

# Manual on Installation of Refinery Instruments and Control Systems

## Part I—Process Instrumentation and Control Section 7—Transmission Systems

API RECOMMENDED PRACTICE 550  
THIRD EDITION, 1974

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## PREFACE

This section is one of a series which make up RP 550, Manual on Installation of Refinery Instruments and Control Systems. RP 550 is composed of four parts:

- Part I —Process Instrumentation and Control
- Part II —Process Stream Analyzers
- Part III—Fired Heaters and Inert Gas Generators
- Part IV—Steam Generators

Part I assays the installation of the more commonly used measuring and control instruments, as well as protective devices and related accessories; Part II presents a detailed discussion of process stream analyzers; Part III covers installation requirements for instruments for fired heaters and inert gas generators; and Part IV covers installation requirements for instruments for steam generators. These discussions are supported by detailed information and illustrations to facilitate application of the recommendations.

With this third edition, the format of RP 550, Part I has been changed to facilitate continuity of presentation, convenience of reference, and flexibility of revision. Each section is now being published individually as follows:

- Section 1—Flow
- Section 2—Level
- Section 3—Temperature
- Section 4—Pressure
- Section 5—Automatic Controllers
- Section 6—Control Valves and Accessories
- Section 7—Transmission Systems
- Section 8—Seals, Purges, and Winterizing
- Section 9—Air Supply Systems
- Section 10—Hydraulic Systems
- Section 11—Electrical Power Supply
- Section 12—Control Centers
- Section 13—Alarms and Protective Devices

In the preparation of these documents, it was necessary to decide on a logical method of presentation: should each point be explained as fully as possible, or should extensive cross-referencing be done between sections?

The final documents contain a combination of these methods of presentation. An attempt has been made to make each section as complete as possible, with cross-referencing done only where very extensive repetition would have been required.

Users of this recommended practice are cautioned to obtain a complete set of sections in order to efficiently accomplish any cross-referencing that is required for a full understanding of the subject matter.

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## FOREWORD

This recommended practice is based on the accumulated knowledge and experience of engineers in the petroleum industry. Its purpose is to aid in the installation of the more generally used measuring, control, and analytical instruments; transmission systems; and related accessories in order to achieve safe, continuous, accurate, and efficient operation with minimum maintenance. Although the information contained herein has been prepared primarily for petroleum refineries, much of it is applicable without change in chemical plants, gasoline plants, and similar installations.

Successful instrumentation depends upon a workable arrangement which incorporates the simplest systems and devices that will satisfy specified requirements. Sufficient schedules, drawings, sketches, and other data should be provided to enable the constructor to install the equipment in the desired manner. The various industry codes and standards, and laws and rulings of regulating bodies should be followed where applicable. The information contained in this publication does not constitute, and should not be construed to be, a code of rules or regulations. Furthermore, it does not grant the right, by implication or otherwise, for manufacture, sale, or use in connection with any method, apparatus, or product covered by letters patent; nor does it ensure anyone against liability of infringement of letters patent.

For maximum plant personnel safety, transmission systems are employed to eliminate the piping of hydrocarbons, acids, and other hazardous or noxious materials to instruments in control rooms. Proper installation is essential in order to utilize the full capabilities which are built into the instrument or transmission system.

In the installation of an instrument, the various components must be accessible for efficient maintenance and certain of these elements must be readable for good operation. Orifices, control valves, transmitters, thermocouples, level gages, and local controllers, as well as analyzer sample points, generally should be readily accessible from grade, permanent platforms, or fixed ladders. In this manual, special consideration is given to the location, accessibility, and readability of the elements.

Users of the various sections of this manual are reminded that in the rapidly advancing field of instrumentation no publication of this type can be complete, nor can any written document be substituted for qualified engineering analysis.

Certain systems are not covered herein because of their very specialized nature and limited use. When one of these systems gains general usage and installation reaches a fair degree of standardization, this section will be revised to incorporate such additional information.

Acknowledgment is made of the work of all the engineers and operating and maintenance personnel who, through years of study, observation, invention, and sometimes trial and error, have contributed to the technology of instrumentation.

Suggested revisions are invited and should be submitted to the director of the Division of Refining, American Petroleum Institute, 2101 L Street, N.W., Washington, D.C. 20037.

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## PART I—PROCESS INSTRUMENTATION AND CONTROL

### SECTION 7—TRANSMISSION SYSTEMS

#### 7.1 Scope

Section 7 discusses recommended practices for the installation of pneumatic and electric measurement and control signal transmission systems. Leased wire and radio transmission are not discussed. The methods described are those generally used throughout the United States. They are based on the assumption that measuring transmitters, transducers, valve positioners, control valves, and other field-mounted devices are properly installed in accordance with the recommendations in the other sections of this manual. It is also assumed that the wiring, piping, and tubing at the control panel comply with requirements in API RP 550, Part I, "Section 12—Control Centers." Fig. 7-1 through 7-4 illustrate comparative pneumatic and electronic arrangements for a typical processing plant installation.

#### 7.2 General

##### 7.2.1 ADVANTAGES OF TRANSMITTED SIGNALS

The use of transmission systems that permit operation of one or more large process units from a remote control center increases personnel safety and convenience. Because the measuring device or transmitter is at, or as near as possible to, the point of measurement, certain advantages accrue. This arrangement reduces to a minimum:

1. The amount of connecting piping carrying process fluids, which may be unstable, corrosive, toxic, viscous, or subject to freezing.
2. The need for purging, sealing, heat tracing, and winterizing.
3. The presence of hazardous or noxious fluids in, if not totally excluded from, the control center.

##### 7.2.2 TRANSMISSION SYSTEM DESIGN CONSIDERATIONS

Major factors in transmission system design that should be considered are:

1. The relationship of time constants between process and transmission and control lines, since this relation-

ship may influence a loop's actual performance.

