ALICAT SCIENTIFIC

# Operating Bulletin

Modbus

## MODBUS-RTU & MODBUS-TCP/IP

*The Fastest Flow Controller Company in the World!*

# RECALIBRATION

**Your Alicat instrument is a precision device and Alicat strongly recommends that you send it to us on a yearly basis for recalibration.**

**A yearly recalibration does a few things:**

- **It insures that your unit is functioning according to specification.**
- **Contamination may cause the instrument to measure flow improperly. Recalibration insures the instrument is clean and free from debris.**
- **Recalibration maintains your LIFETIME WARRANTY!**

**Sending your unit for recalibration is easy and inexpensive. Recalibrations are usually shipped within five days of receipt, so it's fast too.**

**Please keep the original box to return your Alicat instrument for recalibration.**

# ACCESSORIES

**Now that you have your Alicat instrument are you sure you've got everything you need? Alicat accessories can make your job easier.**

**Many of our customers also order:**

- **Power Supplies — A universal wall power supply that makes it easy to power your Alicat unit just about anywhere in the world.**
- **BB9 — Alicat's multi-drop box that allows easy connection of up to nine Alicat instruments to a single USB, RS-232 or RS-485 port.**
- **MD8DB9 — An RS-232 to 8 pin Mini-DIN cable to connect your Alicat instrument to a computer. A variety of other cables are also available.**
- **Flow Vision™ SC — A GUI based Windows®program that allows easy computer access and control for one or multiple Alicat instruments.**
- **Fittings and filters — Keep your instrument properly connected to your process and free from harmful contamination.**

# ALICAT MODBUS OPERATING BULLETIN

Modbus is an application layer messaging protocol that formats data for communications among industrial devices. Alicat supports both Modbus-RTU and Modbus TCP/IP protocols depending on the device configuration.

Devices ordered with the Modbus-RTU application layer communicate over serial RS-232 or RS-485. Modbus data is transmitted through Alicat's default 8-pin mini-DIN connector, a 9-pin or 15-pin D-Sub connector or an RJ45 connector. Note: An RJ45 connecter in a Modbus-RTU device does not indicate support of Ethernet communication or availability of the Modbus-TCP/IP protocol in this unit. In addition to Modbus-RTU support, your device supports standard Alicat serial commands. Please see your operating manual for a description of the supported commands.

Devices ordered with Modbus-TCP/IP support include a dual-RJ45 connector that supports standard 10BaseT & 100BaseT Ethernet communication. See section 3 for information on setting the device's network configuration.

# 1 Modbus Registers

Alicat's deployment of Modbus uses a Master/Slave structure that organizes data into 16-bit registers. Alicat supports Modbus function codes 03 "Read Holding Registers," 04 "Read Input Registers" and 16 "Write Multiple Registers."

Alicat devices use the Modbus PLC numbering convention such that all registers begin at index 1. The values seen in a Modbus Protocol Data Unit are zero based and would be one less than those specified below. If your master controller does not follow this convention, you may need to decrement register addresses by one.

All 32-bit values are handled in consecutive Modbus registers in big-endian format. This means bits 31:16 are in the lower numbered Modbus register and bits 15:0 are in the higher register. All floating-point values are IEEE 32-bit floats.

| Parameter | Access | Register Number | Description |
|---|---|---|---|
| Command ID | RW | 1000 | See Section 1.1 |
| Command Argument | RW | 1001 | |
| Setpoint | W | 1010-1 | See Section 1.2 |
| Mixture Gas 1 Index | RW | 1050 | See Section 1.3 |
| Mixture Gas 1 Pct | RW | 1051 | |
| Mixture Gas 2 Index | RW | 1052 | |
| Mixture Gas 2 Pct | RW | 1053 | |
| Mixture Gas 3 Index | RW | 1054 | |
| Mixture Gas 3 Pct | RW | 1055 | |
| Mixture Gas 4 Index | RW | 1056 | |
| Mixture Gas 4 Pct | RW | 1057 | |
| Mixture Gas 5 Index | RW | 1058 | |
| Mixture Gas 5 Pct | RW | 1059 | |
| Gas Number | R | 1200 | See your Alicat operating manual for a list of gas numbers |
| Device Status | R | 1201-02 | See Section 1.4 |
| Device Statistic 1 Value | R | 1203-04 | |
| Device Statistic 2 Value | R | 1205-06 | |
| Device Statistic 3 Value | R | 1207-08 | |
| Device Statistic 20 Value | R | 1241-42 | |

