

## Ins and Outs of I/P Transducers

### General description

I/P transducers are versatile instruments that use an electrical control signal to proportionally regulate gas pressure. The most common application is in valve actuation, but they can also be used in many other situations. As more processes become automated, I/P's are being used more and more in place of manual regulators.

Overall, I/P's are relatively simple devices, but there are numerous factors to consider before selecting one. The information that follows should provide you with a complete understanding of the factors involved in making the correct product selection, installation, and maintenance. When chosen, installed, and maintained correctly, I/P's should provide many years of reliable service.

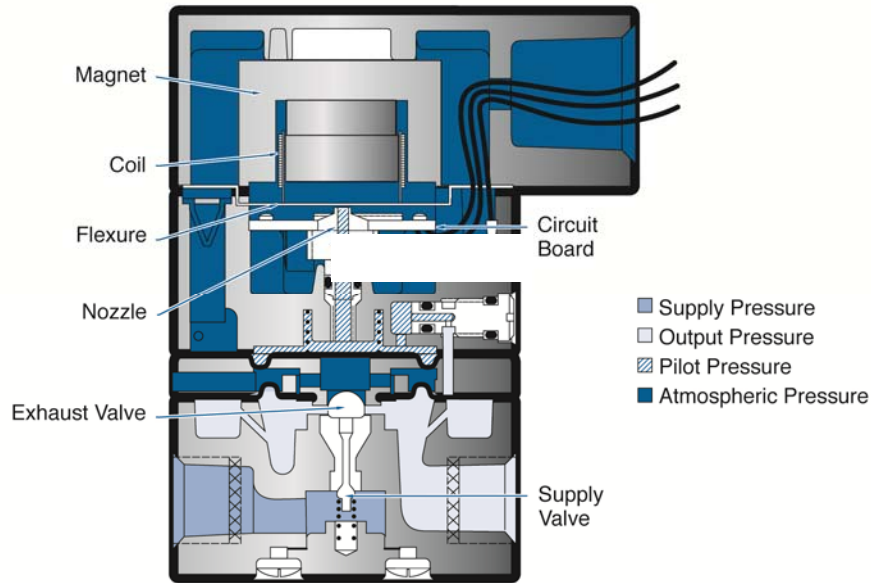
### Principle of operation

Most I/P's utilize a **flapper/nozzle** design. This means that the pressure is controlled by air in a pilot chamber. The opening and closing of the flapper either builds or releases pressure in the pilot chamber. The flapper can be constructed in different ways.

The operation of the unit begins when an internal start-up spring acts on a control diaphragm to allow a small amount of supply pressure, typically 1-1.5 psig, to travel downstream. The downstream pressure works its way through a small orifice into a pilot chamber that acts on the diaphragm to control the output pressure. The pilot chamber is connected to a nozzle that allows the pilot chamber to vent to atmosphere. The nozzle is throttled by a flapper, which can take on many different forms. As the control signal is increased, the flapper closes the nozzle, building pressure in the pilot chamber until the desired output is achieved. At this point the flapper pressure is overcome, and the pilot pressure once again vents to atmosphere, thus maintaining a steady state output pressure.

