BEYOND
MEASURE

SCION INSTRUMENTS

Service Manual

436-GC/456-GC
Gas Chromatograph

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Manual Contents

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BEFORE SERVICING THE 436-GC/456-GC

Safety precautions, prerequisites to service.

SAFETY

Safety precautions servicing the 436-GC/456-GC

Section Contents

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Before servicing the various components of the 436-GC/456-GC observe the following safety precautions.

INFORMATION

In accordance to Bruker commitment to customer service and safety, this instrument and its accompanying documentation complies with the CE (NEN 5509) specifications and the safety requirements for electrical equipment for measurement, control, and laboratory use (CEI/IEC 1010-1)

To prevent any injury to the user or any damage to the instrument it is essential that you read the information in this chapter.

If this manual is not in your mother language and if you have problems understanding the text, we advise you to contact your Bruker office for assistance. Bruker cannot accept responsibility for any damage or injury caused by misunderstanding of the information in this manual.

INDICATIONS

This manual contains warnings and precautionary statements that can prevent personal injury, instrument damage and loss of data if properly followed. Statements of this nature are called to your attention by the following symbols:

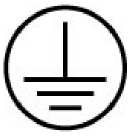
The **CAUTION** calls attention to procedure, practice, **CAUTION** or the like, which, if not correctly performed or adhered to, **could result in inadequate functioning of the instrument.**

The **WARNING** calls attention to a procedure, **WARNING** practice, or the like, which, if not correctly performed or adhered to, **could result in personal injury or damage to the product.**

Specific symbols, drawing attention to safety hazards have been applied on appropriate places on the instrument. The following symbols can be encountered:

Instruction manual symbol. Indicates that the user should refer to the manual before operating the equipment.

Indicates dangerous voltage. (terminals fed from the interior by voltage exceeding 1000 V must be so marked.)



Protective conductor terminal. For protection against electrical shock in case of a fault. Used with field wiring terminals to indicate the terminal, which must be connected to ground before operating equipment.

Radioactive hazard. Indicates that the instrument contains radioactive components, which may cause personal injury when handled incorrectly.

Skin puncture. Indicates sharp or suddenly moving parts such as injection needles that may cause injury.

Hot surface.
Indicates parts that may cause burns when touched.

Cryogenic frostbite. Contains extremely cold material (such as liquid nitrogen, carbon dioxide) that may cause injury when handled carelessly.

Static discharge warning. Item contains parts or information that can be damaged by electrostatic discharge. Take care for proper grounding before handling.

Do not touch. Touching this item may result in damage to the instrument or personal injury.

WARNINGS

The following general safety warnings must be observed during all phases of operation, service, and repair of the 436-GC/456-GC. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and the intended use of the instrument. Bruker, Inc. assumes no liability for failure to comply with these requirements

HEATED COMPONENTS

Turn off the oven and injector/detector heated zones and allow them sufficient time to cool before servicing those areas. If you must perform service on components that have not fully cooled, wear protection gloves.

VOLTAGE CARRYING COMPONENTS

Whenever possible, disconnect the 436-GC/456-GC from its power source before working on or near voltage carrying components of the 436-GC/456-GC.

When the power to the GC is turned on, potentially dangerous voltages exist on these additional components:

- All electronics boards.
- All internal wires and cables connected to these boards.
- To protect against electrostatic discharge, use a static control wrist strap connected to a ground. If you do not use static protection, you may damage the electronics of a board.

BEFORE YOU START

Allow the injectors and oven to cool before removing the covers. The metal surfaces of the GC are very hot and could burn your skin. Turn off the power to the GC and disconnect the power cord at their source.

Be sure to wear an ESD strap grounded to the GC chassis while performing all procedures.

TOOLS REQUIRED

Tools required performing the service procedures described in this manual

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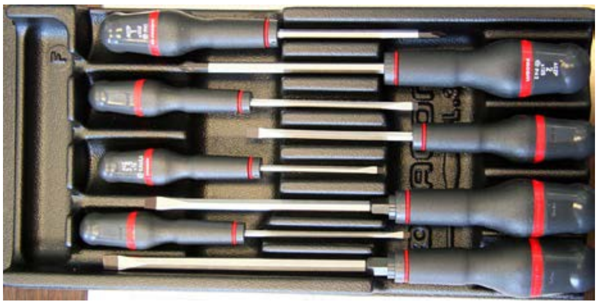
The following tools are required to perform the service procedures described in this manual.

- Electrostatic discharge (ESD) protective wrist strap, CP737948
- Set of 8pc Screwdrivers ,SOGSDDX50K

2x Philips screwdriver PH1 x100
PH2 x125
6x Screwdrivers 0,6 x 3,5 x75
0,6 x 3,5 x100
0,8 x 4,0 x100
1,0 x 5,5 x100
1,2 x 6,0 x150
1,2 x 8,0 x175



- Screwdriver Torx T-20, CP69024
- Screwdriver Torx T-10, CP69023
- Screwdriver long, Torx T-20 ,CPTOOL0072

- Screwdriver long, CPTOOL0002

- Septum Pick, 7200008400

- Wrench ¼” x 5/16”, CP8451
- Wrench 7/16” x ½”, CP8452
- Wrench 3/16” x ¼ , VLOEW1

- Magnifying Scale, CP10405

- Ceramic scoring wafer,190015800

- Probe Simulator, 392553701

- Contact removal tool for heaters,2989961400

- Tube Cutter, AL3169

- Tubing Cutter, AL3208
  Replacement cutting wheels, AL3202

- Plastic Tubing Cutter, AL3206

- Inert Steel Tube Cutter, CP8099
  Replacement blade, CP736832

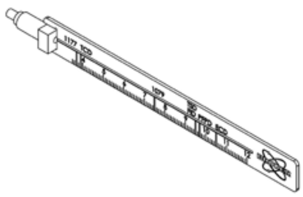
- Removal Tool for temp.probes , 390919600

- Flow Tube, 200187600

- Large Stopper, 394958600
- Injector Nut Wrench, 390842300

- Insert/ferrule positioning tool (PTV/1078), 392538500

- GC Column Scale, 392575001



- Die, rethreading 5/8", 9600161000

- Die nut for Inj/Flame base 7/16"x24, 7200003800

- Gas Leak Detector, RT22839

- Tool Column Fan, CP742416
  Use 3mm socket wrench to loosen the Screw.

- Spanner for PDHID electrode,CP740760

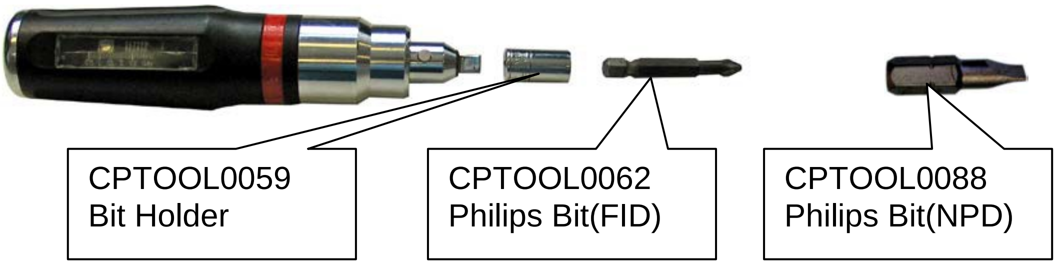
- Stylus-Pen , CP740987

- Pencil magnet , VLPM

- Philips screwdriver 0.2x125,CPTOOL0047

- Screwdriver slotted 5.5x150,CPTOOL0050

- Torx Screwdriver 2.5nM, CPTOOL0058



- 6-point Nut spinner 3/8, CPTOOL0073

- Wrench, CPTOOL0087

- Bake out nut split/splitless, 392521701

- Bake out disk split/splitless, 392573102

- Bake out nut PTV, 392577201

- Bake out disk PTV, 392521602

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SPARE PARTS

Spare parts required to perform the service procedures described in this manual

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Spare parts 436-GC/456-GC

PWA

Part Number	Description	Qty-2yr	Qty-5yr
CP745200	436-GC/456-GC Main board	1	1
CP745210	AC Rectifier Board	1	2
CP745206	436-GC/456-GC Option board (3 analog output & 8 external events)	0	1
CP745207	Detector interface board	1	2
392502101	FID PWA	1	2
392503701	TCD PWA	1	2
392504101	ECD PWA	1	2
392506601	PFPD PWA	1	2
392507001	NPD PWA	1	2
550021F	EFC Module (split/splitless, PTV) Type 21 SI	0	1
550023 F	EFC Module (On Column) Type 23 SI	0	1
550024 F	EFC Module (valves) Type 24	0	1
550025 F	EFC Module (Purge & Trap, Valves) Type 25 SI	0	1
550011 F	DEFC Module (FID) Type 11 SI	0	1
550012 F	DEFC Module (NPD) Type 12 SI	0	1
550013 F	DEFC Module (ECD/TCD) Type 13 (1 channel)	0	1
550014 F	DEFC Module (TCD) Type 14 (2 channels)	0	1
550015 F	DEFC Module (PFPD) Type 15	0	1
550016 F	DEFC Module (TCD) Type 16 (Hydrogen)	0	1
BR746301	LUI assy 456-GC	0	1
BR746300	LUI assy 436-GC	0	1

Chassis

Part Number	Description	Qty-2yr	Qty-5yr
BR746360	Chassis Fan	2	3
392530701	Column Oven Motor, 120V	0	1
392530702	Column Oven Motor, 230V	0	1
392530601	Vent Door Stepping Motor	0	1
CP745221	Line filter, 110V/250V	0	0
CP745223	Circuit breaker, 230V, 10A	0	0
CP745223	Circuit breaker, 110V, 20A	0	0
CP745226	Transformer assembly	0	0
CP745228	Cable voltage selector 230 V	0	0
CP745227	Cable voltage selector 120 V		
CP745214	Cable EFC CAN-bus long	0	0

Part Number	***Description***	***Qty-2yr***	***Qty-5yr***
CP745213	Cable EFC CAN-bus short	0	0
BR745218	LUI data cable long	0	0
BR745211	LUI power cable	0	0
CP740292	Ethernet cross cable yellow, 2.8m	0	0
393320601	Ethernet cross cable red, 2.8 mtr	0	0
BR746367	Analog out Cable Lugs	0	0
BR745241	436-GC/456-GC Cable to sampler CP-84xx	0	0
BR746366	Archon Tekmar Interface Cable	0	0
392555701	LN2 Valve	0	1
392556701	CO2 Valve	0	1
CP741985	Cartridge holder 2 filters	1	3
CP741988	Cartridge holder 4 filters	1	3
392546702	Power fail valve	1	2

Heater & Probes

Part Number	***Description***	***Qty-2yr***	***Qty-5yr***
392523301	Column Heater, 120V	0	1
392541201	Column Heater, 230V	0	1
BR746342	Heater baffle assy, 120V	0	1
BR746343	Heater baffle assy, 230V	0	1
BR746297	Column Oven Temp Probe	0	1
392537401	Injector/Detector Probe assembly	0	1
392539601	Ion Base/On Column/Flash Vaporization Oven Heater, 120V	0	1
392539602	Ion Base/On Column/Flash Vaporization Oven Heater, 230V	0	1
392542501	PTV/SPI Heater, 120V	0	1
392542502	PTV/SPI Heater, 230V	0	1
392598701	split/splitless Heater,120V	0	1
392598702	split/splitless Heater,230V	0	1
392545901	TCD Heater/Probe assy, 120V	0	1
392545902	TCD Heater/Probe assy, 230V	0	1

Injectors

Part Number	***Description***	***Qty-2yr***	***Qty-5yr***
	Common to all injectors		
7200008400	Septum Pick	2	3
394955100	Capillary Column Nut	2	4
390820601	Actuator switch assy.	1	2
	Common to On Column/Flash Vaporization		
390812700	Injector Nut assy., heated	1	3
390842300	Wrench for Heated Injector Nut	1	1
99762802	Septa, 3/8", PK/25	24	70
2869452301	Ferrule, Graphite/Vespel, 1/4", PK/10	1	2
SWSS4021	Compression Nut, 1/4", SST	0	0
392558691	Packed Col. Adapter Kit for 1/4" Glass Column	0	0
392558693	Packed Col. Adapter Kit for 1/4" SS Column	0	0
392551201	On Column/Flash Vaporization Oven assembly	0	0
On Column			
392548201	Injector body EFC	0	0
392543101	Insert	1	2
392558891	Packed Colum Adapter Kit for On Column, 1/8" SS Column	0	0
Flash Vaporization			
392548301	Injector body EFC	0	0
392611943	Flash Vaporization Glass Insert for Megabore (pk of 5)	5	12
392611944	Flash Vaporization Glass Insert for Packed Col. (pk of 5)	5	12
392558892	Packed Colum Adapter Kit for Flash Vaporization, 1/8" SS Column	0	0
392558301	Flash Vaporization Column Guide for 3800	1	1
PTV			
392544501	PTV Inject assy, 120V EFC LCO2	0	0
392544502	PTV Inject assy, 230V EFC LCO2	0	0
392544001	PTV Injector body EFC	0	0
392551601	PTV Inject assy, 120V Manual/EFC25 LCO2	0	0
392551602	PTV Inject assy, 230V Manual/EFC25 LCO2	0	0
392559601	PTV Injector body Manual	0	0
392544511	PTV Inject assy, 120V EFC LN2	0	0

Part Number	***Description***	***Qty-2yr***	***Qty-5yr***
392544512	PTV Inject assy, 230V EFC LN2	0	0
392551611	PTV Inject assy, 120V Manual/EFC25 LN2	0	0
392551612	PTV Inject assy, 230V Manual/EFC25 LN2	0	0
392544531	PTV Inject assy, 120V EFC LCO2 Inert Steel	0	0
392544532	PTV Inject assy, 230V EFC LCO2 Inert Steel	0	0
392544012	PTV Injector body EFC Inert Steel	0	0
392551631	PTV Inject assy, 120V Manual/EFC25 LCO2 Inert Steel	0	0
392551632	PTV Inject assy, 230V Manual/EFC25 LCO2 Inert Steel	0	0
392559612	PTV Injector body Manual Inert Steel	0	0
392544534	PTV Inject assy, 120V EFC LN2 Inert Steel	0	0
392544535	PTV Inject assy, 230V EFC LN2 Inert Steel	0	0
392551634	PTV Inject assy, 120V Manual/EFC25 LN2 Inert Steel	0	0
392551635	PTV Inject assy, 230V Manual/EFC25 LN2 Inert Steel	0	0
392611953	insert, 2mm ID glass wool(pk of 5)	5	12
392611949	insert, 0.5 mm ID open splitless(pk of 5)	5	12
392611947	insert, 2 mm ID open splitless(pk of 5)	5	12
392611946	insert, 3.4 mm ID, frit split(pk of 5)	5	12
392611945	insert, 3.4 mm ID, open split (pk of 5)	5	12
392611954	insert, 3.4 mm ID packed split(pk of 5)	5	12
392611948	insert, 0.8 mm ID SPME(pk of 5)	5	12
0190010906	insert, on column high performance	5	12
0190010907	insert, on column 530 micron	5	12
RT217092145	insert, 3.4 mm ID, frit Gooseneck (each)	25	60
391867201	Aluminum crunch washer, PK/3	4	10
392534202	Graphite ferrule for insert, 5mm, Pk/2	10	24
392595401	Injector Nut assy	1	2
0099763002	Septa, 11 mm, PK/25	24	70
391867600	Septum Support	2	4
392538500	Insert/Ferrule Positioning tool	1	1
5700002800	Needle valve for Septum Purge	0	1
392575190	Cap. Col. Quick Connect Kit	1	1

Split/Splitless			
Part Number	***Description***	***Qty-2yr***	***Qty-5yr***
392599691	split/splitless Inject assy ,SST, 120V EFC21	0	0
392599692	split/splitless Inject assy , SST, 230V EFC21	0	0
392599791	split/splitless Inject assy, SST,120V Manual/EFC25	0	0
392599792	split/splitless Inject assy, SST, 230V Manual/EFC25	0	0
392599694	split/splitless Inject assy, Inert Steel 120V EFC21	0	0
392599695	split/splitless Inject assy, Inert Steel 230V EFC21	0	0
392599731	split/splitless Inject assy, Inert Steel 120V Manual/EFC25	0	0
392599732	split/splitless Inject assy, Inert Steel 230V Manual/EFC25	0	0
392599401	split/splitless Injector body only, SST, EFC21	0	0
392599501	split/splitless Injector body only, SST, Manual/EFC25	0	0
392599411	split/splitless Injector body , Inert Steel EFC21	0	0
392599511	split/splitless Injector body , Inert Steel Manual/EFC25	0	0
392597301	split/splitless Purge head ,SST,EFC21	0	0
392597302	split/splitless Purge head ,SST ,Manual/EFC25	0	0
392597303	split/splitless Purge head , Inert Steel EFC21	0	0
392597304	split/splitless Purge head ,Inert Steel Manual/EFC25	0	0
392611924	Insert, 2mm ID Splitless, pk/5	5	12
392611925	Insert, 4mm ID Splitless, pk/5	5	12
392611937	Insert, 4mm ID Splitless with glass wool, pk/5	5	12
392611936	Insert, 4mm ID Gooseneck Splitless with glass wool, pk/5	5	12
392611940	Graphite O-ring 6.5mmID fits 6.5mm OD liners, pk/10	1	2
8850103100	Viton O-rings, fits split 6.3mm & splitless 6.5mm, pk/25	1	2
CR298713	BTO septa 9mm, pk/50	12	35
CR239778	Marathon septa 9mm, pk/25	24	70
392597501	split/splitless Injector nut	1	3
391866308	Purge head captive screw	1	3
SPI			
CP91833104	SPI Inject assy, 120V EFC	0	0
CP91833105	SPI Inject assy, 230V EFC	0	0
CP743117	Injector Nut assy SS	1	2
SG092034	Insert, 0.8mm ID SPI 0.53mm Columns, pk/5	5	12
CR298777	BTO septa 11.5mm, pk/50	12	35

SPT			
Part Number	***Description***	***Qty-2yr***	***Qty-5yr***
392571495	30CM Trap 5% OV-101	0	2
392571494	30cm Trap carbopack B,carbopack S-III	0	2
392571497	30cm Trap carbopack C, carbopack S-III	0	2
391878800	Transformer SPT	0	1
391878890	Transformer SPT, incl.harness 120V	0	1
391878892	Transformer SPT, incl.harness 230V	0	1
CP741571	Special ferrule	0	2

Detectors

FID			
Part Number	***Description***	***Qty2yr***	***Qty5yr***
0100099300	Detector Body, FID	0	0
392547501	Detector Base	0	1
392548701	Igniter cable	0	0
391783000	Signal cable	0	0
200187200	Igniter Probe	1	2
200187300	Signal Probe	1	2
394958700	Collector Tube	1	2
2100003200	Insulator	0	0
391866302	Screw, Micro seal, 832	0	0
1500334701	Tower Seals, PK/25	2	5
200193800	Flame Tip Assy, 0.02"ID	2	5
200187500	Flame Tip Assy, 0.01"ID	2	5
391706500	Valve, Combo, Black, Air	1	2
391706501	Valve, Combo, Red, Hydrogen	1	2
NPD			
390607700	Detector Body, NPD	0	0
392547501	Detector Base	0	1
390607600	Signal probe	1	2
390607401	Bead probe, tested	2	5
200193800	Flame Tip Assy, 0.02"ID	2	5
2100003200	Insulator, lower	0	0
390607900	Collector, NPD	1	2
2100003100	Insulator, upper	0	0
2740928202	O Ring, .487 ID X .103 wide (pk OF 30)	2	5

Part Number	Description	Qty2yr	Qty5yr
392548801	Bead cable	0	0
391783000	Signal cable	0	0
1500334701	Tower Seals, PK/25	2	5
391706500	Valve, Combo, Black, Air	1	2
391706501	Valve, Combo, Red, Makeup	1	2
391714601	Flow Controller	1	2
ECD			
392547501	Detector Base	0	1
390837603	Pulser cable	0	0
391783000	Signal cable	0	0
200197270	Rebuild ECD, general license (**USA ONLY)**	1	1
200197271	Rebuild ECD, specific license	1	1
391706501	Valve, Combo, Red, Makeup	1	2
392576801	ECD Shim	5	12
392576901	ECD Insulation strip	1	2
392577001	ECD insulation clip	1	2
PFPD			
392547601	Base	0	1
392546101	Igniter assembly	1	2
392549001	High Voltage cable	0	0
391783000	Signal cable	0	0
392517600	Combustor, Sulfur, 2mm, Quartz	5	12
392517800	Combustor Holder, Sulfur, 2mm	2	5
392517700	Combustor, Phosp. 3mm, Quartz	5	12
392517901	Combustor Holder, Phosp. 3mm	2	5
392513800	Combustor Holder Seal	6	15
391714603	Flow Controller, 25 cc/min	1	2
391714604	Flow Controller, 60 cc/min	1	2
1500334701	Tower Seals, PK/25	2	4
5700002800	Needle Valve, Angle	0	1
2718016600	Check Valve	0	0
392513300	Assy., PFPD Tower	0	0
392513301	Assy., PFPD Tower, N. Mode	0	0
392517100	Photomultiplier Tube	1	2
392512800	Photomultiplier Tube, N. Mode	1	2
392515101	Filter, Sulfur	0	1
392515102	Filter, Phosphorus	0	1
392511901	Filter, Nitrogen, RG9	0	1
2740292400	O-Ring, .530 ID	8	16

Part Number	Description	Qty2yr	Qty5yr
2740282600	O-Ring, 128	8	16
2740236100	O-Ring, N Mode Detector Tower	8	16
TCD			
392560711	TCD assy 120 V with transfer line 120V	0	1
392560712	TCD assy 230 V with transfer line 230V	0	1
392560724	TCD assy, Dual 120V with transfer line	0	1
392560725	TCD assy, Dual 220V with transfer line	0	1
CP742895	TCD assy, Nickel 120V	0	1
CP742896	TCD assy, Nickel 220V	0	1
392558701	TCD makeup adapter	0	0
CP740022	Upgrade of single TCD with Nickel filaments	0	0
PDHID			
CP740761	Bias cable assy	0	1
CP740762	Pulser cable assy	0	1
CP740763	High voltage cable	0	1
CP740764	Ground electrode	0	1
VLI23534	Nut for ground electrode D4	0	0
CP740765	Detector cell	0	1
CP740766	PDHID Pulse Discharge module	0	1
CP740769	Miniature Helium purifiers	0	1
CP740773	Electrometer cable assy	0	1
CP740775	gold plated ferrules	0	4
CP740781	Replacement purifier	0	1

Miscellaneous

Part Number	Description	Where used
CP742211	Charcoal filter	Chassis
CP742210	Molsieve/Charcoal filter	Chassis
392528901	Detector blanking plate	Chassis
391885303	Peek tubing 1/16” Green	EFC unit
391885304	Peek tubing 1/16” Blue	EFC unit
391885305	Peek tubing 1/16” Red	EFC unit
391885306	Peek tubing 1/16” Black	EFC unit

Part Number	***Description***	***Where used***
391885307	Peek tubing 1/8” Natural	EFC unit
2815892301	Polyuréthane 1/16 x 1/8” (25FT)	EFC unit split
CP745238	Fuse F-15A/250V, 5x20mm, Glass (24V DC,3AG)	Chassis
CP745239	Fuse T- 10A/250V, 5x20mm, Glass HBC (Heaters)	Chassis
CP745240	Fuse T- 15A/250V, 5x20mm, Glass (Column Heater)	Chassis
BR746380	Fuse F-4A/250V, 6.2x32mm, Ceramic	Column oven Fan
BR746381	Fuse F-10A/250V, 6.2x32mm, Ceramic	Transfomer (120V)
BR746382	Fuse F-8A/250V, 6.2x32mm, Ceramic	Transfomer (230V)
CP742382	Screw M4x6mm RVS Torx	All
CP86756	Screw M3X10 TORX	EFC unit
CP86757	Screw M4X8 TORX	EFC unit
CP741842	Screw Hex M5x60mm	Transformer
CP742269	Washer 5.3 x 25mm	Transformer
1312206000 (8pc)	Nut Hex 1032	Fan-Motor
CP742385 (4pc)	Screw M4x20	Fan-Motor
1431200800 (4pc)	Washer, lock	Fan-Motor
1490107400 (4pc)	Washer, plain	Fan-Motor
CP86745 (2pc)	Screw M3x8 Torx	Vent motor/Power board
CP742386 (4pc)	Screw M4x6 CVD coated	Oven
CP86780 (8pc)	Screw for plastic parts	Chassis Fan
CP822454	Washer 4	Line filter ground
CP742647	Screw 8-32x ½”	Manifold assy 2/Filters
391714250	Viton Ferrule	Chassis
391714300	Pin, sealing, 1/16X3/4	Chassis
391708450	Nut, Viton Ferrule	Chassis
SWB2003	Tee, Brass, 1/8"	Chassis
1600058900	Tee, 1/16" SS	Chassis
CP4006	Stainless Steel 1/16" x 0.75mm	Chassis
391832600	Copper Tubing pretreated 1/8"	Chassis
SWB2021	Nut, brass, 1/8", Swagelok, PK/10	Chassis
SWB200SET	Ferrule set , brass, 1/8", PK/10	Chassis
CP739611	Thumb screw (injector plate)	Chassis
BR746195	Bulkhead assy NG-EFC	Chassis
CP745164	Box 436-GC/456-GC	
CP740812	Battery (3-Volt lithium-mangaan battery, CR2032, FDK America Inc, Varta, Panasonic or other)	Main Board

Field instruction manuals

Field instruction manuals can be found on the Bruker Service Board:

http://forum.bdal.de/

300

COVERS

NOTE

All covers should be handled with the necessary care.

This section contains illustrated parts breakdowns for the 436-GC/456-GC Gas Chromatograph Covers and related components

Before you start

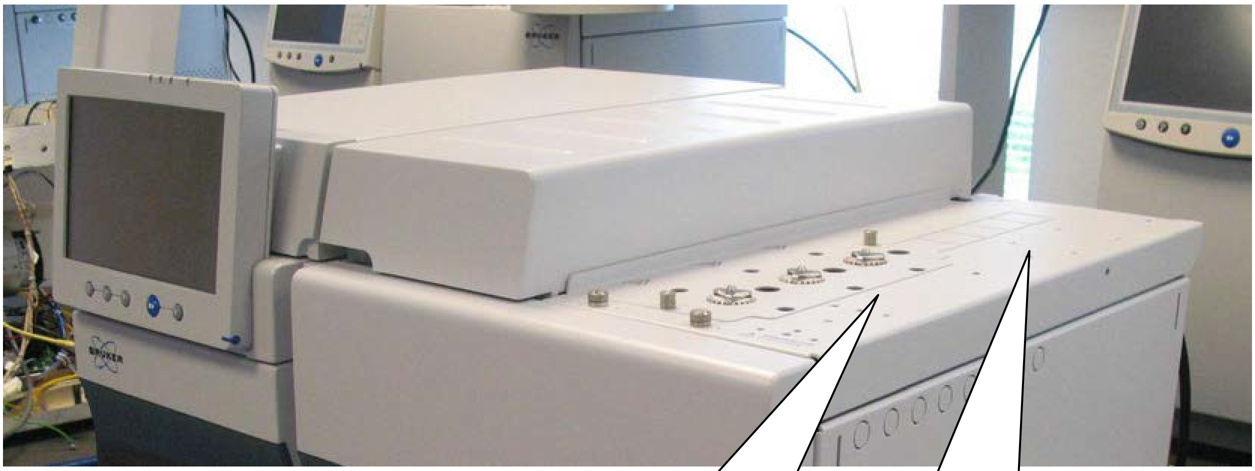
WARNING

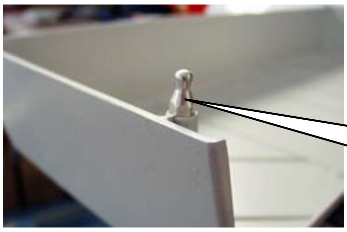
Allow the injectors and oven to cool before removing the covers.
The metal surfaces of the GC are very hot and could burn your skin.
Turn off the power to the 436-GC/456-GC and disconnect the power cord at their source.

310

456-GC Cover RIGHT

456-GC Covers TOP





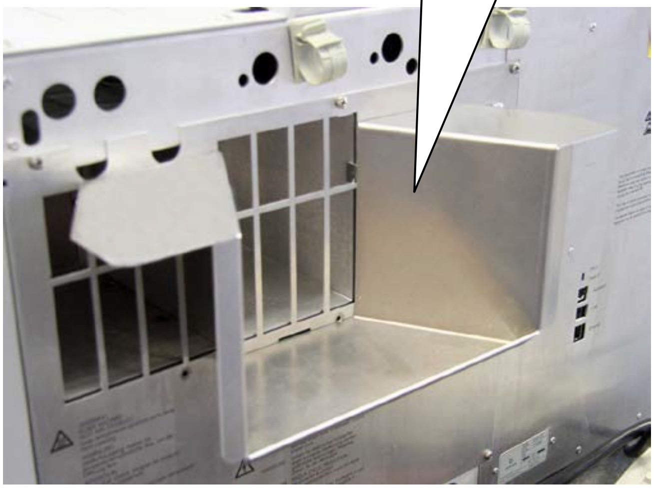
436-GC Cover Right

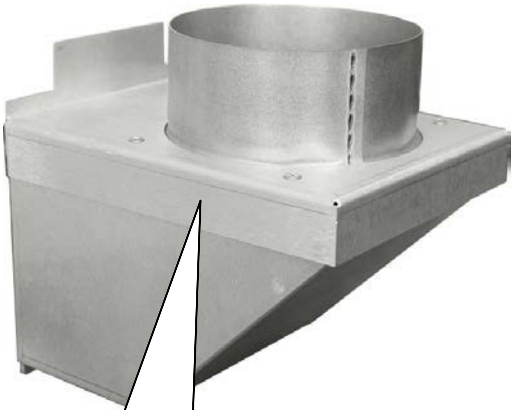
436-GC Cover TOP

Covers REAR (To be detailed)

Exhausts

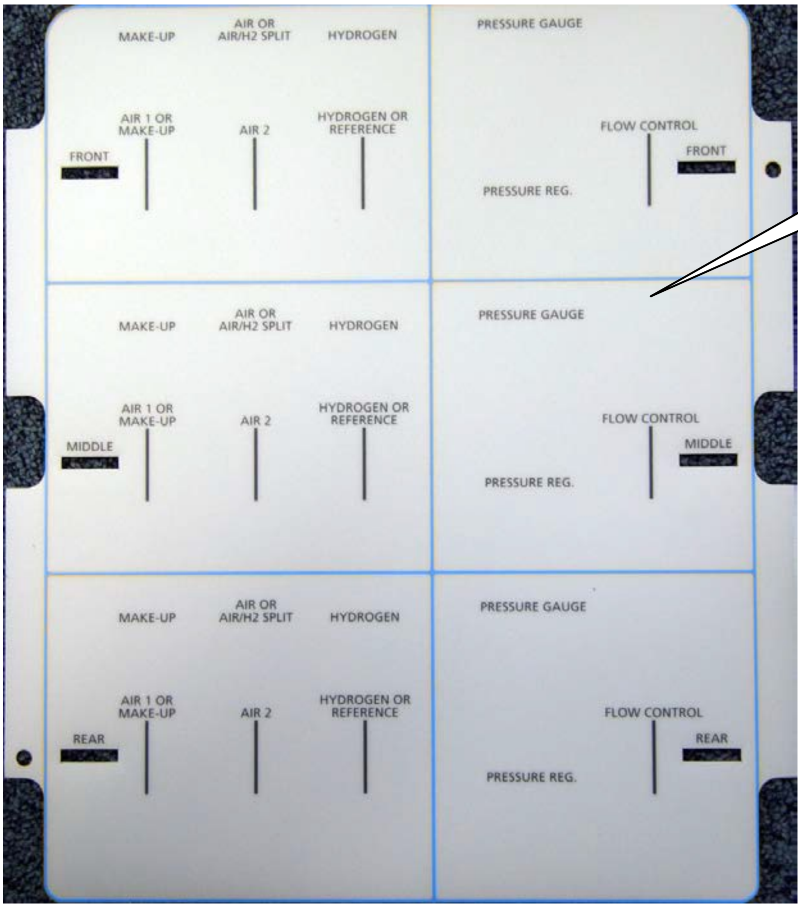
392552701
Column oven deflector kit





CP742562
Exhaust vertical assy

Panel Pneumatic with overlay



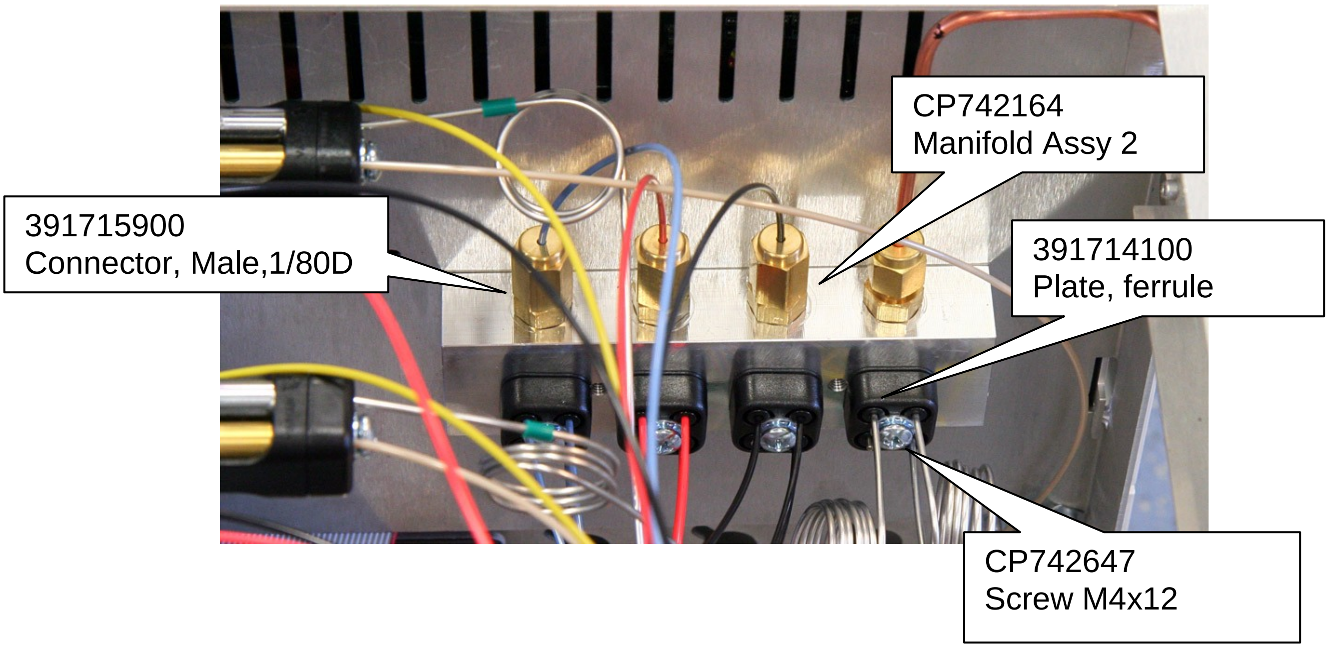
CP742288
Panel, pneumatic with overlay

BASIC

This section contains illustrated parts breakdowns for the 436-GC/456-GC Gas Chromatograph basic and related components

320

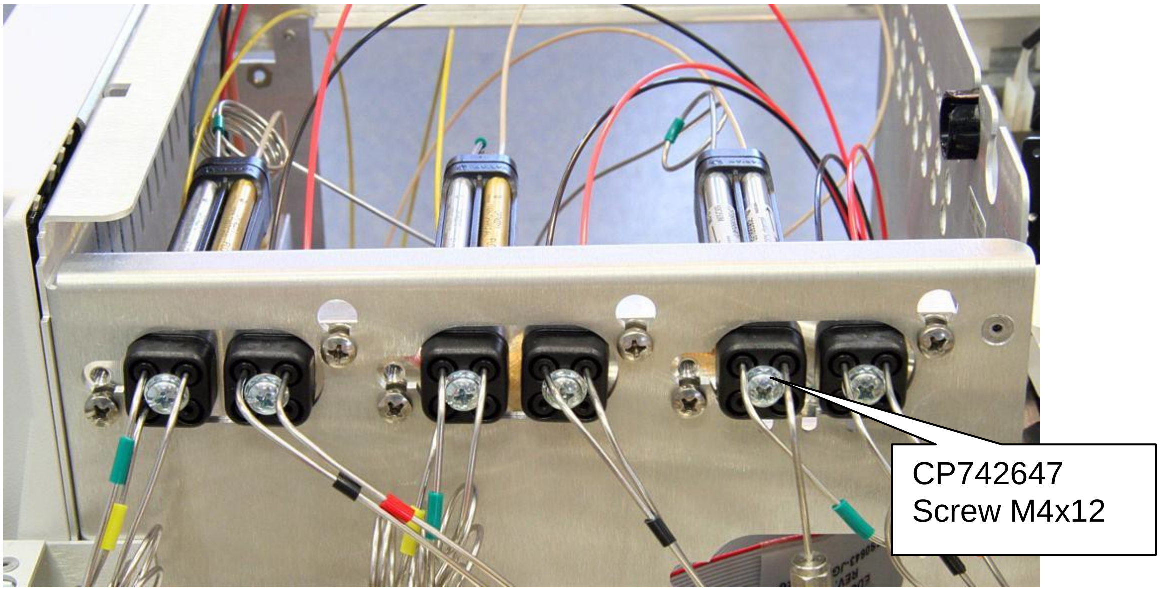
Manifold assy 2



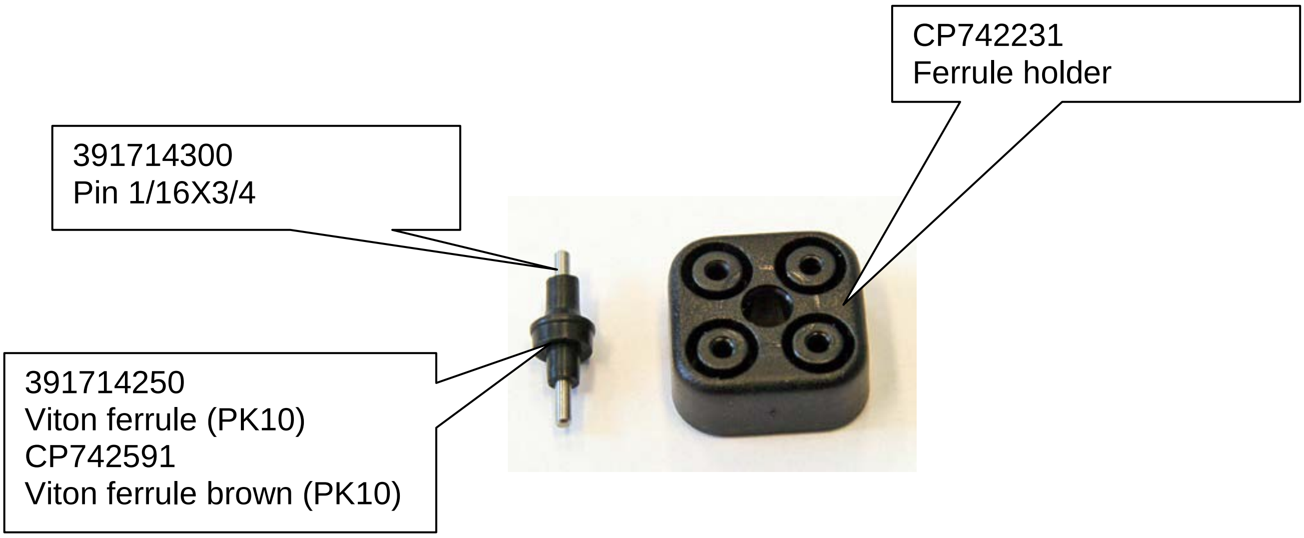
Peek tubing

Description		OD/ID	Part Number
Color coded PEEK tubing Natural		1/8 IN	391885307
Color coded PEEK tubing Natural		1/16 x 0.030 in	391885302
Color coded PEEK tubing Red		1/16 x 0.030 in	391885305
Color coded PEEK tubing Yellow		1/16 x 0.030 in	391885314
Color coded PEEK tubing Green		1/16 x 0.030 in	391885303
Color coded PEEK tubing Blue		1/16 x 0.030 in	391885304
Color coded PEEK tubing Black		1/16 x 0.030 in	391885306
SS tubing		1/16 x 0.75mm	CP4006

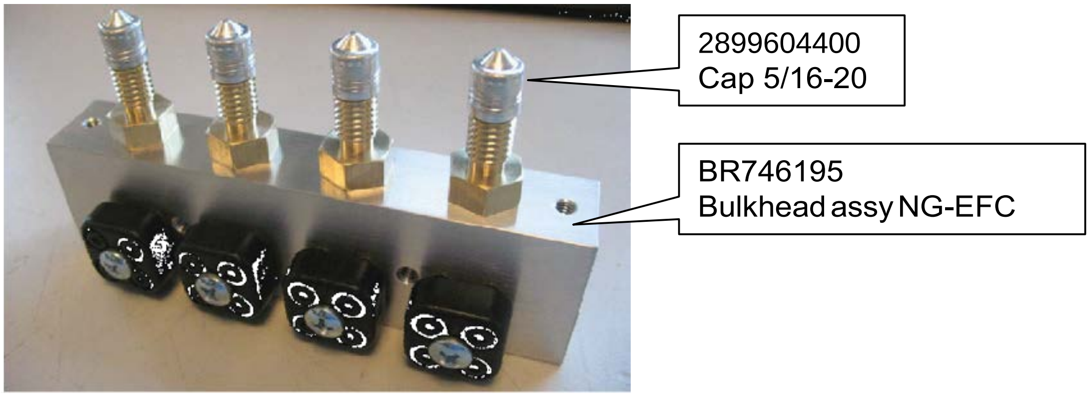
Manifold connection for gases



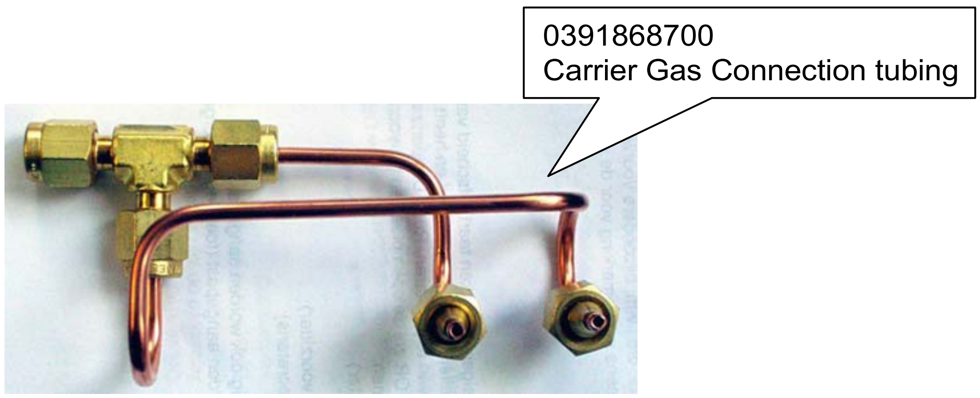
Detailed information on Manifold



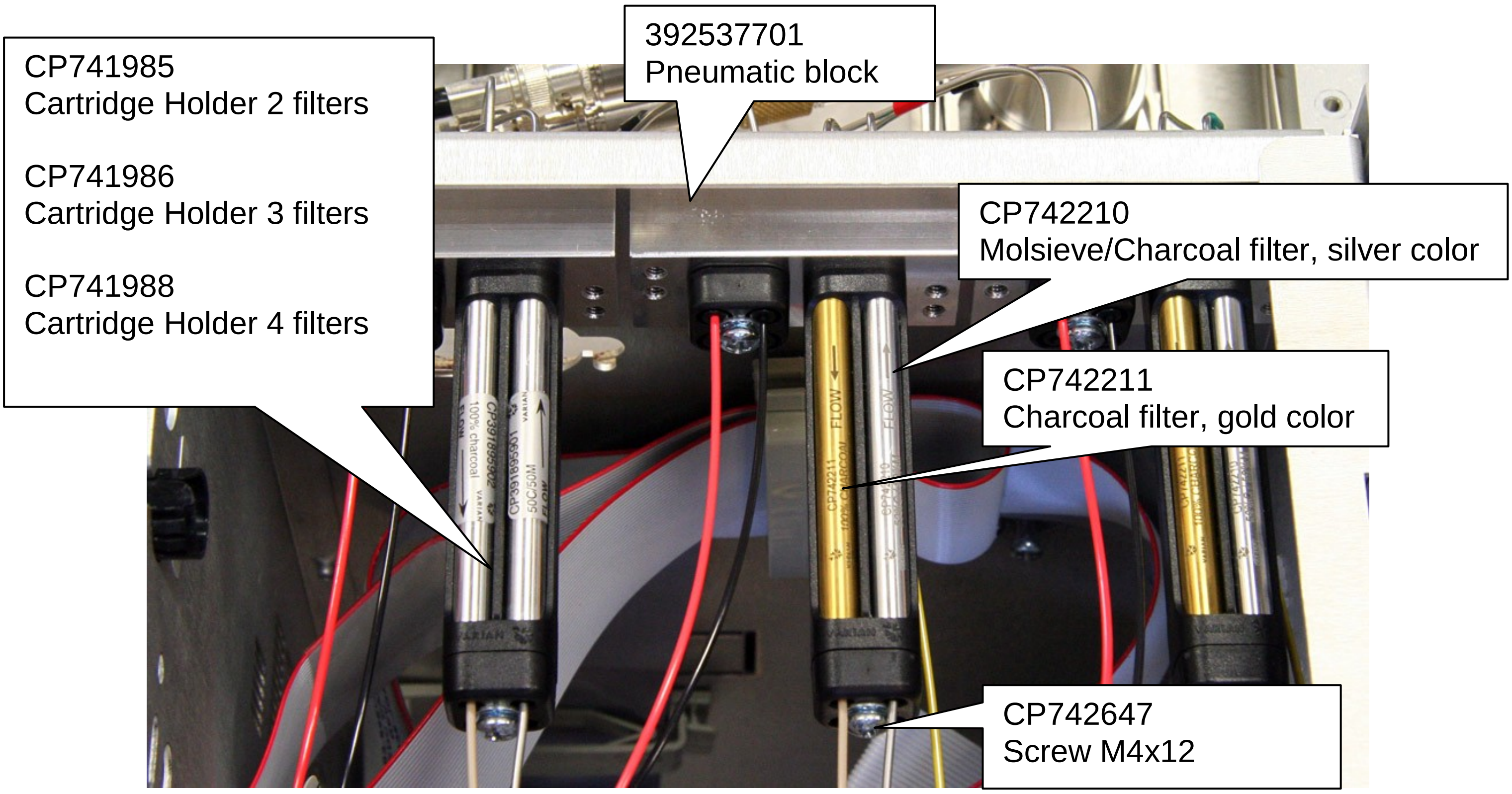
Bulkhead unions



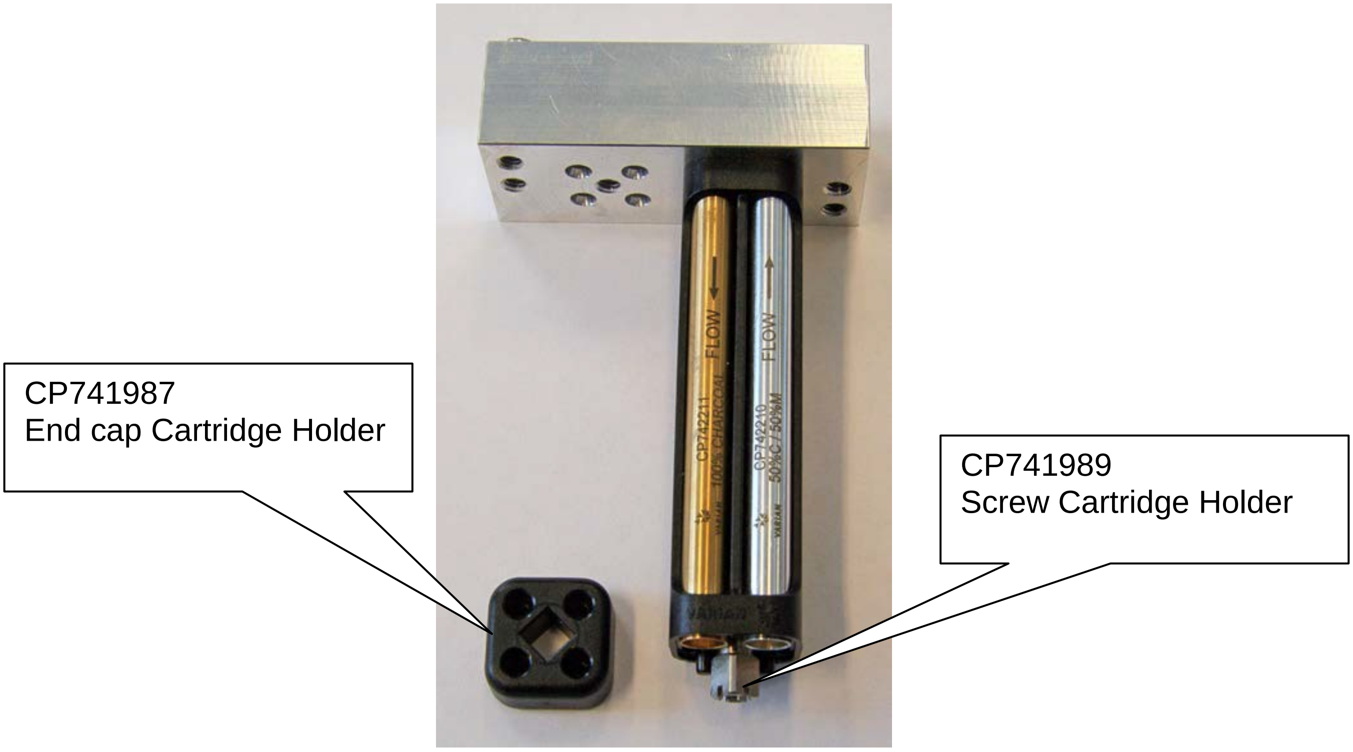
Carrier gas Tee connection



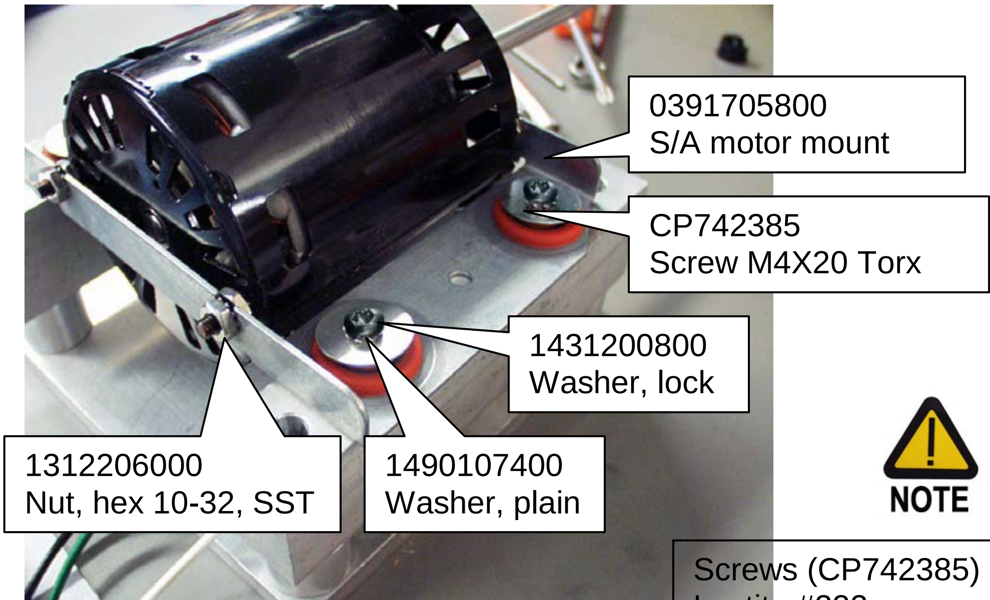
Pencil Filters



Detailed information on Pencil filters



Fan Motor

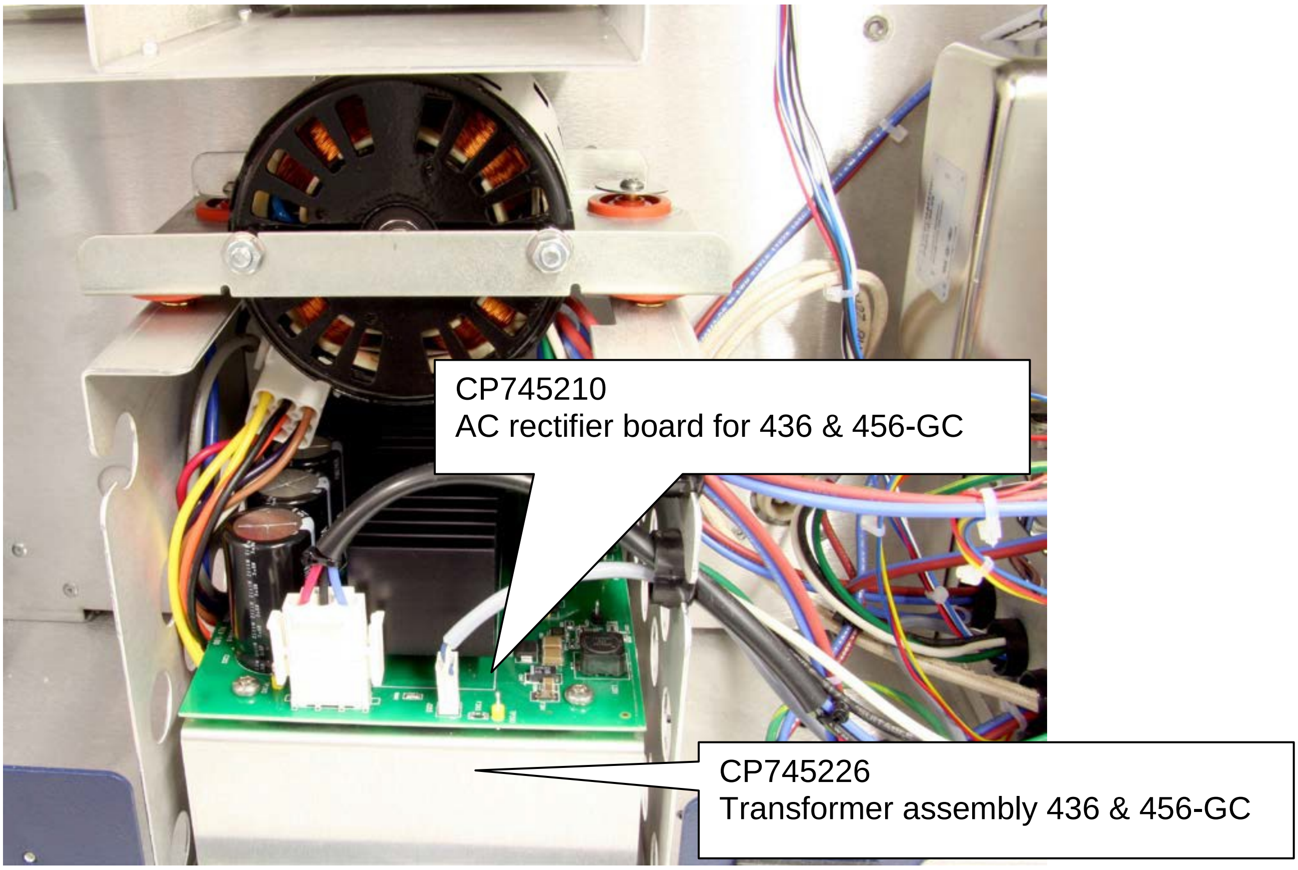


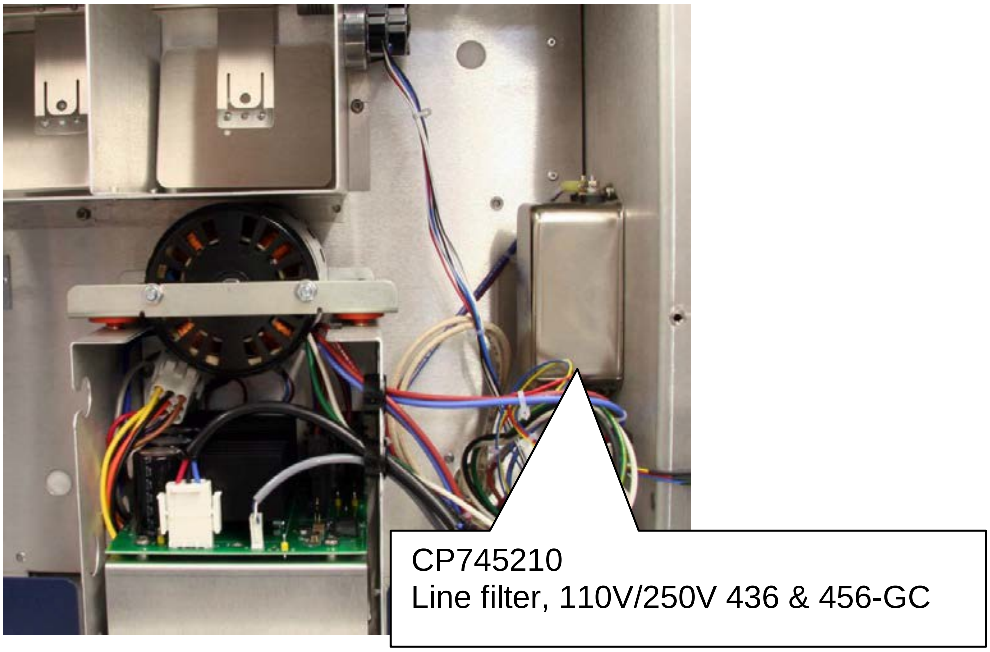
NOTE

Screws (CP742385) are locked with Loctite #222

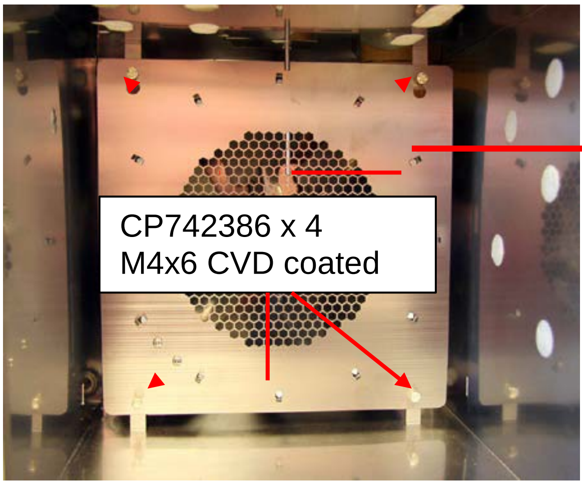
Follow the procedure Fan-Motor adjustment!on page 48 after replacing or removing the Fan-Motor.

