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AIR-COOLED CWS WARM AIR FURNACE

Final Report

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Tecogen Division of Thermo Power Corporation
A Subsidiary of Thermo Electron Corporation
Waltham, Massachusetts

Final

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1. INTRODUCTION AND SUMMARY

Under contract to the United States Department of Energy, Pittsburgh Energy Technology Center, Thermo Power Corporation, Tecogen Division, has developed coal water slurry (CWS) combustion technologies specifically tailored to meet the space heating needs of the residential, commercial, and industrial market sectors. In particular, a versatile residential CWS furnace was developed which is capable of providing heat either in the form of warm air for forced air heating, or hot water as part of a hydronic system. It can also be used to provide domestic hot water heating. In each configuration, an intermediate circulating hot water loop was used for combustor cooling. This furnace was extensively tested and met all the design and operating criteria of the development program, which included combustion efficiencies in excess of 99%, response to full load from a cold start in less than 5 minutes, and steady-state thermal efficiencies as high as 85%.

While this furnace design is extremely versatile, versatility came at the expense of system complexity and cost. To provide a more cost effective CWS-based option for the residential market sector, Tecogen, under contract to the Pittsburgh Energy Technology Center, Contract No. 22-87PC79650, developed a totally air-cooled CWS-fired residential warm air heating system. To minimize system cost and to take advantage of industry manufacturing practices and experience, a commercially available oil/gas solid fuel-fired central furnace, manufactured by Yukon Energy Corporation, was used as the platform for the CWS combustor and related equipment.

A prototype furnace was designed, built, and tested in the laboratory to verify system integrity and operation. This unit was then shipped to the Pittsburgh Energy Technology Center to undergo demonstration operation and serve as a showcase of the CWS technology.

2. TECHNICAL DISCUSSION

To restore coal as an economically and environmentally acceptable fuel alternative for the residential, commercial, and industrial space heating market sectors, coal fuel form is an important consideration. Coal water slurry (CWS) provides important advantages over other coal forms (pulverized, lump, or briquettes) in ease of handling and storage, along with the potential to reduce overall emission levels and pollution control equipment requirements. CWS is amenable to coal cleaning techniques, which are generally water-based processes requiring fine grinding of the coal.

Through previous work at Tecogen, a technically-viable coal water slurry, warm air furnace was developed. This development effort led to the construction and testing of a manufacturing preproduction prototype unit that was capable of meeting all the major requirements set forth for this system.

With the aid of Yukon Energy Corporation, a manufacturer of warm air furnace systems, a design effort was undertaken to transform this system to a manufacturing prototype unit, capable of being mass-produced. This included replacing the circulating intermediate water loop used in the preproduction prototype unit in favor of a totally air-cooled approach in order to minimize first costs. This design effort resulted in a set of drawings that made it possible to estimate the high volume production cost of CWS furnaces: end users would pay \$3,000 per unit. Under this program, the detailed design of this prototype unit was completed and the furnace was built and tested.

2.1 SUMMARY OF PREVIOUS WORK

Under a 2 Phase program, Contract No. DE-AC22-87PC79650 with the United States Department of Energy, Pittsburgh Energy Technology Center (PETC), Tecogen developed a coal water slurry (CWS) fueled residential warm air furnace. During this work, 3 furnace systems were designed, constructed, and tested. These systems ranged from the first generation system, which served as a proof-of-concept unit, to a second generation laboratory test and optimization unit, and finally, to a third generation, preproduction prototype unit that was tested extensively and which demonstrated the technical feasibility of the furnace.

As a result of building on the information obtained through the development of each unit, Tecogen was able to build a system that met or exceeded all the major criteria established for this program. The criteria for this program are summarized in Table 2.1, along with the achievements obtained.

The major component in each of the furnace systems was the combustor. A cutaway drawing of the combustor used in this work is shown in Figure 2.1. Air would enter the combustor through tangential air inlets in the primary chamber. A CWS atomizer was located in the top air inlet and introduced atomized CWS into the combustor with a predominantly tangential velocity. Due to the

TABLE 2.1
PROGRAM CRITERIA

Criteria	Requirement	Program Achievements
Fuel	CWS as primary fuel and No. 2 heating oil as secondary fuel	Achieved
Nominal Input	100,000 Btu/hr	Achieved (Tested 60,000 to 240,000 Btu/hr)
Combustion Efficiency	Greater than 99 percent	Achieved (99.6 percent maximum)
Steady State Efficiency	Greater than 80 percent	Achieved (85 percent maximum)
Response to Full Load from cold start	Less than 5 minutes	Achieved (obtained less than 3 minutes)
Size Constraint	Height: less than 6 feet Floor Space: less than 15 square feet	Actual: 5.5 feet Actual: 13 square feet
Turndown Ratio	Greater than 3:1	Achieved 4:1
Ignition	Automatic	Achieved automatic ignition along with a complete automated control system
Maintenance		
Daily	None	Achieved
Annual	Twice per year	*
Service Life	Greater than 20 years	*

* Program duration was not adequate to confirm these criteria

Figure 2.1 Cutaway Drawing of CWS-Fired Residential Combustor

centrifugal forces established by the tangential flow field, coal particles would be forced outward to the combustor periphery. Various partitions were used to retard the axially downward flow of the particles.

As the coal particles burned, their diameter would decrease, and drag forces would overcome centrifugal forces, allowing the particles to enter the next chamber. By properly sizing the partitions, the residence time of the coal particles in the hottest section of the combustor could be maximized, allowing for high combustion efficiencies.

The third generation furnace system was the culmination of all the information obtained in both phases of this program. The purpose of this furnace was to fully integrate all the components and subsystems that had previously been developed into a unit that could serve as a manufacturing preproduction prototype unit, and then to extensively test the system for both life and cyclic operation. A photograph of the third generation furnace is Figure 2.2.

The third generation furnace was of a water-cooled design, and used a circulating water loop to recover heat from the combustor and a gas-to-water heat exchanger. The heat recovered in the water loop was transferred to the heating load in the form of warm air via a fan coil unit. This approach was chosen because it gave the furnace the versatility to operate not only as a warm air unit, but also as a hydronic unit and to provide domestic hot water.

The third generation furnace was a totally self-contained unit and included the combustor, shell-and-tube heat exchanger, transition box, 2 baghouses, an induced draft fan, a fan coil unit, a water pump, an oil burner assembly, a peristaltic CWS pump, an air compressor needed to supply compressed air to the CWS atomizer, and an automated control system. The automated control system allowed the furnace to start up on oil and transition over to CWS automatically. When the heating requirement was met, the control system would shut off the fuel supply, flush out the CWS lines, and operate the fan and water pump for an appropriate cooldown period. All this was accomplished by the actuation of a single switch that served as a thermostat.

2.2 PROTOTYPE FURNACE DESIGN

The third generation furnace system represented a technically-viable CWS furnace system. However, from a manufacturing perspective, several changes were necessary to reduce the initial cost of the system. These changes resulted in the need to redesign the CWS furnace to reflect a preproduction prototype unit that could be fabricated as a high volume production unit. This design effort had to reflect the constraints imposed by various manufacturing procedures on high volume production of warm air furnaces. This redesign was conducted in conjunction with Yukon Energy Corporation. Located in Minnesota, Yukon Energy is a manufacturer of residential oil, gas, and multifuel solid-fired warm air furnaces.

Figure 2.2 Third Generation Furnace System

One modification made to the design of the laboratory furnace was the removal of the intermediate heat transfer water loop that cooled the combustor and recovered heat from the products of combustion. In the modified design, heat is transferred directly from the products of combustion to the warm air delivered to the heating load, which serves to reduce the cost of the unit. This change in the CWS furnace design was accomplished by having the warm air that passed through the furnace not only recover heat from the heat exchangers, but also cool the combustor. In order to aid in heat transfer, the combustor was redesigned with longitudinal fins.

In an effort to keep the production cost down, a commercially-available oil/gas solid fuel-fired central furnace manufactured by Yukon Energy Corporation was used as the platform for the CWS combustor and related equipment. A photograph of this unit is shown as Figure 2.3 and a furnace schematic is given as Figure 2.4.

A schematic of the CWS furnace system is given as Figure 2.5. The baseplate, main heat exchanger, and casing of the Yukon furnace were utilized as the framework for the CWS furnace. Figure 2.6 shows the Yukon baseplate and main heat exchanger assembly. An IRIS-based CWS combustor and transition chamber were connected to the main heat exchanger, and an induced draft fan was added to ensure the combustion system would operate below atmospheric pressure, eliminating potential coal, ash, or combustion gas leaks into the circulating air. The hot air circulating blower was relocated to ensure a positive cooling air flow across the finned CWS combustor. All combustor auxiliary equipment, including start up fuel oil system, atomizing air system, ignition system, and slurry delivery system were mounted within or on the furnace sheet metal structure, depending on access requirements.

Figures 2.7 thru 2.10 show the CWS combustor at various stages of manufacture and assembly. The combustor consists of an outer stainless steel shell containing 40 1" x 0.12" fins, a 1/2" layer of zirconia insulating wool, and an Inconel liner. The segmented partition plates are made from high density, castable alumina refractory. Figure 2.7 shows the combustor shell during fin installation and Figure 2.8 shows the internal combustor assembly. Figure 2.9 shows the combustor mounted in the furnace casing, along with the refractory transition chamber. This chamber directs the combustion gases to the main heat exchanger and is a drop out point for clinker or ash that accumulates in the combustor. The transition chamber is fitted with an access for material removal. Figure 2.10 is the fully assembled combustor head configuration. The combustor head is water-cooled using a self-contained cooling water system. This system contains the necessary water-to-air heat exchanger, pump, and instrumentation.

Figures 2.11 thru 2.13 show the furnace during various stages of assembly. Figure 2.11 is a view of the back end of the furnace showing the induced draft fan and main heat exchanger. Figure 2.12 shows the combustor end of the furnace with the hot air circulating fan and combustor in place. Figure 2.13 is a photograph of the fully assembled furnace.

Figure 2.3 Yukon Polar Oil-Solid Fuel-Fired Central Furnace

Figure 2.4 Schematic of Yukon Polar Furnace

Figure 2.5 Schematic of Air-Cooled CWS Furnace

Figure 2.6 Furnace Baseplate and Main Heat Exchanger

Figure 2.7 Fabrication of Combustor Shell

Figure 2.8 Internal Combustor Assembly

Figure 2.9 Combustor and Transition Chamber Installation

Figure 2.10 Combustor Head Assembly

Figure 2.11 Furnace Induced Draft Fan and Main Heat Exchanger

Figure 2.12 Furnace Hot Air Circulating Fan and Combustor

Figure 2.13 Fully Assembled Furnace

Along with the mechanical components and subsystems, the furnace was outfitted with a control system to permit automatic operation of the CWS combustion system. The control system includes the necessary relay interlocks, single loop controllers, sensors, and displays to permit safe, reliable operation of the system. Figure 2.14 shows the control system cabinetry and interface components and Figure 2.15 shows the internal configuration.

