA @ 12V dc 1794-OE4, -OE4K - 70mA @ 24V dc; 150mA @ 12V dc 1794-IE4XOE2 - 70mA @ 24V dc; 150mA @ 12V dc
Dimensions (with module installed)	31.8H x 3.7W x 2.1D inches 45.7H x 94W x 53.3D mm
Flexbus Current	20mA
Power Dissipation	1794-IE8, -IB8K - 3.0W maximum @ 31.2V dc 1794-OE4, -OE4K - 4.5W maximum @ 31.2V dc 1794-IE4XOE2 - 4.0W maximum @ 31.2V dc
Thermal Dissipation	1794-IE8, -IB8K - Maximum 10.2 BTU/hr @ 31.2V dc 1794-OE4, -OE4K - Maximum 13.6 BTU/hr @ 31.2V dc 1794-IE4XOE2 - Maximum 15.3 BTU/hr @ 31.2V d
Keyswitch Position	1794-IE8, -IB8K - 3 1794-OE4, -OE4K - 4 1794-IE4XOE2 - 5
Environmental Conditions Operating Temperature	 IEC 60068-2-1 (Test Ad, Operating Cold), IEC 60068-2-2 (Test Bd, Operating Dry Heat), IEC 60068-2-14 (Test Nb, Operating Thermal Shock): 0 to 55°C (32 to 131°F)
Storage Temperature	IEC 60068-2-1 (Test Ab, Un-packaged Non-operating Cold), IEC 60068-2-2 (Test Bb, Un-packaged Non-operating Dry Heat), IEC 60068-2-14 (Test Na, Un-packaged Non-operating Thermal Shock): –40 to 85°C (–40 to 185°F)
Relative Humidity	IEC 60068-2-30 (Test Db, Unpackaged Nonoperating Damp Heat): 5 to 95% non-condensing
Vibration	IEC60068-2-6 (Test Fc, Operating): 5g @ 10-500Hz
Shock	IEC60068-2-27 (Test Ea, Unpackaged shock): Operating 30g Non-operating 50g
Emissions	CISPR 11 Group 1, Class A (with appropriate enclosure)
ESD Immunity	EC 61000-4-2: 4kV contact discharges 8kV air discharges
Radiated RF Immunity	IEC 61000-4-3: 10V/m with 1kHz sine-wave 80%AM from 30MHz to 1000MHz
Conducted RF Immunity	IEC 61000-4-6: 10V rms with with 1kHz sine-wave 80%AM from 150kHz to 30MHz
EFT/B Immunity	IEC 61000-4-4: ±2kV at 5kHz on signal ports
Surge Transient Immunity	IEC 61000-4-5: ±2kV line-earth (CM) on shielded ports
Enclosure Type Rating	None (open-style)
Conductors Wire Size Category[2]	22-12AWG (0.34mm²-2.5mm²) stranded copper wire rated at 75°C or higher 3/64 inch (1.2mm) insulation maximum 2
Certifications (when product is marked)[3]	**UL** UL Listed Industrial Control Equipment **UL** UL Listed for Class I, Division 2 Group A,B,C,D Hazardous Locations **cULus** UL Listed Industrial Control Equipment, certified for US and Canada (1794-IE8, -OE4) **cUL** UL Listed for Class I, Division 2 Group A,B,C,D Hazardous Locations, certified for Canada (1794-IE8, -IE8K, -OE4, -OE4K) **CSA** CSA certified Process Control Equipment **CSA** CSA certified for Class I, Division 2, Groups A, B, C and D Hazardous locations **EEx[3]** European Union 94/9/EEC ATEX Directive, compliant with: EN 50021; Potentially Explosive Atmospheres, Protection "n" (European Zone 2) **CE[3]** European Union 89/336/EEC EMC Directive, compliant with: EN 61000-6-4; Industrial Emissions EN 50082-2; Industrial Immunity EN 61326; Meas./Control/Lab., Industrial Requirements EN 61000-6-2; Industrial Immunity **C-Tick[3] -** Australian Radiocommunications Act compliant with AS/NZS CISPR 11, Industrial Emissions

1 Includes offset, gain, nonlinearity and repeatability error terms.
2 You use this category information for planning conductor routing as described in Allen-Bradley publication 1770-4.1, Industrial Automation Wiring and Grounding Guidelines.
3 For the latest up-to-date information, see the Product Certification link at www.ab.com for Declarations of Conformity, Certificates and other certification details. For notification of any additional release notes, refer to www.ab.com/manuals/.

www.rockwellautomation.com

Power, Control and Information Solutions Headquarters

Americas: Rockwell Automation, 1201 South Second Street, Milwaukee, WI 53204-2496 USA, Tel: (1) 414.382.2000, Fax: (1) 414.382.4444
Europe/Middle East/Africa: Rockwell Automation, Vorstlaan/Boulevard du Souverain 36, 1170 Brussels, Belgium, Tel: (32) 2 663 0600, Fax: (32) 2 663 0640
Asia Pacific: Rockwell Automation, Level 14, Core F, Cyberport 3, 100 Cyberport Road, Hong Kong, Tel: (852) 2887 4788, Fax: (852) 2508 1846

Publication 1794-IN100B-EN-P - June 2004
PN 957899-39
Supersedes Publication 1794-IN100A-EN-P - April 2003

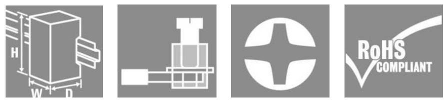
Appendix B

WAVESERIES WAS5 PRO Thermo Data Sheet

Data sheet

WAVESERIES
WAS5 PRO Thermo

Weidmüller Interface GmbH & Co. KG
Klingenbergstraße 16
D-32758 Detmold
Germany
Fon: +49 5231 14-0
Fax: +49 5231 14-292083
www.weidmueller.com



The configurable WAS5/WAZ5 PRO Thermo TC signal isolating converter with external power supply in 17.5 mm width:
for recording, linearising, transforming and isolating thermal voltages into standardised DC current and voltage signals.
Standardised thermocouples of types K, J, T, E, N, R, S and B can be connected to the input side, in compliance with IEC584.
The input and output parameters (e.g. sensor type, temperature range and standardised output signal) can be configured using the DIP switches.
The input/output channels and 24 VDC power supply are completely isolated with 4 kV.
The PRO Thermo is optionally available with screw or tension-clamp wire connections. The 24 VDC supply voltage can be bridged using pluggable ZQV 2.5N jumpers on the module side.
Use the WAVETOOL program available from Weidmüller's website for adjustments and settings.
They can be used in many applications around the world because of their international approvals (cULus, CULusEX and GL).

General ordering data

Type	WAS5 PRO Thermo
Order No.	8560720000
Version	TC isolating transformer, Screw connection
GTIN (EAN)	4032248207336
Qty.	1 pc(s).

Weidmüller

WAVESERIES
WAS5 PRO Thermo

Weidmüller Interface GmbH & Co. KG
Klingenbergstraße 16
D-32758 Detmold
Germany
Fon: +49 5231 14-0
Fax: +49 5231 14-292083
www.weidmueller.com

Technical data

Dimensions and weights

Length	92.4 mm	Length (inches)	3.638 inch
Width	17.5 mm	Width (inches)	0.689 inch
Depth	112.4 mm	Depth (inches)	4.425 inch
Weight	100 g	Net weight	128.8 g

Temperatures

Operating temperature	0 °C...55 °C	Storage temperature	-20 °C...85 °C

Probability of failure

MTTF	270 Years

Input

Number of inputs	1	Sensor	Thermo element (IEC 584) type: K,J,T,E,N,R,S,B
Line resistance in measuring circuit	50 Ω	Temperature input range	-200...+1820 °C

Output

Number of outputs	1	Output voltage, note	0...10 V
Output current	0...20 mA, 4...20 mA	Wire break detection	LED flashing (output value: > 20 mA, >10 V)
Fine adjustment	± 5% (switchable)	cold junction compensation	Yes
load impedance voltage	≥ 1 kΩ	load impedance current	≤ 600 Ω
Offset voltage	max. 0.05 V	Offset current	max. 100 µA
Status indicator	Module active: LED on/ wire breakage: LED flashing/ Error: LED off		

General data

Accuracy	Type K & J: -150°C... 1200°C ±(3°C + 0,1% of range), Type T: -150°C... 400°C ±(3°C + 0,1% of range), Type E: -150°C... 1000°C ±(3°C + 0,1% of range), Type N: -150°C... 1300°C ±(3°C + 0,1% of range), Type R & S: 200°C...1760°C ±(6°C + 0,1% of range), Type B: 500°C...1820°C ±(6°C + 0,1% of range)	Configuration	DIP switch
Current-carrying capacity of cross-connect.	≤ 2 A	Galvanic isolation	3-way isolator
Input/Output	configurable	Linearity	Yes
Mounting rail	TS 35	Power consumption	800...850...950 mW at I_{OUT} = 20 mA
Step response time	without filter: max. 1.4 s; with filter: max. 7.5 s	Supply voltage	24 V DC ± 20 %
Type of connection	Screw connection		

WAVESERIES
WAS5 PRO Thermo

Weidmüller Interface GmbH & Co. KG
Klingenbergstraße 16
D-32758 Detmold
Germany
Fon: +49 5231 14-0
Fax: +49 5231 14-292083
www.weidmueller.com

Technical data

Insulation coordination

Clearance & creepage distances	≥ 3 mm	EMC standards	EN 55011, EN 61000-6
Galvanic isolation	3-way isolator	Impulse withstand voltage	4 kV
Insulation voltage	2 kV_{eff} / 5 s	Insulation voltage input or output/rail	4 kV_{eff} / 1 min.
Insulation voltage input or output/supply	2 kV_{eff} / 5 s	Pollution severity	2
Rated voltage	300 V	Standards	DIN EN 50178, DIN EN 61000-4-2
Surge voltage category	III		

Connection data

Type of connection	Screw connection	Clamping range, rated connection	2.5 mm²
Clamping range, rated connection, min.	0.5 mm²	Clamping range, rated connection, max.	2.5 mm²

Classifications

ETIM 4.0	EC002653	ETIM 5.0	EC002653
ETIM 6.0	EC002653	UNSPSC	31-12-10-07
eClass 5.1	27-21-01-20	eClass 6.2	27-21-01-20
eClass 7.1	27-21-01-20	eClass 8.1	27-21-01-20
eClass 9.0	27-21-01-20		

Product information

Descriptive text accessories	Cross-connector for power supplies and markers – refer to Accessories

Approvals

Approvals	CE, cULus LISTED, cULus LISTED FOR HAZ.LOC. C1D2, EAC
ROHS	Conform

Downloads

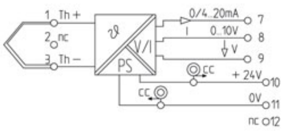
Package insert	instruction sheet.pdf
Software	WaveTool.zip
Declaration of Conformity	Declaration of Conformity.pdf
EPLAN	8560720000.ema
3-D model	

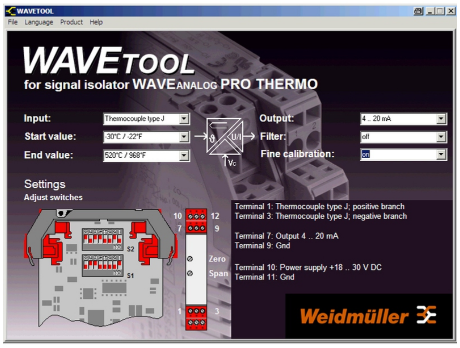
WAVESERIES
WAS5 PRO Thermo

Weidmüller Interface GmbH & Co. KG
Klingenbergstraße 16
D-32758 Detmold
Germany
Fon: +49 5231 14-0
Fax: +49 5231 14-292083
www.weidmueller.com

Drawings

Electric symbol





Screenshot example, Wave tool software

Addresses worldwide
Let's connect.

AE United Arab Emirates
Weidmuller Middle East FZE
Warehouse Q3-79
SAIF-Zone
P.O. BOX 8591
Sharjah
Telephone number +971 65572723
Fax number +971 65572724
wme.info@weidmueller.com

AO Angola
Please contact
Phambili Interface
South Africa

AR Argentina
CPI SA
Bauness 2660
C1431DOF Buenos Aires
Telephone number +54 11 4523 8008
Fax number +54 11 4522 0546
info@cpi.com.ar
www.cpi.com.ar

AT Austria
Weidmüller GmbH
IZ NOE Süd Straße 2b, Obj M 59
2355 Wiener Neudorf
Telephone number +43 2236 67080
Fax number +43 2236 6708-899
office.at@weidmueller.com
www.weidmueller.com

AU Australia
Weidmüller Pty. Ltd.
PO BOX 6944
Huntingwood 2148
Huntingwood Drive 43
Huntingwood NSW 2148
Telephone number +61 2 9671 9999
Fax number +61 2 9671 9911
info@weidmuller.com.au
www.weidmuller.com.au

AZ Azerbaijan
Representative Office
Weidmüller Interface
Demirchi Tower, 4th floor
37, Khojali ave.
AZ 1025 Baku
Telephone number +994 12 488 80 36
Fax number +994 12 488 80 37
rashad.mahmudov@weidmueller.com

BA Bosnia and Herzegovina
Please contact
our Representative Office
Weidmüller Interface GmbH & Co. KG
Serbia

or

BIG electric d.o.o
Mladena Stojanovića 117A
78000 Banja Luka
Telephone number +387 51926277
Fax number +387 51926277
bigelectric@blic.net
www.bigelectric.ba

BE Belgium
Weidmüller Benelux B. V.
Mechelsesteenweg 519 bus 6 en 7
1930 Nossegem
Telephone number +32 2 752 40 70
Fax number +32 2 751 36 06
info@weidmueller.be
www.weidmueller.be

BG Bulgaria
Weid-Bul EOOD
Bul. "Kliment Ohridski" 13
1756 Sofia
Telephone number +359 2 963 2560
Fax number +359 2 963 1098
sofia@weidbul.com
www.weidbul.com

BH Bahrain
Khayber Trading Company
P.O Box 1976
Manama
Telephone number +973 720747
Fax number +973 720331
khayber@batelco.com.bh

BR Brazil
Weidmuller Conexel do Brasil
Conexões Elétricas Ltda.
Av. Presidente Juscelino, 642 - Piraporinha
Diadema, São Paulo
09950-370
Telephone number +55 (11) 4366-9600
Fax number +55 (11) 4362-1677
vendas@weidmueller.com.br
www.weidmueller.com.br

BW Botswana
Please contact
Phambili Interface
South Africa

BY Belarus
TECHNIKON Ltd.
Nezavisimosti pr. 177-9
220125 Minsk
Telephone number +375 17 393-11-77
Fax number +375 17 3930080
wm@technikon.by

CA Canada
W Interconnections Canada Inc.
10 Spy Court
Markham Ontario L3R 5H6
Telephone number +1 (905) 475-1507 Ext. 9836
Fax number +1 (905) 475-2798
support@weidmuller.ca
www.weidmuller.ca

CG Congo
Please contact
Phambili Interface
South Africa

CH Switzerland
Weidmüller Schweiz AG
Rundbuckstraße 2
8212 Neuhausen am Rheinfall SH
Telephone number +41 52 674 07 07
Fax number +41 52 674 07 08
info@weidmueller.ch
www.weidmueller.ch

CL Chile
ATS - INTECH
María Luisa Santander 0475
Santiago
Providencia 7500859
Telephone number +56 2 341 1271
Fax number +56 2 341 1275
felipe@atsintech.com
www.atsintech.com

CPI CHILE LTDA
Av. Presidente Frei Montalva 6001, 47 complejo el cortijo
Santiago - Conchali
Telephone number +562 963 8440
Fax number +562 963 8440
cpi@cpichile.cl
www.cpichile.cl

CN China
Weidmüller Interface (Shanghai) Co. Ltd.
100 Yutong Road
25 F, BM Intercontinental Business Center
200070 Shanghai
Telephone number +86 21-22195008
Fax number +86 21-22195009
customer.hotline@weidmueller.com.cn
www.weidmueller.com.cn

CO Colombia
Automatización Avanzada S. A.
Carrera 97 No., 24 c - 23
Bodega 4
110911 Bogotá-D.C.
Telephone number +57 (1) 547-8510
Fax number +57 (1) 422-3044
comercial@automatizacionavanzada.com
www.automatizacionavanzada.com

CR Costa Rica
ELVATRON S. A.
la Uruca 400 Norte Banco Costa Rica
San Jose Costa Rica
Telephone number +506 2961-060
Fax number +506 5200-609
dirk.haase@elvatron.com
www.elvatron.com

CZ Czech Republic
Weidmüller s.r.o.
Lomnického 5/1705
140 00 Praha 4
Telephone number +420 244 001 400
Fax number +420 244 001 499
office@weidmueller.cz
www.weidmueller.cz

DE Germany
Weidmüller GmbH & Co. KG
Ohmstraße 9
32758 Detmold
Postfach 30 54
32720 Detmold
Telephone number +49 5231 1428-0
Fax number +49 5231 14-292083
weidmueller@weidmueller.de
www.weidmueller.de

DK Denmark
Weidmüller Danmark
Vallensbækvej 18A
2605 Brøndby
Telephone number +45 27747800
kundeservice@weidmuller.dk
www.weidmuller.dk

DZ Algeria
SARL INTER ELECTRIC
1a Angles des Rues Okba Ibn Nafaa et Hassi Beida
2300 Annaba
Telephone number
Fax number
contact@inter-electric.com

EC Ecuador
Elsystec S. A., Electricidad Sistemas y Tecnología
Vasco de Contreras N35-251 y Mañosca
Quito - Pichincha
Telephone number +593 22456510
Fax number +593 22456755
Elsystec@uio.satnet.net

EE Estonia
Please contact
our Representative Office
Weidmüller Interface GmbH & Co. KG
Latvia

or

Soots Interface OÜ
Pärnu mnt 142
11317 Tallinn
Telephone number +372 609 6933
Fax number
info@sootsinterface.ee
www.sootsinterface.ee

EG Egypt
Standard Electric (OMEGA)
1, Abdelhamid Badawy Street
Heliopolis
Cairo
Telephone number +202 21805111
Fax number +202 21805600
stdelec@rite.com

ES Spain
Weidmüller, S. A.
Narcis Monturiol 11-13, Pol. Ind. Sudoeste
8960 Sant Just
Desvern - Barcelona
Telephone number +34 934 803 386
Fax number +34 933 718 055
weidmuller@weidmuller.es
www.weidmuller.es

FI Finland
Weidmüller Suomi, Weidmüller Aktiebolagetin sivuliike
Koy Plaza Vivace
Äyritie 8C
FI 1510 Vantaa
Telephone number +358 20 7351300
Fax number +358 800 114 667
asiakaspalvelu@weidmuller.fi
www.weidmuller.fi

FR France
Weidmüller E. U. R. L.
12, Chaussée Jules César
BP 263 Osny
95523 Cergy-Pontoise Cedex
Telephone number +33 1 34 24 55 00
Fax number +33 1 34 24 55 01
mail@weidmuller.fr

GB Great Britain
Weidmüller Ltd.
Klippon House
Centurion Court Office Park, Meridian East, Meridian Business Park
Leicester
LE19 1TP
Telephone number +44 116 282 3470
Fax number +44 116 289 3582
marketing@weidmuller.co.uk
www.weidmuller.co.uk

GE Georgia
Please contact
our Representative Office
Weidmüller Interface
Azerbaijan.

GH Ghana
Please contact
our Representative Office
Weidmüller Interface GmbH & Co. KG
South Africa.

GR Greece
G.A. Solutions
Ippokratous 11 Metamorfosi
144 52 Athen
Telephone number +30 210 2823233
Fax number +30 210 2823233
info@weidmuller.gr
www.weidmuller.gr

GT Guatemala
Prestelectro, Prestegard Electro, S.A.
Avenida Petapa 44-22, Zona 12
Guatemala City
Telephone number +502 2442-3346
Fax number +502 2476-8945
ventas@prestelectro.com

HK Hong Kong
Weidmuller (Hong Kong) Limited Co. Ltd.
Unit 1617, Metropolis Tower
No. 10 Metropolis Drive, Hunghom, Kowloon
Telephone number +852 3154 8088
Fax number +852 31548099
Info-hk@weidmueller.com.hk

HR Croatia
ElektroPARTNER d.o.o.
Slavonska avenija 24/6
HR-10000 Zagreb
Telephone number +385 (1) 6184 793
Fax number +385 (1) 6184 795
elektropartner@zg.t-com.hr
www.elektropartner.hr

HU Hungary
Weidmüller Kereskedelmi Kft.
Budapest
Gubacsi út 6.
1097
Telephone number +36 1 382 7700
Fax number +36 1 382 7701
info@weidmueller.hu
www.weidmueller.hu

ID Indonesia
PT. Nego Electrindo
Ruko Mega Grosir Cempaka Mas Blok I No. 20 – 22
Jakarta 10640
Telephone number +62 21 42882255
Fax number +62 21 42882266
sales@negoelectrindo.co.id

IE Ireland
Please contact
Weidmüller Ltd.
Great Britain

IL Israel
A. U. Shay Ltd.
23/25, Embar Street
49222 Petach-Tikva
P.O. Box 1 00 49
49222 Petach-Tikva
Telephone number +972 3-923-3601
Fax number +972 3-923-4601
shay@uriel-shay.com
www.uriel-shay.com

ATEKA Ltd.
4, Ha Tavor lane Industrial area Segula
49691 Petach-Tikva
P.O. Box 4710
Petach-Tikva
Telephone number +972 73-200-1311
Fax number +972 3-924 4245
marketing@ateka.co.il
www.ateka.co.il

IN India
Representative Office
Weidmüller Electronics India Pvt. Ltd.
12th Lane North Avenue, Opp Joggers Park,
Kalyani Nagar, Pune
411 006
Telephone number +91 20-41290090
wmi@weidmueller.in
www.weidmueller.com

IS Iceland
Samey Automation Center
Lyngas 13
210 Garoabaer
Telephone number +354 510 5200
Fax number +354 5 10 5201
Samey@samey.is
www.samey.is

IT Italy
Weidmüller S. r.l.
Via Albert Einstein 4
20092 Cinisello Balsamo Milano
Telephone number +39 02 660681
Fax number +39 02 6124945
weidmuller@weidmuller.it
www.weidmuller.it

JM Jamaica
Please contact
W Interconnections Inc.
United States

JO Jordan
Trans Jordan for Electro
PO Box 33 06 07
Amman
Telephone number +962 6 533 2020
Fax number +962 6 533 5800
transjordan@batelco.jo

You can find all Weidmüller addresses and your local contact on the internet at: www.weidmueller.com/countries

Let's connect.

Sales company
Representation abroad
without representation abroad

JP **Japan**
Nihon Weidmüller Co. Ltd.
Sphere Tower Tennoz 2-2-8
Higashi-Shinagawa,
Shinagawa-ku
Tokyo
140-0002
Telephone number +81 3 6711 5300
Fax number +81 3 6711 5333
weidmullerjapan@weidmuller.co.jp
www.weidmuller.co.jp

KE **Kenya**
Please contact
our Representative Office
Weidmüller Interface GmbH & Co. KG
South Africa.

KG **Kyrgyzstan**
Please contact
our Representative Office
Weidmüller Interface
Azerbaijan.

KR **Korea**
Weidmuller Korea Co. Ltd.
9th floor
429, Teheran-ro, Gangnam-Gu
Seoul 135-721
Telephone number +82 2-516-0003
Fax number +82 2-516-0090
info@weidmuller.co.kr
www.weidmuller.co.kr

KW **Kuwait**
Kana Controls General Trading & Contracting Co. W. L. L.
Al Rai Industrial Area, Plot 28-30, St. 31
13016 Safat
B.P. 25593
Telephone number +965 4741373
Fax number +965 4741537
info@kanacontrols.com

KZ **Kazakhstan**
Please contact
Weidmüller Group
Russia

LB **Lebanon**
Progress Engineering & Trading Enterprises
Al Nahr Street
Beirut 11-1111
Telephone number +961 1 444 664
Fax number +961 1 561 880
progress@inco.com.lb

LT **Lithuania**
Please contact
our Representative Office
Weidmüller Interface GmbH & Co. KG
Latvia

or

ELEKTROS IRANGA
Tinklu g. 29 a
LT-5319 Panevezys
Telephone number +370 (45) 582 828
Fax number
info@eliranga.lt

LU **Luxembourg**
Please contact
Weidmüller Benelux B. V.
Netherlands

LV **Latvia**
SIA Abi4
Daugavgrivas 31b
Riga, LV-1007
Telephone number +371 674 70999
Fax number +371 676 24562
abi_4@tvnet.lv

Representative Office
Weidmüller Interface GmbH & Co. KG
Udens str. 12-118
Riga, LV-1007
Telephone number +371 29254766
Fax number +371 674 65637
Ilgonis.rudaks@weidmueller.com
www.weidmueller.com

MA **Morocco**
Sofimed
137, Bd Moulay Ismail Roches Noires
20290 Casablanca
Telephone number
Fax number
contact@sofimedmaroc.com

MD **Moldova**
BERHORD A & D srl
79/1, str. Milescu Spartaru
MD-2075 Chisinau
Moldova
Telephone number +373 (22) 815002
Fax number +373 (22) 815007
atiuleanu@berhord.com
www.ad.berhord.com

ME **Montenegro**
Please contact
our Representative Office
Weidmüller Interface GmbH & Co. KG
Serbia.

MG **Madagascar**
Please contact
Phambili Interface
South Africa

MK **Macedonia**
Please contact
our Representative Office
Weidmüller Interface GmbH & Co. KG
Serbia

or

ELEKTRO - SMK dooel
UL. III Makedonska brigada b.b.
1000 Skopje
Telephone number +389 22460295
Fax number
Elektro-smk@telekabel.net.mk

MN **Mongolia**
Please contact
our Representative Office
Weidmüller Interface
Azerbaijan.

MT **Malta**
E. S. S., Electrical Supplies & Services Ltd.
San Gwakkin Road
Mriehel

Telephone number +356 21255777
Fax number +356 21255999
robert.agius@ess.com.mt

MU **Mauritius**
Mubelo Electrical Ltd.
Office 26, Gateway building,
St Jean Road
Quatre Bornes
Mauritius
Telephone number +230 4670989
Fax number +230 4654051
richard.mubelo@orange.mu

MW **Malawi**
Please contact
our Representative Office
Weidmüller Interface GmbH & Co. KG
South Africa.

MX **Mexico**
W Interconnections S. A. DE C. V.
Blvd. Hermanos Serdán 698,
Col. San Rafael Oriente
72029 Puebla
Telephone number +52 (222) 268 6227
Fax number +52 (222) 286 6242
clientes@weidmuller.com.mx

MY **Malaysia**
Connect Plus Technology Sdn Bhd
No. 43, Jalan PJS 11/22,
Bandar Sunway
46150 Petaling Jaya
Selangor Darul Ehsan
Telephone number +60 3 5633 7363
Fax number +60 3 5633 6562
paul@cptech.com.my
www.cptech.com.my

MZ **Mozambique**
Please contact
Phambili Interface
South Africa

NA **Namibia**
Please contact
Phambili Interface
South Africa

NG **Nigeria**
Please contact
Weidmüller Interface GmbH & Co. KG
South Africa

NL **Netherlands**
Weidmüller Benelux B. V.
Franciscusweg 221
1216 SE Hilversum
P.O. Box 1505
1200 BM Hilversum
Telephone number +31 35 626 12 61
Fax number +31 35 623 20 44
info@weidmuller.nl
www.weidmuller.nl

NO **Norway**
Sivilingeniør J.F. Knudtzen AS
Billlingstadsletta 97
1396 Billingstad
PO Box 160
1378 Nesbru
Telephone number +47 66 98 33 50
Fax number +47 66 98 09 55
firmapost@jfknudtzen.no
www.jfknudtzen.no

NZ **New Zealand**
Cuthbert S. Steward Ltd.
27 Te Puni Street
Petone
PO Box 38496
Wellington Mail Centre 5054
Telephone number (04) 568 6156
Fax number (09) 489 1752
csl@cuthbertstewart.co.nz

Cuthbert S. Steward Ltd
4 Fred Thomas Drive
Aon Building, Ground Floor,
South Entry
Takapuna
PO Box 100 338
North Shore City 745
Telephone number (09) 489 1751
Fax number (04) 568 6056
cslak@cuthbertstewart.co.nz

OM **Oman**
DAN INTERNATIONAL LLC.
Ghala St. 111
BP 2901
Seeb
Telephone number +968 5036 77
Fax number +968 5037 55
yedu@danintl.com

PE **Peru**
IMPEXINCA S.A.C.
Calle Ortiz de Zevallos No. 105, Urb. San Antonio 18
Lima, Miraflores
Telephone number +51 1 447 5608
info@impexinca.pe
www.impexinca.pe

J & W CIA. S. A.
Calle 6 Mz. D Lte. 23, Urb. Ind. Grimanesa 01
Callao
Telephone number +51 1 572 2539
Fax number +51 1 572 0152
contacto@jwcia.com
www.jwcia.com

PH **Philippines**
Enclosure Systems Specialists Inc.
2276 Don Chino Roces Avenue Extension
Room 103/105 Narra Building
1231 Makati City
Telephone number +63 2 813 8580
Fax number +63 2 813 8596
sales_encsys@pldtdsl.net
www.enclosuresystemsph.com

PK **Pakistan**
Automation Controls (Pak)
Apartment No. 33 C III,
Chenab Block, Allama Iqbal Town
Lahore
Telephone number +92 42 37809948
Fax number +92 42 37809950
nadeem@acpak.com.pk
www.acpak.com.pk

PL **Poland**
Weidmüller Sp. z. o. o.
ul. Ogrodowa 58
00-876 Warszawa
Telephone number +48 22 510 09 40
Fax number +48 22 510 09 41
biuro@weidmuller.com.pl
www.weidmuller.pl

PR **Puerto Rico**
Please contact
W Interconnections Inc.
United States

PT **Portugal**
Weidmüller Sistemas de Interface S. A.
Estrada Outeiro Polima, R. Augusto Dias da Silva, Lote B - Esct. 2
São Domingos de Rana
2785-515 Abóboda
Telephone number +351 214 459 191
Fax number +351 214 455 871
weidmuller@weidmuller.pt
www.weidmuller.pt

PY **Paraguay**
Please contact
CPI SA
Argentina

QA **Qatar**
Doha Motors
PO Box 145

Telephone number +974 4651441
Fax number +974 4654579
dmtctech@qatar.net.qa
http://www.dohamotorsgroup.com/td.html

Petroleum Technology Co. W.L.L.
PO Box 16069
5th Floor Toyota tower
Telephone number +974 44419603
Fax number +974 44419604
petrotec@qatar.net.qa
www.petrotec.com.qa

RO **Romania**
Representative Office
Weidmüller Interface GmbH & Co. KG
Ionescu Crum Street, No. 1, 1st Tower, 1st Floor, Office 4
500446 Brasov - Brasov Business Park
Telephone number +40 (268) 446 222
Fax number +40 (262) 205 410
claudiu.totea@weidmueller.com
www.weidmueller.com

RS **Serbia**
Representative Office
Weidmüller Interface GmbH & Co. KG
Ustanicka 189, III sprat
lokal 7a
11050 Beograd
Telephone number +381 112885274
Fax number +381 112885274
zoran.rabrenovic@weidmueller.com

TeLa Elektrik d.o.o.
Ul.Dr Drage Ljočić 6
Beograd
Telephone number +381 11 2772 415
Fax number +381 11 2772 850
office@tela.rs
www.tela.rs

RU **Russia**
Weidmüller Group
7/10 Khlebozavodskiy Passage,
Moskau
115230
Telephone number +7 495 280 72 71
Fax number +7 495 280 72 71
Info@weidmueller.ru
www.weidmueller.ru

SA **Saudi Arabia**
Al Abdulkarim Holding Co.
P.O. Box 4
Dammam 31411
Telephone number +966 3 8337110
Fax number +966 3 8829547
E-mail salehsk@akh.com.sa
www.weidmueller.ae

Saudi Electric Supply Company (SESCO)
P.O. Box 32 98
Al Khobar 31952
Telephone number +966 3 8829546 Ext. 3030
Fax number
E-mail Safdar.Malik@sesco-gex.com
www.sesco-gex.com

SE **Sweden**
Weidmüller AB
Axel Danielssons väg 271
BOX 31025
SE-200 49 Malmö
Telephone number +46 77-143 00 44
Fax number +46 40-37 48 60
info@weidmuller.se
www.weidmuller.se

SG **Singapore**
Weidmüller Pte. Ltd.
70 Bendemeer Road
04-03 Luzerne Building
Singapore 339940
Telephone number +65 6841 5311
Fax number +65 6841 5377
info@weidmuller.com.sg
www.weidmuller.com.sg

SI **Slovenia**
Elektrospoji d. o. o.
Stegne 27
SI- 1000 Ljubljana
Osrednjeslovenska
Telephone number +386 1 511 3810
Fax number +386 1 511 1604
info@elektrospoji.si
www.elektrospoji.si

SK **Slovakia**
ELEKTRIS s.r.o.
Elektrárenská 1
831 04 Bratislava
Telephone number +421 2/4920 0113
Fax number +421 2/4920 0119
bratislava@elektris.sk

Addresses worldwide
Let's connect.

SV El Salvador
Prestegard Electro
11 Avenida Norte No. 240
Edificio Salazar No. 2
San Salvador
Telephone number +503 2271 1690
Fax number +503 2221 3851
prestegard@navegante.com.sv

SY Syria
Please contact
Weidmuller Middle East FZE
United Arab Emirates

SZ Swaziland
Please contact
Phambili Interface
South Africa

TH Thailand
Pisanu Engineering Co. Ltd.
Kwang Dingaeng, Khet Dingaeng
800/2 Soi Trakulsuk, Asoke-dindaeng Road
Dindaeng, Bangkok
10400
Telephone number +66 2 248 2896
Fax number +662 105 6301
ecsales@pisanu.co.th
www.pisanu.co.th

Representative Office
Weidmüller Pte. Ltd.
37/F, Sathorn Square Building
98 North Sathorn Road
Bangkok, Silom Bangrak
10500
Telephone number +66 2 105 6300
Fax number +66 2 642 9220
info@weidmuller.com.sg

TJ Tajikistan
Please contact
our Representative Office
Weidmüller Interface
Azerbaijan.

TM Turkmenistan
Please contact
our Representative Office
Weidmüller Interface
Azerbaijan.

TN Tunisia
Please contact
Weidmüller E. U. R. L.
France

TR Turkey
Weidmüller Elektronik Ticaret Ltd. Sirketi
Kavacik Mah. Orhan Veli Kanik Caddesi 9/1
34810 Beykoz / Istanbul
Telephone number +90 (216) 537 10 70
Fax number +90 (216) 537 10 77
info@weidmuller.com.tr
www.weidmuller.com.tr

TW Taiwan
Weidmuller (Hong Kong) Limited
No. 3, Lane 89, ChaungYang N. Rd
24148 SanChuang City, Taipei
Telephone number +886 921 949 751
roy.lin@weidmueller.com.hk

TZ Tanzania
Please contact
our Representative Office
Weidmüller Interface GmbH & Co. KG
South Africa.

UA Ukraine
LLC WM UKRAINE
Levanevskogo str. 6
Kiev
3058
Telephone number +38 044 490 32 48
Fax number
info@wm-ua.com.ua
wm-ua.com.ua/

Representative Office
Weidmueller Interface GmbH & Co. KG
Z, office 303
7-D, Zdolbunivska str.
Kiev, 2081
Telephone number (mobile) +38 050 440 25 24
info.ua@weidmueller.com

US United States
W Interconnections Inc.
821 Southlake Boulevard
Richmond Virginia 23236
Telephone number +1 (804) 794-2877
Fax number +1 (804) 379-2593
info@weidmuller.com
www.weidmuller.com

UY Uruguay
REWO Uruguay S. A.
AV. Bolivia 2001Esq Rocafuerte
11300 Carracso Montevideo
Telephone number +598 2604 8439
Fax number +598 2604 8439
rewo@rewouruguay.com.uy

UZ Republic of Uzbekistan
Please contact
our Representative Office
Weidmüller Interface
Azerbaijan.