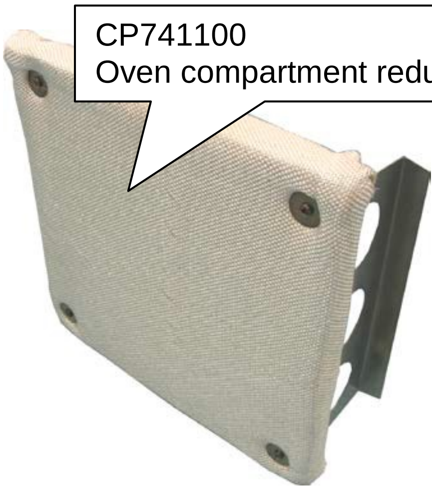
AC RECTIFIER BOARD, LINE FILTER & TRANSFORMER.





Column Oven





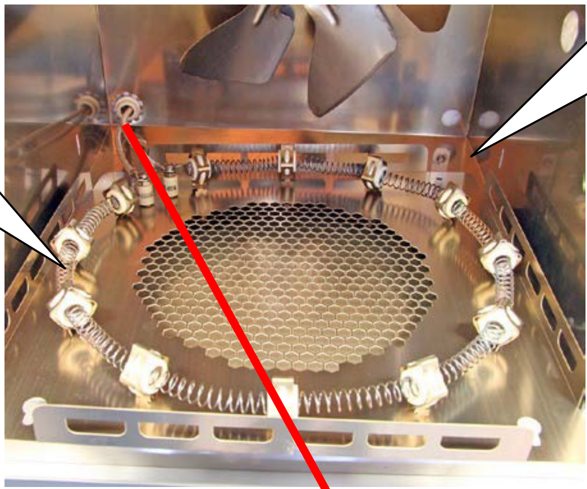
CP741100
Oven compartment reducer

0392541291
Heater baffle assy 230V

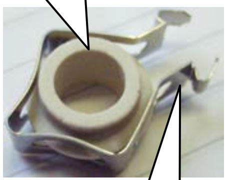
0392523391
Heater baffle assy 120V

0392541201
Column heater 230V

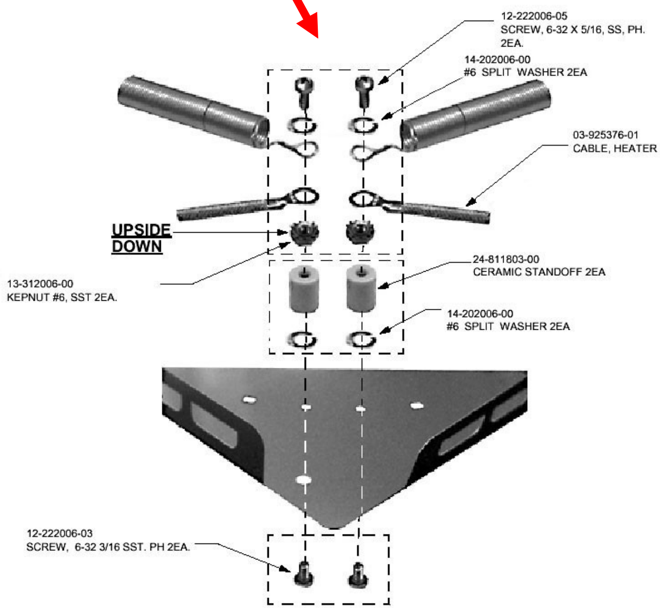
0392523301
Column heater 120V



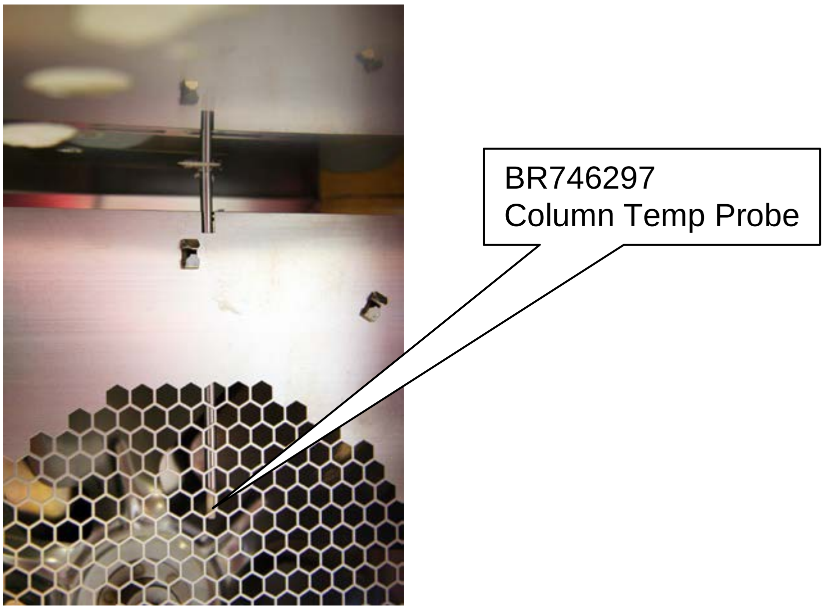
2100001700
Insulator, Heater Coil



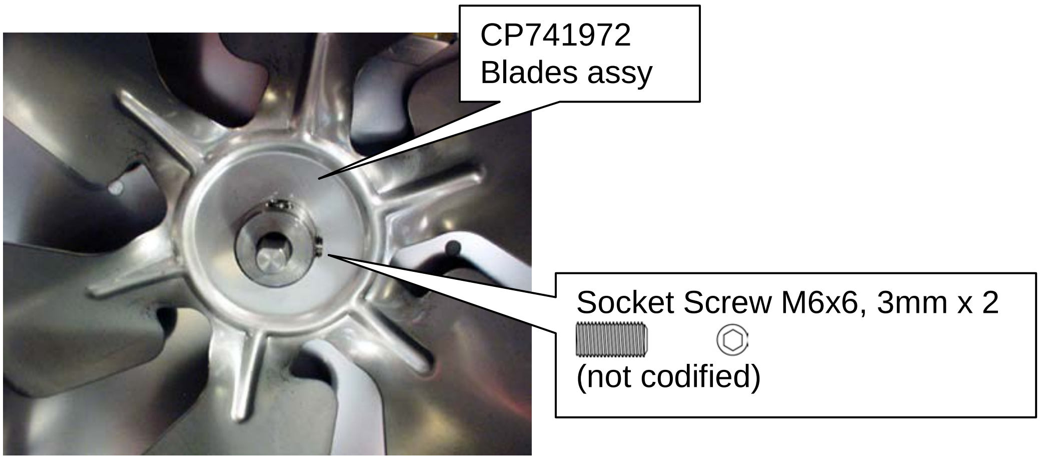
0400020000
Insulator Clip



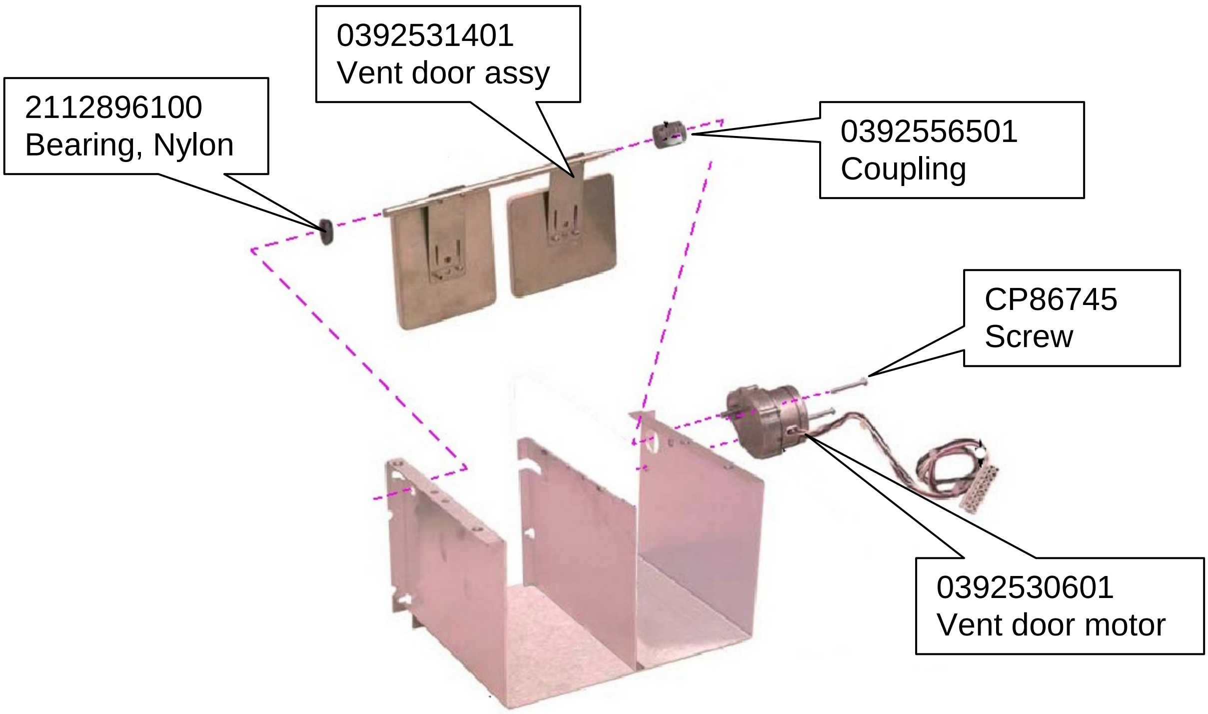
Column temperature probe



Blade assy



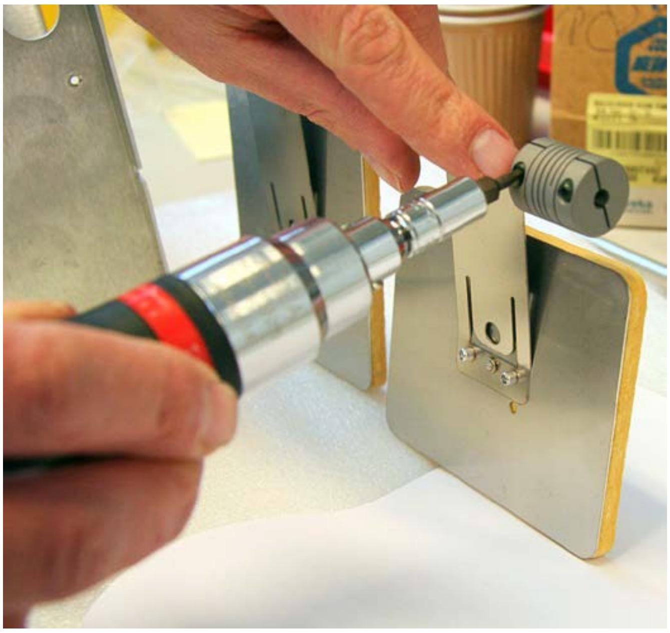
Vent Door



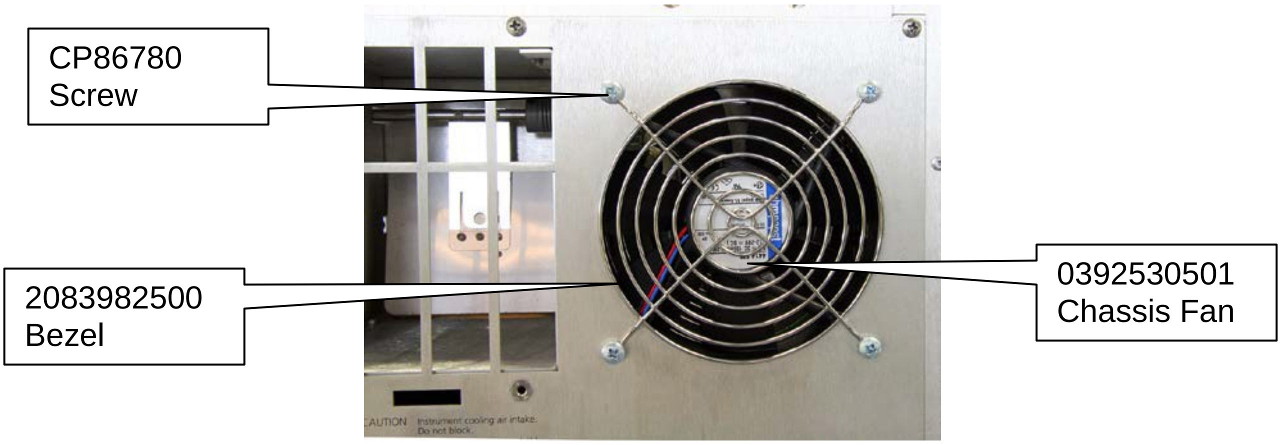
Notes:

1) When assemble the flexible coupling (392556501) onto the vent door assembly (392531401 shaft, make sure is flush against shoulder of the shaft. Tighten screw on coupling 10 in-lb torques.

2) When installing vent motor into the flexible coupling, make sure motor shaft end touches vent shaft end. Prior to tighten the screw on coupling check to make sure the screw is on the flat surface of the vent motor shaft. Tighten the screw on the coupling to lb-lb torque.



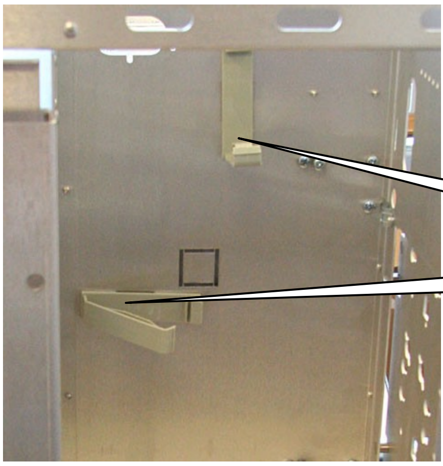
Chassis Fan



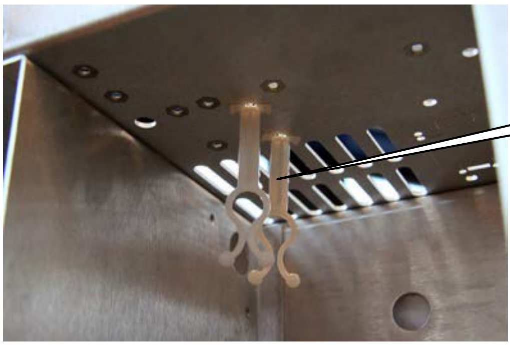
Check chassis-fan blow direction, fan MUST blow air INTO the GC

Miscellaneous

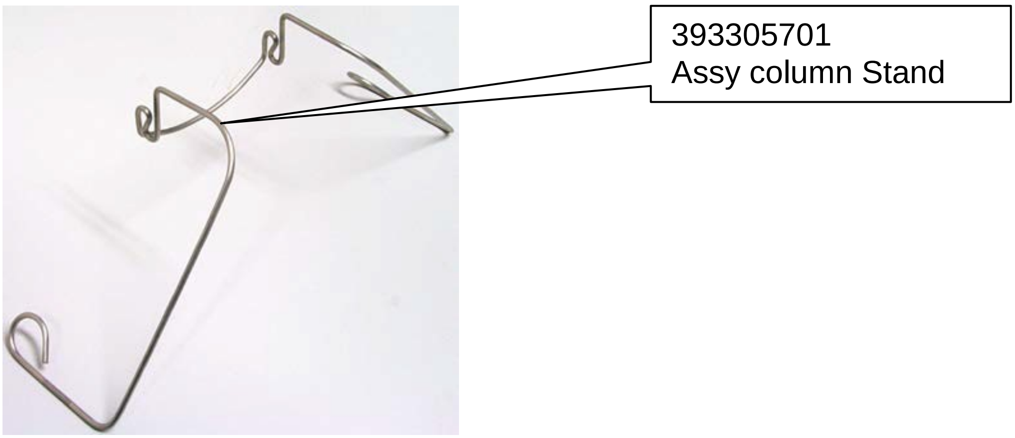
Cable clamp

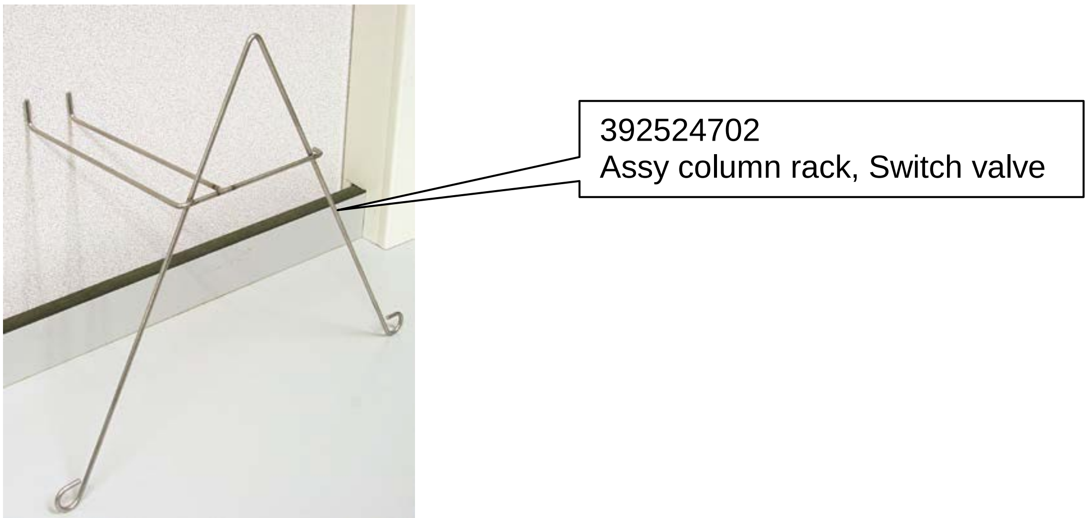


Stand off clamp



Column holder


393305701
Assy column Stand


392524702
Assy column rack, Switch valve

Power cables

CP745236 Power Cord 16A / 250V AC

400

REMOVAL AND REPLACEMENT PROCEDURE

Section contents:

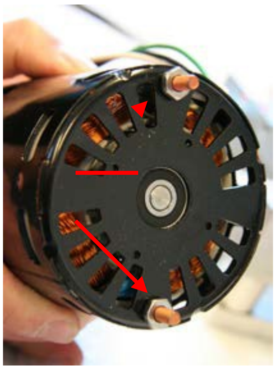
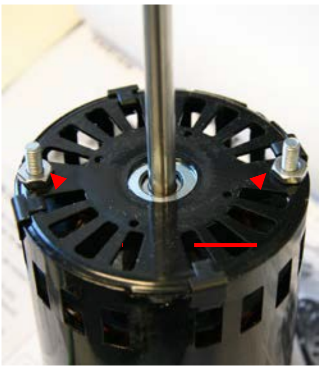
Before you start

Turn off the power to the 436-GC/456-GC and disconnect the power cord at their source.
Take care for proper grounding before handling electronics.

Fan-Motor Adjustment

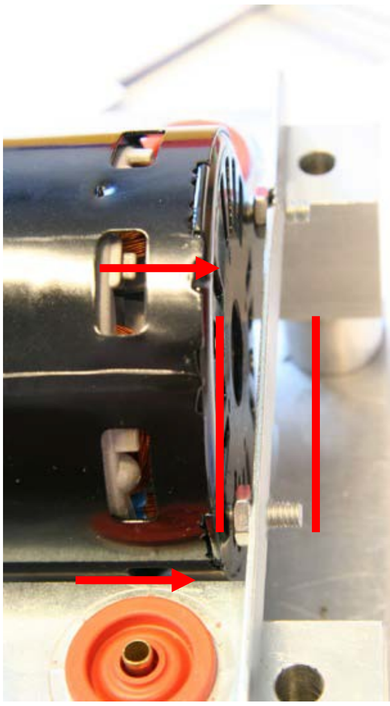
This procedure must be carried out after replacement and/or removal of the Fan-Motor. If not carried out correctly, the Fan-Motor can be damaged in time.

1. Turn all 4 inner nuts hand tight against the motor housing.

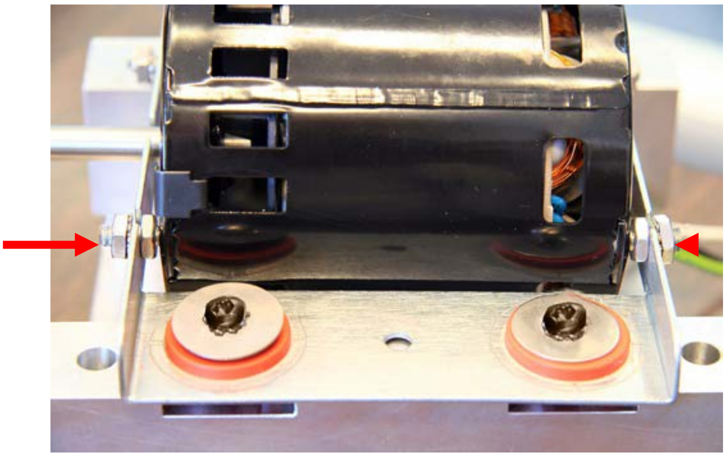
2. Place the Fan-Motor on the motor mount.

3. Turn the 4 inner nuts against the motor mount (hand tight!).



4. Check and correct if necessary (with the inner nuts) if the fan motor housing is parallel with the motor mount.

5. Place the next (4) outer nuts on the thread axis and hand tighten them to the motor mount.



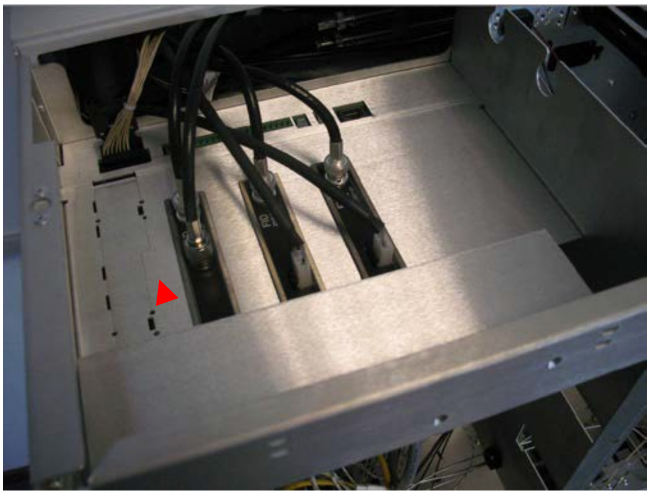
6. Tighten (with a wrench) all 4 **INNER NUTS** into direction of the motor mount.

Removal & Replacing the 436-GC main board.

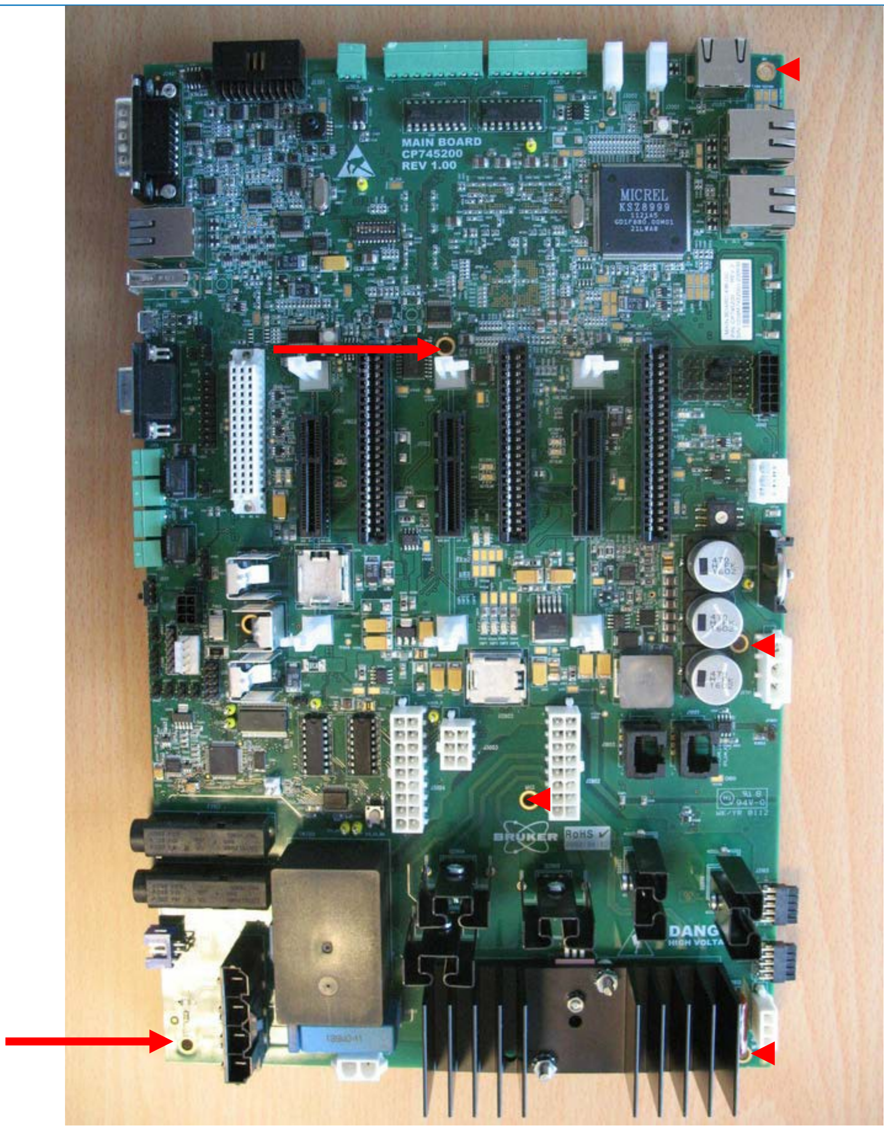
To be detailed.

Removal & Replacing the 456-GC main board.

1. Remove the left side panel and top panel.
2. Remove all detector cables from the PWA's.
3. Remove the Detector PWA, this is done by removing the screws on the chassis.



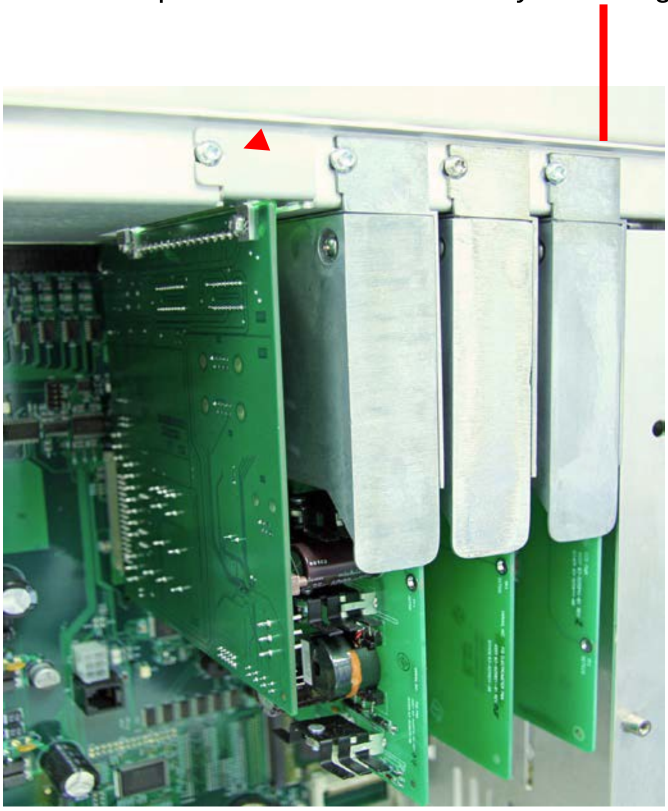
4. “if” an Option board is present remove this board.
5. Remove all cables that connect to the main board.
6. Remove the 6 screws that connect the main board to the frame.



7. Reassemble is the reverse of removal.

Removal & Replacing of the Option board.

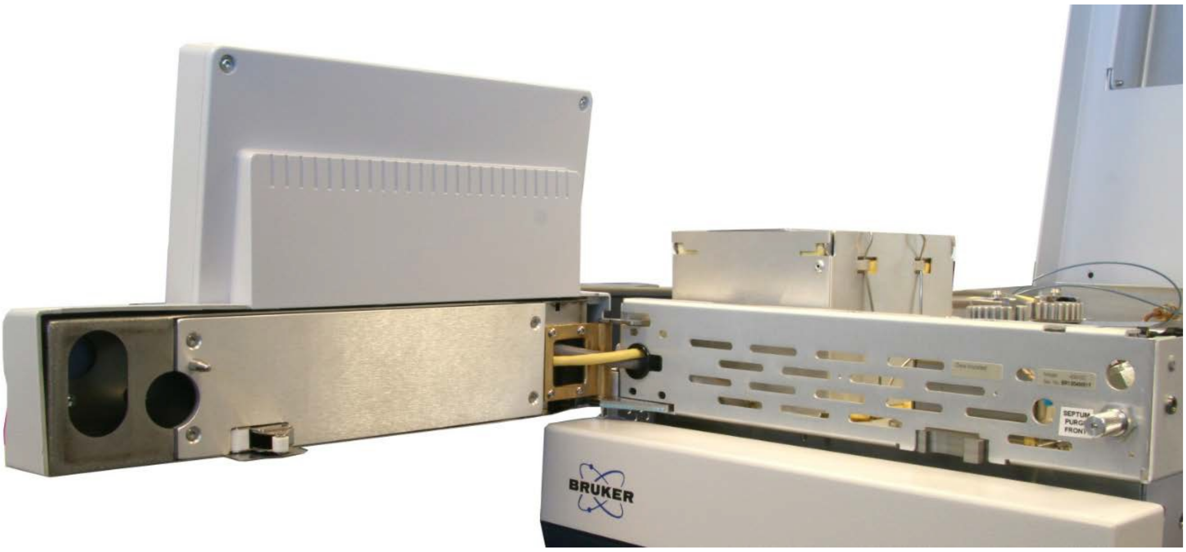
- Remove the Option board this is done by removing the screws on the chassis.



- Make sure all cables are removed.
- Reassemble is the reverse of removal.

Removal & Replacing the LUI assy on 436-GC

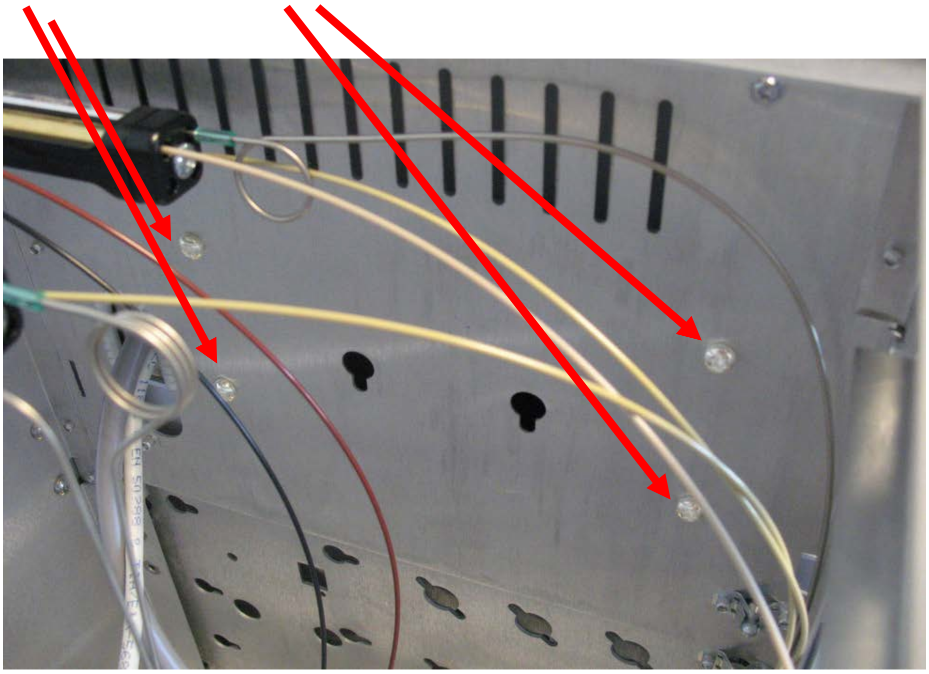
1. Open the display by pushing on the right hand side of the LUI.



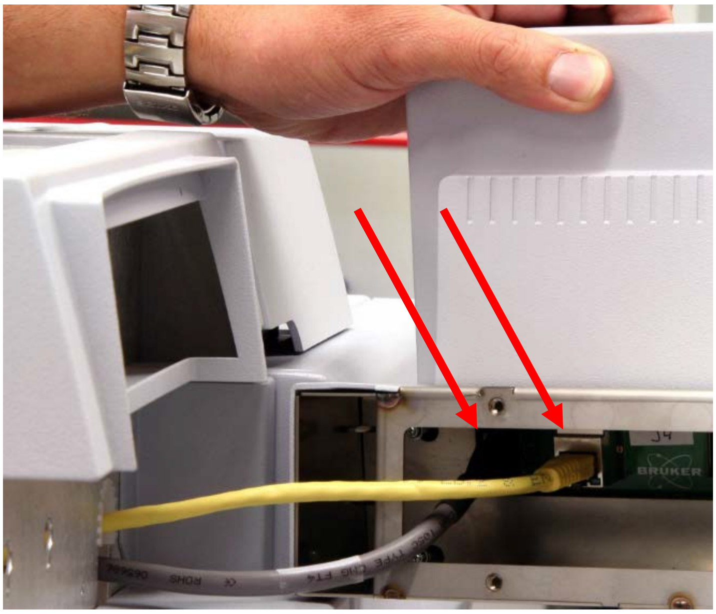
2. Loosen the 4 Torx screws from the lid covering the LUI compartment.
3. Disconnect both the LUI RJ-45 data cable and Power cable.
4. Loosen the 4 Torx screws on the copper hinge to remove the complete LUI assy.
5. Reassemble is the reverse of removal.

Removal & Replacing the LUI assy on 456-GC

1. Loosen the 4 Torx screws.

1. 

2. Disconnect both the LUI RJ-45 data cable and Power cable.

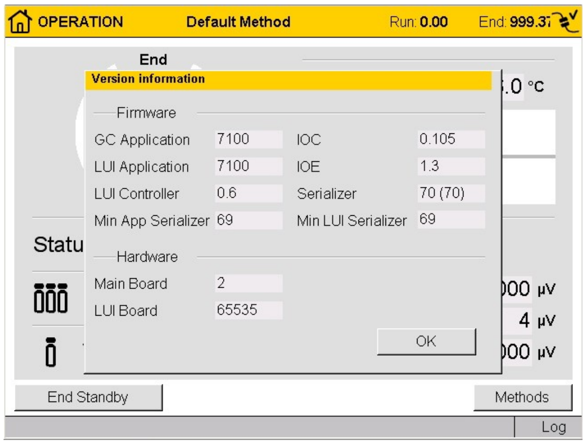
a. 

3. Reassemble is the reverse of removal.

Calibration LUI assy

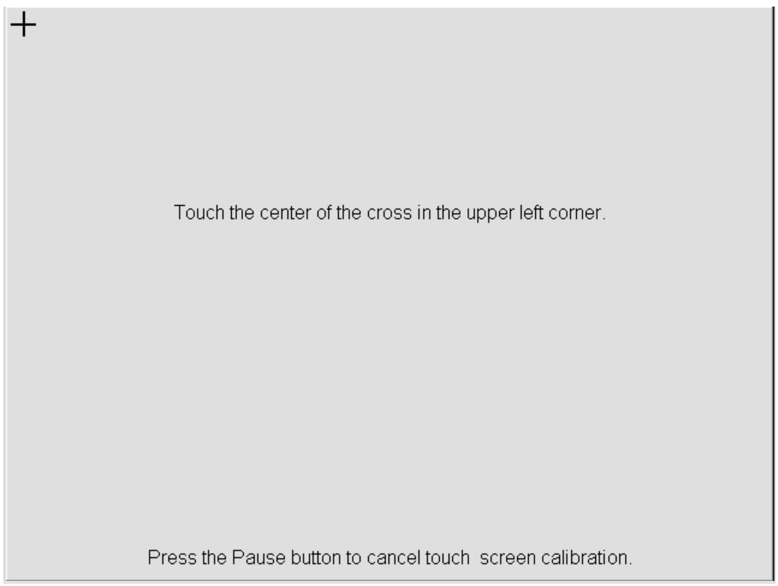
If the touch screen is not working correctly and you're not able to get into the calibration setup via the touch screen then you can access this via the soft keys.

1. Press Question  button on the instrument.



2. Press in the buttons in the following order to go into the calibration screen.

Home Pause Question

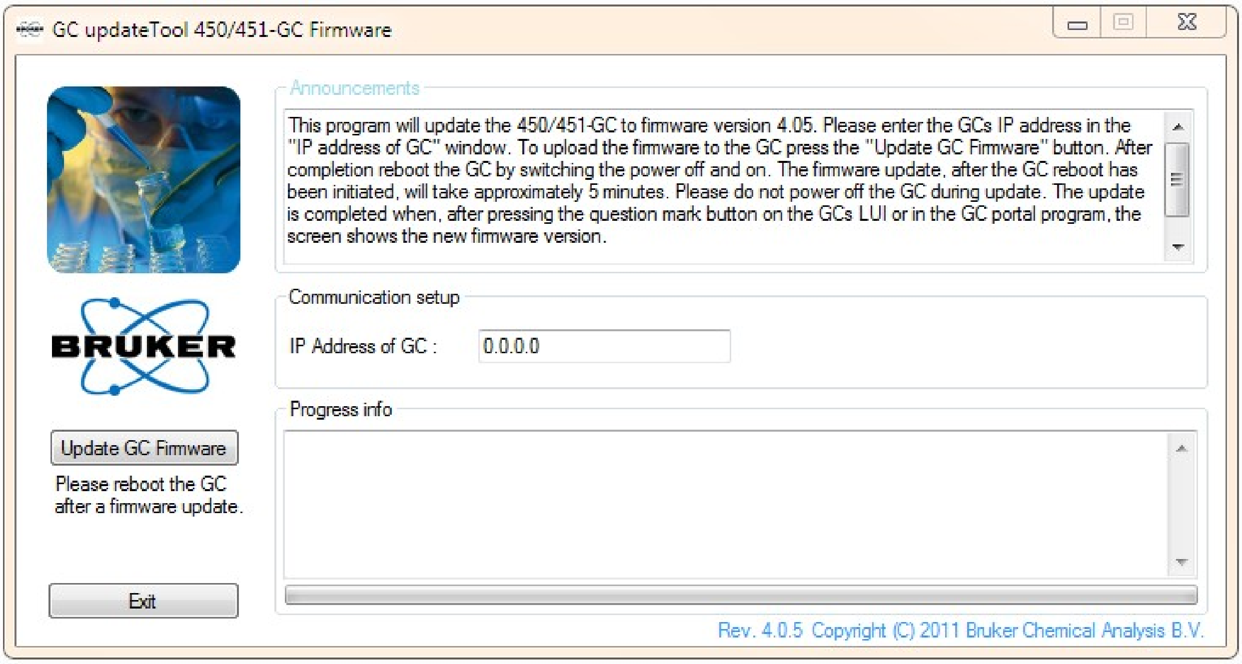


3. Perform the calibration by touching the four corners and middle point.

4. Perform the calibration by touching the four corners and middle point.

Display information (To be detailed)

Upgrade tool.



1. Connect the Ethernet cable to the instrument and your laptop (Cross over cable).
2. Switch on the GC.
3. Start the Update tool.
4. Type in the IP address of the instrument and “Update GC firmware”.
5. Information will be send to GC.
6. When completed reboot the 436-GC/456-GC to install the new firmware on the 436-GC/456-GC.

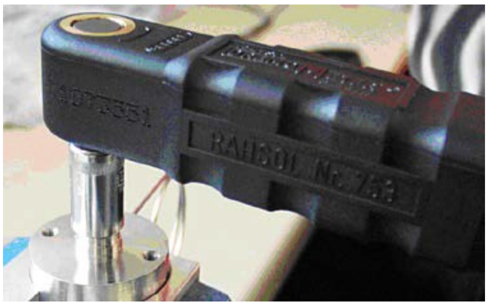
Removal and Replacing FID/NPD Flame tip

Disassembly of FID/NPD

- Remove detector probes.
- Use the recommended tools to remove the screws from the tower.
- Remove the tower from the base, by gently forcing the tower (counter) clockwise.
- Remove the flame-tip with the recommended tool.

Reassembly of FID/NPD

1. Remove the used aluminum washer from the detector base or tower.
2. Check the ferrule of the flame-tip. Replace when damaged.
3. Install the flame-tip and tighten the nut with the recommended tool.
4. The torque of this tool must be adjusted to 3.0 Nm.
5. Tighten the nut until the wrench “clicks” once.
6. Place a new aluminum washer (P/N: 15-003347-01).



7. Install tower and screws carefully. Replace screws when damaged.
8. Tighten the screws of the tower alternating using the recommend tool. The torque of this tool must be adjusted to 2.2 Nm.
9. Tighten the screw until the screwdriver “clicks” once.
10. Reinstall detector probes in the tower.

500

ERROR CODES

How to use error messages to diagnose and correct internal problems with the 436-GC/456-GC

Code	Error Description	Error level	Cause Condition(s)	GC action	Action needed
8	Coolant timed out	Event	Column oven standby EFC21 (gas saver)	Notification Message	Activate method, clear timeout
FID Flame out					
15	Front FID Flameout	Alert	FID signal is < than given threshold No gas supply, flow 0.0 mL/min	Notification Message Auto-re-ignite	Ignite FID flame, check EFC flow (gas supply), set FID gasflows
16	Middle FID Flameout	Alert	FID signal is < than given threshold No gas supply, flow 0.0 mL/min	Notification Message Auto-re-ignite	Ignite FID flame, check EFC flow (gas supply), set FID gasflows
17	Back FID Flameout	Alert	FID signal is < than given threshold No gas supply, flow 0.0 mL/min	Notification Message Auto-re-ignite	Ignite FID flame, check EFC flow (gas supply), set FID gasflows
TCD Air Leak					
18	Front TCD Air Leak	Event	Air Leak	TCD Power off, Electronics off	Check for TCD air-leak
19	Middle TCD Air Leak	Event	Air Leak	TCD Power off, Electronics off	Check for TCD air-leak
20	Back TCD Air Leak	Event	Air Leak	TCD Power off, Electronics off	Check for TCD air-leak
Injector EFC Flow Out of Range					
35	Front EFC Flow Out of Range	Alert/Error[1]	Flow is above max+10% or below -5kPa for more than 10 seconds	Activated Safety Method	Check EFC flows (gas supply)
36	Middle EFC Flow Out of Range	Alert/Error[1]	Flow is above max+10% or below -5kPa for more than 10 seconds	Activated Safety Method	Check EFC flows (gas supply)
37	Back EFC Flow Out of Range	Alert/Error[1]	Flow is above max+10% or below -5kPa for more than 10 seconds	Activated Safety Method	Check EFC flows (gas supply)
Injector EFC Pressure Out of Range					
38	Front EFC Pressure Out of Range	Alert/Error[1]	Pressure is above max+10% or below -5kPa for more than 10 seconds	Notification Message	-
39	Middle EFC Pressure Out of Range	Alert/Error	Pressure is above max+10% or below -5kPa for more than 10 seconds	Notification Message	-
40	Back EFC Pressure Out of Range	Alert/Error[1]	Pressure is above max+10% or below -5kPa for more than 10 seconds	Notification Message	-
Injector EFC Flow ready time out					
41	Front EFC Flow Ready Time Out	Alert/Error	Unit not ready for 10 minutes	Activated Safety Method	Check gas supply, set desired pressure, check EFC device, reboot GC
42	Middle EFC Flow Ready Time Out	Alert/Error	Unit not ready for 10 minutes	Activated Safety Method	Check gas supply, set desired pressure, check EFC device, reboot GC
43	Back EFC Flow Ready Time Out	Alert/Error	Unit not ready for 10 minutes	Activated Safety Method	Check gas supply, set desired pressure, check EFC device, reboot GC
Injector EFC Pressure ready time out					
44	Front EFC Pressure Ready Time Out	Alert Error	Unit not ready for 10 minutes	Activated Safety Method	-
45	Middle EFC Pressure Ready Time Out	Alert Error	Unit not ready for 10 minutes	Activated Safety Method	-
46	Back EFC Pressure Ready Time Out	Alert Error	Unit not ready for 10 minutes	Activated Safety Method	-
FID Flame Ignition					
47	Front FID Flame Reigniting				
48	Middle FID Flame Reigniting				

[1] If the used gas is Hydrogen (H_2) the Error level is Error, in all other cases an Alert is given.