2. Reliability of air and electric power supplies.

3. Routing and installation of tubing, wiring, and piping so as to reduce the possibility of damage from fire, overheating from hot process lines or equipment, and mechanical abuse.

4. Materials and construction to resist corrosion due to chemicals in the atmosphere or splatter from new construction or maintenance work.

5. Provisions for manual control, testing, and ready access to instruments for maintenance.

#### LEGEND

|        |                                                           |
|--------|-----------------------------------------------------------|
| ○      | THERMOCOUPLE POINT                                        |
| □ LA   | LEVEL ALARM FIELD CONTACTS                                |
| □ FA   | FLOW ALARM FIELD CONTACTS                                 |
| □ PA   | PRESSURE ALARM FIELD CONTACTS                             |
| A      | VALVE POSITIONER—TYPE 132 C3                              |
| B      | ELECTRO-PNEUMATIC TRANSDUCER TYPE 138 C3                  |
| C      | PRESSURE TRANSMITTER                                      |
| D      | DIFFER. PRESSURE TRANSMITTER                              |
| E      | LEVEL TRANSMITTER                                         |
| ⊕      | INDICATING RECEIVER                                       |
| ⊖      | INDICATING RECEIVER                                       |
| CV     | CONTROL VALVE                                             |
| CV 3   | CONTROL VALVE WITH POSITIONER                             |
| CV 4   | CONTROL VALVE WITH YOKE-MOUNTED CONTROLLER                |
| CV 4   | CONTROL VALVE WITH YOKE-MOUNTED CONTROLLER AND POSITIONER |
| CV 102 | DUAL CONTROL VALVE WITH MECHANICAL LINKAGE                |
| LC 101 | DIFFERENTIAL TYPE LEVEL INSTRUMENT                        |
| LC 4   | LOCAL INSTRUMENTS                                         |
| LC 4   | EXTERNAL DISPLACEMENT TYPE LEVEL INSTRUMENT               |
| —      | INSTRUMENT AIR SUPPLY LINE                                |
| —      | CONTROL OR TRANSMITTED AIR LINES                          |
| ③      | NUMBER OF LINES REPRESENTED                               |
| ⑥      | MULTI-TUBE CABLE & CABLE NO.                              |

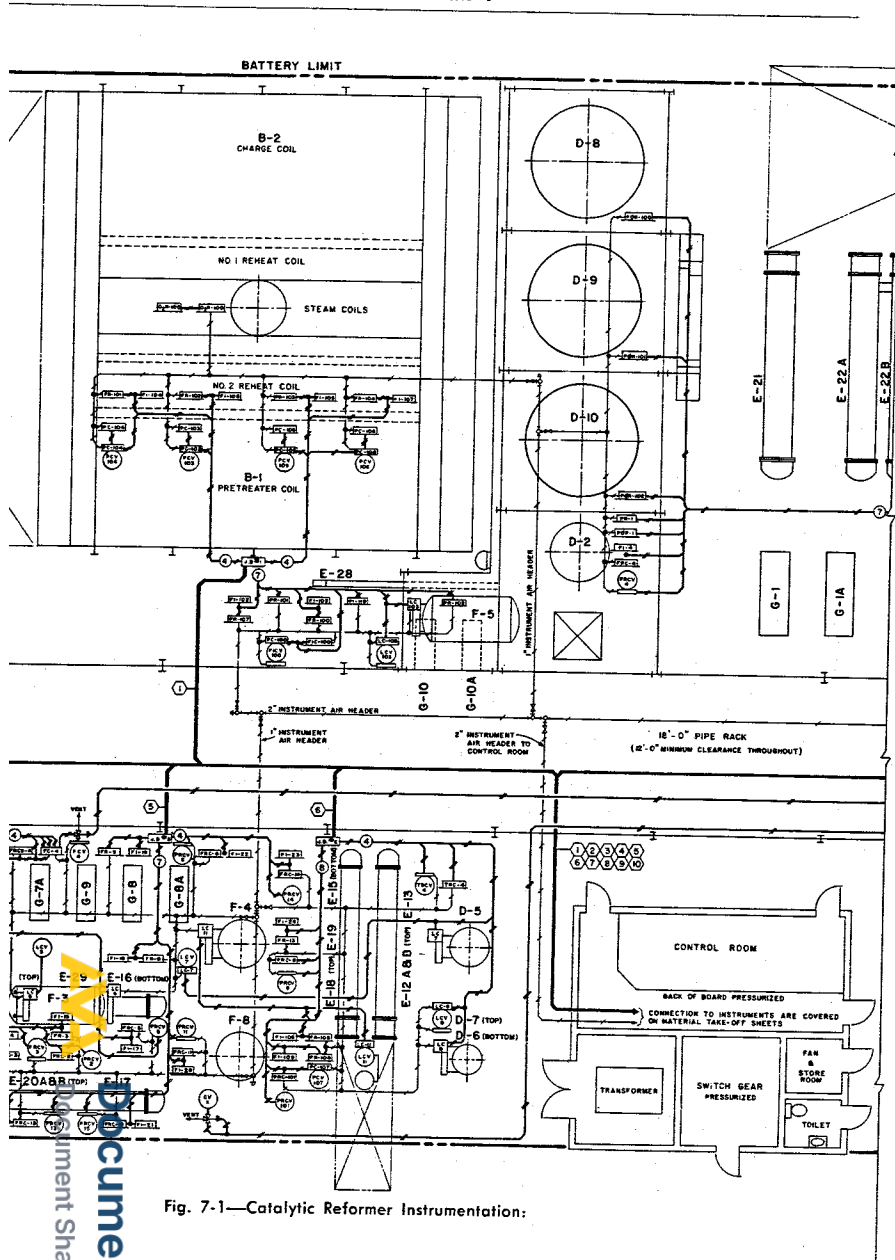
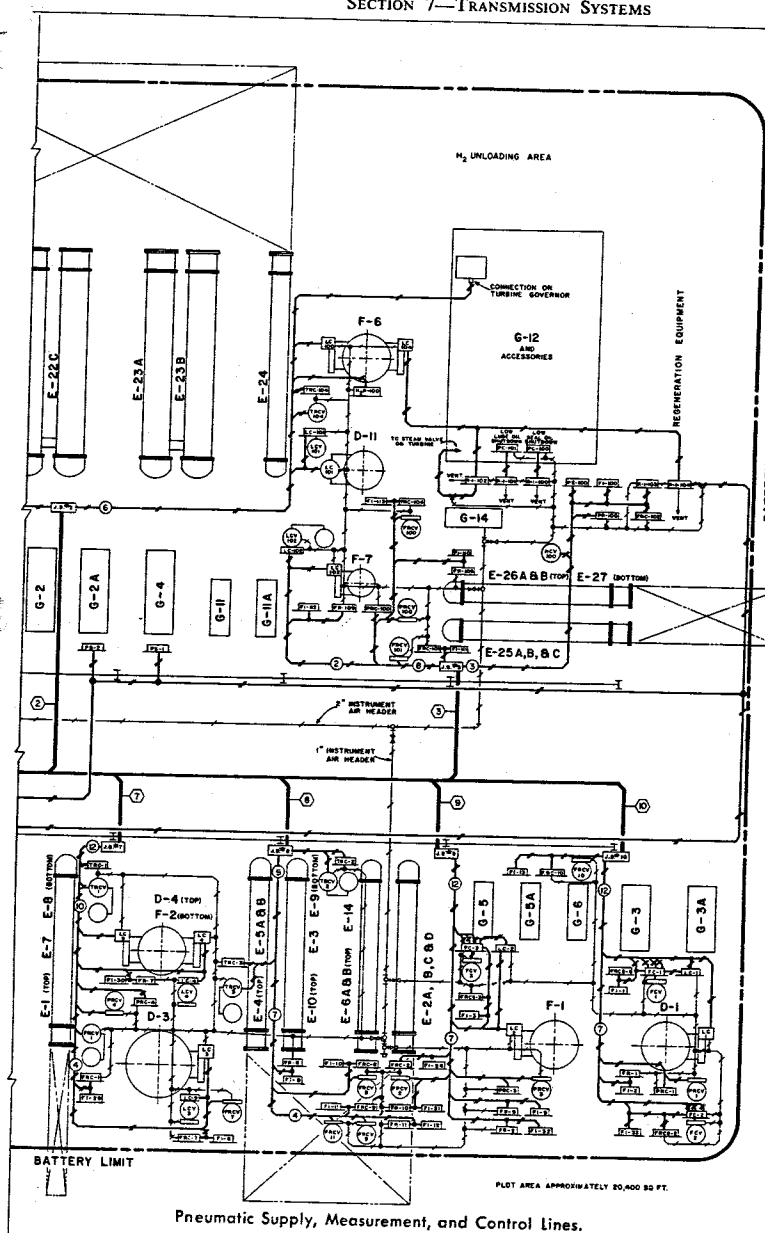
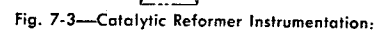