An in-depth Owners Manual was prepared and delivered with the furnace. This Owners Manual, which is included as Appendix A of this report, includes installation instructions, operating procedures, wiring diagrams, and equipment bulletins on the major components. It also contains coal water slurry fuel specifications and typical system operating variables, including key temperatures, pressures, and flowrates. These operating variables were measured during laboratory check-out testing of the unit.

Figure 2.14 Control System Cabinetry

Figure 2.15 Control System Components

APPENDIX A

**TECOGEN
COAL WATER SLURRY
FIRED WARM AIR FURNACE**

OWNERS MANUAL

Model No. - Prototype

Manufactured for:

**US Department of Energy
Pittsburgh Energy Technology Office
Pittsburgh, PA 15236**

Contract No. - DE-AC22-91PC91102

Manufactured by:

**TECOGEN
a Division of Thermal Power Corporation
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INTRODUCTION

This manual provides installation, operation and maintenance instructions for the Tecogen Coal Water Slurry Fired Warm Air Furnace.

UNPACKING AND INSPECTION

The furnace has been shipped as a fully assembled unit. Inspect the unit for visible damage. If damage has occurred, file a claim with the delivery carrier promptly and contact your TECOGEN representative.

RULES FOR SAFE INSTALLATION AND OPERATION

1. Read these rules and the instructions carefully. Failure to follow these rules and instructions could cause a malfunction of the furnace.
2. The installation must comply with local codes. Local codes take precedence over installation instructions found in this manual.
3. Use only the type of fuel approved for the furnace. Overfiring will result in failure of the heat exchanger and cause dangerous operation.
4. Oil storage tanks, piping and valves should be installed and tested in accordance with NFPA 31.
5. There must be a sufficient supply of combustion air to the area in which the furnace is located. If required, a combustion air supply vent should be installed.
6. Connect the furnace to a masonry or factory built chimney NFPA 211 - Appendix A refers to as "chimney for residential type and building heating appliance". This chimney is commonly referred to as Class "A" or All-Fuel.
7. Follow a regular service and maintenance schedule for efficient and safe operation.
8. Before servicing, allow the furnace to cool. Always shut off electricity and fuel to furnace when working on it. This will prevent electrical shocks or burns.

FURNACE SPECIFICATION

FUEL	OIL AND/OR COAL WATER SLURRY
INPUT RATING	200,000 BTU/HR
CIRCULATING AIR	1200-1800 CFM

DANGERS - CAUTION - FIRE HAZARDS

Only burn coal water slurry mixtures or home heating oil.

Do not install a power humidifier on the warm air plenum.

Do not install on a combustible floor.

In the event of a fire, call your fire department immediately. Disconnect power to the unit.

INSTALLATION

Furnace Dimensions

Locating The Furnace

Locate the furnace as close to the chimney or flue as possible and near the center of the heat distribution system.

The furnace should be located so that sufficient air is available for proper combustion and ventilation. The furnace location must comply with minimum clearances required for fire protection and accessibility.

It is recommended that a 2" non-combustible raised pad be used for the furnace to prevent moisture from getting under the furnace and causing corrosion.

See figure below for typical duct and plenum configuration.

DUCTS AND PLENUMS SHALL BE
CONSTRUCTED ENTIRELY OF
SHEET METAL.

TYPICAL INSTALLATION

DUCTS SHOULD BE LARGE ENOUGH
TO HANDLE GRAVITY AIR FLOW IN
EVENT OF ELECTRIC POWER OR
FURNACE FAN FAILURE.

Furnace Exhaust

The furnace is equipped with a variable speed induced draft fan which controls the amount of combustion air into the furnace. This fan is capable of pressurizing the stack system and therefore an air tight stack or chimney is required. The stack should be capable of operating at a positive pressure of 8" of water column without leaks or damage. The National Fire Protection Association (NFPA 211) regulations should be followed regarding chimney heights and clearances.

The chimney should be no less than 8" inside diameter or equal. A draft regulator is not required.

Clearances To Combustibles

Electrical Wiring

All electrical wiring must be done in accordance with the National Electrical Code and the code legally authorized in the area where the installation is being made. 110 VAC is required for the furnace controls and AC motors and 220 VAC is required for the induced draft fan motor which is a variable speed DC motor. The unit is equipped with a DC motor speed controller which rectifies the 220 VAC to the required DC voltage. The unit is internally fused - suitable disconnects and/or circuit breakers should be provided as required.

The slurry pump speed controller has been shipped inside the main control box. This unit should be located on top of the control box adjacent to the furnace pressure controller.

Fuel Tanks And Fuel Lines

Home heating oil tanks and fuel lines must be installed in accordance with the requirement of NFPA 31. See the figure below for installation.

If the fuel lines are under 30' in length, it is satisfactory to use 3/8" O.D. copper tube. Never use tube smaller than 3/8" O.D. If the lines are over 30' in length, 1/2" O.D. tube is recommended. Use good flare connections on the fuel lines and, wherever possible, avoid splicing the tube. Never make a splice or joint underground. Whenever possible, avoid overhead lines; avoid kinks and traps in the lines. Do not fasten fuel lines directly to floor joist, sills, or girders.

When the outlet on the fuel tank is higher than the inlet on the burner, a single line system can be used.

The slurry storage tank should be located approximately 7 feet from the furnace. A 3/8" OD polyethylene tube should be used between the tank and slurry pump inlet. Provisions must be made to allow water flushing of the slurry supply line when the system is to be idled for periods in excess of 12 hours. The slurry tank must be equipped with a suitable agitation device to prevent settling of the slurry and a 12 mesh suction strainer. A suitable method should be provided to allow slurry flow measurement. See figure below as well as the Final Report entitled "Storage, Transportation, and Atomization of CWF For Residential Applications" prepared under DOE Contract No. DE-AC22-89PC89796.

Slurry Specifications

The furnace has been designed to operate on slurry made from low ash, low sulfur bituminous coal. The slurry should have a heating value of greater than 7,500 Btu/lb, an average coal particle size of approximately 20 to 30 microns and a viscosity of approximately 200 centipoise at 80 reciprocal seconds.

A drum of slurry has been supplied with the unit for initial shakedown testing and operation. This slurry was produced with Eastern Kentucky Hazard Coal having the following proximate and ultimate analysis.

KENTUCKY HAZARD PRINCE MINE					
Proximate Analysis			Ultimate Analysis		
	As Received	Dry Basis		As Received	Dry Basis
% Moisture	2.69	xxxxx	% Moisture	2.69	xxxxx
% Ash	3.62	3.72	% Carbon	78.91	81.09
% Volatile	35.93	36.92	% Hydrogen	5.25	5.39
% Fixed Carbon	57.76	59.36	% Nitrogen	1.63	1.67
	100.00	100.00	% Sulfur	0.74	0.76
Btu/lb (HHV)	14144	14535	% Ash	3.62	3.72
% Sulfur	0.74	0.76	% Oxygen (diff.)	7.16	7.37
MAF Btu		15097		100.00	100.00

The size distribution of the coal and a typical slurry viscosity are shown below. The slurry has a 59% coal loading. The slurry has the following additives: 10,000 ppm of Coalmaster A-23-M dispersant and 700 ppm flocon stabilizer (dry mass coal basis). A-23 is available from Henkel Corporation and Flocon is available from Pfizer Chemical. Some settling and changes in properties have probably occurred. The slurry should be resuspended and tested prior to use. Contact Tecogen for recommendations regarding adjustment of slurry properties.

Purge Water And Atomizing Air

The furnace is equipped with a coal water slurry atomizer which uses compressed air as the atomizing media. A schematic of the atomizer is shown below. The atomizer is an annular design with slurry flowing in the central tube while atomizing air flows in the annular passageway around the slurry tube. The airstream shears the slurry to an unstable sheet which breaks the slurry up into fine droplets. Clean, dry compressed at 80 psig must be supplied to the inlet side of the atomizing air regulator. The regulator should be set at 45 psig. The air line to the regulator should be a minimum of 1/2" O.D.

Water is used to flush the slurry atomizer to prevent a build up of slurry in the atomizer slurry tube. City water at a minimum of 60 psig must be supplied to the inlet side of the flush water regulator. The regulator should be set at 20 psig. The water line to the regulator should be an minimum of 1/2" O.D.

Cooling Water Circuit

The furnace is equipped with a cooling water circuit for cooling the head of the combustor and fuel oil nozzle. Heat picked up in these coils is transferred to the circulating air by means of a finned air/liquid heat exchanger. This system was factory filled with a water/ethylene glycol mixture. With the furnace cold the cooling system should be pressurized to 10 psig. If the cooling water pressure is below 10 psig, water should be added. As the furnace warms up, the cooling system pressure will rise due to expansion of the cooling fluid. At the cooling water operating temperature of approximately 220 F the system pressure will rise to approximately 40-50 psig.

OPERATION

The unit is set up to operate in manual (non-thermostatic) control mode. In this mode, the "on/off" switch on the control panel operates the unit independent of room temperature. To convert the unit for automatic temperature control operation please contact Tecogen for the necessary wiring change.

To start the unit on oil, proceed as follows:

1. Check for oil in storage tank and that the oil valve at the tank is open.
2. Make sure electrical connections are made, all fuses are in good condition and the circuit breakers are in the on position.
3. Check the furnace pressure controller to ensure the proper set point is programmed. Press the "Disp" key to display the set point "SP". The set point should be "2". If this set point is not displayed or the controller is not active, please consult the attached controller operating manual or contact a Tecogen service technician.
4. Make sure that atomizing air and flush water is supplied to their respective regulators. Check pressures at regulators.
5. Make sure that the cooling water circuit is adequately charged and that all air is removed from the system.
6. The oil line will have to be purged of entrapped air before proper flow can be established to the fuel oil nozzle. Use the air bleed valve on the fuel oil pump to remove air from the fuel line. Cycle the system on and off until oil appears at the pump.
7. With the oil line clear of air, start system by placing on/off switch in "on" position. When turned on, the induced draft fan, water circulating pump, atomizing air solenoid and ignition spark will be energized. Once the induced draft fan creates a negative pressure in the combustor, closing the combustion chamber pressure switch, the oil pump will be energized and oil combustion initiated.