VE Venezuela
Somerinca C. A.
Corazon de Jesus - 3ra Transversal con calle el Carmen- Los Dos Caminos
Caracas 1070-A
Telephone number +58 2122352748
Fax number +58 2122399341
klocmoeller@cantv.net
www.somerinca.com

VN Vietnam
AUMI Industrial Equipment & Automation Company Limited
E1, La Thanh Hotel
218 Doi Can Street
Lieu Giai Ward, Ba Dinh District
Hanoi City
Telephone number +84 4 37628601
Fax number +84 4 62661391
aumi@aumi.com.vn
www.aumi.com.vn

Representative Office
Weidmüller Pte. Ltd.
Level 16 Saigon Tower Building
29 Le Duan Street
District 1
Ho Chi Minh
Telephone number +848 3520 7717
Fax number +848 3520 7604
info@weidmuller.com.sg

ZA South Africa
Phambili Interface
PO Box 193
1609 Johannesburg, Edenvale
5 Bundo Road, Sebenza
1610 Johannesburg
Telephone number +27 (11) 4521930
Fax number
info@weidmuller.co.za
www.weidmuller.co.za

Representative Office
Weidmüller Interface GmbH & Co. KG
210 Amarand
Avenue, Pegasus Building
181 Pretoria, waterkloof Glen ext 2 -
Telephone number +27 12 003 2906
Fax number +27 (11) 4526455
Jacques.Vosloo@weidmueller.com
www.weidmueller.com

ZM Zambia
Please contact
Phambili Interface
South Africa

ZW Zimbabwe
Please contact
Phambili Interface
South Africa

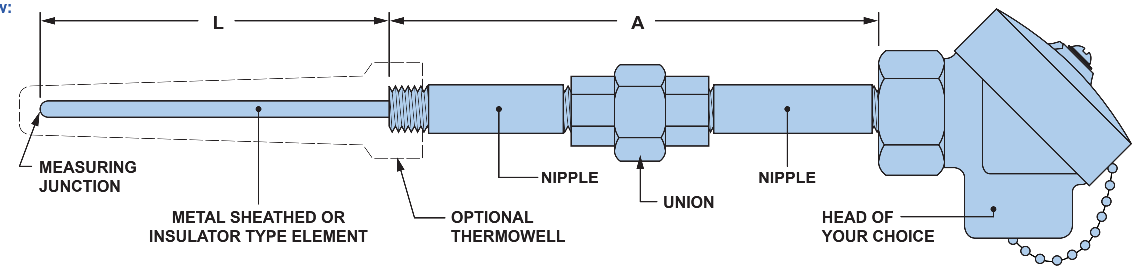
Appendix C

Sandelius Instruments Thermocouple

To order any style on this page see below:

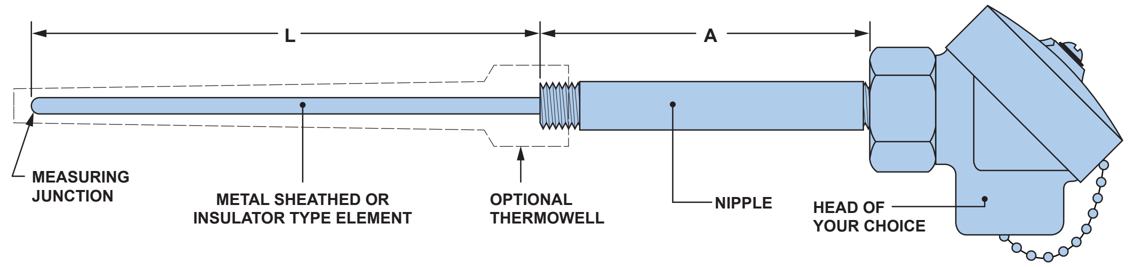
Sandelius Style 1H –

Head Mounted with a Nipple-Union-Nipple (For spring-loading , insert an "S" in front of the style number)



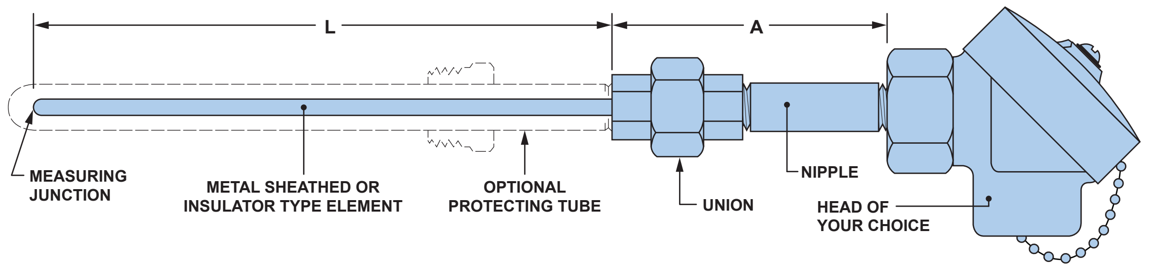
Sandelius Style 2H –

Head Mounted with a Nipple Only (For spring-loading , insert an "S" in front of the style number)



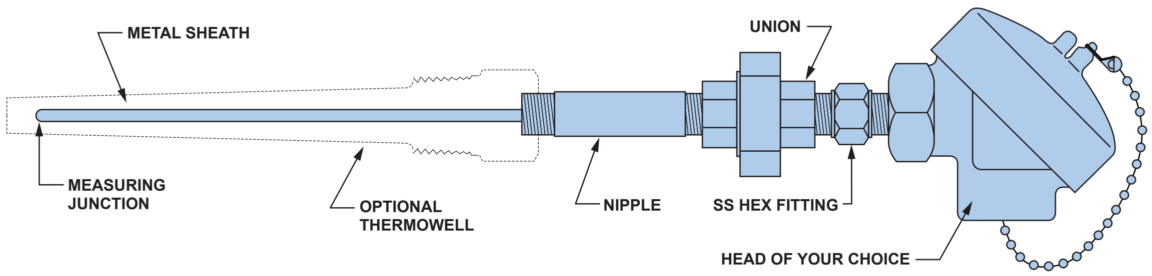
Sandelius Style 3H –

Head Mounted with a Nipple-Union Only (For spring-loading , insert an "S" in front of the style number)



Style 7H –

Nipple-Union-Brazed SS Fitting - Head (For spring-loading , insert an "S" in front of the style number)



To Order Any Style 1H, 2H, 3H or 7H Assembly Specify:

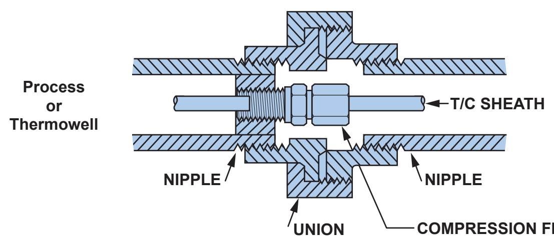
S1H–250K316–G–18–4G6–C46B–(Optional Thermowell)[2]

- See Catalog Section B[1]
- Head Pages A-18 & A-19
- Nominal A Dimension in inches
- Nipple & Union Material
  C–Carbon Steel, G–Galvanized Steel, S–Stainless Steel
- Nipple Sizes
  4– 1/2" NPT; 6– 3/4" NPT, 8– 1" NPT
- L – Length in inches[1]
- Junction Pg. A-10
- Element Pg. A-10 or A-8
- Assembly Style (If spring-loaded is desired, insert a "S" in front of the assembly style).

Optional Internal Pressure Seal

Internal pressure seals are used in applictions where thermowells are subjected to extremely harsh environments which may cause thermowell failure. If the thermowell does in fact fail, the pressure seal confines the process preventing the escape of process liquids and/or gases until a new thermowell can be installed.

This design may also be used to seal off thermocouples which must be inserted directly into a furnace or process stream without the use of a thermowell.



1. To order an assembly complete with a thermowell or protecting tube, simply insert the part number of the thermowell or protecting tube desired from Section B of this catalog. When ordering a complete assembly, the "L" (element) length should be shown as "00" (the element will be precisely matched to the thermowell or protecting tiube).
2. When ordered without a thermowell assembly, Assembly Styles 1H, 2H, 3H, 4H and S5H are shipped unassembled to avoid damage in transit.

To order specfiy Sandelius Assembly Style "P1H" and complete the part number as indicated. (Note Assembly Style "P1H" cannot be spring-loaded).

METAL SHEATH TYPE THERMOCOUPLE ELEMENTS

SANDELIUS NUMBERING SYSTEM

125 J 316

SHEATH O.D IN 1000ths OF AN INCH — CALIBRATION SYMBOL — SHEATH MATERIAL

SHEATH O.D IN 1000ths OF AN INCH

ORDER SYMBOL	APPROXIMATE FRACTION
020	1/50
032	1/32
040	1/25
063	1/16
125	1/8
188	3/16
250	1/4
313	5/16
375	3/8
500	1/2

CALIBRATION SYMBOL

ORDER SYMBOL*	CONDUCTOR MATERIAL	TEMPERATURE RANGE
E	Chromel / Constantan	-328 - 1652ºF**
J	Iron / Constantan	32 - 1382ºF**
K	Chromel / Alumel	-328 - 2282ºF**
R	Platinum / Platinum 13% Rh	32 - 2642ºF
S	Platinum / Platinum 10% Rh	32 - 2642ºF
B	Platinum 6% Rh / Platinum 30% Rh	1598 - 3092ºF
N	Nicrosil / Nisil	32 - 2282ºF
T	Copper / Constantan	-328 - 662ºF**

* Single letter calibration symbol is used for single element. A double letter calibration symbol is used for dual element. EXAMPLE: 125JJ316 is dual element type J.

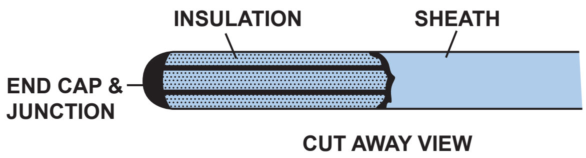
** Type E, K & T may be used for cryogenic temperature as low as -328ºF, but must be specifically ordered to insure accuracy in cryogenic range.

SHEATH MATERIAL

ORDER SYMBOL	MATERIAL
200	Nickel 200
304	304SS
304L	304L
310	310SS
310L	310L
316	316SS
316L	316L
321	321SS
347	347SS
400	Monel 400
446	446SS
600	Inconel 600
601	Inconel 601
625	Inconel 625
800	Incoloy 800
276	Hastelloy C-276
277	Hastelloy X
285	Tantalum
337	Titanium Grade 2
928	Pyrosil

MEASURING JUNCTION STYLES

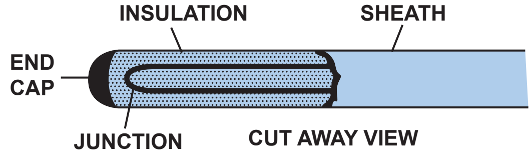
G-GROUNDED JUNCTION



The conductors and sheath material are simultaneously cap welded. This process forms a measuring junction which is an integral part of the end cap and electrically grounded to the sheath. The most common junction style, grounded junctions protect the thermocouple conductors from contamination and offer fast response times.

Order Symbol: **G-Single or Dual Element**

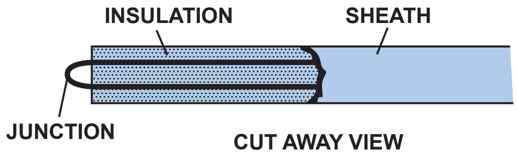
R-REMOTE OR UNGROUNDED JUNCTION



The conductors are first junction welded together. Prior to cap welding the sheath, the junction is covered with insulating material to insulate it from the sheath and end cap. Remote junctions protect the thermocouple conductors from both contamination and outside electrical interference. They are used whenever electrical isolation of the element is desirable.

Order Symbol:
R – Single Element
RC* – Dual Element Common
RS* – Dual Element Separate

E-EXPOSED JUNCTION



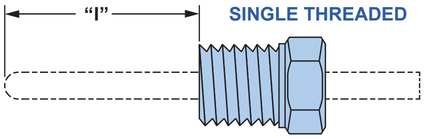
The sheath material is stripped back slightly and the conductors are welded together to form a measuring junction. The exposed insulation is sealed against moisture penetration. Exposed junctions provide the fastest possible response times but do not offer protection to the thermocouple conductors.

Order Symbol:
E – Single Element
EC* – Dual Element Common
ES* – Dual Element Separate

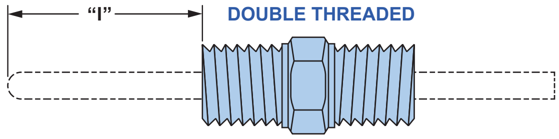
* When ordering dual element remote or exposed junctions, a "C" indicates common junction (all four conductors welded together forming a common junction); an "S" indicates separate junctions (each thermocouple element independently junctioned and isolated from each other).

FIXED FITTINGS – ARE BRAZED OR WELDED TO THE SHEATH

STYLE 1
SINGLE THREADED



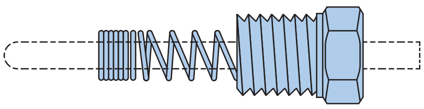
STYLE 2
DOUBLE THREADED



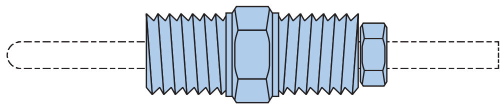
ORDER SYMBOL		THREAD SIZE	MATERIAL	AVAILABLE TO FIT THESE SHEATH O.D. SIZES
STYLE 1	STYLE 2			
F11	F21	1/8" NPT	304SS	0.063, 0.125, 0.188 & 0.250
F12	F22	1/4" NPT	304SS	0.063, 0.125, 0.188, 0.250, 0.313 & 0.375
F14	F24	1/2" NPT	304SS	0.063, 0.125, 0.188, 0.250, 0.313, 0.375 & 0.500
F16	F26	3/4" NPT	304SS	0.063, 0.125, 0.188, 0.250, 0.313, 0.375 & 0.500
F18	F28	1" NPT	304SS	0.063, 0.125, 0.188, 0.250, 0.313, 0.375 & 0.500

SPRING-LOADED FITTINGS

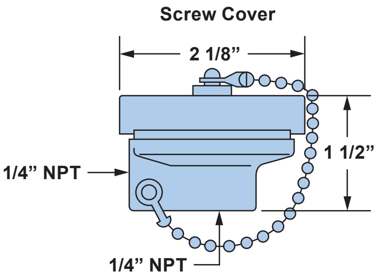
STYLE 1 – SINGLE THREADED

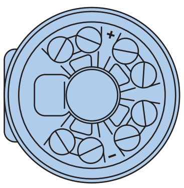


STYLE 2 – DOUBLE THREADED



ORDER SYMBOL		THREAD NPT SIZE	MATERIAL	SPRING TYPE	AVAILABLE SHEATH SIZES
STYLE 1	STYLE 2				
SF14	SF24	1/2" NPT	304SS	Adjustable	0.125, 0.188, 0.250, 0.312 & 0.375
SB14	–	1/2" NPT	BRASS	Adjustable	0.125, 0.188, 0.250, 0.312 & 0.375
SPF14	SPF24	1/2" NPT	304SS	Adjustable with Liquid-tight O-Ring	0.125, 0.188 & 0.250

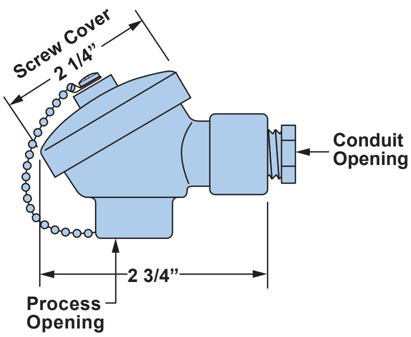




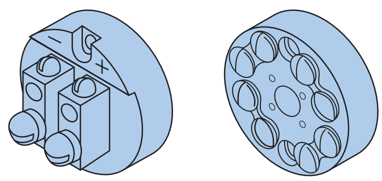
Miniature Weatherproof Thermoset Plastic Head

1/4" NPT x 1/4" NPT with 4 Integral Terminals

Part Number	Ambient Temperature Rating
N22	350° F
W22	800° F

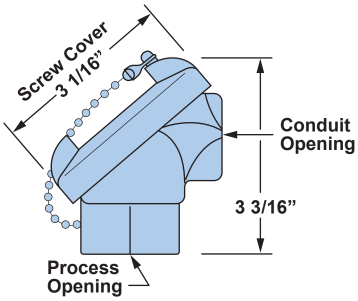


Miniature Aluminum Head (Type M)
Part Number: M44* (1/2" x 1/2" NPT)
(Use "120" Series Terminal Blocks)
Max No. of Terminals: 4 + Ground
*See note on page A-18



Ceramic Terminal Blocks
Fit Miniature Head Type: M

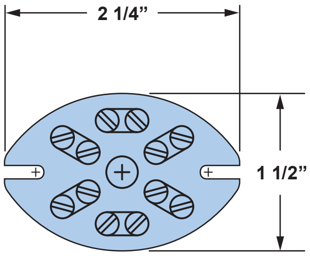
Part Number	Description
CP122	2 - Terminals
CP124	4 - Terminals



Standard Weatherproof Heads

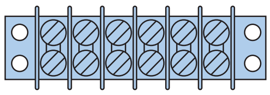
(Use "115F Series" Ceramic Terminal Blocks)
Max. number of terminals: 6+Ground.

Part Number[1]	Type	Description
P46*	P	Polypropylene
PW46*	PW	White Polypropylene[2] (FDA Compliant)
Q46*	Q	Aluminum
R46*	R	Cast Iron
T46*	T	Cast Iron/Aluminum[5] Explosion Proof[4]



115 Series Ceramic Terminal Blocks

Part Number[1]	Description
CP115F	2 Terminals

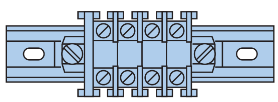


CP129 & CP130 Terminal Strips

CP129 (3/8" spacing) is standard in E & F type heads.
CP130 (7/16" spacing) available with compensated terminals is commonly used in junction boxes.

To Order Specify

CP130–12–K
- Type of Optional Compensated Terminals (Available on CP130 only)
- Number of Terminals (20 max.)
- Part Number

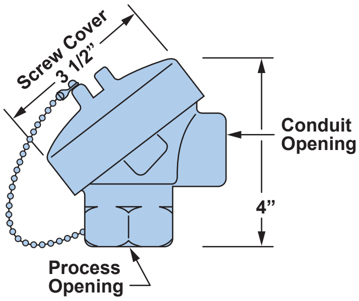


CP140 Tubular Clamp Type Terminal Strip

Commonly used in junction boxes. May be specified as an option for E & F type heads.

To Order Specify

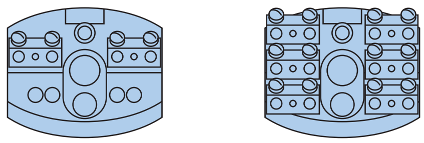
CP140–10
- Number of Terminals
- Part Number



Large Weatherproof Heads

(Use "100 Series" Ceramic Terminal Blocks)
Max. number of terminals: 6+Ground.

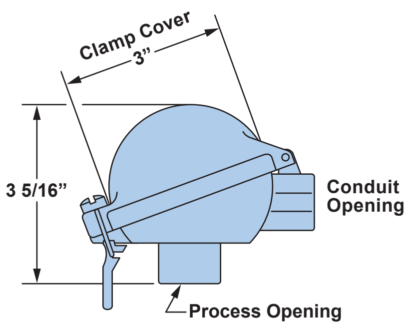
Part Number[1]	Type	Description
A46*	A	Aluminum
C46*	C	Cast Iron



100 Series Ceramic Terminal Blocks

Fit Head Types: A, B, C, D

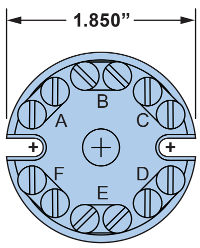
Part Number[1]	Description
CP102	2 Terminals
CP104	4 Terminals
CP106	6 Terminals



Weatherproof Aluminum Head

(Use "117 Series" Terminal Blocks)
Max No. of Terminals: 6 + Ground

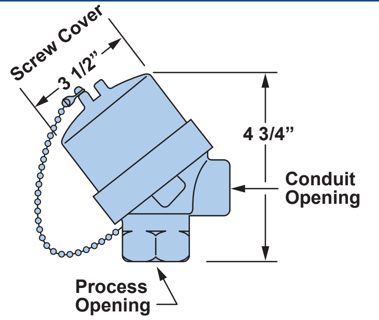
Part Number[1]	Type	Description
H44*	H	1/2" x 1/2" NPT
H46*	H	1/2" x 3/4" NPT



117 Series Ceramic Terminal Blocks

Fit Head Type: H44

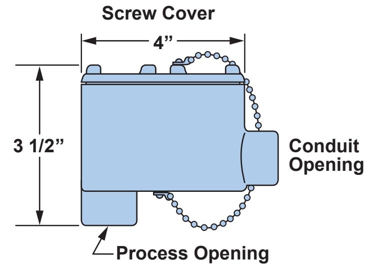
Part Number	Description
CP117	6 Terminals



Large Dome Cover Weatherproof Heads

(Use "100 Series" Ceramic Terminal Blocks)
Max. number of terminals: 6+Ground.

Part Number[1]	Type	Description
B46*	B	Aluminum
D46*	D	Cast Iron



Large Explosion Proof[3] Heads

(Standard Terminal Block is CP129)
Max No. of Terminals: 6 + Ground

Part Number[1]	Type	Description
E46*	E	Aluminum
F46*	F	Cast Iron/Aluminum[5]

To Order Any Head On This Page

C 4 6 B
- Connector block if required.
  B – 2 Terminals   C – 3 Terminals
  D – 4 Terminals   F – 6 Terminals
- Conduit Opening (See table A below)
- Process Opening (See table A below)
- Head Type
- If a tapped internal ground screw is required insert a "G" in front of the part number.

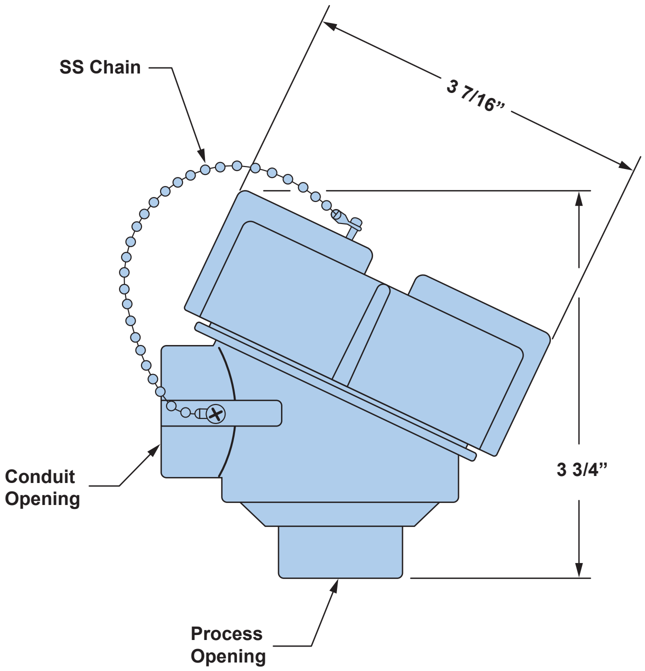
Table A -Connection Sizes[7] (All heads on this page)

NPT SIZE	ORDER CODES	Available on Head Types	
		PROCESS	CONDUIT
1/2	4	All	All
3/4	6	All except H+P	All
1	8	A B C D E F & R	E & F

Notes:

* To order heads complete with terminal block add suffix to specify the number of terminals required B=2 terminals, C=3 terminals, etc.

1. Unless otherwise noted, all head part numbers shown are for heads with 0.5" NPT process openings and 0.75" NPT conduit openings. See Table A for other available sizes.
2. PW series heads may be specially ordered with molded-in terminals. To order insert an "M" before the number of terminals required. Example: PW46MF would have 6 molded-in terminals.
3. Type E & F explosion proof heads are approved for Class 1, Groups B, C, & D; Class 2, Groups E, F & G; Class 3, All Groups.
4. Type T explosion proof heads are approved for Class 1, Groups C & D; Class 2, Groups E, F & G; Class 3, All Groups.
5. Type F & T explosion proof heads have cast iron bodies with aluminum covers.
6. Aluminum & Cast Iron heads are available with epoxy coating add an "X" after the type designation. Example: QX46D.
7. Some NPT sizes are achieved through the use of reducing bushings.



To Order Specify

AE–46–D

- Standard Terminal Block
  - B – 2 Terminal Block (CP162B)
  - C – 3 Terminal Block (CP162C)
  - D – 4 Terminal Block (CP162D)
  - F – 6 Terminal Block (CP162F)
  - Leave blank if no Terminal Block
- Connection Code (See Table B)
- Basic Part Number (See Table A)

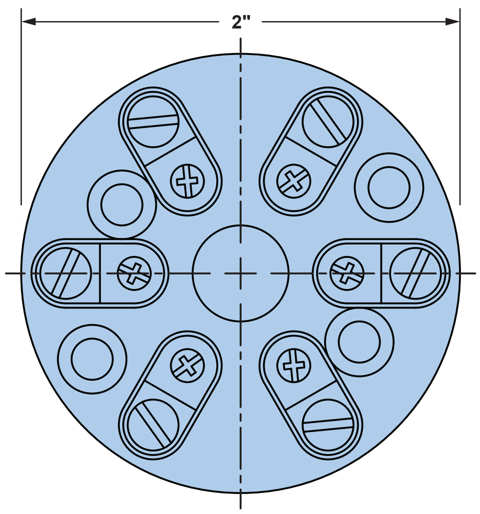
TABLE A - Basic Part Numbers	
Part Number	**Material**
AE	Aluminum, Explosion Proof
AEX	Epoxy Coated Aluminum, Explosion Proof
SE	316SS, Explosion Proof

Table B – Connection Code		
Code	**Process Opening**	**Conduit Opening**
44	1/2" NPT	1/2" NPT
45	1/2" NPT	M20 x 1.5
46	1/2" NPT	3/4" NPT
66	3/4" NPT	3/4" NPT

FM/CSA APPROVALS:
CLASS 1, DIV. 1, GROUPS B, C & D and
Dust Ignitionproof for Class II, Div. 1,
Group E, F and G, Class III
Type 4X and IP68

Ex II 2 G Ex d IIC Gb Ta, IP68
II 2 D Ex tb IIIC Db Ta, IP68

IECEx Approvals:
Ex d IIC Gb
Ex tb IIIC Db

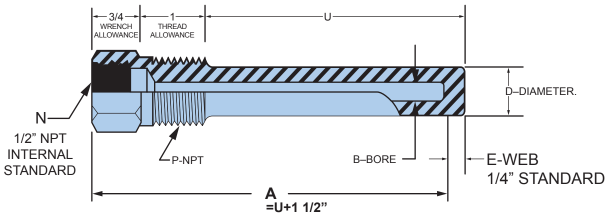


Part Number	Number of Terminals
CP162B	2
CP162C	3
CP162D	4
CP162E	5
CP162F	6

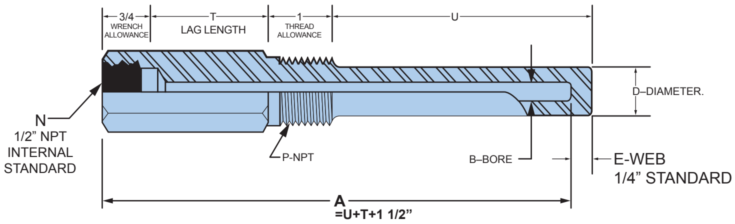
Appendix D
Sandelius Thermowells

120 SERIES THERMOWELLS - THREADED WITH STRAIGHT SHANK

WITHOUT LAGGING EXTENSION



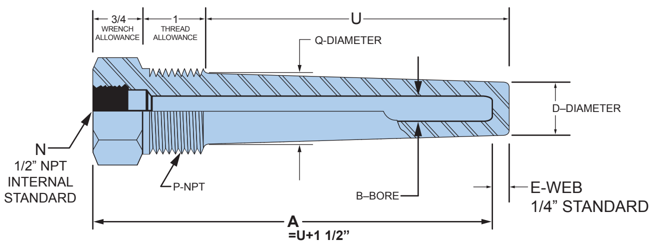
WITH LAGGING EXTENSION



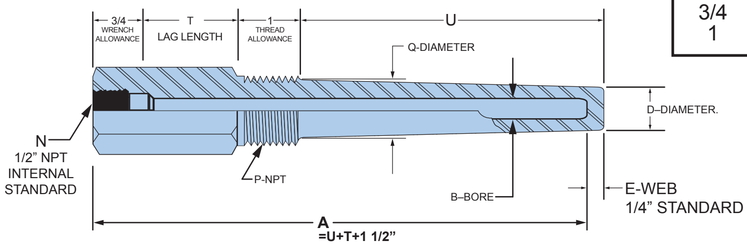
PART NUMBER	B BORE	D	AVAILABLE P-NPT SIZES
122A	0.260	1/2	1/2, 3/4 or 1
122B	0.260	5/8	1/2, 3/4 or 1
122D*	0.260	49/64	3/4 or 1
122E	0.260	7/8	3/4 or 1
122F	0.260	1	1
122G	0.260	1 1/16	1
123B	0.290	5/8	1/2, 3/4 or 1
123D	0.290	49/64	3/4 or 1
123E	0.290	7/8	3/4 or 1
123F	0.290	1	1
123G	0.290	1 1/16	1
124D*	0.385	49/64	3/4 or 1
124E	0.385	7/8	3/4 or 1
124F	0.385	1	1
124G	0.385	1 1/16	1
125D	0.515	49/64	3/4 or 1
125E	0.515	7/8	3/4 or 1
125F	0.515	1	1
125G	0.515	1 1/16	1
126E	0.703	7/8	3/4 or 1
126F	0.703	1	1
126G	0.703	1 1/16	1

130 SERIES THERMOWELLS - THREADED WITH TAPERED SHANK

WITHOUT LAGGING EXTENSION



WITH LAGGING EXTENSION



P-NPT	Q
1/2	5/8
3/4	7/8
1	1 1/16

PART NUMBER	B BORE	D	AVAILABLE P-NPT SIZES
132A	0.260	1/2	1/2, 3/4 or 1
132B*	0.260	5/8	3/4 or 1
132C	0.260	3/4	3/4 or 1
132D	0.260	49/64	3/4 or 1
132E	0.260	7/8	1
133B	0.290	5/8	3/4 or 1
133C	0.290	3/4	3/4 or 1
133D	0.290	49/64	3/4 or 1
133E	0.290	7/8	1
134C	0.385	3/4	3/4 or 1
134D*	0.385	49/64	3/4 or 1
134E	0.385	7/8	1
135D	0.515	49/64	3/4 or 1
135E	0.515	7/8	1
136F	0.703	1	1

* – Items preceded by an asterisk are the most commonly ordered sizes. In the absence of universally recognized thermowell standards, these items may be considered to be standard sizes.

TO ORDER ANY 120 or 130 SERIES THERMOWELL SPECIFY:

132B–3/4–18–M316–

- "T" Dimension (if any)
- Materials. See pg. B-2
- "U" Insertion Length (inches)
- "P" Process Connection
- Part Number

MATERIAL DESIGNATIONS FOR SANDELIUS THERMOWELLS

ORDER CODE	MATERIAL	ORDER CODE	MATERIAL	ORDER CODE	MATERIAL
M304	304 Stainless Steel	MF5	Alloy Steel A182-F5	M602	Inconel 602
M304L	304L Stainless Steel	MF9	Alloy Steel A182-F9	M617	Inconel 617
M304H	304H Stainless Steel	MF11	Alloy Steel A182-F11	M625	Inconel 625
M309	309 Stainless Steel	MF22	Alloy Steel A182-F22	M686	Inconel 686
M310	310 Stainless Steel	M6061	Aluminum 6061-T6	M718	Inconel 718
M316	316 Stainless Steel	M360	Brass 360	M750	Inconel X-750
M316L	316L Stainless Steel	M1018	Carbon Steel C-1018	MPVDF	Kynar
M316H	316H Stainless Steel	MA105	Carbon Steel A105	M400	Monel 400
M317	317 Stainless Steel	M276	Hastelloy C-276	M405	Monel 405
M317L	317L Stainless Steel	M278	Hastelloy B-3	M500	Monel K-500
M317H	317H Stainless Steel	M279	Hastelloy B-2	M200	Nickel 200
M321	321 Stainless Steel	M160	Haynes HR 160	MTFEM	Teflon, PTFE Mechanical Grade
M347	347 Stainless Steel	M800	Incoloy 800	MTFEV	Teflon, PTFE Virgin Grade
M347H	347H Stainless Steel	M800H	Incoloy 800H	M152	Titanium Grade 2
M410	410 Stainless Steel	M800HT	Incoloy 800HT	M155	Titanium Grade 5
M446	446 Stainless Steel	M825	Incoloy 825	MZ702	Zirconium R60702
M2205	2205 Duplex Stainless Steel	M600	Inconel 600	MY99	Other Material, Specify
MA20	Alloy 20 Stainless Steel	M601	Inconel 601		

OPTIONAL FEATURES

The following are some of the optional features available on Sandelius thermowells. To order a thermowell with any of the listed options simply add the suffix (or suffixes by dashes) at the end of the thermowell part number. If an optional requirement must be in compliance with a precise specification or procedure, please reference this on your order. Consult factory for special requirements not listed below.

SUFFIX	OPTIONAL FEATURE
BC	Brass plug with stainless steel chain
SC	Stainless steel plug and chain
TAOS	Tantalum over sheath (Available on 420 series flanged type and 520 series Van Stone type
	Pressure Testing Options
PT(xxxx) PT(xxxx) X(x)	Internal Hydrostatic Pressure Test at stated pressure (psi). Example PT1000 = Internal Pressure Test at 1,000 psi. If there is a specific time requirement, add an “X” then add the time required in minutes. Example: PT2000 X 15 = Internal Pressure Test at 2000 psi for 15 minutes
EP(xxxx) EP(xxxx) X(x)	External Hydrostatic Pressure Test at stated pressure (psi). Example EP1000 = External Pressure Test at 1,500 psi. If there is a specific time requirement, add an “X” then add the time required in minutes. Example: EP2500 X 15 = External Pressure Test at 2500 psi for 15 minutes
	Weld Checking & Performance Options
DB	Dye Penetrant Check – both root and final pass of flange weld
DC	Dye Penetrant Check – final cover pass of flange weld
DR	Dye Penetrant Check – root pass of flange weld
RX	Radiographic examination (X-Ray) of flange weld
PW	Post weld heat treatment
QW	Qualified welder
WP	Weld procedure specification
	Matreial Testing Options
MT	Material Test Reports
NA	NACE MR-01-75. *Thermowell must be made of a NACE recognized material.*
YNA	NACE MR-01-03. *Thermowell must be made of a NACE recognized material.*
PM	Positive material identification
	Cleaning Options
CO	Clean for Oxygen service
CC	Clean for Chlorine service
	Special Certifications
CR	Canadian Registration Number (Canadian province must be specified on order).
	Special Coatings, Stellite or Alloy Welded Tips
Consult Factory	Many types of coatings can be applied to thermowells to add corrosion and/or wear resistance (See page B-12 of this catalog). Thermowells can also be fitted with special welded-on alloy tips made of Stellite or other materials. The number of possible variations is virtually limitless. If you have a special design you need manufactured or would like to investigate possible new, special designs that may improve service life in your application, please call us. We will be glad to work with you.

Appendix E
White Superior Engine Operating Manual

INSTRUCTION MANUAL

Alpena

•

CARE AND OPERATION
AND
PARTS LIST

WHITE® SUPERIOR®

ENGINE-COMPRESSOR

REGISTER NO: 26880 alpena

BUILT FOR: MICHIGAN CONSOLIDATED GAS CO.

ENGINE MODEL: 12-SGT

ENGINE SERIAL NO: 268809

COMPRESSOR MODEL: MW-66

COMPRESSOR FRAME SERIAL NO: 268800

•

MANUFACTURED BY

WHITE SUPERIOR DIVISION

INDUSTRIAL GROUP

WHITE MOTOR CORPORATION

SPRINGFIELD, OHIO

U. S. A.

WARRANTY

The Seller warrants to the Buyer that the equipment to be delivered hereunder will be free from defects in material, workmanship and title and will be of the kind described in the contract. THE FOREGOING WARRANTY IS EXCLUSIVE AND IN LIEU OF ALL OTHER WARRANTIES WHETHER WRITTEN, ORAL OR IMPLIED (INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR PURPOSE). If it appears within one year from the date the equipment is placed in service but no later than eighteen (18) months from the date of delivery to the Buyer, whichever first occurs, that the equipment does not meet the warranty specified above and the Buyer notifies the Seller promptly, the Seller shall correct any defect, at the Seller's option, either by repairing any defective part or parts or by making available, at the Seller's factory, a repaired or replacement part. The liability of the Seller to the Buyer (except as to title) arising out of the supplying of the equipment, or its use, whether on warranty, contract or negligence, shall not in any case exceed the cost of correcting defects in the equipment or part thereof and upon expiration of the warranty period all such liability shall terminate. The foregoing shall constitute the sole remedy of the Buyer and the sole liability of the Seller.

The preceding paragraph shall not apply and the Seller assumes no liability whatsoever for breach of warranty when there is evidence that the defect arose as the result of: (a) abuse or negligence in the operation of the equipment, (b) failure to maintain the equipment properly, (c) overloading or overspeeding, or (d) use of repair parts not approved by the Seller.