## 1.1 Device Commands

Commands can be issued to the Alicat device using Modbus register 1000. Commands are described in the table below. Some commands require a parameter to be passed in Command Argument register 1001 using the “Write Multiple Registers” Modbus function code. A write to only the Command ID register 1000 will be interpreted as having a value of 0 in the Command Argument. Commands take effect at the completion of a Modbus write command.

| Command ID | Action | Argument |
|---|---|---|
| 1 | Change gas number | Gas Table Index |
| 2 | Mix gas | Gas mixture index (236-255) or 0 to use next available |
| 3 | Delete gas mixture | Gas mixture index |
| 4 | Tare | 0 = Pressure<br>1 = Abs Pressure<br>2 = Volume |
| 5 | Totalizer reset | None |
| 6 | Valve setting<br>Exhaust is only supported on dual-valve devices | 0 = Cancel<br>1 = Hold close<br>2 = Hold current<br>3 = Exhaust |
| 7 | Display lock<br>Only supported on devices with a display. | 0 = Unlock<br>1 = Lock |
| 8 | Change P in PID Loop | 0-65535 |
| 9 | Change D in PID Loop | 0-65535 |
| 10 | Change I in PID Loop | 0-65535 |
| 11 | Change control loop variable. | 0 – Mass Flow<br>1 – Volumetric Flow<br>2 – Diff Pressure<br>3 – Absolute Pressure<br>4 – Gauge Pressure |
| 12 | Save current set-point as power-up value. | None |
| 13 | Change control loop algorithm. | 1 – PD<br>2 – PDDI |
| 14 | Read PID value | 0 – PID P<br>1 – PID D<br>2 – PID I |
| 32767 | Change Modbus Slave ID – Modbus/RTU only. | New ID 1-247 |

Reads of the ID register 1000 will return the last executed command. Reads of the argument register 1001 will return the status of the last executed command (see next page).

Command status returns in register 1001 are as follows:

| Status | Description |
|---|---|
| 0 | Success |
| 236-255 | Gas mix index that was created or updated (Mix gas command only) |
| 0x8001 | Invalid command ID |
| 0x8002 | Invalid setting |
| 0x8003 | Requested feature is unsupported |
| 0x8004 | Invalid gas mix index |
| 0x8005 | Invalid gas mix constituent |
| 0x8006 | Invalid gas mix percentage |

## 1.2 Setpoint

The device setpoint should be sent as a 32-bit IEEE floating point value. Setpoint values must be sent together in a Write Multiple Registers command. Any writes to only one half of the setpoint value will cause an error. Setpoint is ignored on devices without a controller.

## 1.3 Gas Mixing

Gas mixing can be performed with 2-5 gases using the mix registers 1050-1059. The mix is a two-step process. First, the desired constituent gas indexes and percentages must be written to the mix registers followed by a write of the Mix Gas command (ID 2) into command register 1000 (with the command argument being optional).

Gas mix percentages are interpreted as integer hundredths of a percent and the total percentage must sum to 100%. For example, to specify a mix of 50%, a value of 5000 should be written into the gas percentage register. The mix will be performed with the first N gases that have a non-zero percentage. As an example, if you wish to mix 3 gases, you would write the index and percentage for those gases into registers 1050-1055 and write a value of zero into 1057-1059.

