The debate concerning the relative merits of electronic versus pneumatic instrumentation took place in the middle of the 20th century. As can be seen from the references for this section, most of the arguments were published during that period, and little additional knowledge has been obtained in more recent decades. Although the debate has been concluded, and the process control industry has decisively moved into the electronic and digital age, knowing the arguments—the advantages and disadvantages of pneumatics versus electronics—can still be educational. For this reason, and because pneumatics are still used in the heating, ventilation, and air conditioning industry and in the control valve portion of control loops, this section has not been deleted from this handbook.

The main advantages of pneumatic systems over electronic instruments lies in their safety in hazardous locations and in the availability of qualified maintenance personnel. However, electronic systems are favored when computer compatibility, long transmission distances, or very cold ambient conditions are expected, or when long-term maintenance is to be minimized (Figure 1.4a).

Perhaps “Pneumatics versus High Technology” would have been a better title for this section. If a process plant uses digital electronic control, it is very difficult to justify the use of pneumatics. Naturally, when evaluating the advisability of pneumatics, one must evaluate the options of analog electronics, digital controllers with or without computers, distributed control systems, and programmable logic controllers. The relative merits of analog vs. digital controls are covered in Section 1.1 of this volume. In the discussion here, references are provided for further reading on the subject.

**FACTORS TO BE CONSIDERED**

In the debate some decades ago, some authors promoted electronics\(^1\)–\(^4\) and others pneumatics.\(^5\)–\(^9\) Table 1.4b summarizes the views on both pneumatic and electronic instruments that are expressed in the first nine referenced articles.

In the area of maintenance, the referenced literature\(^1\)–\(^18\) does not present convincing evidence that electronics guarantees reduced maintenance costs, but it does suggest that electronic instrumentation is easier to maintain and that the life of electronic instruments is longer. This is because of the wear on the pivot points, the change in spring elasticity and diaphragm stretch in pneumatic designs. Maintenance publications, such as those of ISA, have contributed to making maintenance easier by promoting modular component designs and self diagnostics.

The argument that pneumatic instruments need dry, clean air but electronic systems do not is not correct because many electronic control system include I/P (current-to-air) converters and electro-pneumatic valve positioners, which also require dry and clean air. Deuschle,\(^14\) in his detailed cost comparison, points out that the capacity required for the air compressor serving an electronic control system is about 60% of that required for a pneumatic system. For a specific application, the rating approach proposed by Tompkins\(^17\) can be considered for comparing the choice of pneumatics versus electronics.

**HVAC DAMPER ACTUATORS**

The relative performance of electronic and pneumatic damper actuators will be discussed below.

**Pneumatic Actuators**

Pneumatic dampers are usually throttled over a 5 PSI spring range such as from 8 to 13 PSIG. Over this range, the damper will move from the closed to the open position if there is no
friction and no process load, which resist the movement of the damper. Usually both are present.

**Hysteresis**

Resistance forces \( (F_R) \) are present, not only because there is friction between the stem and the hole through which it passes but because there also is linkage stiffness and axle bind at the rotary joints. Therefore, because the air is both the control signal and the power source, its pressure must rise beyond that required to break free and initiate movement, which results in overshoot. On the return stroke, the air signal pressure must drop below the spring force \( (F_S) \) before the spring will overcome friction and start returning the damper. On an actuator with a 4” stroke, this can result in a hysteresis of 1”.

**Spring Range Shift**

When a process load \( (F_L) \) exists on the damper, it will shift the throttling range of the damper. If the actuator area is 15 in.\(^2\), each pound of air signal pressure will generate 15 lb of added force on the diaphragm \( (F_A) \). Therefore, if the process load \( (F_L) \) is, say, 45 lb, that load will shift the throttling range of the damper by 3 PSIG. Depending on the failure position of the damper, either the lower or the upper limit of the range will be shifted. Consequently, if the process load \( (F_L) \) is 45 lb, the throttling of a fail closed (FC) damper will not occur between 8 and 13 PSIG, but the damper will throttle between 5 and 13 PSIG. Similarly a fail open (FO) damper will throttle between 8 and 16 PSI.

**Direct Coupled Electronic Actuator**

When a 2- to 10-VDC signal, generated by a 4- to 20-mADC signal passing through a 500-ohm resistor, directly operates the damper, performance is improved. This is because the direct coupled electronic actuator has a resolution of 160:1, allowing a positioning accuracy that can be as high as 120:1,\(^2\) which is much superior to that of a pneumatic actuator. This actuator uses an internal potentiometer to verify its position with respect to the control signal. Consequently, it is unaffected by friction and process load forces and obeys the relationship between control signal and internal potentiometer within +/-0.05 VDC.