If ignition does not take place, turn system "off", allow system to set for a moment, press "reset" on primary flame controller, and retry. Channel 9 on the temperature display should be monitored when starting system. If ignition does not take place after several attempts, recheck plumbing, wiring and controls.

Do not attempt to restart burner when excess oil has accumulated or when the combustion chamber is very hot.

If furnace fails to operate, call a Tecogen service technician.

8. Once the burner ignites, the circulating air fan will be energized when the air temperature within the furnace reaches 100 F. This fan will remain on until the furnace temperature drops below 70 F or the main power is removed.

Slurry Operation

The furnace will automatically switch over to 100% slurry firing. This will occur once the combustion temperature reaches a sufficiently high temperature to maintain coal water slurry combustion. This temperature is adjustable and is set on temperature relay TS1 in the main control box. The recommended temperature setting for this relay is 1832 F (1000 C).

When the selected combustor temperature is reached, the slurry pump will be energized and the system will operate on both fuel oil and slurry for a predetermined period of time after which the fuel oil flow will be interrupted.

If slurry burning is interrupted or not established, as determined by a drop in the combustion chamber temperature, oil combustion will be re-initiated and the slurry nozzle will be flushed with water.

When the selected combustor temperature is again reached, slurry flow will again be initiated. If slurry combustion is achieved, the system will operate on slurry until the on/off switch is placed in the "off" position or the TS1 temperature relay setpoint is manually increased above the combustion chamber temperature forcing the system to switch back to oil firing.

9. To ensure a successful change over to slurry firing, the slurry properties must be as set forth above and the slurry supply system must provide an uninterrupted flow of slurry to the atomizer. The slurry line should be pre-filled with slurry prior to the combustor reaching operating temperature. This can be achieved by manually operating the slurry pump. A bypass switch in the control cabinet permits energizing the slurry pump controller with the run switch in the off position. The slurry pump should be turned on until slurry is visually detected at the slurry pump outlet.
10. The slurry pump controller should be set at "1" for initiation of slurry combustion. This setting corresponds to a slurry flow of approximately 20 lbs/hr or 170,000 Btu/hr.
11. Once slurry combustion is established, the slurry flow rate should be checked through loss in weight measurement or using a suitable in-line flow meter. Exhaust gas analysis should also be taken to determine the combustion stoichiometry. The system should be operated with an exhaust oxygen concentration of approximately 3% (dry, volume). Exhaust oxygen concentration can be adjusted by varying the slurry flow.

12. The following table gives typical values for the key operating variables:

TYPICAL SYSTEM OPERATING VARIABLES

System Temperatures

TC	1	475 F
	2	270
	3	420
	4	255
	5	160
	6	72
	7	2000
	8	2000
	9	1800
	10	2000

Exhaust Composition (% Vol, Dry)

Oxygen	3.0
CO2	16.2

Atomizing Air Pressure	45 psig
Delta Pressure Combustor	2.0" w.c.
Slurry Pump Setting	1.0
Slurry Flowrate	20 lbs/hr

The schematic on the following page shows the general configuration of the furnace along with the location of the thermocouples listed above.

System Shutdown

When the system run switch is placed in the "off" position or when the flame sensor determines a flame out condition when firing on oil, the system will go through an automatic shutdown sequence. This sequence includes shutdown of the slurry and oil combustion, flushing of the slurry atomizer, timed operation of the induced fan and circulating water pump for controlled cooling. The air circulating blower remains on until the circulating air drops below the 70 F setpoint.

When the system is to remain off for extended periods (approximately 12 hours) the slurry lines from the slurry tank to the atomizer must be flushed with water to prevent settling and hard packing of the slurry. The amount of time before adverse slurry settling will

FURNACE SCHEMATIC

occur will depend on the settling characteristics of the slurry utilized.

An access door to the slurry atomizer has been provided to allow for disconnecting the slurry line at the atomizer. With the slurry pump in manual control, water can be passed through the system into a suitable collection container. Once flushing is complete the line should be reconnected to the atomizer and the access door reinstalled.

This same access door can be used to remove the atomizer for inspection or adjustment.

MAINTENANCE

The oil burner motor should be lubricated every three months with a few drops of good grade light motor oil, No. 10 or 20 S.A.E.

If blower motors have oil caps, oil twice yearly.

The combustor transition chamber should be cleaned of ash and slag periodically. The frequency of cleaning will depend on duration of slurry operation and quantity of ash in the coal. A weekly inspection and clean-out is recommended. The transition chamber is equipped with an ash clean out door to facilitate ash and slag removal. This door is behind the lower end panel on the combustor end of the unit. If loose refractory or metallic pieces are found in the transition chamber, a Tecogen service representative should be contacted regarding repair procedures.

On a regular basis, the chimney and heat exchanger should be inspected for ash and soot buildup. A stiff brush should be used to remove material from these surfaces.

Ashes should be placed in a metal container with a tight fitting lid. The closed container of ashes should be placed on a non-combustible floor or on the ground well away from all combustible materials, pending final disposal.

The fuel oil nozzle and ignitor should be inspected periodically. The nozzle and ignitor assembly should be cleaned of any carbon deposits and the ignitor inspected for signs of cracking of the ceramic insulator. If cracking is found the ignitor should be replaced. The gap between the ignitor tip and burner nozzle should be set at 1/16". This gap is critical to successful oil ignition and cleaning of the nozzle during slurry firing.

The flame detector cad cell and observation window should be cleaned periodically.

The hose on the peristaltic slurry pump should be inspected periodically and replaced if there are any signs of cracking or deterioration.

ELECTRICAL DIAGRAMS

15

EQUIPMENT BULLETINS

Yokokawa UT 30 Indicating Controller

Boston Gear Ratiotrol

Dwyer Differential Pressure Switch

Sprecher + Schuh Motor Starter

Direct Current Control

Series CS3 & CA3 Devices

With direct current control, there is a basic difference between actual DC magnets and modified AC magnets.

- Actual DC magnets are symbolized by their high permissible frequency of operation and long life. They are specially suited for control relay functions. Actual DC magnet systems are available for the smaller types (CS3C, CA3-9C ... CA3-16C). These have the same base area and fixing dimensions as their AC counterparts.
- The holding current must be reduced when an AC magnet is controlled by DC, a situation which is realized with an economy resistor or specially tapped coil having a low ohmic pull-in and a high ohmic holding winding. A late break contact is needed in both cases to switch from the high pull-in to the low holding current consumption. DC coils having pull-in and holding windings are available for the CA3-23A ... CA3-72 contactors. Space requirements and fixing dimensions are the same as for AC control.
- Immediately after energization, the contactor coil of a latched contactor is disconnected from the supply by a contact (65-66) on the latch. This, of course, eliminates any holding current. The latch can be used with all AC contactor types.

DC control
CA 3-9 C + CT 3...
CA 3-16 C + CT 3

DC control
CA 3-23 + CT 3...
CA 3-30 + CT 3
Z1 = Voltage limiting element

DC control
CA 3-37 + CT 3...
CA 3-72 + CT 3
Voltage limiting element
built in

with CV 3 latch
CS 3 + CV 3
CA 3-9 + CV 3...
CA 3-72 + CV 3

Series CA1 Devices

When an AC magnet is controlled by DC, the holding VA must be reduced. This is achieved with an economy resistor. A late-break auxiliary contact switches over to the lower holding VA after pull-in.

For the rectification of AC, a single phase bridge with smoothing, or a three-phase full wave rectifier should be used.

With the CA1-150 ... CA1-480 contactors, which have correspondingly higher holding VA's, the DC switching capacity of the contactors' auxiliary contacts is no longer sufficient. In cases such as these, a CS1A control relay with a special coil is used together with six 10A contact elements.

With the CA1-630 ... CA1-1250 contactors, an economy resistor and a special bridging contactor are fitted at the factory. The magnets of the CA1-1000 and CA1-1250 contactors are always operated with DC. Therefore, when AC control is required, a full-wave rectifier, an economy resistor and a bridging contactor are fitted.

CA 1-60
CA 1-100

$U_s < DC 140; 140...280; \geq 280 V$

CA 1-150...CA 1-480

1) K2A = CS1A-111 111 with special coil.

Process Instrument Control

This option isolates an external reference signal from the **8878**. The reference signal must produce a maximum of 5V or produce the currents listed in Figure 1. These currents represent the signals required to produce zero to base speed of the motor. Cut out the resistors not required as listed in Figure 1 and shown in Figure 2. Production boards will be tailored to produce the required current range.

Isolated Input	Remove
1-5 MA	R1 & R2
4-20 MA	R1
10-50 MA	

FIGURE 1
Scaling Resistors.

Figure 2 shows the Jumper Wire connections required to provide 230 VAC power on the Option Board. Connect the option board for either 115 VAC or 230 VAC operation. Note: (Solid line silkscreened on PWB indicate placement of jumpers).

FIGURE 2

Install and wire the option as shown in Figure 3.

FIGURE 3.

INTERCONNECTION DIAGRAM BETWEEN THE MAIN BOARD
AND THE OPTION BOARD FOR RE1 OR RE2 CONTROLLERS

SPEED POT USED AS RATIO POT

START-UP

1. Turn the Offset Pot (R17) fully counterclockwise.
2. Turn the Gain Pot (R21) fully clockwise.
3. Apply the Minimum Input Signal to Terminals TB4-10 (Positive) and TB4-11 (Negative) and turn on the controller. If the motor rotates, turn the Offset Pot R16 clockwise until the motor stops.
4. Turn the Gain Pot fully counterclockwise.
5. Increase the Input Signal to Maximum and set the Gain Pot for Motor Base Speed.

ISOLATED PROCESS CONTROL INTERFACE

Instruction Manual

Model UT30 (Style B) Digital Indicating Controller Operation Manual

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1. HANDLING CAUTIONS

The Model UT30 Digital indicating controller is thoroughly factory-tested before shipment. When the controller is received, however, check visually if any external damage has occurred during shipment. Confirm that all standard accessories were supplied.

If you have any problems or questions, please contact the nearest YOKOGAWA service center or the dealer from whom the controller was purchased.

1.1 Accessories

The accessories listed in Table 1.1 should be supplied with the instrument. Check that nothing is missing.