If the command argument passed to the mix command is 0 or is omitted, a new gas mix index will be allocated in the next empty gas mix index starting at 255 and working down to 236. If no user mix indices are unused, the command will not be successfully completed and an error will be returned in the command argument register.

If the command argument passed is between 236 and 255, the mixture with the specified index will be either created or updated to the new composition. If the specified index is not valid (the command argument is neither 0 nor 236-255), an error will be returned.

Upon completion of mixing, the command argument register will be updated with the mix result. If the mix was valid, the index of the mixed gas will be returned. If one of the requested mix gas constituents did not exist or the percentage does not add to 100%, an error value will be returned and the mix will not be created.

**Note:** Gas mixing is only available over the Modbus serial interface and cannot be performed from the front panel display.

All gas mixtures are accessible via Gas Select on the front panel, but mixtures may not be created or deleted via the front panel.

## 1.4 Device Status

This register specifies status conditions in the device. The value in parenthesis is the front-panel display of the corresponding condition.

| Bit | Description |
|---|---|
| 0 | Temperature Overflow (TOV) |
| 1 | Temperature Underflow (TOV) |
| 2 | Volumetric Overflow (VOV) |
| 3 | Volumetric Underflow (VOV) |
| 4 | Mass Overflow (MOV) |
| 5 | Mass Underflow (MOV) |
| 6 | Pressure Overflow (POV) |
| 7 | Totalizer Overflow (OVR) |
| 8 | PID Loop in Hold (HLD) |
| 9 | ADC Error (ADC) |
| 10 | PID Exhaust (EXH) |
| 11 | Over pressure limit (OPL) |
| 12 | Flow overflow during totalize (TMF) |
| 13 | Measurement was aborted |

## 1.5 Device Statistics

Your Alicat device can output 20 different configurable data statistics. The default statistics for each device type are specified in the sections below.

For Modbus-RTU devices, the actual statistic and units output on your device can be determined by issuing the Alicat data frame query command (*??D*).

For Modbus-TCP/IP, the available statistics are viewable from the device's embedded webserver. To access, point your web browser to the device's IP address and select the Data I/O tab.

If you wish to customize the output of your device please speak to an Alicat applications engineer.

Unless specified below, all output values are in 32-bit IEEE floating point. If an unused device statistic slot is read on Modbus-RTU, the value 0xFFFFFFFF will be returned. On Mobus-TCP/IP devices unused slots will return an invalid register address error.

The value returned for a pressure reading can be absolute pressure, gauge pressure or differential pressure depending on your device's configuration.

### 1.5.1 Mass Flow Controller

| Register Number | Statistic |
|---|---|
| 1203-04 | Pressure |
| 1205-06 | Flow Temperature |
| 1207-08 | Volumetric Flow |
| 1209-10 | Mass Flow |
| 1211-12 | Mass Flow Setpoint |
| 1213-14 | Mass Total* |

* Mass Total is only available on units with the Totalizer option.

### 1.5.2 Mass Flow Meter

| Register Number | Statistic |
|---|---|
| 1203-04 | Pressure |
| 1205-06 | Flow Temperature |
| 1207-08 | Volumetric Flow |
| 1209-10 | Mass Flow |
| 1211-12 | Mass Total* |

* Mass Total is only available on units with the Totalizer option.

### 1.5.3 Pressure Gauge

| Register Number | Statistic |
|---|---|
| 1203-04 | Pressure |

### 1.5.4 Pressure Controller

| Register Number | Statistic |
|---|---|
| 1203-04 | Pressure |
| 1205-06 | Pressure Setpoint |

# 2 Legacy Registers

For backwards compatibility, the following legacy registers are supported on the Modbus-RTU protocol. These registers are not available on Modbus-TCP/IP devices. Unlisted registers are not configurable via Modbus. Please consult Alicat for assistance if additional configuration is required.