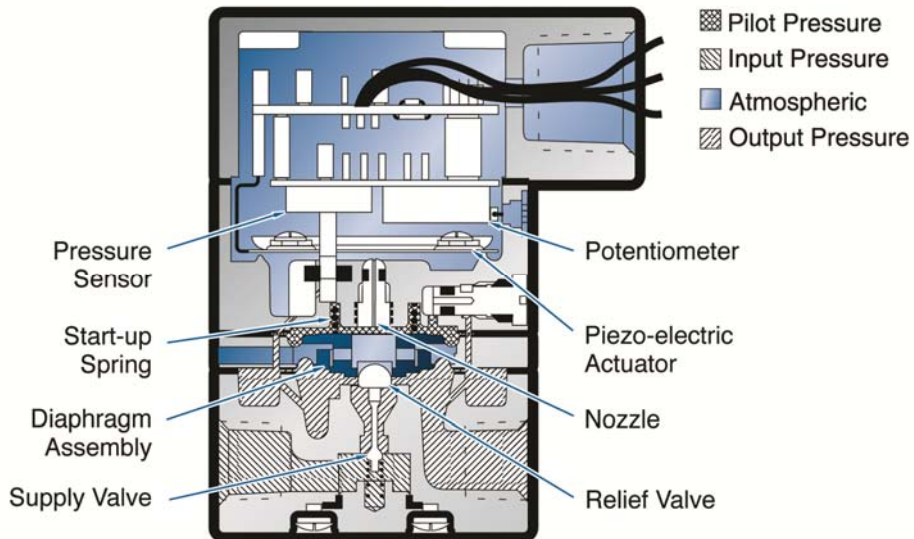
This continues to occur in tiny increments, which is why the I/P vents continuously. This rate of venting is referred to as "consumption rate" and typically ranges from 4-12 scfh. Rates may vary significantly between models and manufacturers. This is an important consideration as compressed air is costly, and it is even more important if the media is natural gas (more on media later).

The most common flapper design uses a coil and magnet actuating a flat spring. This is usually referred to as a **voice coil** design. This design is usually the lowest cost, and offers dependable performance. However, these units will change their output when their mounting orientation is changed, or they are subjected to vibration. Some voice coil designs incorporate a cantilevered beam as the flapper, like the ControlAir Model 590, which provides much better resistance to vibration and change of position. Fig. 1 shows a cutaway of the ControlAir Model 550 voice coil I/P. ControlAir offers three models that are a voice coil design, models 500, 550, 590 and 595.



**Figure 1 – ControlAir Model 550**

Another common flapper design incorporates a ceramic *piezo-electric actuator*. These are commonly utilized in combination with an internal pressure sensor and feedback loop. This results in greater accuracy and insensitivity to vibration and change in position. However, they are usually higher cost and consume more power. Figure 2 shows a cutaway of the ControlAir Model 900 piezo operated I/P with internal feedback.



**Figure 2 – ControlAir Model 900**

The ControlAir model 950 also uses a piezo electric actuator design.

## Electrical Considerations

There are three main electrical considerations in specifying an I/P. The first item is the control signal. The most common is a 4-20 mA. In some applications, particularly with in the case of machine control, voltage control (0-10, 0-5, or 1-9 VDC) is also common. These units are referred to as E/P's.

The second item is the method of connection. Flying leads with ½ in. NPT conduit connection is most common. Most manufacturers also offer DIN connectors for weather tight seal or terminal blocks for ease of connection in panels.

The final electrical consideration is power consumption. Most I/P's are two wire devices. However, loop load varies depending on the output range, and method of construction. Some I/P's that offer higher accuracy may consume more power and may not be suitable in applications where power is at a premium. Some E/P's are also 2 wire devices while others will require a constant power source. All of the ControlAir I/P's and E/P's are 2-wire devices except for the Model 900 E/P. You should check the unit specifications very carefully.

## Pneumatic requirements

There are several pneumatic considerations in choosing the correct I/P. Supply pressure is very important. Some I/P's have a maximum supply pressure as low as 30 psig. Some will work fine with regular shop air, 80-100 psig, or even up to 150 psig. Low supply pressure can also be an issue. Most I/P's work best when the supply pressure is at least 5 psig higher than the maximum output pressure. Be sure to check the unit's specifications carefully in this regard. All of the ControlAir I/P's except the Model 590 will work with a maximum supply pressure of 100 psig or higher depending on output range.