Table 1.1

Accessories	
1. Mounting Bracket	2 pcs.
2. Instruction Manual, Reference Manual	2 copies
(When RS-422 is attached, a copy of relevant instruction manual is supplied with the instrument)

Figure 1.1 External View of UT30

2. GENERAL

2.1 Description

The Model UT30 Digital indicating controller continuously indicates process variable and set point on the two high precision digital display windows, and the bar-graph indicator displays output or deviation.

The UT30 can support direct input signal of thermocouple or RTD (Resistance temperature detector), or DC voltage/current signal (0 to 10 mV, 4 to 20 mA). Because the multirange signal system is used, the input types and ranges may be set arbitrarily by the user.

When a DC voltage/current signal is input, it can be converted into actual physical quantity by scaling function and displayed. By applying one-tip microprocessor, a variety of functions such as automatic tuning, multi-gain, output/set limiter, and output velocity limiter, etc. are provided with standard version. Transmission or communication function (RS-422) for measured values, set point or output values may be selected optionally.

A plenty of functions are provided with this controller. For general use, the controller can be operated immediately after setting the measuring range, alarm set points and PID constants. Use other functions as required.

3. CLEANING CAUTIONS

Never attempt to clean the front panel or key switches with a solvent such as alcohol or benzene.

4. INSTALLATION

4.1 Installation Area

Select an installation area which:

- (1) Is free from mechanical vibration.
- (2) Is free from corrosive gases.
- (3) Has minimum temperature variation (area near normal temperature 23°C is preferable).
- (4) Is not subject to strong heat radiation.
- (5) Is free from strong magnetic fields.

4.2 Mounting

- (1) The controller should be mounted on a at least 2 mm thick steel panel
- (2) Insert the controller into the panel cutout.
- (3) Hold the bottom of the controller and mount it on the panel using the mounting bracket supplied with the controller. In this case, do not fasten the bracket, excessively.

4.3 External Dimensions and Panel Cutout

Figure 4.1 UT30 External Dimensions

5. TERMINAL WIRING DIAGRAM

Table 5.1 Table of UT30 Terminal Assignment

Input Terminals	1 2 3	+ - TC	mV/V Input
	1 2 3	A B b	RTD input
	1 2 3	- +	Current input
Power & Ground Terminals	31 25 36	L1 L2 ⊥	90 to 132 V or 180 to 250 V (must be specified) Ground 50/60 Hz
Alarm Terminals	27 21 32	A1 A2 COM.	Normal (deenergized) open Alarm close (common)
Fail Signal Terminals	28 33	FAIL COM.	Normal (energized) close Deenergized or FAIL open (common)
External Setting input Terminals	4 5	+ -	4 to 20 mA DC
Feedback Resistance Input Terminals	10 16 18	100% 0%	(position proportional output)
External L/R selector Terminals	6 7		When terminals between 6 and 7 close, remote setting (remote setting preferential) When terminals between 6 and 7 open, internal setting
Output Terminals	23 29 34	+ - -	Current Voltage Voltage pulse Output
	23 29 34	NO* (normal open) COM. (common) NC* (normal close)	Contact output
	23 29 34	H CON L	Direct revolution Reverse revolution Motor operated valve contact output (Position pro- portional output)
Transmission Signal terminals	8 14	+ -	PV transmission or SP transmission (option)
Communi- cation Terminals	8 14 9 15 11 19	TX + TX - RX + RX - SG FG	RS-422 (Option)

6. WIRING

Wire the controller as per Chapter 5 controller terminal arrangement and observe the following instructions.

- (1) For thermocouple inputs, use the specified extension wires.
- (2) For RTD inputs, use the wires with low lead wire resistances and with no resistance differences between three wires.
- (3) Use 600 V vinyl insulated wire (JIS C3307) or equivalent or tough vinyl sheathed cable for power supply and its wiring.
And insert a noise filter in the power supply circuit if required.
- (4) The ground terminal should be grounded with a low ground resistance of up to 100 ohms using a wire whose sectional area is 2 mm² or more.
- (5) To minimize noise pickup in input circuit,
 - (a) The measuring circuit wiring should be run as remote as possible from the power and ground lines.
 - (b) It is recommended that shielded wires be used to minimize noise pickup from an electrostatic induction source.
The shielding wire of the cable should be connected to the controller ground terminal (only one ground line).
 - (c) To minimize noise from an electromagnetic induction source, twist measuring line cables in short and equal spaces.
- (6) It is recommended that solderless "crimp-on" lugs (for 3.5 mm, see Figure. with insulation sleeves, be used for leadwire ends.

CAUTION

- (1) Since neither fuse nor power switch is provided with the controller, provide them on back of the mounting panel if required.
- (2) Remote setting input circuit and measuring input circuit are not isolated each other in the instrument.
- (3) For relay contact output exceeding contact rating (250 V AC 3 A resistive load), the load should be turned ON/OFF using an auxiliary relay.
- (4) When an inductive load such as an auxiliary relay is used for relay contact output, connect a CR filter (when AC power is used) or a diode (when DC power is used) parallel to the load for quenching spark.

• DC Relay

• AC Relay

7. DISPLAY

7.1 Indicator Lamps

The following indicator lamps are provided with the controller.

No.	Indicator Lamp	Description
①	AL1 (Alarm 1)	Lights when alarm 1 occurs
②	AL2 (Alarm 2)	Lights when alarm 2 occurs
③	REM (Remote)	Lights in remote setting mode
④	MAN (Manual)	Lights in manual operation mode
⑤	STOP (stop)	Lights in operation stop mode
⑥	D.A (Data access)	Lights during data setting and flashes during tuning
⑦	□, □	Valve position lamps

7.2 Operation Panel

When the power supply is applied to this controller, the initial (1st) panel is displayed.

There are four operation panels including the initial panel.

When operating the controller, select any one of the operation panels.

Bar-graph displayed on the first or second panel is

- Deviation: Full scale corresponds to $\pm 10\%$ Output: Full scale corresponds to 0 to 100%

For position proportional output, the output on the first or second panel displays valve opening.

On the fourth panel, computation output is displayed.

To Initial (1st) Panel

*1: In manual operation mode (MAN), only these panels (1st & 2nd) are indicated.

Bar-graph Display

Displays Output value (OUTPUT) or Deviation (DEV). The bar-graph consists of 11 segments.

- When output value is displayed on the bar-graph, all the 11 segments are used for 0 to 100% display.

- When Deviation (DEV) value is displayed on the bar-graph, the 9 segments are used for -10 to $+10\%$ display.

8. CONTROL

8.1 Control Keys

Here explains the control keys provided with the controller.

No.	Key Name	Description
(A)	Set Key	This key is used to display and change target set point (SP), alarm set points (A1 and A2), ratio (RT) and bias (BS). However, ratio and bias are optional.
(B)	Reverse Key	Together with key or key, this key is used when the data numerical value is to be reduced or when a parameter item is desired to be returned to the previous setting item. This key is also used to manipulate output in manual operation mode.
(C)	Data Setting Key	These keys are used when various data are manually set or changed on a keyboard. key is used to change the least significant digit of the data to be set. key is used to change the second digit from the right most digit and key is used to change the third digit from the right most digit. Each time any of these keys is pressed, the relevant digit changes one step, and if pressed continuously the relevant digit changes continuously carry or down also possible. While pressing key, if any of these keys is pressed, the relevant digit decreases. These keys are also used for manipulating output in manual operation mode.
(D)	Auto/Manual Key	This key is used to switching Auto/Manual mode.
(E)	MODE Key	This key is used to specify Tuning, Local setting/Remote setting or Operation start/stop mode.
(F)	Parameter Key	This key is used to set various parameters.
(G)	Display Key	This key is used for the following usages. 1) Operation panel switching. 2) When operation panel is transferred from data setting, mode selection or parameter setting mode. 3) When auto-tuning is halted on the way (press key simultaneously).
(H)	Entry Key	This key is used as follows. <ul style="list-style-type: none"> • When data is to be registered for various data setting. • Execution command for automatic tuning. • Local setting/Remote setting selection. • Operation start/stop selection.

8.2 Rules of Key Operation

Instructions for Key Operation

- When setting various data or selecting modes, be sure to press **ENT** key to execute registration (for manual output only, **ENT** key is not required to be pressed).
- When **SET**, **A/M**, **MODE** or **PARA** key is used, always start from the operation panel, or press **DSP** key once to return to the initial panel. For example, during parameter setting, even when **MODE** key is pressed for mode selection the controller does not operate.
- Pressing **DSP** key causes the any displaying panel to return to the operation panel (initial panel).
- To reduce the data numerical value, press data setting key while pressing **RVS** key. To reverse parameter item sequence, press **PARA** key while pressing **RVS** key.

8.3 Key Operation for Data Entry

The procedures for entering target set point and parameter data by key operation are common as follows:

Display Example	Operation
	First, display the setting item required. When the setting item is displayed, the D.A lamp lights.
	Using ENT , ↑ , ↓ and RVS keys, enter numeric values. Flashing of period indicates that the display is the data entered by key operation.
	Press ENT key to register the data. Flashing of period halts. Control using the new set point is performed.

8/25/89

9. SETTING

9.1 Setting Flow Chart

- According to the setting flow chart shown below, set the controller various parameters.
- If a measuring range was specified beforehand, the ranging parameters (PC=10) already set have been locked in a file (the password is set to 100).
- When the items shown on this page and measuring range code are set, the controller can initiate operation (see Note below).
- Set the ranging parameters (PC=10), setup parameters (PC=20) and gain parameters (PC=30) if required (if not specified, the controller is operated using the values— see in the parameter lists— set at the factory before shipment).
- Only for the position proportional type model, the mode parameters PC=40 must be set.

P = 175

I = 6

d = c

Ar 50.0

014 100

04 = 0.0
70 = 0.0

Note: Setting measuring range modifies the other target set points or parameter numerical values set previously, so when the measuring range is set, check the values of other setting items.

- (Note 1) When $H0$ (H capital letter) is displayed, press $\overline{ENT}$ key to display $h0$ and reset valve position.
- (Note 2, 3) When the valve is set to 0% or 100% position, operate the valve by key operation or manually.
- (Note 4) Confirm that $H2=100$, then position the valve at 0% to confirm that $H2=0$.

9.2 Parameter Lists

This section describes various parameters to be set on the controller. Refer to the separate. Reference manual for detailed parameter information.