Code	Error Description	Error level	Cause Condition(s)	GC action	Action needed
49	Rear FID Flame Reigniting				
PFPD Board Failure					
50	Front PFPD Board Failure	Alert	Defect PFDP board	Electronics off (all) H2 flow set to 0.0 mL/min	Replace PFPD board
51	Middle PFPD Board Failure	Alert	Defect PFDP board	Electronics off (all) H2 flow set to 0.0 mL/min	Replace PFPD board
52	Back PFPD Board Failure	Alert	Defect PFDP board	Electronics off (all) H2 flow set to 0.0 mL/min	Replace PFPD board
53	Becoming Not Ready (during run)	Event	-	-	-
54	Becoming Ready (during run)	Event	-	-	-
IOC Failure					
55	IOC Bad Addre Chan	Event	-	-	-
56	IOC Bad Cmd	Event	-	-	-
57	IOC Stepper in Motion	Event	-	-	-
58	IOC Bad Parameter	Event	-	-	-
59	IOC Run mode error	Event	-	-	-
60	IOC no Detector	Event	-	-	-
61	IOC Command not Allowed	Event	-	-	-
62	IOC_EFC_BUFFER_OVERFLOW, Unit rebooted	Event	Caused by too many requests requested by IOC to EFC Interface print.	GC reboot the interface print firmware	-
63	IOC_EFC_COMMUNICATION_ERROR, Unit Rebooted	Event	Communication between EFC Interface Print and EFC broken.	GC reboot the interface print firmware	-
Zone Open Sensor (zone)					
67	Column Oven Open Sensor	Error	Column Oven sensor not in use, mis used	Electronics off (all) H2 flow set to 0.0 mL/min	Check Column Oven zone
68	Zone 1 Open Sensor	Error	Zone 1 sensor not in use, mis used	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (1)
69	Zone 2 Open Sensor	Error	Zone 2 sensor not in use, mis used	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (2)
70	Zone 3 Open Sensor	Error	Zone 3 sensor not in use, mis used	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (3)
71	Zone 4 Open Sensor	Error	Zone 4 sensor not in use, mis used	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (4)
72	Zone 5 Open Sensor	Error	Zone 5 sensor not in use, mis used	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (5)
73	Zone 6 Open Sensor	Error	Zone 6 sensor not in use, mis used	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (6)
Shorted Sensor (zone)					
74	Column Oven Shorted Sensor	Error	Shorted sensor. Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check Column Oven zone
75	Zone 1 Shorted Sensor	Error	Shorted sensor. Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (1)
76	Zone 2 Shorted Sensor	Error	Shorted sensor. Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (2)
77	Zone 3 Shorted Sensor	Error	Shorted sensor. Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (3)
78	Zone 4 Shorted Sensor	Error	Shorted sensor. Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (4)
79	Zone 5 Shorted Sensor	Error	Shorted sensor. Defect Sensor	Electronics off (all)	Check zone (5)

Code	Error Description	Error level	Cause Condition(s)	GC action	Action needed
				H2 flow set to 0.0 mL/min	
80	Zone 6 Shorted Sensor	Error	Shorted sensor. Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (6)
Thermal Runaway (zone)					
81	Column Oven Thermal Runaway	Error	-	Electronics off (all) H2 flow set to 0.0 mL/min	Check Column Oven zone
82	Zone 1 Thermal Runaway	Error	-	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (1)
83	Zone 2 Thermal Runaway	Error	-	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (2)
84	Zone 3 Thermal Runaway	Error	-	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (3)
85	Zone 4 Thermal Runaway	Error	-	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (4)
86	Zone 5 Thermal Runaway	Error	-	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (5)
87	Zone 6 Thermal Runaway	Error	-	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (6)
Max Temper Exceeded (zone)					
88	Column Oven Max Temper Exceeded	Error	Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check Column Oven zone
89	Zone 1 Max Temper Exceeded	Error	Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (1)
90	Zone 2 Max Temper Exceeded	Error	Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (2)
91	Zone 3 Max Temper Exceeded	Error	Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (3)
92	Zone 4 Max Temper Exceeded	Error	Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (4)
93	Zone 5 Max Temper Exceeded	Error	Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (5)
94	Zone 6 Max Temper Exceeded	Error	Defect Sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (6)
Min Temper Exceeded (zone)					
95	Column Oven Min Temper Exceeded	Error	Turn device off. Temperature below -10 °C, only for non callable devices	Electronics off (all) H2 flow set to 0.0 mL/min	Check Column Oven zone
96	Zone 1 Min Temper Exceeded	Error	Turn device off. Temperature below -10 °C, only for non callable devices	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (1)
97	Zone 2 Min Temper Exceeded	Error	Turn device off. Temperature below -10 °C, only for non callable devices	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (2)
98	Zone 3 Min Temper Exceeded	Error	Turn device off. Temperature below -10 °C, only for non callable devices	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (3)
99	Zone 4 Min Temper Exceeded	Error	Turn device off. Temperature below -10 °C, only for non callable devices	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (4)
100	Zone 5 Min Temper Exceeded	Error	Turn device off. Temperature below -10 °C, only for non callable devices	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (5)
101	Zone 6 Min Temper Exceeded	Error	Turn device off. Temperature below -10 °C, only for non callable devices	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (6)
Too Slow Response (zone)					
109	Column Oven too slow response	Error	Sensor not used (wrong used), mismatch heated	Electronics off (all)	Check Column Oven zone

Code	Error Description	Error level	Cause Condition(s)	GC action	Action needed
			device. 230 V GC is using 110 V heaters	H2 flow set to 0.0 mL/min	
110	Zone 1 too slow response	Error	Sensor not used (wrong used), mismatch heated device. 230 V GC is using 110 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (1)
111	Zone 2 too slow response	Error	Sensor not used (wrong used), mismatch heated device. 230 V GC is using 110 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (2)
112	Zone 3 too slow response	Error	Sensor not used (wrong used), mismatch heated device. 230 V GC is using 110 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (3)
113	Zone 4 too slow response	Error	Sensor not used (wrong used), mismatch heated device. 230 V GC is using 110 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (4)
114	Zone 5 too slow response	Error	Sensor not used (wrong used), mismatch heated device. 230 V GC is using 110 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (5)
115	Zone 6 too slow response	Error	Sensor not used (wrong used), mismatch heated device. 230 V GC is using 110 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (6)
Too Fast Response (zone)					
116	Column Oven too fast response	Error	Sensor not used (wrong used), mismatch heated device. 110 V GC is using 230 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check Column Oven zone
117	Zone 1 too fast response	Error	Sensor not used (wrong used), mismatch heated device. 110 V GC is using 230 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (1)
118	Zone 2 too fast response	Error	Sensor not used (wrong used), mismatch heated device. 110 V GC is using 230 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (2)
119	Zone 3 too fast response	Error	Sensor not used (wrong used), mismatch heated device. 110 V GC is using 230 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (3)
120	Zone 4 too fast response	Error	Sensor not used (wrong used), mismatch heated device. 110 V GC is using 230 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (4)
121	Zone 5 too fast response	Error	Sensor not used (wrong used), mismatch heated device. 110 V GC is using 230 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (5)
122	Zone 6 too fast response	Error	Sensor not used (wrong used), mismatch heated device. 110 V GC is using 230 V heaters	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (6)
Fan or Heater					
123	No Fan or Heater detected	Error	Hardware error	-	-
124	Watch Dog Heater activated	Error	Hardware error	-	-
EFC Hardware Errors					
125	Front EFC Flow Unit Hardware Error				
126	Middle EFC Flow Unit Hardware Error				
127	Rear EFC Flow Unit Hardware Error				
128	Front EFC Pressure Unit Hardware Error				
129	Middle EFC Pressure Unit Hardware Error				
130	Rear EFC Pressure Unit Hardware Error				
131	Front Detector EFC Channel 1 Hardware Error				
132	Front Detector EFC Channel 2 Hardware Error				
133	Front Detector EFC Channel 3 Hardware Error				
134	Middle Detector EFC Channel 1 Hardware Error				
135	Middle Detector EFC Channel 2 Hardware Error				
136	Middle Detector EFC Channel 3 Hardware Error				
137	Rear Detector EFC Channel 1 Hardware Error				
138	Rear Detector EFC Channel 2 Hardware Error				
139	Rear Detector EFC Channel 3 Hardware Error				
140	Aux 1 EFC Hardware Error				
141	Aux 2 EFC Hardware Error				

Code	Error Description	Error level	Cause Condition(s)	GC action	Action needed
142	Aux 3 EFC Hardware Error				
143	Aux 4 EFC Hardware Error				
144	Aux 5 EFC Hardware Error				
145	Aux 6 EFC Hardware Error				
146	Aux 7 EFC Hardware Error				
147	Aux 8 EFC Hardware Error				
TCD no Air Leak (position)					
230	Front TCD no Air leak	Event	When error (18) is solved within 4 minutes after error (18) appears	Notification Message	-
231	Middle TCD no Air leak	Event	When error (18) is solved within 4 minutes after error (18) appears	Notification Message	-
232	Rear TCD no Air leak	Event	When error (18) is solved within 4 minutes after error (18) appears	Notification Message	-
TCD Air Leak fault (position)					
233	Front TCD Air leak fault	Alert	4 minutes after error (18) where there has been no “No Air Leak”	Turn Electronics and power off	Find source and repair/replace hardware
234	Middle TCD Air leak fault	Alert	4 minutes after error (18) where there has been no “No Air Leak”	Turn Electronics and power off	Find source and repair/replace hardware
235	Rear TCD Air leak fault	Alert	4 minutes after error (18) where there has been no “No Air Leak”	Turn Electronics and power off	Find source and repair/replace hardware
Max Setup Temper Exceeded (position)					
247	Column Oven Max Setup Temper Exceeded	Error	Defect Sensor. Temperature is 10 °C above set temperature limit	Electronics off (all) H2 flow set to 0.0 mL/min	Check Column Oven zone
248	Zone 1 Max Setup temper Exceeded	Error	Defect Sensor. Temperature is 10 °C above set temperature limit	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (1)
249	Zone 2 Max Setup temper Exceeded	Error	Defect Sensor. Temperature is 10 °C above set temperature limit	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (2)
250	Zone 3 Max Setup temper Exceeded	Error	Defect Sensor. Temperature is 10 °C above set temperature limit	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (3)
251	Zone 4 Max Setup temper Exceeded	Error	Defect Sensor. Temperature is 10 °C above set temperature limit	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (4)
252	Zone 5 Max Setup temper Exceeded	Error	Defect Sensor. Temperature is 10 °C above set temperature limit	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (5)
253	Zone 6 Max Setup temper Exceeded	Error	Defect Sensor. Temperature is 10 °C above set temperature limit	Electronics off (all) H2 flow set to 0.0 mL/min	Check zone (6)
Temperature Zone					
260	Column Temperature Out Of Tolerance				
261	Zone 1 Temperature Out Of Tolerance				
262	Zone 2 Temperature Out Of Tolerance				
263	Zone 3 Temperature Out Of Tolerance				
264	Zone 4 Temperature Out Of Tolerance				
265	Zone 5 Temperature Out Of Tolerance				
266	Zone 6 Temperature Out Of Tolerance				
Detector EFC Flow out of range					
304	Front DFC Chan1 out of range	Alert Error[2]	Flow is above max +10 % or below -5 mL/min for more then 10 sec.	Activate Safety Method	Turn off/on flow, check source (gas-supply)
305	Front DFC Chan2 out of range	Alert Error	Flow is above max +10 % or below -5 mL/min for	Activate Safety Method	Turn off/on flow, check source

2 If the used gas is Hydrogen (H_2) the Error level is Error, in all other cases an Alert is given.

Code	Error Description	Error level	Cause Condition(s)	GC action	Action needed
			more then 10 sec.		(gas-supply)
306	Front DFC Chan3 out of range	Alert/Error	Flow is above max +10 % or below -5 mL/min for more then 10 sec.	Activate Safety Method	Turn off/on flow, check source (gas-supply)
307	Middle DFC Chan1 out of range	Alert/Error	Flow is above max +10 % or below -5 mL/min for more then 10 sec.	Activate Safety Method	Turn off/on flow, check source (gas-supply)
308	Middle DFC Chan2 out of range	Alert/Error	Flow is above max +10 % or below -5 mL/min for more then 10 sec.	Activate Safety Method	Turn off/on flow, check source (gas-supply)
309	Middle DFC Chan3 out of range	Alert/Error	Flow is above max +10 % or below -5 mL/min for more then 10 sec.	Activate Safety Method	Turn off/on flow, check source (gas-supply)
310	Rear DFC Chan1 out of range	Alert/Error	Flow is above max +10 % or below -5 mL/min for more then 10 sec.	Activate Safety Method	Turn off/on flow, check source (gas-supply)
311	Rear DFC Chan2 out of range	Alert/Error	Flow is above max +10 % or below -5 mL/min for more then 10 sec.	Activate Safety Method	Turn off/on flow, check source (gas-supply)
312	Rear DFC Chan3 out of range	Alert/Error	Flow is above max +10 % or below -5 mL/min for more then 10 sec.	Activate Safety Method	Turn off/on flow, check source (gas-supply)
313	Front EFC Channel 1, flow ready time out	Alert Error	Unit not ready for 10 minutes	-	-
314	Front EFC Channel 2, flow ready time out	Alert Error[3]	Unit not ready for 10 minutes	-	-
315	Front EFC Channel 3, flow ready time out	Alert Error	Unit not ready for 10 minutes	-	-
316	Middle EFC Channel 1, flow ready time out	Alert Error	Unit not ready for 10 minutes	-	-
317	Middle EFC Channel 2, flow ready time out	Alert Error	Unit not ready for 10 minutes	-	-
318	Middle EFC Channel 3, flow ready time out	Alert Error	Unit not ready for 10 minutes	-	-
319	Rear EFC Channel 1, flow ready time out	Alert Error	Unit not ready for 10 minutes	-	-
320	Rear EFC Channel 2, flow ready time out	Alert Error	Unit not ready for 10 minutes	-	-
321	Rear EFC Channel 3, flow ready time out	Alert Error	Unit not ready for 10 minutes	-	-
NPD Bead					
332	Front NPD bead Shorted				
333	Middle NPD bead Shorted				
334	Rear NPD bead Shorted				
335	Front NPD bead Open				
336	Middle NPD bead Open				
337	Rear NPD bead Open				
339	DataStream Manager Stopped Incorrect				
Local Automation					
340	Local/Automation Injection Position Incorrect				
341	Local/Automation First Vial Incorrect				
342	Local/Automation Last Vial Incorrect				
343	Local/Automation First Injection Volume Incorrect				
344	Local/Automation Second Injection Volume Incorrect				
368	Password Incorrect				
Auto Sampler (AS)					
370	Sampler old firmware	Event	Syringe stepper motor firmware old	-	-
371	Sampler Faulted	Alert	Mismatch AutoSampler	Notification Message	Cable in SID2, check power

3 If the used gas is Hydrogen (H_2) the Error level is Error, in all other cases an Alert is given.

Code	Error Description	Error level	Cause Condition(s)	GC action	Action needed
					switch, jumpers on AS, Reboot GC
372	Sampler Communication error	Alert	No communication AS	Notification Message	Check cables, reboot GC
373	Sampler Tower error	Alert	No response AS-tower. Start AS when AS is turned off	-	-
374	Sampler Carrousel error	Alert	Block carrousel when it's turning	-	-
375	Sampler Syringe Sled error	Alert	Block syringe when it's turning	-	-
376	Sampler Plunger error	Alert	Hall sensor unplugged Switched to SPME mode during syringe use	-	Recalibrate AS, reboot GC
377	Sampler Syringe Missing	Alert	No Syringe available	-	Place Syringe
378	Sampler Vail Missing	Alert	No Vial available Vial detect should be turned on (setup)	Notification Message	Place Vial in position
379	Sampler Dual Dup Mode Delay Expired	Alert	Delay between runs has expired before the second injection. This error will only appear in dual-/ or duplicate mode	Notification Message?	Remove time out, restart seq.
380	Sampler Run not started after Inj	Alert	Run did not start injection. Contact switch on Injector broken?	Notification Message?	restart
381	Sampler Syringe volume exceeded	Alert	Total Injection volume exceeds syringe volume	Notification Message?	Check error source
383	Sampler Tower sensor not found	Alert	Unplugged sensor: sense tower	-	Check source, solve error
384	Sampler Carrousel sensor not found	Alert	Carrousel not in place	-	Check source, solve error
385	Sampler Syringe sled sensor not found	Alert	Unplugged sensor: sled sensor	-	Check source, solve error
386	Sampler Plunger sensor not found	Alert	Unplugged sensor: plunger sensor	-	Check source, solve error
387	Sampler Plunger Strokes exceed limit	Alert	Plunger strokes exceed limit	-	Reset plunger stroke counter
Gas saver timeout expired (position)					
388	Front Gas saver timeout exceeded	Event	Gas saver timeout exceeded	Activate standby method	Activated method, remove time out
389	Middle saver timeout exceeded	Event	Gas saver timeout exceeded	Activate standby method	Activated method, remove time out
390	Rear saver timeout exceeded	Event	Gas saver timeout exceeded	Activate standby method	Activated method, remove time out
391	Run ended before second injection	Alert	Stopped	Notification Message?	Check cause, solve, restart automation?
Miscellaneous					
411	Unavailable operation autom				
412	Unavailable operation non autom	Alert	Running, remote with compassCDS	Notification Message?	Check cause, solve, restart automation?
413	IOP Communication Failure at startup	Error	IOP Communication Failure at startup	Notification Message?	Replace/fix IOP
Auto Sampler (AS)					
414	Sampler Max Plunger speed exceeded	Alert	Set Injection to 60 µL/se (with testclient) using a 10 µL syringe	Electronics off (all) H2 flow set to 0.0 mL/min	Down load method, reset plunger speed
416	Sampler Tray is missing	Alert	Only on 8410 sampler	Notification Message?	Place tray in position
418	Sampler Vial is unreachable	Alert	Only on 8410 sampler, tray has been turned vial becomes unreachable for the tower	Notification Message	Calibrate AS, place vial, solve error
423	Sampler Vial sensor bad	Alert	Defective sensor	Electronics off (all) H2 flow set to 0.0 mL/min	Replace vial sensor
424	Sampler Column standby timeout expired	Event	Standby timeout expired	Activate method, reset time out	Activate method, reset time out
425	IOP Skips ADC Reading	Error	IOP too busy (might be due to EFC) and therefore skips ADC reading	Notification Message?	-
426	Sampler Plunger stuck on sensor	Alert	(errors not reproducible)	Electronics off (all) H2 flow set to 0.0 mL/min	-
427	Sampler Syringe stuck on sensor	Alert	(errors not reproducible)	Electronics off (all) H2 flow set to 0.0 mL/min	-

Code	Error Description	Error level	Cause Condition(s)	GC action	Action needed
428	Sampler Tower stuck on sensor	Alert	(errors not reproducible)	Electronics off (all) H2 flow set to 0.0 mL/min	-
429	Sampler Carrousel stuck on sensor	Alert	(errors not reproducible)	Electronics off (all) H2 flow set to 0.0 mL/min	-
434	Sampler EDS Checksum is bad	Alert	-	-	-
436	IOP Communication failure	Error	IOP Communication failure	Notification Message?	Replace/fix IOP
437	Battery voltage out of range	Event	Battery voltage < 2V or > 4V ➔ error	-	-
439	PGA Calib Failed	Error	IOPSH (measuring system)	-	Recalibrate PGA
440	Temp Calib Failed	Error	-	-	Recalibrate temp
441	Temperature Calibration Failed				
442	Press out of tolerance	Error	Ambient pressure < 15kPa or > 115pKa ➔ error	-	-
443	Boardtemp out of tolerance	Error	Currently in use, only logged	-	GC main board
Out of Tolerance (red_id)					
444	P10V ref out of tolerance	Error	444 to 465 Refvolt out of Tolerance (all voltages on mainboard, part of measuring system) Hazardous by default, basis of all measurement in system.	-	Check power supply requirements/ replace main board electronics
445	AIN10V out of tolerance	Error		-	
446	P5V ref out of tolerance	Error		-	
447	P2V5 ref out of tolerance	Error		-	
448	P24V Prim out of tolerance	Error		-	
449	P24V Sec out of tolerance	Error		-	
450	N24V out of tolerance	Error		-	
451	P5V D out of tolerance	Error		-	
452	P5V out of tolerance	Error		-	
453	N5V out of tolerance	Error		-	
454	P15V out of tolerance	Error		-	
455	N15V out of tolerance	Error		-	
456	P5V DAC out of tolerance	Error		-	
457	VREF1 out of tolerance	Error		-	
458	VREF0 out of tolerance	Error		-	
Out of Tolerance (cts_id)					
459	CTS1 out of tolerance	Error	-	Electronics off (all) H2 flow set to 0.0 mL/min	-
460	CTS2 out of tolerance	Error	-		-
461	CTS3 out of tolerance	Error	-		-
462	CTS4 out of tolerance	Error	-		-
463	CTS5 out of tolerance	Error	-		-
464	CTS6 out of tolerance	Error	-		-
465	Tref out of tolerance	Error	-		-
466	Step motor moving	Error	-		-
Temperature					
470	Maximum Setup Temperature Exceeded				
471	Maximum Temperature Exceeded				
473	Minimum Temperature Exceeded				
474	Open Sensor				
476	Shorted Sensor				
477	Thermal Runaway				
478	Too Fast Response				
479	Too Slow Response				

Code	Error Description	Error level	Cause Condition(s)	GC action	Action needed
Option Board Errors					
482	Analog output buffer underrun	Alert	Buffer underrun		
483	Analog output buffer overflow	Alert	Buffer overrun	Notification Message	-
484	Analog output communication error	Alert	-	Notification Message	-
485	Optionboard external events error	Alert	-	Notification Message	-
Analog Output					
486	Analog Output EEPROM Error				
487	Analog Output Unexpected Error				
Zone					
501	Zone 7 Open Sensor				
502	Zone 8 Open Sensor				
503	Zone 7 Shorted Sensor				
504	Zone 8 Shorted Sensor				
505	Zone 7 Thermal Runaway				
506	Zone 8 Thermal Runaway				
507	Zone 7 Maximum Temperature Exceeded				
508	Zone 8 Maximum Temperature Exceeded				
509	Zone 7 Minimum Temperature Exceeded				
510	Zone 8 Minimum Temperature Exceeded				
511	Zone 7 Too Slow Response				
512	Zone 8 Too Slow Response				
513	Zone 7 Too Fast Response				
514	Zone 8 Too Fast Response				
515	Zone 7 Maximum Setup Temperature Exceeded				
516	Zone 8 Maximum Setup Temperature Exceeded				
517	Zone 7 Temperature Out of Tolerance				
518	Zone 8 Temperature Out of Tolerance				
519	Zone 7 No Response				
520	Zone 8 No Response				
AutoSampler					
600	Tray Missing				
601	Tray Present, Previous=not present Detected				
602	Tray Present, Previous=not present not Detected				
603	Tray Present, Previous=present				
604	Getstatus Error, set Vial Missing				
700					
701					
702					
703					
704					
705					
706					
707					
710					
711					
712					
713					
714					

Code	***Error Description***	***Error level***	***Cause Condition(s)***	***GC action***	***Action needed***
715					
716					
717					
718					
719					
720					
721					
722					
723					
724					
725					
726					
727					
728					
729					
730					
731					
732					
733					
734					
735					
736					
737					
1035					
1036					

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ELECTRONICS

Electronically diagrams, wiring, connector pin outs of the 436-GC/456-GC

Hardware description

Hardware description of the 436-GC/456-GC

Section contents:

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Electronic - pneumatic Injector Controller PWA Circuit Description.

Description of the circuit.

The following functions exist on the board, with major components as indicated:

Function:	Major Components:
Digital Interface	U1,U2,U3,U4
Analog Interface	U5,AR3
Diagnostics	CR1,CR2,R38,R39,R44,R45
Power Control	Q1,Q5,Q6,Q7,VR1
Flow Controller	AR7,AR4,AR5,AR6,AR3,Q3
Pressure Controller	AR7,AR2,AR5,AR6,AR3,Q2
Temperature Controller	AR1,AR5,Q4
Reference Voltage	AR7,R50,C29,R3

Description of the Mercury EFC interface.

The Injector EFC bus is distributed via a 34 pin ribbon cable, which connects J8 on the main board to up to three Injector EFC boards located inside the pneumatics compartment of the GC. J9 on the main board is an identical interface that is intended to support up to three Detector EFC boards.
The signals on the Injector EFC bus are:

Digital Signals.

EFCA1	Address bit
EFCA2	Address bit
EFCA3	Address bit
EFC1SEL	Module Select #1
EFC2SEL	Module Select #2
EFC3SEL	Module Select #3
S2CLK	Serial bus clock
S2IN	Serial data to main board
S2OUT	Serial data from main board
SYSENAB	System enable signal.

Analog Signals.

IEFCANLG	Multiplexed Analog Return signal.
+5VREF	+5.00 Volt Reference.

Ribbon cable pin assignments are as follows:

Pin#	Signal
1,2,17	+15Volts Supply
3,4	-15 Volts Supply
10,11	+5.25 Volts supply
5,6,9	Analog Ground 2
7	IEFCANLG
12,13	-5Volt supply
18,19,20,21	+24Volt supply
15	Proportional Valve return ground
14,16,23,24	Digital/Power Ground
22	+5 Volt Digital supply
8	+5VREF
25	EFCA1
26	EFCA2
27	EFCA3
28	EFCA1SEL
29	EFCA2SEL
30	EFCA3SEL
31	S2CLK
32	S2IN
33	S2OUT
34	SYSENAB

EIC PWA Digital Interface.

The three module Select bits are connected to J2 pins 2,4 & 6. For selection of Module #1, a jumper connects J2 pin 2 to J2 pin 1 on the EFC PWA. When EFC1SEL goes low it selects U1 and permits the address bits EFCA1 through EFCA3 to be decoded.
Modules #2 and #3 are selected in a similar manner by moving the jumper to positions that connect pins 4 to 3 and 6 to 5 respectively.
U2 is a serial EEPROM which is addressed by all address bits high. Serial communication to U2 is via a serial interface comprised of S2CLK, 521N and S2OUT.
U3 is a serial shift register with latched outputs, that is used for configuring the EIC. With SYSENAB low the input shift register of U3 is reset to zero, but the output remains unaffected.
After SYSENAB is released and goes high U3 can be addressed and loaded via the serial interface. In order to strobe the data to the output of U3, U1 should be addressed with (000). Outputs of U3 are assigned as follows:

Bit#	High	Low
QA	Connect Temp. to EFCANLG	Disconnect Temp.
QB	Connect Valve Diag. to IEFCANLG	Disconnect Valve Diag.
QC	Connect Flow to IEFCANLG	Disconnect Flow.
QD	Connect Pressure to IEFCANLG	Disconnect Pressure.
QE	Turn on Split/Splitless Valve	Turn off Valve.
QF	Turn on Septum Valve	Turn off Valve.
QG	Turn on 14 Volt supply	Turn off Supply.
QH	Tur Turn off Block Heater	Turn on Heater.

U4 is a dual 12 bit serial input DAC. It is loaded by writing 24 bits over the serial bus while address (011) is active, and then writing address (010) to load the data.

EIC PWA Analog Interface.

A single analog signal is returned to the main board over the EFC ribbon cable.
This signal is IEFCANLG, and is multiplexed on the EFC PWA. U5 is a quad analog switch that is connected up as a 4 channel multiplexer. Analog signals called Temp,Valve Diag,Pressure & Flow are selected by turning on the appropriate bits from the serial shift register U3. R22,C6,R21,C5,AR3 and R60 form a filter and output buffer circuit for the Flow signal. R60 is a pull up used to improve the capacitive load tolerance of AR3. Similarly R40,R41,C23,C24 and R61 form a filter and output buffer for the Pressure signal.

Diagnostics.

R44 and R45 form a divider for the temperature controller diagnostic output. When the temperature controller is controlling at it's setpoint the output of AR1,7 is at zero volts +/- the opamp offset. The voltage presented at U5,11 is nominally 2.500 volts. A deviation of about 80 millivolts is equivalent to one degree Celsius at the output of AR1,7. This translates to a 40 millivolt change at U5,11.

Power Control.

Q5 & Q6 are used as valve drivers to support up to two switching valves connected to J2,7/8 and J2,9/10. CR3 and CR4 are snubber diodes.
VR1 is a voltage regulator supplying 14 Volt power to the two proportional valve drivers formed by Q2 and Q3.When Q7 is turned on the reference input to VR1 is shorted to ground, effectively turning off the +14 Volt supply. Heater power can be turned off by turning on Q1, which removes base drive to Q4.

Flow Controller.

The Flow Controller is a closed loop Proportional Integral type (P1) controller.
A flow sensor is formed from a differential pressure transducer sensing the pressure drop across a flow restrictor. The Pressure transducer appears as a Wheatstone bridge and is connected to the PWA via J3. The differential outputs of the bridge are connected to J3,4&2, which are then amplified by AR4. AR4 is a low drift instrumentation amplifier. [Gain = 49.4K/(R30) +1 = 80.8] The top of transducer bridge is connected to J3,5 and is driven from the output of opamp AR7,7. The bottom of the bridge is connected to J3,3 and J3,25. This connection also connects a laser trimmed current sense resistor located on the transducer assembly to the bottom of the transducer bridge.
The remaining side of the current sense resistor connects to analog ground at J3,24.
The excitation current flowing through the bridge is sensed by the input to opamp AR7,6 and compared to the 2.5 Volt reference at AR7,5. In this way the bridge excitation current is kept constant with reference to the 2.5 Volt reference.U4 is a digital to analog converter with a voltage output that varies between 0.0 Volts and - VREF. VREF is the +5.00 Volt reference voltage that connects to U4,2&7.
The Flow DAC output connects from U4,3 to R3,3. R3 is a precision low drift resistor network. Part of this network is used to form a summing node at R3,13 and R3,14. This node sums the output of the AR4 and U4,3 together. Under normal conditions the output of AR4 is positive and the output of U4,3 is negative. When the controller is at a controlled setpoint the junction of the summing node approaches zero.
The summing node junction connects to an integrator formed by AR6,C33 and R10, and an inverting amplifier formed by AR5,R4 and R37. The outputs of the integrator and the inverting amplifier are summed together at the node where R31 and R51 join together. In this way the integral and proportional terms of the controller are added together. The summed Integral and Proportional terms provide a driving voltage to AR3,3.The coil of an analog proportional valve is connected to J2,13&14. Q3,R12,R56 and 1/4 of AR3 form a current sink driver for the proportional valve.A voltage at AR3,3 translates into a current scaled by sense resistor R12.In this way a control loop error occurring at the summing node of R3,13 and R3,14 causes a change to the valve coil current in a direction that corrects the error.R55,C38,R56 and R57 keep the current sink stable.R27 and R48 provide a nominal current drive to the proportional valve when the Integrator output is zero volts. Changing the impedance of R27 and R48 provides a means of adjusting the forward gain of the controller.An offset voltage of 1.25 Volts is connected to AR4,5 ensures a positive offset voltage above zero. For a DAC voltage of zero the controller is guaranteed to turn the proportional valve hard OFF.Partial immunity to ground noise is achieved by referencing the bottom of R48 and AR5,10 to the +14VGND.

Notes:

AR6 is a high gain extremely low input bias current precision opamp. It was selected for it's high gain, and the low input bias current permits easy use of high resistor values and low capacitor values in both the flow controller and pressure controller integrators.
R3 is a thin film resistor pack with a 5ppm/C ratiometric drift spec. It is used for it's thermal stability.

Pressure Controller.

The Pressure Controller is a closed loop Proportional, Integral, Derivative type (PID) controller.
A Pressure transducer is connected to J3 appears as a Wheatstone bridge. The differential outputs of the bridge are connected to J3,12&10, which are then amplified by AR2. AR2 is a low drift instrumentation amplifier. [Gain = 49.4K/(R59) +1 = 10.9]
The top of transducer bridge is connected to J3,12 and is driven from the output of opamp AR7,14. The bottom of the bridge is connected to J3,11 and J3,17. This connection also connects a laser trimmed current sense resistor located on the transducer assembly to the bottom of the transducer bridge.
The remaining side of the current sense resistor connects to analog ground at J3,16.
The excitation current flowing through the bridge is sensed by the input to opamp AR7,13 and compared to the 2.5 Volt reference at AR7,12. In this way the bridge excitation current is kept constant with reference to the 2.5 Volt reference.

U4 is a digital to analog converter with a voltage output that varies between 0.0 Volts and - VREF. VREF is the +5.00 Volt reference voltage that connects to U4,2&7.
The Pressure DAC output connects from U4,6 to R3,5. R3 is a precision low drift resistor network. Part of this network is used to form a summing node at R3,11 and R3,12.
This node sums the output of the AR2 and U4,6 together. Under normal conditions the output of AR2 is positive and the output of U4,6 is negative. When the controller is at a controlled setpoint the junction of the summing node approaches zero.

The summing node junction connects to an integrator formed by AR6, C31 and R9, and an inverting amplifier formed by AR5,R5 and R36.
A derivative term is formed by AR5, R7, R8, C25, C26, R34 and R35. The input to the derivative term is connected to output of AR2.
The outputs of the integrator and the inverting amplifier as well as the derivative circuit are summed together by a summing amplifier formed by AR6, R32, R33, R42, and R6. In this way the Integral Proportional and Derivative terms of the controller are added together.
The summed terms at the output of AR6, 14 provide a driving voltage to AR3,5.
The coil of an analog proportional valve is connected to J2, 11&12. Q2, R13, R53 and 1/4 of AR3 form a current sink driver for the proportional valve.
A voltage at AR3,5 translates into a current scaled by sense resistor R13.
In this way a control loop error occurring at the summing node of R3, 11 and R3,12 causes a change to the valve coil current in a direction that corrects the error.
R53,C35, R54 and R49 keep the current sink stable.
An offset voltage of 1.25 Volts is connected to AR2,5 ensures a positive offset voltage above zero. For a DAC voltage of zero the controller is guaranteed to turn the proportional valve hard OFF.
Immunity to ground noise on the +14VGND is improved by the 3.16K and 1K resistor network connected to AR6,12.

Notes:

AR6 is a high gain extremely low input bias current precision opamp. It was selected for it's high gain, and the low input bias current permits easy use of high resistor values and low capacitor values in both the flow controller and pressure controller integrators.
R3 is a thin film resistor pack with a 5ppm/C ratiometric drift spec. It is used for it's thermal stability.
The derivative term input is connected to the output of AR2 instead of the loop error to prevent a change in set point from causing a derivative "kick".

Temperature Controller.

The function of the temperature controller is to provide improved stability and calibration accuracy, by keeping the flow and pressure transducers at a near constant temperature.
The controller has a machined aluminum block which surrounds the two pressure transducers that are plugged into J3. The flow sensor flow restrictor is pressed into this same block.
Q4 functions as a heater and is bolted to the block. RT1 is a thermistor that is located inside the transducer cavity of the block. R30 and R59 are in close proximity to the thermistor.
Under normal use a jumper is installed between J2, 15 & 16 connecting one side of R18 to RT1 to AR1,1.
The output of AR1 provides a negative voltage to the bottom of resistor divider R20 and R18. Under conditions where the controller is at set point and controlling the resistance of RT1 will equal the resistance of R18 and the bridge formed by R18, R19, R20 and RT1 will be in balance with the voltage at AR1,5 approaching zero.
A deviation in temperature from the set point value will cause the output of AR1,1 to change and result in a correcting voltage at AR1,5. The output of AR1,7 drives the Integrator formed by AR1,C22,R47 and R2. As the Integrator output changes it causes a change to the heater drive circuit formed by AR5, R43, R14 and Q4. A voltage at AR5,12 causes a current to flow in Q4, the current sense resistor R14 returns a voltage to AR5,13 forming a current sink circuit. R70 and C42 roll off the amplifier for stability.
A 499 ohm resistor between the base and emitter of Q4 serves to reduce the loop gain of the circuit and help make it stable.
(The minimum current gain of Q4 is approximately 1000.)

As current in Q4 changes it's heat dissipation is also changed. As the control loop needs more heat the drive is increased and for less heat reduced. In this way a closed loop temperature controller with a fixed set point is formed. R18 is the set point value, and can be changed to be any resistance within the range of the thermistor temperature curve.
Zero compensation is included for stability. A capacitance multiplier is formed by AR1, R1, R26 and C21.
This circuit behaves as if it were a capacitor across R23.
The value of capacitance is given by C21*(R26/R1) = 30uF.
The combination of this capacitance and R23 provides a compensating zero which stabilizes the circuit.
R28 and R46 form a resistor divider that sets the maximum current drive as well as changing the forward gain of the controller.

Bake out mode.
If the jumper connecting J2, 15 & 16 is removed the temperature controller will run away and provide full power to the heater Q4, limited only by R28 and R46. Under normal ambient conditions this will cause the Aluminum block temperature to rise to approximately 80C which is a useful bake out temperature that can be used for cleaning of the block and associated components. Under these conditions the current in Q4 will be 567ma, with a power dissipation of approximately 13.5 Watts.
The junction temperature of Q4 under these conditions will be about 94C. (Tjmax = 150C)

Notes:

AR1 is an extremely low input bias current opamp that was chosen because it makes high resistor values and low capacitor values easy to use. It is also a low drift amplifier.
RT1 is a low cost surface mount thermistor with a 10% tolerance of resistance at 25C. At 45C its nominal value is close to 2.37K.

Reference Voltage.

The reference voltage is supplied by the main board, and connects to J1,8. R50 and C29 form a simple filter intended to reduce noise relative to Ground 2 on the EIC PWA. The buffered 5.00V reference is connected to U4,2&7, and then it is divided down to 2.5Volts for the transducer excitation reference. It is divided down once more to 1.25 Volts for the two transducer instrumentation amplifier offsets voltages AR2 and AR4.
Any change in reference relative to Ground 2 is ratio-metrically canceled because it causes equal percentage changes to the DAC output and the transducer excitation current as well as the instrumentation amplifier offset voltage.
Precision resistor pack R3 is used to divide down the reference voltage; this ensures that the temperature drift is kept low.

ADC Circuit Description

System description.

The central ADC system consists of a 16-bit ADC, several voltage references, a programmable-gain amplifier (PGA), a group of analog multiplexers, excitation circuitry for the RTD temperature probes, a barometric absolute pressure sensor, and timing logic to control the system. The logic, which relieves software of any precise timing requirements, is contained in FPGA X2.

ADC.

The ADC is a 16-bit (or 15-bit plus sign) delta-sigma converter. The excellent noise-rejecting characteristics of this conversion technique allow consistent noise levels below ±1/2LSB with the simple supply filtering networks of R53, C59, R81, and C57. The clock frequency at XIN is 320 kHz.

Conversions are started 160 times per second by a hardware-generated pulse on pin 2. A conversion takes 5 milliseconds, after which DRDY\ goes low, generating an interrupt and latching a new, buffered value of BP/UP\ (bipolar/unipolar mode). Software then has over 6 milliseconds to read the converted value and update the buffer holding the next desired value of BP/UP\, before the data from the next conversion will be ready. The converted value is read serially from SDATA, with hardware sending a pulse to SCLK each time SDATA is read, thus shifting out the next bit. When all of the bits have been read, DRDY\ goes high again.

The differential input range of the ADC in unipolar mode is equal to the voltage difference between VREF+ and VREF-, or 2.5V. Since the converter is supplied from +5.25V only, the analog input zero level must be shifted up above ground if negative values are to be converted in bipolar mode. AIN- is connected to +2.5V, so the input range at AIN+ in unipolar mode is +2.5V to +5.0V, and the range in bipolar mode is OV to +5V. Resistors R51, R54, and R55 shift and attenuate the ±10V levels from the PGA output to cover the 0 to +5V input range of the ADC. R50, C60, and C63 smooth the input charge packets which are transferred when the ADC samples its input.

Programmable-gain amplifier and references.

Gains of 1, 2, 4, 8, 16, 32, and 64 are provided by the programmable-gain amplifier. Corresponding full-scale voltages for the ADC, measured at the PGA input, range from 10V down to 156mV (nominal). Resolution depends upon the conversion mode, ranging from 160microV to 2.51.N in unipolar mode, or 320 microV to 5 microV in bipolar mode (nominal). The gain-setting resistors in network R4 have only 1% tolerance, so the overall gain (including R51, R54, and R55) is set slightly low to ensure that the nominal full-scale inputs can be converted without clipping. Similarly, the ADC input voltage with zero volts into the PGA is set slightly above 2.5V, so that PGA inputs all the way down to ground can always be digitized, regardless of component tolerance variations.

Capacitor C62 reduces high-frequency noise from the amplifier, while C50 and C54 suppress digitally-induced noise. R43 limits the current pulse which is drawn from the input voltage source when the input multiplexer switches, charging C50 to a new voltage. The time constants set by these capacitors are short enough to settle to the required accuracy much more quickly than the lms which is available between conversions. In addition, the input multiplexer is set to ground for 200 micro s after each conversion. This elminates any residual crosstalk between channels which might occur if the amplifier is driven into saturation. Note: the muiltiplexer is set to ground by hardware, so this action cannot be stopped by holding the multiplexer setting at a fixed channel in software. Voltmeter readings at the output of the muxtiplexer will be about 3% lower than at the input in this case.

There are three precision reference voltages: +10V, +5V, and +2.5V. The basic accuracy of the +10V reference (U9) is ±0.1%. C13 minimizes the glitches on the reference induced by the DAC switches, which operate asynchronously to the ADC conversions. The other two values are divided down from this reference by resistors in network R4 which have ±0.1% ratio accuracy, giving guaranteed accuracies of ±0.2% for the +5V and +2.5V references. One half of AR5 buffers the +2.5V reference for the ADC.
The other half of AR5, along with Ql, can supply up to 40mA of excitation current at +5V to the RTDs, the barometric absolute pressure transducer, and the EFC modules.

The remaining references voltages (+0.625V and +0.156V) have low precision and stability, being generated by a resistive divider of 1% resistors (R39, R41, and R42). These voltages are used only as transfer standards for calibrating the higher gains of the PGA. Calibration begins by reading the +10V reference on gain 1 and proceeding to higher gains and lower reference voltages. Each reference is measured at a lower gain, which has already been calibrated, immediately before being used to calibrate higher gains, so high accuracy and stability are not needed.

Multiplexers and input sources.

The primary input multiplexer, U16, at the input of the PGA can handle the ±10V signals from the detectors and the +10V reference. All of the remaining signals are scaled to 5V or less, and are selected by the secondary multiplexers (U4, U10, and U15) which
connect to inputs of U16. The secondary multiplexers are less expensive devices which cannot handle voltages exceeding ±5V.

While the multiplexer channel is selected by software, the actual value output to lines MMUXO-5 is double-buffered and delayed by hardware. Like the BP/UP\ signal mentioned above, the value in the output latch which drives the multiplexers is loaded from a buffer when DRDY\ goes low. This setting is then used for the next conversion about lms later. Software reloads the buffer during the interrupt routine, which is triggered by DRDY\, with the value needed for the conversion after the next one.

The RTD probes are excited from the +5V reference through 1K±0.1% resistors. Current through the RTDs varies between 4 and 5mA over the measured temperature range. One section of the excitation resistor network (R3) feeds a fixed resistor, R40. This is used to verify the operation of the complete temperature measurement circuit by reading this ADC channel during run time.

The RAM backup battery voltage is read through resistor R38, which limits the discharge current when the power is off. (Negligible current is drawn when multiplexer U10 has power applied.) C42 reduces the noise which is picked up due to the very high source resistance of R38.

The barometric absolute pressure sensor (MP1 on schematic sheet 1) is used to compensate the electronic flow control system for changes in barometric pressure. Its output voltage at pin 1 depends upon the reference voltage at pin3 and the absolute pressure according to the following formula:

$V_{out} = V_{ref} * (.009 * P - .095)$,

where P is in kilopascals, and voltages are in volts. Normal atmospheric pressure at sea level is about 103kPa, and the reference voltage is 5 volts, so the expected value of Vout under these conditions would be about 4.6V. Atmospheric pressure usually remains within 3% of its nominal value with changes in weather, but decreases by about 3.4kPA for each thousand feet increase in elevation. Thus, voltage readings at pin 1 of MP1 should be between 4.4 and 4.8V at sea level, decreasing by 150mV per thousand feet of elevation above sea level.

Proper operation of the ADC, PGA, and two of the input multiplexers is guaranteed by a successful self-calibration. However, this procedure could not detect a failure of the +10V reference. For this reason, the +5V digital supply voltage is read through multiplexer U 10. Reference operation is tested, but precision is not, since the test is good only to ±5%. Reading the -5V supply through the same multiplexer guarantees that a power supply failure could not cause erroneous readings.

FID Electronics Circuit Description

Power supplies and grounds.

There are four grounds serving the F1D electronics circuitry. Ground 1 is the return for the +5V digital supply. It is connected directly to Ground 4, the unregulated +24V return, at the card edge connector on the Mother board. The analog return is Ground 2, which provides a low-noise return for the ±15V and +5.25V supplies. Ground 3 is the reference for analog signal distribution, which carries almost no DC current. All of the grounds must be tied together externally for the board to function properly.

Three RC filters remove noise from the analog power supplies. These consist of R24 with C13, R23 with C12, and R22 with Cll.

Digital circuits.

U7 decodes bus address information to access latch U6 and buffer U5. The latch holds all of the digital control signals for the board, while the buffer transmits the board identification number and serial data from EEPROM U8 to the bus. R25 allows the inputs of U5 to be pulled high for test, while remaining low in normal operation.

The EEPROM is a 1024-bit device which is used to store calibration data. Software has full control over the serial interface, consisting of the chip select, shift clock, and data inputs (pins 1 - 3, respectively), and must reassemble the stored data from the serial output stream coming from pin 4. When the EEPROM is not selected, its output is high impedance. R26 provides a positive level to CMOS buffer U5 in this case.

Input log amplifier of square-root electrometer.

The electrometer is a multi-stage circuit which produces an output voltage which is proportional to the square-root of the input current. This is accomplished by three amplifier stages, AR1 (dual) and AR2, having logarithmic and exponential responses. The nonlinear responses are generated by the fundamental characteristic of bipolar transistors, which is represented in the following equations:

$$v_{be} = (nkT/q)\log(I_c/I_{sat} + 1) \text{ or } I_c = I_{sat}\,(e(^{qv}be^{/nkT}) - 1),$$

where vbe = base-emitter voltage (volts)
n = emission coefficient (near 1.00)
k = Boltzmann's constant (1.38E-23 Joule/K)
T = Temperature (Kelvins)
q= electron charge (1.6E-19 coulomb)
I_c = collector current
I_{sat} = saturation current
e = base of natural logarithms

Input amplifier AR2 has an extremely high input impedance, with a bias current of only about 40fA (40×10^{-15}A). All of the input current from J1 must therefore flow into the collector of Q1 (pin 8). Negative feedback from the output of AR2 adjusts the base-emitter voltage of Q1 until precisely this current flows into the collector. The output voltage from this stage, which is taken from the emitter of Q1 (pin 6), is therefore $v_{eb}l = -(nkT/q)\log(I_{in}/I_{sat} + 1)$.

The output voltage must be negative in order to forward-bias the base-emitter junction of Q1. However, the negative power supply for AR2 is ground, so its output cannot go below ground. R4 and R5 provide about 700mV of negative offset, allowing the output of AR2 to remain positive, while Q1 is turned on. R5 also stabilizes the loop gain at input currents near full scale (1µA), where the impedance looking into the emitter of Q1 has dropped to 26k.

Since the non-inverting input of AR2 is grounded, the inverting input remains at ground also, keeping the collector of Q1 at ground. This holds the collector-base voltage at zero, which is a necessary condition for the equations above to apply. The input connection at J1 also remains near ground at low input currents, minimizing noise due to variations in input capacitance. R1 limits input current if an excessive voltage is applied to the input, but it also allows the input voltage to rise slightly at the higher input currents.

R2, which isolates the amplifier input from the input cable capacitance for loop stability, has almost no DC voltage drop across it, since only the bias current of AR2 flows through it. C3 also enhances loop stability, and reduces high-frequency noise.

Because of the high impedance levels, this entire circuit must be shielded to work properly at all but the highest input currents. It is also easily upset by test probes even when shields are in place. In any case, the exact output voltage to be expected at a particular input current is unknown, since the saturation current of the input log transistor is unknown. All that can be predicted is that the output voltage will increase (in a negative direction) by about 26mV when the input current is doubled, or by 60mV when the input current is raised by ten times, regardless of the specific current levels.

Reference current log amplifier.

The saturation currents of the individual transistors vary from one unit to the next, and also change rapidly with temperature, doubling with each 10°C rise. In order to maintain stable and predictable calibration, each transistor used in the anti-log stage must be balanced by a matching transistor in a log stage. The anti-log stage uses two transistors, as will be described below, so a second log amplifier is needed for compensation purposes. This stage consists of one section each of AR1 (pins 1-3) and Q2 (pins 6-8), and is very similar to the input log amplifier.

The sum of the two emitter-base voltages of the log transistors is produced directly by connecting them in series. The emitter of Q1 (pin 6) is connected to the base of the Q2 (pin 7), and the output Vsum is taken from the emitter of Q2 (pin 6). The collector of Q2 (pin 6) is connected to the inverting input of AR1 (pin 2), which is held at the same voltage as the noninverting input (pin 3). By connecting the base of Q2 (pin 7) to the noninverting input, the collector-base voltage is forced to be zero. This causes the inverting input to follow the output voltage of AR2 (pin 1). As this voltage varies by a few hundred millivolts over the full range of the input current, the reference current (Tref) through R6 varies between 23 and 24 microamps. The emitter-base voltage of Q2 is thus $v_{eb}2 = - (nkT/q) \log(I_{ref}/I_{sat} + 1)$, and the net voltage at the emitter of Q2 is:

$$v_{sum} - (nkT/q) \log(I_{in}/I_{sat} + 1) - (nkT/q) \log(I_{ref}/I_{sat} + 1)$$

$$= - (nkT/q) \log ((I_{in}/I_{sat}\ 1)(I_{ref} / I_{sat}\ 1)).$$

AR1 is powered from the ±15V power supplies, which could cause avalanche breakdown of the emitter-base junction of Q2, if the amplifier output ever approached the positive supply voltage. While this never occurs in normal operation, even a momentary breakdown can cause a permanent increase in saturation current. CR1 prevents the emitter voltage from rising to a destructive level during testing or other transient fault conditions.

Anti-lot amplifier.

The logarithmically compressed voltage vsum is applied to an anti-log (or exponential) amplifier stage which utilizes the other halves of matched dual transistors Q1 and Q2. Since the anti-log transistors are connected in series, both collector currents are essentially equal. If we assume that all of the transistors are at the same temperature T and have the same saturation current Ise, the base-emitter voltage of each of the anti-log transistors will be half the value of vsum.
Their collector currents must then be $I_c = I_{sat}\, e\text{-}(^{qv}sum/^{2nkT}) - 1)$ from the equation in section 4. Substituting the expression for v_{sum} above, we have

$$L_c = I_{sat}\, (_e(1/2)\log((Iin/Isat + 1)(Iref/Isat + 1))\ \_\ 1)$$

$$= I_{sat}\, (sqrt((Iin/Isat + 1)(Iref/Isat + 1)) - 1)$$

$$= sqrt\ (I_{in} + I_{sat})(I_{ref} + I_{sat})) - I_{sat}$$

$$= sqrt\ ((\ I_{in} + I_{sat})(I_{ref}\ )) -\ I_{sat} \qquad (since\ I_{ref} > 10^9 \times I_{sat})$$

Amplifier AR1 holds the collector of Q1 (pin 1) at ground potential and forces the collector current to flow through R3. The final output voltage at P1-1 is then

$$v_{out} = 2 .05 \times 10^6 \times \text{sqrt}((I_{in}+I_{sat})(I_{ref})) + v_{os},$$

where v_{os} is the sum of the input offset voltage of AR1 and all of the current-related voltage errors. Putting in the nominal value of 25 microamps for I_{ref} gives the following approximate formula for the output voltage:

$$v_{out} = 10^4 \times \text{sqrt}(I_{in} + I_{sat})\ v_{os.}$$

This formula will not be accurate if the temperatures of all of the transistors are not equal. The two halves of each dual transistor are always at the same temperature, since they are fabricated on a single silicon die. Q1 and Q2 track each other in temperature only by being in close proximity in an isolated environment, however, and any thermal disturbance will cause the output of the electrometer to drift. Simply touching one of the transistors can cause a minute or two of drift, and the output may not stabilize for 5 or 10 minutes after soldering in the vicinity of the transistors.

The time constant of the amplifier is set to 45ms by Cl, and C2 eliminates high-frequency noise from digital sources. R8 and C10 prevent glitches from the ADC multiplexer (on the main system board), which reads the output voltage of the electrometer, from disturbing the amplifier output. Such glitches can couple through C1 and the capacitance between the collectors of the two halves of Q1 to disturb the sensitive input node, resulting in a much longer settling time than would be expected.

Electrometer diagnostic features.

In order to determine the input current from the output voltage, the value of vos in the equation in the preceding paragraph must be determined. This is done during operation by closing the switch section of U1 (pins 1-3) which is connected to the output of the reference log amplifier. Current through the anti-log transistors is thus cut off, leaving the output voltage at P1-1 equal to v_{os}.

Though it is not immediately obvious from the equations presented here, closing the switch section of U1 (pins 14-16) which is connected to the output of the input log amplifier results in an output voltage at P1-1 which corresponds to an input current equal to the saturation current of Q1. This measurement is used for diagnostic purposes only. Both of the diagnostic switch sections of U1 are left open in normal operation.

Because the input stage of the electrometer has a logarithmic response, its behavior becomes unpredictable as the input current approaches zero. All of the voltages applied to the circuit are above ground potential, so leakage currents should never cause the input to reverse in polarity and saturate the output positively. However, the response time of the circuit is inversely proportional to the current level, becoming very slow at currents below a few hundred femtoamps. For this reason, it is impractical to test the noise and drift of the electrometer by "capping off' the input with no input current.

To test the electrometer when no external picoamp source is available, an input current source in the picoampere range has been provided. This source relies upon the fact that the current through a capacitor is equal to the product of the capacitance and the rate of change of the voltage across the capacitor. C4 (10pF) is connected to the electrometer input, which remains near ground potential. Applying a positive sawtooth waveform to the other end of C4 should thus produce a steady input current, with negative spikes on the negative transitions of the sawtooth voltage. This waveform (modified somewhat to optimize the recovery of the electrometer from the negative spikes) is generated by an external DAC and applied to C4 through a filter consisting of R10 and C9. The filter removes noise from the external input, while slowing the transitions somewhat. In normal operation, transistor Q3 is turned on by writing a logic 1 to U6-12, shorting C4 to ground. Voltage variations at P1-10 will then not create an undesired current at the electrometer input.

High voltage power supply.

The high voltage power supply provides a stable source of 190VDC at low current. It consists of a linear regulator operating from the +24V supply, an unregulated flyback converter, and a zener diode regulator.

VR1 pre-regulates the power supplied to the flyback converter, thereby stabilizing the current which is supplied by the converter to the zener diode. It also powers U2 and U3, which sets the drive voltage for the gates of Q4-Q6 at 15V.

U4, a TL494, is a controller for pulse-width-modulated switching power supplies. In this application, however, it is used only to provide fixed, 45% duty cycle pulses. The internal error amplifiers are set to their maximum duty cycle condition by tying their noninverting inputs (pins 1 and 16) to ground, and connecting their inverting inputs (pins 2 and 15) to the 5-volt VREF (pin 14). Maximum duty cycle (45%) is achieved by turning off analog switch U1 (pins 6-7), so that R14 pulls the dead time input (pin 4) down to ground. The converter is turned off by closing the switch, pulling up the dead time pin to 5 volts and setting 100% dead time (0% duty cycle). R15 and C19 set the operating frequency to 50kHz.

The outputs of U4 are uncommitted transistors, which conduct alternately without overlap. Their emitters are tied to ground (pins 9 and 10), and their collectors are pulled up to 15 volts through R12 and R13. U3 (pins 1-3) inverts the negative-going pulses from one of the outputs, and two sections of U2 provide provide a high-current drive to switch the large gate capacitance of Q4 quickly. Q4 is on for about 10µs for each pulse, placing 15 volts across 1.2mH inductor L1. The current in Ll ramps up to about 100mA while Q6 is conducting. When Q6 turns off, the voltage on the drain of Q4 (pin 3) rises rapidly, turning on CR2. The energy which was stored in the inductor is transferred into C14. The voltage across C14 stabilizes at the voltage which lets the energy flow out of it at the same rate as it flows in. This occurs at about 210V, with about 500µA flowing through R17 and VR2. R18 and R19 limit the current from the supply to a safe value in case of operator contact, while C15 and C18 reduce noise pickup on this high-impedance line.

Resistors R20 and R21 divide the high voltage by 202 for measurement by the system ADC. The current drawn by this divider drops the nominal voltage at J2-1 to 191VDC. If this point is measured with a typical meter having a 10M input resistance, the nominal reading falls to 173V.

Igniter power supply.

The igniter power converter supplies 6.4Vp-p (unregulated) square waves for the F1D flame igniter. It is driven from both outputs of U4, so the high voltage must be turned on in order to enable the igniter supply. The igniter supply is then turned on by turning on U1 (pins 9-11). U3 and U2 invert and buffer the push-pull outputs to drive transistors Q5 and Q6, as in the high voltage supply. If U1 (pins 9-11) is turned off, R11 pulls U3-6 and U3-9 high, holding both transistors off by grounding their gates. Transformer T1 steps down the 24V square waves at pins 1 and 3 to 6.4Vp-p across pins 4 and 6.

Stray capacitance from the primary of T1 to its secondary circuit couples 50kHz square wave currents into Ground 3. C20 provides a direct path to return these currents to Ground 4.

ECD Electronics Circuit Description

Power supplies and grounds.

There are four grounds serving the ECD electronics circuitry. Ground 1 is the return for the +5V digital supply. It is connected directly to Ground 4, the unregulated +24V return, at the card edge connector on the Mother board. The analog return is Ground 2, which provides a low-noise return for the ±15V, +5.25V, and -5V supplies. Ground 3 is the reference for analog signal distribution, which carries almost no DC current. All of the grounds must be tied together externally for the board to function properly.

Four RC filters remove noise from the analog power supplies. These consist of R43 with C32, R44 with C29, R45 with C30, and R46 with C31.

Digital circuits.

One half of U5 decodes bus address information to access latch U7, buffer U6, and dual DAC U8. The latch holds all of the digital control signals for the board, while the buffer transmits the board identification number (02H) to the bus. R47 and R48 allow the inputs of U6 to be pulled high or low for automatic test. The other half of U5 is used only as an inverter.

Power converter.

A switching regulator, connected in the inverting configuration, generates -50V from the unregulated +24V input. The maximum current drain from the -50V supply is less than 10mA in normal operation. U2 (a TL494) provides all of the functions needed to control the supply: an oscillator, pulse-width-modulation comparator, voltage reference, dual error amplifiers, and output transistors. C4 and R12 set the oscillator frequency to 50kHz, thus applying a 50kHz sawtooth to one input of the pwm comparator. The other input to the comparator is driven by the outputs of both error amplifiers, which are connected in such a way that the amplifier calling for the lower output from the supply dominates. The minimum dead time between output pulses, regardless of the error amplifiers, is set to about 5% by grounding the DT input of U2 (pin 4).

Error amplifier #1, whose inputs are on pins 1 and 2, is used as the primary loop control amplifier. Its inverting input is connected to the +5V±5% reference voltage (pin 14) through R1, and to the output of the supply through R2. Since the noninverting input is connected to ground, the 1C will adjust its duty cycle to drive the inverting input to zero volts also. This will occur only when the output voltage is -50V, since R2 is ten times as large as Rl. Feedback from the error amplifier output (U2-3) is taken through C3 and R4, which stabilizes the loop with a very high DC gain. CR8 prevents pin 2 from being driven to such a low voltage that the 1C quits functioning properly.

Both output transistors are driven in phase, because the Output Control pin (U2-13) is tied to ground. The emitters of the transistors (pins 9 and 10) are grounded, and the collectors (pins 8 and 11) drive Q1 through R10. R11 speeds the turn-off of Q1 in between pulses. When Q I is turned on, the +24V supply is connected to Ll, causing the current through Ll to ramp upward. As soon as Ql is turned off, its collector voltage falls rapidly until CR1 turns on, allowing the inductor current to continue flowing. After a number of pulses, C2 charges to the desired output voltage, and the pulse width stabilizes at the value needed to just maintain the output at -50V.

R13 and R14 divide the output voltage of the -50V supply by 51 for measurement by the system ADC through P 1-3.

Current-to-frequency converter.

The circuitry across the top of the schematic page, including the sections labeled ECD ELECTROMETER, V TO F CONVERTER, and ECD PULSER, forms a feedback loop with the external electron capture detector cell. We will begin the description of this circuitry in the middle, where AR2 and AR3 comprise a current-to-frequency converter.

Feedback capacitor C22 configures amplifier AR2 as an integrator, so a constant current into the collector of Q4 causes a rising, linear ramp at the output of AR2 (pin 6).

