Draft

Stationary Source Enforcement Series

ENFORCEMENT WORKSHOP ON PLANT INSPECTION AND EVALUATION

VOLUME III
PROCESS AND CONTROL EQUIPMENT FLOW CHARTING TECHNIQUES

February 1979

U.S. ENVIRONMENTAL PROTECTION AGENCY
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ENFORCEMENT WORKSHOP ON

PLANT INSPECTION AND EVALUATION

Volume III
Process and Control Equipment
Flow Charting Techniques

Prepared by
John R. Richards
PEDCo Environmental, Inc.
505 S. Duke Street
Durham, North Carolina 27701

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February 1979

FLOWCHARTING TECHNIQUE FOR FIELD INSPECTIONS

A flowchart, by definition, shows the flow of materials through a process. The charts twofold purpose is to simplify a complicated process and to improve communications among people who design, maintain, or operate the process equipment. These people are usually industrial personnel or process engineers. However, the installation of control equipment to reduce emissions from process equipment has created a new group of users--the field inspectors.

The following types of flowcharts are typical of those used by engineers:

Process control instrumentation	Piping design
Material balance	Utility Supply Systems
Electrical system design	Process block diagrams

Two of these types, the process block and the process control instrumentation, have information on plant utilities and material balances that is needed by inspectors for routine evaluation of control equipment performance. With this information, the inspector identifies:

Control equipment type	Emission points
Series or parallel layout	Operating conditions

The typical flowcharts posted on control room monitoring panels too often include too much detail on the process and not enough on the controls.

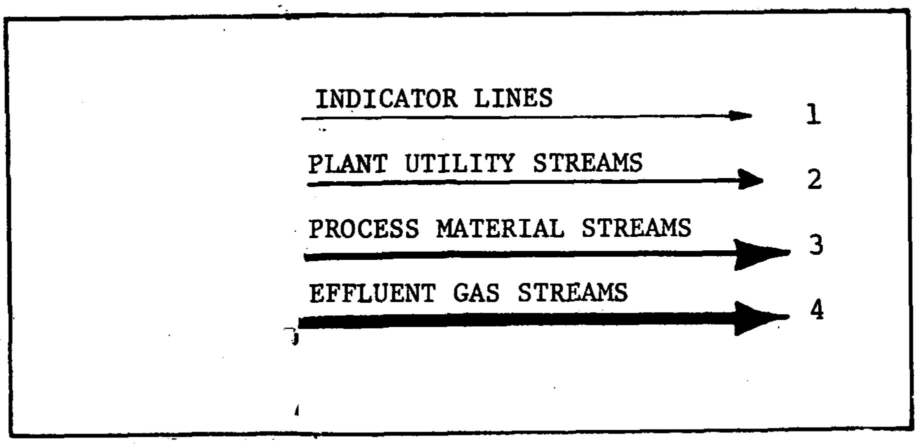
This handout is a guide for creating flowcharts that represent control systems. It is designed to lead you through a step-by-step preparation using many well known and some newly designed sysmbols and notations for:

Effluent gas streams	Plant Utility streams
Emission points	Process and control equipment
Material streams	Instrumentation

The explanations and examples used to present this approach to a flowcharting technique become increasingly involved as the steps in the preparation proceed from the basic lines and to the additions of symbols that represent flows, emissions, equipment, and so forth that make up the complete flowchart.

1.0 FLOW LINES AND EMISSION POINTS

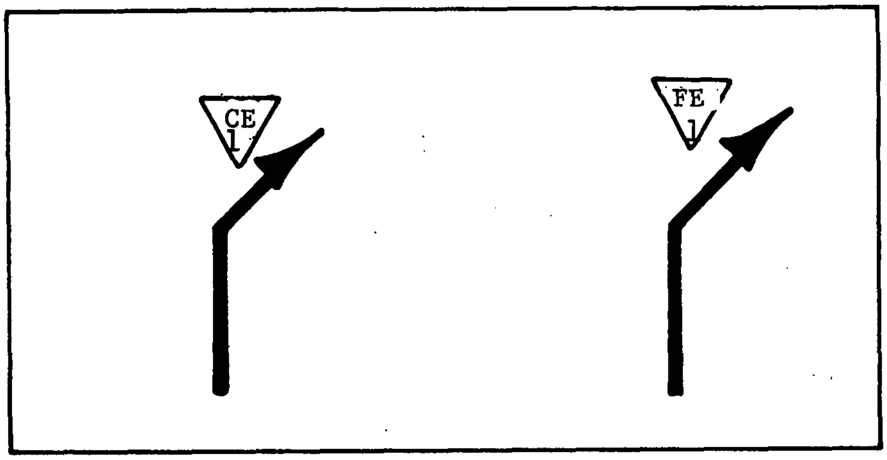
Four line widths (Example 1) are used in the flowchart technique developed herein. Each represents a separate part of a process, as shown by the labels on the lines in the example.