I/P's typically come in several output ranges. The low end of the range is called the **zero**, which corresponds to the low end of the electrical signal as well. The total range is called the **span**. The most common range is 3-15 psig. In the case of a 4-20 mA, 3-15 psig unit, the zero is 4mA giving an output of 3 psig, and the span is 12 psig (15-3). Other common ranges for valve automation are 1-17, 3-27, and 6-30. Many I/P's can be "split-ranged." That is, by making some adjustment, a 3-15 unit can be converted to a 3-9, or 9-15 psig. Units may also be **reverse-acting**, where a 3-15, becomes 15-3. This may be as simple as reversing the wires, or changing switch settings. Some units are available with a **field-selectable** option where by changing a switch setting, a 3-15 can become a 3-27 or 6-30. In this case, the end user may stock one model and use it in different applications

The zero and span may typically be adjusted outside of the factory setting. However, resetting the zero and span could result in sluggish performance, or no output at all. It will also affect accuracy and may shorten the life of the unit as well. You should contact ControlAir if you need to use the unit outside of the normal pressure ranges.

For other applications, many manufacturers offer models with outputs up to 60 or 120 psig. These are referred to as **high output** units. Some I/P's are available down to 0 psig. These are called zero based units. They are more complex in their design in order to keep the start-up pressure required from travelling downstream. Zero based units are most commonly achieved by adding a spring bias in the pneumatic portion of the unit and typically add 10-30% to the unit cost. ControlAir offers high output ranges in Models 500, 550, and 900, and zero-based units in Models 550 and 900.

**Flow capacity** is an extremely important characteristic. Some I/P's are a module only with very limited flow capacity, typically less than 1 scfm, such as ControlAir's 590. Most I/P's come with their own pneumatic base, and have decent flow capacity. Flow capacity is affected greatly by supply pressure. For example, a typical I/P may flow 4 scfm with 20 psig supply pressure, but 12 scfm with 100 psig supply. For applications requiring greater flow capacity (larger valves, or long piping runs), the output from the I/P can be used to control a volume booster like ControlAir models 600, 6000 and 6500, which are air pilot controlled regulators offering greater flow capacities.

## Accuracy

The accuracy of an I/P transducer is defined in several ways. The first and normally the most important measure is **linearity**. The degree to which the relationship between input signal and output pressure is measured as linearity. For example, an I/P with a 4-20 mA signal and 3-15 psig output range should give output readings per the following chart:

Signal (mA)	4	8	12	16	20
Output (psig)	3	6	9	12	15

However, the actual pressure reading will vary slightly. This variation is measured as a percent of span. In this case, the span is 12 (15 minus 3) psig. So if the linearity of the I/P was 1% of span, then the possible variation could be 1% of 12 or 0.12 psig. So in this case, the expected output with a 12mA signal would be between 8.88 – 9.12 psig. Linearity can be as low as 0.1% and as high as 3% of span, depending on the construction and cost of the I/P.

To make matters even more confusing, there are two types of linearity, independent and terminal based. The example above shows **terminal based linearity**. It measures the variability from the theoretical perfect linear line. **Independent linearity** measures the variability from the base line, even though the base line may be shifted. So a tighter spec on independent linearity may not be as accurate as a looser spec on terminal based linearity. Generally, terminal based linearity is twice as accurate as independent linearity

**Repeatability** measures the ability of the unit to come back to the same pressure setting after resetting the input signal.

**Hysteresis** is the variation in the output pressure achieved when increasing the input signal versus decreasing the input signal. For example, when going from 4 mA to 12mA a certain pressure will be attained. A different output pressure will be achieved when going from 20mA to 12 mA.

Unless specified, these three measurements can be additive. Thus a 3-15 psig unit with +/- 1% linearity, +/- 1% hysteresis, and +/- 1% repeatability could be off by +/- 3%, or +/- .36 psig (3% \* span [15-3]).

In very precise applications, one must also be aware of **deadband**. Deadband is the minimum amount of output pressure change that can be achieved, and is usually measured as a percent of span. For example, a 3-15 psig I/P with a deadband of 0.1% of span would have a minimum output pressure change of 0.012 psig.

**Supply pressure effect** is typically an inverse relationship where changes in the supply pressure will cause an inverse change in the output pressure. Output changes due to supply pressure effect are usually small in most I/P's. They can be significant in less precise units and general-purpose manual regulators. Supply pressure effect is usually given as an amount of output change for a given amount of supply pressure change. For

example, for a 25 psig supply pressure change, output pressure will vary +/- 0.05 psig. It can also be expressed as a percent of span.