The warranty given to the Seller by its supplier of special equipment, including but not limited to generators, switchgear and control, reduction gears and centrifugal compressors, is hereby assigned without recourse by the Seller to the Buyer. AS TO THIS SPECIAL EQUIPMENT, WHICH GENERALLY BEARS THE NAMEPLATE OF THE SELLER'S SUPPLIER, THE SELLER ASSUMES NO LIABILITY WHATSOEVER FOR BREACH OF WARRANTY, WHETHER WRITTEN, ORAL OR IMPLIED (INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR PURPOSE).

TABLE OF CONTENTS

The material in the instructions has been arranged in sections each dealing with a specific subject or subdivision of the engine. The sections are arranged alphabetically and the titles and main contents are listed below.

TABLE OF CONTENTS (Cont'd.)

GENERAL ENGINE DATA

1. FOREWORD

The White-Superior Gas Engine is of the heavy duty, vee, multi-cylinder, spark ignited gas type; designed especially for reliability, and long life of trouble-free operation. Compact, rugged construction allows a wide range of applications. Ready accessibility of all wearing parts means simplified maintenance and dependable service. Lubricating oil is pressure-forced to all working parts of the engine. All working parts are totally enclosed to minimize wear and other troubles which might occur if dust or other foreign matter were allowed to reach them.

The engine described in this manual is of the four-stroke cycle type, in which a power stroke occurs once in every two revolutions of the crankshaft. The four-stroke cycle operates as follows: (1) suction stroke, (2) compression stroke, (3) power stroke, and (4) exhaust stroke.

During the suction stroke the exhaust valve is closed and inlet and gas admission valves are open. The descending piston draws a fresh mixture of air and gas into the cylinder.

Near bottom dead center both inlet and gas admission valves close and on the succeeding upward stroke, the piston compresses the mixture. At a point somewhat before top dead center, ignition (from the spark plug) occurs. The spark, igniting the air-gas mixture, results in combustion of the compressed gas. The rapid rise in temperature and pressure of the burning gases forces the piston downward for the power stroke.

Near the end of the power stroke the exhaust valve opens. On the next upward stroke the burned gases are expelled from the cylinder, thus completing the four-stroke cycle.

The exhaust gases are conducted by a manifold to an exhaust gas turbine. This turbine turns on a common shaft (but in a separate compartment) with a centrifugal blower. The blower draws in atmospheric air and forces it under pressure through an intercooler and into the engine intake manifold. The air at this stage is more dense than atmospheric air and therefore each cylinder receives a greater weight of air than it would if the air were taken into the cylinder at atmospheric pressure. This allows a corresponding increase in the amount of gas which can be burned efficiently and gives a proportionally greater output for a given cylinder size and engine speed. Cooling of the intake air also reduces the possibility of detonation.

The valve timing is so arranged that the intake valve opens before, and the exhaust valve closes after, top dead center. During the period of valve overlap some of the supercharging air is blown through the cylinder, resulting in a more complete scavenging of the burned gases. In order that fuel gas will not be lost into the exhaust during this scavenging period the gas admission valve is closed, and opens at approximately the same time as the exhaust valve closes.

The purpose of this manual is to familiarize operating and maintenance personnel with the design and construction of the engine. Thus, they can understand the functions of the various parts and know how to care for them in order to obtain the most satisfactory engine performance.

Engine rated speed and horsepower are stamped on the nameplate and these figures should never be exceeded. Engine model designations and serial numbers are also stamped on the nameplate; and these figures, particularly the serial number, should always be stated when ordering parts or in any correspondence with the factory or sales agencies. Other items stamped on the engine nameplate include bore and stroke, ignition timing and firing order.

STANDARD SIZES AND CLEARANCES AND WEAR LIMITS
MODEL 12-SGT (10" x 10-1/2")

Item	Standard Dimension	Max. (or Min.) allowable worn size or clearance
Cylinder liner Bore	10.000" - 10.002"	
Top Ring Travel Area : (Any Point)		10.020"
Bottom of Liner		10.007"
Piston Skirt Diameter (Bottom)	9.991" - 9.990"	9.985"
Piston Clearance (Skirt Bottom)	.009" - .012"	.016"
Piston Compression Ring - Gap (#1)	.030" - .045"	.110"
Gap (#2 - 3)	.040" - .060"	.190"
Piston Compression Ring (#1)		
Ring Width	.1880" - .1865"	
Ring Groove Width	.193" - .194"	.198" Max.
Ring Side Clearance	.0050" - .0075"	.015"
Piston Compression Ring (#2 - 3)		
Ring Width	.1880" - .1865"	
Ring Groove Width	.191" - .192"	.196" Max.
Ring Side Clearance	.0030" - .0055"	.015"
Piston Oil Ring Gap	.035" - .050"	.100"
Piston Oil Ring Width	.3100" - .3115"	
Piston Oil Ring Groove Width	.313" - .314"	.318"
Ring Side Clearance	.0040" - .0015"	.008"
Piston Pin Diameter	3.4985" - 3.4975"	3.496"
Piston Bore for Pin	3.501" - 3.500"	3.503"
Piston Pin Clearance in Piston	.0015" - .0035"	.005"
Connecting Rod Bushing Bore	3.5020" - 3.5015"	3.503"
Piston Pin Clearance in Rod	.0030" - .0040"	.005"

STANDARD SIZES AND CLEARANCES AND WEAR LIMITS (Cont'd.)
MODEL 12-SGT (10" x 10-1/2")

Item	Standard Dimension		Max. (or Min.) allowable worn size or clearance
Connecting Rod Big End Bearing Bore	6.3790" -	6.3824"	
Bearing Shell Wall Thickness	.2045" -	.2033"	Surface Inspection
Crankpin Diameter	6.376" -	6.374"	6.370"
Crankpin Bearing Clearance	.0030" -	.0084"	.012"
Crankpin Length	6.248" -	6.253"	
Width of Two Rods	6.000" -	5.992"	
Side Clearance of Rods	.248" -	.261"	
Main Bearing Bore	8.0050" -	8.0084"	
Main Bearing Shell Wall Thickness	.2650" -	.2638"	
Main Journal Diameter	8.001" -	7.999"	7.995"
Main Bearing Clearance	.0040" -	.0094"	.013"
Crank Thrust Bearing Width	5.496" -	5.493"	5.488"
Crank Thrust Shoulder Span	5.506" -	5.508"	5.516"
Crankshaft End Play	.010" -	.015"	.025"
Camshaft Bearing Bushing Bore	2.7530" -	2.7546"	
Camshaft Diameter	2.750" -	2.749"	
Camshaft Bearing Clearance	.0030" -	.0056"	.010"
Camshaft End Play Adjustable: - Set	.005" -	.008"	
Valve Rocker Arm Bore (Bushing in Place)	1.7496" -	1.7526"	
Rocker Shaft Diameter	1.7485" -	1.7480"	
Clearance	.0011" -	.0046"	.010"
Valve Rocker Arm Side Clearance Adjustable: - Set	.005" -	.007"	
Valve Stem Diameter	.871" -	.870"	
Valve Guide Bushing Bore	.873" -	.874"	
Clearance	.002" -	.004"	.006"

2. SPECIFIC ENGINE DATA - MODEL 12-SGT

Bore and Stroke	10" x 10-1/2"
Number of Cylinders	12
BHP	2000
RPM	900
Minimum Idle Speed - RPM	600
Operating Range - RPM	*

Firing Order

Counter-Clockwise Rotation -
1R-1L-4R-4L-2R-2L-6R-6L-3R-3L-5R-5L

(NOTE: Right and left cylinder banks and direction of rotation are determined by viewing engine from the flywheel end.)

Lubricating Oil Sump - Capacity (Inc. Cooler)	165 Gallons
Water in Engine	140 Gallons

3. OPERATING PRESSURES AND TEMPERATURES

Lube Oil Pressure - Normal	34-45 p.s.i.
Lube Oil Temperature - Normal IN	150-180° F.
Lube Oil Temperature - Maximum OUT	210° F.
Water Temperature from Engine - Normal	170-180° F.

4. SET-UP TORQUES FOR STUDS AND BOLTS

(NOTE: Torque figures are for threads lubricated with engine oil or similar petroleum base lubricants - DO NOT use any compounds containing molybdenum disulfide as a thread lubricant.)

	Foot Pounds
Main Bearing Cap Stud Nuts	325-350
Block to Bed Stud Nuts	275-300
Camshaft Sprocket Clamp Ring Capscrews	65-75
Connecting Rod Bolt Nuts	340-360
Cylinder Head Stud Nuts	450
Rocker Arm Bracket Capscrews	125
Cam Bearing Cap Capscrews	45-51

*See Compressor Section for Operating Speed Range of Unit.

SET-UP TORQUES FOR STUDS AND BOLTS (Cont'd.)

	Foot Pounds
Flywheel Capscrews ----------------------	720-780
Cam Follower Bracket Capscrews ---------	45-51
Crankshaft Sprocket Assembly Bolt Nut ----	85-95
Vibration Damper Capscrews -------------	300-325
End Cover Capscrews -------------------	65-75

5. IGNITION AND VALVE TIMING IN CRANKSHAFT DEGREES

Inlet Opens ------------------------	41° Before Top Center
Exhaust Closes ---------------------	38° After Top Center

(Check above angles, for camshaft timing purposes only, with .125" valve lash.
Check valve events at point where lash is just taken up (pushrod will not turn).

Ignition Timing ---------------------	40° Before Top Center

(NOTE: ± 2° Tolerance allowed on inlet and exhaust valve timing. Spark timing must be accurate).

Spark Plug Gap ---------------------	.017" - .020"

6. VALVE CLEARANCES - HOT

Inlet Valve --------------------------	.018"
Exhaust Valve -----------------------	.030"
Gas Admission Valve ----------------	.015"

7. ALARMS AND SHUTDOWN SETTING

Water Temperature - Alarm ----------	------
Water Temperature - Shutdown -------	------
Lube Oil Pressure - Alarm -----------	------
Lube Oil Pressure - Shutdown --------	------
Overspeed Shutdown -----------------	990 RPM

STANDARD SIZES AND CLEARANCES AND WEAR LIMITS (Cont'd.)
MODEL 12-SGT (10" x 10-1/2")

Item	Standard Dimension	Max. (or Min.) allowable worn size or clearance
Lubricating Oil Pump Internal Gear Backlash ---------	.007" - .010"	.015"
Lubricating Oil Pump Gear End Play ----------------	.0036" - .0144"	.017"
Lubricating Oil Pump Radial Clearance between Gear Teeth and Housing Bore ---------	.012" - .013"	.015"
Lubricating Oil Pump Shaft Diameter ----------------	1.7500" - 1.7495"	
Lubricating Oil Pump Bushing Bore ----------------	1.753" - 1.754"	
Clearance --------------------	.0030" - .0045"	.008"

LUBRICATING OIL

We recommend that a good grade of compounded mineral oil of a detergent type be used in these engines. The oil should be stable under the temperature conditions encountered in the engine and should be resistant to oxidation, foaming and sludging. The best assurance of obtaining a suitable oil is to use only products of well-known merit, produced by responsible concerns, and used in accordance with their recommendations. See White Superior Engineering Standard ES 1001, immediately following this section.

Both new and used oil can have corrosive elements and the supplier should be careful to furnish oils which are compatible with tin or lead base babbits and it is also highly desirable that it be non-corrosive to copper-lead alloys.

The use of an SAE 40 grade oil is recommended. If the ambient temperatures are below freezing, an oil of lighter grade may be used for intermittent operating conditions and SAE 40 for continuous service.

For low temperature operation, the pour point of the oil, at the minimum starting temperature to be expected, should be carefully considered. It is most essential that the oil be sufficiently fluid so that it will flow to the pump under all conditions.

The oil sump holds the proper amount of lubricating oil, and the running level should be maintained close to the mark on the sight glass. In regard to drainage periods, we suggest that the first batch of oil be drained and filter elements renewed after about 400 hours of service. Thereafter the filter cartridges should be changed and the drainage period can be increased to 1000 hrs. or more, providing the filter cartridges are kept in good shape and the oil remains reasonably clean. Experience will determine when to change filter elements and oil, and in this connection it should be pointed out that it is more economical to maintain the filters in good shape. However, if the oil is badly discolored and loaded with insolubles, it should be drained off when new filter elements are installed. Laboratory checks of the oil to determine the quantity of solids and build up of any corrosive elements should be a regular part of the maintenance procedure. These test results can serve as a guide to oil drain periods.

NOTE: When new elements are installed in the filters, a sufficient amount of lubricating oil must be added into the system to compensate for that which has been drained from the filters.

LUBRICATION OF WHITE SUPERIOR ENGINES AND COMPRESSORS

A. Responsibility for Lubricant Performance.

Lubricating oils are an extremely complex field with many variations in additive packages and base stocks. No specific formulation can guarantee completely satisfactory performance; therefore all major refiners conduct extensive laboratory and field tests to substantiate the performance of their products.

Selection of the proper lubricant is the responsibility of the supplier and the best assurance of obtaining a suitable oil is to use only products of well-known merit produced by responsible concerns, and used in accordance with their recommendations.

B. Engine design, operating conditions, and fuels all have a significant effect on how a lubricant performs in a given situation, therefore, the lubricant must be matched to its application. To assist our customers, White Superior is forming a list of lubricants that have consistantly performed well in our products under specified field conditions. In addition, a list of minimum qualities is presented when selecting a lubricant with which we have no experience.

C. Minimum Qualities of An Engine Lubricant.

1. Viscosity at 210° F. S.U.S. 68-90 Prefer 80.
2. The lubricant must contain adequate rust and corrosion inhibitors which are not detrimental to lead base babbitts or copper lead bearing alloys.
3. The lubricant must contain an appropriate antioxidant for long oil life, and an antifoaming agent.
4. An effective E.P. additive must be employed to prevent scuffing and wear of highly loaded parts.
5. A balanced detergent-dispersant package is required for engine cleanliness. The oil must minimize ring sticking, varnish on pistons, liners, and valve stem, hard combustion chamber deposits, and crankcase sludge.
6. A sulphated ash content of .5 to 1% is generally preferred. The barium and calcium additives appear to give better lube oil consumption, lower wear rates of liners and rings, and increased valve life.
7. The lubricant must be resistant to nitration.
8. T.B.N. D-664 2.0 Minimum.

D. Compressor Lubricant.

Any lubricant which is performing satisfactorily in a White Superior engine may be used for the compressor frame. In addition, the same oil may be used for compressor cylinder lubrication in many instances, however, this should be reviewed on an individual basis with the Springfield office.

E. Drainage Periods.

The lubricating oil should be drained and the filter elements changed after the first 400 hours. Thereafter, the drainage periods can be increased to 1000 hours or more. White Superior strongly recommends periodic laboratory analysis on the oil quality by the supplier or other reputable firm and changing oil only when it has reached the end of its useful life. These checks can also provide information on metal contaminates in the oil and thus give information on the engine condition.

F. Low Ash or Ashless Oils.

Ashless or low ash gas engine oils have generally performed well in our naturally aspirated engines. Most provide excellent cleanliness and long life between oil changes, however, wear rates are somewhat higher than with oils of .5 to 1% ash content.

Several of these oils have not performed as well in the turbocharged engines, however, resulting in high lube oil consumptions, high wear rates, and occasional cylinder scuffing. In at least two instances, changing to a railroad diesel lube manufactured by the same companies with ash contents slightly greater than .5% corrected the problems immediately. Bearing lead corrosion has also been encountered with some of these oils.

G. High Ash Type or Series 3 Oils.

White Superior does not normally recommend operation with lubricants with a sulphated ash content of more than 1% because of possibilities of combustion chamber deposits which may induce detonation or preignition. As a group, these oils do provide excellent cleanliness and wear resistance and some have been used successfully in our turbocharged engines.

To operate successfully on this type of lubricant it must provide very low oil consumption to minimize combustion chamber deposits; in addition, barium additives are generally preferred to calcium since it provides a softer ash.

H. Fuels.

The lubricant must be capable of operating with the type or quality of fuel supplied to the engine. Most refiners supply different oils for diesel engines than for gas engines. In addition, high sulphur content in the fuel (more than 100 grains H_2S per 100 cu. ft. of gas or 1% sulphur for diesel fuel) requires a lubricant with higher TBN or a method of retaining its TBN when operating on such fuels.

LUBRICANTS WITH A HISTORY OF GOOD FIELD PERFORMANCE

A. Naturally Aspirated Engines.

Any good quality lubricant meeting the specific physical qualities and designed for use in four-stroke cycle gas engines should perform adquately in the naturally aspirated engines; however, whenever possible use of one of the lubricants listed for turbocharged engines.

B. Turbocharged Engines.

Company	Product	Comments
Amoco	Super Diesel Lube	
Arco	Osage Super W	
Arco	Gascon GL-UP	
Chevron	RPM DELO Special	
Citgo	G.E.O. 700	
Citgo	C-340	
Conoco	Triangle SI	
Exxon	Estor G	
Exxon	Estor GLX	
Exxon	Estor G3	High Ash
Gulf	Gulfco 645	
Gulf	640	
Imperial	Iolube 40	
Imperial	2243	High Ash
Imperial	G30	
Mobil	G.E.O. 444	
Mobil	Mobilgard 412	
Pacific 66	W1	High Ash
Phillips 66	HDS + 1	
Sohio	XD4	
Sunoco	384	
Shell	G.E.O. 8122	
Shell	Rotella	
Texaco	URSA Extra Duty	

INSTALLATION INSTRUCTIONS

1. GENERAL INSTALLATION

The success of an engine installation depends greatly upon the construction of the foundation and upon the care exercised in lining up the engine to the connected generator. Poor installation will result in excessive vibration and continual change in alignment. The result is poor performance and failure of vital parts. For this reason, The White Motor Corporation cannot guarantee an engine unless the instructions in regard to alignment given in the following have been followed.

Engines and generators are frequently mounted on cast or structural steel sub-frames, at the manufacturer's plant, to provide a complete generating unit. Similar units are also made up with pumps or gears or other equipment driven by the engine. In such cases, the installation method is the same as described in the following text for engine and generator installations; and the term "generator" may be construed to mean any one of these items, as the case may be wherever it appears in the text.

Even though the engine and generator might be mounted on a quite rigid sub-frame, and carefully lined up at the manufacturer's plant during assembly; the possibility of sub-frame deflection, by rough handling during shipment, or by improper bolting to the foundation, still exists. The alignment of engine and generator should therefore be rechecked during installation; and any handling or bolting deflections of the sub-frame, that may have affected this alignment, should be corrected before the unit is placed in operation. The following instructions will cover the method for alignment checking, and will also cover the steps to be taken in making the necessary corrections if misalignment is found.

When preparing the foundation on which the generator unit is to be mounted, always obtain certified outline prints. Do not use figures or cuts in bulletins or sales literature.

The foundation block dimensions, normally shown on outline prints, are minimum figures based on firm ground, hard clay, or gravel under the installation. For sand, mud or other soft sub-soil, the size of the foundation block must be sufficiently increased and its design must be properly revised to compensate for the poorer quality of the footing material.

2. PREPARING THE FOUNDATION BLOCK

A rigid template, of the same length and width as the top edges of the foundation, should be made up to properly locate all engine and other foundation bolts. This template should be securely supported in a level position above the foundation block form. Its height should be such that it will support all foundation bolts at their proper height in accordance with the foundation plan furnished by the manufacturer.

The foundation bolts, with shield tubes around each bolt, should be suspended from properly located holes in the template. The nuts, which hold the bolts in the template, should be adjusted to provide bolt extensions above the foundation block in accordance with the foundation plan furnished by the manufacturer. The shield tubes should be so supported that their upper ends will be flush with the top of the finished foundation block; and their lower ends should be plugged, or otherwise closed in against the foundation bolts, to prevent concrete from entering at that point.

Reinforcement should be placed in the form, and the concrete should be poured in one continuous operation. During pouring, the concrete should be tamped or otherwise worked to remove all air pockets and to insure compactness. Particular attention should be given to working the concrete at the sides of the form or at any other surfaces which may be left exposed in the final installation. After pouring is completed, the concrete should be allowed to thoroughly set and then the forms should be removed. Any surface patching found necessary should be done immediately after the removal of the form while the concrete is still relatively "green". The foundation block should be sprinkled frequently to keep its surface moist for several days after pouring in order that the curing may be regulated for best development of strength and hardness. It should also be protected against freezing during this time; in fact its temperature should be kept above 50°F. for best curing. Sufficient time must be allowed for thorough curing of the foundation block before any equipment is placed upon it.

3. INSTALLING THE COMPLETE UNIT - (Engine on Sub-Base)

(Close reference should be made to the Foundation Plan and Outline Drawing at this time).

When the foundation block has become fully cured, preparations should be made for placing the engine as follows:

(a) Remove the unit from its shipping medium, and move it over the foundation block as near as possible in alignment with its foundation bolts. Keep the sub-base some distance above the foundation, however, in order to allow working room for subsequent operations.

(b) Make certain that the sub-base support flanges are thoroughly cleaned of all rust and dirt or other foreign matter. The above cleaning operations should also include the removal of all grease or oil, which might impair adhesion, from any surfaces which will come into contact with grouting.

(c) Consider jackscrew plate thickness and foundation plate thickness, where these plates are used, and screw the jackscrews down through the sub-base support flanges by an amount sufficient to provide space for 1-1/4" grout thickness. Place one of the steel plates, supplied with the engine, under each jackscrew; and carefully lower the unit down over the foundation bolts until the jackscrews are resting on the plates. Adjust the jackscrews until they all bear equally on their respective plates, and further until the unit is setting level in both longitudinal and transverse directions.

4. CHECKING ENGINE CRANKSHAFT ALIGNMENT

The proper procedure for checking crankshaft alignment is as follows:

(a) Remove lower base cover adjacent to flywheel end of engine.

(b) Observe the inside face of the webs of the last crankshaft throw. If there are no center punch marks in evidence, place one center punch indent in the center of each web approximately one inch up from the base of the shortest web (directly opposite each other).

(c) Insert a dial indicator type of strain gauge so that it will be held by the center punch marks.

(d) Take successive indicator readings in the following positions: as near bottom center as the connecting rod will permit; 90° from top center; top center; 90° from top center (opposite side); and near bottom center (opposite side).

(e) Total variation in readings may not exceed .003".

5. INSTALLING AND ALIGNING THE DRIVEN EQUIPMENT

After the engine has been placed on the foundation and its crankshaft alignment has been checked, but before grouting, the driven equipment should also be placed in its proper position over the foundation in approximate alignment with the engine. If the engine flywheel was removed during the previous operation, it must be remounted before the driven equipment can be aligned.

A flexible coupling must be used between the engine and the driven equipment in order to protect the respective shafts against misalignment strains under all operating and temperature conditions.

See subsequent "C" sections for alignment of the flexible coupling. (This applies only when such equipment is furnished).

Shift the driven equipment or engine or both sideways and also raise or lower it as required to obtain the best possible alignment. Proper lining up may take a little time, but it is absolutely essential. Flexible couplings should not be required to compensate for any misalignment that can be eliminated. Every base plate is slightly elastic; therefore, every unit must be aligned in place.

NOTE: Thin metal shims, totaling 1/16" to 1/8", may be placed under the driven equipment to permit later readjustment of height if such is ever found necessary. Attention should also be given to the longitudinal position of the driven equipment bearings and to any floating and flexible members of the couplings. All longitudinally free or flexible items should be in their respective center positions and ample longitudinal clearance must be provided for full movements in either direction. This is important in order to eliminate any possibility of thrust loadings due to operating thermal expansion or contraction.

After the alignment has been accomplished, it should be checked by means of strain gauge readings on the engine crank adjacent to the flywheel. In this case, the flywheel and coupling weight will be supported by the engine crank; and greater strain gauge readings may be expected with the crank throw in the downward position than with it in the upward position. The difference, however, should not exceed .003".

6. GROUTING THE ENGINE AND DRIVEN EQUIPMENT

After the engine and driven equipment have been placed in position and properly aligned as described under the preceding paragraphs, grouting between their supporting flanges and the foundation should be started.

The grout should be a mixture of the following:

1 part "Embeco"	(100 lb. drum)
1 part Portland Cement	(1 sack)
1 part of clean coarse sand	(1 cu. ft.)
1-1/4 parts of 1/4" pea gravel	(1-1/2 cu. ft.)

(Note: "Embeco" is a product of Master Builders Company of Cleveland, Ohio, which prevents shrinkage when mixed with grout. The White Motor Corp., Superior Division insists that this product or its equal, be used under all equipment where alignment must be maintained).

The grout should be thoroughly mixed and with just enough water used in its mixing to permit its being worked under the support flanges and into the opening around the foundation bolts. After the grouting operation has once been started, it should be continued without interruption until the job is complete under all supporting flanges of the engine and driven equipment.

Allowance should be made for approximately 1/2" of "neat" cement at all exposed surfaces of the grout. This "neat" cement should be placed and troweled smooth soon after the grout has set, and before the grout has dried to any appreciable extent. After the neat cement has set, it should be sprinkled frequently during the next 2 or 3 days to keep its surface moist, in order that the maximum strength and hardness may be developed in the grout. Like the foundation block itself, the grout should be protected against freezing during the curing period, and should preferably be kept at a temperature above 50°F. After the grout and "neat" cement have cured and become thoroughly dry, their exposed surfaces and the surfaces of the foundation as well, should be given several coats of good oil-resistant paint. Sufficient time must be allowed for thorough curing of the grout before removing jackscrews and thereby allowing equipment weights to bear upon it.

7. FASTENING AND FINAL ALIGNMENT

After the grout has become thoroughly cured, the leveling screws may be removed and the foundation bolt nuts may be assembled and tightened. Proper procedure for tightening these nuts is to first evenly and only moderately tighten all nuts for each particular unit. Then retighten each nut a slight additional amount and continue this retightening procedure 2 or 3 times until tightening torque commensurate with bolt size is attained for all nuts.

After several days, the tightness of all nuts should be checked; and the alignment should be rechecked (as previously noted under paragraphs "Installing the Engine" and "Installing and Aligning the Driven Equipment") and should be corrected if such is found necessary.

SERVICE PIPING

GENERAL

Plan all piping carefully and use as short and direct lines as possible. Care should be taken to keep all piping readily accessible. To improve the general appearance of the installation, piping should be laid below the engine room floor when it is possible to do so. Removable floor plates should be provided for access to the piping.

Provide drains at all low points and vents at all high points of each system. Provide clamps to steady the piping against vibration, but so locate the clamps that the pipes will be free to expand or contract with temperature changes. Provide supports for the piping and heavy auxiliaries such that the weight is not imposed on the engine connection.

All pipes and fittings should be thoroughly cleaned before assembly, so as to eliminate all possibility of loose scale, dirt, or other foreign particles from entering the system. Flush out the systems after installation and before making final connections at the engine.

When vibration isolators are supplied with the engine, make sure that every piping system has a flexible connection as close to the engine as possible.

WATER, LUBRICATING OIL, AND FUEL PIPING

An approved piping diagram should be carefully followed with respect to pipe sizes and the location of the various components of the system. Use as few bends as possible and do not make suction or discharge piping longer than necessary. Use gate valves for all liquids, to keep flow resistance at a minimum. When an expansion tank is used in the water system, its main connection to the circulating system should be as close as possible to the water pump inlet.

STARTING AIR PIPING (When Supplied)

Air tanks should conform to A.S.M.E. specifications and should have ample strength for 250 lbs. per square inch pressure. Each tank should be equipped with a safety valve and a globe valve for isolation. A drain valve should be provided at the lowest point and this valve should be accessible.

Tanks should be connected to the starting air header using the specified pipe size. Provide a globe valve next to the engine. All valves and fittings should be suitable for at least 250 lbs. per square inch pressure. The air compressor discharge pipe should be run to the air tank. It should not be connected to the piping between the tank and the starting air header. Air compressor unloader should preferably be connected to the tank with its own piping. Under no circumstances should it be connected to the compressor discharge line.

EXHAUST SYSTEM

When bends are necessary use long sweep fittings. Use the pipe size called for on the outline drawing for lengths up to 30 ft., containing a maximum of three bends. For 3 to 6 bends increase the pipe to the next nominal size and for each additional 30 ft. length increase by one pipe size.

In order to protect the engine and piping from undue strains a length of flexible metal tubing must be installed as near the engine as possible. It is also recommended that flanged connections be used for ease of dismantling and cleaning. For multiple engine installations it is essential that separate exhaust lines be used.

If an exhaust silencer and/or waste heat boiler is installed in the exhaust system of the engine, it should be of size and design offering minimum resistance to engine maximum load exhaust flow. Total flow resistance, including piping losses, should not exceed ten inches of water in the case of supercharged engines, or fifteen inches of water in the case of naturally aspirated engines.

AIR INTAKE SYSTEM

If an air intake silencer and/or filter is used, it should be of size and design suitable for handling the maximum air requirements of the engine with a minimum flow resistance. Total flow resistance, including piping losses, should not exceed ten inches of water for supercharged engines, or seven and one-half inches of water for naturally aspirated engines.

If the engine air intake is installed in the engine room, the room must be provided with adequate ventilators to allow ample cool air for the engine requirements. If any appreciable amount of dust or dirt is present in the atmosphere, an air cleaner of the oil bath type and of proper size should be provided to prevent such dirt or dust from entering the engine and causing undue wear.

FLEXIBLE COUPLINGS
Maximum Permissible Misalignment
(See reverse side of this page for chart.)

The illustration below shows the most commonly used Flexible Couplings with a suggested method for checking alignment for each type.

On the reverse side of this page is a chart which enumerates each type of coupling and lists the maximum permissible misalignment.

It is important to note that the figure given for permissible parallel misalignment is the total allowable.

To check permissible angular misalignment: driver and driven will be considered lined up when dial indicator reading is less than the values listed for each inch of diameter at the indicator stem.

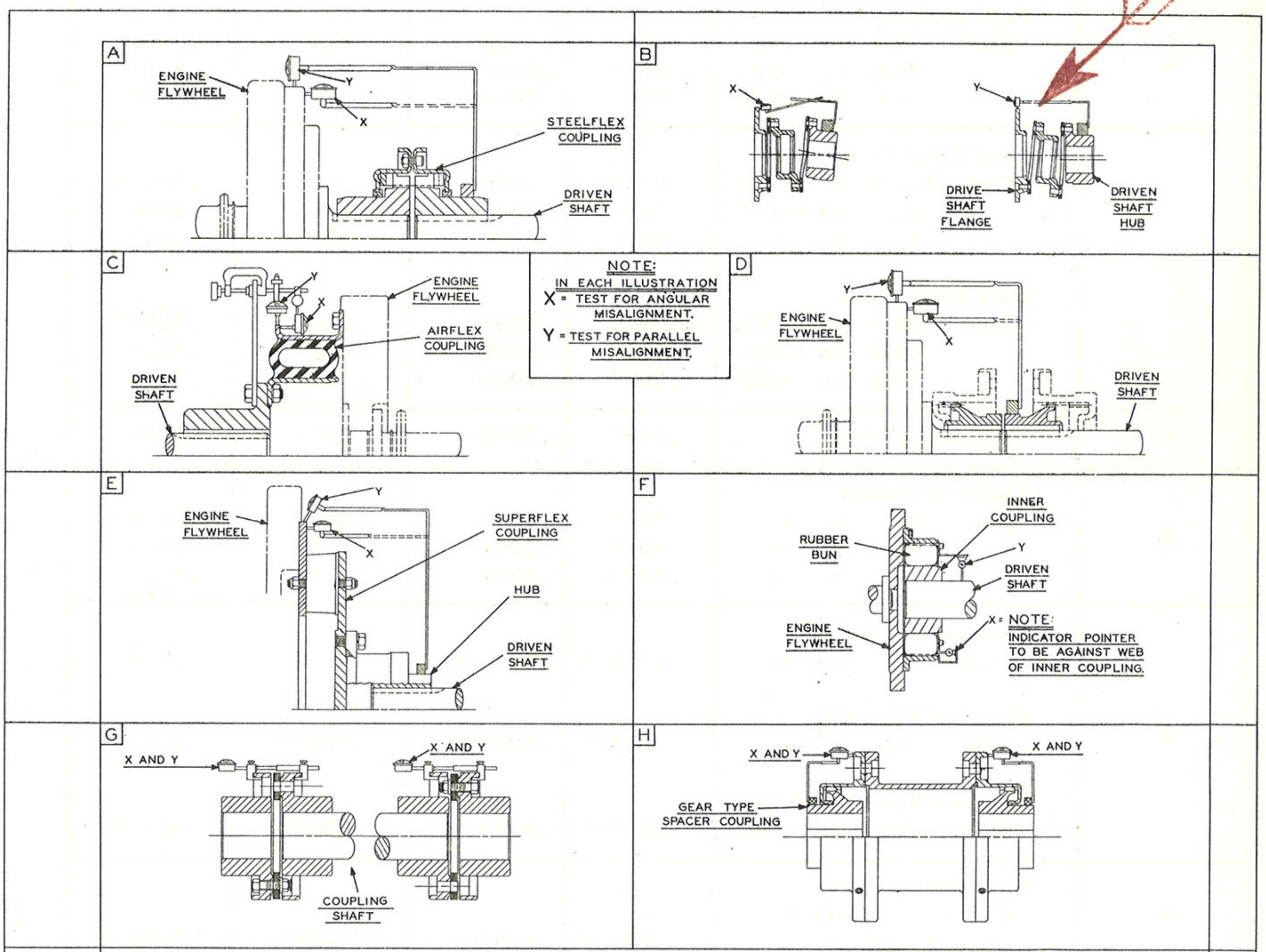


FIG. C 35-1
SUGGESTED METHODS FOR CHECKING ALIGNMENT

FLEXIBLE COUPLINGS
Maximum Permissible Misalignment
(See reverse side of this page for illustration)

Fig. C35-1	Coupling	Initial Permissible Misalignment		Maximum Allowable Realign When Exceeded	
		Parallel	Angular*	Parallel	Angular*
A	Falk Steelflex				
	Size 12F to 15F	.003"	.0004"	.010"	.0015"
	16F to 190F	.004"	.0004"	.014"	.0015"
	200F to 240F	.006"	.0004"	.021"	.0015"
	Falk Steelflex				
	Size 80T to 110T	.003"	.0004"	.010"	.0015"
	120T to 140T	.004"	.0004"	.014"	.0015"
B	Thomas CM or CMR				
	Size 375 to 425	.003"	.0003"	.010"	.0010"
	450 to 600	.004"	.0003"	.014"	.0010"
	700 to 850	.006"	.0003"	.021"	.0010"
	925 to 1000	.007"	.0003"	.026"	.0010"
C	Falk Airflex				
	Size 21A to 28A	.003"	.0003"	.010"	.0010"
	33A to 46A	.004"	.0003"	.012"	.0010"
	53A to 72A	.006"	.0004"	.014"	.0015"
D	Fast Gear Type				
	Size 2-1/2 to 3-1/2	.004"	.0006"	.010"	.0020"
	4 to 4-1/2	.005"	.0006"	.014"	.0020"
	5 to 7	.007"	.0006"	.021"	.0020"
	Falk Gear Type				
	Size 15G to 30G	.004"	.0006"	.010"	.0020"
	35G to 45G	.005"	.0006"	.014"	.0020"
	50G to 60G	.007"	.0006"	.021"	.0020"
E	White Superflex	.004"	.0003"	.010"	.0010"
F	Koppers Holset				
	Size 3 to 6	.004"	.0004"	.010"	.0015"
	7 to 9	.006"	.0004"	.015"	.0015"
	10 to 12	.008"	.0004"	.021"	.0015"
G	Thomas Series 51				
	Size 225 to 600	.0003"*	.0003"*	.0008"*	.0008"*
	Thomas Type SN				
	Size 350 to 600	.0003"*	.0003"*	.001"*	.001"*
	Thomas Type BM & BMR				
	Size 350 to 750	.0003"*	.0003"*	.001"*	.001"*
H	Fast Spacer Type Class A & Class C				
	Size 1-1/2 to 5	.0003"*	.0003"*	.0008"*	.0008"*

* Driver and driven will be considered lined up when dial indicator reading is less than the values listed for each inch of diameter at the indicator stem.