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**Table 1.4b**

<table>
<thead>
<tr>
<th>Features</th>
<th>Electronics Superior</th>
<th>Pneumatics Superior</th>
<th>About Equal</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower initial hardware cost</td>
<td>11, 12, 13, 14, 15, 16, 17*</td>
<td>11</td>
<td></td>
<td>Ref. 13: Cost for either varies all over the map</td>
</tr>
<tr>
<td>Lower installation cost</td>
<td>10, 12, 13, 14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower total installed cost</td>
<td></td>
<td>12, 14, 15, 16*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simpler system design</td>
<td></td>
<td>13, 15, 16*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shorter check-out and start-up</td>
<td></td>
<td>11*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shorter training period</td>
<td></td>
<td>11*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher dependability (reliability)</td>
<td></td>
<td>11, 15, 16*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less affected by corrosive atmospheres</td>
<td></td>
<td>13, 14, 17*</td>
<td></td>
<td>Ref. 14: Air acts as a purge</td>
</tr>
<tr>
<td>Lower maintenance</td>
<td>12, 14, 17</td>
<td>11</td>
<td></td>
<td>Ref. 12 cites user experience</td>
</tr>
<tr>
<td>More compatible with control valves</td>
<td></td>
<td>13, 14, 18*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greater accuracy</td>
<td>11, 12, 16*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior dynamic response</td>
<td>11, 12, 13, 14, 15, 16, 17, 18*</td>
<td></td>
<td></td>
<td>Ref. 13: Normally, the fastest response is not necessary</td>
</tr>
<tr>
<td>Better suited for long transmission distances</td>
<td>11, 12, 13, 14, 15, 17, 18*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior computer capability</td>
<td>11, 12, 13, 14, 17, 18*</td>
<td></td>
<td></td>
<td>Ref. 13: This is the primary reason for selecting electronic instruments</td>
</tr>
</tbody>
</table>

1 Numbers refer to the references listed at the end of this section.

2 An asterisk marks the preference of this author.

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Pneumatic vs. Electronic

If the pneumatic actuator has no positioner, the problems of hysteresis and spring range shift will make its performance inferior to that of a direct coupled electronic design. If the pneumatic actuator is furnished with a positioner, its performance is improved. The amount of improvement depends on the quality of the positioner, which will determine how close the loop performance will approach that of the electronic actuator. In any case, it is not likely that the positioning accuracy of a pneumatic actuator will approach or reach that of an electronic one.

The relative costs of the installed pneumatic and electronic actuators are a function of the quality of the pneumatic positioner used. If the positioner is of reasonably high quality, the installed costs will be similar.

CONTROL SIGNALS

Putting together a pneumatic system can be relatively simple. The 3- to 15-PSIG (0.2- to 1.0-bar) air pressure signal range permits the teeing into of different manufacturers’ equipment with very few problems. Other pressure ranges are seldom used, except when there is reason to amplify the range, such as to 6 to 30 PSIG.

Much has been written about pneumatic transmission lags. In this regard the electronic system is superior; however, pneumatic systems have been successfully operated with 250- to 500-ft (75- to 150-m) lines. When boosters are used, distances of 1000 ft (300 m) and more can be considered. The longer distances can be attained by specifying such requirements as higher air capacities and the use of volume boosters and 3/8 in. (9.38 mm) OD tubing. In order to reduce transmission distances, field-mounted controllers can also be used. According to Buckley, serious limitations on performance are caused by:

1. Control valves without positioners
2. The use of 1/4 in. (6.25 mm) rather than 3/8 in. (9.38 mm) OD tubing
3. Restrictions in manual/automatic switch blocks and plug-in manifolds
4. Inadequate valve positioner air capacities
5. Single-acting (instead of double-acting) positioners on cylinder operators
6. Inadequate field air supplies
7. Multiple process lags

The most common analog electronic control or transmission signal is 4 to 20 mA DC. Considerable engineering must go into all-electronic systems because of impedance restrictions and polarity, power supply, shielding, and grounding requirements. In digital control systems, the buses and networks require substantial engineering, particularly in the area of the interfacing of different suppliers’ products.

The transmission range of the electronic system can be a mile or more with no time lag. However, this feature is important only in a minority of control loops.

With regard to electrical noise, pneumatic instruments are, of course, immune. Electronic systems do experience problems if shielding and grounding are inadequate. In recent years, many manufacturers have designed instruments protected against RFI (radio frequency interference).

CONVERTERS

A pneumatic system does not need additional hardware to operate an air-operated control valve, whereas an I/P converter must be installed if an electronic loop is to operate a pneumatic control valve. Because many transmitter outputs are inherently electronic, pneumatic loops also require I/P converters for applications involving such transmitters on temperature, flow, or analytical measurements.

Electronic systems are superior for data loggers, computers, distributed control, and/or programmable controller applications. The pneumatic system would require I/Ps, P/Is, and pneumatic scanning devices for these applications.

ELECTRICAL SAFETY

In many process industries, some locations are hazardous because of the presence of flammable gases, combustible dusts, and ignitable fibers. Therefore, equipment in hazardous areas must be designed so that it will not cause a fire or explosion (see Section 7.1 in Volume 1 of this handbook for details). Manufacturers and users agree that pneumatic instruments are inherently safe to use in installations in hazardous areas. On the other hand, analog and digital electronic instruments require special protection features if they are to operate in a hazardous environment.

If the area is Class I explosion-proof, where explosive or ignitable mixtures (in air) of flammable gases or vapors constitute the hazard, the electronics must meet different requirements. Divisions 1 and 2 are defined below:

Division 1: Location is likely to have flammable mixtures present under normal conditions or the operating process equipment is likely to require frequent maintenance
Division 2: Location is likely to have flammable mixtures present only under abnormal conditions

The initial and installed costs for electronic systems will be a function of the electrical classifications and of the selected approaches, which are used to meet the requirements of the
National Electrical Code. The choices include explosion-proof housings, purging, and intrinsically safe designs. For Division 2, nonincendiary, nonarcing, and hermetically sealed equipment can also be considered. (Refer to Chapter 7 in the Measurement volume and to References 24 to 26 in this section for more information.)

**THE MODERN DEBATE**

In selecting a control system one must examine the advantages and drawbacks of both analog and digital alternatives, which was the topic of Section 1.1 in this chapter. Digital controls are compatible with computers, distributed control systems, programmable controllers, and digital controllers.

**References**


**Bibliography**