## 2.1 User-Accessible Configuration Registers

For new deployments, Alicat recommends using the Device Command Registers above to set these values.

| Parameter | Access | Register Number | Description |
|---|---|---|---|
| PID control loop P | RW | 21 | 16-bit integer |
| PID control loop D | RW | 22 | 16-bit integer |
| PID control loop I | RW | 23 | 16-bit integer |
| Setpoint | RW | 24 | 0-65535 with 64000 equal to 100% of full scale range. |
| Gas Selection | RW | 46 | 16-bit integer |
| Modbus device ID | RW | 65 | 1-247 |

## 2.2 Device Data Registers

Alicat uses read-only Modbus registers 2,041-2,059 to hold the values of the instrument data as follows:

| Query | Register Number | Data Type |
|---|---|---|
| Pressure | 2041-2042 | 32-bit float* |
| Temperature | 2043-2044 | 32-bit float* |
| Volumetric Flow Rate | 2045-2046 | 32-bit float* |
| Mass Flow Rate | 2047-2048 | 32-bit float* |
| Setpoint | 2049-2050 | 32-bit float* |
| Totalized Mass Flow | 2051-2052 | 32-bit float* |
| Modbus Device ID | 2053 | 16-bit integer |
| Gas Number | 2054 | 16-bit integer |
| Vol. Flow Overage (VOV) | 2055 | 0=ok, 1=error exists |
| Mass Flow Overage (MOV) | 2056 | 0=ok, 1=error exists |
| Pressure Overage (POV) | 2057 | 0=ok, 1=error exists |
| Temp. Overage (TOV) | 2058 | 0=ok, 1=error exists |
| Totalizer Rollover (OVR) | 2059 | 0=ok, 1=error exists |

# 3 Modbus-TCP/IP Configuration

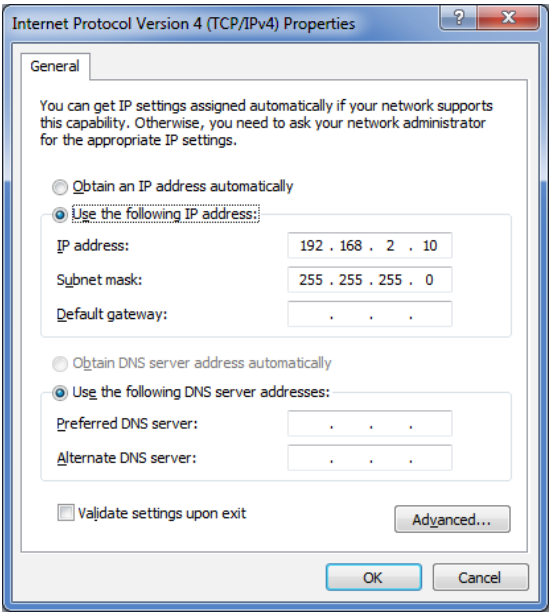
Alicat Modbus-TCP/IP devices have two 10/100Mbps Ethernet ports with an embedded switch. Either port can be used to communicate with the device. In addition, the embedded switch supports packet forwarding allowing daisy-chaining devices in a linear or ring topology.