The noninverting input of comparator AR3 is biased to +3V by R26 and R34. Since the ramp voltage from AR2 is applied to the inverting input of AR3 through R33, the output of the comparator (pin 7) will switch from high to low when the ramp voltage reaches 3V. CR5 and CR6 provide hysteresis, ensuring that the comparator output stays low until the ramp has been reset to zero volts. The output of AR3 is an open-collector transistor, so R25 is needed to pull the output up to 5V when the transistor turns off.

When the comparator output switches low, Q5 is turned on, discharging C22 and resetting the ramp. R31 keeps Q5 turned on until the ramp voltage has fallen all the way to ground. The bias current flowing into pin 2 of AR2 (typically 150nA) would keep the current-to-frequency converter running at about 500 pulses per second even if the collector current of Q4 were zero. R30 sources enough current into the amplifier input node to cancel the input bias current, so that the operating frequency can go below 500Hz in all cases.

Pulser.

Each time the output of comparator AR3 switches from high to low, one-shot U4 generates a positive pulse at pin 13. R24 and C12 set the pulse width to 640ns. Buffer U1 has its individual sections tied in parallel to provide the large drive currents needed to charge the gate capacitances of Q2 and Q3. In between pulses, the outputs of U1 are at ground, and the gate voltage of Q2 is held at -4.5V by R16 and R18. Since Q2 is a p-channel MOSFET, it is turned on when the gate is negative, and the pulser output at J2 is equal to the source voltage at pin 1 of Q2. Q3 (an n-channel device) is turned off during this time, since R20 holds its gate at the same voltage as its source (-50V).

When a pulse from the current-to-frequency converter causes the outputs of U1 to switch to +5V, the gate voltages of both FETs rise by about 5V. Q2 turns off while Q3 turns on, pulling the pulser output to -50V. R19 improves the settling time of the output pulse. C7 forces the gate voltage of Q2 to switch rapidly, while C11 allows the DC voltages at U1and at the gate of Q3 to be different. CR2 clamps the negative excursions of Q3's gate voltage to the -50V supply, so that the FET continues to be turned on hard even at high pulse frequencies, where it may be on more than 50% of the time.

DACs.

Detector operation requires the pulser output to have a variable DC offset, which is provided by one half of a dual DAC (U8). AR5 (pins 1-3), R50, and R51 invert the +10V reference, supplying -10V at U8-4 and U8-18. AR5 (pins 8-10) converts the output current of the DAC to a voltage, which varies from 0 to +9.96V as the digital code written to the DAC varies from 0 to 255. To find the voltage at AR6-3, note that R52 is connected to the inverting input of AR6 (pin 6), which remains at a virtual ground potential. R15 offsets the voltage at AR6-3 down by about half the output range of the DAC, resulting in a voltage range of -769mV to +763mV as the DAC setting is varied from 0 to 255. AR6 (pins 1-3) provides a low-impedance output to drive the pulser, and R17 and C8 keep the high-frequency pulser currents out of the amplifier's output. At the highest pulse frequencies, the DC current flowing through R17 can cause as much as 100mV of drop, especially when driving high capacitances at the pulser output.

The other half of dual DAC U8 operates in exactly the same way, generating a voltage between 0 and +9.96V at AR5-7. In normal operation, analog switch U3 (pins 14 and 15) is open, and the DAC output voltage appears at the bottom end of R27. (The effect of R49 is negligible in series with R27, which is 50,000 times larger.)

Electrometer

The other end of R27 is tied to the inverting input of AR1, which must stay at ground (equal to the noninverting input voltage) for the amplifier to function linearly. This means that a current between 0 and 2nA must flow through R27 into the summing junction at AR1-2. Since the input current of AR1 is only a few femtoamps (1fA = 1E-15A), and no DC current can flow through the capacitors connected to AR1-2 , all of the current supplied by the DAC through R27 must flow out through the ECD input connector. The puller output is normally connected to an electron capture detector (ECD) cell, which draws a small charge from the ECD input through J1 with each pulse.

As the composition of the gas in the cell changes, the magnitude of the charge varies, and the circuitry on this board adjusts the pulse frequency to exactly balance the current set by the DAC with the current from the cell.

The electrometer amplifier (AR1) is configured as an integrator by feedback capacitor C16, so any imbalance between the input currents from the ECD cell and R27 at pin 2 causes the output voltage at pin 1 to slew up or down in response. The idealized output voltage should therefore be a linear ramp downward due to the constant current from the DAC, with sudden rises in voltage when the pulses occur. Because there is a large capacitive feedthrough of the pulse through the cell, which is much faster than the amplifier can follow, there is a large glitch in the amplifier output at each pulse. C15 helps to absorb these rapid changes in current, but the output waveform of AR1 is dominated by the glitches, which obscure the idealized waveform at frequencies above a few kilohertz. R35 and C17 smooth the output waveform further.

Exponential gain compensation.

When the instrument is operating at baseline conditions, a relatively large charge is delivered with each pulse, resulting in a pulse frequency of about 1.6kHz. As the delivered charge per pulse decreases, the frequency may rise as high as several hundred kilohertz to keep the average current constant. The gain of the feedback path thus varies in inverse proportion to the pulse frequency, since the charge per pulse must be inversely proportional to the pulse rate in order to maintain constant average current.

In order to keep the feedback loop gain constant as the pulse frequency changes, an element must be introduced into the circuit whose output varies exponentially with its input.
The collector current of a bipolar transistor varies exactly this way with respect to its base-emitter voltage. The filtered output of the electrometer is buffered by AR 1 (pins 5-7) to provide a low-impedance drive for the emitter of Q4. Since the collector current of Q4 drives the current-to-frequency converter, and both the transconductance of Q4 and the pulse frequency are proportional to the collector current, the desired compensation is achieved.

CR7 and R29 limit the maximum frequency which can be set for the current-to-frequency converter. Frequency settings which approach or exceed the reciprocal of the pulse width (1.6MHz) would cause irregular pulse intervals, which must be avoided.

Diagnostic feedback circuit.

Because the electrometer is configured as an integrator, its output will inevitably swing to one of the power supply rails if a feedback current (proportional to pulse frequency) is not applied to its input. Such a feedback source is provided on the board, so the board may be tested without having an external connection to an ECD cell. To enable this diagnostic feature, analog switch U3 (pins 14 and 15) is closed and switch section U3 (pins 2 and 3) is opened. The output pulses are "stretched" by CR4 and C38, and then summed with the Cell Current DAC output through R49 and R22. Since the average voltage at the bottom end of R27 must remain at zero volts for the integrating electrometer to function, the circuit will adjust the pulse frequency to make the average voltage at the anode of CR4 equal to the opposite of the voltage at AR5-7. Linearity of the diagnostic circuit is improved by C39, which absorbs the pulses without letting the voltage rise significantly. R23 holds the voltage at U3 (pins 2 and 14) below -15V even at the highest frequencies, but has no effect on the operating point of the loop, since it has no DC voltage across it. Stretching the pulses allows operation at lower frequencies at the desired voltage levels from the Cell Current DAC.

Output amplifier.

The information from the electron capture detector is contained in the pulse frequency, so this frequency is converted to a voltage for system use. The output pulse stream is averaged by R21 and C21. Since the DC offset applied to the pulser output carries no signal information, its effect must be removed from this averaged signal. The offset voltage, which appears at AR6-3, is inverted by AR6 (pins 5-7), R52, and R36. Because R41 is equal to R21, the inverted voltage from AR6-7 cancels the pulser DC offset voltage, which appears at J2-1 between pulses. AR4 amplifies the averaged pulse signal, with C20 providing further smoothing. Resistor R40 can be paralleled with feedback resistor R37 through U3 (pins 6 and 7) to select one of two gains for the output amplifier.
R42 adds an offset to the signal, so the normal resting frequency of 1.6kHz produces zero output voltage at AR4-6. R39 and C28 prevent glitches from the system ADC input multiplexer from disturbing AR4.

NPD Electronics Circuit Description

Power supplies and grounds.

There are four grounds serving the NPD electronics circuitry. Ground 1 is the return for the +5V digital supply. It is connected directly to Ground 4, the unregulated +24V return, at the card edge connector on the Mother board. The analog return is Ground 2, which provides a low-noise return for the ±15V, -5V, and +5.25V supplies. Ground 3 is the reference for analog signal distribution, which carries almost no DC current. All of the grounds must be tied together externally for the board to function properly.

Four RC filters remove noise from the analog power supplies. These consist of R13 with C16, R12 with C15, R10 with C13, and R11 with C14.

Digital circuits.

U4 decodes bus address information to access latch U3, DAC U6, and buffer U2. The latch holds all of the digital control signals for the board, while the buffer transmits the board identification number and serial data from EEPROM U5 to the bus. R18 and R20 set the desired operating logic levels, while allowing the inputs to be pulled high or low for test purposes.

The EEPROM is a 1024-bit device which is used to store calibration data. Software has full control over the serial interface, consisting of the chip select, shift clock, and data inputs (pins 1 - 3, respectively), and must reassemble the stored data from the serial output stream coming from pin 4. When the EEPROM is not selected, its output is high impedance. R19 provides a positive level to CMOS buffer U2 in this case.

Input log amplifier of square-root electrometer.

The electrometer is a multi-stage circuit which produces an output voltage that is proportional to the square-root of the input current. This is accomplished by three amplifier stages, AR1 (dual) and AR2, having logarithmic and exponential responses. The nonlinear responses are generated by the fundamental characteristic of bipolar transistors, which is represented in the following equations:

v_{be} = (nkT/q) log(I_c/I_{sat} + 1) or $I_c = I_{sat}$ (e(^{qv}be$^{/nkT}$) _ 1),

where v_{be} = base-emitter voltage (volts)
n = emission coefficient (near 1.00)
k = Boltzmann's constant (1.38E-23 Joule/K)
T = Temperature (Kelvins)
q = electron charge (1.6E-19 coulomb)
Ie = collector current
I_{sat} saturation current
e = base of natural logarithms

Input amplifier AR2 has an extremely high input impedance, with a bias current of only about 40fA (40 x 10-15A). All of the input current from J1 must therefore be supplied from the collector of Q1 (pin 8). Negative feedback from the output of AR2 adjusts the base-emitter voltage of Q1 until precisely this current flows into the collector. The output voltage from this stage, which is taken from the emitter of Q1 (pin 6), is therefore v_{eb}l=(nkT/q) log(I_{in}/I_{sat} + 1). R4 stabilizes the loop gain at input currents near full scale (1µA), where the impedance looking into the emitter of Q1 has dropped to 26k.

Since the non-inverting input of AR2 is grounded, the inverting input remains at ground also, keeping the collector of Q1 at ground. This holds the collector-base voltage at zero, which is a necessary condition for the equations above to apply. The input connection at J1 also remains near ground at low input currents, minimizing noise due to variations in input capacitance. R1 limits input current if an excessive voltage is applied to the input, but it also allows the input voltage to rise slightly at the higher input currents. R2, which isolates the amplifier input from the input cable capacitance for loop stability, has almost no DC voltage drop across it, since only the bias current of AR2 flows through it. C3 also enhances loop stability, and reduces high-frequency noise.

Because of the high impedance levels, this entire circuit must be shielded to work properly at all but the highest input currents. It is also easily upset by test probes even when shields are in place.
In any case, the exact output voltage to be expected at a particular input current is unknown, since the saturation current of the input log transistor is unknown. All that can be predicted is that the output voltage will increase (in a positive direction) by about 26mV when the input current is doubled, or by 60mV when the input current is raised by ten times, regardless of the specific current levels.

Reference current log amplifier.

The saturation currents of the individual transistors vary from one unit to the next, and also change rapidly with temperature, doubling with each 10°C rise. In order to maintain stable and predictable calibration, each transistor used in the anti-log stage must be balanced by a matching transistor in a log stage. The anti-log stage uses two transistors, as will be described below, so a second log amplifier is needed for compensation purposes. This stage consists of one section each of AR1 (pins 1-3) and Q2 (pins 6-8), and is very similar to the input log amplifier. AR4 (pins 5-7) inverts the +10V reference voltage to produce the negative reference current needed by this stage.

The sum of the two emitter-base voltages of the log transistors is produced directly by connecting them in series. The emitter of Q1 (pin 6) is connected to the base of the Q2 (pin 7), and the output vsum is taken from the emitter of Q2 (pin 6). The collector of Q2 (pin 8) is connected to the inverting input of AR1 (pin 2), which is held at the same voltage as the noninverting input (pin 3). By connecting the base of Q2 (pin 7) to the noninverting input, the collector-base voltage is forced to be zero. This causes the inverting input to follow the output voltage of AR2 (pin 1). The temperature drift of this voltage is compensated by CR1, which keeps the reference current relatively constant as the temperature changes. As this voltage varies by a few hundred millivolts over the full range of the input current, the reference current (Iref) through R5 varies between 23 and 24 microamps. The emitter-base voltage of Q2 is thus $v_{eb2} = (nkT/q)\ \log(I_{ref}/I_{sat} + 1)$, and the net voltage at the emitter of Q2 is

$$v_{sum} = (nkT/q)\ \log(I_{in}/I_{sat} + 1) + (nkT/q)\ \log(I_{ref}/I_{sat} + 1)$$

$$= (nkT/q)\ \log\ ((I_{in}/I_{sat} + 1)(I_{ref}/I_{sat} + 1)).$$

AR1 is powered from the ±15V power supplies, which could cause avalanche breakdown of the emitter-base junction of Q2, if the amplifier output ever approached the negative supply voltage. While this never occurs in normal operation, even a momentary breakdown can cause a permanent increase in saturation current. CR2 prevents the emitter voltage from rising to a destructive level during testing or other transient fault conditions.

Anti-log amplifier.

The logarithmically compressed voltage vsum is applied to an anti-log (or exponential) amplifier stage which utilizes the other halves of matched dual transistors Q1 and Q2. Since the anti-log transistors arc connected in series, both collector currents are essentially equal. If we assume that all of the transistors are at the same temperature T and have the same saturation current Isat, the base-emitter voltage of each of the anti-log transistors will be half the value of v_{sum}.
Their collector currents must then be $I_c = I_{sat}\ (e\text{-}(qv_{sum}/2nkT) - 1)$ from the equation in section 4. Substituting the expression for v_{sum} above, we have

$$I_c = I_{sat}\ (e(1/2)\log((lin/Isat + 1)(Iref/Isat + 1)) - 1)$$

$$= I_{sat}\ (sqrt((lin/Isat + 1)(Iref/Isat + 1)) - 1)$$

$$= sqrt((I_{in} + I_{sat})(I_{ref} + I_{sat})) - I_{sat}$$

$$= sqrt\ ((I_{in} + I_{sat})(I_{ref})) - \quad I_{sat} \qquad (since\ I_{ref} > 10^9\ x\ I_{sat})$$

Amplifier AR1 holds the collector of Q1 (pin 1) at ground potential and forces the collector current to flow through R3. The final output voltage at P1-1 is then

$$v_{out} = 2.05 \times 10^{6} \times \text{sqrt}((I_{in} + I_{sat})(I_{ref})) + v_{os},$$

where v_{os} is the sum of the input offset voltage of AR1 and all of the current-related voltage errors. Putting in the nominal value of 25 microamps for Iref gives the following approximate formula for the output voltage:

$$v_{out} = 10^{4} \times \text{sqrt}(I_{in} + I_{sat})\ v_{os}.$$

This formula will not be accurate if the temperatures of all of the transistors are not equal. The two halves of each dual transistor are always at the same temperature, since they are fabricated on a single silicon die. Q1 and Q2 track each other in temperature only by being in close proximity in an isolated environment, however, and any thermal disturbance will cause the output of the electrometer to drift. Simply touching one of the transistors can cause a minute or two of drift, and the output may not stabilize for 5 or 10 minutes after soldering in the vicinity of the transistors.

The time constant of the amplifier is set to 45ms by C1, and C2 eliminates high-frequency noise from digital sources. R7 and C12 prevent glitches from the ADC multiplexer (on the main system board), which reads the output voltage of the electrometer, from disturbing the amplifier output. Such glitches can couple through C1 and the capacitance between the collectors of the two halves of Q1 to disturb the sensitive input node, resulting in a much longer settling time than would be expected.

Electrometer diagnostic features.

In order to determine the input current from the output voltage, the value of v_{os} in the equation in the preceding paragraph must be determined. This is done during operation by closing the switch section of Ul (pins 1-3) which is connected to the output of the reference log amplifier. Current through the anti-log transistors is thus cut off, leaving the output voltage at P1-1 equal to v_{os}.

Though it is not immediately obvious from the equations presented here, closing the switch section of U1 (pins 14-16) which is connected to the output of the input log
amplifier results in an output voltage at P1-1 which corresponds to an input current equal to the saturation current of Q1. This measurement is used for diagnostic purposes only. Both of the diagnostic switch sections of U1 are left open in normal operation.

Because the input stage of the electrometer has a logarithmic response, its behavior becomes unpredictable as the input current approaches zero. All of the voltages applied to the circuit are above ground potential, so leakage currents should never cause the input to reverse in polarity and saturate the output positively. However, the response time of the circuit is inversely proportional to the current level, becoming very slow at currents below a few hundred femtoamps. For this reason, it is impractical to test the noise and drift of the electrometer by "capping off" the input with no input current.

To test the electrometer when no external picoamp source is available, an input current source in the picoampere range has been provided. This source relies upon the fact that the current through a capacitor is equal to the product of the capacitance and the rate of change of the voltage across the capacitor. C4 (10pF) is connected to the electrometer input, which remains near ground potential. Applying a negative sawtooth waveform to the other end of C4 should thus produce a steady input current, with positive spikes on the positive transitions of the sawtooth voltage. This waveform (modified somewhat to optimize the recovery of the electrometer from the positive spikes) is generated by an external DAC and applied to C4 through a filter consisting of R9 and C8. The filter removes noise from the external input, while slowing the transitions somewhat. In normal operation, transistor Q3 is turned on by writing a logic 1 to U3-12, shorting C4 to ground. Voltage variations at P1-10 will then not create an undesired current at the electrometer input.

Bead power supply.

The bead power supply has four sections: a regulated bias voltage source, a linear current regulator, a DAC to set the current, and a switching pre-regulator for the current regulator. R26, R27, and AR4 (pins 8-10) provide a stable, low impedance source of -4V to bias the bead. C25 keeps switching supply noise out of AR4, and R28 prevents C25 from destabilizing AR4.

DAC U6, together with AR4, generates a voltage which varies between 0 and -10V with 12-bit resolution. C29 eliminates DAC output noise due to digital sources. The Thevenin equivalent of the DAC output (through R21 and R15), combined with the -10V reference (through R16), is a generator which varies between -4V and -10V, with a source resistance of 6K. This equivalent generator drives the inverting input of AR3 and resistor R14. Ignoring R28 for the moment, the other end of R14 is held at -4V, irrespective of the bead current. AR3 will adjust its output, which controls the bead current through Q4, to bring its noninverting input to the same voltage as the inverting input. The result is that R17 must have the same voltage drop across it as does R14. As the DAC setting is varied from 0 to 4095, this voltage drop goes from 0 to 572mV, and the current through R17 varies from 0 to 3.8A. Since the bead current switching supply is floating, all of the current through R17 also flows through the bead (connected across J2-2&3), and the DAC controls the bead current. C19 suppresses digital noise.

To keep the power dissipation in Q4 low, a switching pre-regulator holds the voltage across Q4 at 390mV. U7 is operated in the flyback mode, alternately connecting T1-4 to ground and then opening the connection. When T1-4 is grounded, CR3 is reverse-biased, and the current in the primary of T1 rises linearly. When the output switch in U7 opens, the voltages at T1-4 and T1-9 rise rapidly, turning on CR3, and transfering the energy stored in the primary into C22 and C23. CR4 and VR1 clamp the voltage spike across the primary, absorbing the energy stored in the leakage inductance of T1. C30 supplies the high current pulses required when U7 turns on.

The voltage across Q4 is amplified by AR4 (pins 12-14), which is configured as a differential amplifier by R22-R25. U7 adjusts its duty cycle to maintain 1.24V at its feedback pin (U7-2), which occurs when the voltage across Q4 is 390mV. C32 provides a high-frequency feedback path to preserve loop stability. When the bead is unplugged, the feedback loop is opened, and the regulator would continue to increase its output voltage indefinitely. This is prevented by CR5, which closes the loop and holds the output voltage steady when it rises to 1.9V. (Normal output voltages are always below ground, since the bead resistance is between 0.5 and 0.75Ohmm.) CR6 prevents U7 from being latched up by driving pin 2 negative during a transient or fault condition, and R31 limits the current from AR4 when either CR6 or CR5 is conducting. C33 and R32 provide loop frequency compensation, and CR7 allows the supply to be turned off by setting U3-5 low.

TCD Electronics Circuit Description

Power supplies and grounds

There are four grounds serving the TCD electronics circuitry. Ground 1 is the return for the +5V digital supply. It is connected directly to Ground 4, the unregulated +24V return, at the card edge connector on the Mother board. The analog return is Ground 2, which provides a low-noise return for the ±15V and +5.25V supplies. Ground 3 is the reference for analog signal distribution, which carries almost no DC current. All of the grounds must be tied together externally for the board to function properly.

Three RC filters remove noise from the analog power supplies. These consist of R39 with C28, R40 with C29, and R41 with C30.

Digital circuits

U8 decodes bus address information to access latch U6, buffer U9, and DACs U3 and U4. The latch holds all of the digital control signals for the board, while the buffer transmits the board identification number and filament temperature limit status to the bus. R42 allows the inputs of U9 to be pulled high for test, while remaining low in normal operation.

Power Converter

The TCD requires a variable, stable, floating excitation source, which is derived from the unregulated +24V instrument supply. U1 is a current-mode switching regulator controller, operating as a flyback regulator at 40kHz. Its internal pass transistor is connected between pin 4 (VSW) and pin 3 (ground). When the switch turns on, the primary current of T1 begins to increase at about 0.8A/µs. Current flow stops abruptly when the switch turns off, causing the voltage at U1-4 to rise rapidly. CR8 and VR3 clamp the voltage at 25V above the input supply voltage, conducting until the energy stored in the leakage inductance of T1 is gone. VR2 does not normally conduct, but will protect U1 if a transient raises the +24V supply excessively.

When the primary current is interrupted, and the voltage on primary pin 5 of the transformer rises, the voltages on secondary pins 7 and 10 also go positive. Diodes CR2 and CR9 are then forward biased, allowing current to flow in both secondaries. Because the secondaries are bifilar wound, the voltages across the secondary windings remain equal to each other throughout the cycle. The main output from CR9 is smoothed by C7, and the high-frequency ripple and noise are further attenuated by L2, C3, and C5. The rectified voltage across C4 is equal to the main output voltage, which is floating. This provides a ground-referenced feedback signal, allowing the output voltage to be controlled without any direct connection to the main secondary circuit. Leakage inductance in T1 degrades the tracking accuracy between the two secondary voltages. This effect is reduced by loading the sense output with R2, and by choosing CR2 to have a longer recovery time than CR9.

The sense voltage at C4 is combined through R4, R5, and R26 with the output of the bridge voltage control DAC at AR4-1, which varies between 0 and -10V. U1 adjusts its conduction duty cycle to try to hold its feedback pin (pin 2) at 1.24V. The output voltage across C7 follows the DAC setting according to the following equation:

$$V_{out} = -3.14 * V_{DAC} + 4.14.$$

CR3 prevents the output voltage from falling below about 10V at low DAC settings, so that the circuitry powered by the floating supply remains active. CR4 keeps U1-2 from going negative if the DAC is set to a large (negative) output while the converter is disabled, which would otherwise cause U I to lock up. High-frequency noise between ground 4 and ground 2 is filtered off of the control signal by C11, to avoid instability in the switching converter. C1 and R3 provide feedback loop compensation for U1, and CR5 holds the control pin of U1 (pin 1) low when U6-19 is low, thus turning off the converter.

Bridge voltage regulator and monitor

The TCD bridge excitation voltage is set by the bridge voltage control DAC, U3. AR1 converts the current output from the DAC to a voltage, which varies from 0 to -10V at the amplifier output. C16 reduces digital noise interference. The DAC output is shifted and attenuated by R18 (pins 3, 4, 13, and 14) to create a control voltage that remains within the common mode range of buffer AR2, which is powered from the floating power supply. The high impedance input of AR2 virtually eliminates any current from the ground-referenced DAC circuitry from flowing into the floating circuitry, which would cause a signal offset as the current flowed back to ground through the bridge. Two more sections of R18 divide the 10-volt reference by two, and the other section of AR2 buffers the connection to the floating circuit. A differential control voltage, which varies from 0 to -5V between AR2-7 and AR2-1, is thus available to set the bridge excitation voltage.

The remaining sections of R18, combined with R19, R20, and AR3, form a differential amplifier with a gain of 5.62, referenced to the return side of the floating supply. The feedback is taken from the supply side of the TCD bridge, so the amplifier output tries to force the bridge voltage to be 5.62 times the differential control voltage between R18-5 and R18-6. The feedback path is completed from AR3-1 through CR11, VR1, and R6, to the supply side of the bridge. Regulator VR1 has internal circuitry which holds its output (pin 2) 1.25 volts above its adjust pin (pin1). It also supplies current limiting and thermal overload protection, in the event of excessive load. C6 provides a low impedance at the input of VR1 at high frequencies, to maintain stability of the regulator. C12 stabilizes the overall loop response.

Excitation voltages, bridge current, and signal voltage are all available for measurement at the card edge connector. Analog switch U5 connects one of these four voltages at a time to P1-3, depending upon which output of decoder U8 is low. The selection is made by latching the appropriate value into U6, pins 12 and 15. The bridge supply and return voltages are divided by 50.9 through resistors R33, R34, R35 and R36. The bridge signal voltage is divided by 11 through R38 and R37, in order to minimize the disturbance to the signal amplifier when a direct measurement is made through switch U5. Bridge current is sensed by measuring the voltage drop across R6 with differential amplifier AR4 (pins 57). The amplifier gain is 1, so the scale factor of the voltage at P1-3 is 200mA/V.

Temperature limit circuit

In normal operation, the filaments of the thermal conductivity detector bridge rise and fall in temperature as the surrounding gas composition changes. Since the filaments have a positive temperature coefficient of resistance, their peak temperature can be limited by reducing the bridge excitation voltage whenever a filament reaches a preset maximum resistance. Resistors R9, R10, and R6 form a bridge circuit with the bridge element connected between J1-5 and J1-3. With K1 closed, the inputs of amplifier AR1 (pins 2 and 3) are connected across this bridge. When the filament resistance reaches about 82Ohm, the temperature-sensing bridge is balanced, and the output of AR1 (pin 1) begins to drop. This pulls down the adjust pin of VR1 through CR6 and U2, decreasing the detector excitation, and holding the filament resistance at the preset limit.

The other half of AR1 amplifies the output of a similar bridge, which senses the resistance of the filament connected between J I -5 and J 1-2, using resistors R6, R13, and R14. The outputs of both halves of AR1 are combined with the output of the main control amplifier, AR3, through diodes CR11, CR6, and CR7. Whichever amplifier calls for the lowest bridge excitation controls the loop, with the other amplifier outputs both at the positive supply rail. C2 stabilizes the loop when one of the temperature-limit amplifiers is in control. Opening K1 effectively raises the point on R6 where the inverting inputs of AR1 are connected, thereby lowering the filament resistance which is required to cause limiting.

As long as AR3 is in control of the loop, the 1.25V differential between pins 1 and 2 of VR1 appears across the base-emitter junction of Q2 and R7. Q2 sources about 6mA into optocoupler U2, turning it on, and bringing its output (pin 7) low. When temperature limiting occurs, sending the output of AR3 to the positive rail, CR10 becomes reverse biased. This turns off Q2 and U2, and indicates the limit condition with a high level on the output of U2.

To maintain normal bridge voltage control with no detector plugged in, the temperature-limit circuit must be defeated. U2 disconnects the outputs of the limit amplifiers from VR1 when it is turned off, by setting a logic high at U6 pin 2.

Bridge balance DAC and signal amplifier

Bridge signals down to one microvolt must be detected by the instrument, so it is necessary to have the bridge balanced to within 1mV or less for efficient digitization of the signal. Balance is adjusted by DAC U4 and the associated circuitry. Four sections of R21, a precision-tracking network, provide an effective shunt resistance of 1K across the bridge element connected between J 1-3 and J1-4. The reference voltage to the DAC is just exactly the voltage across this resistance. The DAC inverts this voltage, and multiplies it by the ratio of the DAC setting to 4096. The DAC output voltage is applied to a 500Q resistance, consisting of two paralleled sections of R21, which sources current into the bridge at J1-3 (which is also Ground 3). Since this current can be as high as 28mA, Q3 is used to boost the current output capability of amplifier AR5 (pin 1). When the DAC is set to mid-scale, the variable current through the 5000 resistance exactly cancels the current through the fixed 1K shunt, and there is no effect on the bridge balance. Setting the DAC either above or below 2048 allows the bridge to be offset in either direction.

For the DAC to work properly, pin 2 (AGND) must be held at the same voltage as pin 1 (IOUT), which is at Ground 3. However, the current from this pin must be returned directly to the floating supply, so the current does not have to flow back through the bridge. AR5 (pins 5-7) buffers Ground 3 for this purpose. C17 and C21 reduce the effect of digital noise on the balance circuit.

The bridge signal at J1-2 is amplified by AR6. Gain is set to 2, 20, or 200, by closing one of the switches of U7. Only one switch should be closed at a time. C23 sets the time constant of the amplifier to 50ms for noise reduction. The capacitors connected to the inputs of AR6 all reduce digital noise interference, and R30 and C27 also attenuate noise from the switching power converter noise. R28 and C31 reduce the disturbance caused by switching the loads connected to the output of AR6.

Signals from the bridge balance circuit appear at the signal amplifier only if a bridge is connected. In order to be able to test the circuit board without a detector, a high-resistance bridge (R17) is always present on the board, in parallel with the normal detector connection. All of the board functions are operational in this state, but the balance control is about 40 times more sensitive, due to the greater bridge resistance. As noted in the preceding section, the temperature limit function must be defeated for the circuit to operate without an external bridge.

PFPD Electronics Circuit Description

Power supplies and grounds

There are four grounds serving the PFPD electronics circuitry. Ground 1 is the return for the +5V digital supply. It is connected directly to Ground 4, the unregulated +24V return, at the card edge connector on the Mother board. The analog return is Ground 2, which provides a low-noise return for the ±15V and +5.25V supplies. Ground 3 is the reference for analog signal distribution, which carries almost no DC current. All of the grounds must be tied together externally for the board to function properly.

Three RC filters remove noise from the analog power supplies. These consist of R464 with C47, R47 with C48, and R48 with C49.

Digital circuits

U11 decodes bus address information to access buffered shift register U10, latch U12 and buffer U14, as well as a dual DAC. The latch holds all of the digital control signals for the board, while the buffer transmits the board identification number and status data to the bus.

Commands and data for the on-board microcontroller (U9, an 87C751) are transferred from the bus through shift register U10. When a byte is directly latched into the register, flip-flop U7 is simultaneously set. Its output (pin 5) tells the microcontroller that a byte is available. The microcontroller then pulses U10-13 lowto transfer the latched data into the shift register, followed by 8 pulses to U10-11 to shift the data out through U10-9. When all of the data bits have been read, the microcontroller pulses U7-1 low, clearing the latch to inform the CPU that the buffer is available for another byte.

Most of the outputs of the 87C751 control analog functions, which may be disturbed by noise on the digital control lines. VR2 regulates the +5V power for U9, keeping the noise from the system +5V supply off of the microcontroller's outputs.

The reset signal for the microcontroller comes from latch U12. Software must reset U9 with a positive pulse lasting at least one microsecond before it will execute its program.

Electrometer

AR2 (pins 1-3) converts the small current from the photomultiplier tube into a voltage. On the most sensitive range ("Range 10"), both switch sections 1 and 2 (pins 2-3 and 6-7) of U3 are open, leaving R21 as the only feedback resistor. The effective feedback resistance is reduced on ranges 9 and 8 by closing switch section 1 or 2, respectively, placing either R19 or R20 in parallel with R21, for feedback resistances of 2M or 198k. These resistances produce nominal full-scale output voltage (10mV at AR1-1) at currents of $5x10^{-10}$, $5x10^{-9}$, and $5x10^{-8}$ on the three ranges, which are 5 times higher than the currents implied by the Range settings.

The range setting is directly controlled by the microcontroller (U9), remaining static only when the user selects Range 10. On the less sensitive ranges, AR2 is set to the most sensitive range while waiting to detect the start of a flame pulse, changing to the selected range setting only during the integration time. Since the microcontroller samples the user range selection only once during each flame pulse cycle, the setting at AR2 will not reflect changes in the method until the next pulse occurs.

Capacitor C19 sets the time constant of the electrometer to 100µs on Range 10. This is about 1000 times faster than the standard FPD electrometer, in order to follow the rapid changes in current during the flame pulses. Since the noise is low on the less sensitive ranges, no extra capacitors are used to set the time constant on these ranges, and the time constant falls to 10µs and 1µs on Ranges 9 and 8, respectively.

A switchable current source is provided at the electrometer input to test entire signal path. As long as latch output U12-12 remains low, switch U8 (pins 6-8) is turned on. This holds Q1 off, disconnecting the diagnostic current from the electrometer input. Turning off U8 allows the emitter of Q1 to drop to -600mV, placing 9.4V across R29 and injecting 470nA into the input.

Gated Integrator

The output of the electrometer is fed to the integrator, AR2 (pins 5-7), through a set of resistors and analog switches. Between pulses, section 4 of U4 (pins 14-15) is open, while section 1 of U4 (pins 2-3) is closed. This keeps C22 discharged and holds the output of AR2 (pin 7) near ground. When the desired integration time begins, the shunt switch across C22 is opened, and section 4 of U4 is closed.
A current proportional to the output voltage of the electrometer then flows into C22 through the resistors connected between AR2-1 and U4-14. The integrator output ramps in a negative direction until U4 (pins 14-15) is opened again. The current then stops flowing, and the integrator output remains constant.

Optimum dynamic range exists when a voltage of +10V at the electrometer output results in a peak integrator output voltage of -10V at the end of the integration time.
Since the integration time varies with the mode selection, the resistance between the electrometer output and the integrator input must vary in direct proportion to the integration time, in order to keep the peak integrator output voltage constant. As the microcontroller adjusts the integration time, it also turns on the appropriate analog switches, shunting some combination of resistors R22-R25, R31, and R32, to leave a net resistance which is proportional to the integration time. Since the integration time is much shorter in "SWEEP" mode than in normal operation, a dedicated resistor (R30) is switched in for this mode, with all other integrator gain-setting analog switches open.

Sampler and Filter

At the end of the integration period, switch U5 (pins 14-15) is turned on for 500µs, charging C24 to the output voltage of the integrator. The integrator can then be reset without affecting the detector output. The high input impedance of AR3 (a unity-gain buffer) at pin 3 isolates C24 from the input of the following filter, but leakage currents of a few picoamps may still exist. The saw tooth waveform produced by the leakage is not visible at the detector output at normal pulse rates. If no pulses are detected for one second, the microcontroller initiates a new cycle of integration and sampling anyway, preventing the sampler from slowly drifting off into saturation.

A filter consisting of AR3 (pins 5-7) and its associated resistors and capacitors smooth's the steps coming from the sampler. It is a two-pole filter, having repeated real poles, with a bandwidth of 0.9Hz. The DC gain of the filter is -1, to compensate for the inversion which takes place in the integrator. R26 and C25 prevent glitches due to switching of the system ADC multiplexer from disturbing AR3.

Trigger Comparator

The ouput of the electrometer (AR2-1) connects to the inverting input of the trigger comparator, U6. Between pulses, the electrometer output voltage is lower than the threshold voltage at the non-inverting input, and the open-collector output of U6 is pulled high by R43. When the electrometer voltage rises above the threshold voltage, the comparator output goes low, generating an interrupt to the microcontroller and starting the timing period. R42 provides about 15mV of hysteresis to prevent oscillations during the relatively slow variations of the electrometer output voltage.

The desired trigger voltage at the non-inverting input of U6 is set by section A of dual DAC U13. AR4 (pins 1-3), together with R40 and R41, inverts the +10V reference voltage, applying -10V to the reference input of U13. The DAC output (at AR4-7) is then 10 * N / 256, where the DAC setting N varies between 0 and 255. R35 and R36 divide the DAC output by about 4, giving a trigger voltage range at U6-2 of 0 to 2.55V. Since the comparator is fast enough to respond to narrow noise glitches, C30 is placed inside the electrometer shield to remove digital noise. R34 prevents C30 from slowing down the hysteresis feedback excessively.

Triggering always occurs at 10nA input current in the normal operating modes, since the electrometer is always set to the most sensitive range while waiting for a trigger pulse. If
a lower DC level is applied to the electrometer input, the comparator output will remain high, and the microcontroller will initiate integration cycles once per second. At higher DC input levels, the comparator is constantly in the triggered state. The microcontroller then starts a new cycle as soon as the 70ms holdoff period from the previous cycle expires, producing 14 cycles per second. This faster rate makes viewing waveforms on an oscilloscope much easier and speeds the reaction of the output voltage to operator actions.

Igniter Supply

The igniter power supply provides a regulated current of 3.2ADC to a load of about 0.5 to 0.7 Ohms. The +24VDC system supply voltage is stepped down through an LT 1074 switching regulator (U2), connected in the buck topology. The regulator operates at 100kHz, connecting and disconnecting the +24V input with its output (pin4). When pin 4 is switched to +24V, the current in L1 rises. When the switch is opened, the voltage at pin 4 drops rapidly to -0.5V, and the inductor current, which had been flowing through VR4, flows through CR9. C13 smooths the output voltage as the current in L1 rises and falls.

Load current flows through R14, creating a voltage drop of 0.32V at 3.2A. The difference between this voltage and the voltage set by R17 and R18 is amplified in AR1 and applied to the PWM comparator input of U2. The duty cycle of the regulator shifts in the appropriate direction to force the two voltages to be the same. R16 and C18 set the bandwidth of the feedback loop to prevent oscillations. The error amplifier in U2 is not used, since it requires an input voltage of +2.2V, which is much too large for this application. C17 keeps high-frequency noise out of the error amplifier input, so that it does not interfere with the external amplifier control.

The igniter power supply is turned on and off with a signal from latch U12-19. This signal is inverted by U7 (pins 8-13), which is a flip-flop connected as an inverter. (The inversion is required to turn the supplies off when latch U12 is reset by the SYSENAB signal.) When the control signal from U7-9 is high, diode CR10 is turned on. Pin 6 of AR1 is pulled well above pin 5, forcing the output of AR1 to ground and lowering the output current close to zero.

U11 (pins 9-15) decodes two signals from latch U12 (pins 15-16), to select which one of three diagnostic voltages is applied to the Detector Miscellaneous input of the system ADC. Selecting the Y2\ output of U11 (pin 10 low) turns on analog switch U8 (pins 911). The voltage at the top of R14, which is equal to the igniter current (in amps) divided by 10, is applied to the ADC multiplexer input. R39 limits current through U8 if there is a short at the multiplexer input, preventing destruction of the switch and pcb traces. Selecting the Y1 \ output of U11 (pin 11 low) applies the voltage on the high side of the igniter, divided by 11 through R37 and R38, to the ADC input. The division is necessary, because the igniter voltage will rise to the full +24VDC supply voltage when the igniter is disconnected.

High Voltage Supply (sheet 2)

The high voltage power supply is a balanced inverter which is adjustable from -300 to -900 Volts. A TL494 switching regulator controller (U1) furnishes the reference voltage, two error amplifiers, a pulse-width modulator, and the power switching transistors on a single chip.

One error amplifier regulates the high voltage output, which is summed with the output of a DAC (U13, section B) through R7 and R8, and applied to the inverting input of the amplifier (U1-2). Since the non-inverting input (U1-1) is held at ground, the inverting input must also remain at zero volts, forcing the high voltage output at J2 to vary from 0 to -900 VDC as the DAC output voltage varies from 0 to +10VDC. Feedback from the amplifier output (U1-3) through R4 and C2 determines the regulator loop characteristics and maintains stable operation. Capacitor C4 reduces coupling of output switching noise and nearby digital signals into the amplifier input.

If the detector's photomultiplier tube is exposed to ambient light with high voltage applied, excessive anode current will flow. Damage is prevented under such conditions by shutting down the high voltage supply whenever the detector output signal exceeds ten to twelve volts. Under normal signal conditions, the non-inverting input of the second error amplifier (U1-16) is held negative through R11. CR7 prevents the input from dropping below -300mV, which would cause the device to malfunction. When the signal voltage rises above +10V, current through R10 pulls U1-16 positive. The error amplifier output (U1-3) also rises, with a gain of three (determined by R3 and R9), thus reducing the supply voltage. Note that the outputs of both error amplifiers appear at U1-3. Since they share a common pull-down resistor, the amplifier whose output is more positive controls the composite output terminal.

Pulse-width modulation at a 20kHz rate (set by R1 and C3) controls the supply output voltage. The ends of the primary winding of T1 are alternately connected to ground through R2 and R6 by the switching transistors in U1. The resistors limit the primary current, allowing pulse-width control of the output voltage and protecting the switching transistors if the supply is shorted. Diodes CR1 and CR2 prevent the ends of the primary from dropping below ground, which also clamps the positive excursions at +30V, due to the coupling between the halves of the winding. VR1, C1, and C9 provide a stable, low-impedance source of +15V to the switching supply.

The control signal which turns on the igniter supply (U7-9) also enables the high voltage supply. When this signal is low, the dead-time control input of U1 (pin 4) is pulled low through R13. This sets the dead time, when neither switching transistor is turned on, to its minimum value of 3%. When the control signal is high, the DT pin (U 1-4) is raised above 3.5V through CR8, setting the dead time to 100% and shutting down the supply. C5 pulls U1-4 up when the supply is turned on, creating a soft start, as the dead-time control voltage is slowly pulled down through R13.

Transformer T1 has a turns ratio of about 29:1 from the secondary to one half of the primary. The peak secondary voltage of about 275V maximum is quadrupled by the network consisting of CR3-6 and C6-8 and C11. R5 and C10 attenuate the 20kHz ripple and introduce a maximum drop of 75V under normal loading.

Since pin 2 of U1 is at a virtual ground, R12 and R7 divide the high voltage output by a factor of about 2700. This creates the HV_ SENSE signal, which is routed through analog switch U8 (pins 2-3) to the ADC for diagnostics. AR4 (pins 12-14) is a unity-gain buffer which isolates the supply from the glitches created by switching of the system ADC input multiplexer.

Software description

Software description of the 436-GC/456-GC

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Electrical diagrams

Interconnection diagrams of the 436-GC/456-GC

Section contents:

Rectifier Board

Main Board

LUI Board

Option Board

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ILLUSTRATED PARTS BREAKDOWN

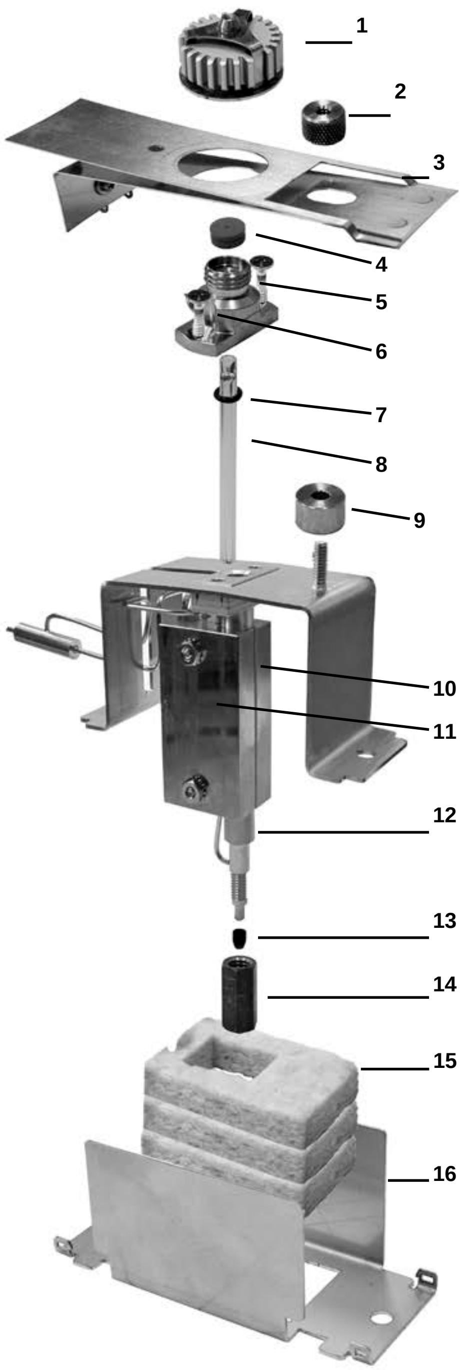
Illustration and part numbers for the components that make up the 436-GC/456-GC.

This section contains illustrated parts breakdowns for the 436-GC/456-GC Gas Chromatograph Injectors and related components

INJECTORS

710

split/splitless Injector Assembly



1. Injector Nut (392597501)
Injector Nut Wrench (390842300)

2. Knob (392597101)

3. Inject Switch Assembly (390820601)

4. Septum, 9 mm
BTO (lowest bleed, CR298713)
Marathon (Autosampler, CR239778)
Advanced Green 3 (general purpose, CR246713)

5. Septum Purge Head

Pneumatic Type	Stainless Steel	Inert Steel
EFC21	392597301	392597303
EFC25 or Manual Pneumatics	392597302	392597304

6. Purge head screw (2x 391866308)

7. O-ring, Liner
Graphite, 6.5mm for Splitless (392611930)
Viton, 6.3mm (8850103100)

8. Glass Insert (default 392611936)
Siltek Insert (RT2104602145)

9. Spacer (392598101)

10. Temperature Probe (392537401)

11. Heater, 120V 100W- 392598701
230V 100W- 392598702

12. Injector Body
Stainless Steel (392599401)
Inert Steel (392599411)
Manual (392599501)

13. Column Ferrule (see table below)

14. Capillary Column Nut (394955100)

15. Insulation

16. Cover

Column ID	*Holes*	*Teflon Max 250°C*	*Vespel Max 350°C*	*40% Graphite /60% Vespel Max 400°C*	*Graphite Max 450°C*	*SilTite Metal, GC/MS*
0.18 mm ID and smaller	1		CR212103	CR213103		
0.25 mm ID	1	CR214104	CR212104	CR213104	CR211104	
	2			CR213124		
0.25 mm ID and smaller	1					*SG073300*
0.32 mm ID	1		CR212105	CR213105	CR211105	*SG073301*
	2			CR213125	CR211125	
*0.53 mm ID **	*1*	*CR214108*	*CR212108*	*CR213108*	*CR211108*	*SG073302*

* Note: Limited application use when using 0.53mm columns

Programmable Temperature Vaporizing (PTV) Injector

1. a. Injector Nut CP8400/8410 (392595401; default)
b. Injector Nut (394966601)
Injector Nut Wrench (390842300)

2. Automatic Start Switch (390820601)

3. Septum, 11.5 mm
BTO (lowest bleed, CR298777)
Marathon (Auto sampler, CR239787)
Advanced Green 3 (general purpose, CR246725)

4. Septum Support (391867600)

5. Insert Ferrule (392534201)

6. Glass Insert, default 392611945
Siltek RT217092145

7. Injector Body

Pneumatic Type	Stainless Steel	Inert Steel
EFC	392544001	392544011
Manual Pneumatics	392559601	392559611

Cryo tube LCO_2 (392557901)
Cryo tube LCN_2 (392557902)

8. Column Ferrule, see table below

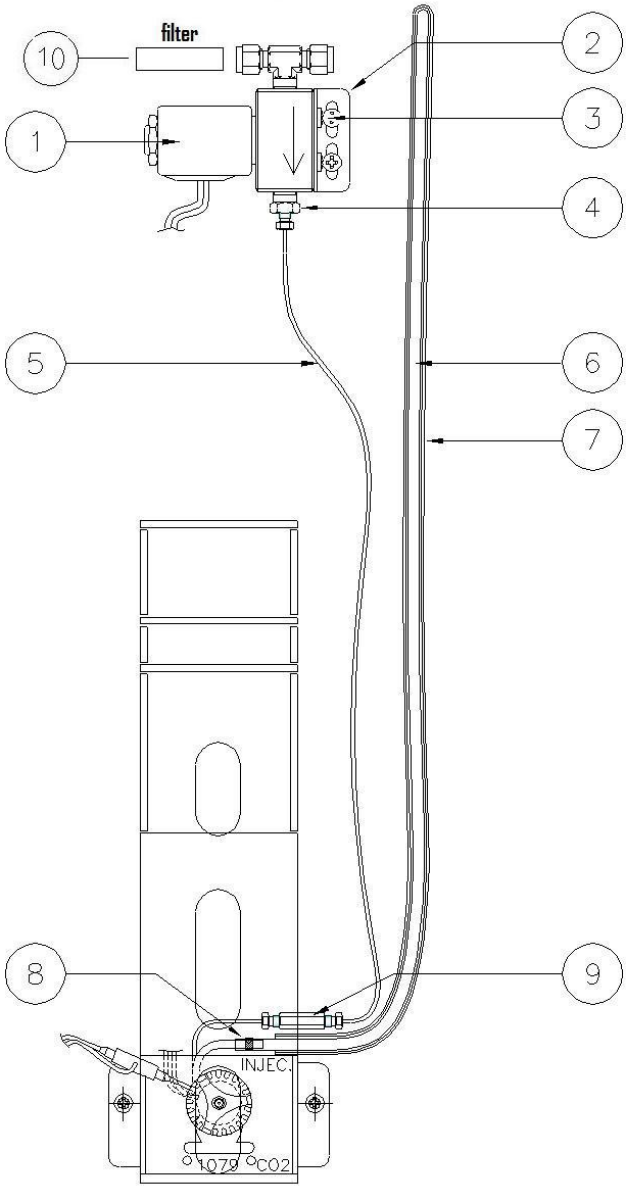
9. Bottom Nut (394955100)
(CP742351 Brass 1/16")

Temperature Probe (392537401)

Heater, 120V 100W- 392542501
230V 100W- 392542502

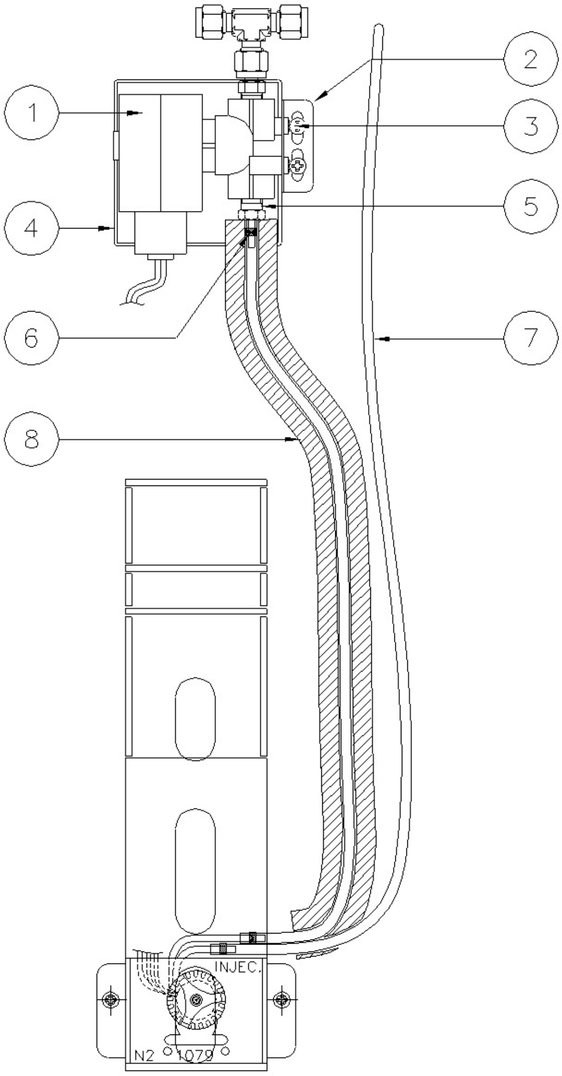
Column ID	***Holes***	***Teflon*** ***Max 250°C***	***Vespel*** ***Max 350°C***	***40% Graphite /60% Vespel Max 400°C***	***Graphite*** ***Max 450°C***	***SilTite*** ***Metal, GC/MS***
0.18 mm ID and smaller	1		CR212103	CR213103		
0.25 mm ID	1	CR214104	CR212104	CR213104	CR211104	
	2			CR213124		
0.25 mm ID and smaller	1					SG073300
0.32 mm ID	1		CR212105	CR213105	CR211105	SG073301
	2			CR213125	CR211125	
0.53 mm ID	1	CR214108	CR212108	CR213108	CR211108	SG073302

Cooling option LCO2 (PTV Injector)



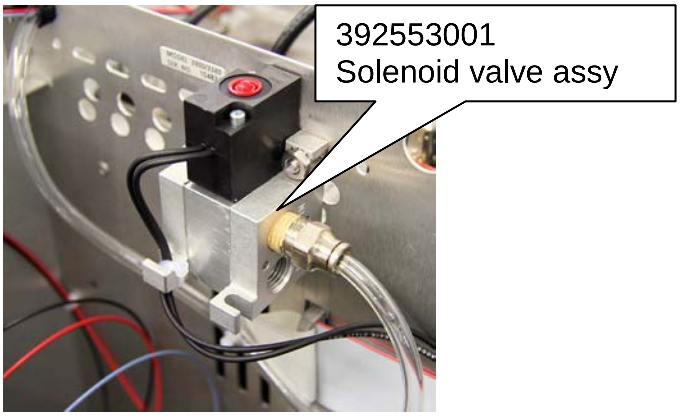
1. LCO2 valve (392556701)
2. bracket, Injector cryo (392556201)
3. Screw 10-32 x1/4 (1222206004)
4. 1/8MPT pipe adapter (2821153500)
   Teflon tape (CP12059)
5. Peek tubing, natural (391885300)
6. 1/8IN tubing insulation (8848907100)
7. Tubing Silicon 0.25mmID (8910011800)
8. Clamp (2899310500)
9. 1/16 x1/16 Valco union (VLZU1)
10. Particle filter for LCO2 (2um) (CP741148)

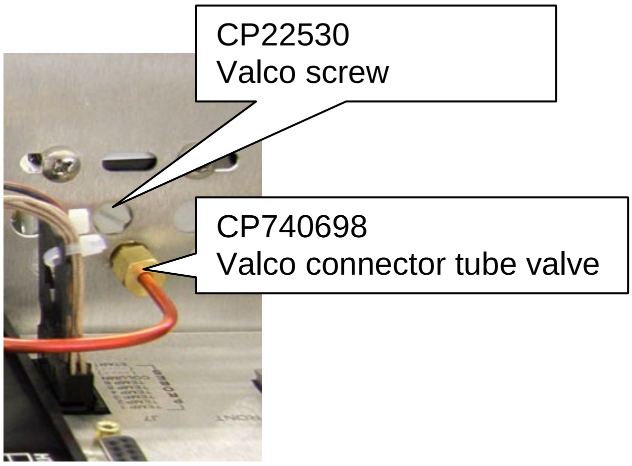
Cooling option LN2 (PTV Injector)