TURBOCHARGER SERVICE PIPING

Plan piping connections to the turbocharger carefully and follow these recommended flange loadings:

MAXIMUM PERMISSIBLE TURBOCHARGER FLANGE LOADS

	MAX. BENDING MOMENT FT. - LBS.		DEAD WEIGHT FLANGE LOADS* - LBS.	
Turbo Frame Size	Comp. Inlet	Turb. Exhaust	Comp. Inlet	Turb. Exhaust
L-10, H-15	200	200	100	150
L-10 (Vaneless Diff.)	100			
L-20, H-30, H-35	250	325	150	300
L-20 (Vaneless Diff.)	125			
L-40, H-50	300	475	200	400
L-40 (Vaneless Diff.)	150			
L-60, H-70	350	850	250	600
L-60 (Vaneless Diff.)	175			
L-100, H-110	400	1300	300	800
L-100 (Vaneless Diff.)	200			

* Applied perpendicular to, equally distributed around the face of, and in a direction toward the turbocharger flanged connection. The load must not result in bending moments at the flange greater than those specified above. Loads must not be exceeded as a result of impact, engine vibration, sudden violent movements of the engine and turbocharger environment (such as a power shovel) or restraint to thermal growth.

NOTE: Pipes must not be used for turbocharger support.

OPERATING INSTRUCTIONS

CAUTION

SAFETY NOTICE

Operating personnel working on this equipment MUST observe the following procedure when starting the engine:

I. With GAS OFF and IGNITION GROUNDED, crank engine over for a minimum of 10 seconds to purge cylinders and exhaust system of any gas.

II. Continue cranking engine and turn ignition ON and keep gas turned OFF for a minimum of 2 seconds.

III. Now, turn starting fuel on with "START FUEL" signal.

IV. If engine fails to start within 5 seconds, turn off "START FUEL" signal; then ground the ignition.

V. NOTE: Repeat Steps 1 through 5 for each and every starting attempt. ALWAYS make sure to purge the engine first as described in Step No. 1.

Before the operator attempts to run the engine, he should carefully study the chapters of this manual dealing with mechanical details.

1. STARTING THE ENGINE FOR THE FIRST TIME (Follow this sequence for initial set-up).

   When starting the engine for the first time or after a major overhaul, the following steps should be taken:

   A. Service the air intake filters. Also check the condition of lubricating oil filters.

   B. Remove the cylinder head cover lids and lubricate valve stems with oil Only a small amount of oil is required.

   C. Fill the engine lubricating oil sump to the proper level with clean high-grade lubricating oil of the proper viscosity. (See Section B of this manual for oil recommendations.) Prime the lubricating oil system with the priming pump. The lubricating oil level should be checked after this operation, and oil added if necessary.

      Drain off any condensation or leakage that may have collected in the turbo-charger casings.

      Fill the hydraulic governor with proper lubricating oil (see Governor Bulletin in the "Auxiliary Equipment" section of this manual).

D. Open vent cocks or break connections at high points in the water system to prevent air lock and fill the cooling water system with clean treated water (see Section W of this manual).

E. With the governor link disconnected, make certain the gas control linkage has no binding and then reconnect linkage to governor. With governor on "0" position, adjust rods between gas control shaft and metering valves until gas metering valves are .010" open (See Fig. 1). Use the final rod to each individual valve for this adjustment.

F. Make sure that the fuel gas is shut off and ignition system is grounded.

Bar the engine over by hand at least two complete revolutions in order to make certain that it turns freely and that no water may have partially filled any cylinder due to some error or broken parts. This precaution may prevent serious further damage to the engine cylinder heads, pistons, liners, rods or even cylinder block. BE SURE TO REMOVE THE BARRING LEVER AND DISENGAGE THE BARRING DEVICE AFTER BARRING OVER THE ENGINE.

G. Check all fuel gas, oil, water, and other connections and tighten as found necessary. Make certain that all valves for water and lubricating oil are in proper operating position.

H. Set up the air-fuel control system as detailed below. This is to be done without running the engine. The adjustments listed below (1 thru 6) are air/fuel control panel adjustments.

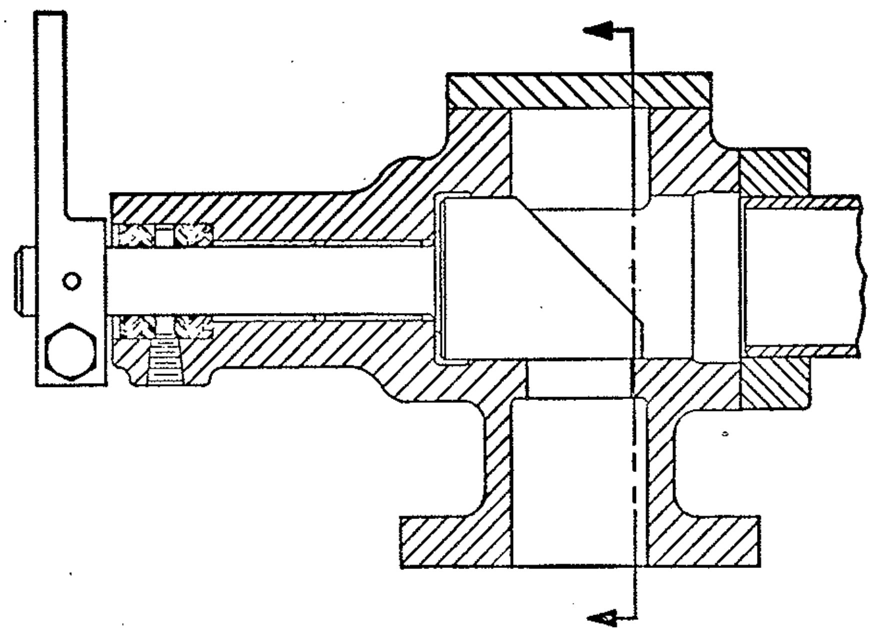
(1) Fill the manometer up to the zero line with mercury. This must be done by removing the glass tube from the holder. The caps on the glycerin filled pressure gauges must be removed so that the gauge bodies are vented to atmosphere. Figure 2 shows the location of the manometer and pressure gauges.

(2) Turn on the supply pressure to the control system and set supply regulator to 45 psig. (See Figure 3.)

(3) Turn the ratio control valve (Figure 2) clockwise until it stops. Then back it off two complete turns.

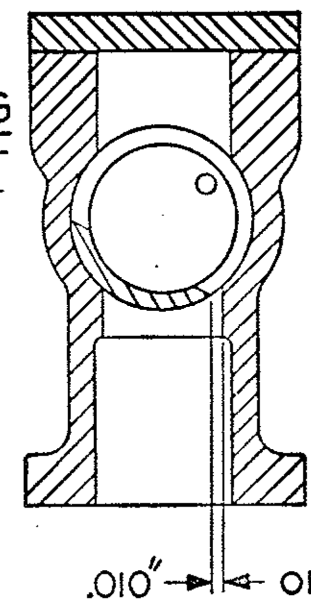
(4) Remove the rubber protective cap on the computing relay and turn the reset rate adjustment counterclockwise until it stops. Then back it off 1/4 turn (See Figure 4). Replace protective cap after adjustment.

(5) Using the minimum air manifold pressure (Figure 5) regulator adjustment screw and the air-gas offset pressure pushbutton, set the manometer reading to the initial offset pressure value indicated on the air-fuel curve (Figure 6).



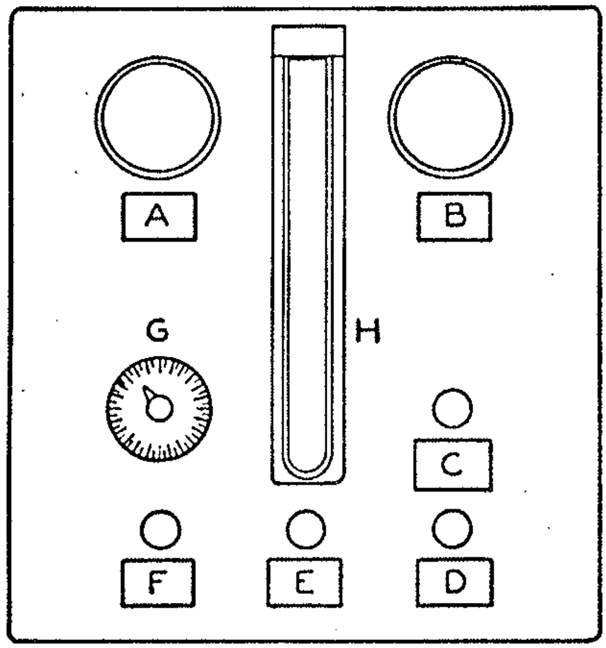
SECTION THRU
METERING VALVE ASSEMBLY

GAS METERING
VALVE ADJUSTMENT



GAS METERING VALVE

FIGURE NO. 1
SECTION-D



FRONT VIEW OF AIR/FUEL CONTROL PANEL

LEGEND

A – PRESSURE GAUGE – GAS MANIFOLD
B – PRESSURE GAUGE – AIR MANIFOLD
C – PUSH BUTTON VALVE – LOW AIR MANIFOLD PRESSURE
D – PUSH BUTTON VALVE – AIR MANIFOLD DIFFERENTIAL
E – PUSH BUTTON VALVE – AIR GAS OFFSET PRESSURE
F – PUSH BUTTON VALVE – GAS MANIFOLD DIFFERENTIAL
G – RATIO CONTROL VALVE
H – MANOMETER

NOTE: WHEN USING D OR F, THE RIGHT LEG OF THE MANOMETER CORRESPONDS TO THE RIGHT BANK OF THE ENGINE AND THE LEFT LEG OF THE MANOMETER CORRESPONDS TO THE LEFT BANK OF THE ENGINE. WHEN USING C, A MANIFOLD PRESSURE IS INDICATED BY A LOWER MERCURY LEVEL IN THE RIGHT LEG OF THE MANOMETER.

FIGURE NO. 2

SECTION-D

A–60 TO 125 PSIG SUPPLY – – – – – – – – NOTE; IF GAS IS USED FOR THE SUPPLY IT MUST BE SHUT OFF WHEN THE ENGINE IS NOT RUNNING. THIS SYSTEM CONTINUOUSLY VENTS THE CONTROL MEDIUM.

B–TO AIR MANIFOLD RIGHT BANK

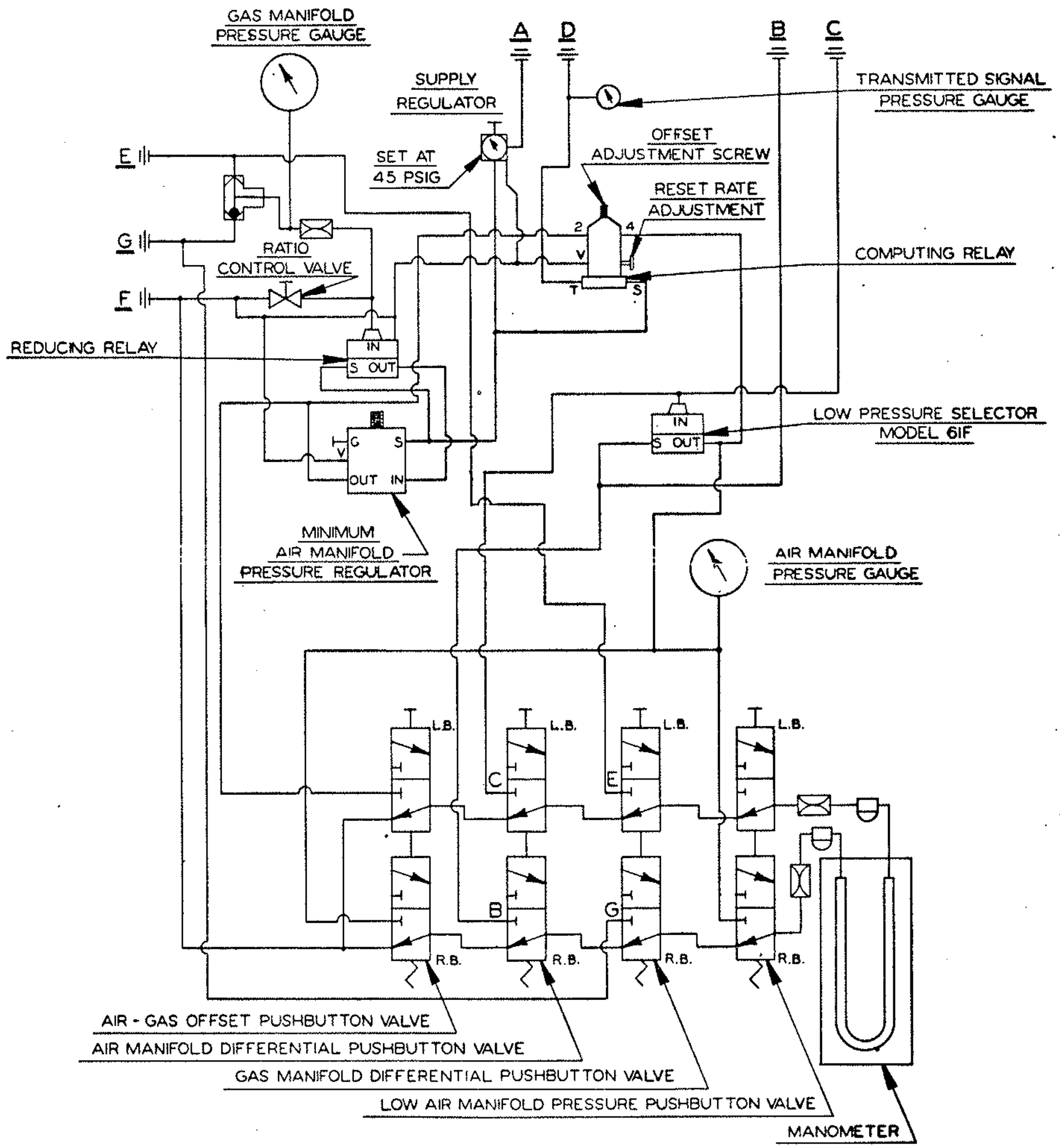
C–TO AIR MANIFOLD LEFT BANK

D–TO AIR CYLINDERS

E–TO GAS MANIFOLD – LEFT BANK

F–TO TURBO AIR INTAKE

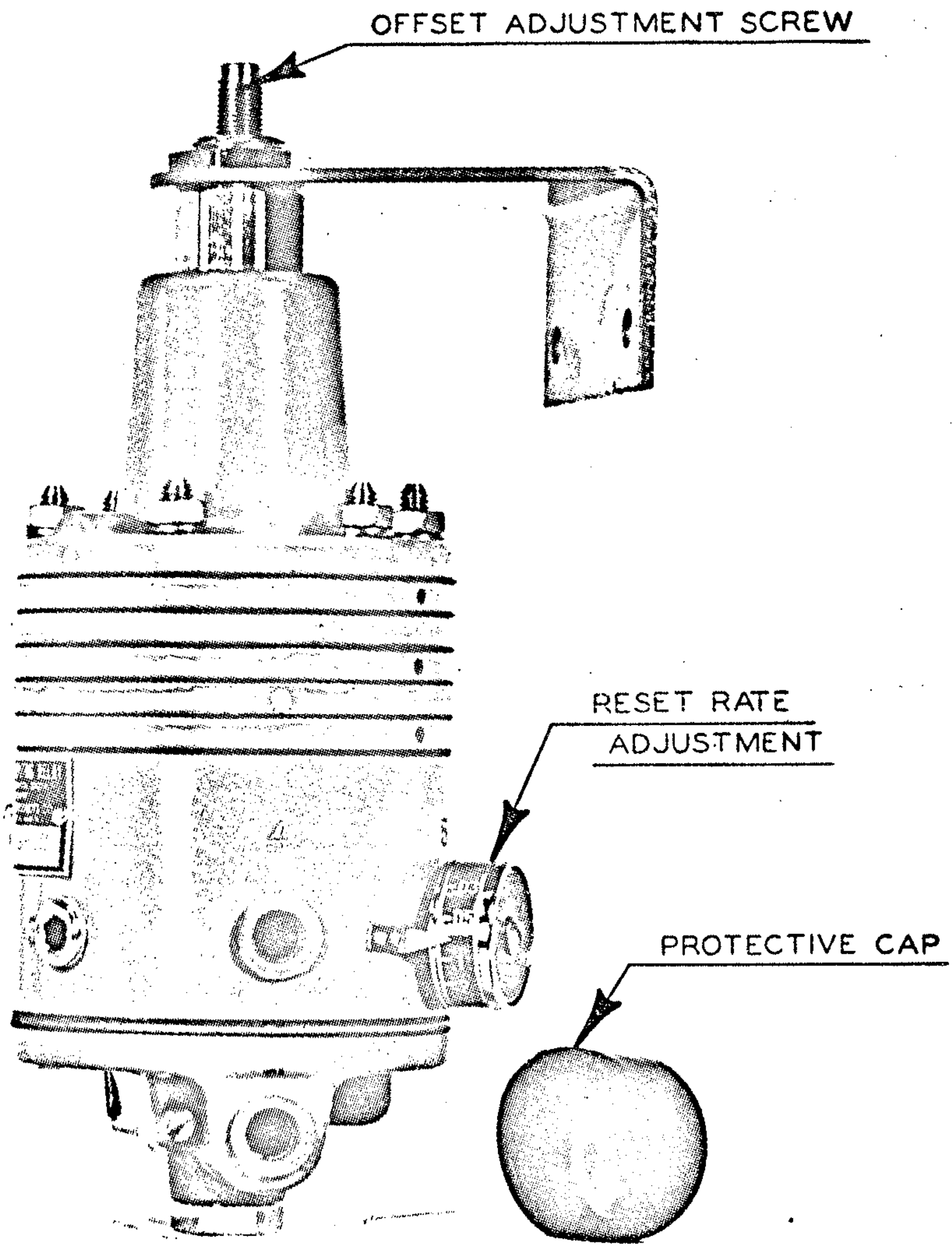
G–TO GAS MANIFOLD – RIGHT BANK



AIR/FUEL CONTROL PANEL SCHEMATIC

FIGURE NO. 3

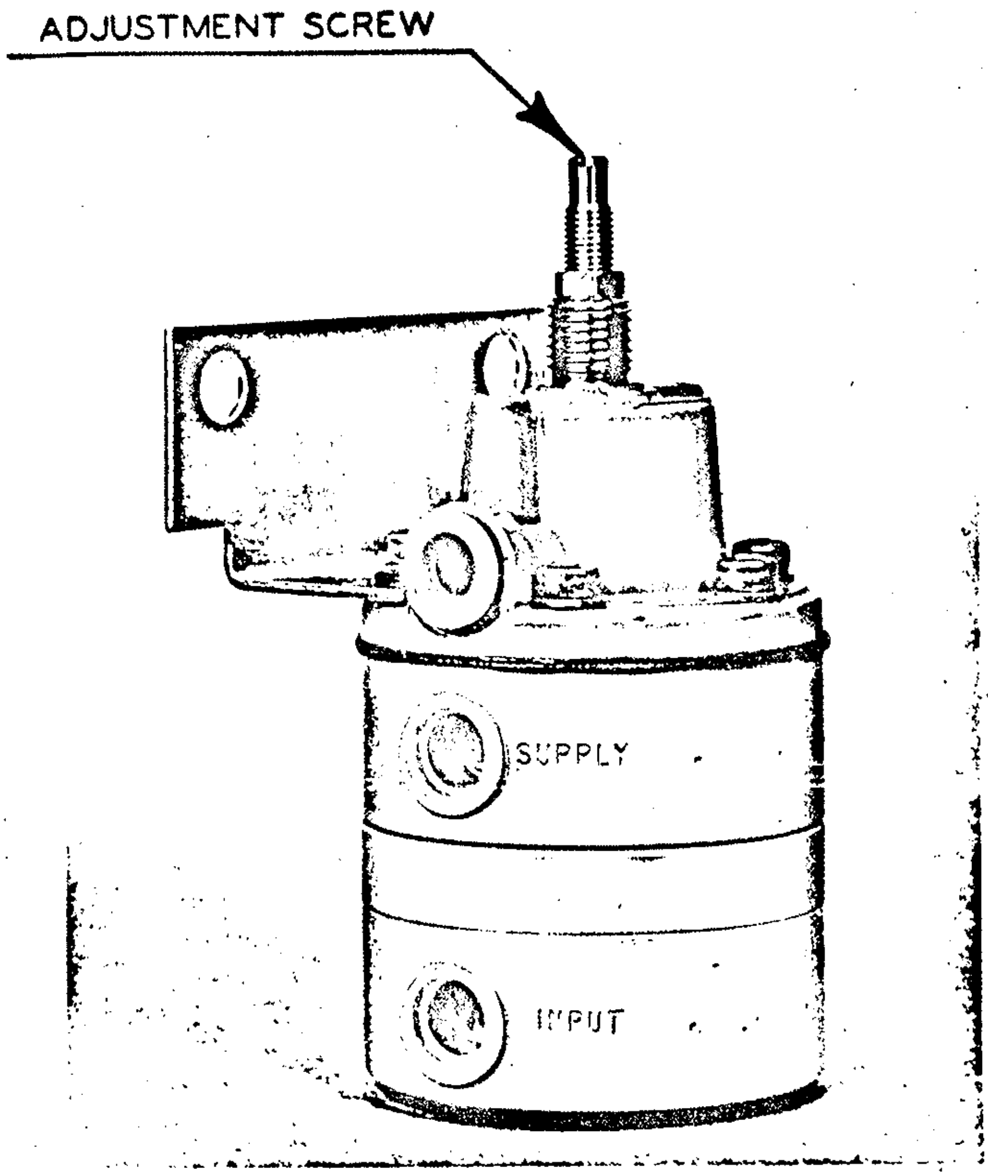
SECTION-D



COMPUTING RELAY

FIGURE NO.4

SECTION-D



MINIMUM AIR MANIFOLD PRESSURE REGULATOR

FIGURE NO. 5
SECTION-D

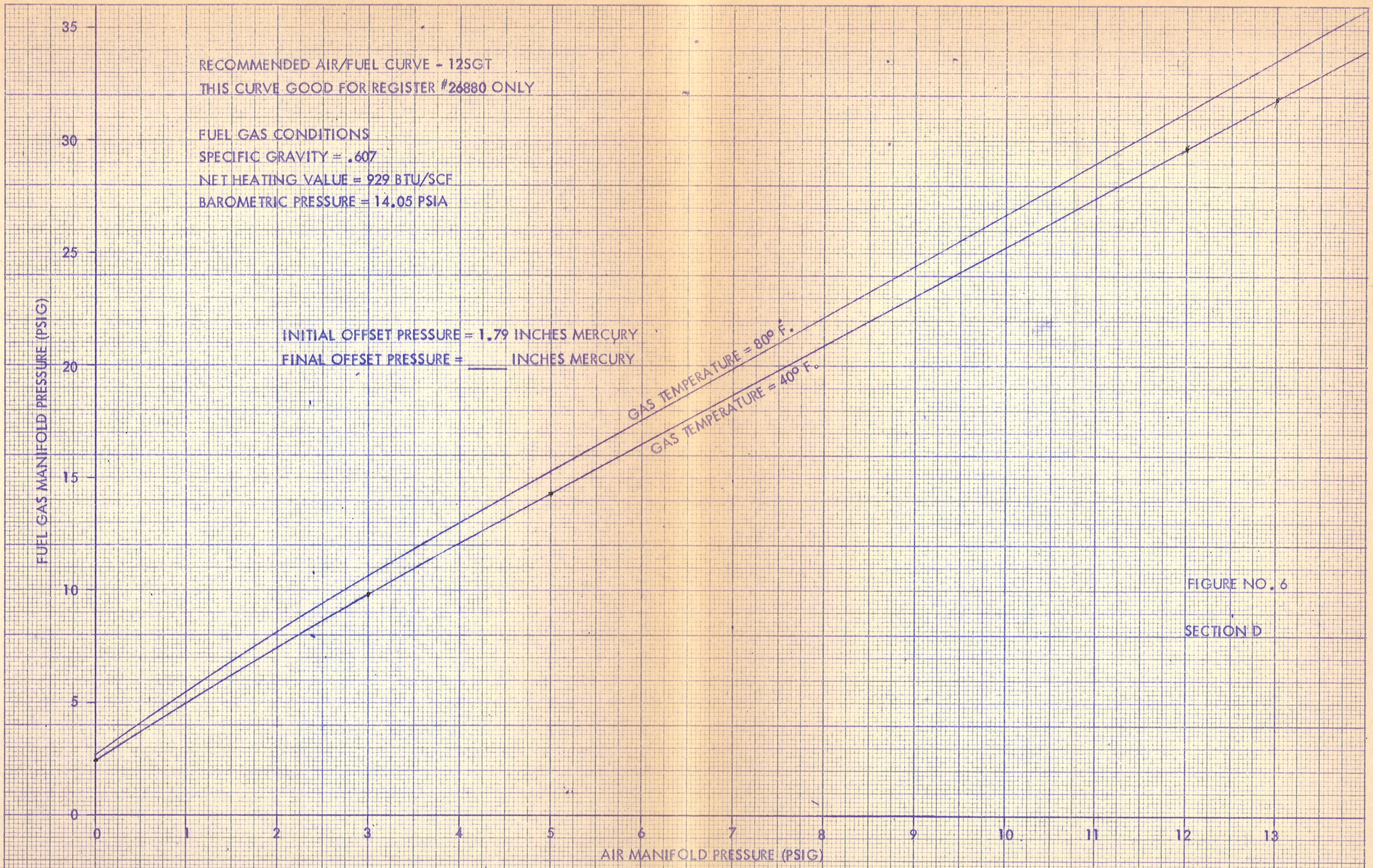


FIGURE NO. 6

SECTION D

11/23/76 GRB

(6) The transmitted signal pressure gauge (located inside the panel) will now read either less than 5 or greater than 35 psig at this time. If the gauge reads greater than 35 psig, reduce the reading to zero "0" by turning the "offset adjustment screw" on the computing relay counter-clockwise. In either case, after the pressure reads less than 5 psig, turn the "offset adjustment screw" clockwise until the signal begins to SLOWLY drift upward. It should take the gauge 10 - 15 seconds to reach 40 psig after making this adjustment. See Figure 4 for location of "offset adjustment screw".

At this time, the air butterflies on the engine should be in the full open position and the air/fuel control system is ready for the engine to be started. Further adjustment of this system (covered later in this section) is required for normal operation.

I. Set up the starting system as detailed below. The first three (3) adjustments are made before the engine is started. Figures 7 and 8 detail the starting system assembly and logic and are to be used with the procedure described below.

(1) Disconnect the run fuel signal line from the control panel to the starting system assembly. It may be necessary to plug the line temporarily to prevent gas from being vented.

(2) Adjust the regulator in the starting bypass loop so that the spring is compressed about 1-1/4 inches.

(3) Adjust the main engine control panel such that the start fuel signal follows the cranking signal by 10 to 15 seconds or more as desired for a purge cycle.

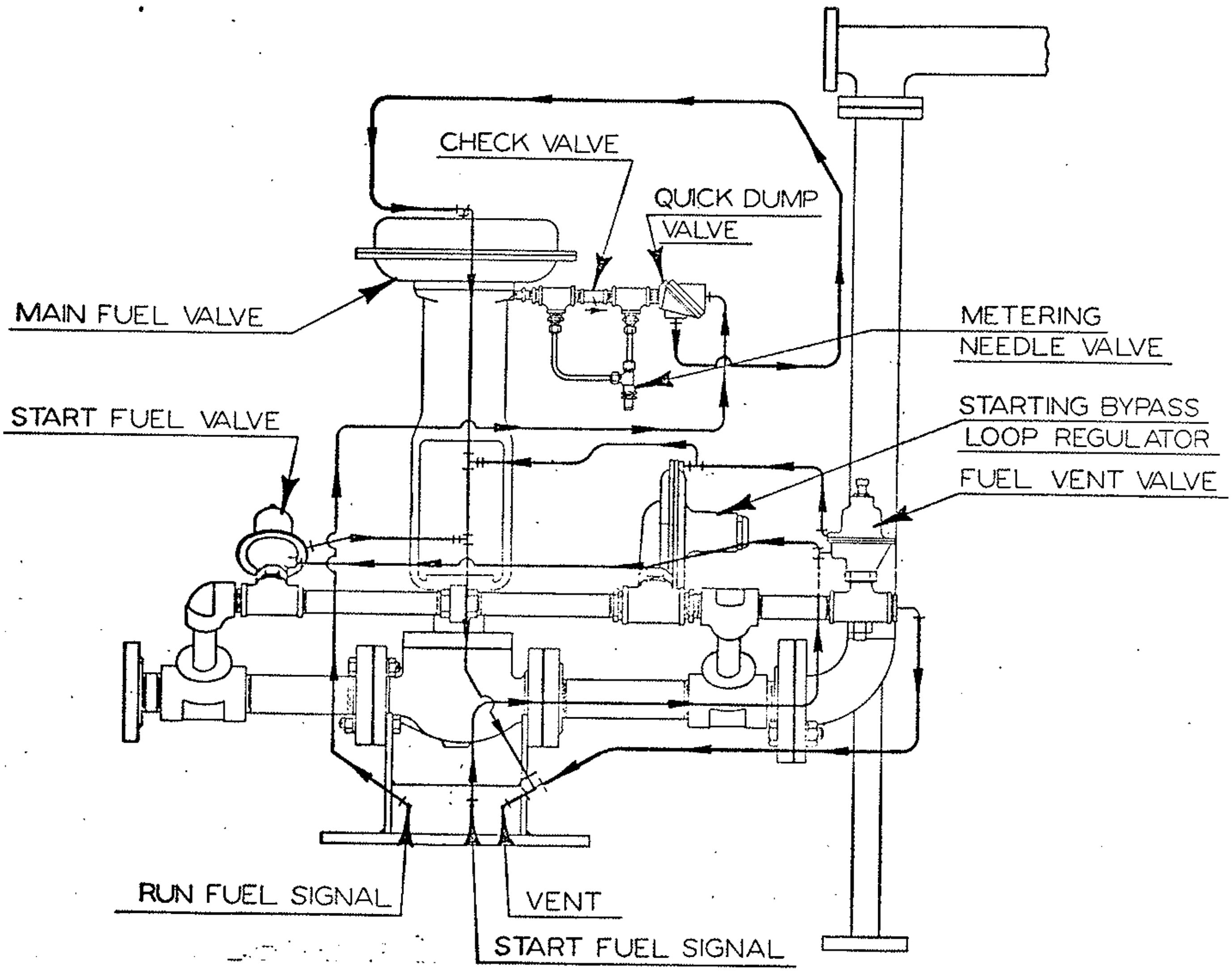
NOTE: Always purge the engine by cranking it for at least 10 - 15 seconds with fuel and ignition off before starting the engine.

(4) Start the engine.

NOTE: The safety control becomes operative only after the engine starts and lubricating oil pressure reaches approximately 10 psi. Therefore, there is NO SAFETY CONTROL WHEN STARTING. It is important that the operator use good judgement at this time.

a. This can be done by limiting the fuel (if necessary) with the governor load limit and while the engine is being cranked, activate the starting bypass with a 35 psig pressure signal. The regulator adjusted in step #2 above also limits the fuel for starting.

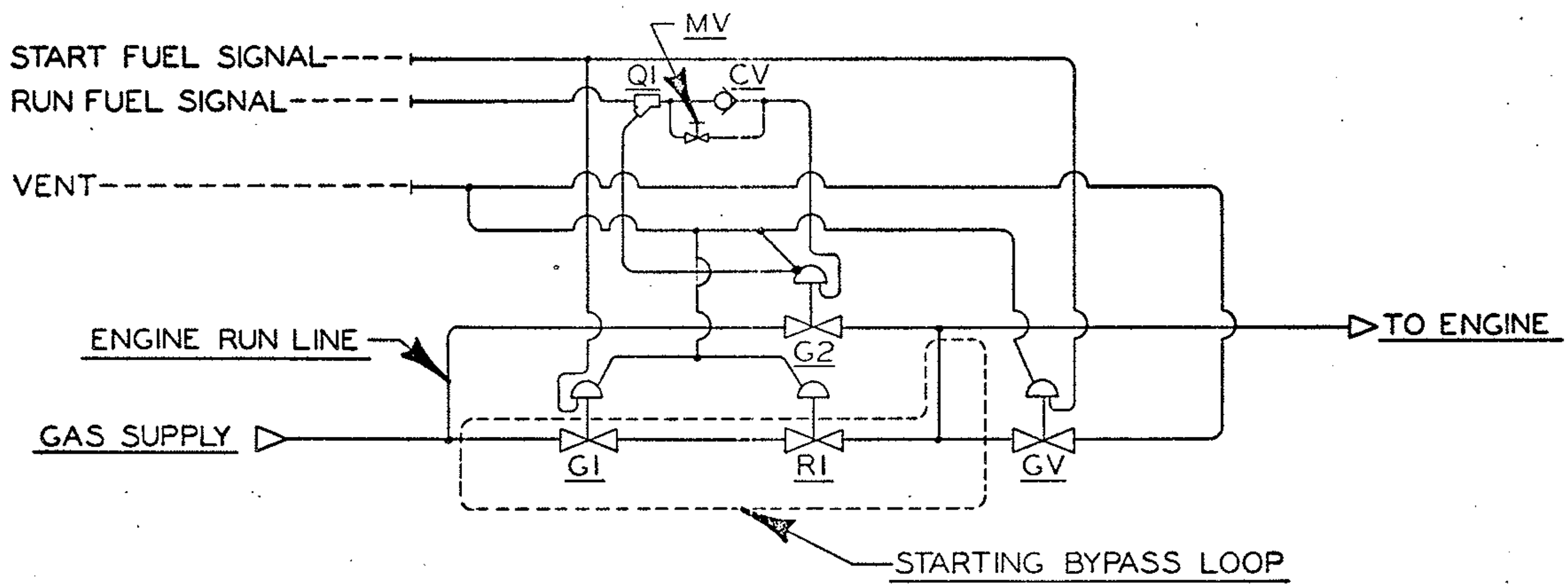
b. Another method is by activating the starting bypass with a 35 psig pressure signal and while cranking the engine, slowly open a manual off-on fuel valve in the fuel line.



STARTING SYSTEM ASSEMBLY

FIGURE NO. 7
SECTION-D

R1 - STARTING BYPASS LOOP REGULATOR
GV - FUEL VENT VALVE
G1 - START FUEL VALVE
G2 - MAIN FUEL VALVE
Q1 - QUICK DUMP VALVE
CV - CHECK VALVE
MV - METERING NEEDLE VALVE



STARTING SYSTEM ASSEMBLY SCHEMATIC

FIGURE NO. 8
SECTION-D

(5) Once the engine is running, set the governor load limit on 10.

(6) Now the engine should be running on the starting system bypass with the main fuel valve still completely shut off and the governor in the wide open position.

(7) The air manifold pressure should now be set to 0.1 to 0.2 inches of mercury pressure. This is done by using the minimum air manifold pressure regulator and the low air manifold pushbutton switch in the air/fuel control panel (see Figures 2, 3 and 5).

(8) Adjust the control panel as necessary to insure that the run fuel signal when the engine is running in the range of 350 RPM to 450 RPM. Perhaps the simplest method of doing this is to adjust the regulator in the starting bypass loop such that the engine runs at 400 RPM and then making the necessary adjustment to turn the run fuel signal on at that speed.

(9) Adjust the regulator in the starting system bypass loop so that the engine runs at 500 RPM with no load on it and the governor in the wide open position.

(10) Shut the engine down and be sure the fuel is shut off ahead of the starting system assembly.

(11) Depending on the amount of time the engine has been run, it may be necessary to check the bearings. This procedure is detailed in Item J.

(12) Set the metering needle valve on the starting system assembly at 3/4 turns open and time the opening of the main fuel valve.

(13) The main fuel valve should open 1/2 of its full stroke in about 45 seconds to a minute after a run fuel signal is applied. Adjust the metering valve on the assembly as necessary to get this proper rate of opening for the main fuel valve.

(14) Reconnect run fuel signal line between engine and control panel plus be certain all other control lines that need to be connected for final operation are properly connected.

(15) The engine and control panel are now ready for starting with automatic control.

(16) Try a couple of starts with automatic control and make any final adjustments necessary.

(17) Once the system is satisfactory, be sure to tighten the setscrew on the metering needle valve to lock its position.

CAUTION: Never turn the fuel on with the engine stopped. Be sure the engine is turning, either by cranking or by its own firing when the fuel is on in order to avoid filling the exhaust and air manifolds with gas. When barring the engine by hand, be sure that both the ignition switch and the fuel are turned off.

J. After running the engine at no load for a few minutes, it must be shut down and checked for proper functioning, by removing the cylinder block cover plates and making certain that all bearings are receiving proper lubrication and are not running hot. If this inspection is satisfactory, then the break-in period may be continued.

During the initial period of operation, special attention should be given the engine as follows:

Watch the engine oil pressure carefully to make certain that it does not drop below 20 psi. Engine oil inlet manifold pressure should be 35-45 psi at full rated engine speed. Water outlet temperature should be watched as indicative of general engine operating conditions. The engine should preferably not be operated at heavy load unless the temperature of the water leaving the engine is at least 120° F. Occasional shutdown and rechecking of bearings during initial operation period is also advised.