## 3.1 IP Address Configuration

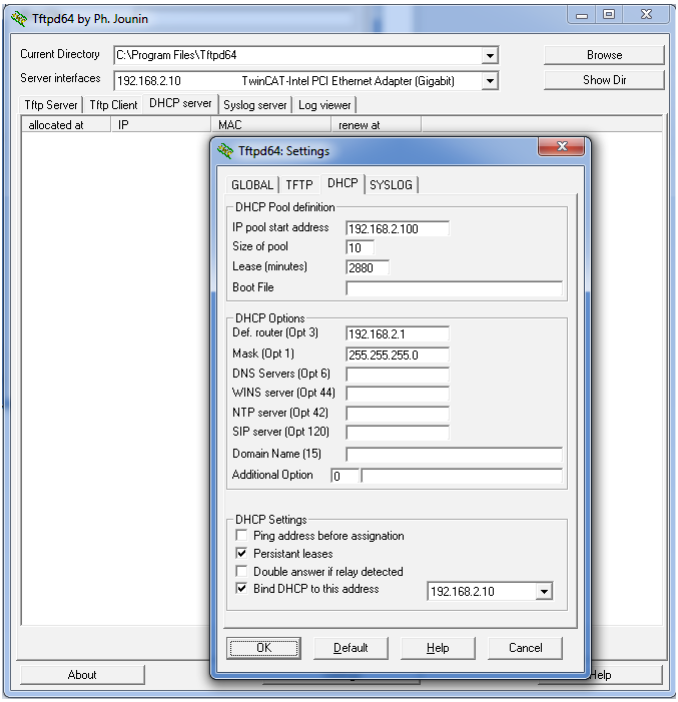
The out-of-the-box configuration of your device is to use DHCP to obtain an IP address. There is an embedded web server in the device which supports assigning a static IP address to the device. To do so, you must first assign an address using DHCP.

The following shows an example of configuring the address using Microsoft Windows:

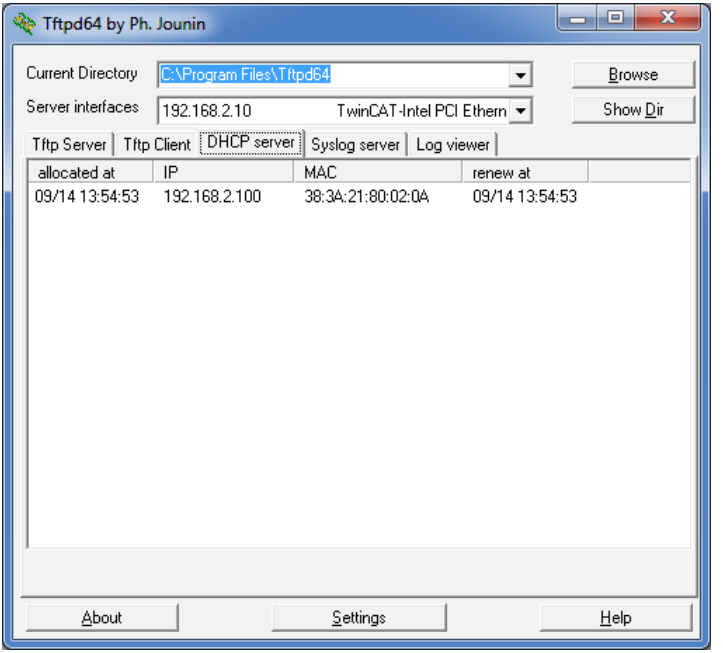
First, assign a static IP to an unused network interface:



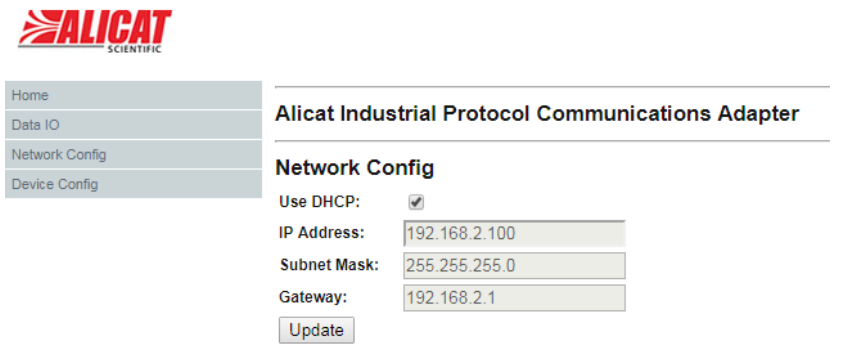
Second, configure a DHCP server to give a known IP address to your device on the static network. This example uses the open source Tftpd64 tool (http://tftpd32.jounin.net):



After connecting your Alicat device directly to the static port and supplying power to the device, you should see an address allocated to the device by the DHCP server:




The network configuration can then be changed using the device's embedded webserver. Navigate to the Network Config tab, uncheck the "Use DHCP" box, and enter the desired static IP address into the form.