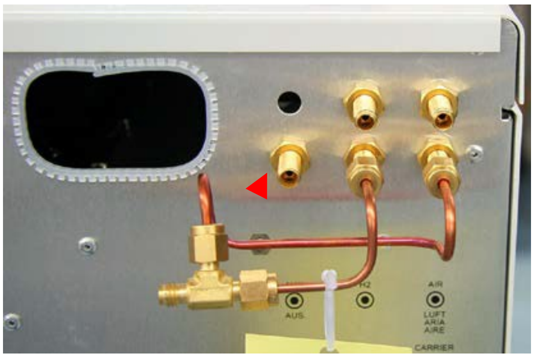


1. LN2 valve (392555701)
2. bracket, Injector cryo (392556201)
3. Screw 10-32 x3/8 (1222206006)
4. Cover square (2323093800)
5. Swagelok union B2TA12(2869512900)
   Teflon tape (CP12059)
6. Clamp (2899310500)
7. 1/8IN tubing insulation (8848907100)
8. Insulation hose (CP86656)

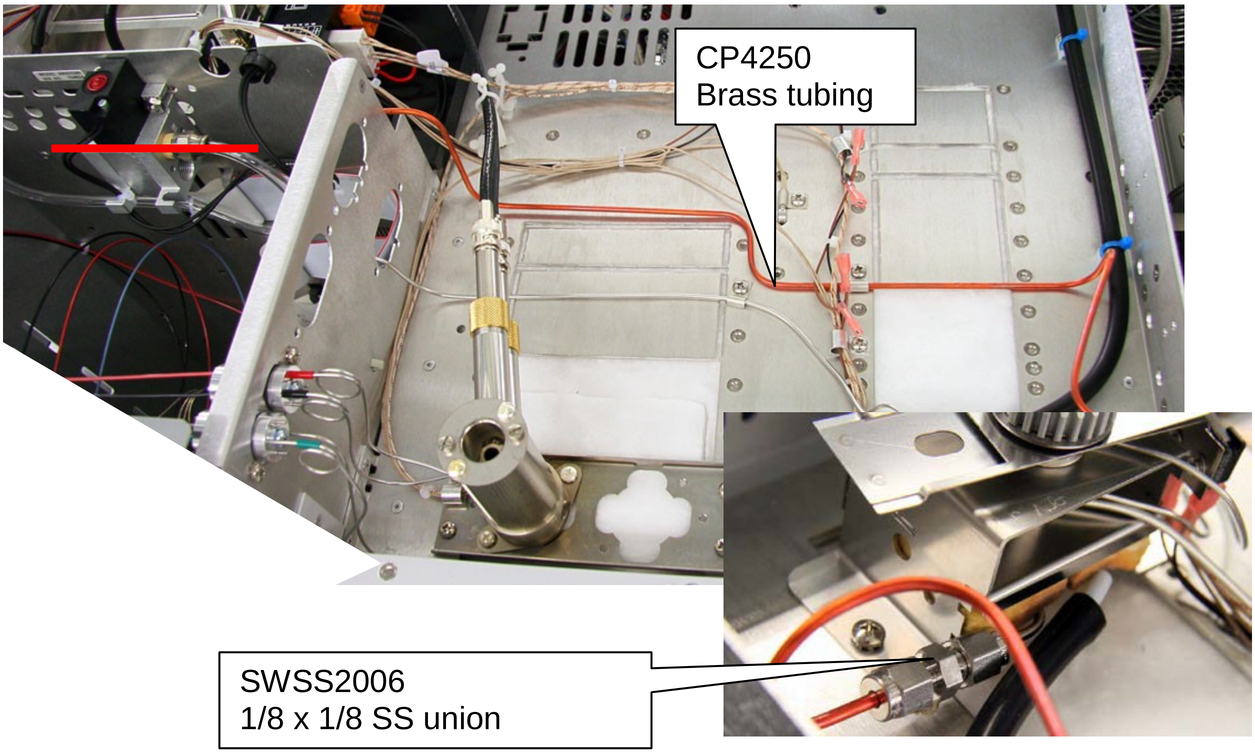
Cooling option AIR (PTV Injector)



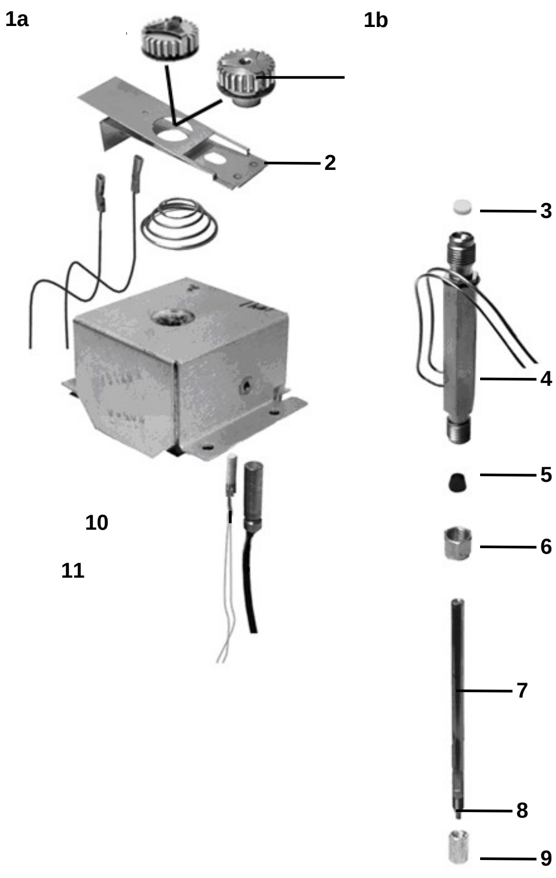




Air tubing from the solenoid is connected to the AIR (luft)



On Column Injector



1. a. Injector Nut CP8400/8410 (392595501 default
b. Injector Nut (390812700)
Injector Nut Wrench, 390842300

2. Automatic Start Switch (390820601)

3. Septum, 9.5 mm
BTO (lowest bleed, CR298705)
Marathon (Auto sampler, CR239188)
Advanced Green 3 (general purpose, CR246124)

4. Injector Body
EFC23 type (392548201)

5. Injector Body Ferrule
40% Graphite/60% Vespel (up to 400°C), CR213400
Graphite (up to 450 °C), CR211400

6. Injector Body Nut (Stainless Steel, SWSS4021)

7. Injector Insert (Stainless Steel, 392543101)
Injector Insert (For Headspace injection, CP742552)

8. Column Ferrule, see table below

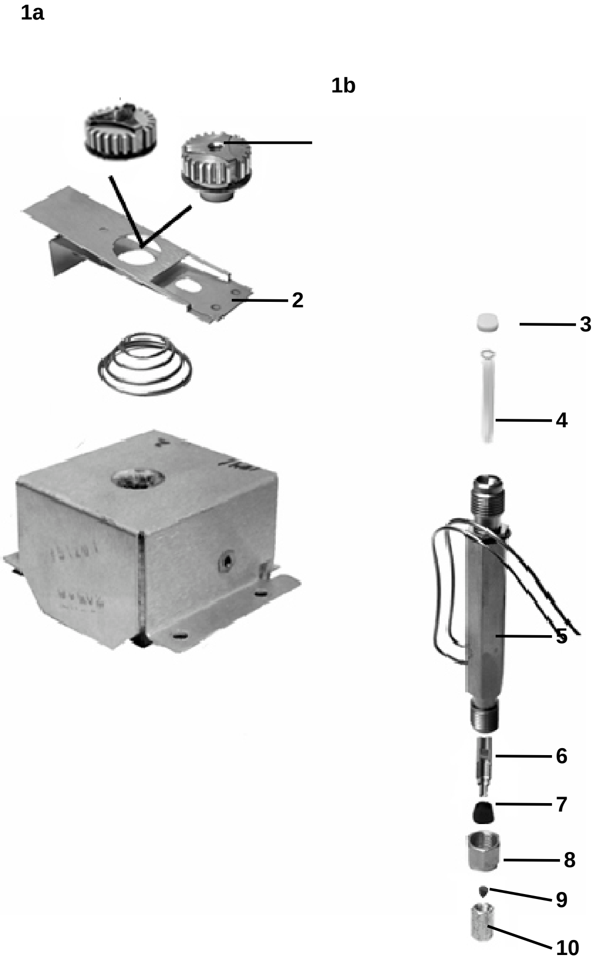
9. Capillary Nut (394955100)

10. Temperature Probe (392537401)

11. Heater, 120V 125W- 392539601
230V 125W- 392539602

Column ID	*Teflon Max 250°C*	*Vespel Max 350°C*	*40% Graphite /60% Vespel Max 400°C*	*Graphite Max 450°C*	*SilTite Metal, GC/MS*
0.53 mm ID	*CR214108*	*CR212108*	*CR213108*	*CR211108*	*SG073302*

Flash Vaporization Injector



1 a. injector nut CP8400/8410 (392595501) Default
b. Injector Nut (390812700)
Injector Nut Wrench (390842300)

2 Automatic Start Switch (390820601)

3 Septum, 9.5 mm
BTO (lowest bleed, CR298705)
Marathon (Auto sampler, CR239188)
Advanced Green 3 (general purpose, CR246124)

4 Glass Insert, default 392611943

5 Injector Body, EFC23, 392548301

6 Column Guide, 392558301

7 Ferrule,
40% Graphite/60% Vespel (up to 400°C), CR213400
Graphite (up to 450 °C), CR211400

8 Injector body Nut, SWSS4021

9 Column Ferrule, see table below

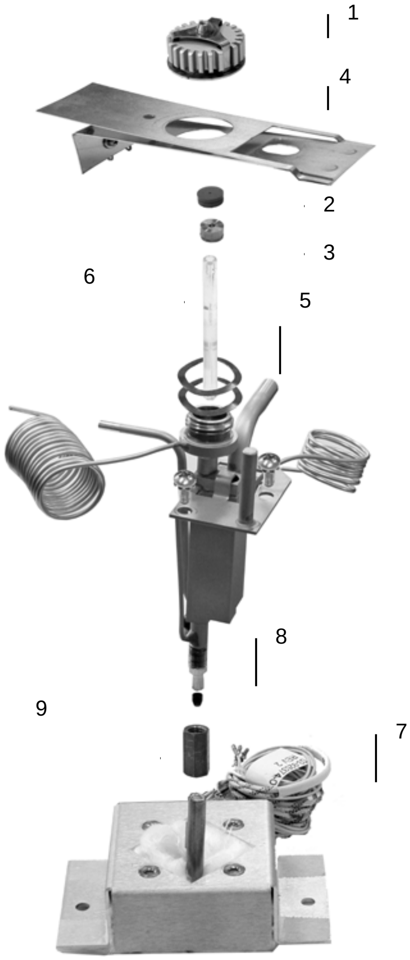
10 Column Nut (394955100)

Temperature Probe (392537401)

Heater, 120V 125W- 392539601
230V 125W- 392539602

Column ID	*Teflon Max 250°C*	*Vespel Max 350°C*	*40% Graphite /60% Vespel Max 400°C*	*Graphite Max 450°C*	*SilTite Metal, GC/MS*
0.53 mm ID	*CR214108*	*CR212108*	*CR213108*	*CR211108*	*SG073302*

Septum Equipped Programmable Injector (SPI) Injector



1 Injector Nut (394966601)
Injector Nut Wrench, 390842300

2 Septum, 7/16"
BTO (Lowest bleed, CR298777)
Marathon (Auto sampler, CR239787)
Advanced Green 3 (general purpose, CR246725)

3 Septum Support (391821100)

4 Inject switch assembly (390820601)

5 Wave spring washer (1492000500)

6 Glass Insert, default SG092034

7 Heater/Probe harness 120V(391833400)
Heater/Probe harness 230V(391833401)

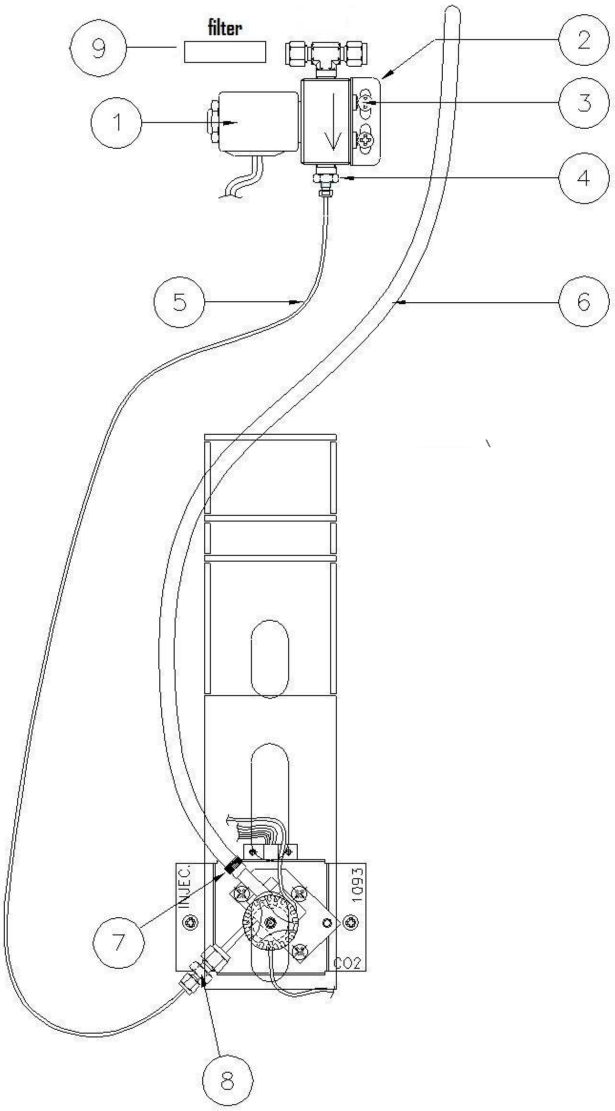
8 Column Ferrule, see table below

9 Bottom Nut (394955100)
(CP743117: SS nut for HT application 2 pcs.)

SPI injector assy,
120V (CP91833104)
230V (CP91833105)

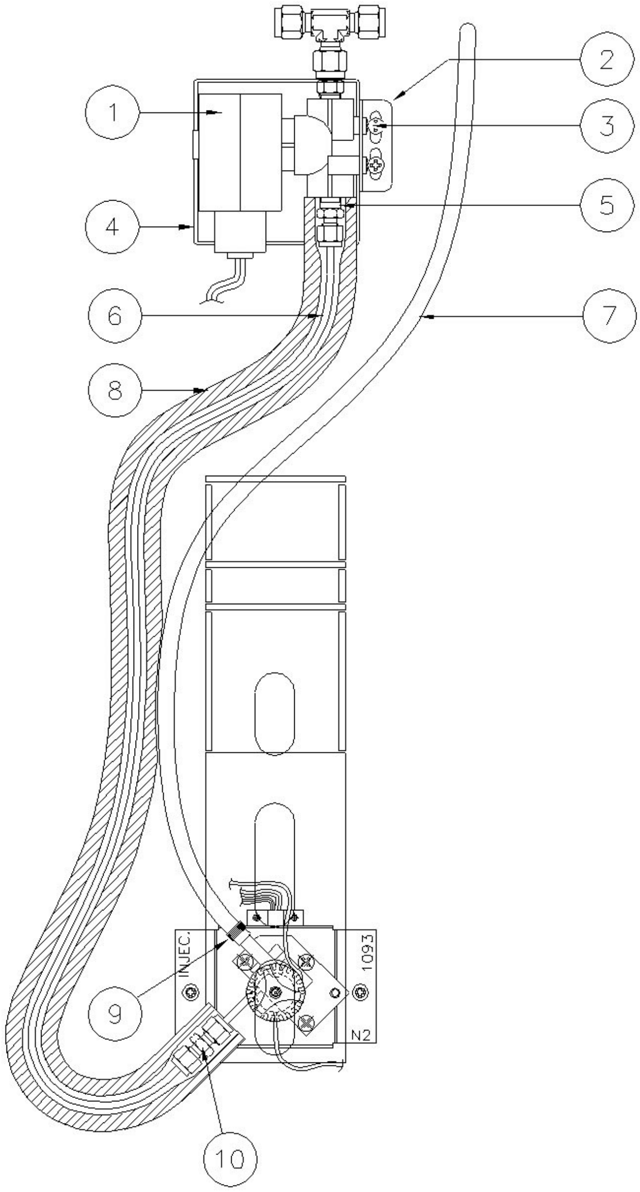
Column ID	***Teflon*** ***Max 250°C***	***Vespel*** ***Max 350°C***	***40% Graphite /60% Vespel Max 400°C***	***Graphite*** ***Max 450°C***	***SilTite*** ***Metal, GC/MS***
0.53 mm ID	*CR214108*	*CR212108*	*CR213108*	*CR211108*	*SG073302*

Cooling option LCO2 (SPI Injector)



1. LCO2 valve (392556701)
2. bracket, Injector Cryo (392556201)
3. Screw 10-32 x1/4 (1222206004)
4. 1/8MPT pipe adapter (2821153500)
   Teflon tape (CP12059)
5. SS tubing 1/16x0.50 (CP4004)
6. Tubing Silicon 0.25mmID (8910011800)
7. Cable tie (2211972700)
8. 1/8 x1/16 Reducing union (SWSS20061RU)
9. Particle filter for LCO2 (2um) (CP741148)

Cooling option LN2 (SPI Injector)



1. LN2 valve (392555701)

2. bracket, Injector cryo (392556201)

3. Screw 10-32 x3/8 (1222206006)

4. Cover square (2323093800)

5. 1/8 Male connector(SWB20012)
Teflon tape (CP12059)

6. Cupper tubing (CP743115)

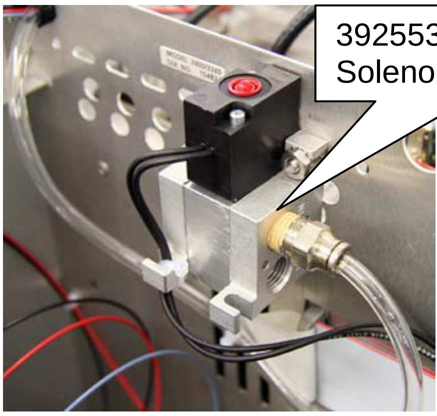
7. Tubing TFE (391884601)

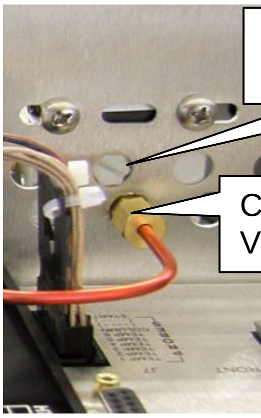
8. Insulation hose (CP86656)

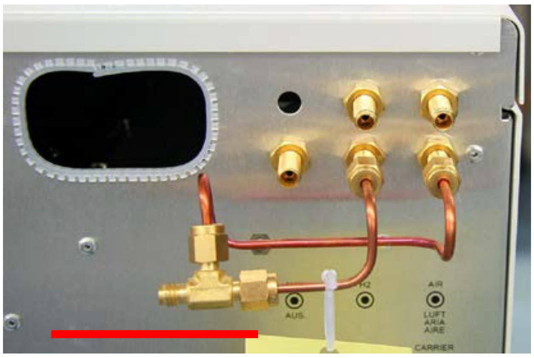
9. Clamp (CP741550)

10. 1/8 SS unions (SWSS2006)

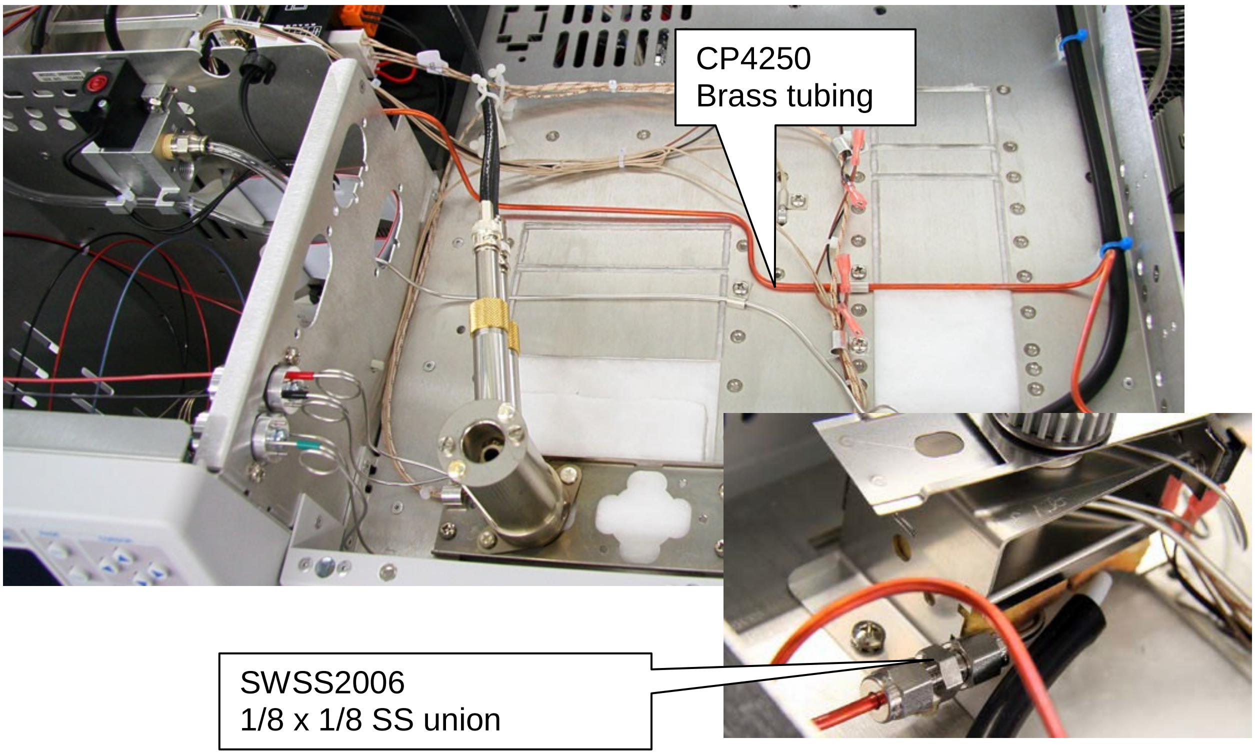
Cooling option AIR (SPI Injector)



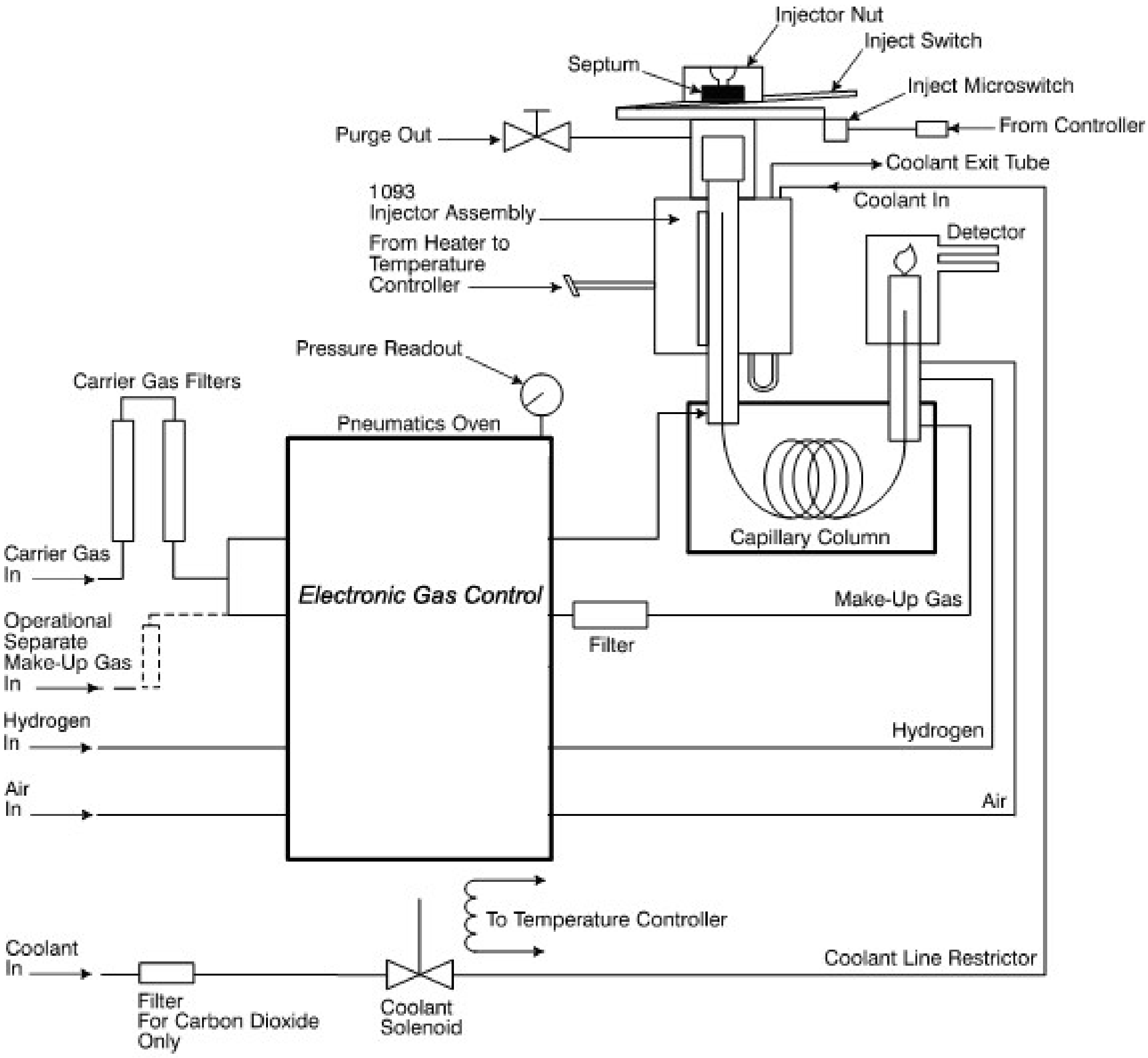




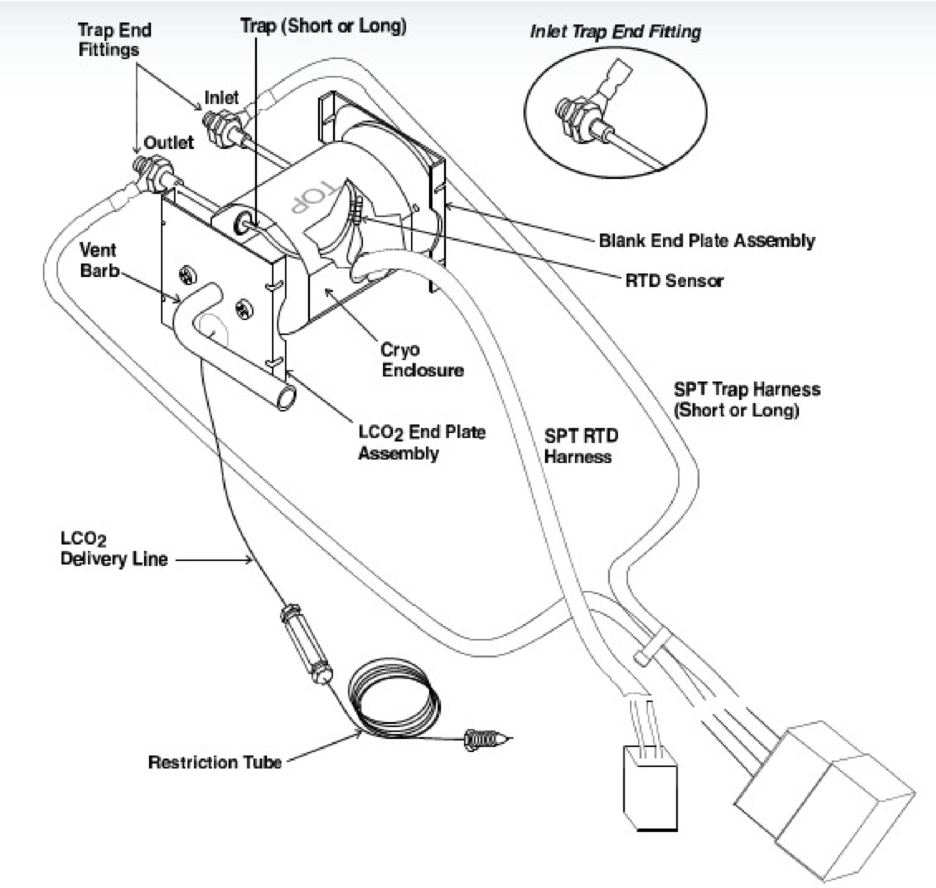
Air tubing from the solenoid is connected to the AIR (luft)

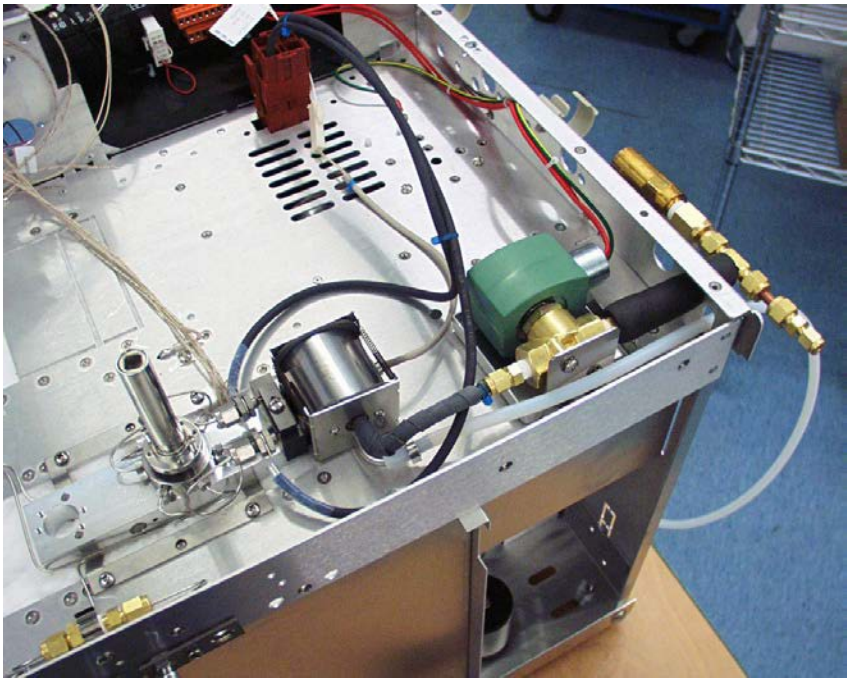


Flow diagram SPI injector



SPT Sample Pre concentration Trap (SPT) Injector





SPT-LN_2 Option

Trap descriptions

Short Traps	***Part Number***
Short Trap Assembly Kit (8 cm), silanized glass beads	392571392
Short Trap Assembly Kit (8 cm), blank	392571391
Blank Trap	392571301
Packed, Glass Beads	392571302
Long Traps	
Long Trap Assembly Kit (30 cm), blank	392571491
Blank Trap	392571401
Tenax GR/Charcoal	392571402
Tenax GR	392571403
Carbopack B, Carbosieve SIII	392571404
5% OV101 on Chromosorb G/HP, HayeSep D	392571405
Carbopack C, Carbopack B, Carboxen 1000, Carboxen 1001	392571406
Carbopack C, Carbosieve SIII	392571407
HayeSep D	392571408
Tenax TA, Charcoal	392571409
Tenax TA	392571410
Tenax GR, Carbopack B, Carbosieve SIII	392571411
Kit, Blank Trap	392571491
Kit, Tenax GR/Charcoal	392571492
Kit, Tenax GR	392571493
Kit, Carbopack B, Carbosieve SIII	392571494
Kit, 5% OV101 on Chromosorb G/HP, HayeSep D	392571495
Kit, Carbopack C, Carbopack B, Carboxen 1000, Carboxen 1001	392571496
Kit, Carbopack C, Carbosieve SIII	392571497
Kit, HayeSep D	392571498
Kit, Tenax TA, Charcoal	392571499
Kit, Tenax TA	392571480
Kit, Tenax GR, Carbopack B, Carbosieve SIII	392571481

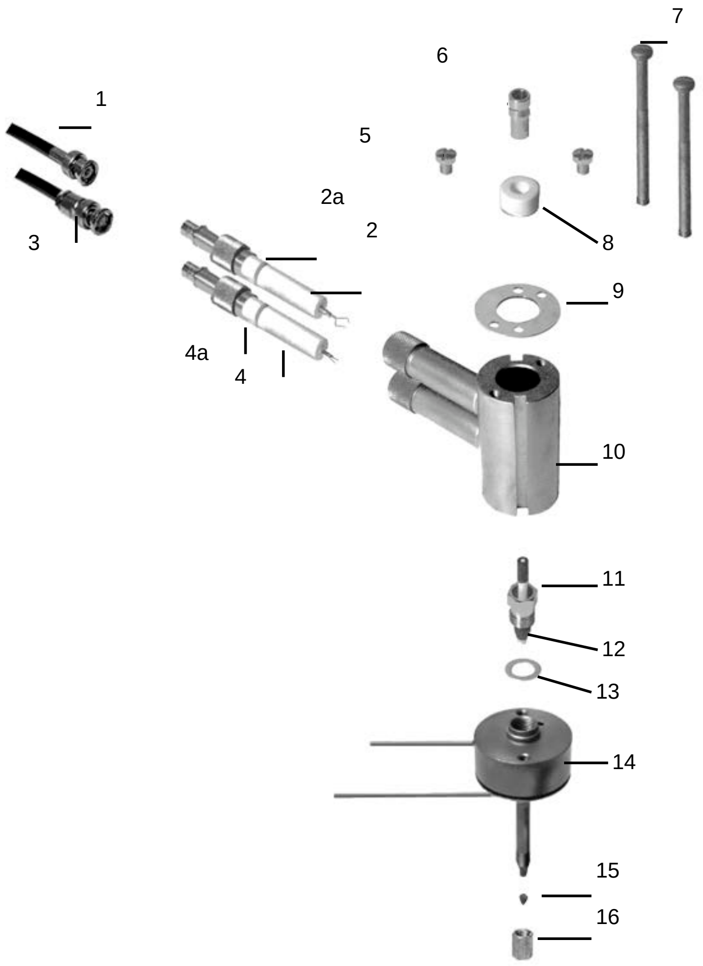
Part Description	***Part Number***
Cryo Valve: LCO2	392555501
LN2	392555701
Ferrule for Restriction Tube (LCO2)	2869450201
Nuts for Restriction Tube (LCO2)	2869450101
Insulation Tubing (LN2)	CP86656
Outlet Filter (LCO2)	2759082600
Restriction Tube, 22" Long (LCO2)	391885301
SPT PCB	391875800
SPT Transformer	391878800
Transfer Line from LN2 Supply to GC,(1/4" Copper, 50' Length)	3700014600
Trap Clamping Bar	391876500
Trap Mounting Block	391876400
Union (LCO2)	2821145700
Transfer Line from LCO2 supply to GC,(1/16" stainless steel, 10')	391885200
Ferrules for stainless steel Transfer Line (Front)	SWSS1031
Ferrules for stainless steel Transfer Line (Back)	SWSS1041
Nuts for stainless steel Transfer Line	SWSS2041
Ferrules for stainless steel Transfer Line (1/8") (Front)	SWB2031
Ferrules for stainless steel Transfer Line (1/8") (Back)	SWB2041
Nuts for stainless steel Transfer Line (1/8")	SWB2021
Vespel ferrule 1/8 x 1/16	CP741571
Installation Kit, LCO_2	391880101
Installation Kit, LN_2	391880102

This section contains illustrated parts breakdowns for the 436-GC/456-GC Gas Chromatograph Detectors and related components

DETECTORS

720

FID Flame Ionization Detector



1 Signal Cable (391783000)

2 Signal Probe (200187300)
2a O-ring (baked, 0390596004)

3 Ignitor Cable (392548701)

4 Ignitor Probe (200187200)
4a O-ring (baked, 0390596004)

5 Screws, 8-32 x ¼" (1214200804)

6 Collector Tube (394958700)

7 Tower Screws, 8-32x2" ¾" (391866302)

8 Ceramic Insulator (2100003200)

9 Tower Top Plate (3400073100)

10 Detector Tower Body (100099300)

11 Flame Tip, 0.01 in. Capillary Tip (200187500)

11 Flame Tip, 0.02 in. Standard Tip (200193800)

12 Ferrule: Vespel (100%) max. 350°C (CR212200)
Graphite/Vespel 40/60 max. 400°C (CR213200)
Graphite (100%) max. 450°C (CR211200)

13 Aluminum Seal Washer (1500334701)

14 Detector Base (392547501)

15 Column Ferrule

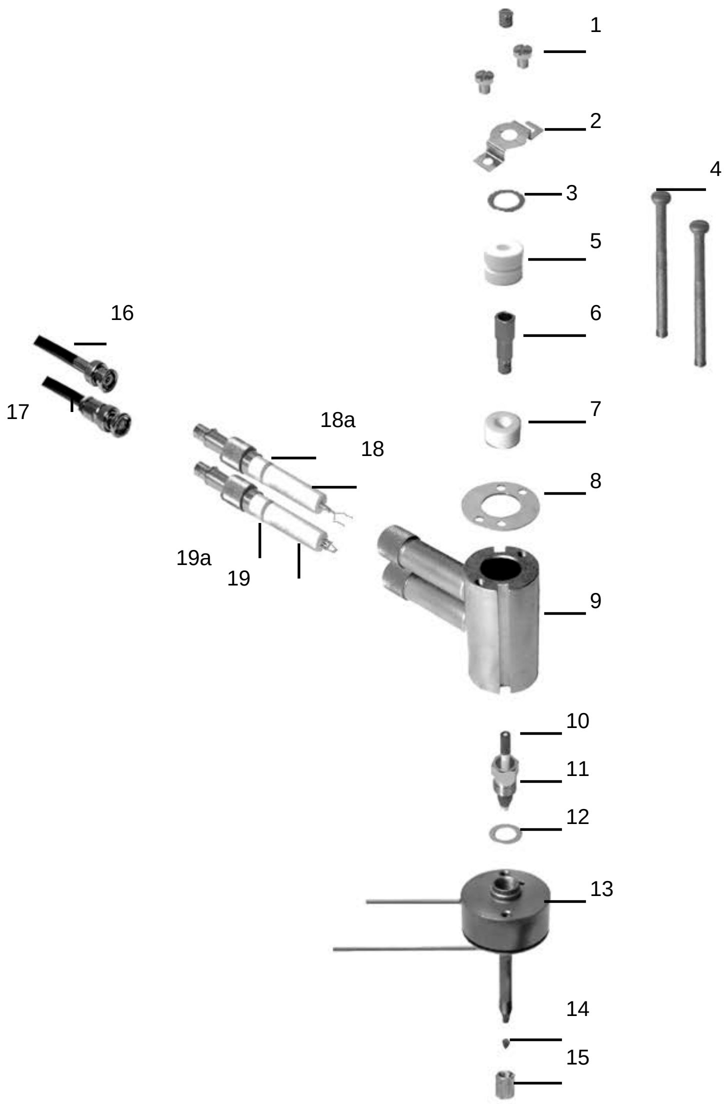
16 Column Nut (394955100)

Temperature Probe (392537401)

Heater, 120V 125W- 392539601
230V 125W- 392539602

--- Flow Tube (200187600)
--- Large Stopper (394958600)

NPD Nitrogen Phosphorus Detector



1 Screws, 8-32 x ¼" Fillister head (1214200804)

2 NPD Top Clamp (800022900)

3 O-ring (2740928202)

4 Tower Screws, 8-32 x 3" (391866301)

5 Upper Insulator (2100003100)

6 Collector Tube (390607900)

7 Ceramic Insulator (2100003200)

8 Tower Top Plate (3400073100)

9 Detector Tower Body (390607700)

10 Flame Tip, 0.010 in. Standard Tip (200193800)

11 Ferrule: Vespel (100%) max. 350°C (CR212200)
Graphite/Vespel 40/60 max. 400°C (CR213200)
Graphite (100%) max. 450°C (CR211200)

12 Aluminum Seal Washer (1500334701)

13 Detector Base (392547501)

14 Column Ferrule

15 Column Nut (394955100)

16 Signal Cable (391783000)

17 NPD bead cable (392548801)

18 NPD Signal Probe (390607600)
18a O-ring (baked, 0390596004)

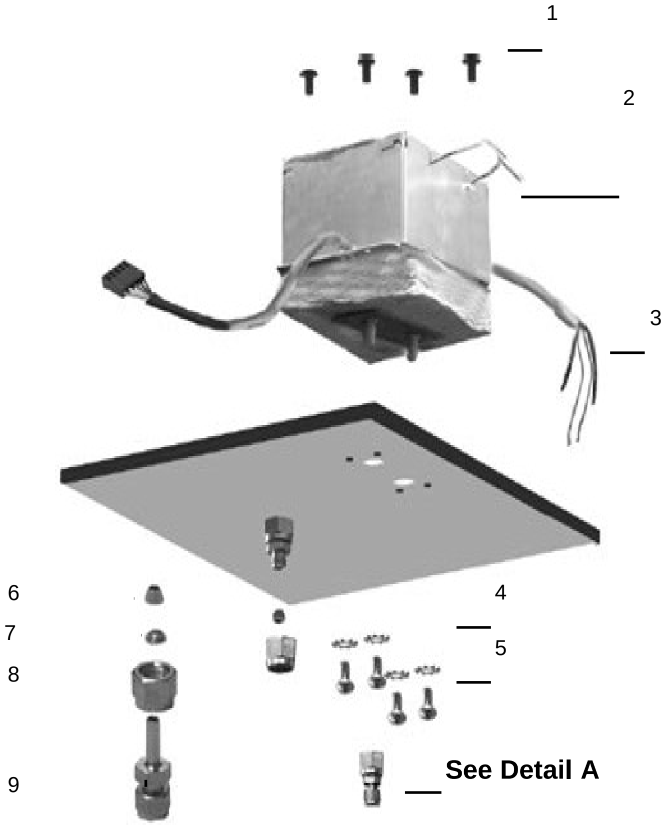
19 NPD bead, unconditioned (390607400)
, conditioned (390607401)
19a O-ring (baked, 0390596004)

Temperature Probe (392537401)

Heater, 120V 125W- 392539601
230V 125W- 392539602

--- Flow Tube (200187600)

TCD Thermal Conductivity Detector



Detail A

1 Screws, 8-32 x 3/8” Fillister head (1290116300)

2 TCD assy 120V (392560701)
TCD assy 230V (392560702)

TCD assy w/transferline 120V (392560711)
TCD assy w/transferline 230V (392560712)

TCD assy, Dual 120V (392560721)
TCD assy, Dual 220V (392560722)

3 Heater/Probe assembly 120V (392545901)
Heater/Probe assembly 230V (392545902)

Temperature probe (392537401)(only used at Dual TCD)

4 Washer, 8-32 x 3” (1431200800)

5 Screw 8-32 x 3/8 (1290116300)

6 Ferrule front 1/8 SS (SWSS2031)

7 Ferrule back 1/8 SS (SWSS2041)

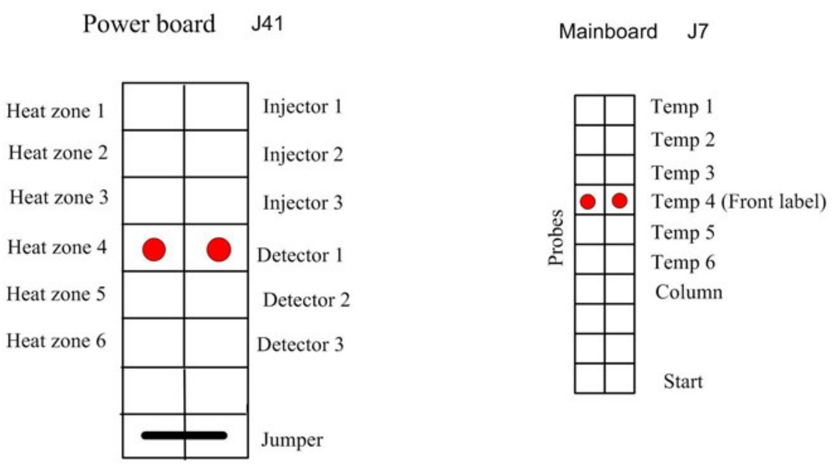
8 Nut 1/8 SS (SWSS2021)

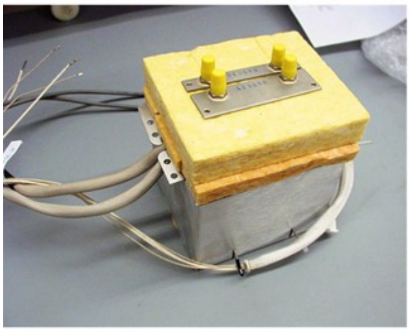
9 Adapter 1/16 to 1/8 SS (SWSS100R2)

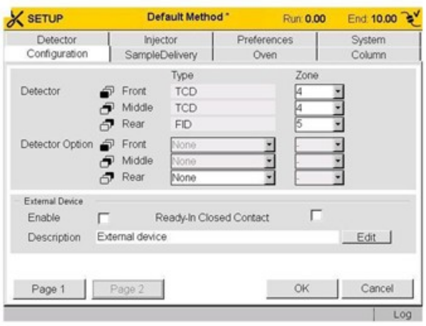
Setup and heater/probe connections

Dual TCD Connections

450 GC DUAL TCD connections



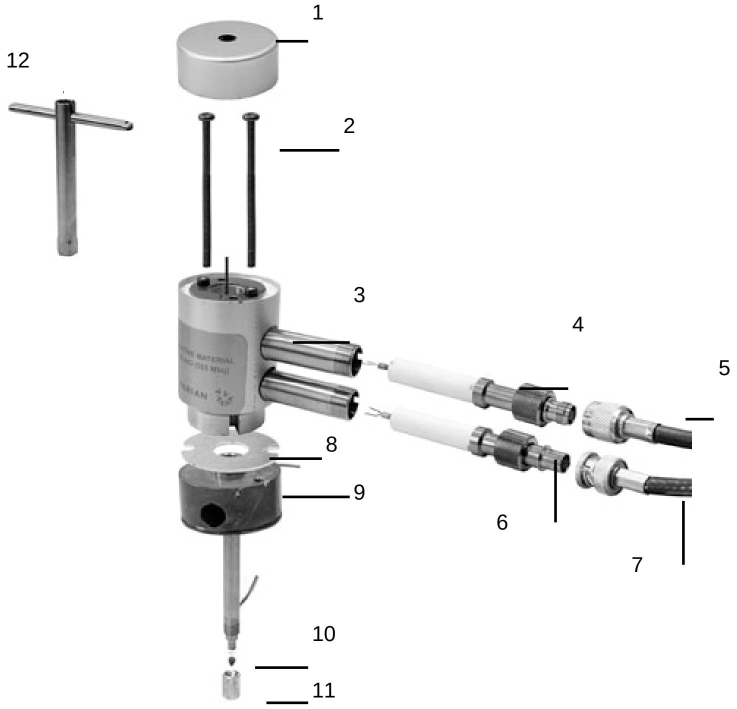




TCD assy, Dual 120V pn 392560721
TCD assy, Dual 230V pn 392560722
TCD assy, Dual 101V pn 392560723

Dual TCD assy always contains 1x heater (2 wires) and 2 temperature probes (4 wires), only the temperature probe (front) needs to be connected,the second temperature probes is NOT connected.

ECD Electron Capture Detector



1. Tower Top Cover (100102300)

2. Tower screw (391866300)

3. Rebuilt ECD SPECIFIC license (200197271)

4. Pulser Probe (200197400)

5. Pulser Cable (390837603)

6. Signal Probe (200197300)

7. Signal Cable (391783000)

8. Shim (392576801)

9. Detector Base (392547501)

10. Column Ferrule

11. Column Nut (394955100)

12. Tool (7200008100)

Temperature Probe (392537401)

Heater, 120V 125W- 392539601
230V 125W- 392539602

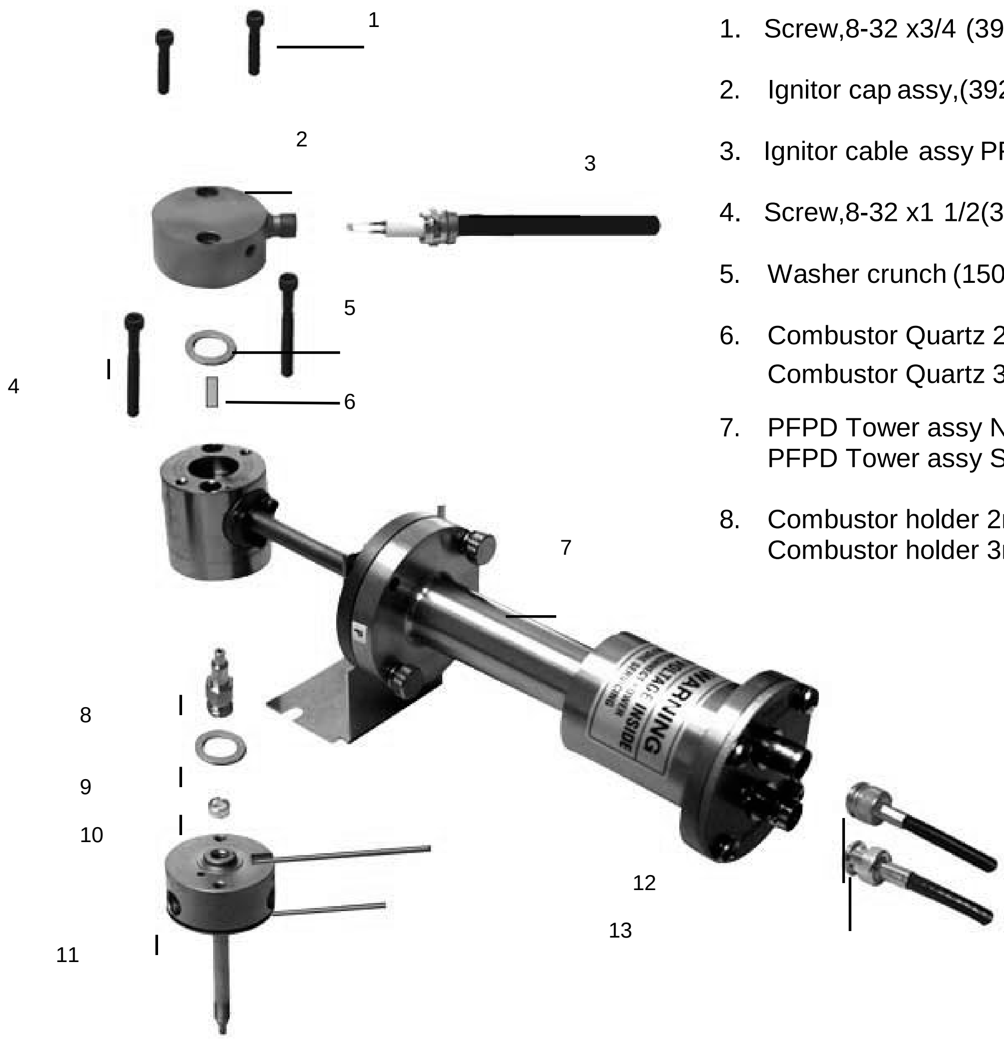
--- Flow Tube (200196700)

Insulation strip (392576901)

Insulation clip (392577001)

Contact potential settings for different Firmware versions.