Note: For setting ranges and units, the controller uses special expressions as follows:

EU: Display in engineering unit

EU(): Display in engineering unit corresponding to full scale (unit at scaling for °C, °F or linear input)

Example: For full scale –200 to 1200°C, EU(5%) is –130°C

EU()S: Display in engineering unit corresponding to span

Example: For full scale –200 to 1200°C, EU(5%) is 70°C

9.2.1 Setting Target Set Point, Alarm, Ratio and Bias

Symbol	Item	Unit	Setting Range	Value Set at Factory before Shipment	Description
SP	Target set point	EU	EU(0%) to EU(100%)	EU(0%)	
A1	Alarm set point 1	EU	EU(0%) to EU(100%)	EU(100%)	See F3 and F4 of setup parameter (PC=20)
A2	Alarm set point 2	EU	EU(0%) to EU(100%)	EU(0%)	
RT	Ratio	Fold	0.000 to 9.999	1.00	
BS	Bias	EU	EU(–105%) to EU (105%)	0.0	

9.2.2 Setting Parameters

For the model whose range was specified when ordering, by setting parameters from proportional band [P] to tuning code [TC] shown in the following basic parameter list, the controller may be operated. (At this time, for the ranging parameters (PC=10), setup parameters (PC=20), gain parameters (PC=30) valve position control modes (PC=40) and file lock code (PC=password), the values set at the factory before shipment were kept.)

Fundamental Parameters

Symbol	Item	Unit	Setting Range	Value Set at Factory before Shipment	Description
P	Proportional band	%	0, 0.1 to 999.9	100.0	0: ON/OFF operation
I	Integral time	sec	0, 1 to 6000	0	0: OFF
D	Derivative time	sec	0, 1 to 6000	0	0: OFF
MR	Manual reset value	%	-5.0 to 105.0	50.0	Used in P or PD action
OH	Output high limit value	%	$-5.0 \leq OL$	100.0	
OL	Output low limit value	%	$< OH \leq 105.0$	0.0	
CT	Cycle time	sec	1 to 100	10	Displayed only by relay output voltage pulse output type controller
TC	Tuning code	—	0, 1, 2	2	0: No automatic tuning 1: For process apt to generate hunting 2: For general process
PC	Parameter call code	—	0, 10, 20, 30, 40, password	0	(Note 1)
LC	Key lock code	—	0 to 4	0	(Note 2)

Note 1: Parameter Call Code

PC Code	Parameter That Can be Called	Object of Parameter
10	Ranging parameter	Measuring range setting, Scaling of linear input
20	Setup parameter	Adding enhanced functions
30	Gain parameter	Correcting process loop gain
40	Valve opening control mode	Valve opening/closing position control
Password	File lock code	A man who does not know the password is inhibited to change important parameters

Note 2: Key Lock Code

By setting this code, the following keys can be locked.
Only the key lock code can be displayed or changed even when key is locked.

LC Code	Keys That Can be Locked
0	None
1
2	,
3	, ,
4	, , ,

Ranging Parameters

Be sure to set measuring range code (U0) unless it was specified when ordering.

Symbol	Item	Unit	Setting Range	Value Set at Factory before Shipment	Description
U0	Measuring range code	—	000 to 215	TC DC voltage } : 131 DC current } RTD : 201	(See Note 3, 4)
U1	Linear range decimal point	—	0, 1, 2, 3	1	0: 0 to 9999 1: 0.0 to 999.9 2: 0.00 to 99.99 3: 0.000 to 9.999
U2	Linear range high limit value	EU	$-1999 \leq U3$ $< U2 \leq 9999$	100.0	$U2 - U3 \geq 1000$
U3	Linear range low limit value	EU		0.0	
U4	Remote setting input range code	—	050 (Fix)	050	4 to 20mA DC input
U5	Temperature display unit symbol	—	0, 1, 2	0	0: °C 1: °F, 2: No unit
U6	Measured value extraction of square root ON/OFF	—	0, 1	0	0: OFF 1: ON
U7	Measured value low cut	%	0.0 to 5.0	1.0	Percentage for measured value
U8	Remote set point extraction of square root ON/OFF	—	0, 1	0	0: OFF — 1: ON
U9	Remote set point low cut	%	0.0 to 5.0	1.0	Percentage for remote set point

Note 3: Measuring Range Codes

Input Type (Range)				Measuring Range Code
Thermo-couple	R	0 to 1700°C	32 to 3100°F	100
	S	0 to 1700°C	32 to 3100°F	110
	B	0 to 1800°C	32 to 3300°F	120
	K	0 to 800°C	32 to 1500°F	130
	K	-200 to 1200°C	-300 to 2300°F	131
	E	0 to 800°C	32 to 1500°F	140
	J	0 to 800°C	32 to 1500°F	150
	L	0 to 800°C DIN	32 to 1500°F	151
	T	-199.9 to 400.0°C	-300 to 750°F	160
	U	-199.9 to 400.0°C DIN	-300 to 750°F	161
	N	0 to 1300°C	32 to 2400°F	170
	W	0 to 2300°C	32 to 4200°F	180
mV mA		0 to 10 mV	-1999 to 9999	-000
		-10 to 10 mV	Scaling possible	001
		0 to 100 mV	(decimal point may be changed)	010
		-100 to 100 mV		011
		4 to 20 mA		050
DCV (option)		0 to 1 V	-1999 to 9999	020
		-1 to 1 V	Scaling possible	021
		0 to 5 V	(decimal point may be changed)	030
		1 to 5 V		031
		0 to 10 V	(option)	040

Above table applies to the Model code UT30-1□□.

Note 4: Measuring Range Codes

Input Type (Range)			Measuring Range Code
*JPt100	0.0 to 100.0°C	32.0 to 212.0°F	200
	0.0 to 200.0°C	32.0 to 400.0°F	201
	0.0 to 400.0°C	32.0 to 750.0°F	202
	-50.0 to 150.0°C	-50.0 to 300.0°F	203
	-100.0 to 100.0°C	-150.0 to 212.0°F	204
	-199.9 to 500.0°C	-300 to 1000°F	205
*Pt100	0.0 to 100.0°C	32.0 to 212.0°F	210
	0.0 to 200.0°C	32.0 to 400.0°F	211
	0.0 to 400.0°C	32.0 to 750°F	212
	-50.0 to 150.0°C	50.0 to 300.0°F	213
	-100.0 to 100.0°C	-150.0 to 212.0°F	214
	-199.9 to 500.0°C	-300 to 1000°F	215

Above table applies to the Model code UT30-2□□.

• JIS '89 Pt100/DIN, JIS '89 JPt100

Setup Parameters PC=20

Setup parameters provide the more enhanced functions with the controller. Operate the controller without setting these parameters unless it is required (in this case, the controller is operated using the values set at the factory before shipment).

Symbol	Item	Unit	Setting Range	Value Set at Factory before Shipment	Description
E0	Measurement input correction	EU	EU(-5%)S to EU(5%)S	EU(0%)S	
E1	Remote setting bias	E1	EU(-30%)S to EU(30%)S	EU(0%)S	
E2	Output velocity limit	%/s	0, 1 to 100	0	0 means OFF
E3	Setting high limit value	EU	EU(0%)≤E4 <E3≤EU(100%)	EU(100%)	Available measuring range of object set point (SP) is specified.
E4	Setting low limit value	EU		EU(0%)	
E5	Set point ascending velocity	EU/Min	EU(0%)S to EU(100%)S	EU(0%)S	EU(0%)S means OFF
E6	Set point descending velocity	EU/Min	EU(0%)S to EU(100%)S	EU(0%)S	EU(0%)S means OFF
E7	Measurement input filter	s	0, 1 to 120	0	First order lag 0 means OFF
E8	Remote setting input filter	s	0, 1 to 120	0	First order lag 0 means OFF
E9	Integration control point	%	0, 10 to 150	100	0 means OFF
F0	Preset output	%	-5.0 to 105.0	0.0	Set output value at burn out or operation stoppage
F1	Alarm gap	EU	EU(0%)S to EU(5%)S	EU(0.5%)S	
F2	Output value ON/OFF gap	EU	EU(0%)S to EU(5%)S	EU(0.5%)S	At ON/OFF control
F3	Type of alarm 1	—	0 to 8	1	See Note 5
F4	Type of alarm 2	—	0 to 8	2	
F7	Dead band	%	1 to 10 for valve opening span	1	Display available only for position proportional output.
F8	Position proportional output ON/OFF gap	%	0.1 to 0.5 for valve opening span	0.1	Display available only for position proportional output.
Y1	Transfer output selection (when/RET is used)	—	0, 1, 2, 3, 4	0	0: Measured value (corresponds to range) 1: Set point (corresponds to range) 2: Output value 3: Measured value (corresponds to E4 to E3) 4: Set point (corresponds to E4 to E3)
Y2	Direct/reverse operation	—	0, 1	0	0: Reverse operation 1: Direct operation
Y3	Restart mode		0, 1, 2	0	0: Status before power failure is kept 1: Manual operation 2: Operation is halted
Y4	Set point tracking selection	—	0, 1	0	When switching from local to remote mode. 0: Local set point performs tracking to remote set point. 1: Local set point does not perform tracking to set point.
C0	Baud rate	—	0 to 6	6	See Note 6 (when/RS422 is used)
C1	Parity	—	0, 1, 2	0	
C2	Stop bit plus transfer bit length	—	0, 1, 2, 3	2	
C3	Communication address	—	1 to 16	1	

Note 5: Types of Alarms

Code	Content * ¹	Contact * ²
0	Alarm off	Open
1	Measurement input high limit alarm	Open
2	Measurement input low limit alarm	Open
3	Positive deviation high limit alarm * ³	Open
4	Negative deviation low limit alarm	Open
5	Positive deviation high limit alarm	Close
6	Negative deviation low limit alarm	Close
7	With stand-by function in 2 * ⁴	Open
8	With stand-by function in 4 * ⁴	Open

*1: When measured value is greater than alarm setpoint, alarm lamp is on for high limit alarm, and vice versa for low limit alarm.

*2: Status in normal operation (alarm lamp is off)

*3: Setting unit in deviation alarm is EU () S.

*4: The alarm function does not operate immediately after turning the power on, but once low limit alarm point is exceeded the alarm function is activated.

Note 6:

Code Item	0	1	2	3	4	5	6
C0	150	300	600	1200	2400	4800	9600
C1	Non-parity	Even	Odd	—	—	—	—
C2	1+7	2+7	1+8	2+8	—	—	—

(Refer IM 5B4B3-10E)

Gain Parameters PC=30

Gain parameters provide the more enhanced functions with the controller.

Operate the controller without setting these parameters unless it is required (in this case, the controller is operated using the values set at the factory before shipment).

Symbol	Item	Unit	Setting Range	Value Set at Factory before Shipment	Description
G0	Gain at measured value 0%	%	0 to 500	100	11 types total
G1	Gain at measured value 10%				
.	.				
.	.				
GA	Gain at measured value 100%				

Valve Opening Control Modes PC=40

This valve position control mode setting must be performed only for the position proportional output type model.