Fig. 7-1—Catalytic Reformer Instrumentation:

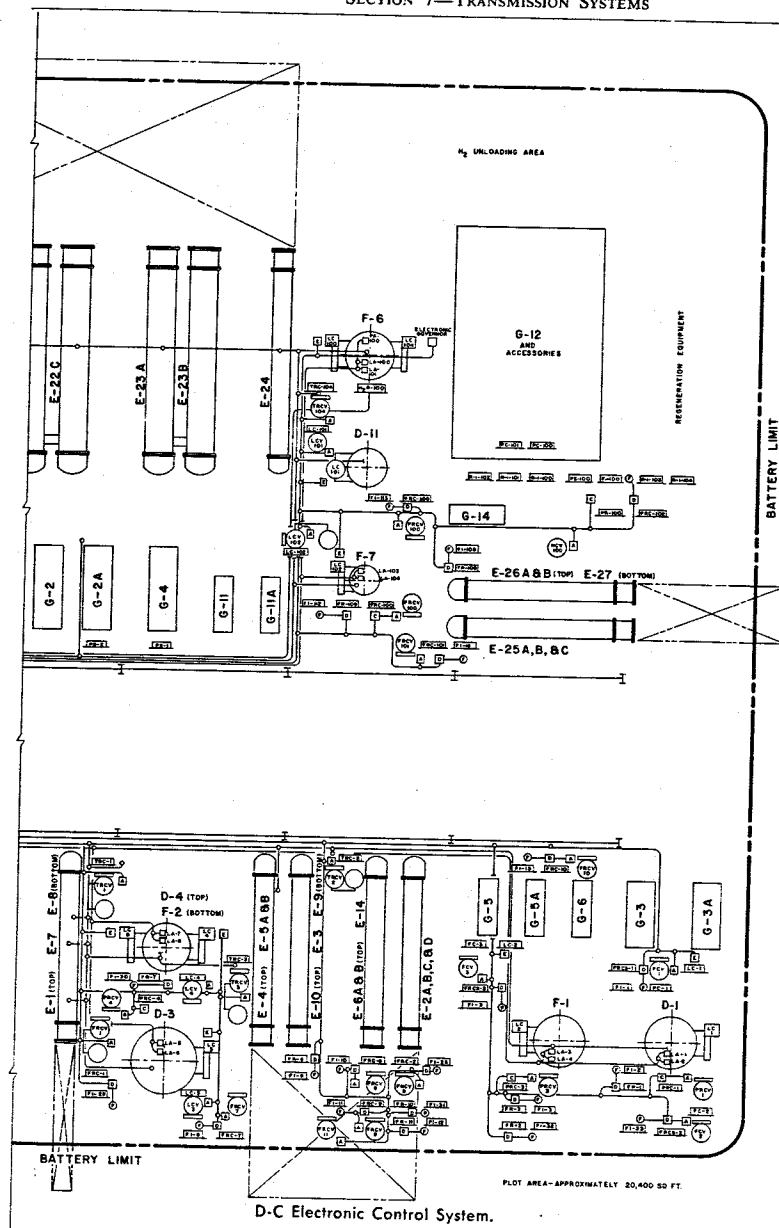


Pneumatic Supply, Measurement, and Control Lines.