K. Finalize the air/fuel control system as detailed below. Reference Figures 2, 3, 4, 5, and 6.

(1) Start the engine and load it to bring the gas manifold pressure up to 4 - 6 psig.

(2) Using the air-gas offset pressure valve, check the initial offset value and if necessary adjust it to the offset value indicated on the curve. Use the offset adjustment screw on the computer relay (Figure 4).

(3) Using the ratio control valve, bring the air manifold pressure on to the air/fuel curve (Figure 6).

(4) Slowly load the engine up to about 26-28 psig gas manifold pressure; keeping the air manifold pressure close to the air/fuel curve with the ratio control valve.

NOTE: At this time the air manifold pressure balance should be checked using the air manifold differential valve and the manometer. This differential should be kept to less than 0.1 inches mercury at full load and speed. It can be adjusted by the individual linkages on the air cylinders; the preferable method is dropping the higher air manifold pressure until a balanced condition is reached. This is also the time to check and adjust, if necessary, the gas manifold balance. The gas manifold differential should be kept to less than 0.25 inches mercury at full load and speed. Again the preferable method is reducing the higher gas manifold pressure.

(5) At 26-28 psig gas manifold set the air manifold pressure exactly on the air/fuel curve with the ratio control valve.

(6) Drop the engine load to get a 4-6 psig gas manifold pressure and check to see if the air manifold pressure is on the air/fuel curve. If not, bring it onto the air/fuel curve with the offset adjustment screw on the computing relay.

(7) Increase engine load until the gas manifold pressure is again 26 - 28 psig. If the air manifold pressure is not exactly on the air/fuel curve, use the ratio control valve to bring it onto the curve.

(8) Repeat (6) and (7) until no correction is necessary. When satisfied that the air manifold pressure tracks the gas manifold pressure the same as the air/fuel curve, check the offset pressure and record it on the curve in the space provided for future reference.

(9) With the engine running at minimum speed and no load,set the minimum air manifold pressure to 0.1 inches mercury. This is done using the low air manifold pressure switch, the manometer, and the minimum air manifold pressure regulator adjustment. It is important that this is set to a pressure and not a vacuum for proper operation of the air/fuel control system.

(10) The air/fuel control system is now properly adjusted for engine operation over the complete load and speed range. From this point on, no further adjustments are to be made and "tinkering" with this system beyond this point will only cause problems. Any changes in engine performance should be investigated for their individual causes and not "adjusted out" by tinkering with the air/fuel control system.

2. NORMAL STARTING PROCEDURE

It is obvious that many of the aforementioned steps need not be taken in normal starting of the engine after it has been operated. However, water and oil levels should be checked and replenished as required before starting. All valves in fuel, water, oil and air lines should be also checked for proper operating positions before starting.

After starting, make certain that lubricating oil pressure is up to normal operating range before applying load.

3. PRECAUTIONS IN CASE OF TURBOCHARGER FAILURE

In the event of failure of the turbocharger, the engine must be withdrawn from service until necessary repairs are made. Attempting to operate with an inoperative turbocharger could result in severe damage to operating parts.

4. STARTING MOTOR VENTING

If gas is used to operate the starting motor, BE SURE that the exhaust from the motor is vented to the outside of the building or some other safe location. Fumes MUST NOT be allowed to come in contact with fire or sparks.

5. ENGINE OPERATION AND ADJUSTMENT UNDER LOAD

A. General Combustion Characteristics

Spark ignition engines tend to have the most rapid combustion when the mixture of fuel and air is near or equal to the chemically perfect proportion for complete combination of fuel and oxygen of the air. This very rapid and intense combustion produces high combustion chamber temperatures and oftentimes a violent pressure rise and mechanical shock called detonation. A naturally aspirated carburetor engine is usually set to have a mixture ratio which is slightly rich, resulting in a slower and less violent combustion for best engine life.

The turbocharged engine differs from the naturally aspirated engine in the proper control of the air/fuel ratio. In the turbocharged engine, the air taken into the engine should be so varied as to operate the engine at a leaner mixture than the chemically perfect value, to avoid detonation, by proper use of the increase in air available. This additional air in the turbocharged engine results in lower temperatures in the combustion chamber and exhaust system by dilution of the mixture with an excess of air, and scavenging of the combustion chamber through the valve overlap by "blow through" air gives a further temperature reduction.

The leaner mixture possible in a turbocharged engine is very important in reducing temperatures of the engine parts, making it possible to carry the heavier loads of the turbocharged engine without damage or shortening the engine life. A rich mixture will cause high temperatures, both in the combustion chamber and exhaust system, which may destroy the inlet and exhaust valves and seats as well as the turbocharger. The exhaust temperatures at the turbocharger turbine inlet must be less than 1175° F. at all times.

B. Exhaust Temperature Limits

Exhaust temperature limiting must be observed during the engine warm-up. Air-to-gas fuel mixture adjustments must be made as necessary to give smooth operation under load without excessive exhaust temperatures. Exhaust temperatures at the turbocharger turbine inlet should be less than 1150° F. average at all times. The exhaust temperatures at the cylinder head outlet should not exceed 1225° F. at any time and preferably not over 1200° F. at full load.

C. Governor Travel

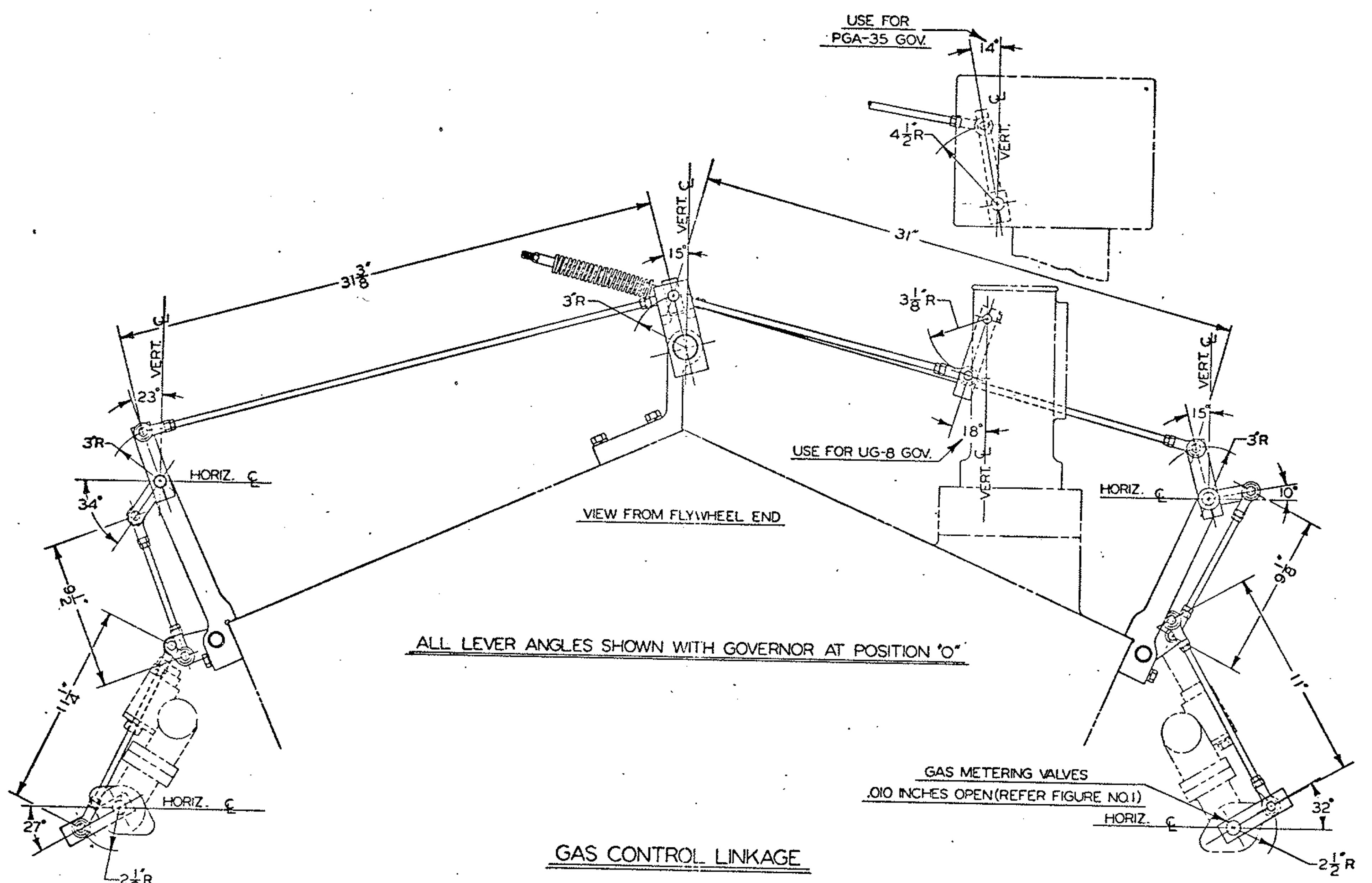
When the gas linkage is set in accordance with Figure 9, the proper governor travel for the load range should be obtained. The "Governor Load Indicator or Rack Dial Lever", as the case may be, should read "zero" with the gas valves closed and approximately 85% of full travel with the engine operated at full load. The final linkage adjustment may not be precisely the same as Figure 9 because of necessary adjustments made in above set-up procedures for optimum engine starting and operation.

D. Air Butterfly Linkage

The air butterfly linkage should be set in accordance with Figure 10. Like the gas linkage, the final set-up may not be exactly the same as Figure 10 due to final adjustments made during engine set-up.

E. Spark Timing

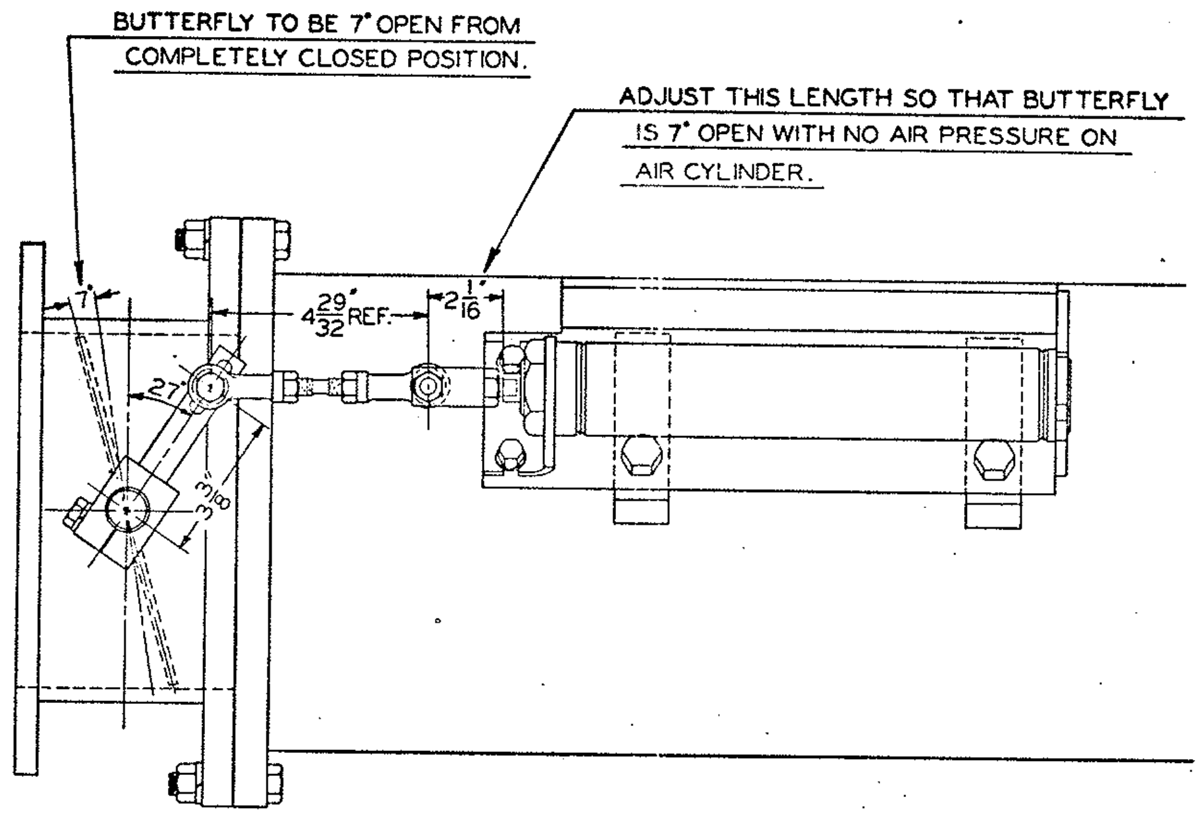
For proper spark timing, see Section A.



GAS CONTROL LINKAGE

FIGURE NO.9

SECTION-D



AIR BUTTERFLY LINKAGE

FIGURE NO. 10

SECTION - D

BEDPLATE - CRANKSHAFT - MAIN BEARINGS

CRANKSHAFT ALIGNMENT

1. BEDPLATE

The cast iron bedplate is heavily ribbed to form the rigid structure upon which the remainder of the engine is built. The transverse members, which form the main bearing supports, are line-bored and match-marked with their respective caps; hence the caps must always be replaced in accordance with these markings. The caps are held in place by alloy steel capscrews which are safety wired in pairs.

An oil suction strainer is mounted on the front end of the engine in the suction passage between the engine sump and the lube oil pump.

The bedplate is machined to accommodate the lube oil manifold and passages are drilled at each main bearing to carry oil from the manifold to the crankshaft bearings.

2. CRANKSHAFT

The crankshaft is forged from a solid billet of high quality steel and is accurately machined. Oil passages are drilled from the main bearing journals to lubricate the crankpins and to carry oil for lubrication of the piston pins and for cooling of the pistons.

The forward end of the crankshaft is extended for the auxiliary drives. Also, a torsional vibration damper is mounted on the front end. The rear end of the crankshaft has an integrally forged power take-off flange. A dual sprocket at the flywheel end drives the two camshafts.

Throw rings and a labyrinth seal prevent oil leakage around the power take-off flange.

3. MAIN BEARINGS

The "trimetal" main bearing shells are of the split precision type requiring no shims or hand fitting. Upper and lower bearing shells are not interchangeable. When installing new bearing shells or in replacing old ones in the engine, care should be taken that the shell and the bearing saddle are both thoroughly cleaned before any assembly is attempted; but under no circumstance should any filing, scraping or other fitting be done on either bearing shell or saddle.

End thrust of the crankshaft is taken by two half-ring thrust bearings, one on each side of the rear main bearing saddle. These fit into machined recesses in the bedplate and are prevented from turning by the bearing cap. With the bearing cap off, they can be rotated around the journal for removal. These bearings must be installed so that their grooved faces contact the thrust surfaces of the crankshaft.

The following procedure should be followed in removing the main bearing shells for inspection or cleaning or other service: (Note: The snifter valves should be opened during this operation, if cylinder heads have not been removed from the engine for other servicing or inspection reasons).

(a) Turn the crankshaft to a position where one of the throws adjacent to the bearing is in a horizontal position. This leaves an open space above the crank web through which the cap and bearing can be removed. The bearing can be removed most conveniently from the left side through the opening forward of the bearing, or from the right side through the opening to the rear of the bearing. The front main bearing can be removed only from the right side and the rear main bearing only from the left side.

    Remove the safety wire and capscrews from the bearing caps. (A special wrench is provided for removing the capscrews). Lift the cap (two workmen will be needed for this) and lay it on its side by tilting the top away from the horizontal crank throw. Then slide it along the crank web and out through the opening. It may be necessary to turn the crankshaft a few degrees one way or other in order to find the best position for removing the cap.

    Lift the bearing shell off the journal if it has not remained in the cap.

(b) Place a small piece of brass rod, of proper size, in the lubricating oil hole in the main bearing journal and allow it to project about 5/32" beyond the journal.

(c) Bar the crankshaft over slowly by hand. The projecting brass rod should catch the lower bearing shell; and by turning the crankshaft far enough, the lower bearing shell will be forced around to a position where it may be lifted from the shaft.

(d) Upper and lower main bearing shells are not interchangeable and must be placed back in their original positions after removal for any reason. Note that the upper shell has an oil groove cut completely around the circumference and is dowelled in the cap. Bearing shells should be marked to indicate location (i.e. number of bearing and whether upper or lower).

NOTE: Use only pencil markings on the inside diameter or outside diameter or parting line faces of bearing shells. If punch marks or number stamps are used, thay should be made only on the ends of the shells and should be made very lightly.

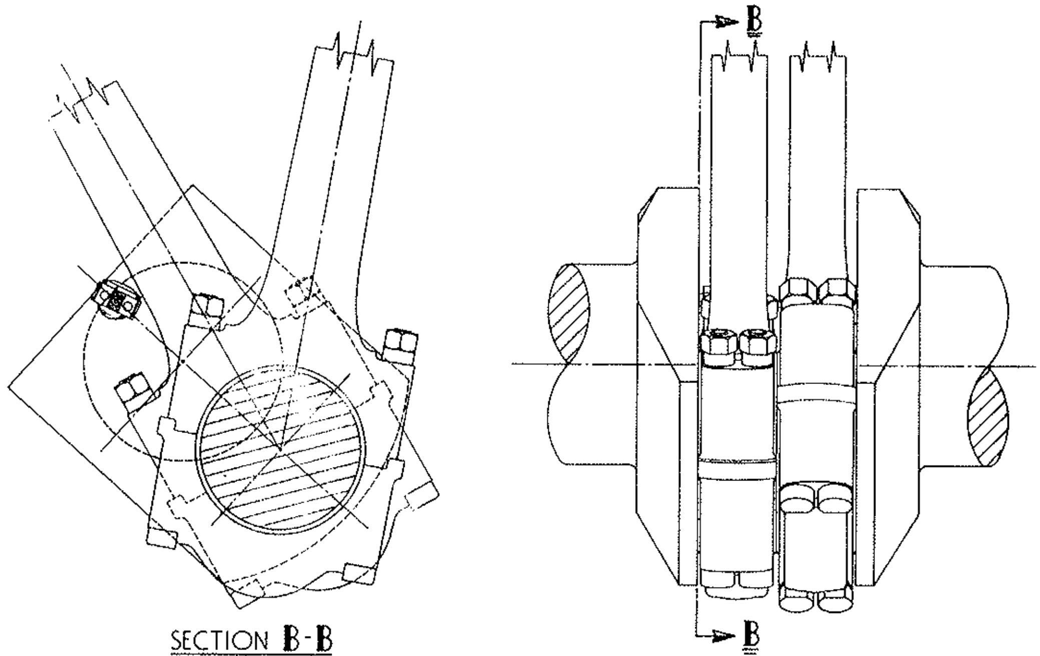
Carefully clean the crankshaft and bearing shells and saddles before attempting to replace the bearing shells. The lower main bearing shells may be replaced by barring over the crankshaft as described above. Be sure to remove the brass rod from the crankshaft oil hole before replacing the upper bearing shell and bearing cap. The bearing cap capscrews should be tightened uniformly with a torque indicating wrench to the torque reading called for in Section A.

The bearing surface consists of a thin plating of babbitt over a backing of special bronze. If more than 20% of the babbitt has been worn away, exposing the bronze, the shells should be replaced.

4. CRANKSHAFT ALIGNMENT

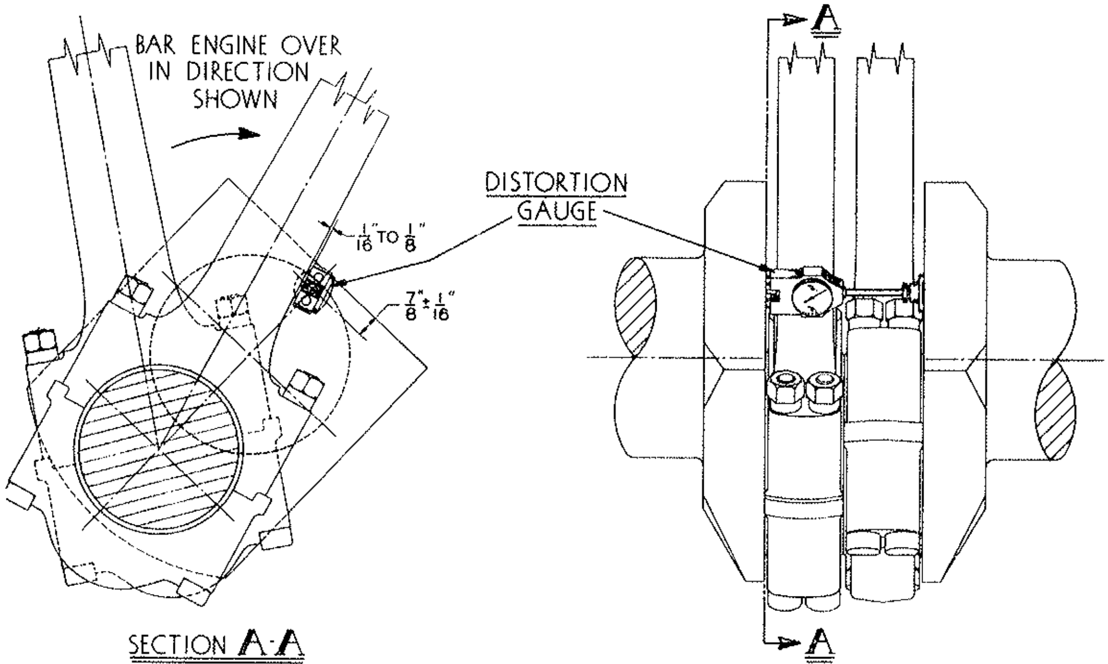
The crankshaft alignment should be checked, at major overhauls or at intervals of approximately 12,000 service hours. A good idea of the alignment may be obtained by checking wear of the main bearings. If not more than 20% of the babbitt plating has been worn away, it will be satisfactory to use the same bearings until the next overhaul period. However, if the wear is uneven, it is best to replace all the bearing shells in order to maintain proper alignment.

Comparison of the strain gauge measurements taken at the upper and lower positions will show the crankshaft alignment conditions. Normally the measurements made with the cranks at the upper position are slightly greater than the measurements for the same cranks at the lower position. However, the difference in the measurement for any one crank should not exceed .002" except for the crank adjacent to the flywheel which should not exceed .003". If such is found to be the case, new bearing shells should be installed in the engine.



VIEW B

APPROXIMATE RELATIONSHIP OF CONNECTING RODS TO DISTORTION GAUGE AFTER MEASUREMENTS HAVE BEEN TAKEN



VIEW A

APPROXIMATE RELATIONSHIP OF CONNECTING RODS TO DISTORTION GAUGE BEFORE TAKING MEASUREMENTS

FIG. F-1

CYLINDER BLOCK AND CYLINDER LINERS

CYLINDER HEADS AND VALVES

1. CYLINDER BLOCK

The cylinder block is a special alloy iron casting of rigid construction. The top decks and intermediate bridge sections are line-bored to receive and properly locate the cylinder liners. The camshaft bearing supports are cast integral with the block on both sides, and are precision line-bored with their respective bearing caps. Removable covers provide access to the camshaft, cam followers, connecting rods and main bearings.

The cylinder block is attached to the bedplate with studs and self-locking nuts. Thin composition gaskets are used to make an oil tight joint between the block and the bedplate. When replacing a block that has been removed, clean the two mating surfaces thoroughly and use new gaskets, applying a light coating of "Glyptal" or similar sealant to both sides of the gaskets.

2. CYLINDER LINERS

The cylinder liners are made of a special alloy iron and are machined all over. The bore is hone finished to very close limits. The cylinder liner is of the wet type; and has a flange at its upper end which is clamped in a counterbore in the cylinder block, by the cylinder head, to hold the liner in its proper position. The joint between this flange and the cylinder block is made water-tight by a special gasket. The liner is located by a projecting pin in the flange which fits into a slot in the top deck of the cylinder block. Three special moulded rubber compound rings fit the grooves near the lower end of the liner to seal water and oil where the liner fits the intermediate bridge section of the block.

3. REMOVING THE CYLINDER LINER

(a) Bar the engine over until the crankpin, under the liner to be removed, is in the lower dead center position.

(b) The liner can be easily removed by providing a special tool as shown in Fig. H-1. Place a steel bar through eye bolt of the tool and turn clockwise to free the liner from its seat. If the liner is stuck fast, it may be necessary to use a jack to help free it. Rest the jack on a heavy steel bar placed across the webs of the crankshaft.

(c) After the liner is free, engage the eye bolt with an overhead hoist and withdraw the liner from the block, using a steady, even pull, making certain that the hoist is directly over the liner and provide means to guide the liner to prevent cocking or binding.

(d) NOTE: If a special liner tool is not available, place a heavy flat steel bar across the webs of the crankshaft, and place a heavy duty jack on top of this bar. Use another bar of suitable length on top of the jack, and operate the jack upward until the bar contacts the bottom end of the liner. Continue operating the jack upward until the top of the liner projects about 2 inches above the top of the block. (On cylinders where crankshaft counterweights are encountered, it may be found necessary to place a heavy bar or timber across the cylinder block handhole opening in order to support the jack).

(e) Attach two clamps under the liner flange, 180° apart, and fasten a rope sling to the clamps in such manner that the sling can be centrally engaged by an overhead hoist. Withdraw the liner from the block using a steady even pull and making certain that the hoist is directly over the liner to prevent any cocking or binding.

(f) Place the liner on the floor in a vertical position.

4. INSTALLING CYLINDER LINER IN BLOCK

(a) Thoroughly clean the cylinder liner, taking care to remove all carbon, scale, sediment, or other deposits.

(b) Inspect the cylinder liner for wear, cracks, nicks, or corrosion pits, or any other damage.

(c) If a ridge is found inside the liner at the top of the piston ring travel, this should be removed in order to eliminate any possibility of damage to the piston rings.

(d) Inspect and clean the cylinder block water jackets of scale or lime deposits. Inspect and clean the machined section of the block where the cylinder liner fits the block.

NOTE: It is generally more convenient to fit the piston and piston ring to the liner before reinstalling it in the cylinder block. Such procedure is recommended at this time although the description of the work to be done will be presented under Section K of this manual.

(e) Install new metallic water seal gasket under the liner top flange, using a sufficient amount of heavy grease to hold the gasket to the flange.

(f) Install rubber rings in grooves at the lower end of the liner without use of any type of lubricant. Make certain that the rings fit their grooves in an evenly stretched condition and that they have not been twisted during this installation.

(g) Using a medium grade gear oil or an approximate 50% mixture of engine lubricating oil and "STP" and a paint brush, coat the outside diameters of the liner and seal rings and also the machined upper and lower bores of the cylinder block lightly and evenly to assist the entry of the liner into its final seating without twisting or shearing of the liner rubber seal rings.

(h) Assemble the special liner tool over cylinder head studs; and with a suitable bar placed through the eyebolt, slowly turn counter-clockwise to force the liner down into its seat. IN FORCING THE LINER INTO ITS FINAL POSITION BE CERTAIN THAT THE WATER SEAL GASKET FITS IN ITS PROPER PLACE AND IS NOT PINCHED OR SHEARED OR OTHERWISE DAMAGED.

NOTE: If a special liner tool is not available, attach clamps to the liner flange and, using a rope sling and hoist, lower the liner carefully into the cylinder block, making certain that the bottom rubber ring bears evenly all around the bevel on the lower bored section of the block. Also make certain that the metallic upper seal ring properly enters the counterbore in the top deck of the cylinder block. NOTE: It will probably be necessary to force the liner the last few inches into the block. This may be done by using a bar fitting across the top of the liner and around diametrically opposed cylinder head studs, and by installing spacers and cylinder head nuts above the bar and pulling down evenly on the cylinder head nuts. It may also be accomplished by placing a heavy timber across the top of the liner and driving on the timber with a heavy bar or sledge hammer.

(i) Recheck the inside diameter of the liner at the level of the intermediate cylinder block bridge to make certain that it is still to size and round within .002". A faulty installation in which the rubber seal ring may have rolled up or torn may cause the liner to go considerably out of round and result in scoring of the piston and liner.

5. CYLINDER HEADS

The engine cylinders are fitted with individual alloy iron cylinder heads, designed for maximum strength and uniform cooling. Inlet and exhaust ducts are designed with ample section and of proper shape for low flow resistance. The joint between the cylinder head and the cylinder liner is made gas-tight by a metallic gasket.

Each head is fitted with an inlet valve, an exhaust valve, a gas admission valve, an air starting valve, an air starting check valve, and one spark plug. (The air starting valve is omitted when air motor or electric cranking motors are used).

Starting air is admitted to the heads from individual openings in the air starting manifolds. (Not applicable with air motor or electric starting).

The exhaust manifolds, one for each bank of cylinders, are fastened to the machined sides of the cylinder heads. Air intake elbows are also bolted to the same side of the heads and to the portion of the block which serves as the intake manifold. Each air intake elbow has a throttling butterfly to control air flow and maintain the proper mixture ratio in the cylinder.

6. REMOVING CYLINDER HEAD ASSEMBLY

(a) Drain head by removing pipe plug on left side. (This will eliminate the possibility of spilling water into cylinder when lifting off head).

(b) Disconnect gas vent lines and gas adjusting valve assembly. Remove cylinder head cover and valve rocker shaft assembly. Disconnect spark plug cable and control linkage to air butterflies. Remove capscrews holding ignition wire conduit to cylinder head.

(c) Remove water outlet standpipe. Remove two capscrews holding inlet water jumper to cylinder block.

(d) Remove exhaust manifold and air inlet elbow capscrews. NOTE: If all cylinder heads are to be removed from the engine, it will also be necessary to remove or support the exhaust manifolds.

(e) Remove four socket head capscrews holding head to cylinder block. Remove cylinder head nuts.

(f) In lifting off the head, use the special lifting device which employs the long stud in the center of the head and one of the outlet water standpipe capscrew holes. Guide the head in order to avoid damaging the studs. Be careful not to damage the flexible thermocouple wire conduit.

7. SERVICING CYLINDER HEADS

Carefully examine valve ports and remove any carbon or dirt deposits found therein. Also inspect water jackets for deposits of dirt or lime or other foreign matter. Any deposits found in the water jacket should be washed or blown out of the head, or cleaned out with a proper solvent solution.

8. INSTALLING CYLINDER HEADS

(a) Check all gaskets and replace any found to be damaged.

(b) Using the special lifting device, lift the head over the engine with a hoist and lower in place. Pay particular attention to the seating of the gas seal gasket.

(c) Replace cylinder head nuts and tighten down evenly until head fits snugly to top of liner. Do not use over 25 foot pounds of torque at this time.

(d) Insert capscrews through exhaust manifold flange and tighten to a snug fit to line up the cylinder head with the manifold.

(e) Install four socket head capscrews in cylinder head, but do not tighten.

(f) Replace gas adjusting valves and gaskets, but do not tighten capscrews.

(g) Replace air inlet elbow and gaskets, but do not fully tighten capscrews.

(h) Install water outlet standpipe, but do not fully tighten capscrews. Also install capscrews in inlet water jumper, but do not tighten.

(i) Fully tighten the cylinder head nuts, using a crisscross pattern to the value given in Section A, using a torque indicating wrench. It is better to work crisscross around the head at least three times, working gradually up to the final torque setting the last time around. PULL NUTS DOWN EVENLY. Improper tightening may ruin the cylinder head or liner or even crack the liner ledge of the cylinder block.

(j) Fully tighten all capscrews mentioned in steps (d) to (h) above.

(k) Replace rocker shaft assembly and cylinder head cover. (Refer to instructions on servicing rocker shaft assemblies, Section L).

(l) Reconnect spark plug cable, control linkages, gas vent lines, and re-attach ignition wire conduit.

9. INLET AND EXHAUST VALVES

Each cylinder head is fitted with one inlet and one exhaust valve, each valve being made of a special alloy steel best suited for its respective application. Dual concentric valve springs are used on each valve. The spring retainers are held on the valve stems by hardened steel split keepers.

10. VALVE INSPECTION AND CARE

To secure long life, the valves must be properly seated. It is therefore advisable to inspect the valves, especially the exhaust valve at regular intervals. If the seats, both on the valve and in the head, are polished and not excessively pitted, and if the contact area appears to be continuous all the way around both valve and seat faces, then grinding or lapping is not necessary, and in fact may be detrimental. However, if the seats appear rather rusty in places, or if pitted areas are of sufficient size to extend almost across the valve seating area, it is then advisable to reface the valve and regrind the valve seating face in the head. In severe cases, replacement of valves may be necessary. After refacing or replacing valves, it may be desirable to lightly lap the seats with fine lapping compound to insure proper seating.

Valve stem guides should be carefully inspected for signs of excess wear and cracks, and should be replaced where such is found. Valve springs should be carefully inspected for pits or cracks and should be replaced with new springs if any such defects are found.

11. REMOVING VALVES FROM HEAD

(a) Depress the valve spring retainer, with a pronged lever or special tool, sufficient to allow removal of the split keepers.

(b) Remove keepers and slowly release pressure on the spring retainer.

(c) Lift out spring retainer and valve springs. Remove valve spring spacer.

(d) Turn head over and remove valve.

12. LAPPING VALVES TO THEIR SEATS

(a) Place the head, with the lower deck up, on an improvised stand or work bench.

(b) Place a weak spring between the valve head and valve stem bushing.

(c) Apply lapping compound to the valve seat and rotate the valve back and forth with a valve lapping crank tool, applying some pressure against the seat, but allowing the spring to lift the valve off the seat frequently to replenish the compound between the seating surfaces.

(d) After a perfect seat is obtained, thoroughly clean the valve head and seat, remove the lapping-in spring and reassemble the valve, reversing the operations given for disassembly.

NOTE: Any lapping of valve to its seat should be of very light nature, since this operation tends to wear a groove in the face of the valve. If heavy lapping appears necessary, both valve and seat should be refaced with proper grinding equipment.

13. AIR STARTING CHECK VALVES

The air starting check valves, one per head, are guided in bushings, which are pressed into the heads.

These valves should also seat tightly and occasional regrinding may be necessary to prevent compression loss.

14. REMOVING AND INSTALLING AIR STARTING CHECK VALVE

(a) Remove cover from check valve assembly.

(b) Remove elastic stop nut from valve stem. This can be facilitated by making a special tool to grip the head of the valve. Such a tool can be made by boring a hole having a 30° taper (total angle) in the end of a piece of bar stock. (Some of the earlier valves are made with a screw driver slot in the head).

(c) Unscrew spring retainer and lift out spring.

(d) Turn head over and remove valve.

(e) Place a weak spring between valve head and body, apply grinding compound to valve seat and revolve back and forth as outlined above for inlet and exhaust valves.

To reassemble air starting check valve assembly, reverse above operations. The correct valve lift is achieved by threading the spring retainer and the elastic stop nut down until the top of the stop nut is even with the bottom of the chamfer on the valve stem threads. Back-off the retainer firmly against the nut to insure a secure interlocking fit.

15. AIR STARTING VALVES (Not applicable with air motor or electric starting)

The air starting (distributing) valves, one per head, are operated by push rods lifted by cams on the engine camshafts.

(a) Time the air starting valve to open as specified in Section A.