Symbol	Item	Unit	Setting Range	Value Set at Factory before Shipment	Description
H0	Reset valve position setting	—	Valve position	—	Set the valve positions 0% and 100% already controlled to the positions before the valve is controlled.
H1	Valve closed position setting	—	Valve position	—	Setting for 0% position
H2	Valve full open position setting	—	Valve position	—	Setting for 100% position

Note: When H0, H1 or H2 is displayed

“ H ” or “ h ” means as follows:

H : controlled status

h : uncontrolled status

File Lock Code PC=password

Symbol	Item	Unit	Setting Range	Value Set at Factory before Shipment	Description
FL	File Lock Code	—	0, 1, 2	0	Parameter to be locked 0: None 1: PC=10 2: PC=10, 20, 30, 40

10. OPERATION

10.1 Auto/Manual (Operation) Transfer

While displaying an operation panel, by pressing $\overline{A/M}$ key, the automatic and manual operation modes may be selected alternately (balanceless, bumpless transfer).

In manual mode, the MAN lamp lights.

For the output operation in manual operation mode, use the data setting keys ($\overline{\Delta}$, $\overline{\nabla}$ and $\overline{\square}$) and reverse key ($\overline{RVS}$). It is not necessary to press $\overline{ENT}$ key for the data registration.

The manual operation mode was set at the factory before shipment.

10.2 Mode Transfer

(Auto tuning, local setting/remote setting, operation start/stop transfer).

Mode Transfer Sequence

Note 1: While a "." is in flashing status, if $\overline{ENT}$ key is pressed the mode is transferred and the panel returns to the initial panel.
If $\overline{DISP}$ key is pressed, the panel returns to the initial panel in the current mode.

Note 2: In manual operation mode, automatic tuning is not executed when tuning code is 0 or operation is halted.

Note 3: When external contact for local/remote transfer is close, local/remote transfer using key is disabled.

Note 4: The tuning code was set to 2, and local setting operation mode was selected at the factory before shipment.

10.2.1 Execution of Auto-tuning

Auto-tuning is the controller functions to measure process characteristics and to set the PID constants automatically. When auto-tuning is executed, the instrument turns ON/OFF controller to deliver maximum*¹ and minimum*² outputs alternately. By catching the change in measurement input value corresponding to these outputs, PID constants suited for the controlled process are computed and automatically updated.

*1 100% or output high limit value (OH), however, 100% only for the relay output or voltage pulse output model.

*2 0% or output low limit value (OL), however, 0% only for the relay output or voltage pulse output model.

Two types of computed PID constants are selected by the auto-tuning code [TC] (for fundamental parameters, refer to paragraph 9.2.2).

CAUTION

Don't apply auto-tuning for the process such as described below.

- (1) Process with quick response such as flow rate or pressure process.
- (2) Process which is greatly disturbed even by temporary ON/OFF output signal from the controller.

Display Example	Operation
<p>Press MODE key once to display the panel shown on the left. When auto-tuning is executed, press ENT key. Pressing ENT key, initiates D.A lamp flashing and operation panel 2 is displayed. When tuning complete, D.A lamp is off and the panel returns to the initial panel</p> <p>Note: During auto-tuning, key operation is disabled. If tuning is to be stopped, press RVS and DSP keys at the same time. In this case, control is continued using PID constants just before starting the tuning.</p>

10.2.2 Local Setting/Remote Setting Transfer

- When local setting mode is transferred to remote setting mode, the setpoint may be changed slowly using the setpoint ascending velocity (E5) or setpoint descending velocity (E6).
- When remote setting mode is transferred to local setting mode, all remote set values turn local set values or local set values just before starting remote operation.
- Using an external contact, local setting mode may be transferred to remote setting mode and vice versa.

(In the remote setting mode (external contact is close), transfer by key operation is disabled.)
The panel returns to the initial panel.

Display Example	Operation
<p>Press MODE key twice. (Panel shows the case transfer from local setting mode to remote setting mode.)</p> <p>Press ENT key to execute transfer and the panel returns to the initial panel.</p>

10.2.3 Operation Start/Stop Transfer

- In operation stop status, the controller output is fixed to the preset output value (F0), and it cannot be changed manually.
- In operation stop status, the output is not changed even when various parameters are set or changed.

Display Example	Operation
<p>The display shows 'PV' followed by '24.5' in a large digital font. Below this, there is a smaller display showing 'STOP' in a digital font. An arrow points to the 'STOP' display with the label 'Flashes'.</p>	<p>Press key three times. (Panel shows the case transfer from operating status to operation) stop status.)</p> <p>Press key to execute transfer and the panel returns to the initial panel.</p>

10.3 Manual Operation for Position Proportional Output Model

When the MAN indicator lamp lights, the relay contacts (H and L) can be operated. Press one of the keys , and to close the relay contact (H) (valve open state).

Press one of the keys , and while pressing the key to close the relay contact (L) (valve closed state).

When none of the keys , and is pressed, each contact is at neutral position.

11. MAINTENANCE

11.1 Troubleshooting

When the power supply is applied to this controller, if the operation panel is not displayed, follow the troubleshooting flow sequence shown below, and find a suitable remedy for the problem.

However, if a complicated problem does occur, please contact the dealer from whom the controller was purchased or the nearest YOKOGAWA service center.

11.2 Self Diagnostic Function

Each time the power supply is turned on, the controller automatically performs an internal check for abnormalities. When the power is turned on, the controller checks such items sequentially as shown in Table 11.1, and if any abnormality is found, the controller displays the abnormality type (in normal state, the Initial panel is displayed).

Table 11.1

	Item	Symptom	Display Example	Remedy
①	RAM failure	RAM cannot read or write	E000 appears then disappears	Contact the dealer from whom the controller was purchased or the nearest YOKOGAWA service center. Note: When of the items ①, ② and ④ occurs, the output is zero and the fail signal terminals are open concurrently. For the position proportional output model, the output turns neutral in failure. If ③ occurs, the preset output value is output.
②	ROM failure		E001 appears then disappears	
③	Request for calibration	Calibration data is destructed	rcAL	
④	CPU failure		Does not update	

11.3 Other Abnormality Display List

Abnormal Status	Display Example	Action
PV input disconnection	b.011t	Preset output value (in auto mode) is obtained for output. Check thermocouple and its connection.
PV input overflows Positive side Negative side	08r -08r	Adjustment is continued at PV limit value. Check if the setting PV input range is proper or PV input connection is correct.
Reference junction compensation error	r11	Adjustment is continued to be output with the reference junction compensation neglected. Repair is required.
Auto tuning error	E200	Control is continued using the PID values set before auto tuning (use $\overline{\text{RVS}}$ key to erase E200 display). Reperform auto tuning, if the error reappears, the control seems be outside of the possible tuning range, so set the PID values in manual mode before use.
A/D converter error	E300	Control turns into manual mode and the output now is maintained. Repair is required.

**SERIES
1800**

Low Differential Pressure Switches for General Industrial Service

Compact, economically priced switches in 8 standard ranges. Set points from 0.15" to 85" W.C. Repetitive accuracy within 2%. U.L. and C.S.A. listed, F.M. approved.

Model 1823 pressure switch. U.L. and C.S.A. listed, F.M. approved.

Series 1823 pressure switch. Conduit enclosure removed to show electric switch.

Construction and dimensions. Series 1823 pressure switches.

One of our most popular pressure switches. Combines small size and low price with 2% repeatability for enough accuracy for all but the most demanding applications. Set point adjustment inside the mounting spud permits mounting switch on one side of a wall or panel with adjustment easily accessible on the opposite side.

U.L. and C.S.A. listed, F.M. approved.

***Model 1823 shown; (1823 replaces 1820, 1821 and 1822 which are similar).**

Environmental (MIL) Switch

Unlisted Model 1820 can be furnished with special snap switch sealed against the environment for temperatures down to -65° F., high humidity and/or for government applications. Similar to standard Model 1823 except dead band is slightly greater. Specify Model 1820 (Range No.) "MIL" in ordering.

Weatherproof Enclosure

16 ga. steel enclosure for unusually wet or oily conditions. Withstands 200 hour salt spray test. Gasketed cover. Weight 5½ lbs. Switch must be installed at factory. Specify "WP" in addition to switch catalog number.

Explosion-Proof Housing

Cast iron base and aluminum dome cover. Approximate weight 7½ lbs. Specify "EXPL" in addition to switch catalog number.

PHYSICAL DATA

Temperature limits: -30°F for dry air or gas to 180°F.

Maximum surge pressure: 25 psig

Rated pressure: 10 psig.

Pressure connections: ½" NPT.

Electrical rating: 15 amps, 120-480 volts, 60 Hz. A.C. Resistive ½ H.P. @ 125 volts, ¼ H.P. @ 250 volts, 60 Hz A.C. See INSTALLATION for derating information above 130° F.

Wiring connections: 3 screw type, common, normally open and normally closed.

Set point adjustment: Screw type inside mounting spud.

Housing: Aluminum die casting. Steel fittings zinc plated, dichromate dipped for 200 hour salt spray test.

Diaphragm: Silicone rubber on nylon with aluminum support plate.

Calibration Spring: Stainless steel.

Mounting spud: ½" pipe thread.

Weight: 1 lb., 5 oz.

Installation: Diaphragm vertical.

SERIES 1823 SWITCHES: OPERATING RANGES AND DEAD BANDS. U.L. and C.S.A. Listed, F.M. Approved.

Model Number	Operating Range Inches, W.C.	Approximate Dead Band	
		At Min. Set Point	At Max. Set Point
1823-0	0.15 to 0.5	0.06	0.06
1823-1	0.3 to 1.0	0.08	0.08
1823-2	0.5 to 2.0	0.10	0.12
1823-5	1.5 to 5.0	0.14	0.28
1823-10	2.0 to 10	0.18	0.45
1823-20	3 to 22	0.35	0.70
1823-40	5 to 44	0.56	1.1
1823-80	9 to 85	1.3	3.0

Suggested Specification

Differential pressure switches shall be diaphragm operated with 4" diaphragm to actuate a single pole double throw snap switch. Motion of the diaphragm shall be restrained by a calibrated spring that can be adjusted to set the exact pressure differential at which the electrical switch will be actuated. Motion of the diaphragm shall be transmitted to the switch button by means of a direct mechanical linkage. Switches shall be Dwyer Instruments, Inc. Catalog No. 1823-_____ for the required operating ranges.