## Calibration

When received from the factory, I/P's should already be calibrated to their correct setting. However, due to shock and vibration in shipping, varying supply pressures, or variations in mounting position, most I/P's should be calibrated, preferably at the point of use. Calibrating the I/P is a relatively simple process that should only take a minute or two. There should be two adjustment screws that are easy to access, one marked **zero** and the other marked **span**. Do not supply air or electrical to the unit until all connections have been made. Once the connections are made, supply the air to the unit before the electrical signal. Depending on the output range, there should be a small pressure rise, but less than the lowest value of the output range. If it is a zero-based unit, there should be no output.

Always check the **zero** setting first. Apply the minimum electrical signal and observe the output pressure. It should be the minimum value of the pressure range. For example, a 4-20 mA, 6-30 psig unit should give a 6 psig output at 4mA. If the output is not 6, turn the zero screw until the output pressure reaches 6. The screw may be turned in different directions depending on whether the unit is an I/P or E/P.

Once the zero has been set, apply the maximum electrical signal, in this case, 20 mA. The output should be close to the desired output, in this case 30 psig. Turn the **span** screw in the appropriate direction to achieve the desired pressure. Some I/P's have **interactive zero** and span. In that case, after adjusting the span, the zero may need to be adjusted again, especially if the span was adjusted by a large amount. Most I/P's will allow you to go higher or lower than the standard settings. However, this will likely degrade the accuracy of the unit. You should check with ControlAir as to how much the span can be adjusted from the nominal settings.

Reverse acting is accomplished by either reversing the connections, or by changing switch settings on the unit (sometimes this needs to be done at the factory). Be careful to read the instruction manual before attempting to operate a unit in the reverse acting mode. In reverse acting, a 4-20 mA signal will give an output of 15-3 psig. In this case, again give the unit the low signal, 4 mA, but using the zero screw make sure the output is 15 psig. The maximum signal, 20 mA should give an output of 3 psig.

Many I/P's allow for **split range** operation. That is the unit will operate in one half its normal span. For example, a 3-15 psig unit will have a total span of 6 psig, not 12. It can operate as 3-9, 9-15, or in reverse acting as 15-9 or 9-3. Once the switch settings have been set, the calibration procedure is the same. Start with the low electrical signal, 4 mA, and using the zero screw, set the desired pressure. Then go to the maximum input, 20mA and set the output using the span screw.

The ControlAir Models 900 and 950 come with a **field-selectable** option. They may come from the factory as a 4-20 mA, 3-15 psig, but may be changed to a 3-27 or 6-30 psig by changing switch settings. After changing the switch settings, recalibrate the unit in forward or reverse acting as described above.

Please note that not all I/P's are suitable for reverse-acting, split range, or field selectable outputs. If these are important criteria for use in your application, make sure that you specify an I/P that offers this type of flexibility.

## Mounting Options

There are several mounting options for I/P's. Units will most likely come with a bracket for panel mounting, or direct mounting to a control valve. It is also common for them to be available with hardware to mount to a 1½ in. or 2 in. diameter pipe.

Some I/P's are designed with space savings in mind. The ControlAir Models 550, 590, and 900 may be attached directly to a DIN rail. There is also a manifold mounting option for the 550 and 900 where a single pneumatic connection can supply up to 15 I/P's. This eliminates the need to run individual supply connections to multiple I/P's, eliminating the need for costly fittings, tubing, and potential leak points. Of course, each I/P will have its own output connection.

## Media

The most common media for I/P's is compressed air. They can also be used with many other inert gases. However, due to the constant consumption of the media, one must consider the environmental impact of the release of gas into the environment. You should review the specifications before using the I/P with media other than compressed air.

Many I/P's are used in applications where the media is sweet natural gas. ControlAir makes a version of the Model 950 designed specifically for use with natural gas. It incorporates two key safety features. First, it comes with a tapped exhaust port so that the constant gas consumption and gas released when reducing the pressure setting can be piped away to a safe location. Second, it comes with a sealed conduit fitting to ensure that gas does not travel down the conduit.