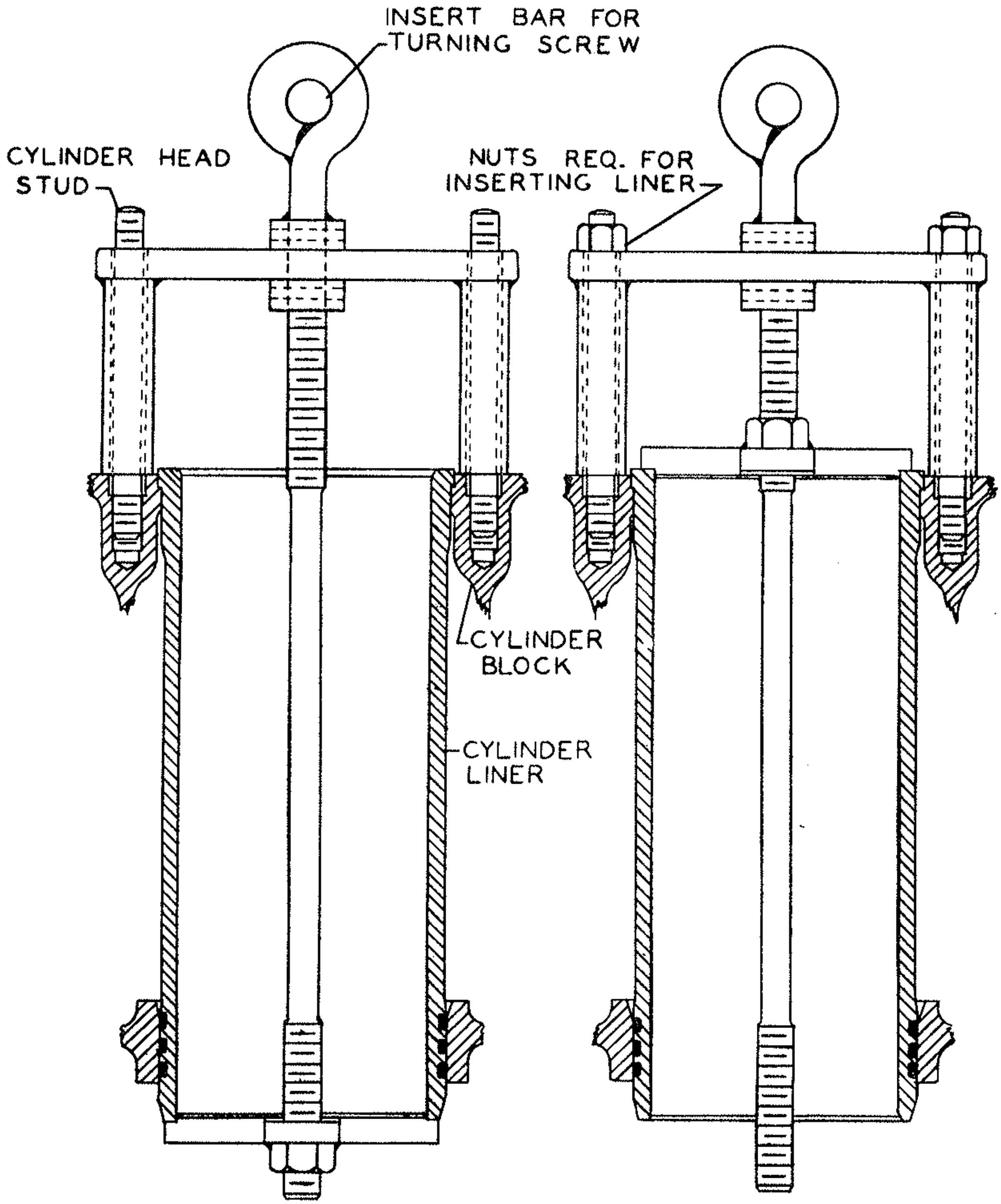
(Be sure that the camshaft is properly timed). Failure to time air starting valve correctly may result in serious damage if the valve should hit the stop plug on bottom of valve cap.

This valve is easily accessible for inspection or grinding by unscrewing the cap. To regrind, proceed as outlined above for inlet and exhaust valves.

16. GAS ADMISSION VALVES

The gas admission valves, one per head, are used to admit fuel gas to the cylinders during a portion of the intake stroke. They are operated by cams on the camshaft, through push rods and rocker arms. The lower end of each admission valve guide bushing is equipped with two seals to minimize gas leakage along the stems. Any leakage which does occur is carried away by a vent line.

The gas admission valves are removed and serviced in the same manner as inlet and exhaust valves. Whenever the valves are removed, the seals should be examined for wear or damage and replaced with new ones if necessary. The seals must be installed with the sealing lip toward the head of the valve.



REMOVING LINER

INSERTING LINER

FIG. H-1 ED.2
CYLINDER LINER TOOL

PISTON AND CONNECTING ROD

1. PISTONS

The pistons are cast of a special alloy iron, and are machined and ground to close limits. They are designed to provide ample strength and wearing qualities, and to allow uniform expansion and rapid heat transfer.

The space immediately below the piston crown is sealed from the engine crankcase by a special aluminum pipe plug to provide a suitable chamber through which the piston cooling oil circulates. Drilled passages are provided to conduct cooling oil from the piston pin to the chamber and return the overflow back to the crankcase.

The piston is equipped with four piston rings, all being located above the piston pin. The top ring is a chrome plated compression type. The next two rings are taper faced compression rings, and the last one is of the ventilated oil scraper type. Drain holes are drilled around the oil ring groove to conduct the excess oil back into the engine base. These holes should be cleaned out when the piston is removed for inspection or replacement of rings.

Piston pins are held in place by internal expanding type lock rings.

2. PISTON PINS

The hollow piston pins are of hardened special steel, ground to very close tolerance. They are of the full floating type with ample bearing areas.

Stamped steel plugs are pressed into each end of the piston pin and are rolled into grooves at the ends of the pin bore to provide an oil-tight seal. Two radial holes are drilled through the wall of the pin, at its center, to receive piston cooling oil from the rifle drilled connecting rod. Sets of six holes each are drilled, at the ends of the pin just inside the steel plugs, to conduct cooling oil from the center of the pin to the drilled passage in the piston.

3. CONNECTING RODS

The connecting rods, of the automotive type, are made of H section forgings of high quality steel, carefully heat treated and machined. The rod cap is of the conventional box type.

The crankpin end of the rod is split to retain the precision type "Trimetal" bearing shells by means of four alloy steel bolts and castellated nuts locked with cotter pins. The cap and rod are precision machined as an assembly, and the complete assembly must be ordered for replacement. Upper and lower bearing shells are not interchangeable and it is important that each be installed in its proper location. Note that the lower shell has an oil groove cut completely around its circumference. Note also that both upper and lower crankpin bearing shells are positioned in the connecting rod by means of a tang on each bearing shell.

When replacing connecting rod shells, BE SURE that the upper and lower bearing shells are installed correctly with regard to the oil groove in the lower shell, as noted above, and also that the shells are located properly with their respective tangs.

The crankpin bearing is lubricated by oil that is received from one of the adjacent main bearings through an oil hole in the crankshaft. An oil groove in the bearing shell bore, picks up the oil from the crankpin and delivers it to the piston pin bearing and cooling chamber, through an oil hole which communicates with a rifle drilled hole in the connecting rod.

The upper end of the connecting rod carries a pressed-in bronze bushing. This bushing is grooved on both inside and outside surfaces at its center, with four communicating holes between the grooves to carry oil for piston pin lubrication and piston cooling. The bushing is precision bored after assembly in the rod to insure proper size and location. If this bushing is replaced in the field, extreme care should be used in maintaining the bore of the new bushing parallel to and properly spaced from the crankpin bore.

4. REMOVING PISTON AND CONNECTING ROD

(a) Remove lower inspection covers from both sides of block.

(b) To provide wrench clearance, bar the engine over until the crankpin is in a convenient position. Then working through the near side inspection opening, loosen but do not remove nuts at that side of the rod. Bar engine over until crank throw is at the opposite side of engine and repeat above procedure. A special wrench is provided for the connecting rod nuts.

(c) Scrape off any carbon that may have been formed around the upper portion of the cylinder liner. Also examine the liner for a wear shoulder at the high point of piston ring travel. If such a shoulder is found, it should be tapered off by scraping or honing in order to allow removal of the piston and rings. Blow out or wipe off any carbon or other foreign matter that is left by the above operations.

(d) Bar the engine over until the crankpin is in top dead center. Remove nuts, bolts and connecting rod cap and lower crankpin bearing shell. Exercise caution so that these parts do not fall into the bottom of the bedplate.

NOTE: The lower half crankpin bearing shell may remain in the cap, when the cap is removed from the rod, or it may stick on the crankpin. In either case it should be carefully removed and wiped clean and marked with a grease pencil for later identification. Likewise the upper half bearing shell may stick on the crankpin or it may remain in the rod when rod and piston are removed in subsequent operations. It too should be carefully removed and cleaned and marked.

(e) Attach the special lifting device to the piston using the tapped holes in the crown. The eye of the lifter should be toward the center of the engine. Using an overhead hoist, lift the piston and rod out of the cylinder. Guide the connecting rod into the liner to avoid damaging the cylinder wall.

(f) Move the hoist away from the engine and set the piston and connecting rod down on a wooden rack.

5. DISASSEMBLING PISTON AND CONNECTING ROD

(a) Stand assembly on piston crown, and place wooden wedges between the sides of the rod and the piston skirt to hold the rod upright and to prevent the assembly from tipping over.

(b) A lock ring removing tool will be of considerable assistance in removing piston pin lock rings.

(c) After the lock rings are removed, slip a rope sling over the foot of the rod and holding it in place with the hoist, push out the piston pin.

(d) If it is desired to remove the piston rings, this can be done with an expanding tool (see Fig. K-2). Do not expand rings more than is necessary to clear the piston.

(e) The piston cooling chamber pipe plug may be removed, for inspection and cleaning of the chamber, by means of a piece of 1-5/8" hexagonal bar stock and a wrench. It is suggested that this be done every other major overhaul. When re-assembling the aluminum pipe plug be sure that it is tightened up carefully. Stake the threads with a punch.

6. PISTON AND CONNECTING ROD MAINTENANCE

Stuck or worn rings are perhaps the chief item of piston maintenance. Stuck rings may generally be freed, without resorting to scraping, by soaking the piston in a 30% solution of No. 9 "Oakite" in kerosene for 24 hours or longer. The rings may then be removed with an expanding tool. (See Fig. K-2). The piston ring groove and ring lands and oil drain holes should be cleaned, and the grooves should be inspected for wear.

At annual overhauls, the piston pin should be cleaned and given a thorough surface inspection. Magnaflux inspection is warranted if the engine has been operated in heavy service for a considerable period of time. When magnafluxing, plug all oil holes in the piston pin (corks can be used) so as to prevent magnaflux powder from entering the inside passages of the pin.

Connecting rods should be carefully cleaned and given a thorough surface inspection. Magnaflux inspection may be warranted if the engine has been operated in heavy service for a considerable period of time. Particular attention should be given to cleaning of the rifle drilled hole through the rod. Connecting rod bolts should also be carefully inspected, with magnaflux inspection being warranted as noted above.

Clean and carefully inspect the crankpin bearing shells for bearing surface wear or other deterioration. Bearings with a few slight pit marks may be reused; but if such failure has progressed to any appreciable extent or if the babbitt appears worn through to the bronze backing over an area exceeding 25% of the bearing surface, the shells should be replaced with new ones.

7. REASSEMBLY OF PISTON AND CONNECTING ROD

(a) Clean all parts and inspect for damage or wear, replacing badly worn or damaged parts with new ones. Oil all parts before assembly.

(b) Fit new piston rings inside cylinder liner and check ring gap. (NOTE: Rings must be placed squarely in the cylinder for gap checking: - They should be checked near the bottom of the cylinder for minimum gap; and near the top of the cylinder at its point of greatest wear, for maximum gap). Worn rings should be used only in case of emergency when new rings are not available; and then only in cases where they were carefully removed from the piston and thoroughly inspected for cracks or other damage. Such rings should be placed back in the same groove from which they were originally removed. Rings which were stuck in their grooves to the point where they were not easily removable after solvent soaking, should NEVER be reused.

(c) Install rings in their proper position on piston with the expanding tool furnished with the engine. (See Fig. K-2).

(d) Place piston upright on its crown and insert connecting rod in the same position it was in when removed. (Note match-marks on piston crown and rod).

(e) Line up pin bores in the piston and rod and install piston pin. Use wooden wedges to hold the rod upright as explained above.

(f) Replace piston pin lock rings in piston.

8. <u>REPLACING PISTON AND CONNECTING ROD IN CYLINDER</u>

Piston and connecting rods, if reused, should be placed back in the same cylinder and in the same position as before their removal.

Pistons should be placed with the valve clearance reliefs in the crown toward the center of the engine in order to properly align their clearance reliefs with the valves. The taper bored ring guide, furnished with the engine, should always be used when replacing pistons in the cylinders; in order to properly compress the piston rings and guide them into the cylinder bore.

To replace piston and connecting rod assembly into cylinder, proceed as follows:

(a) Attach lifting device to piston. Lift the assembly with an overhead crane and blow off dirt with an air hose. Also wipe engine crankpin clean.

(b) Fit the crankpin end upper bearing shell into its seat in the connecting rod. NOTE: These bearing shells are manufactured with a slightly greater span, across their open ends, than the bore of the connecting rod; and they should have sufficient spring action to maintain their proper position during further assembly if reasonable care is exercised. Upper and lower shells are not interchangeable.

NOTE: In replacing old shells, or installing new ones, care should be taken that both bearing shells and bearing saddles are thoroughly cleaned before assembly. Since the shells are of precision type, no filing, scraping or other fitting work should be done on either shells or saddles under any circumstances.

(c) Bar the engine crankshaft over to bring the crankpin to top center position. Place the piston ring guide on the top of the cylinder liner. Lubricate piston, liner, crankpin, and crankpin bearing with engine oil.

(d) Carefully lower the assembly into the cylinder. Guide the connecting rod lower end to prevent its striking and damaging the cylinder wall. Pay attention to each piston ring as it enters the guide and make certain that ring gaps are staggered.

(e) Insert lower crankpin bearing shell in connecting rod cap and assemble cap to connecting rod with match-marks in their proper relation.

(f) Install connecting rod bolts, lubricate nuts, and screw them down as tightly as possible by hand.

(g) Remove lifter from piston.

(h) Bar the engine over to obtain wrench clearance in the same manner as when removing rod bolts. Then with a torque wrench, (taking at least three uniform tightening steps on all bolts), the nuts should be tightened to the torque value given in Section A.

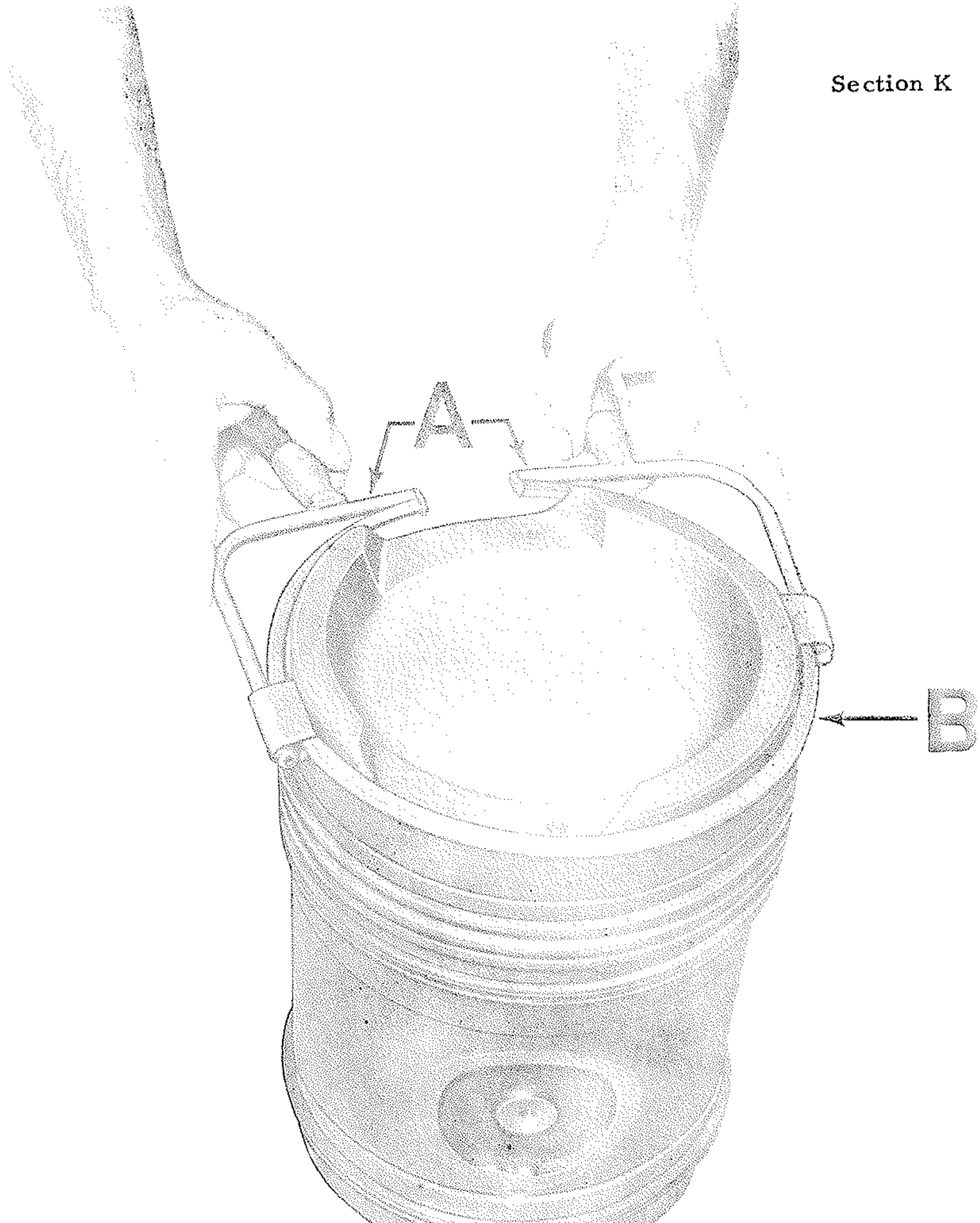


Fig. K-2
PISTON RING EXPANDING TOOL

A - Expanding Tool
B - Piston Ring

CAMSHAFT AND VALVE OPERATING GEAR

1. GENERAL

The camshafts are located in the cylinder block, one on each side of the engine. They are mounted in pressure lubricated split precision type bearings, fitted in line-bored supports which are an integral part of the cylinder block assembly structure. A camshaft bearing is located on each side of every cylinder, providing 7 bearings on each shaft for a 12 cylinder engine and 9 bearings for a 16 cylinder engine.

Each camshaft is driven from the flywheel end of the crankshaft by a two strand roller chain. The camshaft sprockets are clamped to the sprocket hubs by clamping rings and capscrews secured by lockwire. This design allows relative rotation for timing adjustments by loosening the clamping screws. A gear bolted to the hub of the camshaft on the control side of the engine drives a gear train for the engine governor, magneto drive, tachometer, and overspeed shutdown device.

The camshafts are made of ground and polished steel shafting. Four cams, inlet and exhaust, gas admission, and air starting, are provided at each cylinder. Each cam is located in proper angular relation by a Woodruff key. The cams are made of heat treated alloy steel for long life, and are precision ground. (Air starting cams are omitted when air or electric cranking motors are used).

2. CAMSHAFT TIMING

Camshaft timing specifications are noted in Section A. The camshafts are adjusted at the factory and the camshaft sprockets are then tightly clamped to the hubs. If the instructions given in subsequent paragraphs are carefully followed when removing and reinstalling the camshafts, there should be no necessity for changing this adjustment.

Adjustment of camshaft timing should be done with the aid of a dial indicator gauge used to determine correct cam lift for checking valve events. The indicator should be arranged to bear on top of the rocker arm adjusting screw for the particular valve to be checked. Make sure the adjusting screw bears firmly against its push rod before setting dial indicator to "zero". This will insure accurate cam lift measurements. The camshaft sprocket should be so clamped to its hub that valve opening and closing occurs at the proper crankshaft position. (See Section A).

IMPORTANT: It is essential that the two camshafts be phased together to produce the firing sequence given in Section A. Since the crankshaft turns two revolutions while the camshaft turns one, it is possible to have one bank of cylinders a full crankshaft revolution off from its proper timing, even though both camshafts appear to be properly timed to their respective cylinder banks. Failure to obtain proper firing sequence can result in severe stresses in the crankshaft and driven equipment.

3. CAMSHAFT IDLERS

Each camshaft drive chain is provided with two idlers. One is a fixed assembly while the other is adjustable to provide proper chain tension. The adjustable idler sprockets rotate on roller bearings, while the fixed idlers are fitted with pressed-in precision bushings, pressure lubricated from the engine system.

4. ADJUSTING CHAIN TENSION

It is essential to maintain proper tension in the chains. If too tight they will be overloaded and may break; if too loose, they may whip and vibrate, causing excessive wear. The idlers, and consequently chain tensions, are adjusted by means of adjusting screws. The adjustments should be checked periodically to prevent excessive slack in the chains.

To adjust chain tension:

(a) Remove camshaft sprocket cover.

(b) Bar the engine over to produce slack in the chain span opposite the adjustable idler. The chain has proper tension when movement on the slack side of the chain approximates 1/4"

(c) Loosen clamp nut on idler shaft (using the special wrench provided for this purpose) and lock nut on idler adjusting screw.

To tighten chain tension turn adjusting screw clockwise.

To loosen chain tension turn screw counter-clockwise.

(d) After adjustments are completed always tighten nuts to maintain proper tension.

The chain should be replaced promptly when worn out or when the rollers mesh near the ends of the teeth. Worn sprockets should be replaced when a new chain is installed because deformed teeth will promptly injure the new chain. If it is necessary to replace both chain and sprockets, and new sprockets are not immediately available, "hooks" should be dressed off and teeth otherwise corrected as much as possible.

The installation of a few new parts in a generally worn chain should be considered only a temporary expedient. The re-use of individual parts is not good practice - complete new links are better. A chain that has broken due to accident should be replaced because some sections have probably been stressed to a degree that has impaired the press fit of pins and bushings in the link plates.

5. TO REMOVE THE CHAIN

(a) Remove camshaft sprocket cover.

(b) Bar the engine crankshaft over to the firing top center of number one cylinder. Lay a straight edge across the exposed face of the camshaft sprocket and scribe a reference line on the face of the sprocket. This will allow reassembly without necessity of complete retiming operations.

(c) Bar engine over until chain connecting link is in a convenient spot.

(d) Release tension on chain idler as previously noted under number 4.

(e) Remove connecting link by withdrawing the lock and driving the link pins evenly through the link cover plates and withdrawing the link.

(f) Attach a piece of soft annealed wire to one end of the chain and holding to this wire, bar the engine over until chain is disengaged from sprockets, and then lift out of the engine.

To reassemble, reverse above operations, making certain that chain tension is properly adjusted. Also make certain that the reference mark, made on the camshaft sprocket before removal of chain, is in proper position when number one cylinder is at correct top dead center, before reconnecting roller chain.

IMPORTANT: REFER TO NOTES UNDER CAMSHAFT TIMING.

6. CAMSHAFT BEARINGS

The camshafts are equipped with split precision type bearings. If the camshafts are removed, the bearing shells should be marked or tagged for identification and reinstalled in their original locations.

7. REMOVAL OF CAMSHAFT

To remove the camshaft from the engine, proceed as follows:

(a) Remove camshaft sprocket cover and cam compartment covers. Also remove valve rocker shaft assemblies and valve push rods, to release their downward forces on the cam followers.

(b) Disconnect drive chain (see 5 above).

(c) Remove drive assembles for magnetos, overspeed shutdown device, and tachometer.

(d) Remove struts over camshaft bearing caps.

(e) Make arrangements to support all cam follower rollers (to prevent the roller assemblies from dropping when the camshaft is removed).

(f) Arrange a sling or provide some other means of preventing the shaft from falling. Remove the capscrews which fasten the cam bearing caps to the cylinder block.

(g) Remove bearing caps and lift out the camshaft.

To replace the camshaft in the engine, reverse the above operations, with additional precautions as follows:

(a) Make certain that all bearings and their respective mounting saddles are thoroughly cleaned all over before assembly. Lubricate camshaft and bearing surfaces with engine oil when assembling.

(b) Make certain that the reference mark, made on the camshaft sprocket before removal of chain, is in proper position when number one cylinder is at correct top dead center, before reconnecting roller chain.

IMPORTANT: REFER TO NOTES UNDER CAMSHAFT TIMING.

(c) Tighten cam bearing capscrews evenly to torque value given in Section A.

(d) Make sure that the seals attached to the struts are in good condition and properly in place. The seals should be cemented to the struts.

(e) Retime magnetos (See Section M).

8. CAMSHAFT INSPECTION

Thoroughly clean and inspect the camshaft assembly. Examine the drive sprocket for wear, or pits on the tooth surface, and for cracks or broken teeth. Examine the cam tracks for wear or cracks or other damage.

9. CAM FOLLOWERS

The cam followers consist of guides equipped with hardened steel rollers running on hardened steel pins. An individual cast alloy iron cam follower bracket for each cylinder of the engine, with accurately machined bores for the cam followers, is bolted to the cylinder block, immediately over the camshaft.

10. CAM FOLLOWER REMOVAL

To remove the cam follower bracket assembly from the engine, proceed as follows:

(a) Remove cylinder head cover, valve rocker shaft assembly and push rods.

(b) Remove capscrews holding bracket to cylinder block.

(c) Remove the cam follower bracket assembly. (Note: In lifting out the assembly, it will be necessary to support the cam followers and to lift them from below in order to prevent their dropping out of the guide block). Cam followers should be marked in order that their original position may be identified at reassembly.

To replace the cam follower bracket on the engine, reverse the above procedure. Make sure that the mounting gasket is in good condition, or use a new one. Tighten mounting capscrews evenly with a torque wrench to the value given in Section A.

11. CAM FOLLOWER SERVICING

(a) Remove cam follower and roller assemblies from guide block. Carefully clean and inspect all parts before reassembly.

(b) Service each cam follower in the following manner: - Remove the rivet which locates the roller pin in the follower body. Remove roller pin and roller. Inspect all parts for wear or cracks or other damage. When reassembling the roller and roller pin in the follower, make certain that the small flat on the roller pin is assembled at the upper side; and use a new rivet and make certain that it is tight in the follower.

12. VALVE PUSH RODS AND ROCKER ARMS

Valve push rods are fabricated of seamless steel tubing with hardened steel ball type inserts at their lower ends and socket type inserts at their upper ends.

The die forged valve rocker arms are carried on the rocker shafts supported by a bracket attached to the cylinder head. Bronze bushings are pressed into the rocker arms to minimize bearing friction on the rocker shafts. The push rod ends of the rocker arms are fitted with ball type adjusting screws and lock nuts. These should be checked and reset periodically to provide valve clearances as specified in Section A. The valve contact ends of the rocker arms are hardened to reduce wear and are form ground for proper valve action. The rocker shaft and rocker arms are drilled for proper lubrication of all bearing surfaces.

13. VALVE ROCKER ARM ASSEMBLY REMOVAL AND SERVICING

To remove and service the valve rocker arm assembly, proceed as follows:

(a) Remove cylinder head cover lid and cylinder head cover.

(b) Remove capscrews, and lift off rocker shaft assembly.

(c) Remove capscrews in retaining collars and remove collars and inlet and exhaust rocker arms from rocker shaft. Remove shims and tag them for replacement in proper locations. To remove gas valve rocker, remove nut and roll pin and push out gas valve rocker shaft.

(d) Remove lock nuts and remove valve adjusting screws from rocker arms. Clean adjusting screws thoroughly, including oil holes. Inspect for wear or cracks or other damage which might make them unsuitable for further service.

(e) Clean rocker arms thoroughly, including oil holes, and inspect for cracks or other damage. Inspect valve end for wear. Inspect bushing for wear and replace if necessary: - When pressing a new bushing in place, make certain that its oil holes are properly aligned with the holes in the rocker arm.

(f) Inspect rocker arm shafts for wear. Thoroughly clean out the oil holes in the shafts.

Reassembly procedure for the rocker arm assemblies is similar to disassembly, but in reverse order. However, the following additional precautions must be observed.

(a) Reinstall shims in original locations. Check side clearance of inlet and exhaust rockers. This should be .005" - .007". If necessary, adjust the clearance by means of the laminated shims. Tighten capscrews which hold retaining collars and install lockwires.

(b) Screw adjusting screws all the way into the rocker arms before installing the assembly on the cylinder head in order to avoid any possibility of holding a valve open and bending its stem.

(c) Tighten bracket capscrews with a torque wrench to the value given in Section A.

(d) Bar the engine crankshaft over to firing top dead center (all valves closed) for each cylinder in sequence and set each valve clearance adjusting screw to provide the clearance specified in Section A between the valve stem end and the rocker arm nose. Lock the adjusting screw with the locknut after setting valve clearance.

S-1800 IGNITION SYSTEM
(12 and 16 Cylinder Engines)

GENERAL

The S-1800 breakerless ignition system, consists of two Generator-distributors, two Ignition Cable Assemblies, and one transformer coil per spark plug. The assembly is a low tension system generating and distributing low tension current through low tension cables to the individual transformer coils. The transformer coils step up the voltage to a high tension voltage which is conducted to the spark plugs through short lengths of high tension cable.

The magnetos are mounted at the flywheel end of the engine, one on each side, and are gear driven from the two camshafts. The drive adapters are aligned with the camshafts (to give proper gear backlash) at the factory and the adapters are then dowelled to the housing. If the drives are removed, it is important that they be reinstalled in their original locations, and with the dowels in place.

CHECKING IGNITION TIMING

The spark timing should be checked and reset, if necessary, whenever camshaft timing is checked or changed, or whenever the camshaft drive chain is serviced or replaced. Changing camshaft timing will change the magneto timing. The procedure for checking ignition timing is as follows:

CAUTION: ALWAYS BE SURE THE MAGNETO IS PROPERLY GROUNDED BEFORE BARRING THE ENGINE OVER.

1. Bar the engine in the direction of normal rotation until number one piston of the bank being checked is moving upward on the compression stroke (both valves closed). Remove plug from timing window in top of magneto and continue to rotate the engine until timing pointer on large distributor gear is centered in timing window. This indicates the unit is in position to energize the number one segment (terminal A, cylinder No. 1) of the distribution block. The flywheel pointer should indicate the prescribed timing. Rotate the adjustable drive coupling as required.

2. The final timing should always be determined with timing light and with the engine at full rated speed. Differing combustion and detonation characteristics of well head gas at various locations makes it highly advisable to adjust the ignition timing accordingly. For recommended ignition timing, see Section A.

INSTALLATION OF IGNITION SYSTEM

(a) Magneto

1. Rotate engine in direction of rotation until cylinder No. 1 is in firing position on the compression stroke (See Section A).

2. Check magneto for proper rotation, remove plug from timing window in top of magneto and turn drive shaft in direction of rotation

until timing pointer on large distributor gear is centered in timing window.

3. Remove all backlash from engine drive train by turning the engine drive shaft for the magneto opposite the direction of rotation.

4. If intermediate drive disc is used, install same on engine adjustable drive member. If necessary, unlock adjusting screw of adjustable drive member on engine shaft and by turning screw, adjust drive member until slots in the intermediate disc align with drive lugs on magneto drive member while keeping timing pointer on large distributor gear centered in timing window.

5. Install magneto leaving a 1/64 inch total end clearance between the engine drive member, intermediate disc and drive member on magneto. Bar the engine over slowly to make a complete revolution of the magneto drive shaft and see that the intermediate drive disc in the coupling is free in all positions and has sufficient end play.

6. Recheck timing as given in Checking Ignition Timing.

(b) Wiring (see S-1800 Ignition Bulletin in Auxiliary Equipment Section).

1. Connect the cable plug to the receptacle in the magneto.

2. Install juction box and connect to magneto as per Letter Code.

3. Connect junction box to transformers as indicated below:

12-Cylinder Engine

Each Bank Firing Order CCW Rot.	Each Bank Firing Order CW Rot.	Magneto Terminal	Ignition Transformer Connect Number coded wire to Negative Terminal
1	1	A	1
4	5	B	2
2	3	C	3
6	6	D	4
3	2	E	5
5	4	F	6

NOTE: Gray colored wire is common transformer positive connection to terminal "N".

16-Cylinder Engine

Each Bank Firing Order CCW Rot.	CW Rot.	Magneto Terminal	Ignition Transformer Connect Number coded wire to Negative Terminal
1	1	A	1
3	4	B	2
2	7	C	3
5	6	D	4
8	8	E	5
6	5	F	6
7	2	G	7
4	3	H	8

NOTE: Gray colored wire is common transformer positive connection to terminal "N".

(c) Transformer

1. Mount each transformer as close as possible to each spark plug.

2. Connect the high-tension terminal of the transformer to the spark plug.

MAINTENANCE

It is not necessary to open the magneto for periodic inspection. Keep the system clean and dry. Inspect lead wires, connections and mounting security.

STARTING THE ENGINE WITH COMBINATION PRESSURE-TEMPERATURE SWITCH (When Supplied)

In order to start the engine, it is necessary to make the lube oil pressure switch temporarily ineffective until sufficient lube oil pressure has built-up. To do this, turn the small knob on the pressure-temperature switch box to the "ON" position. It will lock in the "ON" position until the lube oil pressure builds up, at which time it will release to the "RUN" position, insuring automatic shutdown control. If sufficient lube oil pressure fails to develop after the engine is started, the knob WILL NOT release to "RUN"; therefore, the automatic shutdown control will NOT function. The operator MUST MAKE SURE that the knob returns to the "RUN" position.

STOPPING THE ENGINE

The engine is normally stopped by shutting off the valve in the gas supply line.

SPARK PLUG MAINTENANCE

Spark plug should be cleaned and gaps reset (see Section A) once a week (or as often as operating conditions require). The gap should be set by bending only the outer electrode.

TROUBLE SHOOTING

In case of defective ignition, it must first be determined whether the fault is in the magneto or, as is more probable, elsewhere. In general, when only one cylinder misfires, the fault is in the spark plug. The most common spark plug difficulties are as follows:

Spark Plug Gap Too Wide:

While the precise spark plug gap is not critical, the gap between electrodes of a spark plug normally should be .020". Difficulty in starting, also missing at low speed, are very often due to the spark plug gap being too wide.

The voltage required for spark to jump the gap increases as the gap widens, with consequent increase in ignition system troubles and repairs. Inasmuch as the spark has a tendency to burn the electrodes and thereby gradually to increase the gap, it is recommended that the plugs be examined at least monthly under any conditions and oftener if necessary. Readjust the spark plug gap to .020" by bending the outer electrode only.

Spark Plug Short Circuited:

This is usually caused by a cracked or porous insulator, or by fouling of the electrodes or insulator. Any of these will cause misfiring by permitting the current to stray from its intended path across the gap. To correct this condition, clean or change the plug, whichever proves necessary.

Cables:

Misfiring in one cylinder, either continuous or intermittent, may be due to a chafed or broken cable, or a loose cable connection. The metal terminals of the cables must not contact any metal parts of the engine.

Irregular Firing:

If the cables and plugs are in good condition and yet the ignition is irregular, the trouble is possibly in the magneto or control unit. See the manufacturer's bulletin in the "Auxiliary Equipment" section of this manual.

NOTE:

It is to the operator's advantage to maintain a close check on the condition and operation of spark plugs, wiring harness and magneto. Failure of only one cylinder to properly carry its share of the load, due to one or more of the malfunctions noted above, will result in loss of output shaft horsepower, higher loading on the remaining cylinders, and the engine will not run as smoothly as when all cylinders are firing evenly. The unburned gases passing through a misfiring cylinder may cause backfiring in the exhaust system.

On engines equipped with an exhaust pyrometer, a misfiring cylinder can be readily noted by checking each cylinder's exhaust temperature.

Suspected misfiring of an engine not equipped with a pyrometer may be checked either by noting a change in the tone of the exhaust, a reduction in speed of the engine output shaft or by a change in the intake manifold gauge reading. In this connection, log sheets should be kept of the engine's day to day performance so that any deviation from normal operation will be more readily apparent.

Prompt action on the part of the operator toward correcting such malfunctions will result in extended service life of the engine.

GOVERNOR AND CONTROLS

1. GENERAL

Operation of the engine, including a description and functional analysis of the special controls, is covered in Section D, Operating Instructions.

2. GOVERNOR MOUNTING AND DRIVE

The governor drive is mounted in the top of the camshaft drive housing at the flywheel end of the engine. The governor drive shaft is driven, at its lower end, by an intermediate shaft and bevel gearing from the camshaft assembly on the control side of the engine. The governor is mounted on top of the drive assembly and is driven by a serrated adaptor at the upper end of the drive shaft, thus allowing removal of the governor without disturbing drive alignment.

For details and a breakdown of governor components, see the governor bulletin contained in the "Auxiliary Equipment" section of this manual.

3. OVERSPEED GOVERNOR

The overspeed governor is chain-driven from a small sprocket on one of the camshafts. In case of overspeed, the governor trips a valve in the control system and produces a shutdown.

The drive chain should be checked, and adjusted if necessary, whenever the camshaft drive chains are checked. Adjustment procedure is as follows:

(a) Loosen lock nut and back off locking screw (in drive housing) slightly.

(b) Remove the two capscrews which hold the locking cap.

(c) Turn the cap counterclockwise to tighten or clockwise to loosen chain tension.

(d) Replace and tighten capscrews in the locking cap and check chain tension. There should be approximately 1/4" of movement on the slack side of the chain.

(e) When proper chain tension has been obtained, carefully align the idler sprocket with the chain and tighten the locking screw and nut.

LUBRICATING OIL SYSTEM

1. GENERAL ENGINE LUBRICATION

The lubricating oil system consists of the oil sump (located in the engine bedplate), the lubricating oil pump, the filters and strainers, the oil cooler and the manifolds and piping required to convey the lubricating oil to all working parts of the engine.

Drilled passages in the bedplate carry oil from the manifold to the main bearings. Drilled passages in the crankshaft carry oil from the main bearings to the crankpin bearings; and rifle drilled connecting rod passages carry oil further for piston pin lubrication and piston cooling. Drilled passages and connecting lines in the cylinder block provide lubrication for camshaft bearings and valve gear and other working parts of the engine. Oil drippings from the valve rocker arms drains back to the sump through the push rod openings.