PFPD Pulsed Flame Photometric Detector

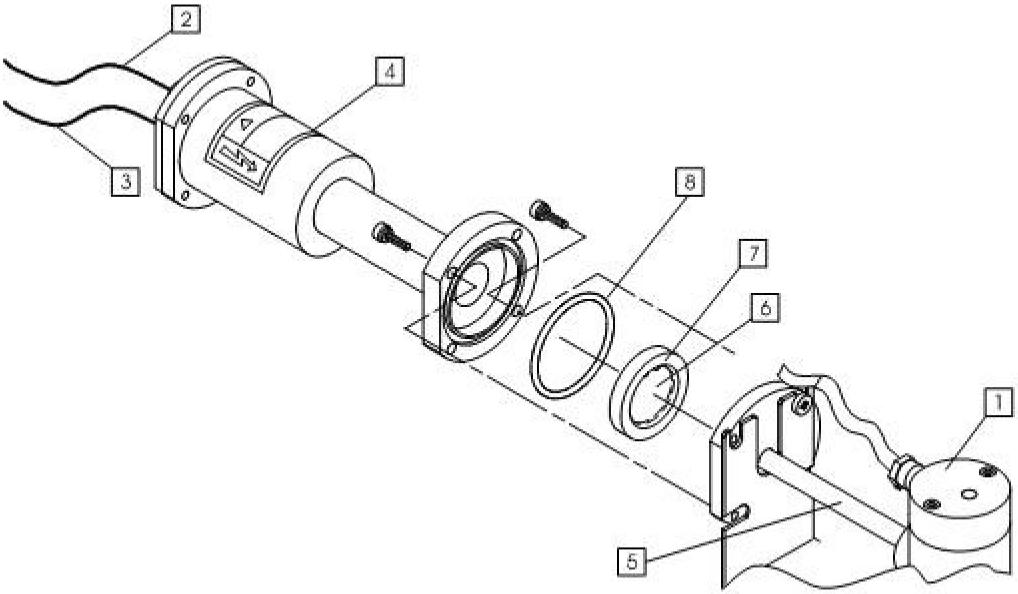


1. Screw,8-32 x3/4 (392519401)
2. Ignitor cap assy,(392513400)
3. Ignitor cable assy PFPD,(392546101)
4. Screw,8-32 x1 1/2(391866307)
5. Washer crunch (1500334700)
6. Combustor Quartz 2mm (392517600) Sulfur
   Combustor Quartz 3mm (392517700) P/N
7. PFPD Tower assy N Mode (392513301)
   PFPD Tower assy S/P Mode (392513300)
8. Combustor holder 2mm (392517800) Sulfur
   Combustor holder 3mm (392517900) P/N
9. Washer crunch (1500334700)
10. Seal Combustor holder(392513800)
11. Detector base PFPD (392547601)
12. High voltage cable assy (392549001)
13. Signal cable assy (391783000)

Temperature Probe (392537401)

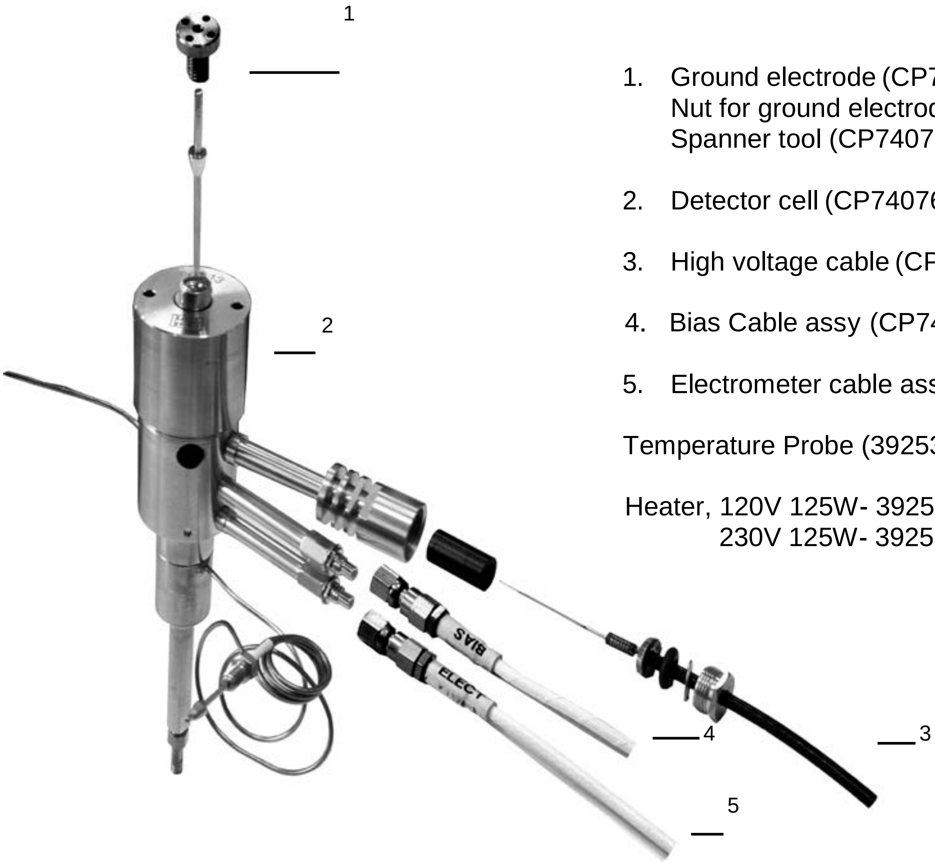
Heater, 120V 125W- 392539601
230V 125W- 392539602

Replacing the Optical filter



1. Igniter cap
2. Photomultiplier tube (PMT) high voltage cable
3. Photomultiplier tube (PMT) signal cable
4. Photomultiplier tube (PMT) housing
5. Light pipe assembly
6. Glass filters a) Sulfur Mode BG-12 deep violet glass filter
   b) Phosphorus Mode BG-12 yellow glass filter
   c) Sulfur& Phosphorus Mode WG-345 glass filter
7. Filter holder
8. O-ring

PDHID Pulsed Discharge Helium Ionization Detector

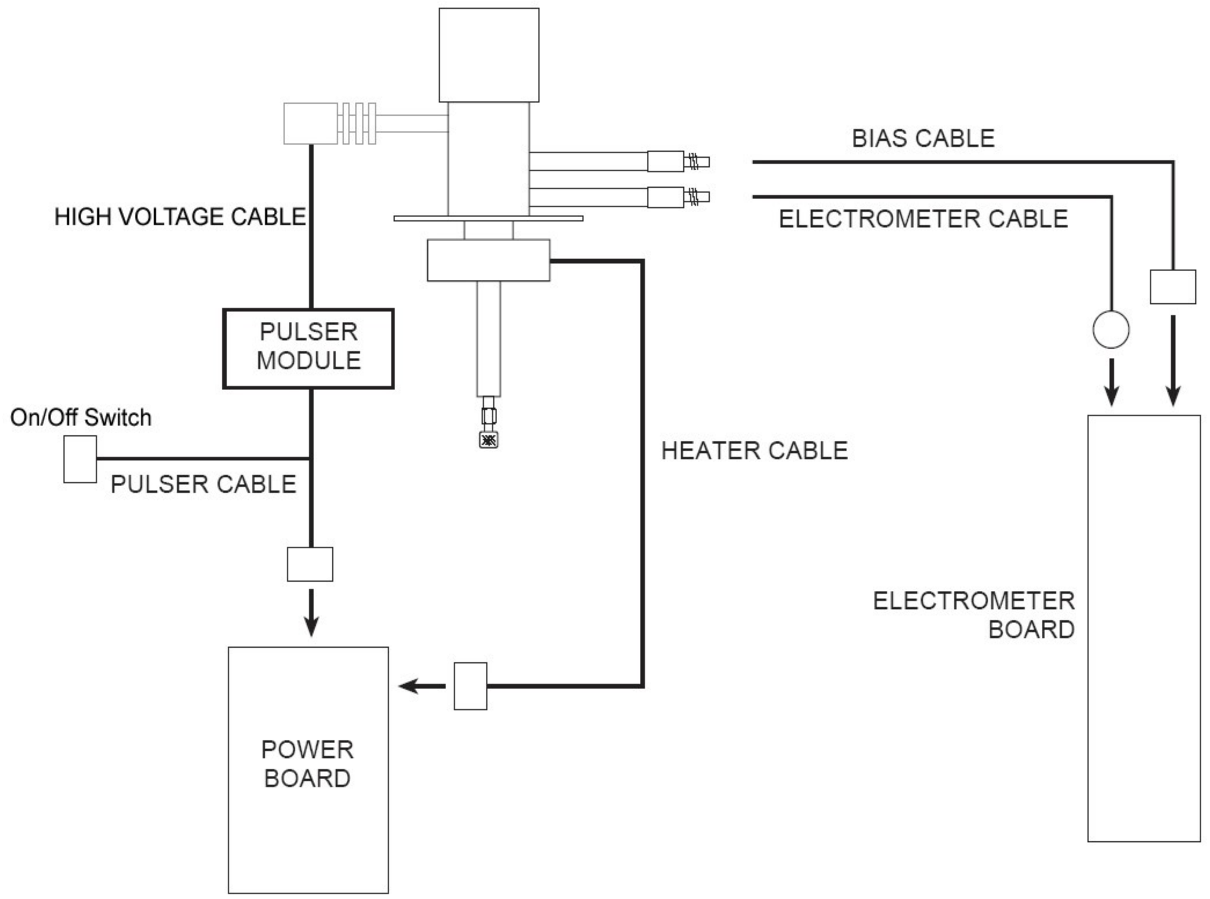


1. Ground electrode (CP740764)
   Nut for ground electrode (VLI23534)
   Spanner tool (CP740760)
2. Detector cell (CP740765)
3. High voltage cable (CP740763)
4. Bias Cable assy (CP740761)
5. Electrometer cable assy (CP740773)

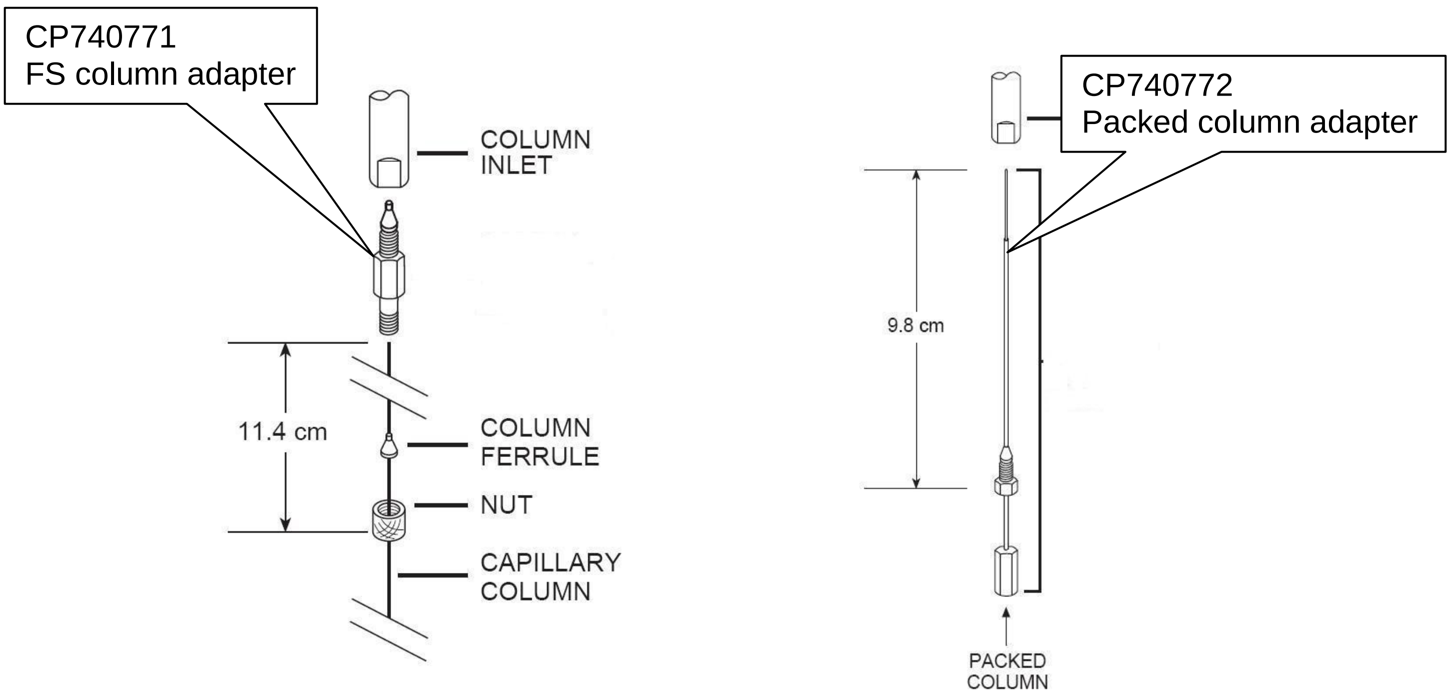
Temperature Probe (392537401)

Heater, 120V 125W- 392539601
230V 125W- 392539602

Overview PDHID



Column connections

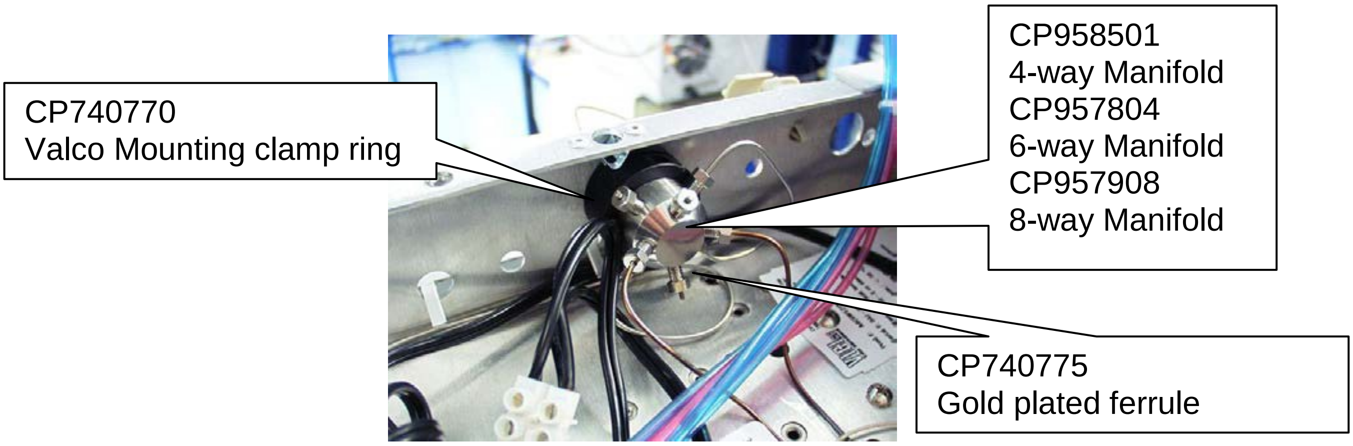


Helium Purifier

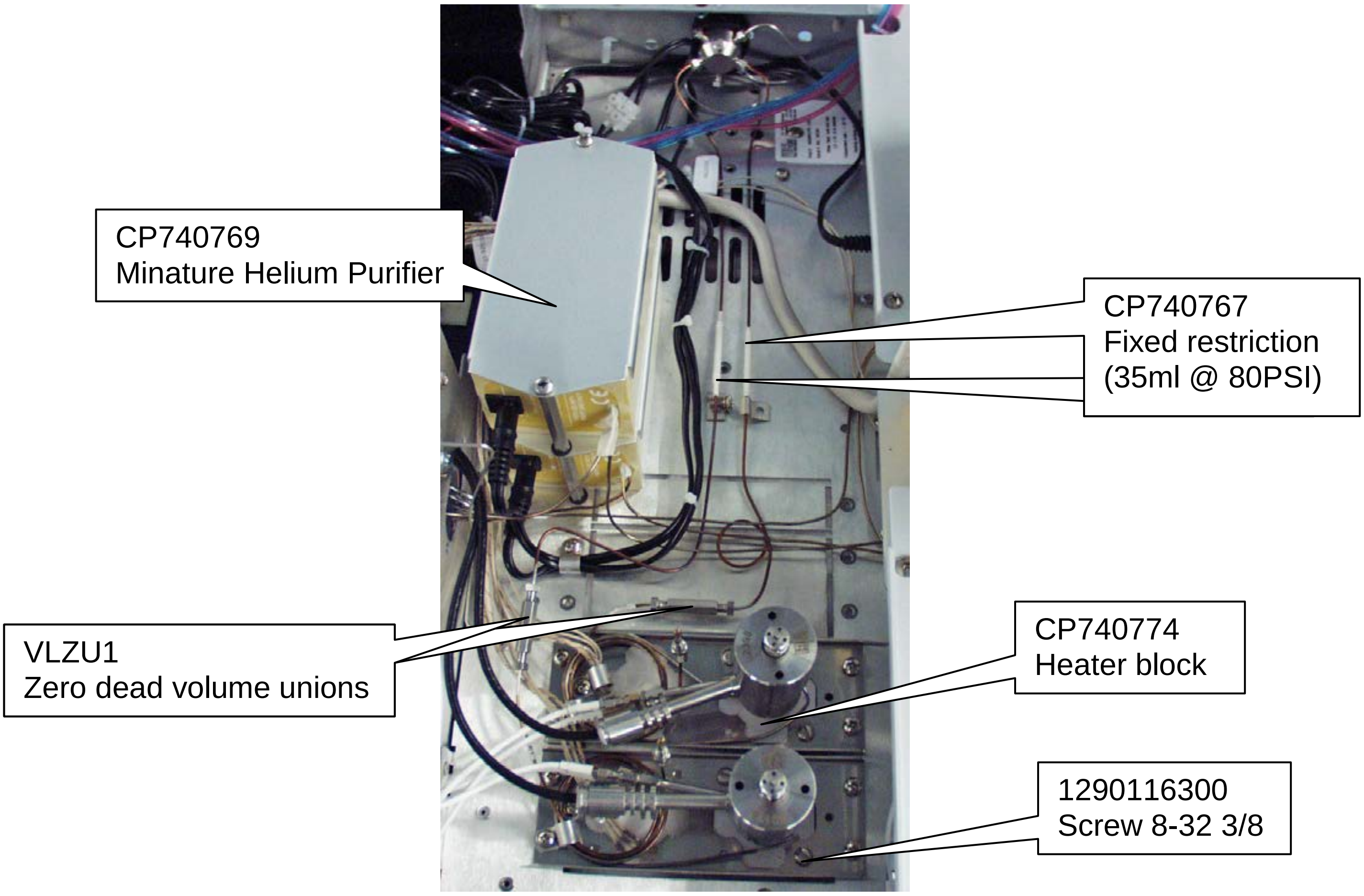
Power supply PDHID

Pulse Discharge module

Valco manifold TIGA



Minature helium Purifier



For more information on the PDHID please refer to the : User manual.

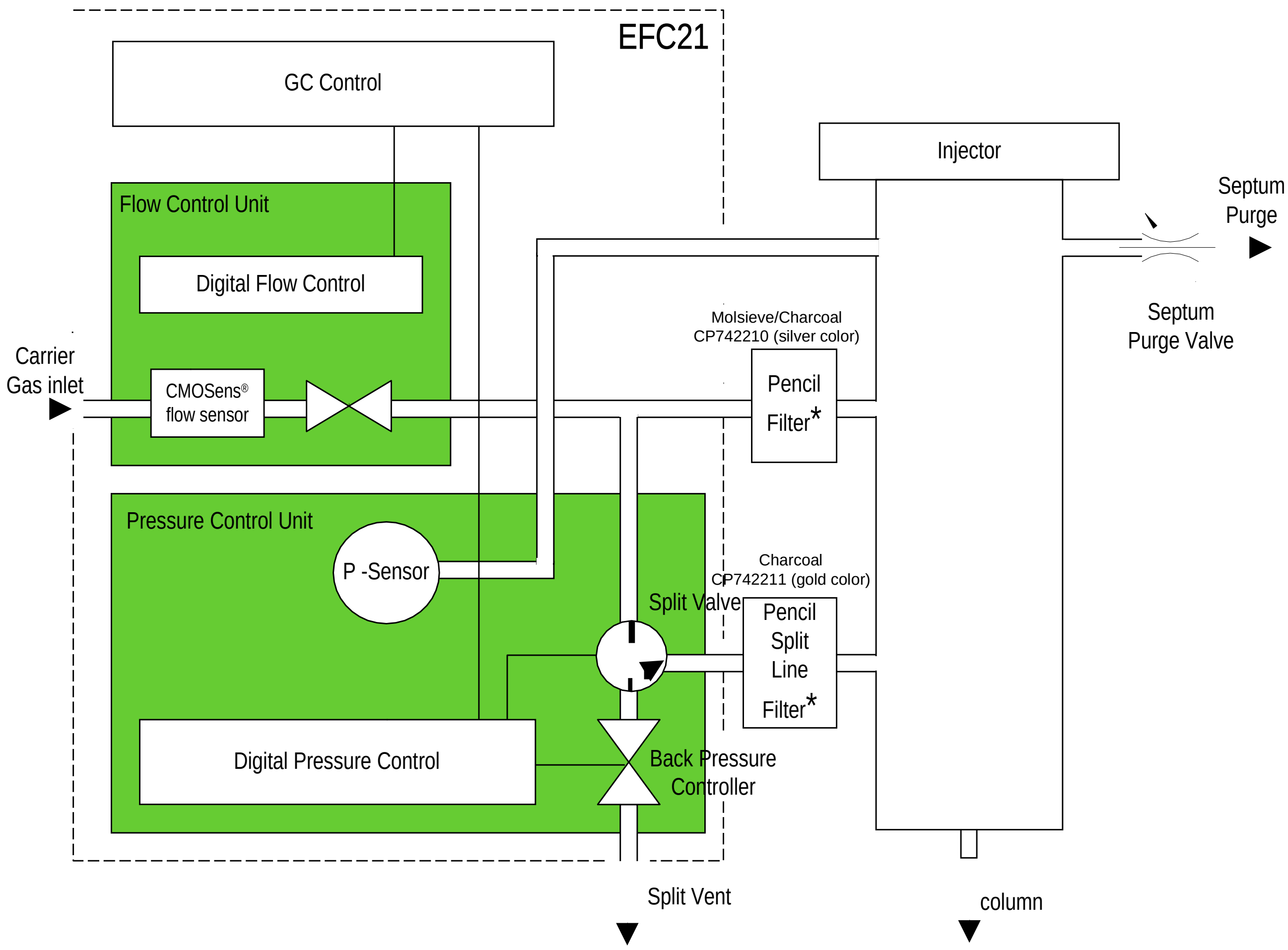
This section contains illustrated parts breakdowns for the 436-GC/456-GC Gas Chromatograph Electronic flow control and related components

ELECTRONIC FLOW CONTROL

730

Electronic Flow Control Type 21

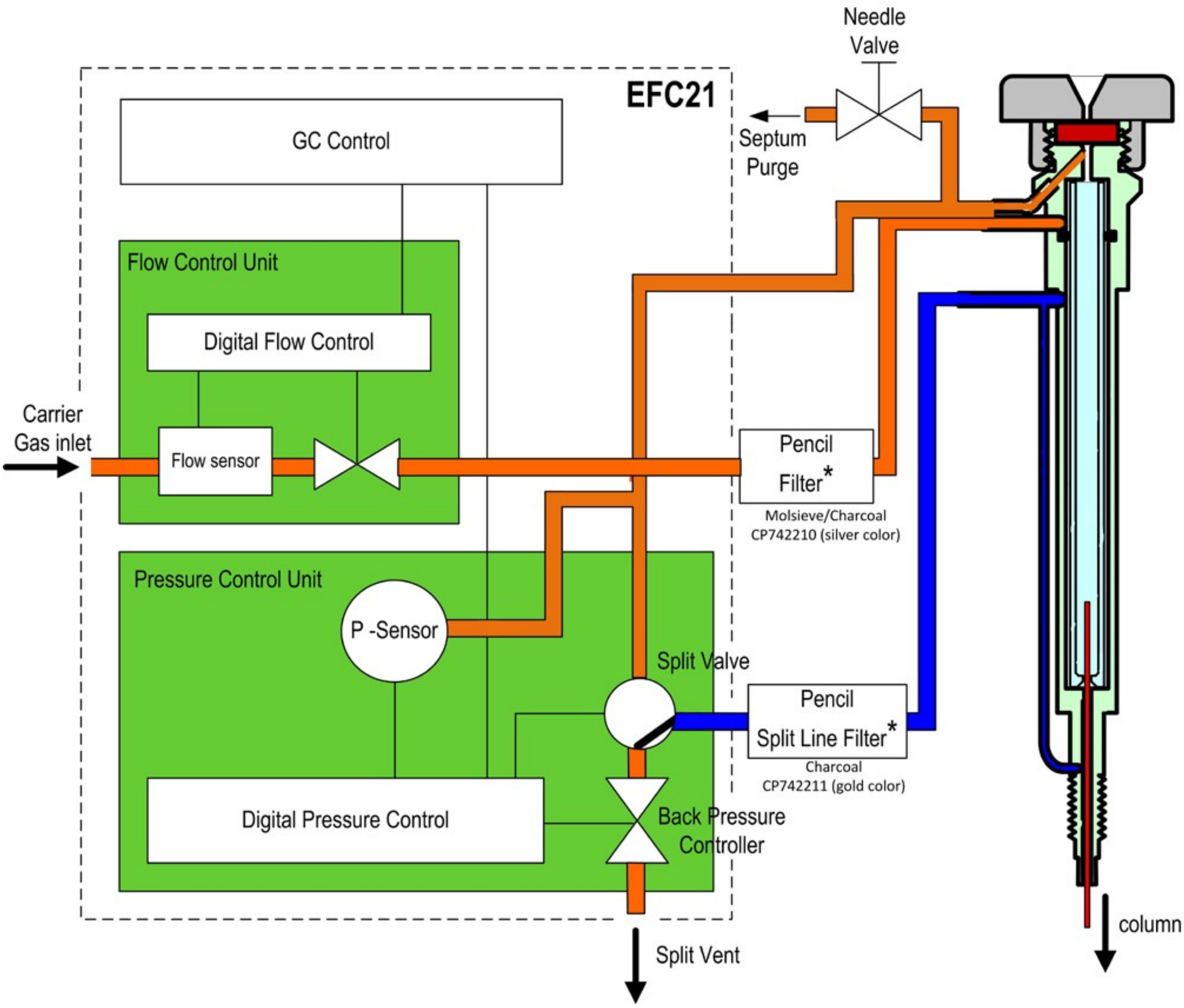
The EFC module used on an 1177 injector is the EFC21 or EFC25.
The EFC21 or EFC25 type is designed specifically for the split/splitless and PTV injectors to support their various modes of operation. It duplicates the behavior of the Split/Splitless manual pneumatics system in that there is an inlet mass flow controller supplying carrier gas to the injector and a pressure control valve downstream from the injector which sets the injector pressure. As injector pressure determines the rate of carrier gas flow through the column, this pressure is monitored close to the point of injection.
Type EFC21 allows the user to set constant injector pressure or constant flow. In addition the split ratio can be programmed.



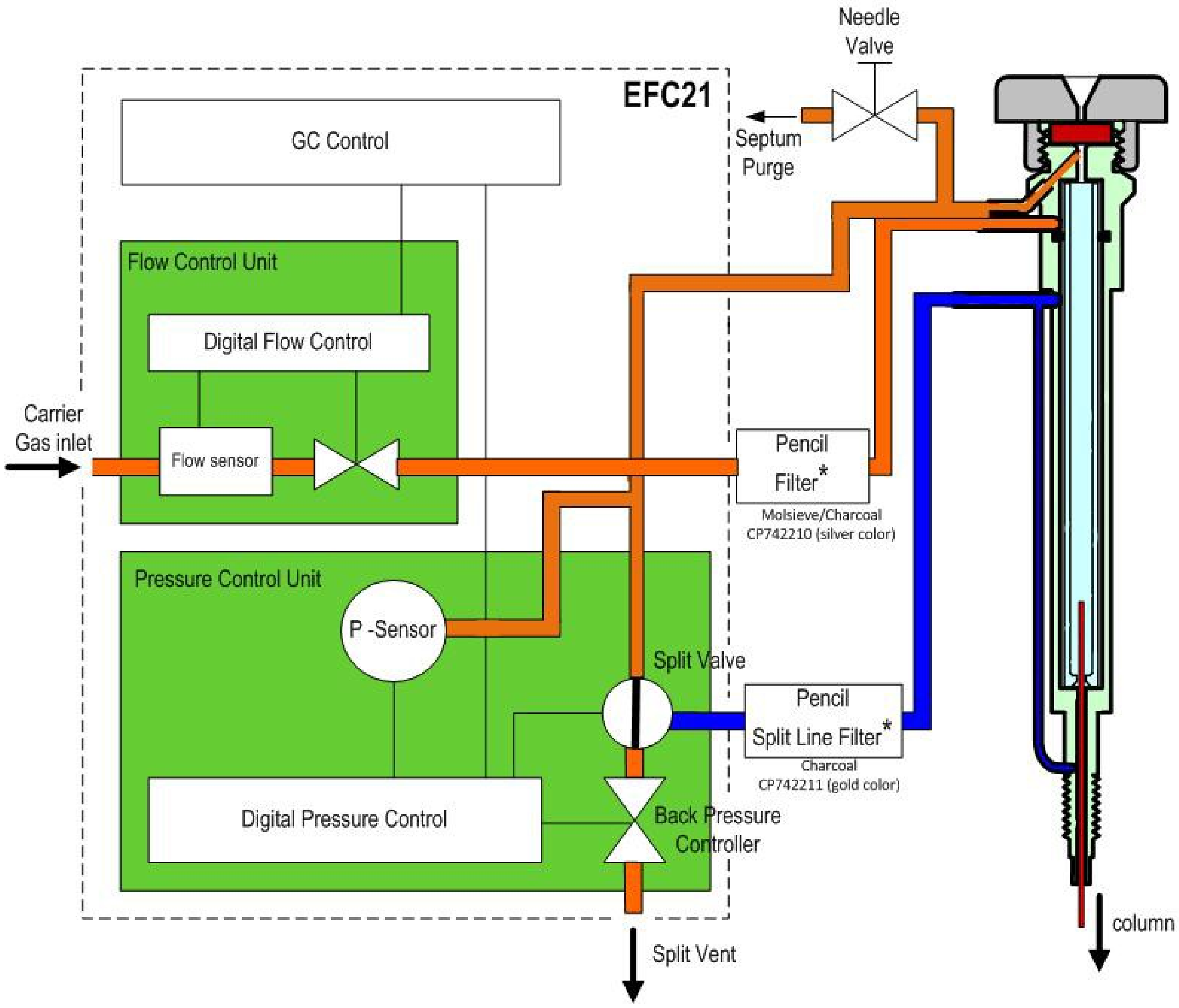
Optimized use:

- For capillary columns
- Flow & Pressure control
- Split injection use with split/splitless injector
- Splitless injection use with split/splitless injector
- Split injection use with PTV injector
- Splitless injection use with PTV injector

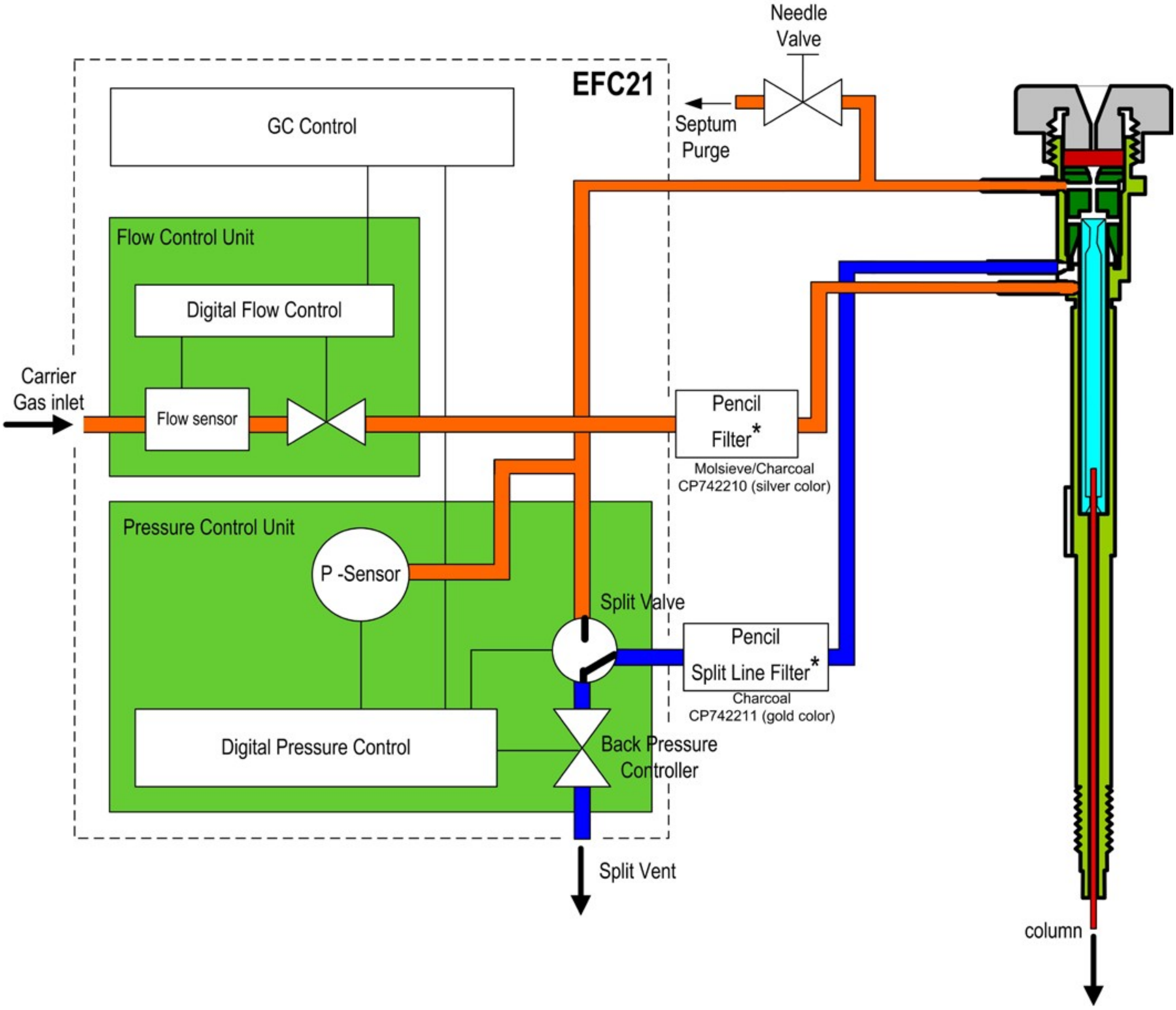
Split injection use with split/splitless injector



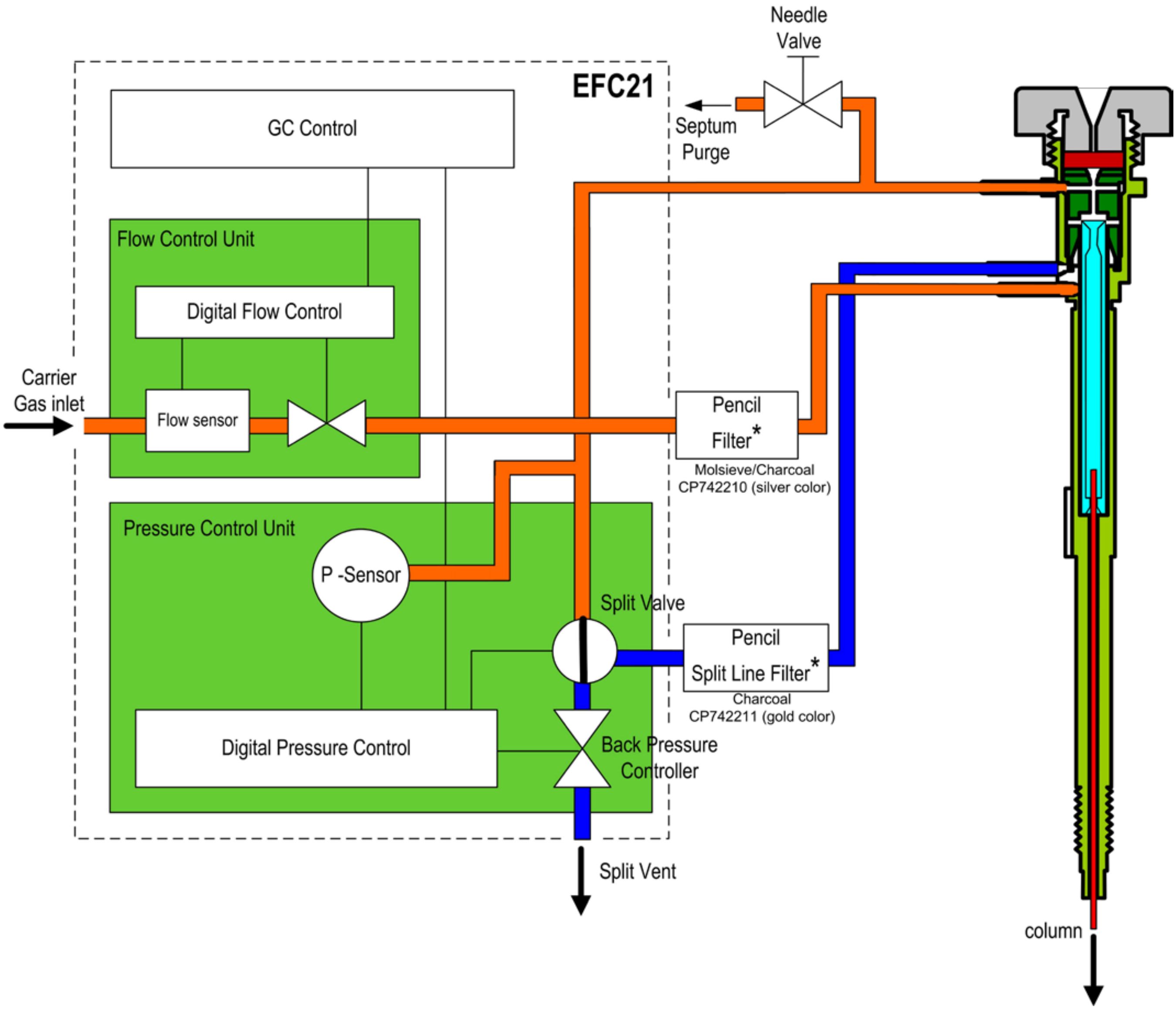
Splitless injection use with split/splitless injector



Split injection use with PTV injector



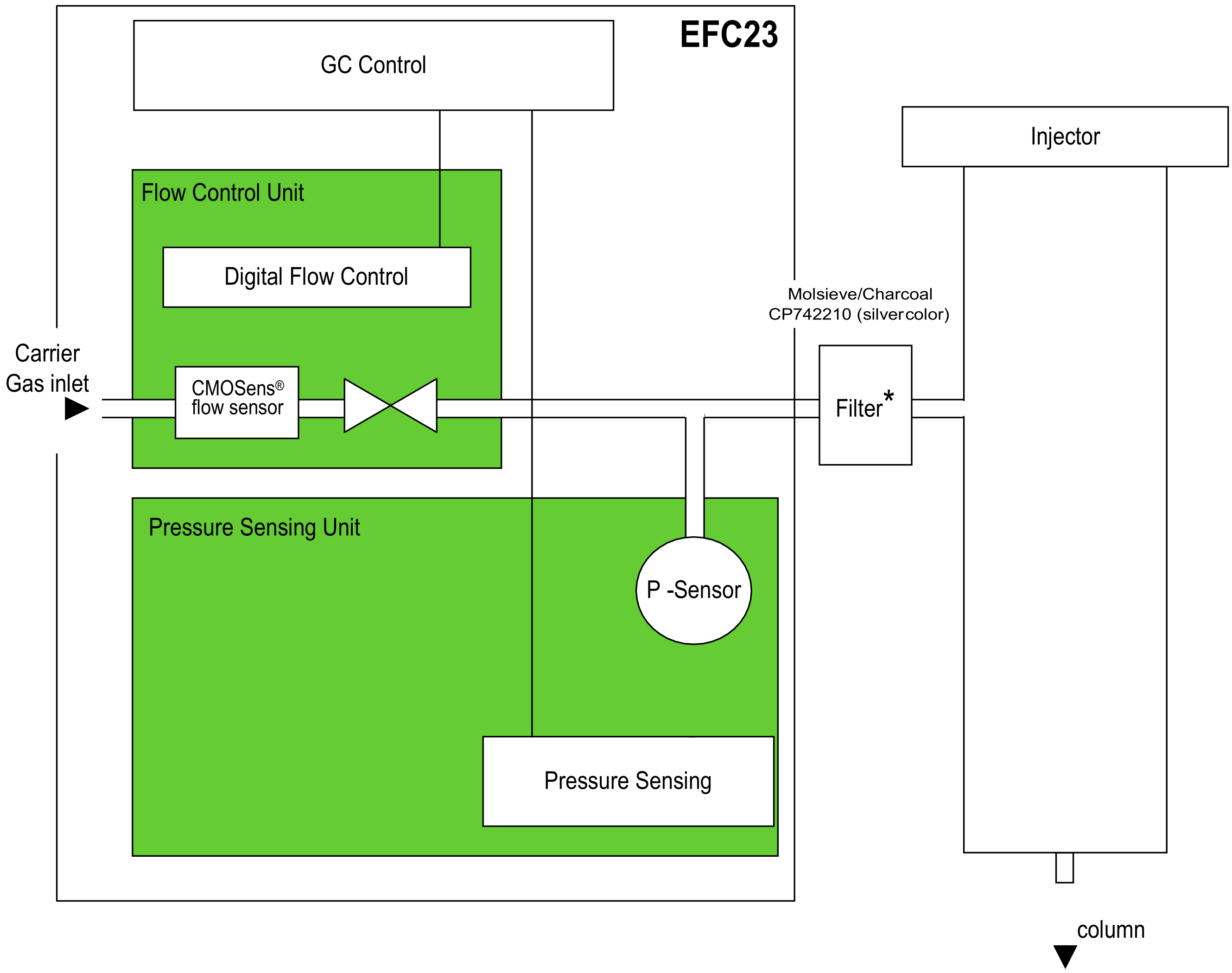
Splitless injection use with PTV injector



Electronic Flow Control Type 23

EFC23 sets a required carrier flow into the Injector/Column system. A leak in the system would be indicated to the user by a drop in inlet pressure.

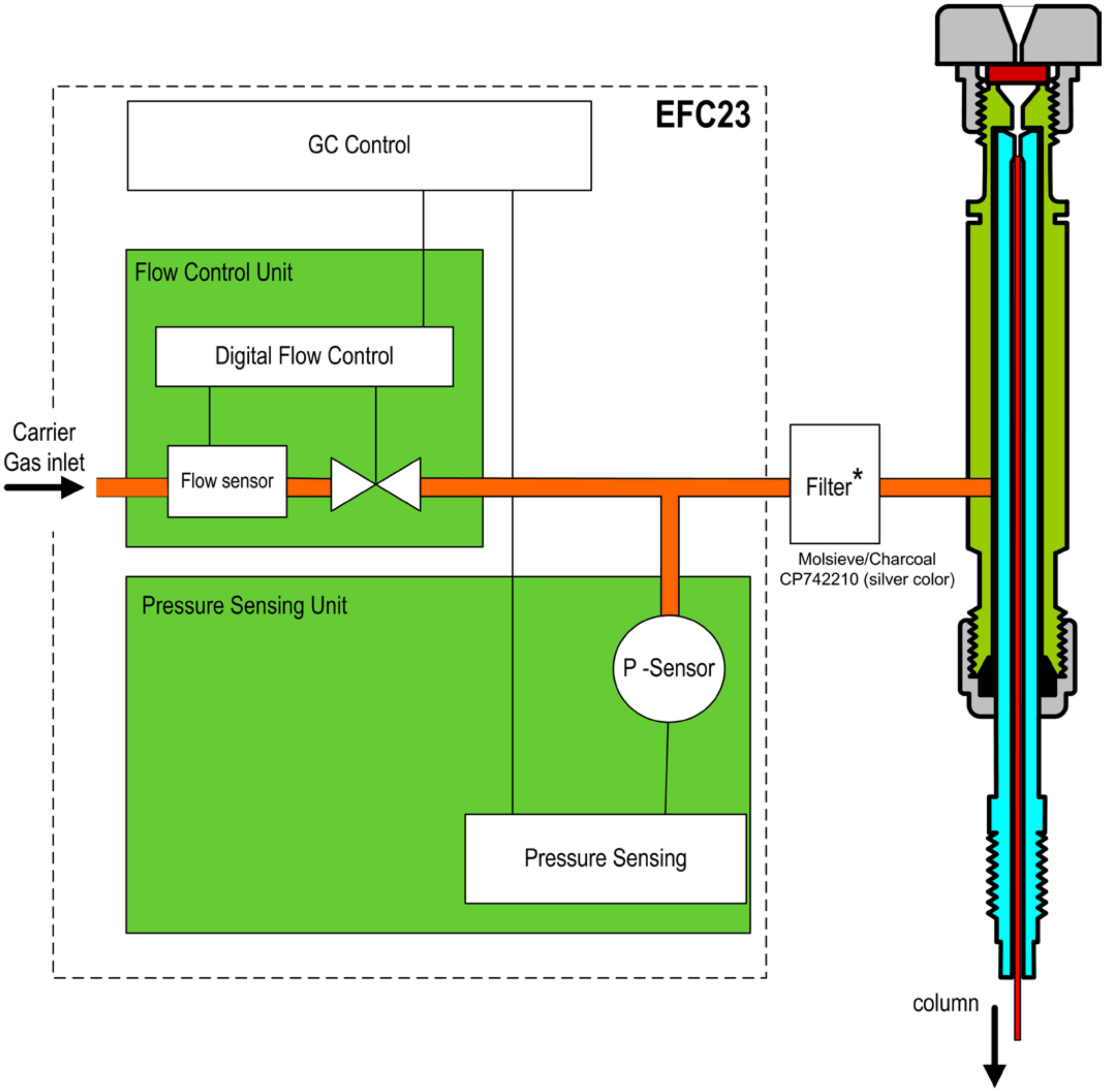
This EFC type is designed specifically for the On Column injector to support its various modes of operation. In simple terms it duplicates the behavior of the On Column manual pneumatics system in that there is an inlet mass flow controller supplying carrier gas to the injector and a pressure control valve downstream from the injector which sets the injector pressure. As injector pressure determines the rate of carrier gas flow through the column, this pressure is monitored close to the point of injection.
The type EFC23 flow diagram shown below is an indication of the control mechanism of this type of EFC module.



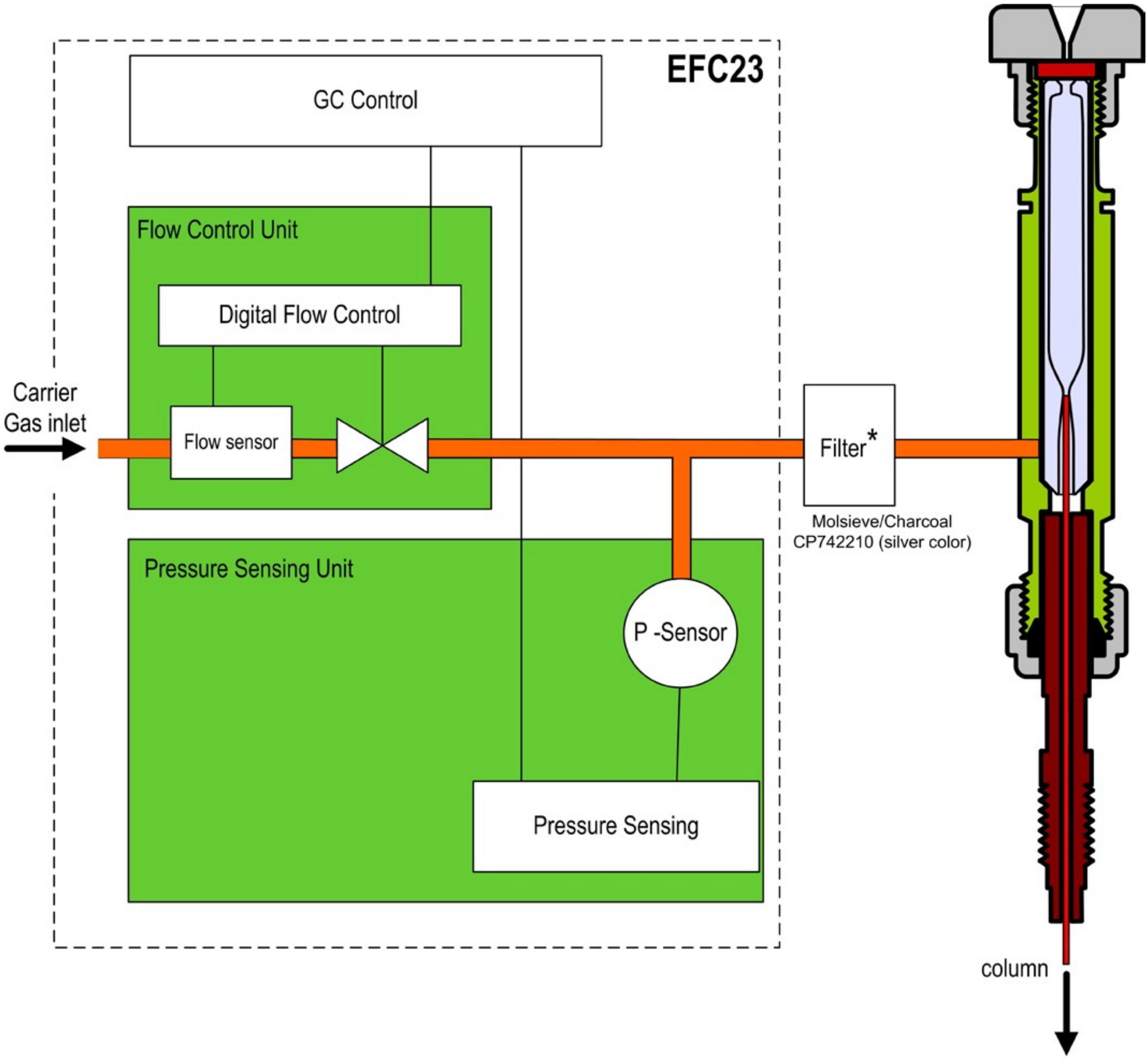
Optimized use:

- For wide bore columns
- Flow control, Including constant flow
- Use with On Column/Flash Vaporization/SPI injectors

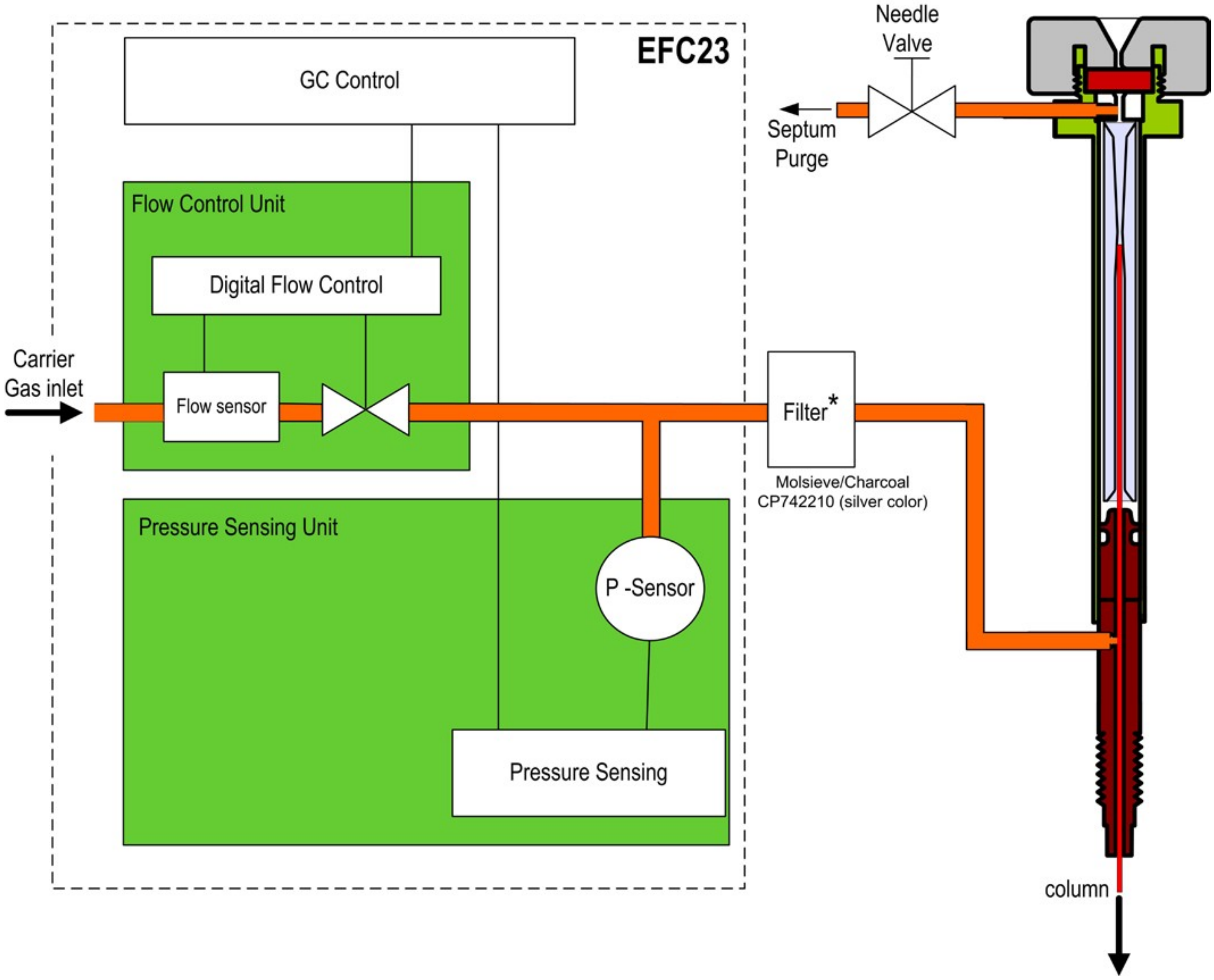
Injection use with On Column injector



Injection use with Flash Vaporization injector



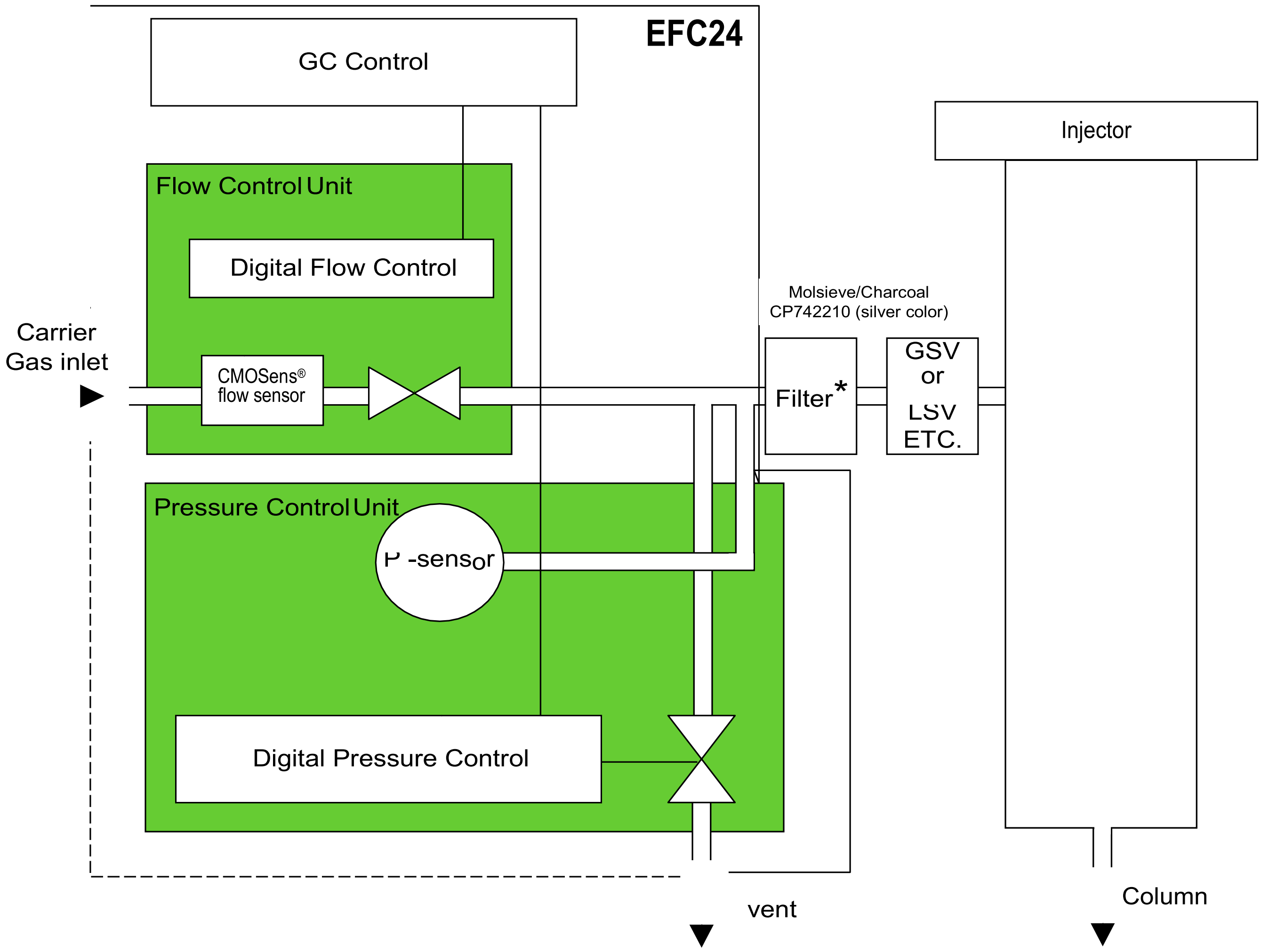
Injection use with SPI injector



Electronic Flow Control Type 24

The EFC24 is used to control the On Column Injector in combination with Gas or a Liquid sampling valve.