How to Order: See price list, Bulletin S-26.

SERIES 1823 DIFFERENTIAL PRESSURE SWITCHES

Specifications – Installation & Operating Instructions – Parts List

Dwyer**INSTALLATION AND OPERATION****INSTALLATION**

1. Select a location free from excessive vibration where oil or water will not drip upon the switch and where ambient temperature will not exceed 130°F. See special housings for unusual conditions.
2. While not required, positioning the pressure connections down is recommended. Mount the switch with the diaphragm in a vertical plane. Must be recalibrated for each change in operating position.
3. Connect switch to source of pressure differential. Metal tubing with 1/4" O.D. is recommended but any tubing system which will not restrict the air flow unduly is satisfactory. Note that the low pressure connection may be made to the 1/2" stud at the back of the switch if desired. If so connected, drill 1/16" diameter holes in the Spring Retainer flange (PN 1823-309) and the head of Adjustment Screw (PN 1823-289) to provide opening to the switch interior and plug the other low pressure connection.
4. Electrical connections to the standard single pole, double throw snap switch are provided by means of screw terminals marked "common", "norm open", and "norm closed". The normally open contacts close and the normally closed contacts open when pressure increases beyond the set point.
5. Switch loads should not exceed the maximum specified current rating of 15 amps resistive. Switch capabilities decrease with an increase in ambient temperature above

130°F, high load inductance, or rapid cycle rates. Whenever an application involves one or more of these factors, the user may find it desirable to limit the switched current to 10 amps or less in the interest of prolonging switch life.

ADJUSTMENT

1. If the switch has been factory preset, check the set-point before placing in service to assure it has not shifted in transit.
2. If switch has not been preset or if it is desired to change the set point, observe the following procedure:
 - a. To adjust the set point turn the slotted Adjustment Screw (PN 1823-289) clockwise to increase the set point and counter-clockwise to decrease the set point.
 - b. Important Note. The following is a recommended procedure for calibrating or checking calibration: Use a "T" assembly with three rubber tubing leads, all as short as possible and the entire assembly offering minimum flow restriction. Run one lead to the pressure switch, another to a manometer of known accuracy and appropriate range, and apply pressure through the third tube. Make final approach to the set point slowly. Note that manometer and pressure switch will have different response characteristics due to different internal volumes, lengths of tubing, oil drainage, etc. Be certain switch is checked in position it will assume in use, i.e., vertical, horizontal, etc.

CROSS SECTIONAL VIEW

Part No. Name

1823-005	Conduit Enclosure (1)
1823-022	Switch Body Assembly – Aluminum Die Casting Diaphragm Assembly .008" Silicone on Nylon and Aluminum Assembly Ring (1)
1823-035	"O" Ring 1/2" X 5/8" (1)
1823-077	Mounting Nut – 1/2" Electrical Nut – Steel (1)
1823-078	Conduit Cover Assembly (1)
1823-091	Conduit Enclosure Fasteners – Tinnerman Speed Nut (4)
1823-093	Retaining Ring (1)
1823-109	Calibration Spring – Stainless Steel (1)
1823-199	Insulation Shield – 1/32" Thick Hard Fibre (1)
1823-200	Switch Button – Nylon (1)
1823-242	Micro-Switch #BZ-RW84-A2
1823-266	Mounting Washer – 1-5/32" O.D. X .844" I.D. – Steel (2)
1823-289	Calibration Adjustment Screw (1)
1823-309	Calibration Spring Retainer – Brass (1)
1823-490	Switch Bracket – Steel (1)
1823-1H	#6-32 X 1 Steel Screw #6L Brass Washer #6-32 Lock Nut
1823-2H	#6-32 X .5/16" Steel Screw

When corresponding with the factory regarding 1800 series switch problems, please refer to the call-out numbers in this view to assure proper identification. Be sure to include the operating range and any optional features. Field service is not recommended. Contact the factory for service information.

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Boston Gear

Ratiotrol®

DC MOTOR SPEED CONTROL

BETA

INSTALLATION AND OPERATING MANUAL BETA

FOR

BETA RB SERIES RATIOTROL 1/12 - 2 HP

BOSTON GEAR

An Imo Delaval Company

IMO

QUINCY, MASS. U.S.A.

RATIOTROL BETA SINGLE-PHASE ADJUSTABLE-SPEED DC MOTOR CONTROLLERS

GENERAL INFORMATION

DESCRIPTION

Ratiotrol Beta controllers statically convert single-phase AC line power to regulated DC for adjustable-speed armature control of shunt-wound and permanent-magnet motors. The controllers are Underwriters Laboratories Listed.

ENCLOSURE

Totally enclosed, non-ventilated, constructed of rugged die-cast aluminum alloy. Gasketed, screw fixed cover excludes contaminants. Provision for conduit entry is included top and bottom by two (2) 3/4-14 NPT tapped holes. Standard unit is easily and inexpensively convertible to NEMA Type 3, 4 or 12.

MODEL TYPES

Table 1. RATIOTROL BETA MODEL MATRIX

MODEL	FUNCTION			CONFIGURATION		OPERATOR CONTROLS		POWER SOURCE AND HORSEPOWER RANGE	
	UNIDIRECTIONAL RUN - STOP	ARMATURE SWITCH REVERSING	ARMATURE CONTACTOR REVERSING AND D. B.	OPEN CHASSIS	ENCLOSED	LOCAL (INTEGRAL)	REMOTE (*)		
								115VAC 50/60 Hz	230VAC 50/60 Hz
RB1	X			X			X	1/12 - 1HP	N/A
RB1B	X				X		X		
RB1S	X				X	X			
RB1R		X			X	X			
RB2*	X			X			X	RECONNECTABLE UNITS	
RB2B	X				X		X		
RB2S	X				X	X		115VAC 50/60 Hz	230VAC 50/60 Hz
RB2R		X			X	X		1/12 - 1HP	3/4 - 2HP
RB3			X	X			X		
RB3B			X		X		X		
RB3R			X		X	X			

*Operator controls provided by user

OPERATOR CONTROLS

Table 2. OPERATOR CONTROLS

CONTROLLER SUFFIX	OPERATOR CONTROLS
B or no Suffix	None
S	1. RUN/STOP Switch – 2 maintained positions 2. MOTOR SPEED Pot – 5K ohm, 1/2 watt
R (RB1, 2)	1. RUN/STOP Switch – 2 maintained positions. 2. FWD/REV Switch – 3 maintained positions with center detent position for antiplug protection. 3. MOTOR SPEED Pot – 5K ohm, 1/2 watt
R (RB3 only)	1. RUN/STOP Switch – 2 maintained positions 2. FWD/REV Switch – 2 momentary positions with return to center 3. MOTOR SPEED Pot – 5K ohm, 1/2 watt

RATINGS

1. Service Factor 1.0
2. Duty Continuous
3. Overload Capacity 150% for 1 minute
4. AC Line Fuse Interrupting Capacity 5000 amperes

Table 3. RATINGS

COMPONENT			RATED HORSEPOWER								
			1/12	1/6	1/4	1/3	1/2	3/4	1	1 1/2	2
1-PHASE 50 OR 60 H _z AC INPUT (FULL LOAD)	Line Amps	115VAC Unit	2.0	3.9	5.0	6.0	8.7	12.4	15.0	—	—
		230VAC Unit	—	—	—	—	—	5.9	8.8	12.6	15.8
	KVA		.30	.48	.58	.71	1.0	1.4	2.0	3.0	4.0
DC OUTPUT (FULL LOAD)	Motor Armature Amps	90V	0.9	2.0	2.8	3.5	5.4	8.1	10.5	—	—
		180V	—	—	—	—	—	3.8	5.5	8.2	11.6
	Motor Field Amps	50V	—	1.0	1.0	1.0	1.0	1.0	1.0	—	—
		100V	—	—	—	—	—	1.0	1.0	1.0	1.0
FULL LOAD TORQUE (LB. FT.) With 1750 RPM BASE SPEED MOTORS			.25	0.5	0.75	1.0	1.5	2.2	3.0	4.5	6.0
WEIGHT LBS. (kg)	RB1, RB2		3.25 (1.48 kg)								
	RB3		3.8 (1.73 kg)								
	RB1B, RB1S RB2B, RB2S RB1R, RB2R		5.5 (2.5 kg)								
	RB3B, RB3R		6.05 (2.75 kg)								

OPERATING CONDITIONS

1. Line Voltage Variation $\pm 10\%$ of rated
2. Line Frequency Variation ± 2 Hz
3. Ambient Temperature (*) 0 C to 40 C (32 F to 104 F)
4. Altitude (standard) 3300 feet (1000 meters) maximum
 (*) 55° C (131 F) maximum in enclosed areas where RB1, RB2, or RB3 open chassis units are mounted.

PERFORMANCE CHARACTERISTICS

1. Controlled Speed Range 0 to motor base speed
2. Speed Regulation (See Table 4) — Regulation percentages are of motor base speed under steady-state conditions.
- 3. Efficiency (at maximum speed)
 - a. Controller 99%
 - b. Controller with motor 85%
4. Displacement Power Factor (Rated Speed/Rated Load) 87%
5. Acceleration (non-adjustable) By fixed ramp with current limit override
6. Current Limit (non-adjustable) 150% full-load torque (typical)

Table 4. SPEED REGULATION CHARACTERISTICS

REGULATION METHOD	VARIABLE				
	LOAD CHANGE 95%	LINE VOLTAGE $\pm 10\%$	FIELD HEATING (1) COLD/NORMAL	TEMPERATURE $\pm 10^{\circ}\text{C}$	SPEED RANGE
Standard Voltage Feedback with IR Compensation	2%	$\pm 1\%$	5-12%	$\pm 2\%$	50:1
Optional Speed (Tach) Feedback (2)	1%	$\pm 1\%$	0.2%	$\pm 2\%$	100:1

(1) Does not apply to Permanent-Magnet Motors

(2) Unidirectional Models Only

Figure 1. TYPICAL BETA ENCLOSED CONTROLLER

7. Dynamic Braking – Supplied in Models RB3, RB3B and RB3R. Provides initial braking torque and stops per minute as shown in Table 5. The dynamic braking resistor is rated for stopping a typical load when the motor load inertia does not exceed the motor armature inertia.

HIGHER INERTIA LOADS AND/OR ARMATURE VOLTAGE HIGHER THAN RATED MAY EXTEND BRAKING TIME BEYOND THE WATTAGE RATING OF THE DYNAMIC BRAKING RESISTOR.