Example 1

The arrow on the ends of the lines indicate either the location of equipment (line 1) or the direction of flow of a stream (lines 2, 3, and 4)

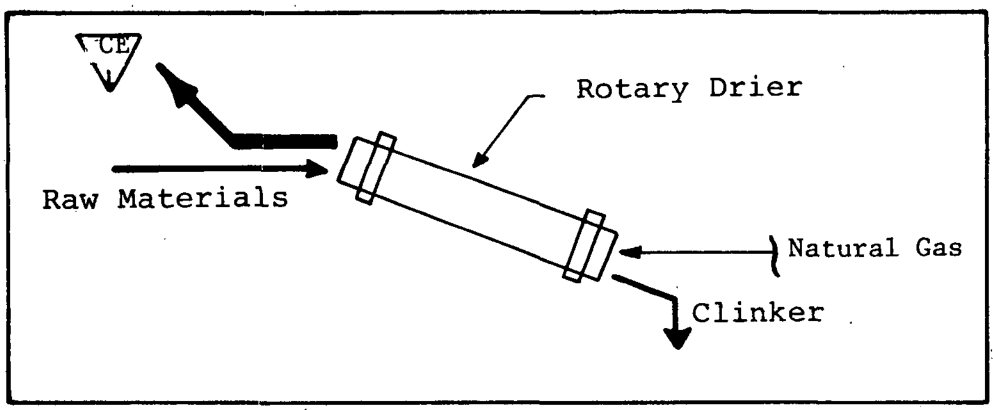
The triangle-shaped label (example 2) is a notation that differentiates between types of sources: the CE denotes contained effluent and the FE denotes fugitive effluent. The number in the triangle identifies the emission point; this number is assigned from left to right in the process flow by the inspector.



Example 2

The widest, most eyecatching line (#4), was chosen for the contaminated effluent gas stream because it is generally the stream of primary interest to inspectors.

The medium line (#3) represents major material streams in the process; inclusion of all would overcrowd and complicate the chart unnecessarily. In a power plant, this major stream would be the flow of coal feed to the boiler; in te Kraft pulp mill, it would be the black liquor, digested pulp, and several others. In Example 3, the raw materials flow through the drier into the clinker.



Example 3

The fine lines (#1 and #2) may point to equipment such as a rotary drier or to the flow of a substance such as natural gas (Example 3). The inverted-S indicates that the natural gas flow system is not shown.

The last pages of this handout (pp. 15-22) are pictorial representations of process equipment, control equipment, accessories, and pipes and flow lines. Each pictorial symbol has lines of varying width for effluent gas, major material, and plant utility streams, as appropriate. Most of these symbols are in common use.[1,2] Others have been created for this handout. Still others may need to be developed by inspectors to communicate basic information on control system designs and operating characteristics. So, empty blocks are provided on the last pages for adding more symbols.

2.0 PLANT UTILITIES

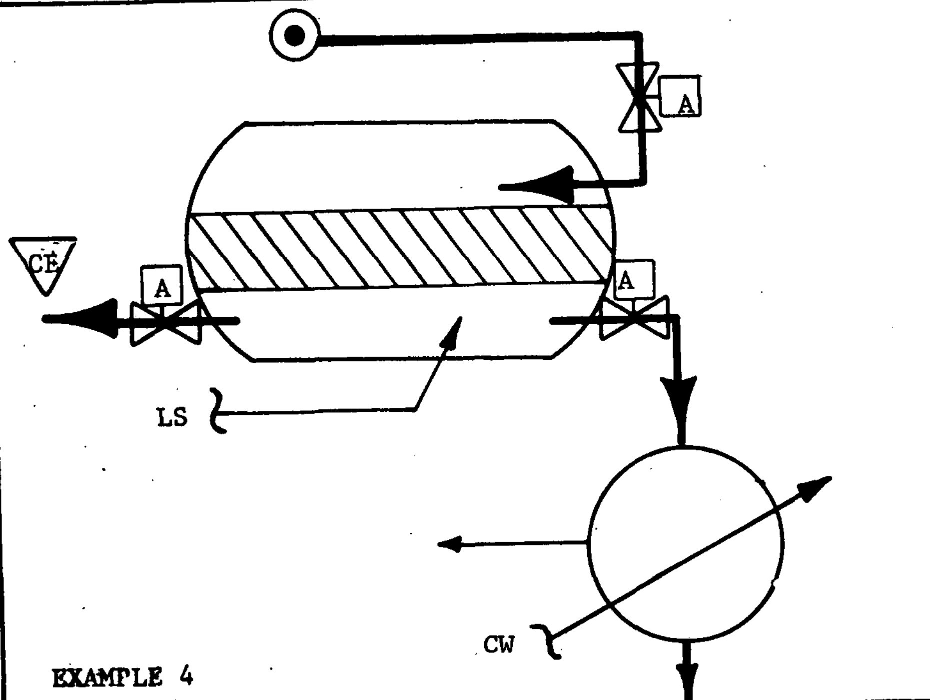
In most processes, there are many plant utility streams which could be represented if one wished to completely describe the system. Most of these are of only incidental interest. We have chosen a set of notations from the many in common use to indicate the presence of streams. These are listed below:

<u>Utility Streams</u>

A - Plant Air
B - Brine
BW - Boilerfeed Water
C - Catalyst
CW - Cooling Water
DW - Distilled Water
FG - Fuel Gas
FO - Fuel Oil
FC - Fuel Coal*
FW - Fuel Wood (Hogged Scrap)*
HM - Heating Medium
HS - High Pressure Steam
LS - Low Pressure Steam
PW - Potable Water
SC - Steam Condensate

The notations with an asterisk are new and thus are not now in common use; these were added because we are not aware of any being used consistently for coal and wood.

Example 4 shows two plant utility streams--the LS flowing to the carbon adsorption bed and the CW flowing to the indirect heat exchanger. The "A" notation represents motor-operated valves (box 59, page 21) for regulating air flow in the plant. Example 4 also shows how to add control and process equipment to a flowchart. The symbols for the adsorber (boxes 35 and 43, pages 18 and 19) the exchanger (box 10, page 15) and the flow lines to each are drawn with #2 lines. The circle with the dark center shows the exit point of the air flow line (top of Example 4) from the rest of the process which is not shown in the figure.



EXAMPLE 4

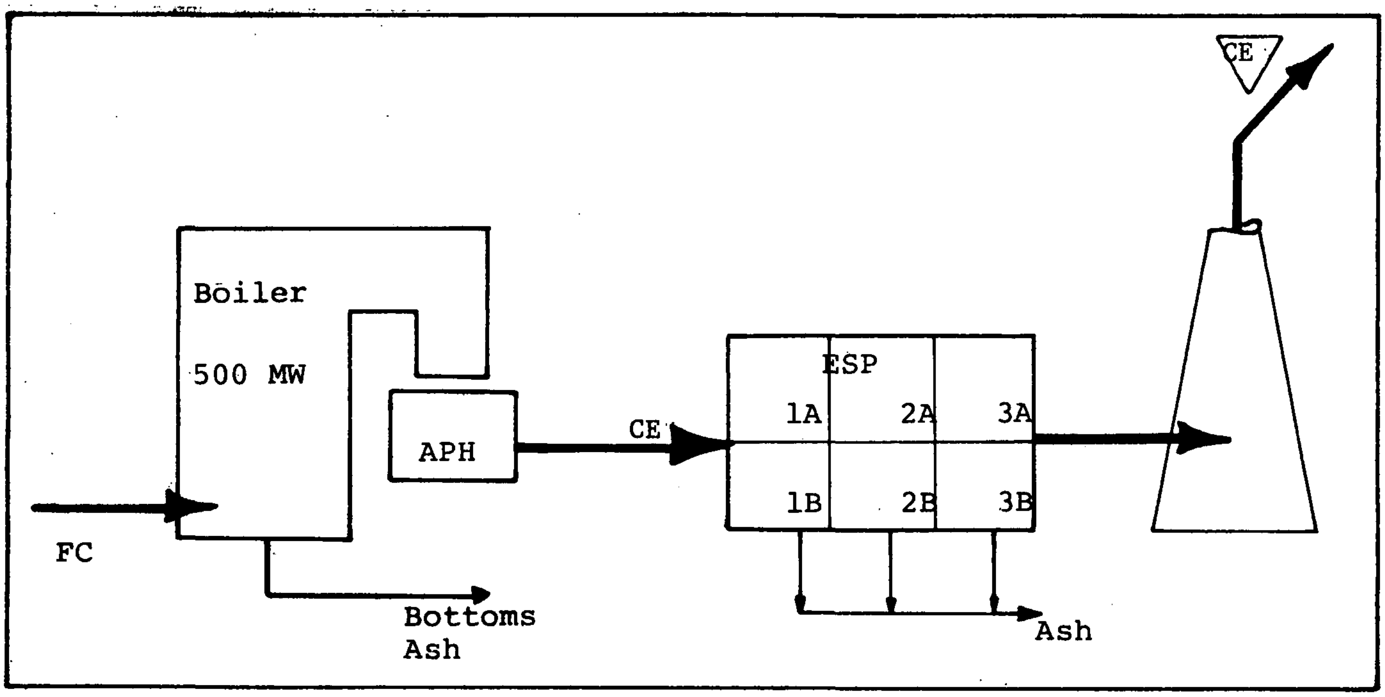
3.0 PROCESS AND CONTROL EQUIPMENT