## 7



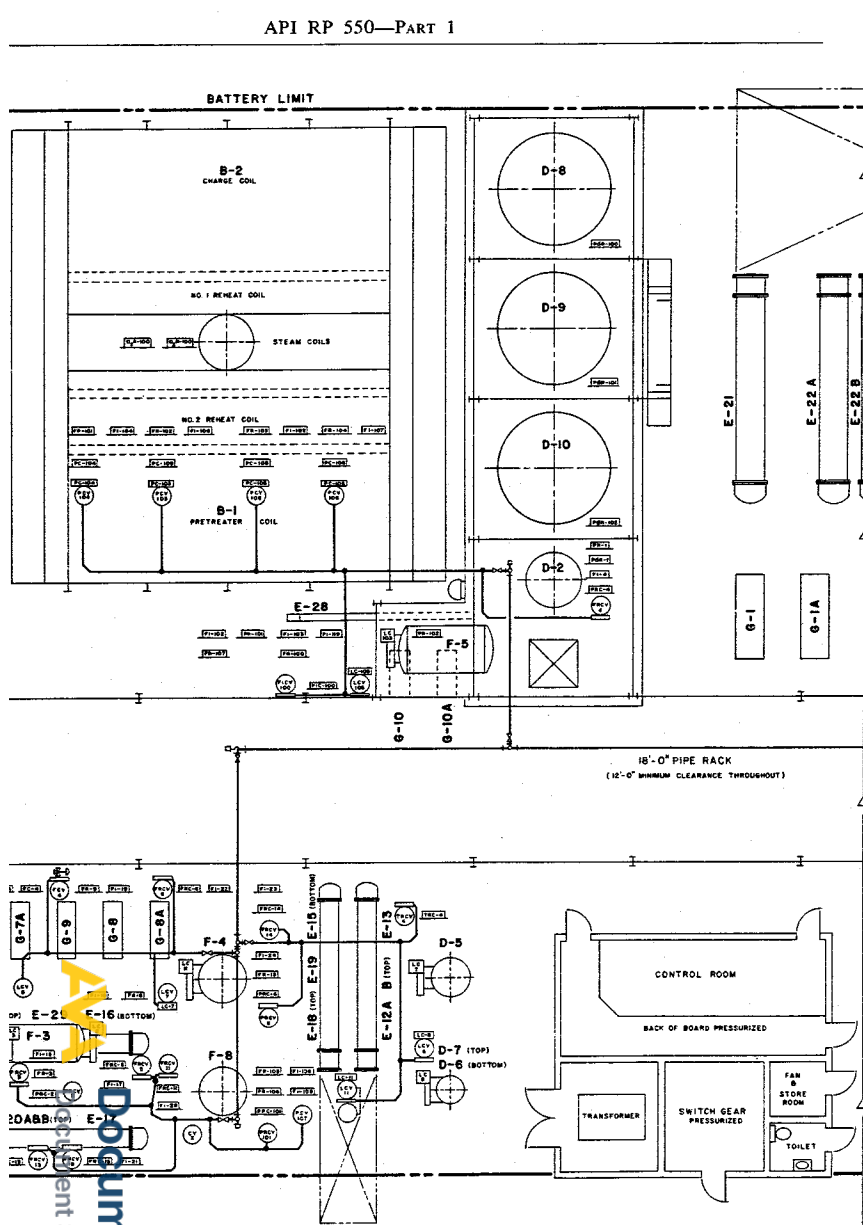
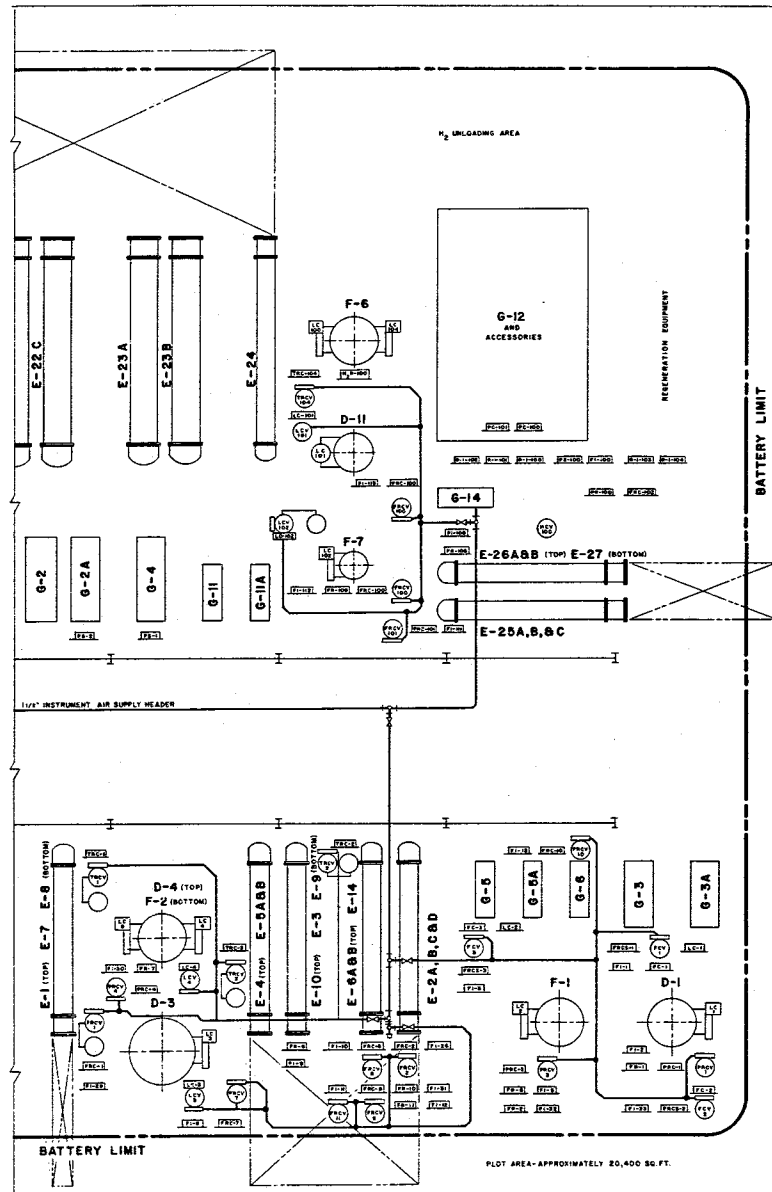