Table 5. DYNAMIC BRAKING CHARACTERISTICS

COMPONENT	UNIT	RATED HORSEPOWER								
		1/12	1/6	1/4	1/3	1/2	3/4	1	1-1/2	2
Braking Torque %	115V	200	180	129	103	66	44	34	—	—
	230V	—	—	—	—	—	190	130	88	62
Stops Per Minute	115V	20	15	12	11	8	6	2	—	—
	230V	—	—	—	—	—	6	1	1	1

INSTALLATION AND WIRING

BE SURE TO READ ALL THE FOLLOWING INSTALLATION AND WIRING INSTRUCTIONS BEFORE INSTALLING THE CONTROLLER.

1. Unpack the controller.
2. Remove the controller front cover (if applicable) and check components in the controller. Report shipping damage to the carrier.
3. The controller can be mounted in any of four configurations, as shown in Figure 2. For panel and surface mounting, see Figure 8. For through and below panel mounting, see Figure 9.

Figure 2. SERIES BETA MOUNTING CONFIGURATIONS

4. Conduit entry is made by driving a 5/8" diameter pipe nipple, socket or similar rigid object through the conduit opening. On all models install a 3/4" x 14 conduit fitting or pipe. **NOTE: DO NOT USE A PUNCH SINCE THIS WILL LEAVE SHARP PROTRUSIONS AROUND THE OPENING.** To prevent component damage from knockout fragments, apply masking tape to the inside of the knockout before removing it.
5. Remove the proper calibration wire(s) from the controller main board with a wire cutter, as shown in Table 6 and Figure 3.

Table 6. CALIBRATION WIRES

CONTROLLER		REMOVE WIRES
115V	230V	
1/12	1/6	R9 - R14
1/8	1/4	R9 - R14
1/6	1/3	R9 - R14
1/4	1/2	R10 - R14
1/3	3/4	R10 - R14
1/2	1	R11 - R14
3/4	1-1/2	R13 - R14
1	2	None

Figure 3. MAIN BOARD CONNECTIONS

6. Be sure the main board is connected for the correct voltage. Figure 3 shows the main board connected for 230 volt operation. For 115 volt operation, the yellow and white leads on Transformer T1 connect to the 115V tabs, and the feedback jumper connects to the 90V ARM tab. **NOTE: Model RB1 Controllers are designed for 115 volt operation only.**
7. Replace the front cover (if applicable) on the chassis.
8. Mount the controller. If the controller is subjected to vibrations, it must be shock mounted. **NOTE: Never mount the controller immediately beside or above the heat-generating equipment, or directly below water or steam pipes. If the controller is mounted in an enclosure, be sure the temperature in the enclosure does not exceed 55 C.**
9. Prepare for wiring by removing the front cover (if applicable) and attaching it to the chassis as shown in Figure 4.

Figure 4.
INTERNAL VIEW BETA CONTROLLER

CAUTION

- a. SEPARATE OVERCURRENT PROTECTION IS REQUIRED BY THE NATIONAL ELECTRICAL CODE. THE USER IS RESPONSIBLE FOR CONFORMING WITH THE NATIONAL ELECTRICAL CODE AND ALL APPLICABLE LOCAL CODES WHICH GOVERN SUCH PRACTICES AS WIRING PROTECTION, GROUNDING, DISCONNECTS AND OTHER PROTECTION.
 - b. THE AVAILABLE SHORT-CIRCUIT CURRENT OF THE INPUT SUPPLY MUST BE LESS THAN 5,000 AMPERES SYMMETRICAL OR CONTROLLER DAMAGE MAY RESULT. Short circuit current can be limited by sizing the input supply transformer at 50KVA or less, or by using correctly sized current limiting fuses in the input supply to the controller.
 - c. NEVER USE POWER FACTOR CORRECTION CAPACITORS ON THE INPUT LINE TO THE CONTROLLER. These capacitors can damage the solid-state components.
10. Use # 14 AWG stranded wire and connect the line and motor wiring to Terminal Strip TB1 as shown in Figure 5. Route the wiring as shown in Figure 4.

Figure 5.
AC POWER AND MOTOR CONNECTIONS

*Motor may be either permanent magnet or shunt wound. If permanent magnet, it will not have shunt field windings.

NOTE: Connections shown in Figure 5 do not provide positive disconnect of power from the motor on Models RB1 and RB2. Model RB1 should only be connected to 115VAC power. Models RB2 and RB3 are shipped for connection to 230VAC power, but they are reconnectable for 115VAC power per Figure 3. If one side of AC line is neutral, connect that side to terminal L1.

- ## MODELS RB1, RB1B, RB2, RB2B, RB3 and RB3B

- Figure 6. CONNECTIONS MODELS RB1 & RB2**

NOTES:

- Figure 7. CONNECTIONS MODELS RB3 & RB3B**

STARTUP AND OPERATION

1. Be sure all operator switches are in STOP or in neutral center position.
2. Turn the MOTOR SPEED control pot to zero on its dial.
3. Apply AC power to the controller.

MODELS RB1, RB2, RB1B and RB2B

4. Close the run contact between Terminals 3 and 4.
5. Turn the MOTOR SPEED control pot until the motor rotates. See Notes 1, 2 and 3.

MODELS RB3 and RB3B

4. Push the RUN FWD button.
5. Turn the MOTOR SPEED control pot until the motor rotates. See Notes 1, 2 and 3.
6. Reverse Operation – Push the STOP button and then push the RUN REV button. The motor will dynamically brake to a stop and then accelerate in the opposite direction. Do not exceed the braking capabilities listed in Table 5.

MODELS RB1S and RB2S

4. Place the RUN/STOP switch in RUN position.
5. Turn the MOTOR SPEED pot until the motor rotates. See Notes 1, 2 and 3.

MODELS RB1R and RB2R

4. Place the RUN/STOP switch in RUN position.
5. Place the FWD/REV switch in FWD position.
6. Turn the MOTOR SPEED pot until the motor rotates. See Notes 1, 2 and 3.
7. Reverse Operation – Place the FWD/REV switch in REV position. If the motor load inertia exceeds the motor inertia, place the RUN/STOP switch in STOP position before changing the FWD/REV switch.

MODEL RB3R

4. Place the RUN/STOP switch in RUN position.
5. Push the FWD/REV switch into FWD position. This position is momentary. When the switch is released, it returns to the center position.
6. Turn the MOTOR SPEED pot until the motor rotates. See Notes 1, 2 and 3.
7. Reverse Operation – Place the RUN/STOP switch in STOP position and then return it to RUN position. Next, push the FWD/REV switch into REV position. This position is momentary. When the switch is released, it returns to the center position. The motor will dynamically brake to a stop and then accelerate in the opposite direction. Do not exceed the braking capabilities listed in Table 5.

NOTE: If motor rotation is opposite to that desired, stop the motor, remove the AC supply, and interchange the motor armature leads at Terminals A+ and A- in the controller.

NOTES:

If motor rotation is opposite to that desired, stop the motor, turn-off the AC supply, and interchange the motor armature leads A+ and A- in the controller.

Turn the **MOTOR SPEED** pot to zero on its dial to check minimum speed, which is normally set for zero. To readjust minimum speed, turn the MIN SPD pot on the main board. See figure 4.

The **MOTOR SPEED** pot controls forward, reverse and jog speeds from minimum speed to maximum speed.

MAINTENANCE

Maintenance consists of keeping the controller clean and dry. Refer to maintenance instructions supplied by the motor manufacturer. If the motor does not rotate, check the fuse on top of the controller. The fuse type is shown on the controller data label.

CAUTION

SUBSTITUTE FUSES CAN CAUSE CONTROLLER DAMAGE.

WARNING

BE SURE THE AC INPUT POWER IS REMOVED BEFORE WORKING ON THE CONTROLLER. High voltage within the controller can cause electric shock resulting in personal injury or loss of life.

Table 7. TROUBLESHOOTING

INDICATION	POSSIBLE CAUSE	CORRECTIVE ACTION
1. Controller fuse F1 blows when controller is turned on.	Wiring faulty, incorrect or grounded. Motor shunt field shorted or grounded. Controller shorted.	Check all external wiring terminating in the controller. Repair or replace motor. Repair or replace controller.
2. Controller fuse F1 blows when motor starts to turn.	Motor armature shorted or grounded. Shorted SCR, SCR1 or SCR2, or circuit board faulty.	Repair or replace motor. Replace circuit board or shorted SCR.
3. Controller Fuse F1 blows while motor is running.	Loose or corroded connection, or wiring faulty, incorrect or grounded. Overload. Circuit board faulty.	Check all terminal connections and wiring between the line, controller, and motor. Check motor armature current. If current exceeds controller rating, check for a mechanical overload or faulty motor. Also check shunt field current. Low shunt field current causes excessive armature current. Replace circuit board.
4. Motor does not rotate.	Wiring faulty, incorrect or grounded. Fuse F1 blown. MOTOR SPEED pot faulty. RUN/STOP or FORWARD/STOP/REVERSE switch faulty. Controller faulty.	Check all external wiring terminating in the controller. Replace F1 with exact replacement. Replace pot. Replace switch. Repair or replace controller.
5. Minimum speed excessive.	High line voltage. Shorted SCR, SCR1 or SCR2, or circuit board faulty.	Check for rated line voltage $\pm 10\%$. Replace circuit board or shorted SCR.
6. Motor does not reach top speed.	Low line voltage. Overload. Circuit board faulty.	Check for rated line voltage $\pm 10\%$. See Indication 3. Replace circuit board.
7. Unstable speed, inadequate regulation, or low torque.	Wrong calibration wire(s) removed. Motor faulty. Circuit board faulty.	See Table 6 and Figure 3. Check motor commutator and brushes. Refer to motor manufacturer's instructions. Replace circuit board.

Figure 8. RB1, RB2 & RB3 MOUNTING DIMENSIONS

Figure 9. RB1, RB2, RB3 (TYPES B, S, R) MOUNTING DIMENSIONS

PARTS LIST

1. Power Device Kit (SCR's and power diodes)	67482
2. Main Board	67469
3. Reverse Board, RB3 only	67470
4. NEMA Kit (NEMA 3, 4, 12, 13)	67474
5. Run-Stop Switch, RB1 and RB2	67476
6. Run-Stop Switch, RB3	67477
7. Reverse Switch, RB1 and RB2	67478
8. Reverse Switch, RB3	67479
9. Run Speed Potentiometer	60246
10. Fuse, ABC15, RB1	67481
11. Fuse, KTK20, RB2 and RB3	67480
12. Run Speed Knob	60288

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