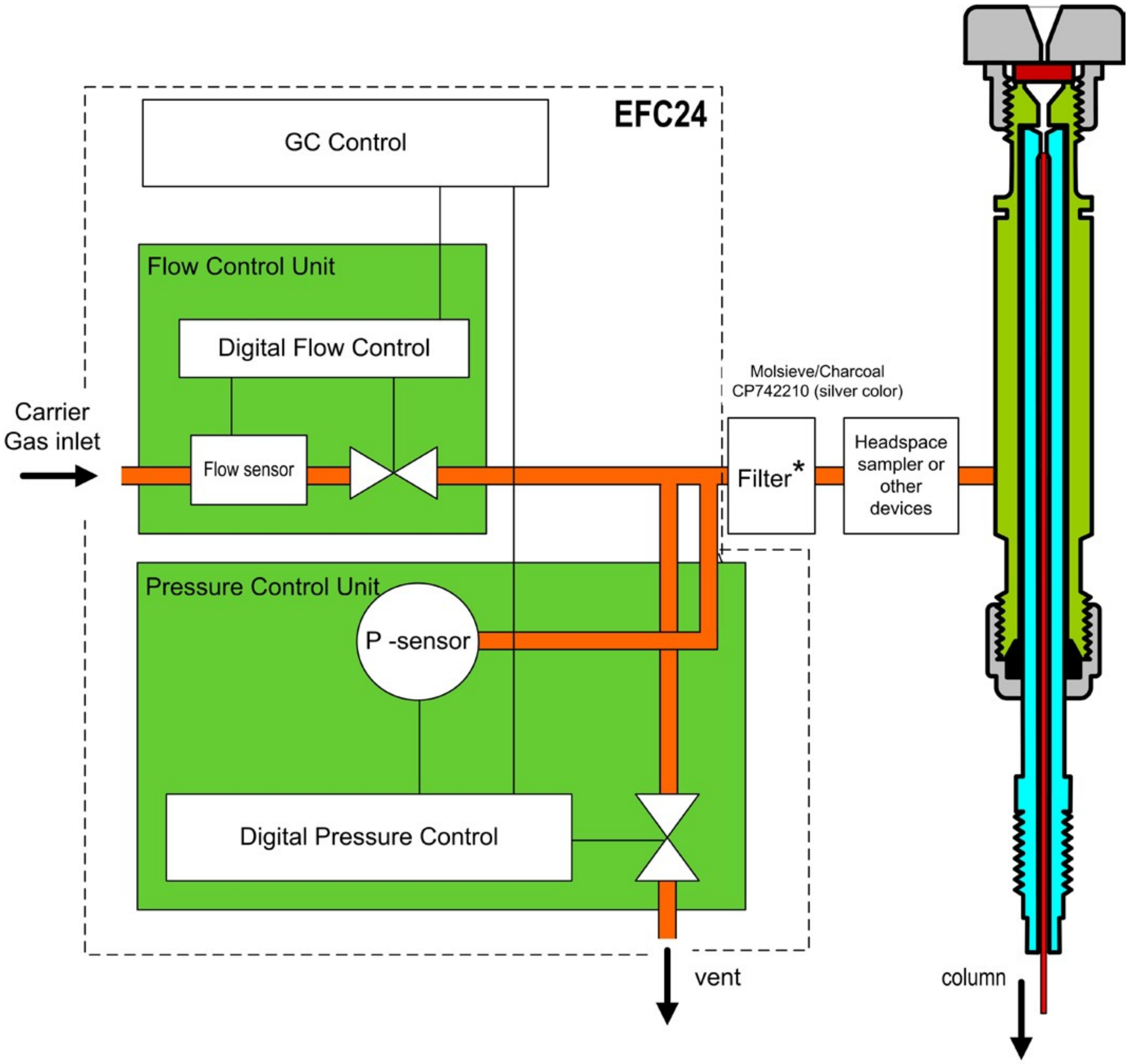
This EFC type is designed specifically for the On Column injector to support its various modes of operation. In simple terms it duplicates the behavior of the On Column manual pneumatics system in that there is an inlet mass flow controller supplying carrier gas to the injector and a pressure control valve downstream from the injector which sets the injector pressure. As injector pressure determines the rate of carrier gas flow through the column, this pressure is monitored close to the point of injection.
The type EFC24 flow diagram shown below is an indication of the control mechanism of this type of EFC module.



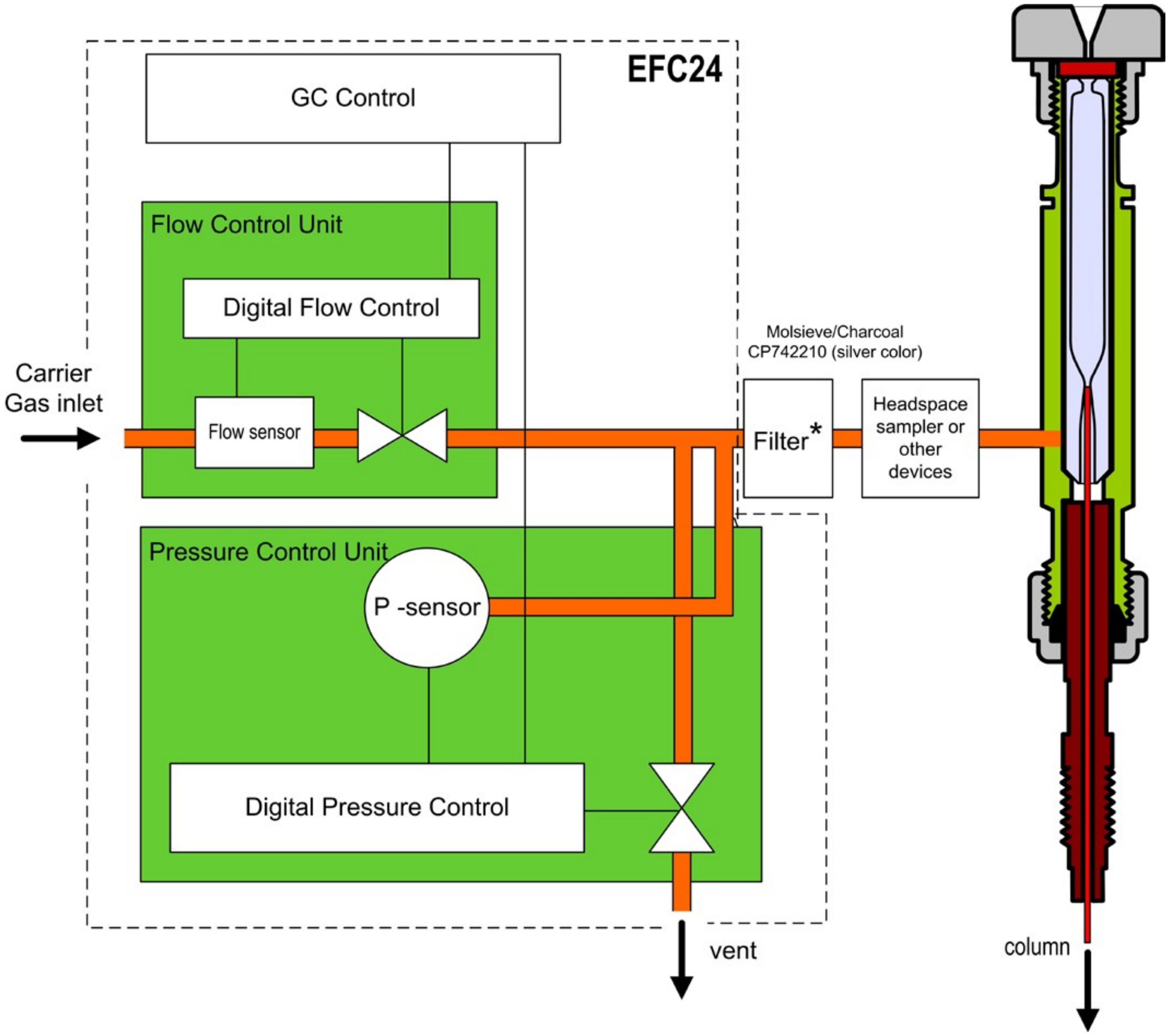
Optimized use:

- For Valved systems
- Flow & Pressure control
- Use with On Column/Flash Vaporization injectors

Injection use with On Column injector

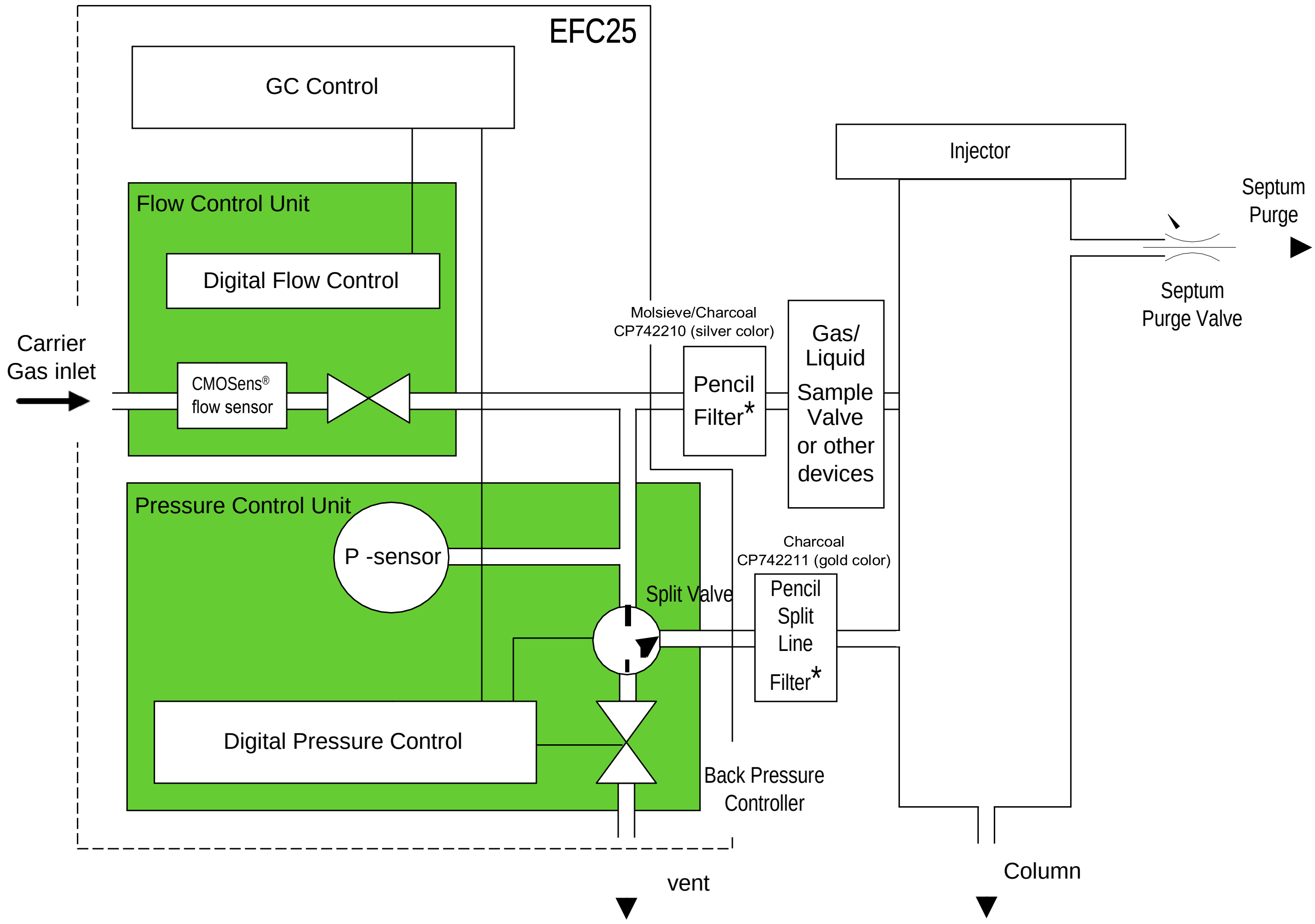


Injection use with Flash Vaporization injector



Electronic Flow Control Type 25

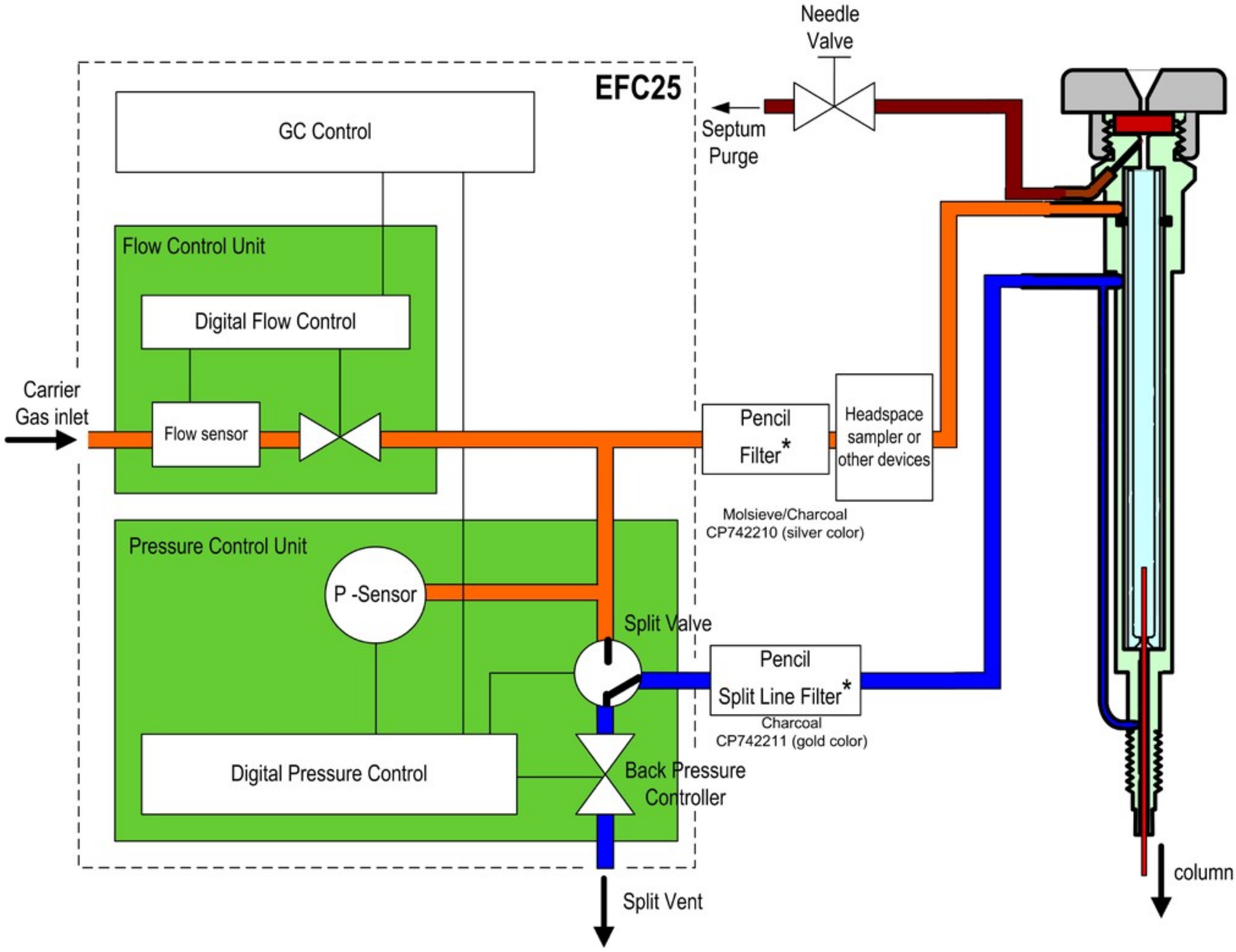
The EFC25 is almost identical as the EFC21 the only exception is that the pressure is monitored at the module itself rather than at the Injector. This allows the EFC25 to be used with Gas or Liquid Sample Valve's and Purge and Trap devices upstream from the Injector.



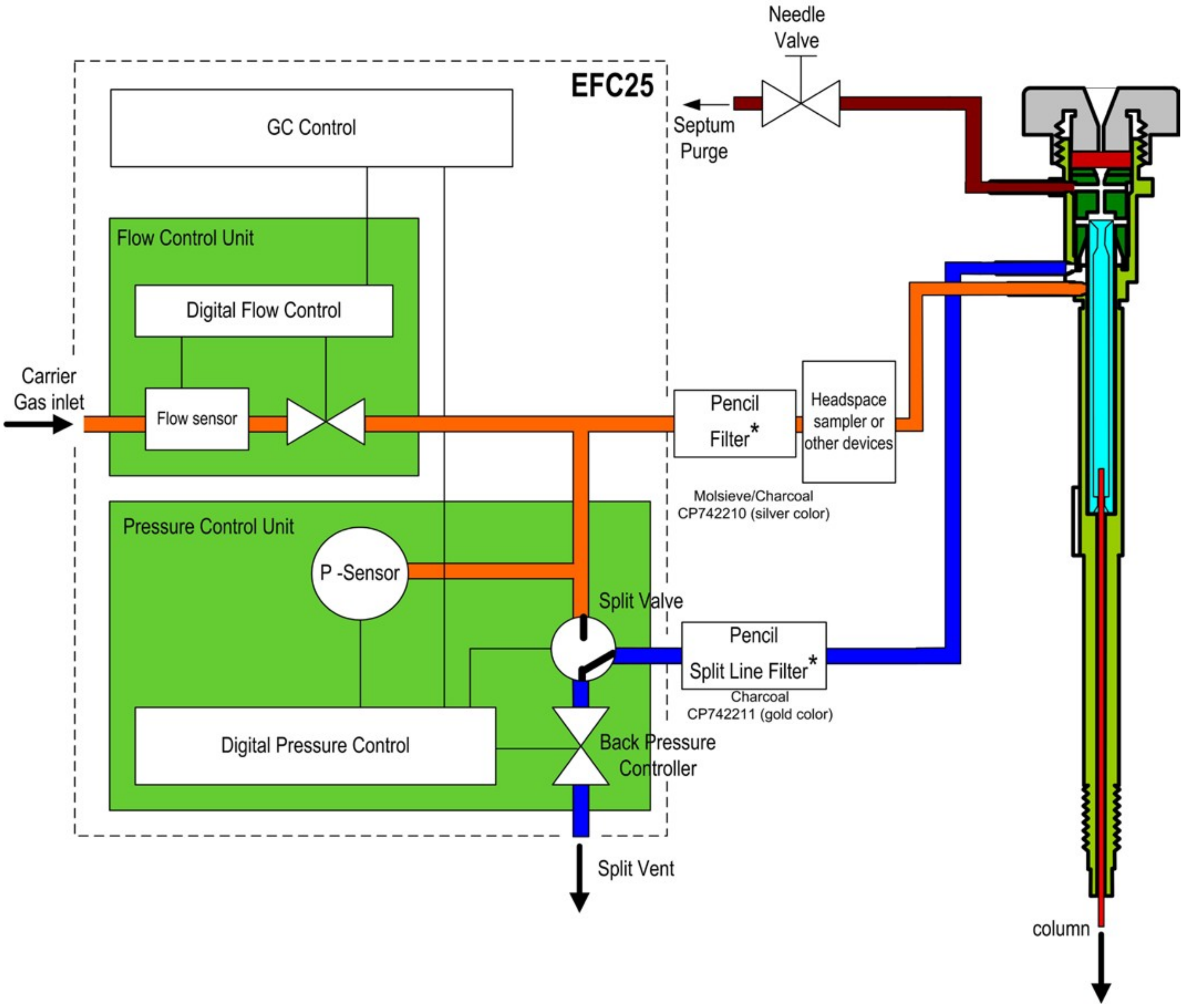
Optimized use:

- For Valved systems, Purge Trap systems, headspace
- Flow & Pressure control
- Use with split/splitless/PTV injectors

Injection use with split/splitless injector



Injection use with PTV injector



EFC Units

EFC Module	Part Number
EFC 21 SI	550021F
EFC 23 SI	550023F
EFC 24 SI	550024F
EFC 25 SI	550025F
DEFC 11 SI	550011F
DEFC 12 SI	550012F
DEFC 13 SI	550013F
DEFC 14 SI	550014F
DEFC 15 SI	550015F
DEFC 16 SI	550016F

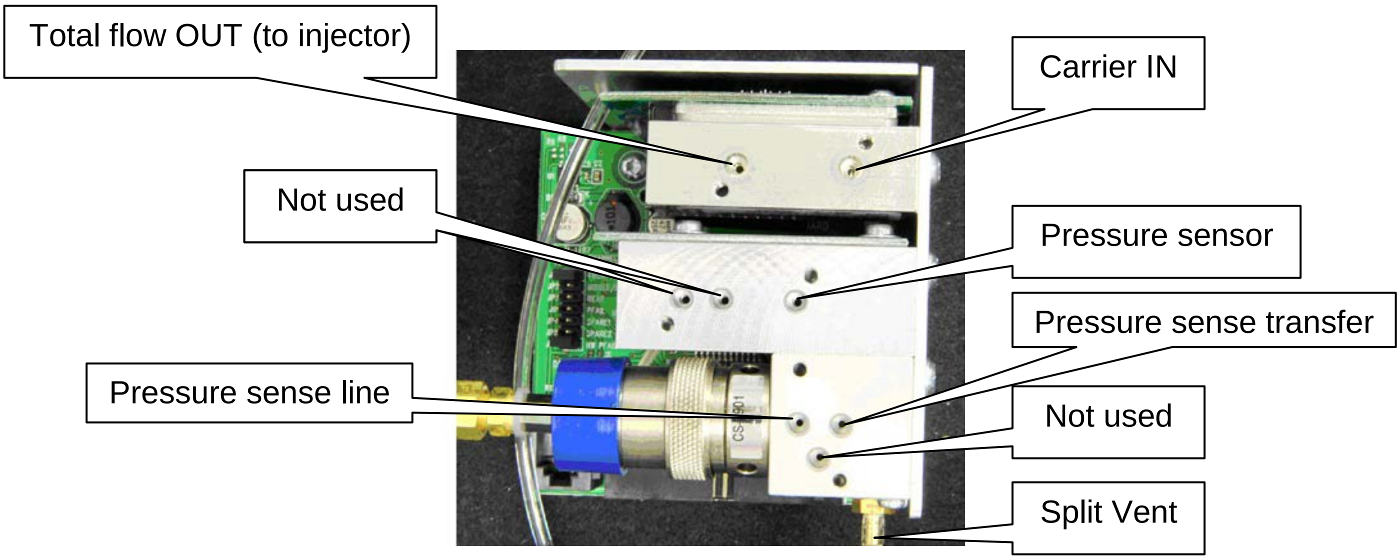
Module Configuration Matrix:

EFC Module	Unit Slot 1	Unit Slot 2	Unit Slot 3
EFC 21 SI	SI 1	SI 3	
EFC 23 SI	SI 2	SI 9	
EFC 24 SI	SI 1	SI 4	
EFC 25 SI	SI 1	SI 3	
DEFC 11 SI	SI 5	SI 7	SI 6
DEFC 12 SI	SI 5	SI 7	SI 6
DEFC 13 SI	SI 8		
DEFC 14 SI	SI 5	SI 5	
DEFC 15 SI	SI 6	SI 7	SI 6
DEFC 16 SI	SI 7	SI 7	

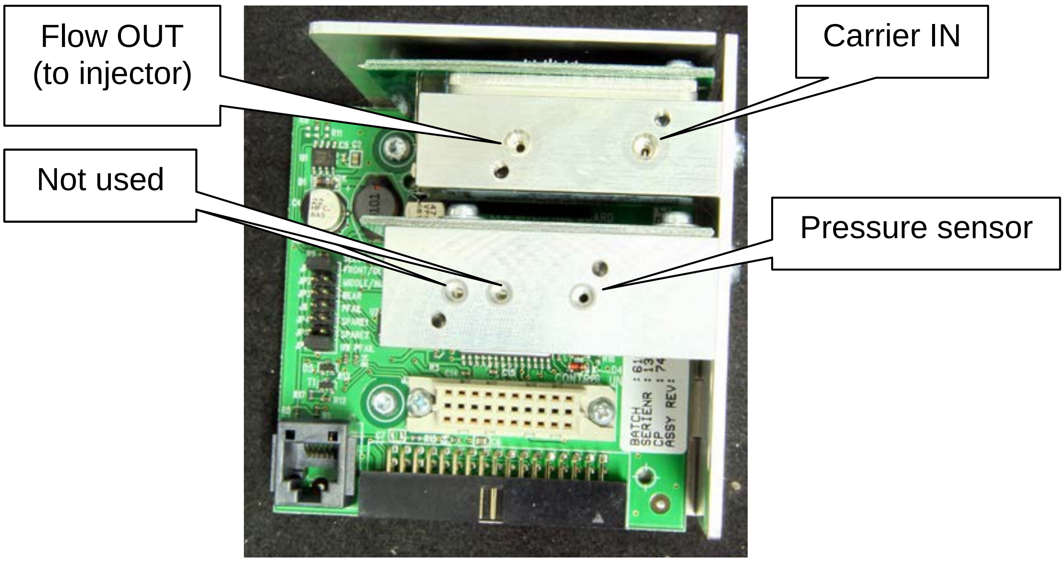
Unit ID color		Description
Red		MFC High Flow
Green		MFC Low Flow
Yellow		PC High Flow
Pink		PC Low Flow
Blue		DMFC, multiple gas calibration
Orange		DMFC, air calibration
Grey		DMFC, H2 calibration
Black		DMFC, multiple gas calibration with Chemraz seals
Dark blue		Pressure sensing unit

EFC & DEFC Layout

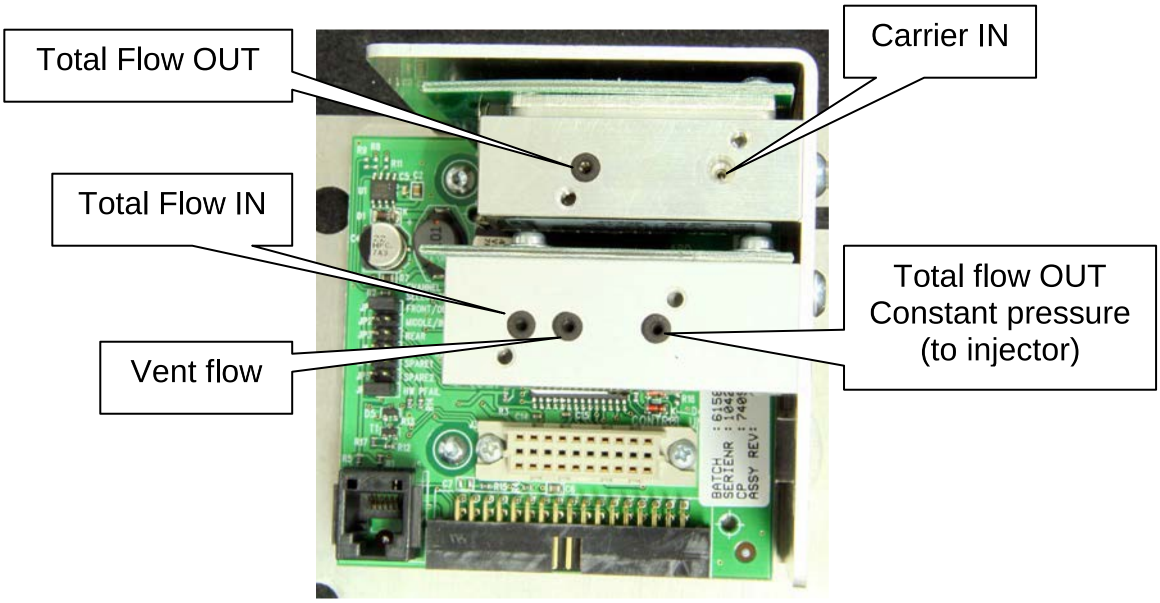
EFC Type 21 layout



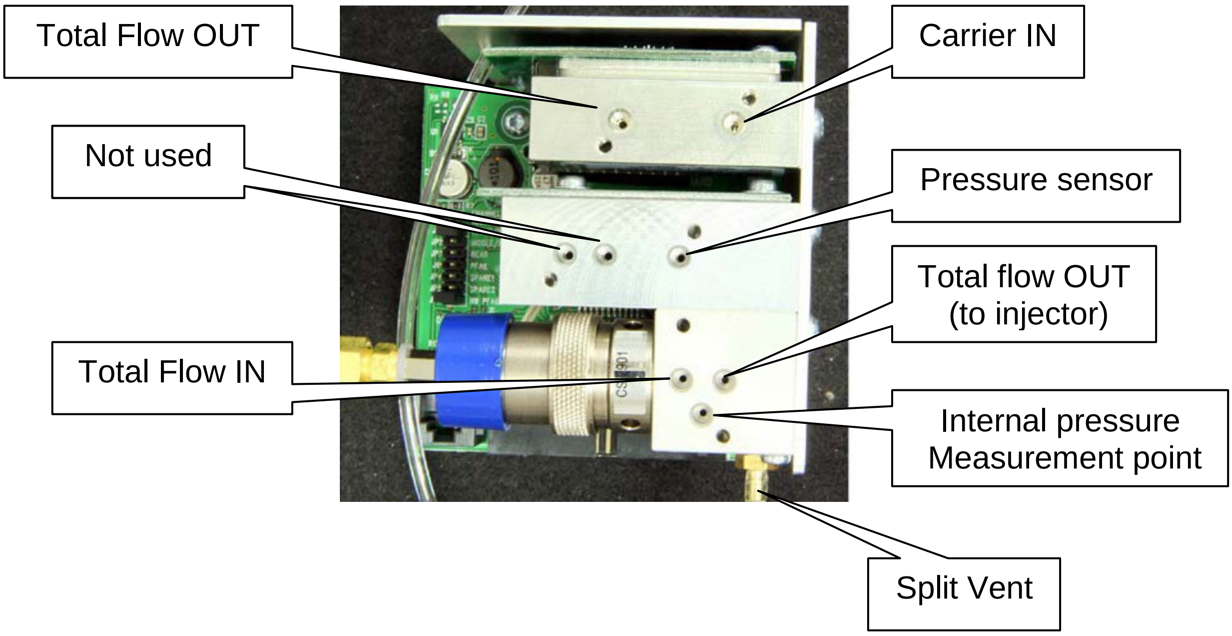
EFC Type 23 layout



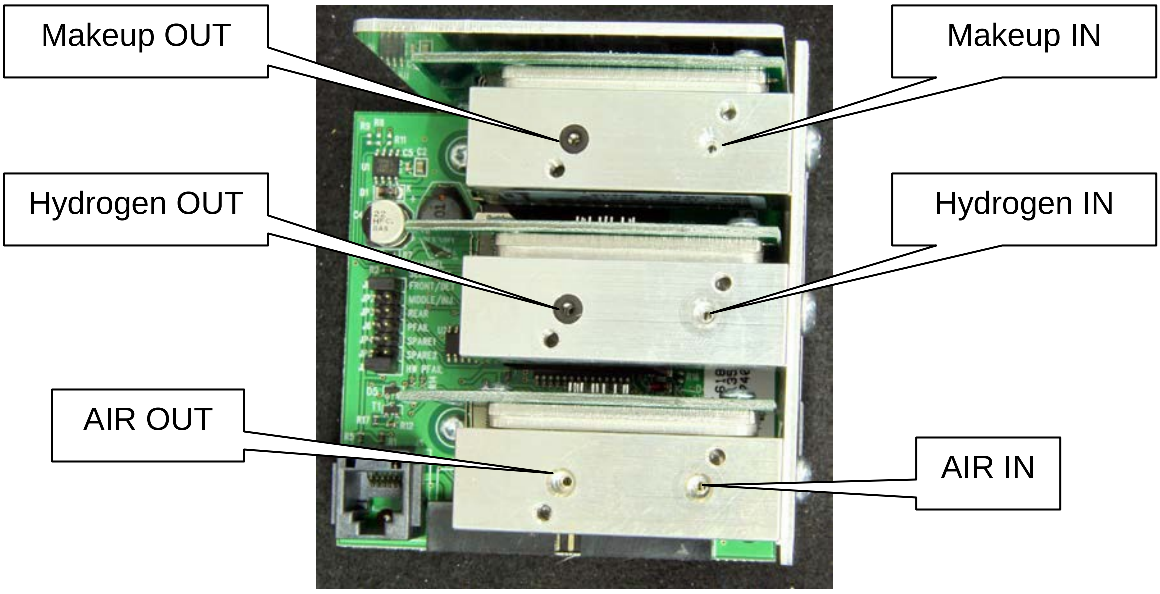
EFC Type 24 layout



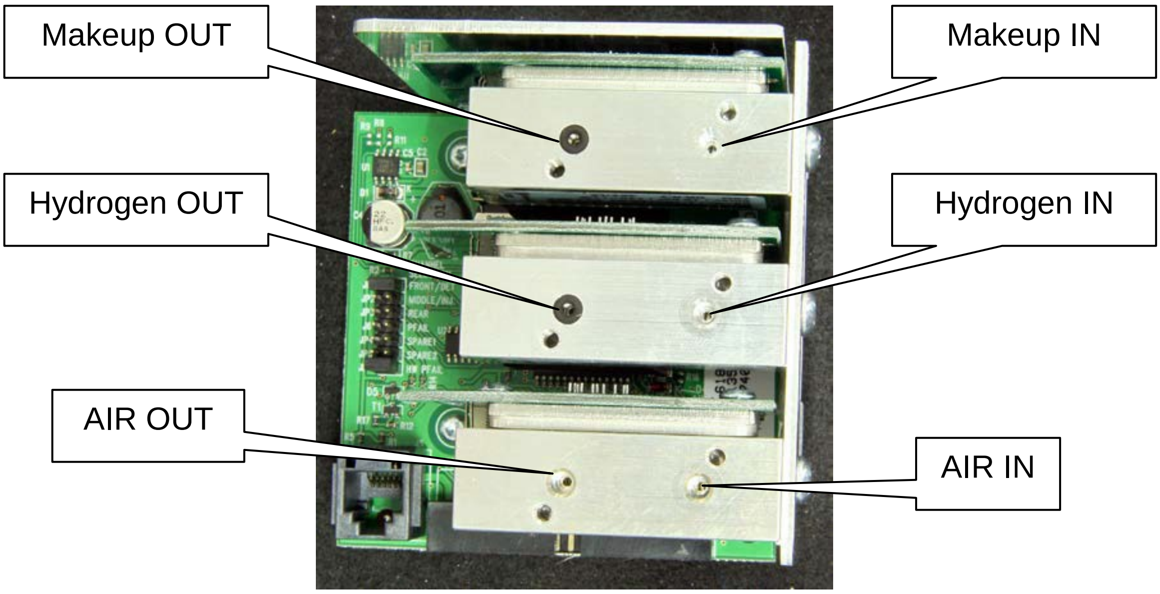
EFC Type 25 layout



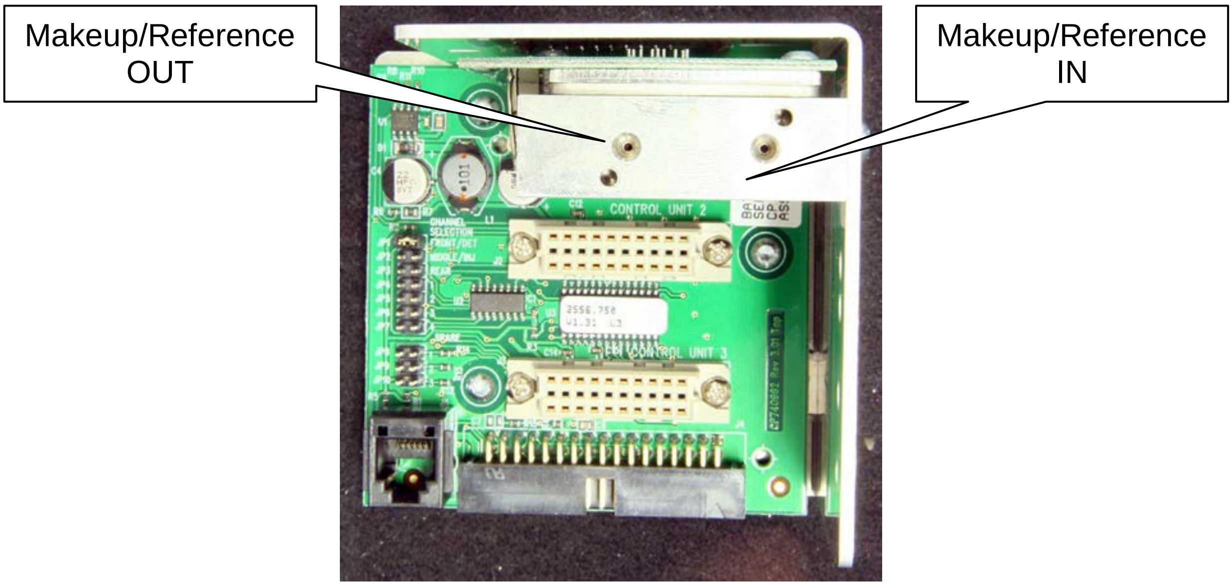
DEFC Type 11 (FID) layout



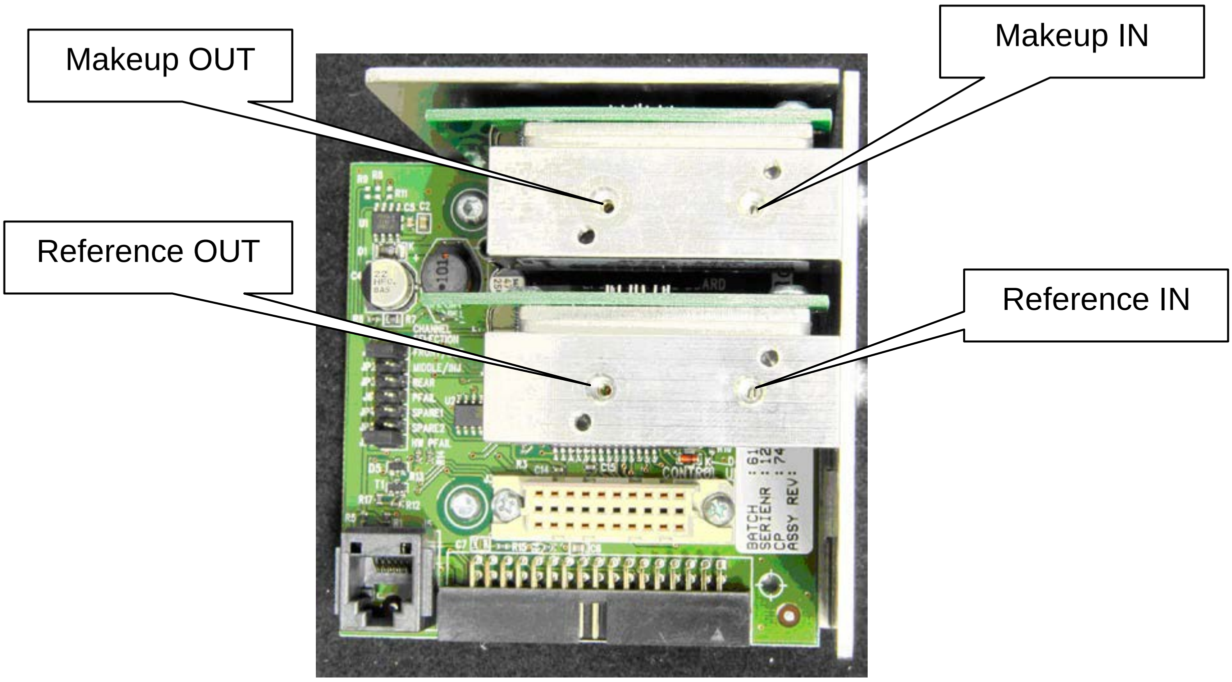
DEFC Type 12 (NPD) layout



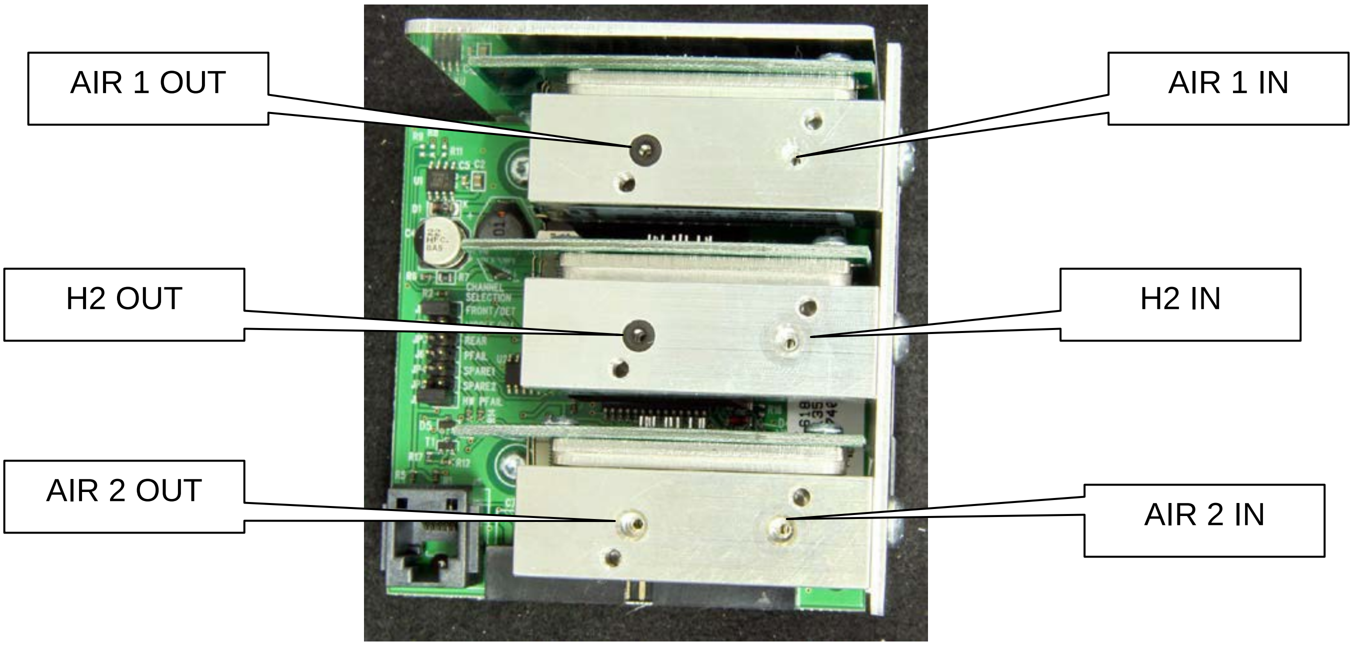
DEFC Type 13 (TCD / ECD) layout



DEFC Type 14/16 (TCD) layout



DEFC Type 15 (PFPD) layout



This section contains illustrated parts breakdowns for the 436-GC/456-GC Gas Chromatograph Manual flow control and related components

MANUAL FLOW CONTROL

740

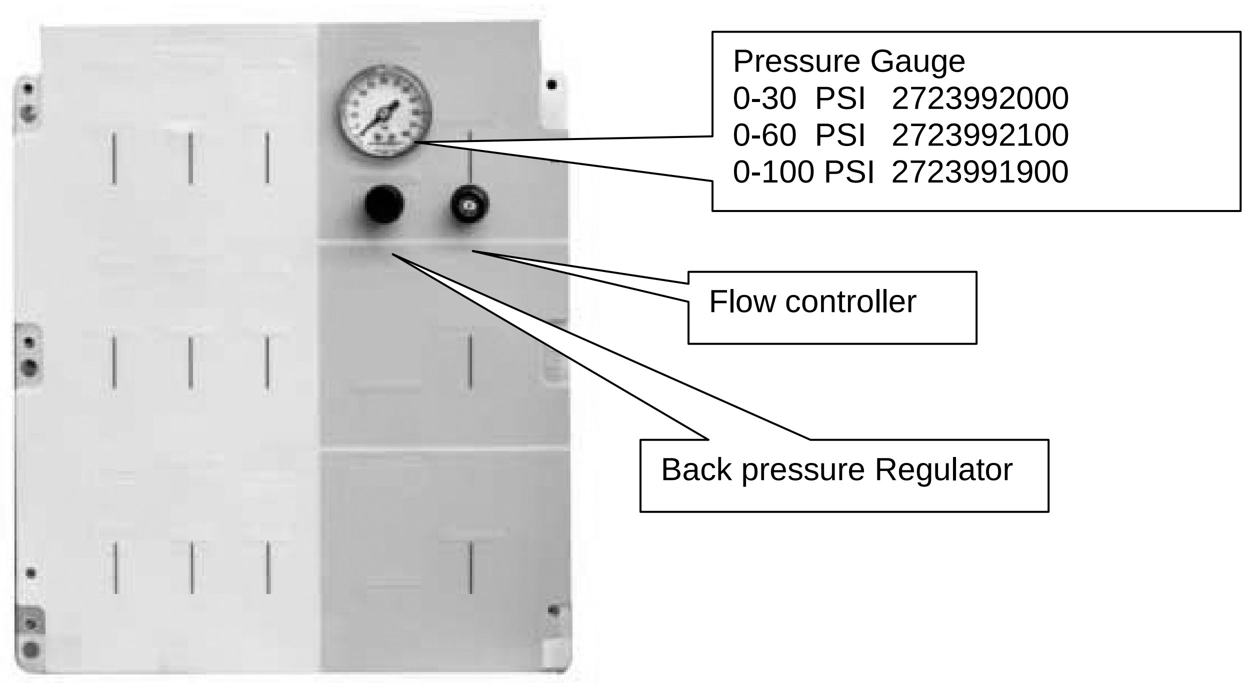
Overview EFC to Pneumatic Injector control

Sample Introduction System	***Standard Pneumatics System***	***Optional Pneumatics System***	***Part numbers***
split/splitless Liquid Injector	Type EFC21	Manual pneumatics - inlet flow controller/back pressure regulator with pressure gauge.	Flow controller: 2718013500 Back pres. reg.: 391817400 Gauge 0-60PSI : 2723992100
PTV PTV Liquid Injector	Type EFC21	Manual pneumatics - inlet flow controller/back pressure regulator with pressure gauge.	Flow controller: 2718013500 Back pres. reg.: 391817400 Gauge 0-60PSI: 2723992100
On Column Liquid Injector	Type EFC23	Manual digital flow controller with pressure gauge	Flow controller: 391714600 3-Digit readout: 2359981300 Gauge 0-60PSI: 2723992100
On Column Liquid Injector	Type EFC24	Manual pressure regulator with gauge.	Pres. regulator: 100104700 Gauge 0-100PSI: 2723991900 Gauge 0-30PSI : 2723992000
Flash Vaporization Liquid Injector	Type EFC23	Manual digital flow controller with pressure gauge	Flow controller: 391714600 3-Digit readout: 2359981300 Gauge 0-60PSI: 2723992100
Flash Vaporization Liquid Injector	Type EFC24	Manual pressure regulator with gauge.	Pres. regulator: 100104700 Gauge 0-100PSI: 2723991900 Gauge 0-30PSI : 2723992000
Gas or Liquid Sampling Valves	Type EFC24	Manual pressure regulator with gauge.	Pres. regulator: 100104700 Gauge 0-100PSI: 2723991900 Gauge 0-30PSI : 2723992000 Gauge 0-60PSI : 2723992100
Purge and Trap with either split/splitless or PTV	Type 25 EFC	Manual pneumatics - inlet flow controller/backpressure regulator with pressure gauge.	Flow controller: 2718013500 Back pres. reg.: 391817400 Gauge 0-60PSI : 2723992100
Headspace with either split/splitless or PTV	Type 25 EFC	Manual pneumatics - inlet flow controller/back pressure regulator with pressure gauge.	Flow controller: 2718013500 Back pres. reg.: 391817400 Gauge 0-60PSI : 2723992100
SPI Liquid Injector (SPI)	Type 23 EFC	Manual digital flow controller with pressure gauge	Flow controller: 391714600 3-Digit readout: 2359981300 Gauge 0-60PSI : 2723992100

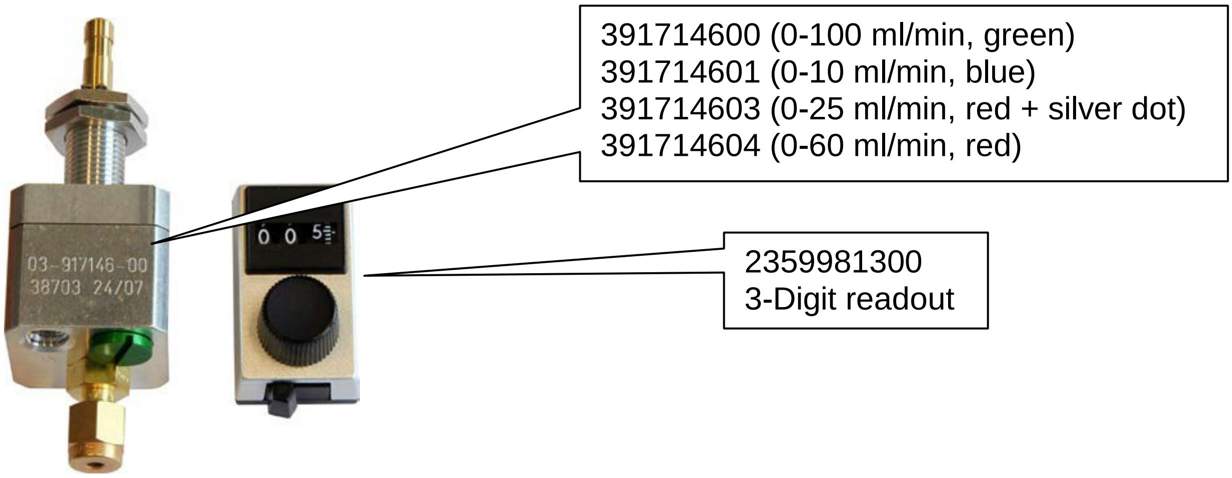
Overview EFC to Pneumatic Detector control

Detector Type	***Standard Pneumatics System***	***Optional Pneumatics System***
FID (Flame Ionization Detector)	Type DEFC11	**Hydrogen:** Valve 0-60 ml/min : 391706501 **Make-up:** Valve 0-60 ml/min : 391706501 **Air:** Valve 0-450 ml/min : 391706500
NPD (Nitrogen Phosphorus Detector)	Type DEFC12	**Hydrogen:** Flow controller 0-10 ml/min : 391714603 3-Digit readout : 2359981300 **Make-up:** Valve 0-60 ml/min: 391706501
ECD (Electron Capture Detector)	Type DEFC13	**Make-up:** Valve 0-60 ml/min : 391706501
TCD (Thermal Conductivity Detector)	Type DEFC14/16	**Make-up:** TCD Make-up :392560501 **Reference:** TCD Reference :392560502
PFPD (Pulsed Flame Photometric Detector)	Type DEFC15	**Hydrogen:** Flow controller 0-25ml/min : 391714601 3-Digit readout : 2359981300 **Air 1**: Flow controller 0-60 ml/min :391714604 3-Digit readout: 2359981300 **Air 2**: Flow controller 0-60 ml/min : 391714604 3-Digit readout : 2359981300

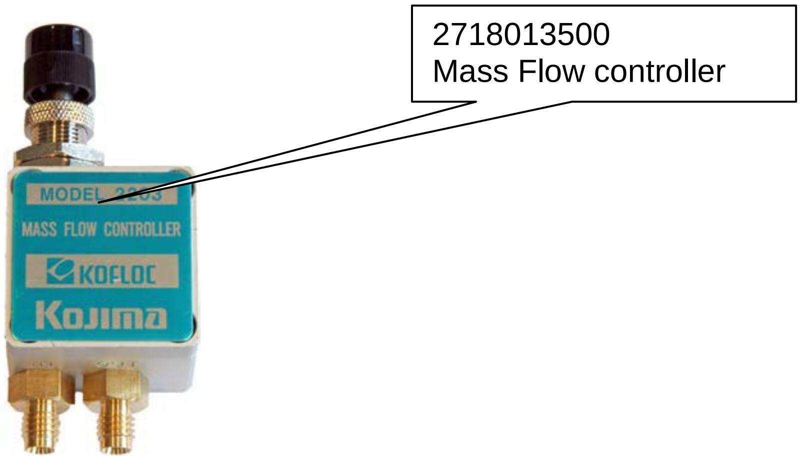
Pressure Gauge



Flow controller



Mass Flow controller



Pressure controller

100104700
Pressure regulator
0-100PSI

Back pressure regulator

391817400
Back pressure regulator
0-60PSI

Valve control for manual flow

391706501
Valve 0-60ml/min

391706500
Valve 0-450ml/min

This section contains illustrated parts breakdowns for the 436-GC/456-GC Gas Chromatograph Cryogenic column oven and related components

CRYOGENIC COLUMN OVEN

Assy, Column oven cryo LN_2

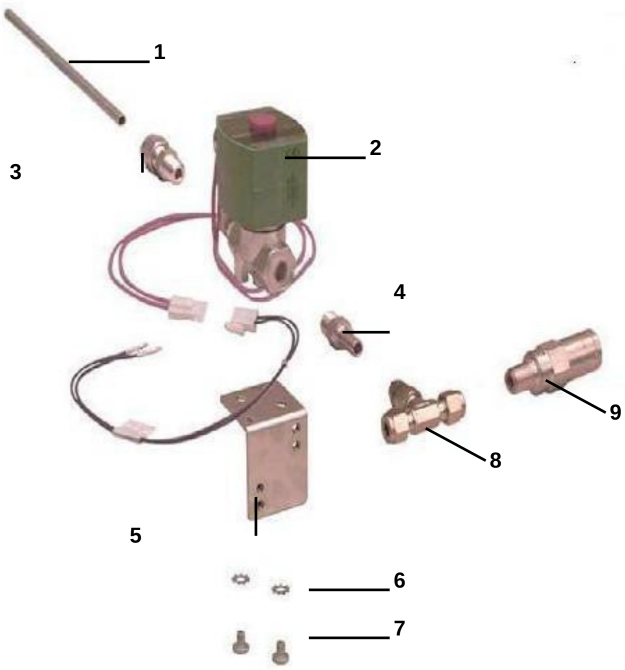
Instructions guide for LN_2

Assy, Column oven cryo LCO_2

Instructions guide for LCO_2

750

Assy, Column oven Cryo LN_2



Column oven cryo LN_2

1 Liquid N2 outlet tube (392537801)

2 LN2 Valve (392555701)

3 1/4Tx1/8 PBR male (SWB40012)

4 B-4-TA-1-2 Adapter (2869513000)

5 Bracket ,Cryo valve (392526101)

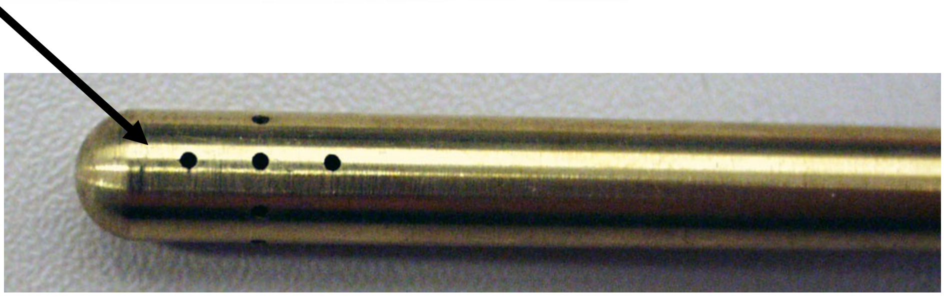
6 Washer (1431201000)

7 Screw 10-12x3/8 (1222201006)

8 ¼" Brass union tee (SWB4003)

9 Pressure relief valve (5700023500)

Liquid Nitrogen outlet tube

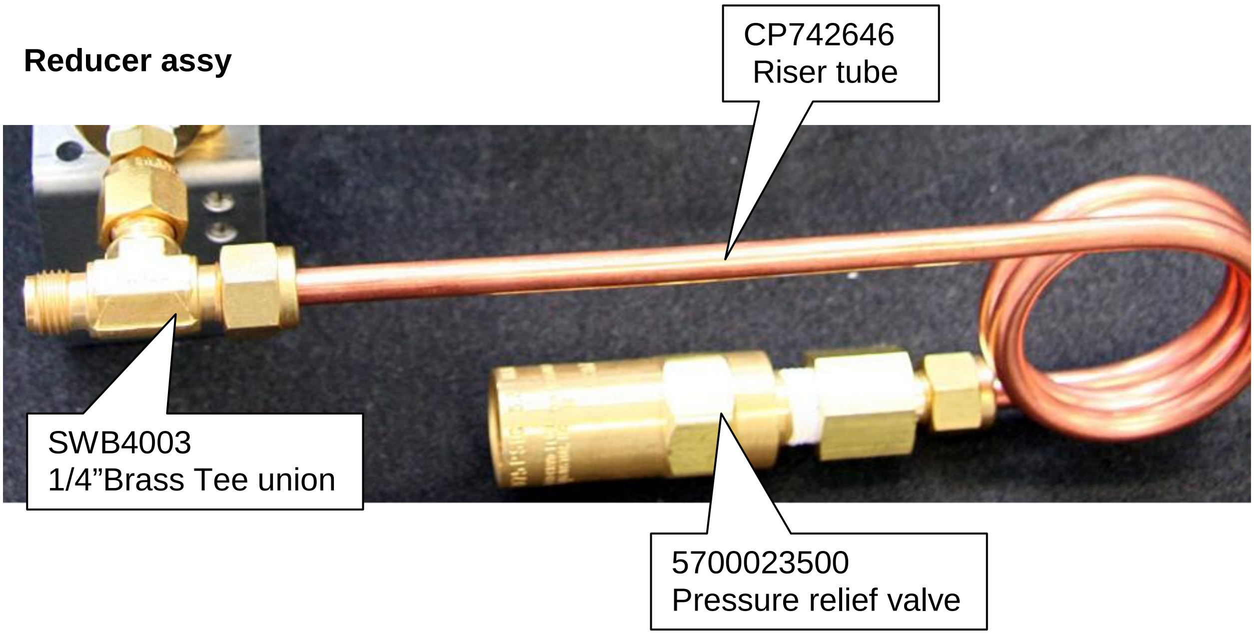


> **NOTE:**
> When installing Liquid Nitrogen outlet tube into the 1/4Tx1/8PBR Male connector make holes on the end of the outlet tube is upward prior to tightening.