Symbols for fabric filter bags represent the cleaning techniques and the flow pattern of contaminated gas through the filters. For example, the reverse air filter (box 31) shows that the particulate laden gas goes through the outside of the bag and exits through a plenum chamber at the top of the bag assembly. The cleaning technique is a reverse airflow supplied by an independent fan (box 62) which pulls in ambient air. The symbol for the pulse jet fabric filter (box 33) is similar, but it has venturi (box 48) above each. Multicompartment fabric filters (box 30) are illustrated by a large rectangle partitioned into smaller rectangular compartments. Only one bag is shown to reduce the time and space required to draw the symbol; however, in the space to the left of the large rectangle, the field inspector may indicate the number of bags and the bag material.

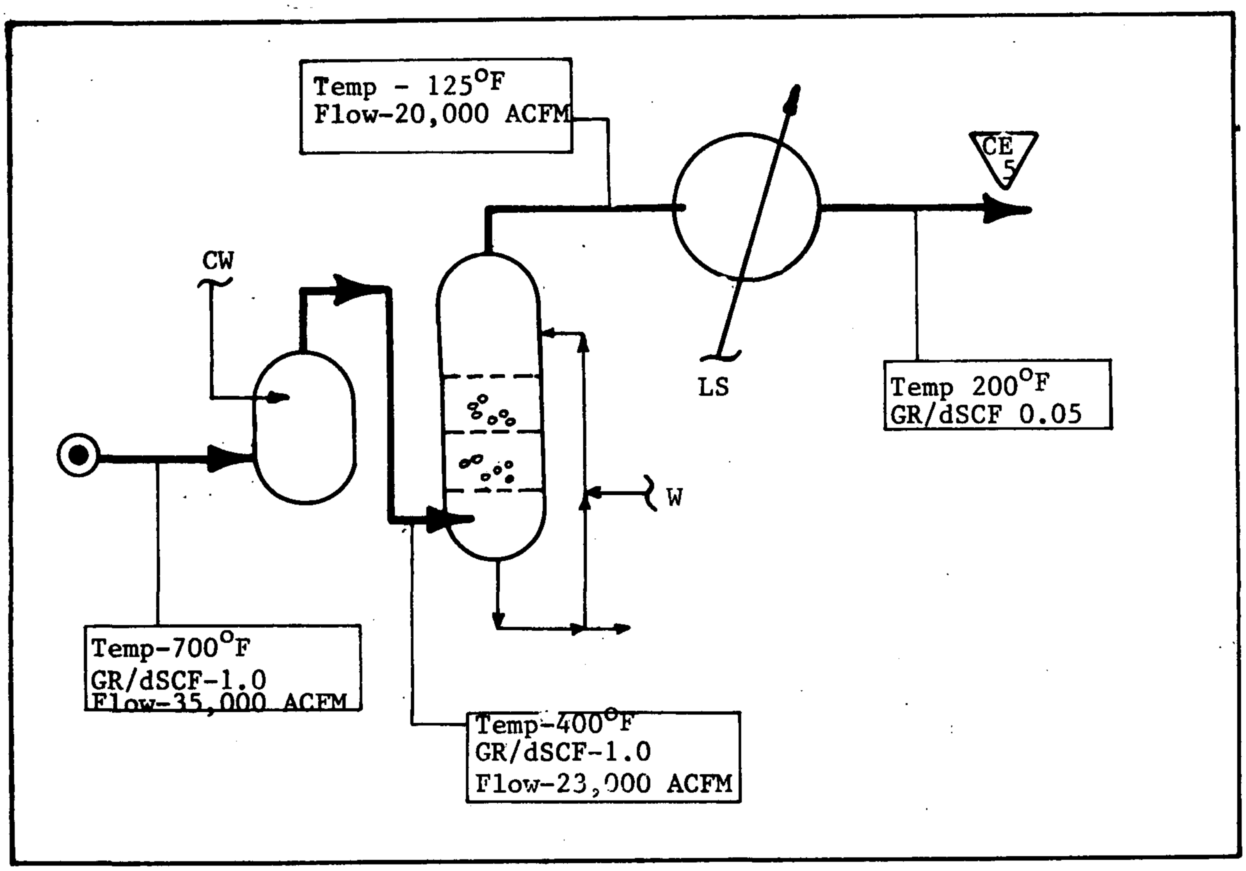
Because the most important characteristics of electrostatic precipitators (ESP's) is the number and arrangement of transformer-rectifier (TR) sets, the symbol is a top view of an ESP showing the arrangement of TR sets (boxes 28 and 29, page 18). It is particularly important to clearly indicate the plant numbering system for each TR set; this information ties the various monitoring instruments to the ESP layout on which the diagnosis of ESP performance depends. In the extra space in the ESP symbol, the field inspector may wish to indicate the SCA or other parameters of interest.