Fig. 7-4—Catalytic Reformer Instrumentation:



Electronic Control System (Air-Operated Valves).

ments and the effect of federal regulation and local codes.

ture field-control room interface re-addition of a digital process com-

## ic Systems

ssmission has been used in processing than thirty years. Because of its desirable features, it is still preferred where transmission process time consume. A typical refinery layout for y, measurement, and control lines is and 7-2.

nally used for pneumatic transmission rred size is ¼-inch outside diameter ical wall thickness variation from 0.030 This size gives optimum performance, um transmission time constant versus -handling capacity—approximately 1 ot per minute (scfm)—of the majority smitters and controllers. Tubing of h a typical wall thickness variation 062 inches is used in instances where nd controller have greater air-handling scfm, and transmission time constants for good overall control. Refer to API "Section 5—Automatic Controllers."

## RD PNEUMATIC SIGNAL RANGES

is industries, the preferred transmission : 3 to 15 pounds per square inch gage ished by SAMA \* Standard PMC 2- sure for Pneumatic Controllers and stems. Another pressure range 3 to established in this same SAMA Stan- r range is normally confined to boiler special applications.

duty operators are involved, the conal of 3 to 15 psig is amplified to pres- 1 psig through the use of valve posi- c relays, or other boosters. Also, the ol signal is coupled with high-pressure s to provide greater power for position- rs, such as those used on the slide c cracking processes.

aratus \* American Association, 370 Lexington , N.Y. 10017

## 7.3.3 TUBING AND FITTING MATERIALS

### 7.3.3.1 General

No one tubing material or configuration, single tube or bundled tubes, is universally satisfactory for all installations. Some of the points to be considered are:

1. Environmental factors, such as climatic temperature extremes, effect of sunlight, exposure to corrosive materials, and exposure to vibration.
2. Installation costs.
3. Material costs.

Tubing material is either metallic or plastic. Both metallic and plastic tubes are available as singles or in bundles. Single metallic tubes with a plastic coating or sheath are also available.

### 7.3.3.2 Single Metallic Tubes

The preferred metallic tubing material for transmission installations is copper, particularly in instances where bare single tubes are installed. Although copper can be made to various degrees of hardness, dead-soft annealed copper tubing is generally preferred. Aluminum is used in special cases. Stainless steel may be used in very special cases.

Brass tubing fittings are used with copper tubing. However, from the many types available good quality flareless fittings that are easily and simply installed should be selected to minimize leaks. Long continuous tubing runs should be used to minimize the number of joints. API RP 550, Part 1, Section 5 discusses fitting characteristics relative to flow restrictions.

Because of the presence of deteriorating substances in processing plant atmospheres, longer and more reliable service can be obtained on single copper tubing runs by using plastic-coated tubing. Two common coatings are polyethylene and polyvinyl chloride (PVC). Bare ends and fittings must be protected or they will corrode; see Par. 7.3.4.2.c.

Aluminum tubing is often preferred for locations where atmospheric sulfur attack may be expected. However, even though bare aluminum tubing is resistant to sulfur attack, it is subject to deterioration by other compounds. It can be corroded by salt-contaminated atmospheres. It is also subject to electrolytic corrosion when in contact with other metals and should be installed electrically isolated (insulated) from them. Magnesia insulation severely corrodes aluminum material. Similarly, pits and pinholes have developed in aluminum tubing due to corrosion from spray or rebound from guniting. Therefore, in areas where con-

siderable guniting is probable or where scraps of insulation can lodge on the tubing, some sort of permanent protection should be provided. Most users will install aluminum tubing only if it is sheathed in plastic, such as polyethylene or PVC. Aluminum tubing is more vulnerable to fire and arc welding sparks than is copper tubing. Vibration often causes aluminum tubing to work-harden and crack and, for this reason, only soft annealed aluminum tubing should be used. When installing aluminum tubing, care should be taken not to stretch it because it has a tendency to pull apart.

Anodized aluminum tubing fittings (flareless type) are normally used with aluminum tubing. The anodizing:

1. Provides corrosion resistance.
2. Helps prevent galling of the fitting at the ferrule and the threads.

### 7.3.3.3 Single Plastic Tubes

Plastic tubing can be obtained in several materials each of which has its own particular chemical and physical characteristics. These should be thoroughly explored and compared to the expected operating environment in order to make a satisfactory selection. A comparison of the properties of plastic tubing is given in Table 7-1.