An oil filler opening and an oil level sight glass are provided on the operating side of the engine bedplate. The running oil level should be maintained near the level mark on the sight glass for best engine performance and life. The oil should be changed whenever inspection reveals the presence of dirt, sludge, dilution, or acidity in harmful quantities. (See Section B). The engine should be drained immediately after a period of operation, while the oil is still hot and will flow freely. Remove the hand hole covers and clean the crankcase with lint-free and ravel-free rags each time the oil is changed.

In order to avoid unnecessary contamination of new oil, it is a good idea to also drain the lubricating oil filters and cooler whenever changing oil in the engine. Allowance must then also be made for filling those items when refilling the engine.

It is extremely important that dirt and other foreign matter be kept out of the lubricating oil system. Whenever a lubricating oil line or accessory is dismantled, the openings left by the dismantling should be covered with clean rags or blank gaskets.

2. LUBRICATING OIL STRAINER

The lubricating oil suction strainer, mounted at the front end of the engine base, is of the screen wire basket type. The strainer basket should be inspected and cleaned during oil changes. The basket may be removed through the cover plate opening at the end of the strainer assembly. It is necessary to drain the sump in order to remove the basket.

3. LUBRICATING OIL PUMP AND DRIVE

The lubricating oil pump is mounted on the engine front end housing and is driven directly from the engine crankshaft by sprockets and a roller chain. The lubricating oil pump is of the gear type, with sufficient capacity to insure ample oil flow and pressure for all engine operating conditions. The steel pump gears are mounted on hardened steel shafts which run in bronze bushings.

The pump sprocket is carried on ball bearings in the drive housing. The splined end of the driving shaft in the pump engages a mating spline in the sprocket hub. The pump can be removed without disturbing the drive. The lubricating oil pump is driven by the same chain which drives one of the cooling water pumps. (See Section W for chain adjusting procedure).

4. LUBRICATING OIL FILTERS (When Supplied)

The full flow lubricating oil filters are of the replaceable cartridge type and are mounted on the engine. The filter elements should be changed when oil conditions warrant and it is suggested that a change period of 400 hours be adopted at first. Experience will indicate if longer element life is possible, and in this connection it should be noted that it is more economical to maintain the filters in good condition. Do not expect the filters to clarify the oil. If a detergent type of oil is used it can be dark, even black, and still be entirely satisfactory.

A bypass relief valve is installed between the filter inlet manifold and the main lube oil header. This valve is set to open at 30 pounds per square inch to permit oil flow to the engine when starting with cold oil. A filter is provided in this circuit to insure that filtered oil enters the engine. The pressure regulating valve is mounted in the oil line ahead of the filters. The oil gauge on the instrument panel is connected to the oil line after the filters.

The necessity of changing filter elements is best indicated by the pressure drop through the filters. When filter cartridges are new we have a pressure drop of about 5 pounds per square inch through the filters. The elements should be changed when a drop of 10 to 12 pounds per square inch has been reached with warm oil. This pressure drop is indicated on the differential pressure indicator, when supplied. The indicator is pre-set and is not adjustable. A stem extends from the unit as the differential pressure increases and a red indicator is visible when the pre-set pressure has been reached.

NOTE: FOR INSTRUCTIONS FOR REPLACING ELEMENTS (See vendor's bulletin in "Auxiliary Equipment" Section).

5. LUBRICATING OIL COOLER

Operation:

The oil to be cooled is passed through the shell of the oil cooler unit and around the outsides of the tubes. Cooling water flows through the inside of the tubes.

Cleaning - Chemically:

Either the inside or the outside of the tubes can be cleaned by the use of a proper solvent. For cleaning the outside of the tubes, fill the shell of the cooler with a mixture of one part Oakite No. 9 and four to six parts of kerosene. Allow to soak and then flush thoroughly with water. Blow out the water with compressed air.

To remove hard scale from the water side it is advisable to use a weak solution of hydrochloric acid. A 20 to 50 percent solution (in water) of Dearborn Chemical Formula 134, or Oakite No. 32, or the equivalent, may be used. Connect the cooler to a circulating pump and tank to circulate the solution through the tubes. After cleaning, drain the solution, flush with water, and neutralize any remaining acid by flushing with a 1 to 2 percent solution of either caustic soda or soda ash.

CAUTION: These solvents are dangerous acids and should be kept off the skin and clothing. Wear rubber gloves when handling them and avoid breathing the fumes. In case any of the chemical is accidentally spilled on the body, wash immediately with water.

Acid solution used for cleaning the jackets of engines can be used also for cleaning the coolers, by circulating through the engine jackets, and through the coolers, in series.

Cleaning - Mechanically:

To clean the inside of the tubes only, drain the cooling water from the tubes. Remove both bonnets.

The inside of the tubes can be cleaned with a wire brush or cleaning rod.

6. LUBRICATING OIL PRESSURE REGULATOR

The oil pressure regulator is mounted in the oil pump discharge line, with its return line being connected back to the engine oil sump. The setting of this valve is such that a normal oil pressure as specified in Section A will be maintained in the engine oil header when the engine is operated at normal engine speeds, and with normal oil temperature and with clean filter elements, and with no stoppage in oil cooler or oil lines.

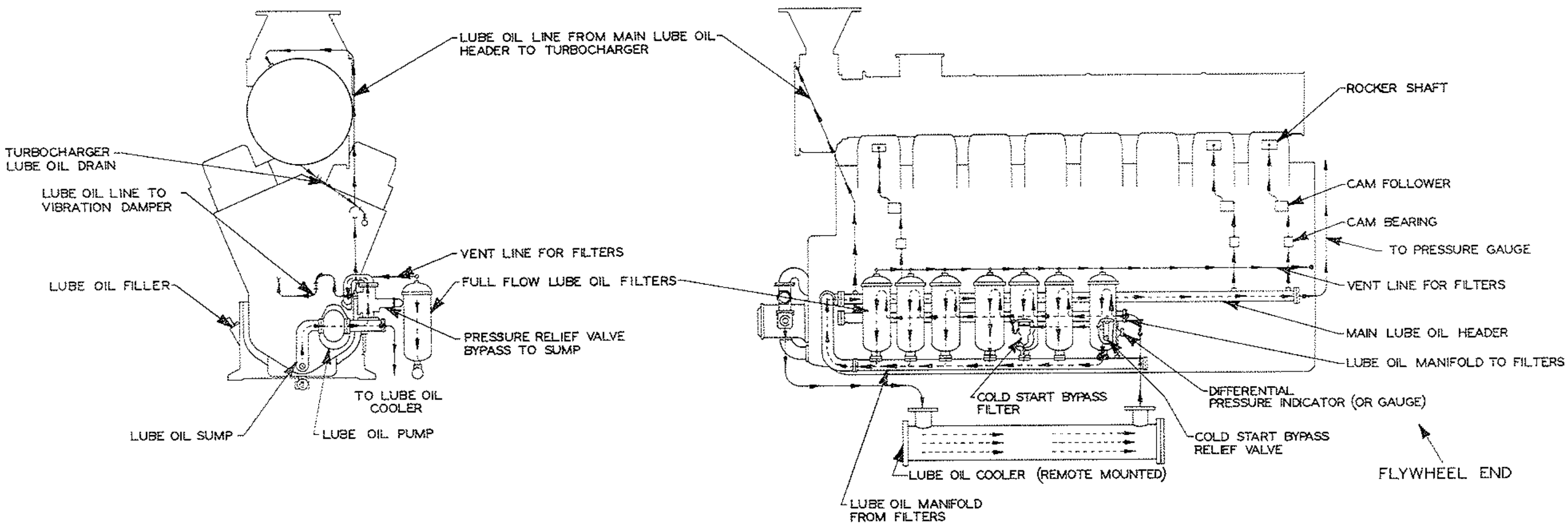


FIG. T-1

LUBRICATING OIL SUPPLY SYSTEM

I. PRINCIPLES OF OPERATION OF THE STARTING SYSTEM

(Refer to Section D for details and set-up of the system).

1. The start fuel signal is a step signal that should follow the cranking signal by a minimum of 10 to 15 seconds or whatever more is desired for a purge cycle by the customer. This delay provided by the control panel allows the engine and exhaust system to be purged of any unburned fuel. The control panel must keep the ignition grounded during the purge cycle and activate the ignition at the same time or a little before the start fuel signal. This signal closes the vent and opens the control valve in the starting bypass loop providing the engine with the correct amount of fuel for starting.

2. The run fuel signal is to come on after the engine is running at idle on the starting bypass. This can be determined in a number of ways by the maker of the control panel; one suggested way is by sensing engine jacket water pressure build-up.

3. The run fuel signal is a step signal that opens the main gas valve after engine is running on the starting bypass. It is important that the main gas valve is opened slowly in order to keep from flooding the engine. A metering needle valve is provided with this system that is to be used to control the rate of opening of the main gas valve.

4. Both signals are 33 to 37 psi and must remain on for running and vent quickly for shutdown.

5. A delayed ground on ignition during shutdown is to be supplied by the maker of the control panel so that unburned fuel is not allowed to pass through the engine and possibly accumulate in the exhaust piping and cause problems later.

6. The vent is intended to vent the fuel gas line between the start fuel valve and the main fuel valve and the engine when it is shut down, and it should be piped to some safe location outside the building.

II. PRINCIPLES OF OPERATION OF THE AIR/FUEL CONTROL SYSTEM

1. DESCRIPTION

The air/fuel control system is a simple pneumatic control which is designed to set and hold a predetermined, correct air manifold pressure for any speed and load condition on the engine. It will do this regardless of ambient air temperature or turbocharger efficiency change provided there is adequate blower pressure. Basically, the system senses load from the gas manifold pressure, determines the required air manifold and if necessary, moves the butterfly throttle position until the air manifold comes in line with the correct value.

The air/fuel control system can be broken down into three major areas:

A. The Air/Fuel Curves.

Each unit is supplied with a set of curves describing the correct air manifold/gas manifold pressure relationship. Correct use of the curves allows the engine to operate in an area of acceptable performance from the viewpoints of fuel consumption, exhaust temperaturnes, load acceptance and stability. Operation on other than the specified line effects penalties in at least one of these areas. The curves are made up for each particular installation in that such things as fuel gas composition and altitude are taken into account. (Refer to Section D for details and set-up of the system.)

B. The Butterfly and Actuator Assembly.

The major components of this assembly include the air cylinder, the butterfly valve, and the associated linkage. There is an assembly for each bank located on the turbocharger end of the air intake manifolds. The air cylinder is a pneumatic linear actuator with a four-inch stroke, using air to load and a spring to return. The spring is designed to provide a linear stroke over an operating signal pressure range of 5 psig to 38 psig. The linkage is designed to provide the proper relationship between the stroke of the air cylinder and the angle of the butterfly. Both air cylinders use the same air signal from the panel.

C. The Control Panel.

There are two major functions in the control panel. The one is chiefly a measuring and indicating function. It involves the gas manifold pressure gauge, air manifold pressure gauge, the 15-inch manometer, the gas manifold differential pushbutton valve, the air manifold differential pushbutton valve, the low air manifold pressure pushbutton valve and the air-gas offset pressure pushbutton valve. All are used in conjunction with the manometer. The gauges are continuous direct reading.

The other function is the control function. The control panel sets the proper engine air manifold pressure as a function of the gas manifold pressure. The system compares the two gas manifold pressures. It takes the higher of the two pressures and converts it through the use of a series of fixed and variable orifices and relays to a usable signal which serves as the input set point to a differential reset relay. This relay compares this set point with the lower of the two air manifold pressures and if an error is present modifies the transmitted control pressure signal which opens or closes the butterflies until the error is reduced to zero.

2. CONNECTIONS

These are seven tubing connections on the bottom of the panel. Referring to Figure 3, Section D, they are:

A. Supply pressure - The panel requires 60 to 125 psig clean dry air or sweet gas. There is a regulator inside which reduces this to 45 psig. Because some of the instruments are continuously venting, a gas powered panel must be shut off when the engine is down and activated only shortly before start-up. Because of the lack of venting provisions an air panel must not be supplied with gas.

B. Air manifold pressure, right bank.

C. Air manifold pressure, left bank.

D. Transmitted signal pressure to air cylinders.

E. Gas manifold pressure, left bank.

F. Vent line to turbocharger air intake. This line vents gas back to the engine.

G. Gas manifold pressure, right bank.

All connections on the panel, between the panel and the engine, and on the engine itself must be checked for leaks and maintained.

3. INITIAL SET-UP DESCRIPTION (Refer to Section D for a detailed step by step procedure).

A. Supply Pressure.

The supply pressure should be set to 45 psig utilizing the supply regulator and gauge provided in the control panel.

B. Minimum Air Manifold Pressure.

It is desirable to prevent the air manifold signal to the computing relay from dropping below a certain fixed value, in most cases zero. This feature is included in this control panel and it is set by turning the adjustment on top of the minimum air manifold pressure regulator. This determines the minimum value the computing relay will use as a set point.

C. Offset Pressure

This setting is used when installing the air/fuel curve into the computing relay. It is actually the difference between the modified gas signal and the air manifold signal. The computing relay works about this point to maintain it. The offset pressure is set by turning the screw at the top of the computing relay. The pressure can be checked on the manometer by depressing the air/gas offset pressure pushbutton valve. An offset pressure is indicated on the fuel/air curve and serves as the initial setting. The final value will probably be slightly different. Changing the offset pressure has the effect of shifting the air/fuel curve along the horizontal axis.

D. Ratio Control

The ratio control valve is located on the front of the panel. It is a needle valve whose flow capacity is varied with respect to a fixed orifice inside the panel which has the effect of changing the slope of the air/fuel curve. Clockwise rotation will increase the air manifold pressure set point for a given gas manifold pressure.

E. Reset Rate

This is the graduated knob on the side of the computing relay. It is used to match the response of the controller to the engine. Turning it clockwise will have the effect of slowing the reaction time of the computing relay. It should be set as far counterclockwise as possible without excessive hunting by the computing relay.

F. Manifold Balance

The control panel has provisions for checking the bank to bank balance of the air and gas manifolds. The gas manifold differential valve and the air manifold differential valve are located on the front of the panel and used with the manometer. The right bank of each is read on the right side of the manometer facing it.

The gas manifolds should be balanced within 1/2 inches mercury at all loads and speeds. This is important as it determines the load split on each bank. Chief causes of imbalance are manifold leaks and improperly set control linkages. Normally the linkage is factory set and should not have to be adjusted.

The air manifold balance should balance out to within 0.1 inches mercury at all loads and speeds. The position of one butterfly with respect to the other can be altered by adjustment of the actuator linkage. The adjustment is accomplished by breaking loose the lock nut on the clevis and rotating the cylinder rod while holding the clevis. When the desired position is achieved, lock the position with the locknut. The desirable method is to bring the higher pressure down.

Both the fuel gas and air linkages should be periodically checked and maintained to be free of all binding and also to eliminate all free motion that may occur.

G. Changing the Air/Fuel Curve in the Computing Relay

Once the air/fuel curve is installed into the computing relay, it will remain there unless the settings are disturbed. If it is desired to change this installed curve because of a long-term change in fuel temperature, it can be done with the ratio control valve alone. If there is a daily variation of fuel temperature, install the curve of the average temperature. A fuel temperature change of $\pm$ 15° F. can be tolerated with no adjustment.

COOLING WATER SYSTEM

1. GENERAL

Cooling water systems on stationary engines vary considerably due to characteristics of installation, plant requirements, or customer preference. Inasmuch as complete and specific water flow diagrams are furnished for each installation, detailed discussion of these various systems will not be attempted here; rather we will confine this section to a description of the water flow through the engine together with recommendation for servicing and maintaining the system, including accessories.

The engine jackets and entire circulating system should be filled with clear, soft water of non-corrosive characteristics.

The circulating pump delivers cooling water to two engine water manifolds, which run along the sides of the engine. From the manifolds the water enters the water jackets in the cylinder block, flows around the cylinder liners, and is directed into the cylinder heads through jumpers which are held to the head and block by capscrews. Soft composition gaskets are placed under the water manifold and jumpers to make the connections water tight.

Each cylinder head has an outlet into a water outlet manifold. There are two manifolds, one for each bank of cylinders. From the outlet manifolds the water flows to a thermostatic valve (which may bypass all or a portion of it back to the pump suction to maintain proper temperature) and then to a radiator or heat exchanger. Cooling water for the turbochargers is supplied through piping connected to the engine water manifolds, and its circulation is described in detail in the turbocharger instruction manual.

When a water cooled heat exchanger is used in the system an additional pump is required to circulate raw water through the heat exchanger.

The temperature of the discharge water from the manifold should be as specified in Section A, with a temperature rise through the engine in accordance with the load. The engine is supplied with a water temperature shutdown which becomes operative when the water temperature reaches a predetermined critical point. Thermometers are mounted in the engine intake and discharge lines and also in the water lines to and from the air intercoolers.

The engine should not be operated at full load unless the water temperature is at least 120°F. In case overheating should occur, the load should be removed and the engine run at "no load" until the temperature has gone down to normal. If overheating has been caused by insufficient water in the system, it is preferable to replenish the system with hot water. If hot water is not available, add cold water slowly and cautiously.

2. COOLING WATER PUMPS

One or two built-in centrifugal cooling water pumps, as required, are mounted on the front end of the engine and driven from the crankshaft. One pump circulates engine jacket water. The other circulates water through the intercoolers, which cool the air coming from the turbochargers. The lubricating oil cooler may be in either water circuit as required by the particular application. The water pump shaft is mounted in the support casting, or bracket, on ball bearings. A carbon ring type mechanical water seal assembly is provided on the pump shaft. When the seal becomes worn to the point of excessive leakage, it should be replaced with a new seal. A pipe tap in the support casting provides means for connecting a drain line to carry off any leakage which occurs.

A water slinger is provided as an extra precaution to prevent water from traveling along the shaft and damaging the bearing.

3. COOLING WATER PUMP DRIVE

The pump sprockets are carried on ball bearings in the drive housing. Splines on the pump shafts engage mating splines in the sprocket hubs. The pumps can be removed without disturbing the drives.

Two drive chains are used, one for each pump. One of these chains also drives the lubricating oil pump. Each is equipped with an adjustable idler for adjusting tension. The tension should be checked at regular intervals (see Section Z) and adjusted as required. Adjusting procedure is as follows:

(a) Remove the cover plate over the end of the crankshaft to gain access to the chains.

(b) Back off the lock nut on the adjusting screw and loosen the two capscrews in the retaining plate just enough to allow the adjusting ball nut to be turned.

(c) Turn the ball nut counter-clockwise to tighten or clockwise to loosen chain tension. There should be approximately 1/4" of movement on the slack side of the chain.

(d) Retighten retaining plate capscrews and adjusting screw lock nut.

NOTE: The remarks about chain drives which appear in Section L also apply here.

4. HEAT EXCHANGERS

Shell and tube design heat exchangers are usually furnished with Superior engines. These units are very similar to the Lubricating Oil Coolers described in Section T and the same installation, operation and maintenance instructions are applicable to both units.

COOLING WATER TREATMENT

1 - Use clean fresh water (not contaminated with organic matter).

2 - Add not less than 200 grains (about 1/2 oz.) sodium chromate (commercial grade) per gallon. If the bi-chromate is used, add also caustic soda (about 30 percent of the bi-chromate) sufficient to bring the pH up to 8.5 or more. (Commercial corrosion inhibitors of this type may also be available from Dearborn Chemical Company, National Aluminate Company (NALCO), or other reputable chemical companies).

3 - Maintain these concentrations by daily color and pH tests. A sample of the newly treated water which will have a strong canary yellow color should be kept in a closed bottle for reference. After the first few weeks when a protective film is forming, not much additional chromate should be required, in absence of organic matter or leakage.

4 - Where the water is scale-forming, add 1 oz. of a polyphosphate (Nalco or Calgon) per 500 gallons.

5 - It is important to note that even much higher concentration of the chromates in the water (several times as high as stated) do not cause any harm to the installation, whereas a neglected solution which has been permitted to get rather weak can, under certain conditions, even accelerate corrosion. Therefore, be sure to keep concentration preferably on the higher side.

6 - Each time the water is changed chromates should be added in the given proportions. If the total amount of the cooling water is known the dose of the chromates can be easily figured and deposited in a part of the cooling system, such as the surge tank for instance.

7 - Chromates are toxic and of course should not be taken internally. They should be washed off the skin to avoid "chrome itch".

8 - Added make-up water should preferably also be chemically treated by chromate addition as this prevents a gradual dilution which could be overlooked. (If a special storage tank for engine cooling water only is provided, the treatment could be added to the tank in accordance with its capacity as the chemical does not evaporate and apparently will not affect the tank adversely. This would minimize the work of the crew and prevent adding untreated water to the system).

9 - Since organic dirt and lube oil neutralize the action of the chemical it is imperative to try to keep the entire water system clean and to periodically check the solution and add chemicals when found necessary.

10 - The clearer and yellower the cooling water solution appears, the safer its protection will be. Before going to the chromate treatment it is suggested to clean and wash out the cooling system thoroughly.

ENGINE STORAGE DURING FREEZING WEATHER

When preparing an engine for storage where it may be subjected to freezing weather, the following precautions should be taken:

1 - Be sure all water drain plugs are removed from engine block, water pump, and any engine mounted heat exchanger or oil cooler.

2 - Raise the front end of the engine or skid and place a heavy timber under the raised end of the engine to promote draining of all water jacket cavities and oil cooler tubes.

Observance of these suggestions will greatly lessen chances of damage to the engine or oil cooler from expansion of entrapped water.

MAINTENANCE AND INSPECTION

1. GENERAL RULES

Observing the following General Rules will go a long way toward insuring satisfactory and trouble-free operation of the engine. During the first 300 to 500 hours of operation, the engine should be checked frequently; together with all accessory equipment such as auxiliary pumps, filters, coolers, drives, etc. Refer to other sections of this manual for detailed checking instructions.

When working on the engine, the importance of cleanliness cannot be over-emphasized. Rags should be used for all wiping operations instead of waste, because waste leaves lint which may work into the engine oil passages and cause their stoppage. All tools and work places should be kept free from grit, dust or dirt.

Machined surfaces of parts should never be allowed to come in contact with hard materials such as steel or concrete floors; but should be placed on wooden supports or wrapped in clean rags. When parts are removed from the engine, the resultant openings should be covered with blank gaskets or their equivalent to prevent entry of foreign matter.

In general, gaskets and packings may be reused as long as they remain in good condition. However, they should be renewed at the first indication of deterioration. Copper gaskets should be either annealed each time they are reused or replaced with new ones. Cotter pins, lockwires, and lockplates should never be reused, but should be replaced with new parts at every assembly.

2. KEEP YOUR ENGINE CLEAN

Constant diligence in maintaining the engine in clean condition will pay real dividends in time, effort, and repair costs. Inspect the engine and clean it at regular intervals.

3. LEAVE WELL ENOUGH ALONE

When the engine is running satisfactorily and smoothly, do not continually try to better the operation with minor adjustments.

4. INSPECTING REPAIRS

At completion of any adjustment or repair job, always make a thorough inspection to see that all parts have been correctly replaced, that bolts and nuts are tight, and that all cotter pins and locking wires and lockplates are in place. If work involves rotating parts, bar the engine over at least two full revolutions, with compression relief valves open (so that camshafts are turned one revolution) to be sure that all parts are clear. Be sure that no extra parts, tools or rags are left inside the engine.

5. INSPECTION AND MAINTENANCE ROUTINE

The following routine for regular inspection and maintenance work is suggested as a guide for the operator, but experience with the engine over a period of time may indicate changes that should be made in the schedule.

6. KEEP A COMPLETE LOG OF ENGINE OPERATION

A complete log, recording regular hourly entries of all pressures, temperatures, dirt accumulation on filters, and other pertinent data, should always be kept of the engine operation; and back sheets should be consulted frequently and compared with present conditions. In this way gradual changes may be detected and investigated; and minor troubles can be corrected before serious ones develop. Any unusual noises or other irregularities should be noted and investigated as soon as possible.

In the following, work to be done under each routine should include work listed under preceding routines. For example, work performed at "Overhaul" includes everything listed under all other routines.

7. DAILY ROUTINE

(a) Check oil level in sump and add oil if necessary. Also check the quality of the oil. Oil should be changed when inspection discloses the presence of dirt or sludge in harmful quantities, or dilution, or excess acidity. Note: If the engine oil is to be changed, it should be done immediately after a period of operation, while the oil is still hot and will flow freely. Clean out the engine oil sump whenever engine lubricating oil is changed.

(b) Check lubricating oil filter(s). It is a good idea to mount pressure gauges on both sides of the filter(s). When the pressure drop exceeds ten to twelve pounds per square inch, the filter elements should be changed.

(c) Check water level in surge tank (when used). When a water pump is used, inspect water pump shaft seal for leakage, and replace (or repack) if necessary. (See Section W). If frequent additions of water are required, check entire system for leaks.

(d) Check fuel gas system for leaks.

(e) Check the governor lubricating oil for level and quality with engine running. Replenish or replace as found necessary. (See Governor Bulletin in "Auxiliary Equipment" section).

(f) Check alarm system, when furnished.

8. <u>WEEKLY ROUTINE</u> (150-200 OPERATING HOURS)

(a) Check and clean air intake filter elements. This may be necessary at more frequent intervals under extreme dust conditions.

(b) Check control shaft bearings and control linkage to make certain that all parts operate freely.

(c) Check spark plugs and re-gap, if necessary. (Experience will indicate if this is a necessary weekly routine).

(d) Check the outboard bearing lubrication (when used). Refer to "Auxiliary Equipment" section.

9. <u>BI-MONTHLY ROUTINE</u> (400-1600 OPERATING HOURS)

(a) Check the governor and control linkage for loose or worn parts. Drain, flush, and refill the governor with new oil. See Manufacturer's Bulletin.

(b) Check and readjust the tension of the camshaft and overspeed governor drive chains, if required.

(c) Inspect the governor gear drive. Also inspect the drives for the magnetos, and the engine lube oil and water pumps. Readjust water pump and lubricating oil pump drive chain tension, if necessary.

(d) Remove the side cover plates and inspect camshafts for worn cams. Check for loose or worn rollers or pins in the followers.

(e) Remove crankcase breather screen element and wash thoroughly clean in solvent or fuel oil.

(f) Remove cylinder head cover lids and check intake, exhaust, and gas admission valve clearances.

(g) Check magnetos for proper spark timing. (See Section M).

10. OVERHAUL

Overhaul should not be considered as long as an engine continues to operate normally and satisfactorily. In fact, unnecessary servicing, if done hurriedly or under improper conditions, can frequently result in maladjustments and other operating difficulties that might not have appeared if the engine had not been disassembled.

Overhaul should only be considered when general engine performance, as indicated on operating logs (see Paragraph 7), has deteriorated, or when other abnormal operating conditions might indicate its desirability. Some of the items to be considered in this respect are the following: Excess lube oil consumption, abnormal exhaust temperature or smoke at normal loads, continued abnormal operating pressures or temperatures, knocks or other abnormal sounds that might indicate wear or looseness.

In view of varied operating conditions, it is impossible to predetermine the exact operating period between overhauls for any particular installation. For light duty or intermittent operation or low operating speeds, a period of several years may pass before overhaul becomes necessary; for continuous duty or higher operating speeds, more frequent overhauls will be required. Under extreme operating conditions, or in cases where poor quality fuels or lubricants or coolants have been used, overhaul operations may be required at intervals of even less than one year's duration.

(a) Remove the cylinder heads and clean them thoroughly. Check the valve stems, guides, and springs. Regrind the valve heads and seats. Clean out any scale or other deposits which may appear at the water inlets or outlets, and in the intake and exhaust ports.

(b) Remove the piston and connecting rod assemblies, thoroughly clean them and inspect for excessive wear or cracks. Check the crankpin bearings for wear or babbitt failure. Replace the shells with new ones if more than 25% of the babbitt area in either half of the shell is worn through. Remove and check the piston pins for proper clearances. Examine the piston pin bushings. Check the connecting rod bolts carefully. Replace piston rings with new ones, if stuck or worn. (See Section K).

(c) Inspect the cylinder liners and record the amount of wear. Remove any shoulders worn at ends of ring travel.

(d) Remove the main bearing caps and check the condition of the bearing shells. Replace the shells with new ones if more than 20% of the babbitt area in either half of the shell is worn through. Clean out the crankshaft oil passages.

(e) Check all inlet, exhaust, gas admission, and air starting cams (when used) and examine the cam follower rollers and pins.

(f) Examine the cylinder jackets. If scale is over 1/16" thick, it should be removed by scale remover solution.

(g) Remove and inspect water and lubricating oil pumps. Note condition of bearings, shafts, and seals. Replace if necessary.

(h) Examine all engine mounting and holding down bolts.

(i) Check the alignment of the engine with the driven members. Refer to "Auxiliary Equipment" section for lubrication and care of outboard bearings when used.

(j) Inspect entire linkage between governor and control shafts for lost motion and wear. Replace any parts which show wear.

(k) Clean out crankcase thoroughly. If cleaning solvent is used, be sure that it is completely drained out and the crankcase wiped dry after cleaning is completed.

(l) Inspect the lubricating oil relief valve.

(m) Inspect and calibrate all dial type gauges and thermometers.

(n) Check alarm and safety switches and valves. If relay contacts appear dirty, they may be cleaned by drawing a clean piece of paper between the contact points as the points are pressed together lightly. Never use sandpaper, crocus or emery cloth as these tend to embed insulating particles in the contact surfaces.

If the contact points are burned, they may be dressed up by using a burnishing tool or by the light application of a fine thin file.

(o) Clean the radiator or heat exchanger and oil cooler; and check for leaks, or plugging of the tubes.

(p) Disassemble and inspect turbochargers. See the Manufacturer's Bulletin in the "Auxiliary Equipment" section.

11. OPERATION AFTER OVERHAUL

Whenever any parts of the engine have been dismantled and reassembled, the following precautions should be taken to ensure that it is in satisfactory condition for operation.

(a) Inspect carefully for cleanliness inside the engine. Make certain that neither tools, rags, nuts, bolts, cotter pins, nor other foreign material is left inside the engine.

(b) Make certain that all parts have been correctly reassembled, and that all bolted joints have been correctly tightened and locked.

(c) Make certain that all piping has been replaced and that all connections are properly tightened. Check all valves for proper operating position.

(d) Bar the engine crankshaft over at least two complete revolutions to make certain that all operating parts are free.

Remove "Barring Lever" and disengage barring device before starting engine.

(e) Replace all covers that have been removed for service access to the engine.

(f) Observe all other precautions as listed in Section D of this manual, under STARTING THE ENGINE FOR THE FIRST TIME.

The engine should be given a break-in run after overhaul, in order to allow new parts to wear in to proper bearing conditions, and should NOT be run at high loads until such a break-in run has been completed.

12. TROUBLE SHOOTING (Common troubles and their remedies)

Following are some possible operating difficulties, their possible causes and suggested correctional procedures:

(a) TROUBLE: LOW LUBE OIL PRESSURE

Causes	Procedure
Clogged filters, stoppage in cooler or piping, high oil temperature, defective or improperly adjusted pressure regulating valve, worn lube oil pump, worn bearings.	Change filter elements, clean cooler or piping. Check oil temperature or oil flow through cooler. Check condition and setting of valves. Check pump condition and pump bearing clearances and end play. Check main and connecting rod clearances.

(b) TROUBLE: OVERHEATING

Causes	Procedure
Pump not running, water shut off, heat exchanger or radiator fouled.	Check pump and valves, clean out heat exchanger or radiator.

(c) TROUBLE: INABILITY TO CARRY LOAD

Causes	Procedure
Governor load limit set too low, low gas pressure.	Check load limit setting and gas pressure.

(d) TROUBLE: EXCESSIVE NOISE IN FRONT OR REAR END

Causes	Procedure
Loose chain drives, (when chain drive is used). Improper gear backlash, loose gears, (when gear drive is used).	Check chain tension or gear drives, (always shut down engine for this).

(e) TROUBLE: EXCESSIVE NOISE AT ONE OR MORE CYLINDERS

Causes	Procedure
Worn crankpin(s) or bearing(s).	Check bearing clearances and condition of bearings.

(f) TROUBLE: EXCESSIVE SMOKE COMING FROM CRANKCASE

Causes	Procedure
Piston rings stuck.	Install new piston rings.

(g) TROUBLE: DIFFICULTY IN STARTING

Causes	Procedure
Piston rings worn or stuck, valves not seating properly, spark plugs, magnetos, transformers or ignition wiring in poor condition.	Recondition valves or replace rings as required. Clean and re-gap spark plugs (or replace if necessary). Test magnetos and transformers and replace if necessary. Check wiring and repair or replace as necessary.

Appendix F

Yokogawa Model EJA110E-JMS4G-U12EB/FF1/D1
Differential Pressure Transmitter

General Specifications

Model EJA110A Differential Pressure Transmitter

DPharp

GS 01C21B01-00E

The high performance differential pressure transmitter model EJA110A can be used to measure liquid, gas, or steam flow as well as liquid level, density and pressure. It outputs a 4 to 20 mA DC signal corresponding to the measured differential pressure. Model EJA110A also features remote setup and monitoring through communications with the BRAIN™ terminal and CENTUM CS™ or μXL™ or HART® 275 host.

■ STANDARD SPECIFICATIONS

Refer to GS 01C22T02-00E for FOUNDATION Fieldbus communication type and GS 01C22T03-00E for PROFIBUS PA communication type marked with "◇."

□ PERFORMANCE SPECIFICATIONS

Zero-based calibrated span, linear output, wetted parts material code 'S' and silicone oil.

Reference Accuracy of Calibrated Span

(including the effects of zero-based linearity, hysteresis, and repeatability)

±0.065 % of Span

For spans below X

$\pm[0.015 + 0.05 \frac{X}{Span}]$ % of Span

where X equals:

Capsule	X kPa {inH_2O}
L	3 {12}
M	10 {40}
H	100 {400}
V	1.4 MPa {200 psi}

Square Root Output Accuracy

The square root accuracy is a percent of flow span.

Output	Accuracy
50 % or Greater	same as reference accuracy
50 % to Dropout point	$\frac{\text{reference accuracy} \times 50}{\text{square root output (\%)}}$

T00E.EPS

Ambient Temperature Effects

Total Effects per 28 °C (50 °F) Change

Capsule	Effect
L	±[0.08 % Span + 0.09 % URL]
M	±[0.07 % Span + 0.02 % URL]
H	±[0.07 % Span + 0.015 % URL]
V	±[0.07 % Span + 0.03 % URL]

Static Pressure Effects

Total Effects per Change

L capsule

±[0.07 % Span+0.052 % URL] per 3.4 MPa {500 psi}

M, H and V capsules

±[0.1% Span+0.028 % URL] per 6.9 MPa {1000 psi}

Effect on Zero (can be corrected at line pressure)

L capsule

±[0.02 % Span+0.052 % URL] per 3.4 MPa {500 psi}

M, H and V capsules

±0.028 % of URL per 6.9 MPa {1000 psi}

Overpressure Effects (M, H and V capsules)

±0.03 % of URL per 16 MPa {2300 psi}

Stability

±0.1 % of URL per 60 months (M, H and V capsules)
±0.2 % of URL per 12 months (L capsule)

Power Supply Effects "◇"

±0.005 % per Volt (from 21.6 to 32 V DC, 350 Ω)

□ FUNCTIONAL SPECIFICATIONS

Span & Range Limits

Measurement Span/Range		kPa	inH_2O(/D1)	mbar(/D3)	mmH_2O(/D4)
L	Span	0.5 to 10	2 to 40	5 to 100	50 to 1000
	Range	-10 to 10	-40 to 40	-100 to 100	-1000 to 1000
M	Span	1 to 100	4 to 400	10 to 1000	100 to 10000
	Range	-100 to 100	-400 to 400	-1000 to 1000	-10000 to 10000
H	Span	5 to 500	20 to 2000	50 to 5000	0.05 to 5 kgf/cm^2
	Range	-500 to 500	-2000 to 2000	-5000 to 5000	-5 to 5 kgf/cm^2
V*1	Span	0.14 to 14 MPa	20 to 2000 psi	1.4 to 140 bar	1.4 to 140 kgf/cm^2
	Range	-0.5 to 14 MPa	-71 to 2000 psi	-5 to 140 bar	-5 to 140 kgf/cm^2

T01E.EPS

*1: For Wetted parts material code other than S, the ranges are 0 to 14 MPa, 0 to 2000 psi, 0 to 140 bar, and 0 to 140 kgf/cm^2.

URL is defined as the Upper Range Limit from the table above.