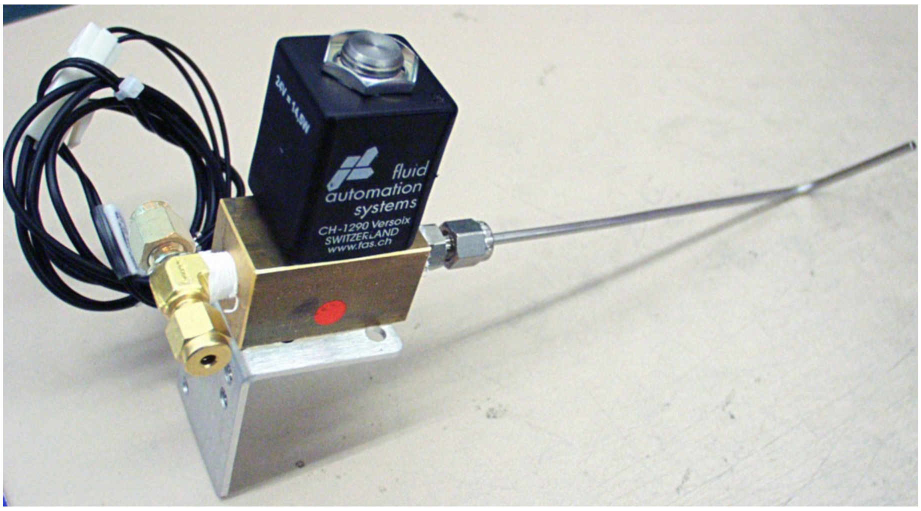
PBR Male connecter

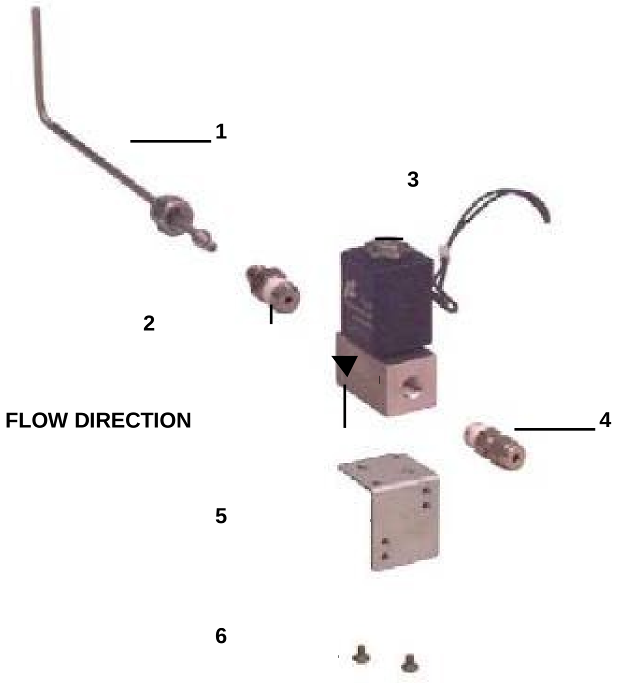
> **NOTE:**
> Install Teflon pipe (CP12059) fitting threads prior to installation.
>
> Turn 2.5 windings on the thread, clockwise position.
> Connect the connector to the OUT.

Reducer assy



Assy,Column oven Cryo LCO_2





1 CO_2 Outlet tube (392549701)

2 Adapter,1/8x1/8SS (SWSS20012)

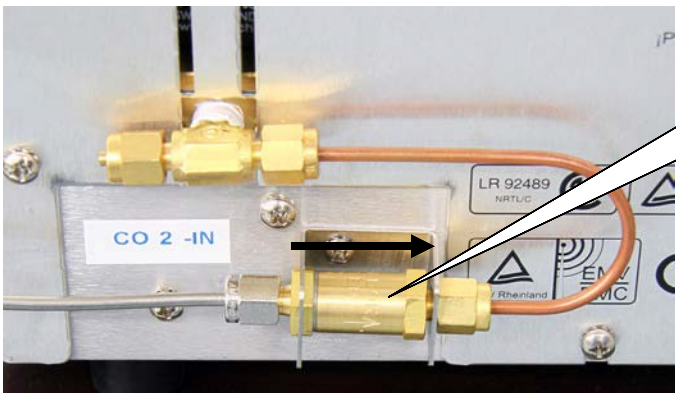
3 LCO_2 valve (392556701)

4 1/8IN Adapter (SWB20012)

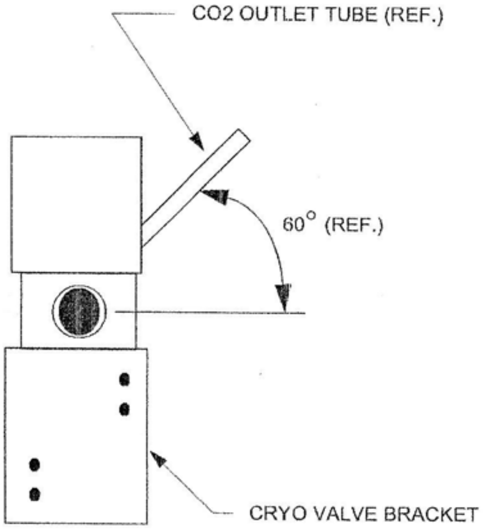
5 Bracket,Cryo valve(392526101)

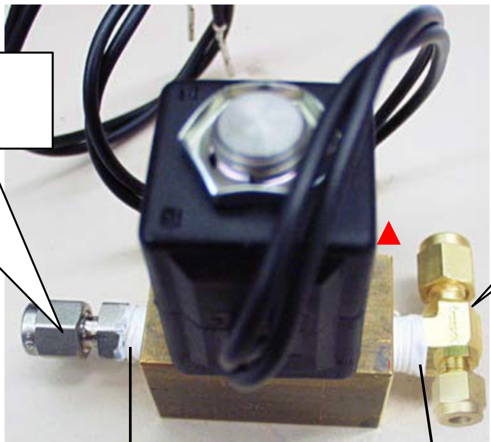
6 Screws 10-32x1/4SS (1222206004)

CP741148
Particle filter for LCO



LCO_2 Outlet tube reference





NOTE:
Install Teflon pipe (CP12059)fitting threads prior to installation.

1)Turn 2.5 windings on the thread, clockwise position.

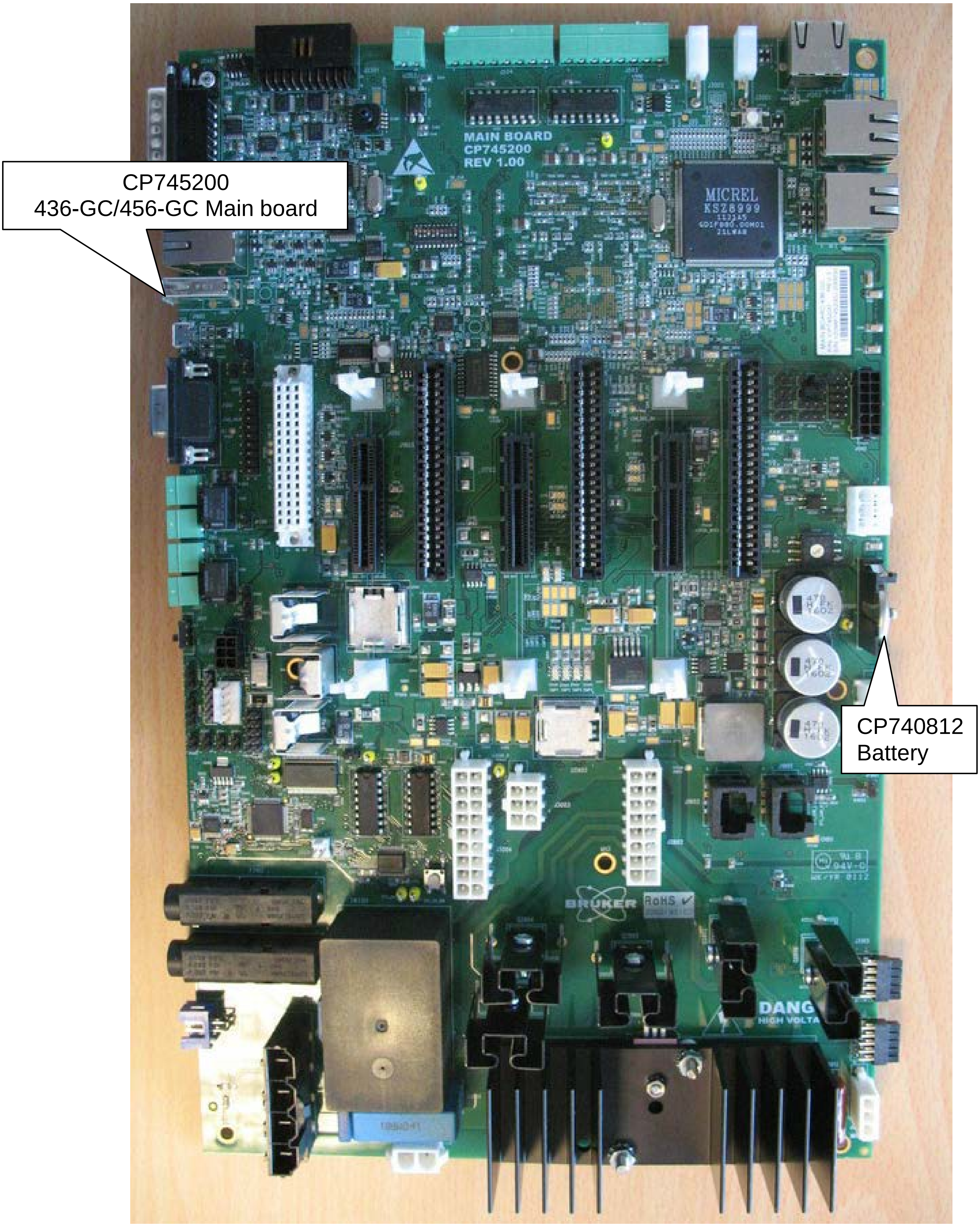
2)Turn 3.5 windings on the thread, clockwise position.

This section contains illustrated parts breakdowns for the 436-GC/456-GC Gas Chromatograph Electronics and related components

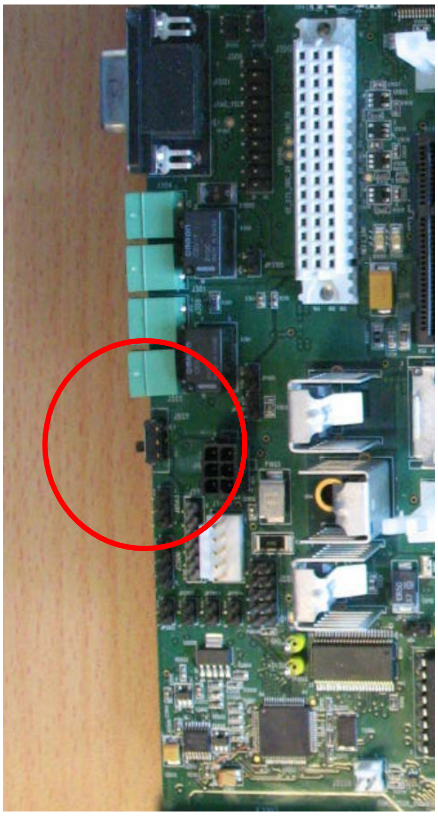
ELECTRONICS

760

436-GC / 456-GC MAINBOARD



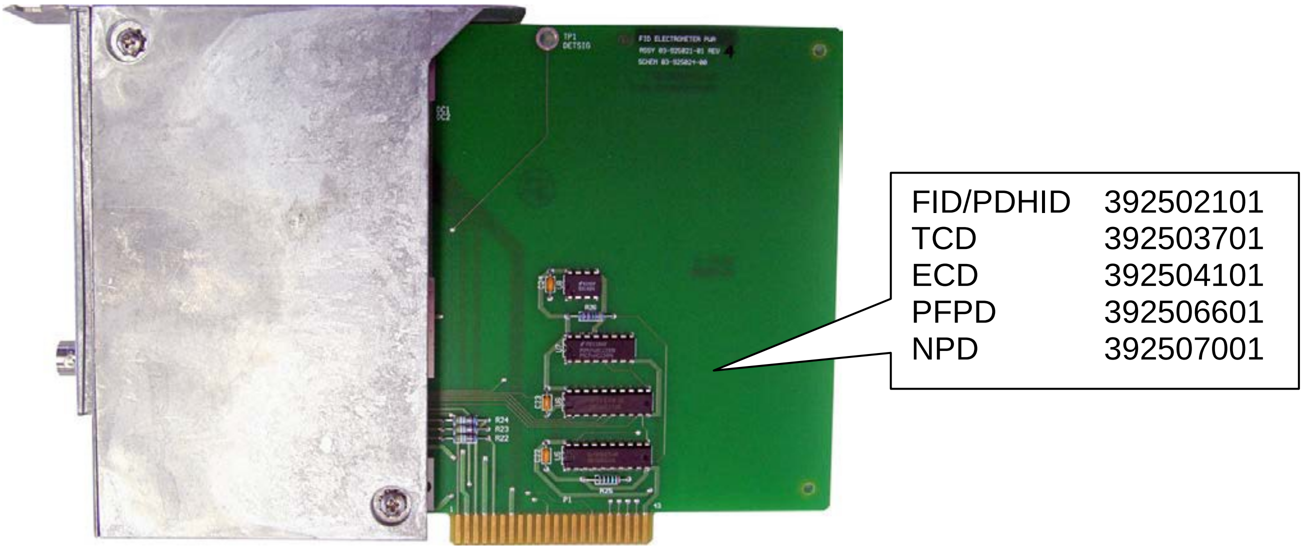
BOOTP Selector



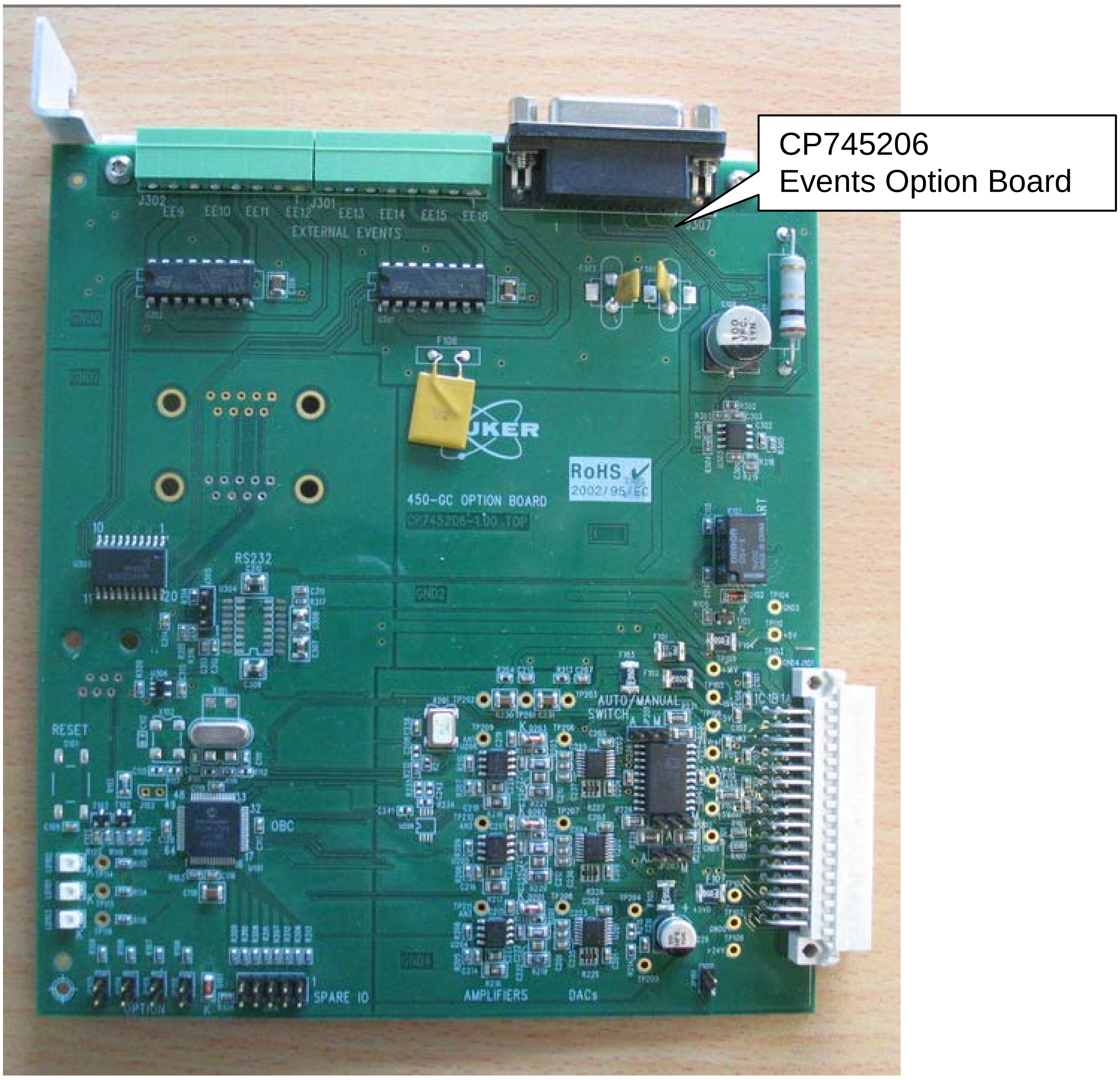
Assigning an IP address can be done in 2 Modes:

- Upper position is BOOTP mode (see IP settings)
- Lower position is Fixed mode (see LUI settings)

PWA


FID/PDHID 392502101
TCD 392503701
ECD 392504101
PFPD 392506601
NPD 392507001

Option Board



LUI Assy 456-GC

LUI Assy 436-GC

Analog cables

The 436-GC/456-GC has a number of analog cables options, depending on the device to which the cable is connected. All cables have a 15-pin Dsub connector on one end to attach to Analog Out connector on the 436-GC/456-GC option board and have appropriate connectors on the other end of the cable for the devices to which they are being attached.

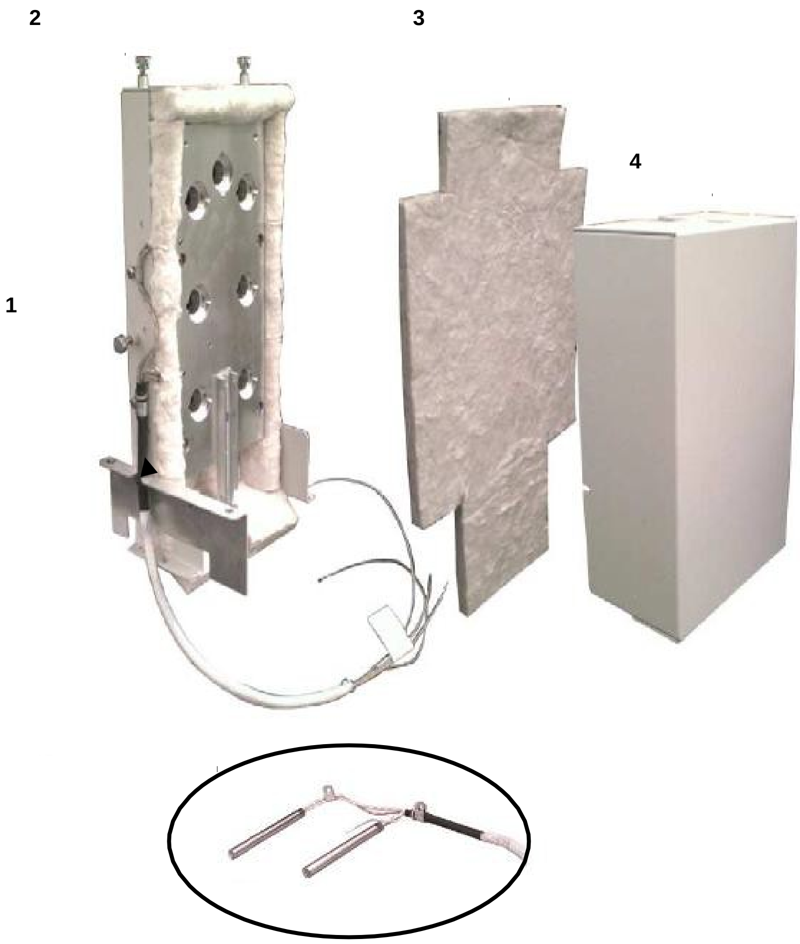
Partnumber	***Description***	***Picture***
BR746366	436-GC/456-GC to Sample Introduction Device Cable. Provides sync connections to Archon, Tekmar LAC 3000 P&T, OI Analytical 4560 P&T, and Genesis Headspace.	N.A.
CP745206	436-GC/456-GC Option Board. The board allows the control of 8 extra external events and 3 analog outs of detector signals.	N.A.
BR746367	436-GC/456-GC Analog Cable. Provides 3 sets of shielded analog signal pairs, terminated with spade lugs and 2 seta of sync signals.	N.A.
BR745241	436-GC/456-GC Cable GC to Sampler CP-84xx	N.A.

This section contains illustrated parts breakdowns for the 436-GC/456-GC Gas Chromatograph Valve oven and related components

VALVE OVENS

770

Assy, Large valve oven



1. Valve heater 120V (392555301)
   Valve heater 230V (392555302)

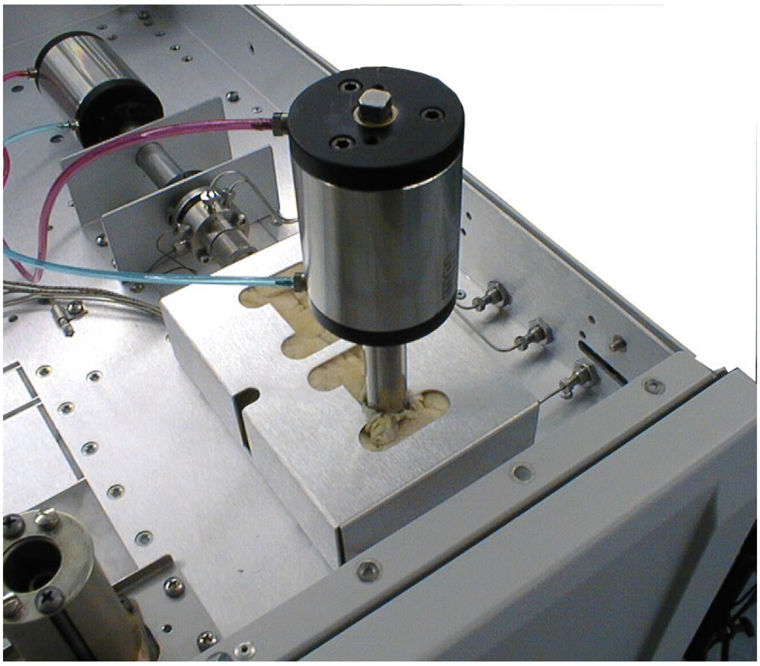
   Clamp cable (2211991800)

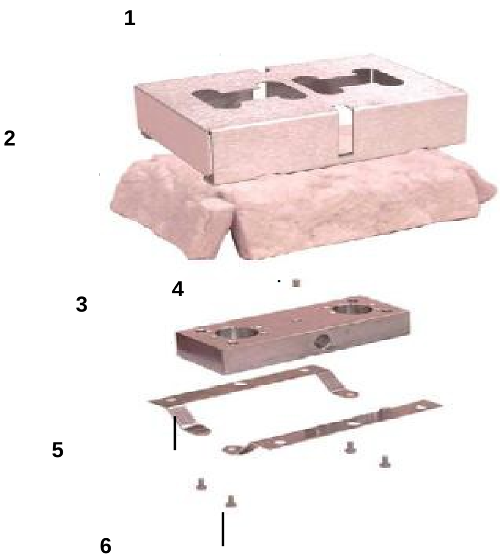
2. Knurled thumb screw(1290313400)

3. Insulation ,valve oven (392555101)

4. Valve oven cover standard (392554601)
   Valve oven cover (purged valves)(CP741769)

Assy, Dual valve oven





1. Cover, Dual valve oven(392567601)
2. Insulation ,Dual valve oven (392568301)
3. Block ,Dual valve oven (391717000)
4. Srews 8-32 x3/16 (1162200803)
5. Bracket, 2 pcs.(400099400)
6. Screws 8-32 x3/8 (1290116300)

Valve heater 120V (392539601)
Valve heater 230V (392539602)

Probe (392537401)

This section contains illustrated parts breakdowns for the 436-GC/456-GC Gas Chromatograph Valve oven and related components

VICI VALVES

Gas sampling valves

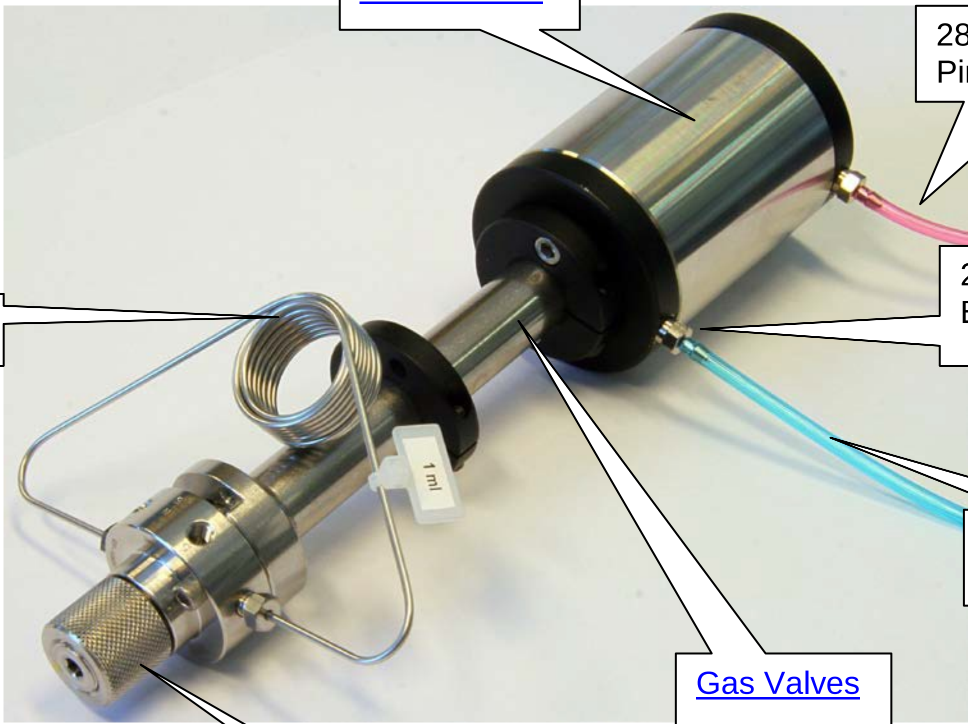
Liquid valves

For more information on the valves installed in Analyzers please refer to:

Service manual Custom solution

780

Gas Sampling Valves



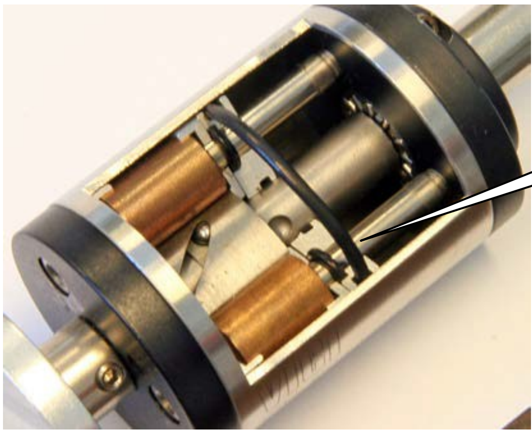
Gas sampling Valves

	WE bore 1.0mm (0.040")
Description	***P/N***
6 port 2-pos valve air act 225C/400psi	VLA4C6WE
8 port 2-pos valve air act 225C/400psi	VLA4C8WE
10port 2-pos valve air act 225C/400psi	VLA4C10WE

	UWE bore 0.75mm (0.030")
Description	***P/N***
4 port 2-pos valve air act 225C/400psi	VLA4C4UWE
6 port 2-pos valve air act 225C/400psi	VLA4C6UWE
8 port 2-pos valve air act 225C/400psi	VLA4C8UWE
10port 2-pos valve air act 225C/400psi	VLA4C10UWE
12port 2-pos valve air act 225C/400psi	VLA4C12UWE
14port 2-pos valve air act 225C/400psi	VLA4C14UWE

Air actuators

Description	P/N
Valco actuator 25.7°(14 Port)	391832504
Valco actuator 30° (12 Port)	VLA30S
Valco actuator 36° (10 Port)	CP88505
Valco actuator 45° (8 Port)	391832503
Valco actuator 60° (6 Port)	CP88504
Valco actuator 90° (4 Port)	VLA90S



CP65850
Set of O-rings

Rotors

WE Type	
Description	***P/N***
Rotor 4 port Valve	VLSSAC4WE
Rotor 6 port Valve	VLSSAC6WE
Rotor 8 port Valve	VLSSAC8WE
Rotor 10 port Valve	VLSSAC10WE

UWE Type	
Description	***P/N***
Rotor 4 port Valve	VLSSAC4UWE
Rotor 6 port Valve	VLSSAC6UWE
Rotor 8 port Valve	VLSSAC8UWE
Rotor 10 port Valve	VLSSAC10UWE
Rotor 12 port Valve	VLSSAC12UWE
Rotor 14 port Valve	VLSSAC14UWE

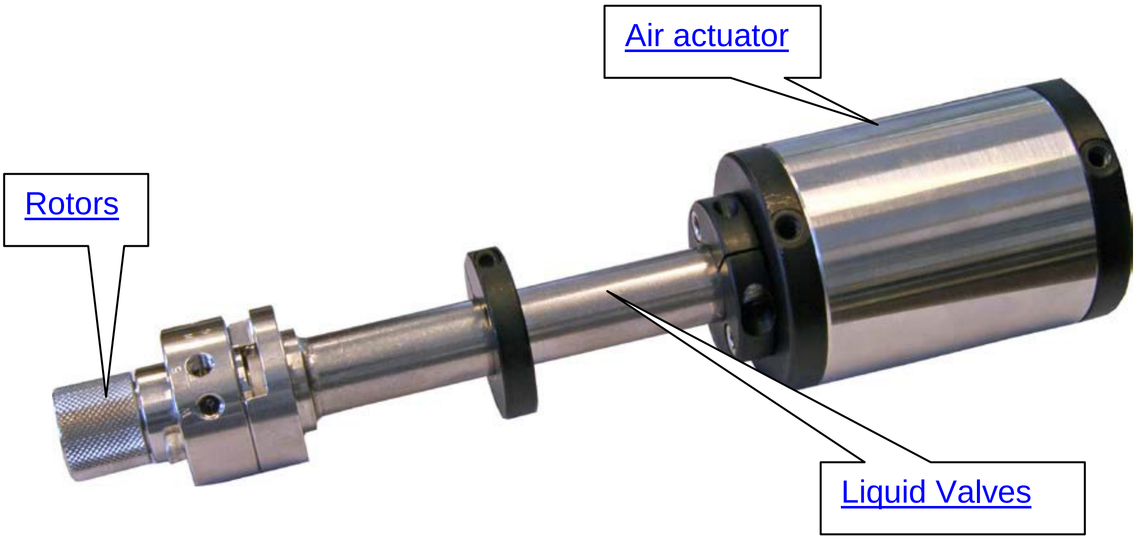
Rotor

Sample loops

Description	*P/N*
Sample loop 5 ul Inert Steel	VLSL5CUWUM
Sample Loop 10 ul	VLSL10CW
Sample loop 10 ul Inert Steel	VLSL10CUWUM
Sample Loop 20 ul	VLSL20CW
Sample loop 20 ul Inert Steel	VLSL20CUWUM
Sample Loop 50 ul	VLSL50CUW
Sample loop 50 ul Inert Steel	VLSL50CUWUM
Sample Loop 100 ul	VLSL100CW
Sample loop 100 ul Inert Steel	VLSL100CUWUM
Sample Loop 250 ul	VLSL250CUW
Sample loop 250 ul Inert Steel	VLSL250CUWUM
Sample Loop 500 ul	VLSL500CUW
Sample loop 500 ul Inert Steel	VLSL500CUWUM
Sample Loop 1 ml	VLSL1KCUW
Sample loop 1 ml Inert Steel	VLSL1KCUWUM
Sample Loop 2 ml	VLSL2KCUW
Sample loop 2 ml Inert Steel	VLSL2KCUWUM
Sample Loop 5 ml	VLSL5KCUW
Sample loop 5 ml Inert Steel	VLSL5KCUWUM

Remove label before installing in the Valve oven.

Liquid Sampling Valves



Liquid sampling Valves

Description	***P/N***
VALCO VALVE A4CI4WE.2+1.0 1/1	VLA4CI4WE.2/1-VNL
VALCO VALVE A4CI4UWE.2+1.0 1/1	CP14423

Air actuators

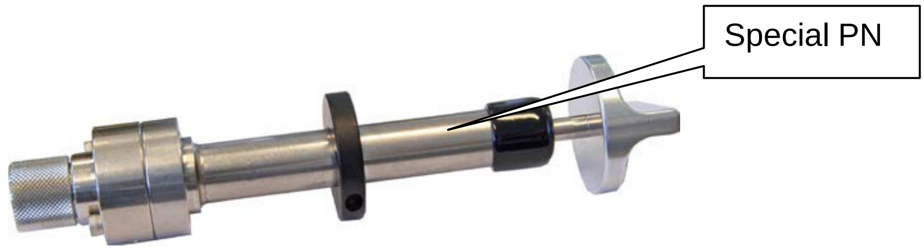
Description	***P/N***
Valco actuator 90° (4 Port)	VLA90S

Rotors

WE Type	
Description	***P/N***
Rotor 0.2/1.0ul	VLSSACI4WE.2/1
Rotor 1.0ul	VLSSACI4WE1
Rotor 0.1ul	VLSSACIWE.1

UWE Type	
Description	***P/N***
Rotor 1.0ul	VLSSACI4UWE1

Manual controlled Sampling Valves



Purged head Sampling Valves (suffix –PH)

Hasteloy C Sampling Valves (suffix –HC)

NOTE: Hastelloy C and Purged Head Valves use the same Air actuator and rotor material as standard valves

Micro-electric actuators for Stream Selection Valves (multi-position)

Cables for EMT Actuators

Description;	Part number;
EMT Cable to RS232	CP89103
EMT Cable to SID1	CP8910302
EMT Cable to 800MIB Box	390793814

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PREVENTIVE MAINTENANCE

How to prolong the life of the 436-GC/456-GC Gas Chromatograph

PREVENTIVE MAINTENANCE

Preventive maintenance how to prolong the life of the 436-GC/456-GC

Section contents:

- Maintenance schedule
- Maintenance required tool
- Electrode cleaning on PDHID
- Preventive maintenance on 436-GC/456-GC

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This chapter is intended to help you maintain the 436-GC/456-GC Gas Chromatograph in good order by using the procedures mentioned in this section.
Please note that Bruker service personnel should perform those procedures.
Users must perform first line maintenance mentioned in the reference manual.

MAINTENANCE SCHEDULE

The frequency with which you need to perform maintenance will vary depending upon the following:

- The level of usage of the 436-GC/456-GC.
- Other environmental factors, such as dirt, ambient temperature, etc.

Trained Bruker service engineer should perform a routine check every year.

MAINTENANCE REQUIRES PROPER TOOLS, SPAREPARTS AND SUPPLIES

Each maintenance procedure includes a list of materials required for that procedure. Some of the required tools, parts, and supplies that you will need to maintain the 436-GC/456-GC are included with the instrument. Others you must supply yourself. Many of the required tools and parts are available from Bruker, see section 120 (Tools required).

The printed circuit boards in the 436-GC/456-GC can be damaged by electrostatic discharge (ESD). Do not touch any of the boards unless it is absolutely necessary. If you must handle them, use a grounded wrist strap and take other antistatic precautions.

ELECTRODE CLEANING ON PDHID

The PDHID discharge electrode can become coated with oxidized material with extensive use. The following steps should be taken to clean the electrode. These steps should be taken when the sensitivity of the system begin to decrease to the point where the desired results are effected. Therefore, it is important that a standard is run periodically to determine that sensitivity is adequate. The cleaning should be done as seldom as possible.

Tools required:

1) ¼" special spanner wrench (CP740760)

2) ¼" wrench

3) 600 grit emery cloth

4) Methanol

5) De-ionized water

Cleaning steps: (Handle electrode with care)

1) Turn the PDHID pulser voltage off.

2) Use both wrenches to remove the electrode from the top of the PDHID. **It is imperative that a backup wrench be used when removing the electrode. Failure to do so will result in not repairable damage to the detector.**

3) Use the emery cloth to polish the oxidized material off the electrode.

4) Wash the electrode in Methanol.

5) Wash the electrode in De-ionized water.

6) Replace the electrode back in the detector. **Be sure to use a backup wrench when tightening the electrode in place.**

PREVENTIVE MAINTENANCE ON 436-GC/456-GC

This Preventive Maintenance document is an interactive sheet, including notes.

Preventive maintenance document.

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Bulletins concerning the 436-GC/456-GC

TECHNICAL INFORMATION

Technical information about the 436-GC/456-GC

Section contents:

- Overview released bulletins
- compassCDS BOOTP settings
- Fixed IP setting on System

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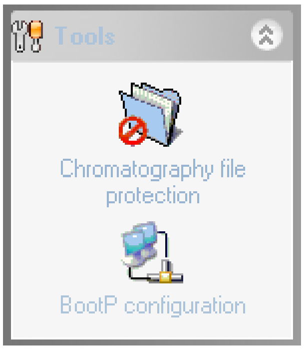
OVERVIEW RELEASED BULLETINS

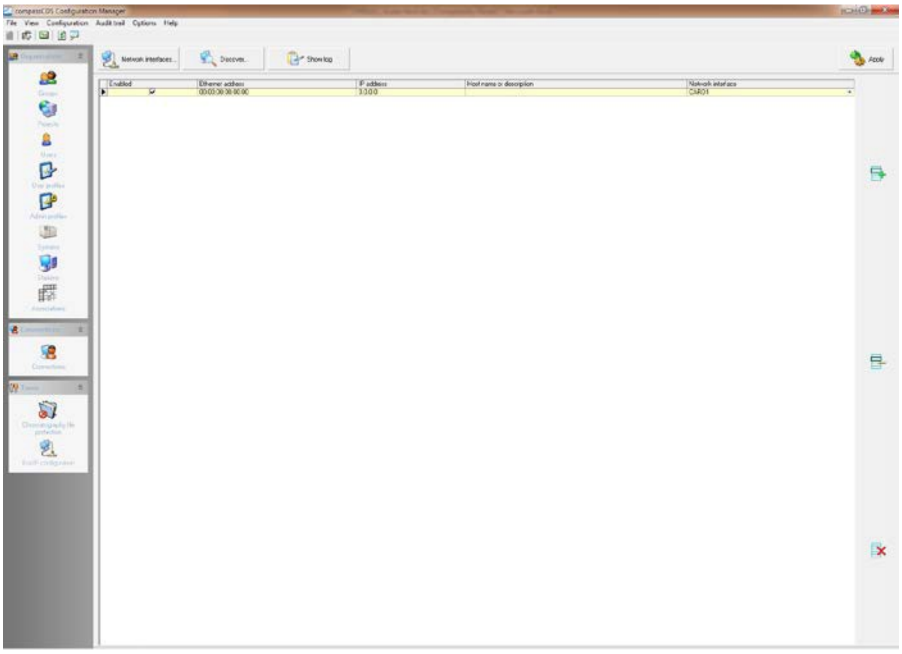
Service Bulletins

HOW TO SET THE IP ADDRESS IN COMPASS-CDS WORKSTATION USING BOOTP

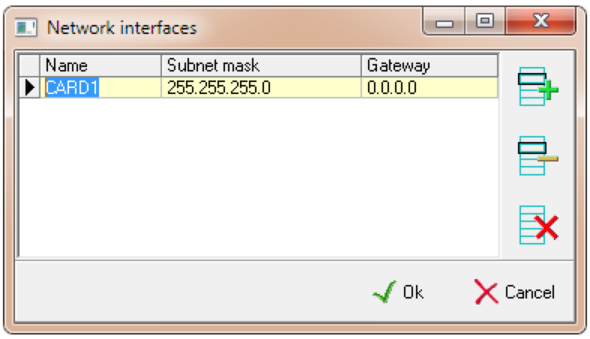
1) Select the network card of your computer and write down the IP address of the card.
2) As “example” IP address network card : 10.2.128.1 or can be determined by the customer.
3) Subnet mask and Gateway can be determine by the customer, if not then change the Subnet mask to a value that is compatible with the instrument.(see Card1)
4) Open compassCDS configuration manager and select in the TOOLS bar.



5) Select in TOOLS bar the BootP configuration.



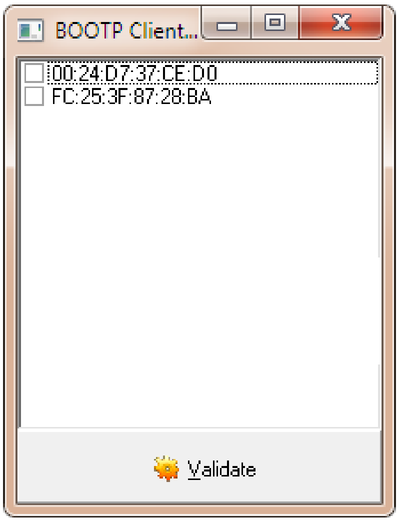
6) Make sure that the network interface is compatible with the GC settings.



7) Then select

8) Make sure the BOOTP button on the GC is in the “upper” position and switch on the 436-GC/456-GC.

9) When the MAC address appears select the address and press the validate button.



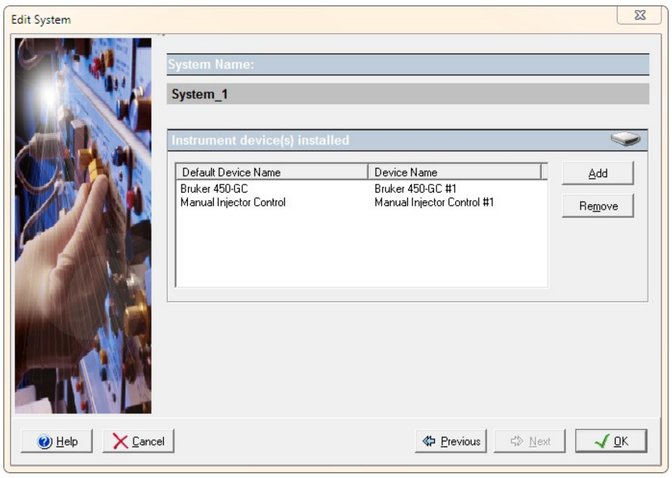
10) Fill in the IP address and the host name or description and press apply.

11) Go to the Organization bar and select System to create a new system.

12) Create a new instrument and select the Acquisition and Sequence server and press

13) Select Groups/project and press

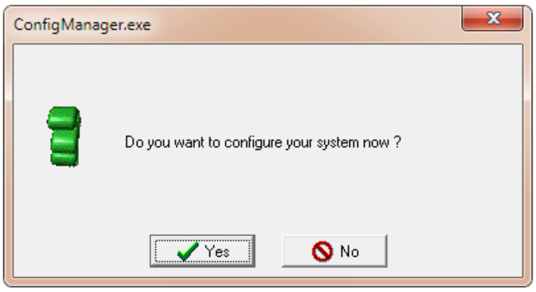
14) Add the devices (example 436-GC/456-GC and NO sampler)



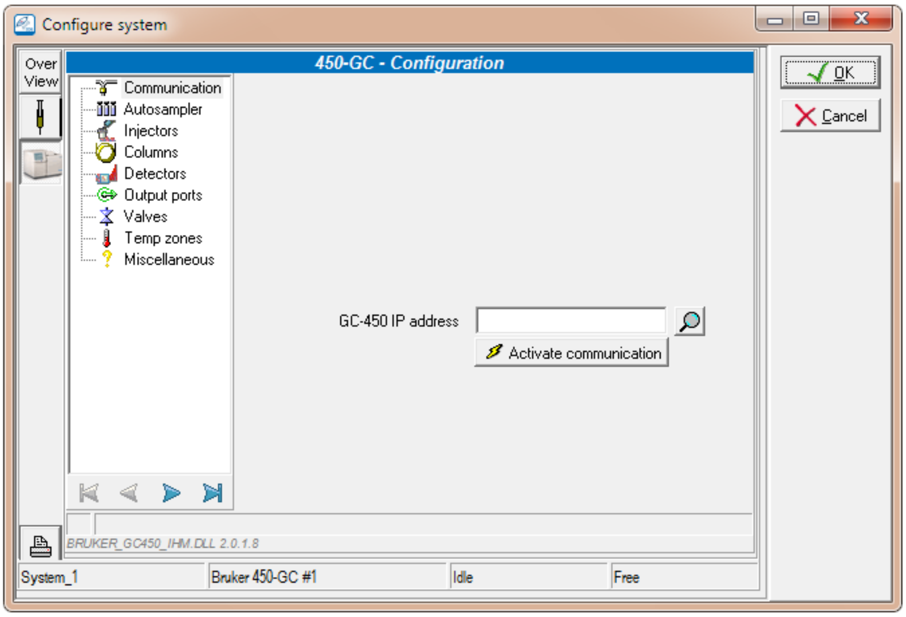
15) When a sampler is installed on the 436-GC/456-GC then only the Bruker GC-450 driver must be installed.

16) Press OK .

17) Press Yes to access the system.



18) Select communication and press the magnifying glass to see the instrument or type in the IP address.



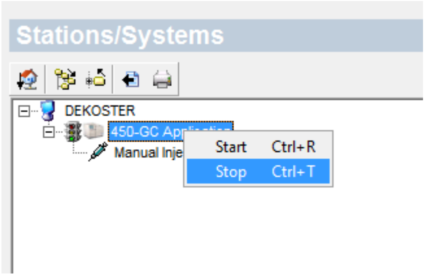
19) Press

20) The following messages should appear:

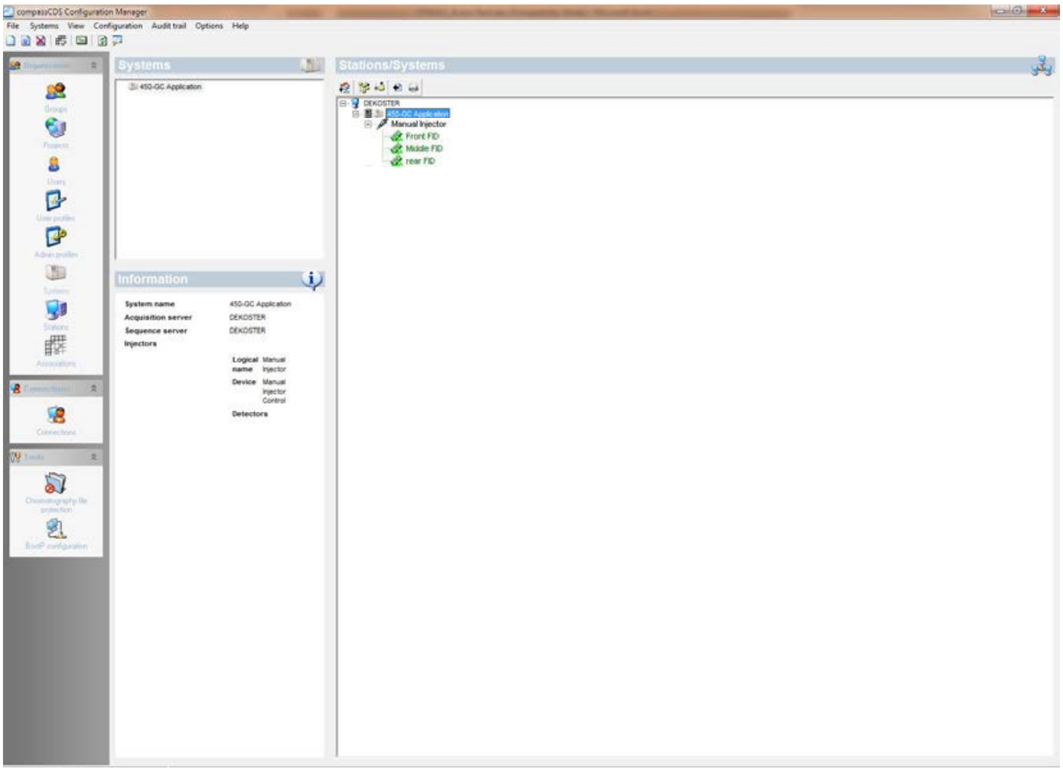
- Parameters activated
- Setup received from instrument

21) Press OK.

22) Stop and Start the instrument.



23) Instrument is ready to be used with compassCDS.

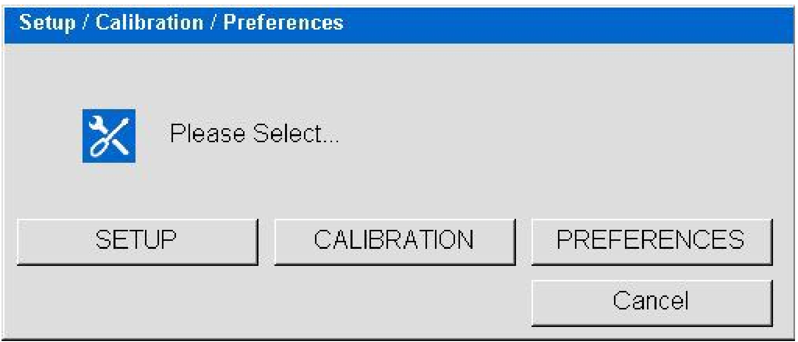


HOW TO SET A FIXED IP ADDRESS IN THE 436-GC/456-GC

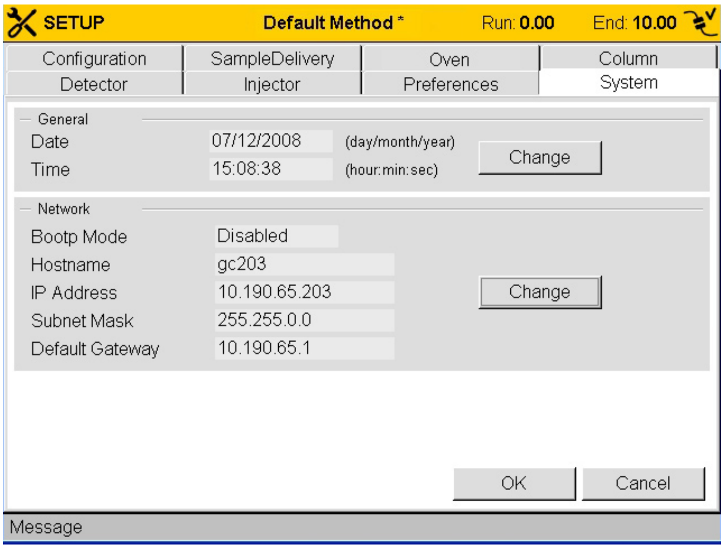
1) Make sure the BOOTP button on the GC is in the “lower” position the Fixed Mode and switch the 436-GC/456-GC on.

2) Press the button with the Setup-icon on the LUI.

3) Press the button “SETUP” on the Touchscreen.



4) Select the System tab.



5) Select "Change" and fill in the IP address and Hostname, make sure that the Subnet Mask and Default Gateway are compatible with the PC settings.