Individual plastic tubes are light, corrosion-resistant, and sufficiently resilient to withstand flexing or vibration. However, most of these plastic tubes cannot withstand elevated temperatures and some even support combustion. Plastic tubes lose strength at elevated temperatures and, as a result, the use of bare single plastic tubes must be limited to areas in which tubes will not be exposed to fire, overheating from adjacent equipment, or sparks from arc welding. Bundled plastic tubing that is more fire resistant than individual tubes can be obtained. At low temperatures plastic tubing flexibility is reduced. Because one cannot predict what the exact temperature will be at the time of installation, it is not good practice to specify tubing for which the manufacturer's stated "minimum installation temperature" is higher than the lowest temperature to be expected at the plant site during the time actual installation will be accomplished.

Long-term, leak-free installations have been achieved by careful selection and installation of fittings for plastic tubing. Metal fittings are often used with plastic tubing. Some, specifically designed for plastic tubing, are equipped with metal inserts to reinforce the end of a tube and strengthen its joint. Plastic ferrules are sometimes used with metal fittings. Also available are plastic fittings, some of which can be crimped in

place with a special crimping tool. Crimping requires the joint be completed before the special crimping tool can be removed.

### 7.3.3.4 Bundled Metallic Tubes

Bundled metallic tubing is available from several manufacturers in a variety of material combinations, including variations in tubing materials, protective coatings, and armor. Copper is the most popular material for bundled metallic tubing and is available in three sizes: ¼-inch OD by 0.030-inch wall; ⅜-inch OD by 0.032-inch wall; and ½-inch OD by 0.035-inch wall. Aluminum tubing is also offered as a standard but only in ¼-inch OD by 0.035-inch wall size. Some manufacturers offer ¼-inch OD steel tubing.

Metallic tubing is available in parallel or spiral lay, both of which are used extensively. The spiral lay has a shorter minimum bending radius than the parallel lay and is normally selected when an installation requires much bending and weaving. The length of the lay (feet/crossover) varies with each manufacturer. Some make the lay long to achieve optimum flexibility for ease of attaching fittings at the junction box.

The metallic tubes are each continuously numbered throughout their entire length at approximately two-inch intervals to permit positive identification of every tube. In addition, some manufacturers include an insulated conductor for sound-powered phones to facilitate installation connections and instrument calibration.

The metal tube bundles may be wrapped with a plastic tape and encased in flexible armor, or they may be directly encased in a heavy extruded plastic jacket. If further protection is required, a thick extruded plastic may be used to cover the tape and this cover may be further protected by flexible armor which also may have a plastic jacket. Available materials of construction are:

1. Tape (around the tubing bundle), such as asphalt-impregnated jute, Mylar®, or vinyl insulating tape.
2. Flexible armor, such as galvanized steel, aluminum, bronze, or monel.
3. Extruded plastic jacket (directly over the metallic tube bundle or tape wrapping), such as polyethylene or PVC.
4. External jacket (over the flexible armor), such as asphaltized jute or PVC.

Single metallic tubes in a bundle utilize standard tubing fittings as discussed in Par. 7.3.3.2. The complete bundle is connected to a junction box (Fig. 7-5,

® Registered trademark.

Table 7-1—Properties of Plastic Tubing

| Properties (see Note 1)               | Low-Density Polyethylene | High-Density Polyethylene | Nylon        |
|---------------------------------------|--------------------------|---------------------------|--------------|
| Specific gravity/cubic centimeter     | 0.92                     | 0.955                     | 1.05         |
| Tensile strength, psi                 | 2200                     | 3000                      | 3800         |
| Elongation at break, % (see Note 2)   | 32000                    | 92000                     | 40000        |
| Tensile strength, pounds (see Note 3) |                          |                           |              |
| 1/2 in. ch                            | 32                       | 70                        | 65           |
| 3/4 in. ch                            | 70                       | 142                       | 160          |
| Bending Radius, inches                |                          |                           |              |
| 1/2 in. ch                            | 3/4                      | 1                         | 3/4          |
| 3/4 in. ch                            | 1 1/2                    | 1 3/4                     | 1 1/4        |
| Bending Temperature, °F               | -70                      | -70                       | -70          |
| Operating temperature, °F             |                          |                           |              |
| 1/2 in. red                           | -100 to +130             | (see Note 6)              | (see Note 6) |
| 3/4 in. red                           | -100 to +175             | -70 to +220               | -70 to +230  |
| Pressure, psig                        |                          |                           |              |
| 1/2 in. x 0.040 in.                   | 400                      | 950                       | 825          |
| 3/4 in. x 0.040 in.                   | 240                      | 575                       | 600          |
| Characteristics                       |                          |                           |              |
| 1. Resistance                         | Poor                     | —                         | —            |
| 2. Resistance                         | Good                     | Good                      | Fair         |
| 3. Resistance                         | No (see Note 4)          | No                        | No           |
| 4. Resistance                         | (see Note 5)             | (see Note 5)              | Excellent    |
| 5. Resistance                         | (see Note 6)             | (see Note 6)              | Poor         |
| 6. Resistance                         | (see Note 6)             | (see Note 6)              | Very Poor    |
| 7. Resistance                         | (see Note 6)             | (see Note 6)              | Very Poor    |
| 8. Resistance                         | Poor                     | Poor                      | Do Not Use   |
| 9. Resistance                         | None                     | None                      | None         |
| 10. Resistance                        | None                     | None                      | None         |

polyethylene Copolymer, called PVC, with added plasticizers, fillers, stabilizers, etc., is used for instrument air tubing because it becomes brittle slightly below 0 F, or long-term dimensional stability (i.e., with pressure as low as 15 psig air, it will increase in size without reaching any equilibrium). It is flame resistant and has other good properties for use as tubing jacketing. The lower numbers are more flexible.