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If you would like additional information regarding the use of this product, please contact:

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## Limited Lifetime Warranty

Alicat Scientific, Inc. warrants to the original purchaser (hereinafter referred to as "Buyer") that instruments manufactured by Alicat Scientific (hereinafter referred to as "Product") shall be free from defects in materials and workmanship for the life of the Products.

Under this warranty, the Products will be repaired or replaced at manufacturer's option, without charge for parts or labor when the Product is carried or shipped prepaid to the factory together with proof of purchase.

The foregoing shall constitute the exclusive and sole remedy in lieu of other remedies of the Buyer for any breach by Alicat Scientific of this warranty to the maximum extent permitted by law.

This warranty does not apply to any Product which has not been installed or used in accordance with the Product operation and installation specifications provided to Buyer verbally or in writing by Alicat Scientific for the proper and normal use of the Product.

Buyer agrees hereunder that Alicat reserves the right to void any warranty, written or implied, if upon Alicat's examination of Product shall disclose to Alicat's satisfaction that the Product failure was due solely, or in part, to accident, misuse, neglect, abuse, alteration, improper installation, unauthorized repair or improper testing by Buyer or agent of Buyer.

Alicat Scientific shall not be liable under any circumstances for indirect, special, consequential, or incidental damages in connection with, or arising out of, the sale, performance, or use of the Products covered by this warranty.

Alicat Scientific does not recommend, warrant or assume responsibility for the use of the Products in life support applications or systems.

Alicat's warranties as herein above set forth shall not be enlarged, diminished or affected by, and no obligation or liability shall arise or grow out of Alicat's rendering of technical advice in connection with Buyer's order of the Products furnished hereunder.

If Product becomes obsolete, Alicat Scientific, at its own discretion, reserves the right to repair the Product with available replacement parts or upgrade the Product to a current, commercially available version of the original Product. Should upgrading the Product be deemed necessary by Alicat, Buyer hereby agrees to pay an upgrade fee equal to seventy percent of the retail value of the replacement Product. Alicat Scientific hereunder makes no claim that replacement Products will look, function or operate in the same or similar manner as the original product.

When a Product is returned to Alicat Scientific for recalibration this service is considered normal preventative maintenance. Recalibration of Product shall not be treated as a warranty service unless recalibration of Product is required as the result of repairs to Product pursuant to this Warranty. Failure of Buyer to send Product to Alicat Scientific for recalibration on a yearly basis after a period of 36 months from date of manufacture will remove any and all obligations regarding repair or replacement of Product as outlined by this Warranty to Buyer from Alicat Scientific.

This Warranty is in lieu of all other relevant warranties, expressed or implied, including the implied warranty of merchantability and the implied warranty of fitness for a particular purpose, and any warranty against infringement of any patent.

Continued use or possession of Products after expiration of the applicable warranty period stated above shall be conclusive evidence that the warranty is fulfilled to the full satisfaction of Buyer.

Alicat makes no warranty as to experimental, non-standard or developmental Products.

Accessories purchased from Alicat are not covered by this warranty.

Conformity / Supplemental Information:

The product complies with the requirements of the Low Voltage Directive 2006/95/EC and the EMC Directive 2004/108/EC and carries the CE Marking accordingly. Contact the manufacturer for more information.