Yokogawa Electric Corporation
2-9-32 Nakacho, Musashino-shi, Tokyo, 180-8750 Japan
Phone: 81-422-52-5690 Fax.: 81-422-52-2018

29th Edition April 2013

Zero Adjustment Limits

Zero can be fully elevated or suppressed, within the Lower and Upper Range Limits of the capsule.

External Zero Adjustment "◇"

External zero is continuously adjustable with 0.01 % incremental resolution of span. Span may be adjusted locally using the digital indicator with range switch.

Mounting Position Effect

Rotation in diaphragm plane has no effect. Tilting up to 90 ˚ will cause zero shift up to 0.4 kPa {1.6 inH_2O} which can be corrected by the zero adjustment.

Output "◇"

Two wire 4 to 20 mA DC output with digital communications, linear or square root programmable. BRAIN or HART FSK protocol are superimposed on the 4 to 20 mA signal.

Failure Alarm

Output status at CPU failure and hardware error;

Up-scale: 110%, 21.6 mA DC or more(standard)

Down-scale: -5%, 3.2 mA DC or less

-2.5%, 3.6 mA DC or less (Optional code /F1)

Note: Applicable for Output signal code D and E

Damping Time Constant (1st order)

The sum of the amplifier and capsule damping time constant must be used for the overall time constant. Amp damping time constant is adjustable from 0.2 to 64 seconds.

Capsule (Silicone Oil)	L	M	H and V
Time Constant (approx. sec)	0.4	0.3	0.3

Ambient Temperature Limits

(approval codes may affect limits)

-40 to 85 ˚C (-40 to 185 ˚F)

-30 to 80 ˚C (-22 to 176 ˚F) with LCD Display

Process Temperature Limits

(approval codes may affect limits)

-40 to 120 ˚C (-40 to 248 ˚F)

Ambient Humidity Limits

5 to 100 % RH @ 40 ˚C (104 ˚F)

Working Pressure Limits (Silicone Oil)

Maximum Pressure Limit

Capsule	Wetted parts material code H, M, T, A, D, and B	S
L	3.5 MPa {500 psi}	16 MPa {2300 psi}
M, H, and V	16 MPa {2300 psi}	16 MPa {2300 psi}

Minimum Pressure Limit

See graph below

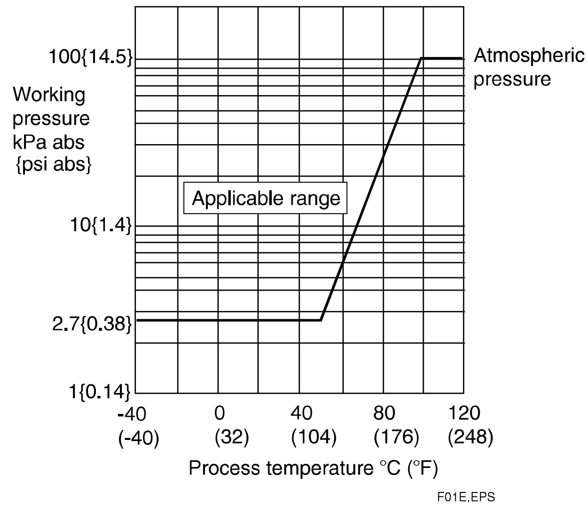


Figure 1. Working Pressure and Process Temperature

Supply & Load Requirements

(Safety approvals may affect electrical requirements)
With 24 V DC supply, up to a 570 Ω load can be used. See graph below.

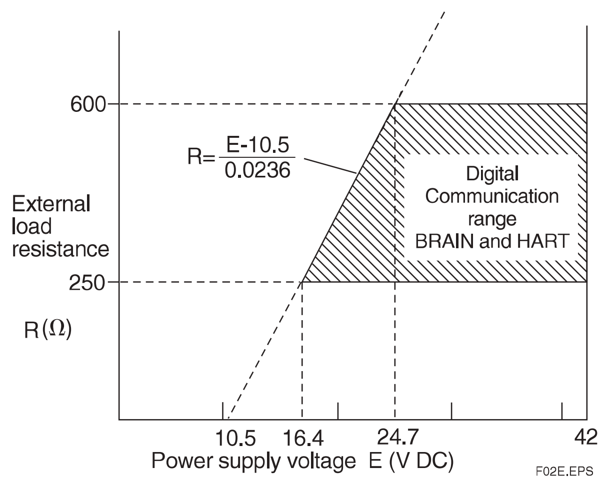


Figure 2. Relationship Between Power Supply Voltage and External Load Resistance

Supply Voltage "◇"

10.5 to 42 V DC for general use and flameproof type

10.5 to 32 V DC for lightning protector (Optional code /A)

10.5 to 30 V DC for intrinsically safe, Type n, nonincendive, or non-sparking type

Minimum voltage limited at 16.4 V DC for digital communications, BRAIN and HART

Load(Output signal code D and E)

0 to 1335 Ω for operation

250 to 600 Ω for digital communication

EMC Conformity Standards "◇" CE , N200
EN61326-1 Class A, Table2 (For use in industrial locations)
EN61326-2-3

European Pressure Equipment Directive 97/23/EC
Sound Engineering Practice

Safety Requirement Standards
EN61010-1
- Altitude of installation site: Max. 2,000 m above sea level
- Installation category: I
- Pollution degree: 2
- Indoor/Outdoor use

Communication Requirements "◇"

BRAIN

Communication Distance
Up to 2 km (1.25 miles) when using CEV polyethylene-insulated PVC-sheathed cables. Communication distance varies depending on type of cable used.

Load Capacitance
0.22 μF or less (see note)

Load Inductance
3.3 mH or less (see note)

Spacing from power line
15 cm or more.

Input Impedance of communicating device
10 kΩ or more at 2.4 kHz.

Note : For general-use and Flameproof type.
For Intrinsically safe type, please refer to 'OPTIONAL SPECIFICATIONS.'

☐ PHYSICAL SPECIFICATIONS

Wetted Parts Materials

Diaphragm, Cover flange, Process connector, and Vent/Drain Plug
Refer to 'MODEL AND SUFFIX CODE.'

Capsule Gasket
For wetted parts material code S, Teflon-coated SUS316L.
For wetted parts material code other than S, PTFE(Teflon).

Process Connector Gasket
PTFE Teflon
Fluorinated rubber for Optional code /N2 and /N3

Non-wetted Parts Materials

Bolting
SCM435, SUS630, or SUH660

Housing
Low copper cast-aluminum alloy with polyurethane paint (Munsell 0.6GY3.1/2.0)

Degrees of Protection
IP67, NEMA4X

Cover O-rings
Buna-N, fluoro-rubber (optional)

Name plate and tag
SUS304 or SUS316 (option)

Fill Fluid
Silicone, Fluorinated oil (option)

Weight
3.9 kg (8.6 lb) without integral indicator, mounting bracket, and process connector.

Connections
Refer to the model code to specify the process and electrical connection type.
Process Connection of Cover Flange:
DIN 19213 with 7/16 inch × 20 unf female thread.

< Settings When Shipped > "◇"

Tag Number	As specified in order *1
Output Mode	'Linear' unless otherwise specified in order
Display Mode	'Linear' unless otherwise specified in order
Operation Mode	'Normal' unless otherwise specified in order
Damping Time Constant *2	'2 sec.'
Calibration Range Lower Range Value	As specified in order
Calibration Range Higher Range Value	As specified in order
Calibration Range Units	Selected from mmH_2O, mmAq, mmWG, mmHg, Pa, hPa, kPa, MPa, mbar, bar, gf/cm^2, kgf/cm^2, inH_2O, inHg, ftH_2O, or psi. (Only one unit can be specified)

T07E.EPS

*1: Up to 16 alphanumeric characters for BRAIN and 8 characters for HART including '-' and '.' will be entered in the amplifier memory. If specified Tag includes other characters than above, it will not be entered in the amplifier memory.
*2: If using square root output, set damping time constant to 2 sec. or more.

< Related Instruments > "◇"

Power Distributor: Refer to GS 01B04T01-02E or GS 01B04T02-02E
BRAIN TERMINAL: Refer to GS 01C00A11-00E

< Reference >

1. Teflon; Trademark of E.I. DuPont de Nemours & Co.
2. Hastelloy; Trademark of Haynes International Inc.
3. Monel; Trademark of Inco Alloys International, Inc.
4. HART; Trademark of the HART Communication Foundation.
5. FOUNDATION; Trademark of Fieldbus Foundation.
6. PROFIBUS; Registered trademark of Profibus Nutzerorganisation e.v., Karlsruhe, Germany.

Material Cross Reference Table

SUS316L	AISI 316L
SUS316	AISI 316
SUS304	AISI 304
S25C	AISI 1025
SCM435	AISI 4137
SUS630	ASTM630
SCS14A	ASTM CF-8M

T09E.EPS

7. Other company names and product names used in this material are registered trademarks or trademarks of their respective owners.

< Specification Conformance >

The model EJA110A maintains a specification conformance to at least 3 σ.

■ MODEL AND SUFFIX CODES

Model	Suffix Codes	Description		
EJA110A	....	Differential pressure transmitter		
Output Signal	**-D**	4 to 20 mA DC with digital communication (BRAIN protocol)		
	-E	4 to 20 mA DC with digital communication (HART protocol, refer to GS 01C22T01-00E)		
	-F	Digital communication (FOUNDATION Fieldbus protocol, refer to GS 01C22T02-00E)		
	-G	Digital communication (PROFIBUS PA protocol, refer to GS 01C22T03-00E)		
Measurement span(capsule)	**L**	0.5 to 10 kPa {50 to 1000 mmH$_2$O} {2 to 40 inH$_2$O} {5 to 100 mbar}		
	M	1 to 100 kPa {100 to 10000 mmH$_2$O} {4 to 400 inH$_2$O} {10 to 1000 mbar}		
	H	5 to 500 kPa { 0.05 to 5 kgf/cm^2} {20 to 2000 inH$_2$O} {50 to 5000 mbar}		
	V	0.14 to 14 MPa { 1.4 to 140 kgf/cm^2}[*1] {20 to 2000 psi} {1.4 to 140 bar}		
Wetted parts material[*11]		[Body][*2]	[Capsule]	[Vent plug]
	S#	SCS14A	SUS316L[*5]	SUS316[*13]
	H#	SCS14A	Hastelloy C-276[*6*12]	SUS316[*13]
	M#	SCS14A	Monel[*6]	SUS316[*13]
	T	SCS14A	Tantalum[*6]	SUS316[*13]
	A#	Hastelloy C-276 equivalent[*3]	Hastelloy C-276[*6*12]	Hastelloy C-276[*12]
	D	Hastelloy C-276 equivalent[*3]	Tantalum[*6]	Hastelloy C-276[*12]
	B#	Monel equivalent[*4]	Monel[*6]	Monel
Process connections	**0**	without process connector (Rc1/4 female on the cover flanges)		
	1	with Rc1/4 female process connector		
	2	with Rc1/2 female process connector		
	3	with 1/4 NPT female process connector		
	4	with 1/2 NPT female process connector		
	☆ **5**	without process connector (1/4 NPT female on the cover flanges)		
Bolts and nuts material			[Maximum working pressure]	
	☆ **A**	SCM435	16 MPa {160 kgf/cm^2}[*9]	
	B	SUS630	16 MPa {160 kgf/cm^2}[*9]	
	C	SUH660	16 MPa {160 kgf/cm^2}[*9]	
Installation	**-2**	Vertical impulse piping type, right side high pressure, process connector upside[*7]		
	-3	Vertical impulse piping type, right side high pressure, process connector downside[*7]		
	-6	Vertical impulse piping type, left side high pressure, process connector upside[*7]		
	-7	Vertical impulse piping type, left side high pressure, process connector downside[*7]		
	-8	Horizontal impulse piping type, right side high pressure[*8]		
	☆ **-9**	Horizontal impulse piping type, left side high pressure[*8]		
Electrical connection	**0**	G1/2 female, one electrical connection		
	☆ **2**	1/2 NPT female, two electrical connections without blind plug		
	3	Pg 13.5 female, two electrical connections without blind plug		
	4	M20 female, two electrical connections without blind plug		
	5	G1/2 female, two electrical connections and a blind plug		
	7	1/2 NPT female, two electrical connections and a blind plug		
	8	Pg 13.5 female, two electrical connections and a blind plug		
	9	M20 female, two electrical connections and a blind plug		
	A	G1/2 female, two electrical connections and a SUS316 blind plug		
	C	1/2 NPT female, two electrical connections and a SUS316 blind plug		
	D	M20 female, two electrical connections and a SUS316 blind plug		
Integral indicator	**D**	Digital indicator		
	E	Digital indicator with the range setting switch[*10]		
	☆ **N**	(None)		
Mounting bracket	☆ **A**	SECC Carbon steel	2-inch pipe mounting (flat type)	
	B	SUS304	2-inch pipe mounting (flat type)	
	J	SUS316	2-inch pipe mounting (flat type)	
	C	SECC Carbon steel	2-inch pipe mounting (L type)	
	D	SUS304	2-inch pipe mounting (L type)	
	K	SUS316	2-inch pipe mounting (L type)	
	N	(None)		
Optional codes		/□ Optional specification		

T04E.EPS

The '☆' marks indicate the most typical selection for each specification. Example: EJA110A-DMS5A-92NA/□
The '#'marks indicate the construction materials conform to NACE material recommendations per MR01-75. For the use of SUS316 material, there may be certain limitations for pressure and temperature. Please refer to NACE standards for details.

*1: For Wetted parts material code H, M, T, A, D, and B, the range limits are 0 to 14 MPa{0 to 140 kgf/cm^2}.
*2: Indicates material of cover flanges and process connectors.
*3: Indicated material is equivalent to ASTM CW-12MW.
*4: Indicated material is equivalent to ASTM M35-2.
*5: Diaphragm material is Hastelloy C-276 or ASTM N10276. Other capsule wetted parts materials are SUSF316L, SUS316L or ASTM grade 316L.
*6: Indicates diaphragm and other capsule wetted parts material.
*7: If necessary, specify Mounting bracket code C, D or K.
*8: If necessary, specify Mounting bracket code A, B or J.
*9: For Capsule code L when combined with Wetted parts material code H, M, T, A, D, and B, the maximum working pressure is 3.5 MPa {35 kgf/cm^2}.
*10: Not applicable for Output signal code F and G.
*11: ⚠ Users must consider the characteristics of selected wetted parts material and the influence of process fluids. The use of inappropriate materials can result in the leakage of corrosive process fluids and cause injury to personnel and/or damage to plant facilities. It is also possible that the diaphragm itself can be damaged and that material from the broken diaphragm and the fill fluid can contaminate the user's process fluids.
Be very careful with highly corrosive process fluids such as hydrochloric acid, sulfuric acid, hydrogen sulfide, sodium hypochlorite, and high-temperature steam (150°C [302°F] or above). Contact Yokogawa for detailed information of the wetted parts material.
*12: Hastelloy C-276 or ASTM N10276.
*13: SUS316 or ASTM grade 316.

■ OPTIONAL SPECIFICATIONS (For Explosion Protected type "◇")

For FOUNDATION Fieldbus explosion protected type, see GS 01C22T02-00E.
For PROFIBUS PA explosion protected type, see GS 01C22T03-00E.

Item	Description	Code
Factory Mutual (FM)	FM Explosionproof Approval *1 *3 *4 Applicable standard: FM3600, FM3615, FM3810, ANSI/NEMA250 Explosionproof for Class I, Division 1, Groups B, C and D Dust-ignitionproof for Class II/III, Division 1, Groups E, F and G Hazardous (classified) locations, indoors and outdoors (NEMA 4X) Temperature class: T6 Amb. Temp.: –40 to 60°C (–40 to 140°F)	**FF1**
	FM Intrinsically safe Approval *1 *3 *4 Applicable standard: FM3600, FM3610, FM3611, FM3810, ANSI/NEMA250 Intrinsically Safe for Class I, Division 1, Groups A, B, C & D, Class II, Division 1, Groups E, F & G and Class III, Division 1 Hazardous Locations. Nonincendive for Class I, Division 2, Groups A, B, C & D, Class II, Division. 2, Groups E, F & G, and Class III, Division 1 Hazardous Locations. Enclosure: "NEMA 4X", Temp. Class: T4, Amb. Temp.: –40 to 60°C (–40 to 140°F) Intrinsically Safe Apparatus Parameters [Groups A, B, C, D, E, F and G] Vmax=30 V, Imax=165 mA, Pmax=0.9 W, Ci=22.5 nF, Li=730 µH [Groups C, D, E, F and G] Vmax=30 V, Imax=225 mA, Pmax=0.9 W, Ci=22.5 nF, Li=730 µH	**FS1**
	Combined FF1 and FS1 *1 *3 *4	**FU1**
ATEX	ATEX Flameproof Approval *2 *4 Applicable standard: EN 60079-0, EN 60079-1 Certificate: KEMA 02ATEX2148 II 2G Ex d IIC T4, T5, T6 Amb. Temp.: T5; –40 to 80°C (–40 to 176°F), T4 and T6; –40 to 75°C (–40 to 167°F) Max. process Temp.: T4; 120°C (248°F), T5; 100°C (212°F), T6; 85°C (185°F)	**KF21**
	ATEX Intrinsically safe Approval *2 *3 *4 Applicable standard: EN50014, EN50020, EN50284 Certificate: KEMA 02ATEX1030X II 1G EEx ia IIC T4, Amb. Temp.: –40 to 60°C (–40 to 140°F) Ui=30 V, Ii=165 mA, Pi=0.9 W, Ci=22.5 nF, Li=730 µH	**KS2**

T05-1E.EPS

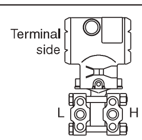
*1: Applicable for Electrical connection code 2, 7 and C (1/2 NPT female).
*2: Applicable for Electrical connection code 2, 4, 7, 9, C and D (1/2 NPT and M20 female).
*3: Applicable for Output signal code D and E.
For intrinsically safe approval, use the safety barrier certified by the testing laboratories (BARD-400 is not applicable).
*4: Lower limit of ambient temperature is –15°C (5°F) when /HE is specified.

Item	Description	Code
Canadian Standards Association (CSA)	CSA Explosionproof Approval *1 *3 *4 Applicable standard: C22.2 No. 0, No. 0.4, No. 25, No. 30, No. 94, No. 142 Certificate: 1089598 Explosionproof for Class I, Division 1, Groups B, C and D Dustignitionproof for Class II/III, Division 1, Groups E, F and G Division2 'SEALS NOT REQUIRED' , Temp. Class: T4, T5, T6 Encl Type 4x Max. Process Temp.: T4; 120°C (248°F), T5; 100°C (212°F), T6; 85°C (185°F) Amb. Temp.: –40 to 80°C (–40 to 176°F) Process Sealing Certification Dual Seal Certified by CSA to the requirement of ANSI/ISA 12.27.01 No additional sealing required. Primary seal failure annunciation: at the zero adjustment screw	**CF1**
	CSA Intrinsically safe Approval *1 *3 *4 Applicable standard: C22.2 No. 0, No. 0.4, No. 25, No. 30, No. 94, No. 142, No. 157, No. 213 Certificate: 1053843 Encl Type 4x, Temp. Class: T4, Amb. Temp.: –40 to 60°C (–40 to 140°F) Vmax=30 V, Imax=165 mA, Pmax=0.9 W, Ci=22.5 nF, Li=730 µH Process Sealing Certification Dual Seal Certified by CSA to the requirement of ANSI/ISA 12.27.01 No additional sealing required. Primary seal failure annunciation: at the zero adjustment screw	**CS1**
	Combined CF1 and CS1 *1 *3 *4	**CU1**
IECEx Scheme	IECEx Intrinsically safe, type n and Flameproof Approval *3 *4 *5 Intrinsically safe and type n Applicable Standard: IEC 60079-0:2004, IEC 60079-11:1999, IEC 60079-15:2005, IEC 60079-26:2005 Certificate: IECEx KEM 06.0007X Ex ia IIC T4, Ex nL IIC T4 Enclosure: IP67 Amb. Temp.: –40 to 60°C (–40 to 140°F), Max. Process Temp.: 120°C (248°F) Electrical Parameters: [Ex ia] Ui=30 V, Ii=165 mA, Pi=0.9 W, Ci=22.5 nF, Li=730 µH [Ex nL] Ui=30 V, Ci=22.5 nF, Li=730 µH Flameproof Applicable Standard: IEC 60079-0:2004, IEC60079-1:2003 Certificate: IECEx KEM 06.0005 Ex d IIC T6...T4 Enclosure: IP67 Max.Process Temp.: T4;120°C (248°F), T5;100°C (212°F), T6; 85°C (185°F) Amb.Temp.: –40 to 75°C (–40 to 167°F) for T4, –40 to 80C (–40 to 176°F) for T5, –40 to 75°C (–40 to 167°F) for T6	**SU2**

T05-2E.EPS

*1: Applicable for Electrical connection code 2, 7 and C (1/2 NPT female).
*2: Applicable for Electrical connection code 2, 4, 7, 9, C and D (1/2 NPT and M20 female).
*3: Applicable for Output signal code D and E.
For intrinsically safe approval, use the safety barrier certified by the testing laboratories (BARD-400 is not applicable).
*4: Lower limit of ambient temperature is –15˚C (5˚F) when /HE is specified.
*5: Applicable for Electrical connection code 2, 4, 7, C and D (1/2 NPT and M20 female).

■ OPTIONAL SPECIFICATION

Item		Description		Code
Painting *10	Color change	Amplifier cover only		**P□**
		Amplifier cover and terminal cover, Munsell 7.5 R4/14		**PR**
	Coating change	Epoxy resin-baked coating *11		**X1**
316 SST exterior parts		Exterior parts on the amplifier housing (name plates, tag plate, zero-adjustment screw, stopper screw) will become 316 SST *12		**HC**
Fluoro-rubber O-ring		All O-rings of amplifier housing. Lower limit of ambient temperature: −15°C (5°F)		**HE**
Lightning protector		Transmitter power supply voltage: 10.5 to 32 V DC (10.5 to 30 V DC for intrinsically safe type, 9 to 32 V DC for Fieldbus communication type.) Allowable current: Max. 6000 A (1×40 µs), Repeating 1000 A (1×40 µs) 100 times		**A**
Oil-prohibited use *6		Degrease cleansing treatment		**K1**
		Degrease cleansing treatment with fluorinated oilfilled capsule. Operating temperature −20 to 80°C		**K2**
Oil-prohibited use with dehydrating treatment *6		Degrease cleansing and dehydrating treatment		**K5**
		Degrease cleansing and dehydrating treatment with fluorinated oilfilled capsule. Operating temperature −20 to 80°C		**K6**
Calibration units *1		P calibration (psi unit)	(See Table for Span and Range Limits.)	**D1**
		bar calibration (bar unit)		**D3**
		M calibration (kgf/cm^2 unit)		**D4**
Sealing treatment to SUS630 nuts		Sealant(liquid silicone rubber) is coated on JIS SUS630 cover flange mounting nuts against stress corrosion cracking.		**Y**
Long vent *2		Total length: 119 mm (standard: 34 mm); Total length when combining with Optional code K1, K2, K5, and K6: 130 mm. Material: SUS316 or ASTM grade 316.		**U**
Fast response *7		Update time: 0.125 sec Amplifier damping time constant: 0.1 to 64 sec in 9 increments Response time (with min. damping time constant): max. 0.5 sec (for L capsule: max. 0.6 sec)		**F1**
Failure alarm down-scale *3		Output status at CPU failure and hardware error is –5%, 3.2 mA or less.		**C1**
NAMUR NE43 compliant *3 *9		Output signal limits: 3.8 mA to 20.5 mA	Failure alarm down-scale: output status at CPU failure and hardware error is –5%, 3.2 mA or less.	**C2**
			Failure alarm up-scale: output status at CPU failure and hardware error is 110%, 21.6 mA or more.	**C3**
Stainless steel amplifier housing *4		Amplifier housing material: SCS14A stainless steel (equivalent to SUS316 cast stainless steel or ASTM CF-8M)		**E1**
Gold-plate *5		Surface of isolating diaphragms are gold plated, effective for hydrogen permeation.		**A1**
Configuration		Custom software configuration		**R1**
Body option *8		Right side high pressure, without drain and vent plugs		**N1**
		N1 and Process connection, based on DIN 19213 with 7/16 inch×20 unf female thread, on both sides of cover flange with blind kidney flanges on back		**N2**
		N1, N2, and Mill certificate for cover flange, diaphragm, capsule body, and blind kidney flange		**N3**
Wired tag plate		Stainless steel tag plate wired onto transmitter		**N4**

T06E.EPS

*1: The unit of MWP (Max. working pressure) on the name plate of a housing is the same unit as specified by Option code D1, D3, and D4.
*2: Applicable for vertical impulse piping type (Installation code 2, 3, 6, and 7) and Wetted parts material code S, H, M, and T.
*3: Applicable for Output signal code D and E. The hardware error indicates faulty amplifier or capsule. When combining with Option code F1, output status for down-scale is –2.5%, 3.6 mA DC or less.
*4: Applicable for Electrical connection code 2, 3, 4, A, C, and D. Not applicable for Option code P□ and X1.
*5: Applicable for Wetted parts material code S.
*6: Applicable for Wetted parts material code S, H, M, and T.
*7: Applicable for Output signal code D and E. Write protection switch is attached for Output code E.
*8: Applicable for Wetted parts material code S, H, T, and M; Process connection code 3, 4, and 5; Installation code 9; and Mounting bracket code N. Process connection faces on the other side of zero adjustment screw.
*9: Not applicable for Option code C1.
*10: Standard polyurethan painting can be used in acid atmosphere, whereas the epoxy resin-baked coating (Option code X1) can be used in alkaline atmosphere. Anti-corrosion coating, the combination of polyurethan and epoxy resin-baked coating, is available by special order as sea water, alkaline, and acid resistant.
*11: Not applicable for color change option.
*12: 316 or 316L SST. The specification is included in option code /E1.

Item	Description		Code
Data configuration at factory *7	Description into “Descriptor” parameter of HART protocol		**CA**
Mill Certificate	Cover flange *1		**M01**
	Cover flange, Process connector *2		**M11**
Pressure test/ Leak test Certificate *6	Test Pressure: 3.5 MPa{35 kgf/cm^2}*3	Nitrogen(N2) Gas*5 Retention time: 10 minutes	**T01**
	Test Pressure: 16 MPa{160 kgf/cm^2}*4		**T12**

T10E.EPS

*1: Applicable for Process connections code 0 and 5.
*2: Applicable for Process connections code 1, 2, 3, and 4.
*3: Applicable for Capsule code L when combined with Wetted parts material code H, M, T, A, D, and B.
*4: Applicable for Capsule code M, H, and V and Capsule code L when combined with Wetted parts material code S.
*5: Pure nitrogen gas is used for oil-prohibited use (Option code K1, K2, K5, and K6).
*6: The unit on the certificate is always MPa regardless of selection of option code D1, D3, or D4.
*7: Applicable for Output signal code E.

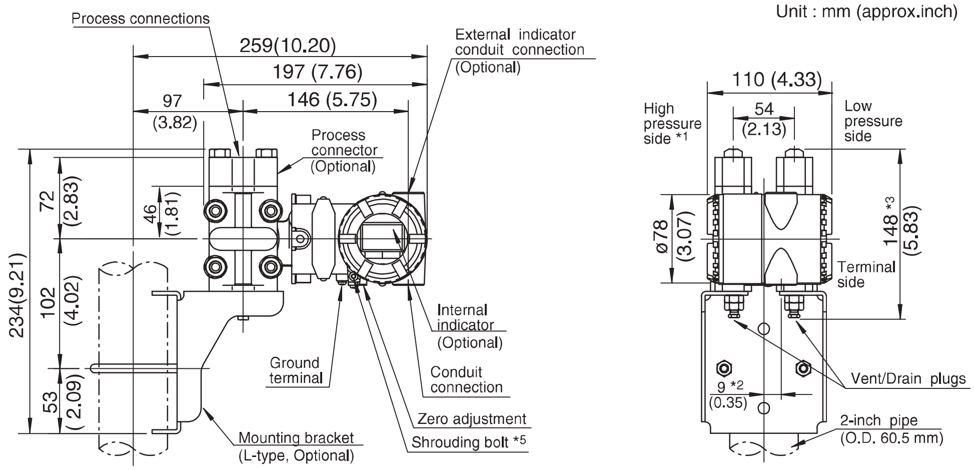
■ DIMENSIONS

● Model EJA110A

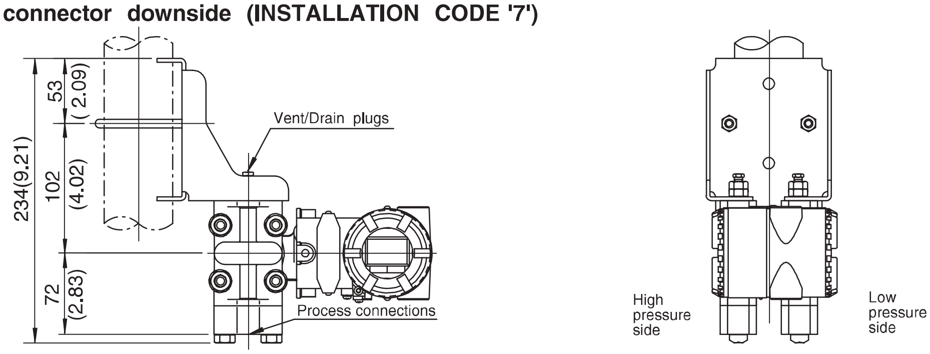
Vertical Impulse Piping Type

Process connector upside (INSTALLATION CODE '6') (For CODE '2' or '3,' refer to the notes below.)

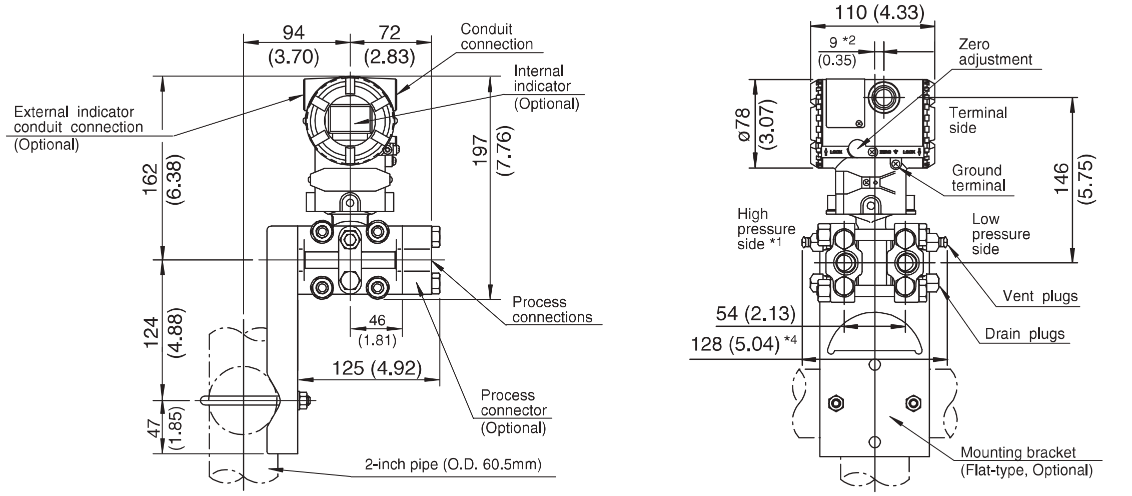
Unit : mm (approx.inch)



Process connector downside (INSTALLATION CODE '7')



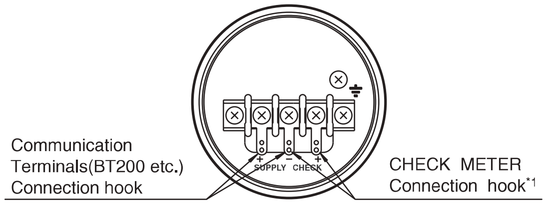
Horizontal Impulse Piping Type (INSTALLATION CODE '9') (For CODE '8', refer to the notes below.)



F03E.EPS

* 1: When Installation code 2, 3, or 8 is selected, high and low pressure side on above figure are reversed. (i.e. High pressure side is on the right side.)
* 2: 15 mm(0.59 inch) for right side high pressure.(for code 2, 3 or 8)
* 3: When Optional code K1, K2, K5, or K6 is selected, add 15 mm(0.59 inch) to the value in the figure.
* 4: When Optional code K1, K2, K5, or K6 is selected, add 30 mm(1.18 inch) to the value in the figure.
* 5: Applicable only for ATEX and IECEx Flameproof type.

● Terminal Configuration



● Terminal Wiring

SUPPLY + −	Power supply and output terminal
CHECK + −	External indicator (ammeter) terminal*1
⏚	Ground terminal

*1: When using an external indicator or a check meter, the internal resistance must be 10 Ω or less. Not available for Fieldbus communication(Output signal code F and G).

F05E.EPS

■ SELECTION GUIDE

Application	Type	Model	Capsule	Measurement Span		Maximum Working Pressure	
				kPa	inH_2O	MPa	psi
Differential Pressure	Traditional-Mounting*1	EJA110A	L M H V	0.5 to 10 1 to 100 5 to 500 0.14 to 14MPa	2 to 40 4 to 400 20 to 2000 20 to 2000 psi	16*4 16 16 16	2250*4 2250 2250 2250
Flow	Integral Orifice	EJA115	L M H	1 to 10 2 to 100 20 to 210	4 to 40 8 to 400 80 to 830	3.5 14 14	500 2000 2000
Differential Pressure & Liquid Level with Remote Seals	Extended Flush Combination	EJA118N EJA118W EJA118Y	M H	2.5 to 100 25 to 500	10 to 400 100 to 2000	Based on Flange Rating	
Draft Range	Traditional-Mounting*1	EJA120A	E	0.1 to 1	0.4 to 4	50 kPa	7.25
Differential Pressure & Liquid Level	Traditional-Mounting*1	EJA130A	M H	1 to 100 5 to 500	4 to 400 20 to 2000	32 32	4500 4500
Liquid Level, Closed or Open Tank	Flush Extended	EJA210A EJA220A	M H	1 to 100 5 to 500	4 to 400 20 to 2000	Based on Flange Rating	
Absolute (vacuum) Pressure	Traditional-Mounting*1	EJA310A	L M A	0.67 to 10*2 1.3 to 130*2 0.03 to 3 MPa*2	2.67 to 40*2 0.38 to 38 inHg*2 4.3 to 430 psi*2	10 kPa*2 130 kPa*2 3000 kPa*2	40 in H_2O*2 18.65*2 430*2
Gauge Pressure	Traditional-Mounting*1	EJA430A	A B	0.03 to 3 MPa 0.14 to 14 MPa	4.3 to 430 psi 20 to 2000 psi	3 14	430 2000
Gauge Pressure with Remote Seal	Extended	EJA438N	A B	0.06 to 3 MPa 0.46 to 7 MPa	8.6 to 430 psi 66 to 1000 psi	Based on Flange Rating	
Gauge Pressure with Remote Seal	Flush	EJA438W	A B	0.06 to 3 MPa 0.46 to 14 MPa	8.6 to 430 psi 66 to 2000 psi	Based on Flange Rating	
High Gauge	Traditional-Mounting*1	EJA440A	C D	5 to 32 MPa 5 to 50 MPa	720 to 4500 psi 720 to 7200 psi	32 50	4500 7200
Absolute & Gauge Pressure*3	Direct-Mounting	EJA510A EJA530A	A B C D	10 to 200 0.1 to 2 MPa 0.5 to 10 MPa 5 to 50 MPa	1.45 to 29 psi 14.5 to 290 psi 72.5 to 1450 psi 720 to 7200 psi	200 kPa 2 10 50	29 290 1450 7200

T08E.EPS

*1: Traditional-mounting is 1/4 - 18 NPTF process connections (1/2 - 14 NPTF with process adapters) on 2-1/8" centers.
*2: Measurement values in absolute.
*3: Measurement values in absolute for EJA510A.
*4: When combined with Wetted parts material code H, M, T, A, D, and B, the value is 3.5 MPa (500 psi).

< Ordering Information > "◇"

Specify the following when ordering
1. Model, suffix codes, and optional codes
2. Calibration range and units:
   1) Calibration range can be specified with range value specifications up to 5 digits (excluding any decimal point) for low or high range limits within the range of -32000 to 32000.
   2) Specify only one unit from the table, 'Settings when shipped.'
3. Select linear or square root for output mode and display mode.
   Note: If not specified, the instrument is shipped set for linear mode.
4. Select normal or reverse for operation mode
   Note: If not specified, the instrument is shipped in normal operation mode.
5. Display scale and units (for transmitters equipped with integral indicator only)
   Specify either 0 to 100 % or engineering unit scale and 'Range and Unit' for engineering units scale: Scale range can be specified with range limit specifications up to 5 digits (excluding any decimal point) for low or high range limits within the range of -19999 to 19999.
6. Tag Number (if required)