It can be exerted without permanent deformation.

Highly available are compounded low-density polyethylenes with additives for flame resistant characteristics.

Low-density polyethylene is insoluble in practically all solvents, although it will swell in some degree. Environmental stress cracking can occur unless the highest grades are used. At temperatures of 100 F or less there is no noticeable swelling. Polyethylene is often used as instrument air tubing. At temperatures above 100 F it becomes increasingly soluble in aliphatic and chlorinated hydrocarbons. It increases slightly as the density increases. In other words, high-density polyethylene is more chemically resistant than low-density polyethylene. Information suggested.

7-6, and 7-7) or at a panel by means of terminal fittings designed for the specific type of bundle configuration. Appropriate terminal fittings are available from the bundled tube manufacturer.

### 7.3.3.5 Bundled Plastic Tubes

Bundled plastic tubing, like bundled metallic tubing, is available from several manufacturers in a variety of material combinations, including variations in tubing materials, protective coatings, and armor. Polyethylene is the most popular tubing material for bundled plastic tubing. Virgin polyethylene of either 1/4-inch OD by 0.040-inch wall size or 3/8-inch OD by 0.062-inch wall size is recommended. Both low- and high-density polyethylene tubing is available. High-density polyethylene is stiffer, harder, less easily cut, and has a higher pressure rating than low-density polyethylene. Some manufacturers offer heat stabilized nylon plastic bundled tubes in three sizes: 1/4-inch OD by 0.030-inch wall; 3/8-inch OD by 0.035-inch wall; and 1/2-inch OD by 0.035-inch wall. Heat stabilized nylon can withstand service temperatures to 230 F.

One advantage of bundled plastic tubing, when compared to bundled metallic tubing, is its flexibility. When unarmored, it has a shorter minimum bending radius than does bundled metallic tubing. However, some plastic materials become brittle at low ambient temperatures. Thus, the tubing selected should have a manufacturer's stated minimum installation temperature below that expected at the plant site.

For resistance to aging from sunlight, almost all plastic tubes are compounded with carbon and are black in color. When all the tubes in the bundle are black, each tube is continuously numbered through its entire length at approximately two-inch intervals to permit positive identification. Where sunlight aging is not a problem, some manufacturers can supply tubes of different colors as a means of positive identification. There is a practical limit to the number of tubes in a bundle that can be easily identified by color coding. To facilitate making connections during installation and instrument calibration, some manufacturers include a pair of communication wires in the bundled plastic tubing.

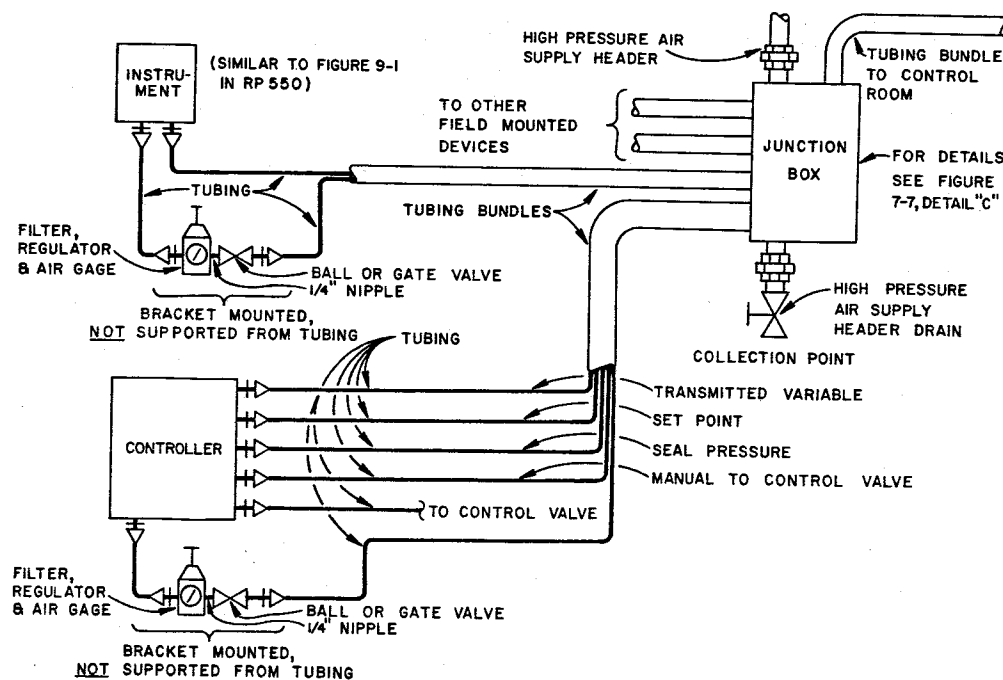
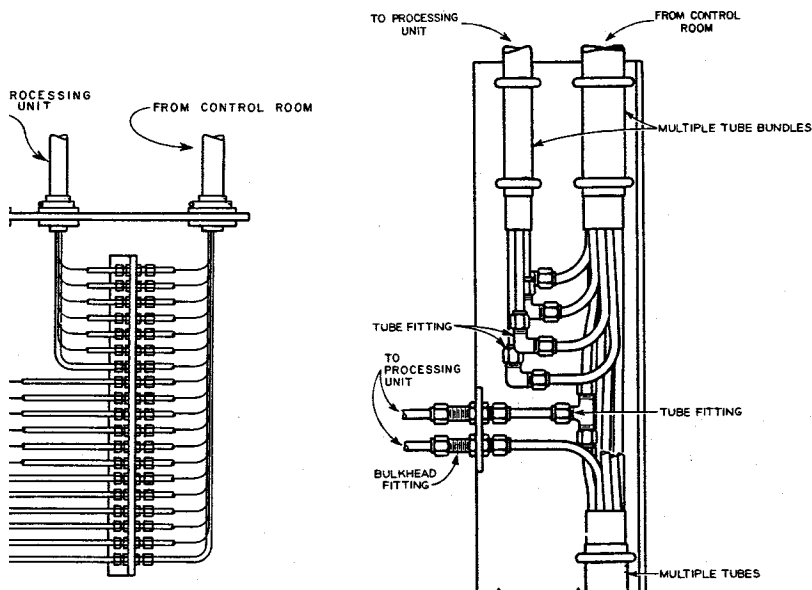


Fig. 7-5—Bundled Tubing Usage at Process Unit.



junction arrangement to join several small one large tubing bundle.