## Gas Viscosity, Density and Compressibility:

| # | Gas | | Absolute Viscosity* 25°C | Density ** 25°C 14.696PSIA | Compressibility 25°C 14.696PSIA |
|---|---|---|---|---|---|
| 0 | Air | Air | 184.918 | 1.1840 | 0.9997 |
| 1 | Argon | Ar | 225.593 | 1.6339 | 0.9994 |
| 2 | Methane | CH4 | 111.852 | 0.6569 | 0.9982 |
| 3 | Carbon Monoxide | CO | 176.473 | 1.1453 | 0.9997 |
| 4 | Carbon Dioxide | CO2 | 149.332 | 1.8080 | 0.9949 |
| 5 | Ethane | C2H6 | 93.540 | 1.2385 | 0.9924 |
| 6 | Hydrogen | H2 | 89.153 | 0.08235 | 1.0006 |
| 7 | Helium | He | 198.457 | 0.16353 | 1.0005 |
| 8 | Nitrogen | N2 | 178.120 | 1.1453 | 0.9998 |
| 9 | Nitrous Oxide | N2O | 148.456 | 1.8088 | 0.9946 |
| 10 | Neon | Ne | 311.149 | 0.8246 | 1.0005 |
| 11 | Oxygen | O2 | 204.591 | 1.3088 | 0.9994 |
| 12 | Propane | C3H8 | 81.458 | 1.8316 | 0.9841 |
| 13 | normal-Butane | n-C4H10 | 74.052 | 2.4494 | 0.9699 |
| 14 | Acetylene | C2H2 | 104.448 | 1.0720 | 0.9928 |
| 15 | Ethylene | C2H4 | 103.177 | 1.1533 | 0.9943 |
| 16 | iso-Butane | i-C4H10 | 74.988 | 2.4403 | 0.9728 |
| 17 | Krypton | Kr | 251.342 | 3.4274 | 0.9994 |
| 18 | Xenon | Xe | 229.785 | 5.3954 | 0.9947 |
| 19 | Sulfur Hexafluoride | SF6 | 153.532 | 6.0380 | 0.9887 |

| # | Gas | | Absolute Viscosity* 25°C | Density ** 25°C 14.696PSIA | Compressibility 25°C 14.696PSIA |
|---|---|---|---|---|---|
| 20 | 75%Ar / 25% CO2 | C-25 | 205.615 | 1.6766 | 0.9987 |
| 21 | 90% Ar / 10% CO2 | C-10 | 217.529 | 1.6509 | 0.9991 |
| 22 | 92% Ar / 8% CO2 | C-8 | 219.134 | 1.6475 | 0.9992 |
| 23 | 98% Ar / 2% CO2 | C-2 | 223.973 | 1.6373 | 0.9993 |
| 24 | 75% CO2 / 25% Ar | C-75 | 167.451 | 1.7634 | 0.9966 |
| 25 | 75% Ar / 25% He | HE-75 | 230.998 | 1.2660 | 0.9997 |
| 26 | 75% He / 25% Ar | HE-25 | 234.306 | 0.5306 | 1.0002 |
| 27 | 90% He / 7.5% Ar / 2.5% CO2 Helistar® A1025 | A1025 | 214.840 | 0.3146 | 1.0003 |
| 28 | 90% Ar / 8% CO2 / 2% O2 Stargon® CS | Star29 | 218.817 | 1.6410 | 0.9992 |
| 29 | 95% Ar / 5% CH4 | P-5 | 223.483 | 1.5850 | 0.9993 |

*in micropoise (1 Poise = gram / (cm) (sec)) **Grams/Liter
Reference: NIST REFPROP 7 Database

### Flow Conversions:

| | | | | | | |
|---|---|---|---|---|---|---|
| SCFM | 1.00 = 28.3160 | SLPM | SLPM | 100.00 = 3.5316 | | SCFM |
| SCFH | 1.00 = 0.4719 | SLPM | SLPM | 100.00 = 211.9093 | | SCFH |
| SCIM | 100.00 = 1.6390 | SLPM | SLPM | 1.00 = 61.0128 | | SCIM |
| SCIH | 1000.00 = 0.2732 | SLPM | SLPM | 1.00 = 3660.7688 | | SCIH |

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