## Safety Ratings

I/P's used in the process industries require certain hazardous area clarifications depending on the application. These classifications are a subject unto themselves. I/P's for use in the US are typically certified to be used in certain hazardous locations by Factory Mutual [www.fmglobal.com](http://www.fmglobal.com). In Canada, products are certified to standards set by the Canadian Standards Assoc. (CSA) [www.csa.ca](http://www.csa.ca). In Europe and other parts of the world, I/P's are required to meet the requirements of the ATEX directive.

Products that display the marks of these organizations have been tested and approved for use in the hazardous areas identified on the product labeling.

Units may also display the CE mark. CE Marking on a product is a manufacturer's declaration that the product complies with the **essential requirements** of the relevant European health, safety and environmental protection legislation.

## Troubleshooting

Normally, I/P's are very reliable devices. However, if not properly specified, installed, or maintained, they could present some problems.

**New Units – Problems with brand new units** are typically associated with incorrect wiring or insufficient power. Double check all wiring connections to make sure they are correct and secure. Even though most units operate as 2-wire devices, some require more power than others do. Make sure that your control signal has a sufficient amount of power as specified by the manufacturer of the I/P. The power will be given either as a minimum voltage, or as a loop load measured in ohms resistance.

Another failure mode is no output at all, zero. This is most often caused by too high of a supply pressure. The maximum supply pressure on some I/P's is as low as 30 psig. If the supply pressure is too high, the start-up spring may not be strong enough to open the supply valve to let any air downstream, or the unit may fail prematurely.

Inability to reach maximum output pressure is an occasional complaint. The number one reason for this is that the supply pressure is lower than the maximum output. Make sure supply pressure is at least 5 psig higher than the maximum output of the unit.

The inability to get to the **zero** setting is another common problem, particularly in high output units. These have heavier start-up springs due to higher supply pressures. If the supply pressure is too low, the start-up spring exerts too much pressure, then the low setting becomes difficult to maintain. Make sure supply pressure is at least 5 psig higher than the maximum output of the unit.

Units in service – Occasionally, units in service may fail. Following are several potential failure modes with causes, remedies, and suggestions for preventing them in the future.

The number one reason for I/P failure is a blocked orifice. Passage of air from the regulated side through the orifice into the pilot chamber is critical. If the air or gas contains contamination and/or moisture, the orifice can become clogged. Slow reaction time to change of signal, or no reaction at all, are signs of a blocked orifice. This can be easily remedied by removing the orifice screw, and clearing the blockage, or replacing the screw. Better yet, it can be prevented by installing airline and/or coalescing filters before the I/P.

Occasionally, a unit will output supply pressure, and not regulate. Or, it will regulate, but will constantly be exhausting at a rate much greater than normal. This is a sign that either the main supply valve is not sealing, or there is a diaphragm failure. Typically, the supply valve is easily accessible. Contamination is the most common problem here. Clean the valve and the seat. Better filtration will prevent this in the future.

Also, check the seat to see if it is worn. Constant cycling of the supply pressure will slam the valve into the seat, causing it to deform over time. In high cycling applications, this can be prevented by making sure that solenoid valves are positioned after, not before the I/P.

Failure of the circuit board(s) and/or actuators may also occur. Most common reasons for this are contamination and/or excessive vibration. Attempts to minimize these conditions will extend the life of the I/P considerably.

The common thread here is that proper selection and installation combined with supplying clean and dry air/gas will result in properly working instruments for long periods of time.

ControlAir offers a wide variety of I/P products to suit most applications. To help make product selection easy, you can view and download the ControlAir I/P selection chart at:

[www.controlair.com/downloads/IP Selection Chart.pdf](http://www.controlair.com/downloads/IP%20Selection%20Chart.pdf)

If you would like to receive it as a wall poster, send an e-mail to [info@controlair.com](mailto:info@controlair.com).

Hopefully the information presented here will assist you in the future!