NOTE: Suggested method for breakout from a large continuous bundle to a small bundle and single tubes.

Fig. 7-6—Typical Unenclosed Junction for Use in Collection Area.

be bundles are wrapped with a plastic encased in either flexible armor or an jacket. If protection is required against arrangement of thermal barriers, fire like can be provided. Some of the als of construction are:

d tubing bundle), such as Mylar® or ape.

or, such as galvanized steel, aluminum, l.

stic jacket (over tape wrapping), such thylene.

et (over flexible armor), such as PVC

istic tubes in a bundle utilize the same ngs as do individual plastic tubes dis- 7.3.3.3. The complete bundle is con- tion box or at a panel (Fig. 7-5, 7-6, ans of terminal fittings designed for the f bundle configuration. Appropriate

terminal fittings are available from the bundled tube manufacturer.

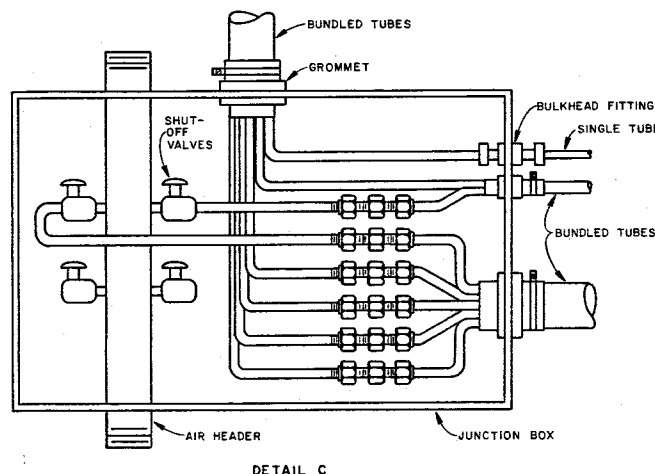
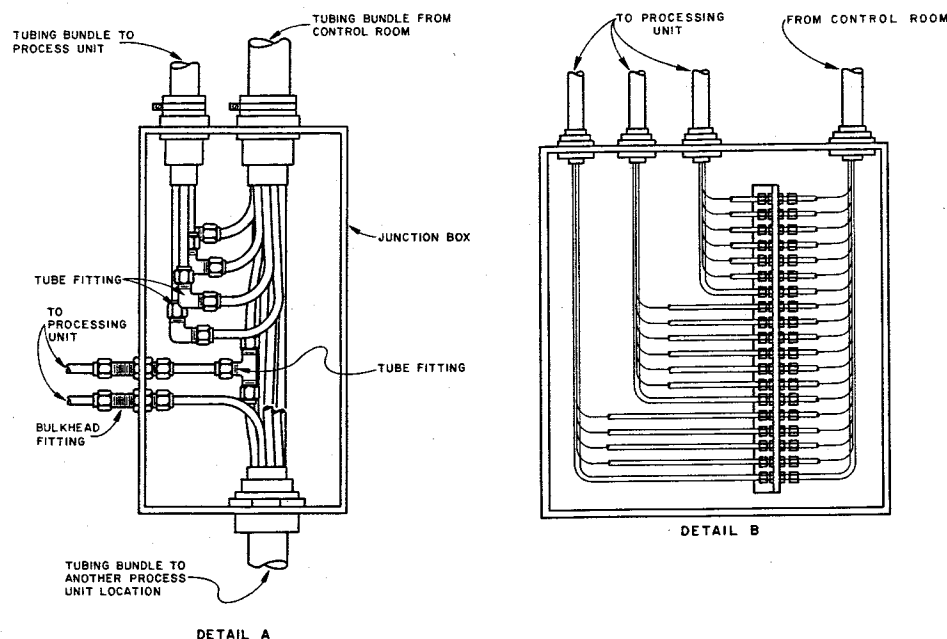
### 7.3.4 INSTALLATION

#### 7.3.4.1 General

Single or bundled tubes may be run from field-mounted instruments to the central control room. The selection of either single or bundled tubes is based on engineering economics guided by the information contained in Par. 7.2.2 and 7.3.3.1.

Single or bundled tubes run from various field-mounted instruments to collection points around a processing unit. From the various collection points the tubes meet and follow a common route to the control room. Fig. 7-1 illustrates this. Individual tubes are run to junction boxes, which serve as collection points, and then from each of the junction boxes, bundled tubes are routed together to the panel in the control room.

On another installation, a more economical arrangement might be to eliminate junction boxes and to run long-length single tubes from the field directly to the



DETAIL A  
NOTE: Junction box utilized for breakout from a large continuous bundle to a small bundle and single tubes.

DETAIL B  
NOTE: Junction box used to join several small tubing bundles to one large tubing bundle utilizing a terminal plate and bulkhead fitting.

DETAIL C  
NOTE: Junction box combining an air header and connections between a large tubing bundle and a variety of takeoffs.

Fig. 7-7—Enclosed Junction Box Configurations.