The process and control system symbols in Example 5 represent a typical coal-fired boiler of 500-megawatt generating capacity. In this case, the ESP has six separately energized sections, each section supplied by a TR set; the inlet fields are 1A and 1B; there are two parallel layouts with three TR sets in each. The boiler symbol includes a block labelled APH, which simply means that the effluent passes through the air preheater (APH) before entering the ESP and that the ESP is a cold-side unit. In recent installations in which low sulfur coal is being burned, the utility has installed the ESP between the boiler and the air preheater. This type is termed a hot-side ESP and has significantly different operating characteristics than the more conventional cold-side type.

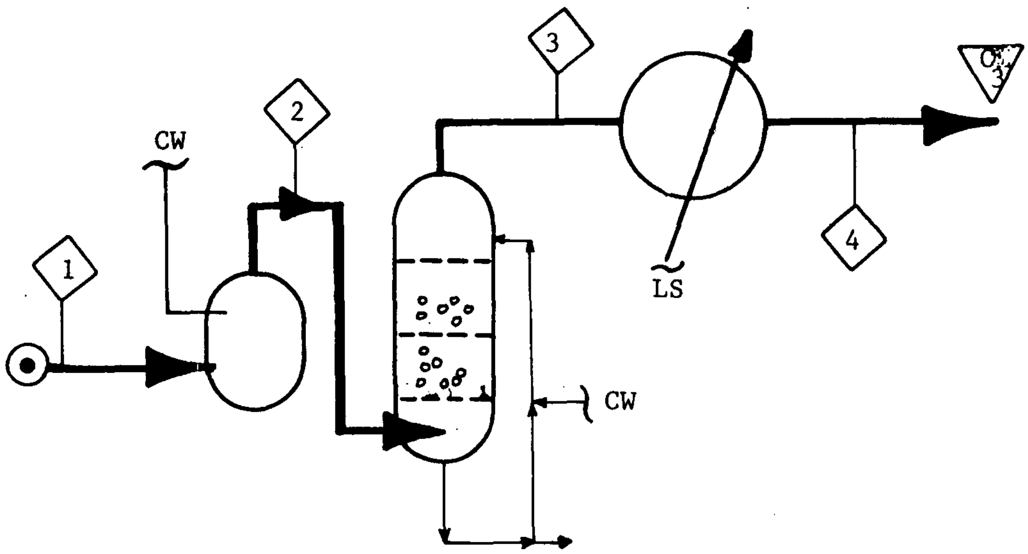
In some cases, it may be desirable to put some of the process/control system operating data in rectangular boxes or in tables on the flowchart to facilitate comparisons of observed conditions with those typical of the installation. The boxes and the tabular form are illustrated in Examples 6 and 7.



Example 5



Example 6



Stream	Temp, ^oF	gr/dSCF	Flow, ACFM	Comments
1	700	1.0	35,000	
2	400	1.0	26,000	
3	125	0.1	17,700	
4	200	0.1	20,000	

Example 7

4.0 INSTRUMENTATION

The delegation of enforcement authority to the States with respect to Standards of Performance for New Sources (NSPS) means that more instruments will be encountered by the field inspectors. Inspection of continuous monitors and use of the CM data for performance diagnoses will become integral parts of the source inspection routine for major point sources; thus flowchart symbols were deemed necessary to indicate the type, location, and number of such monitors. Since no well-accepted notations could be identified, we prepared some symbols. It is unimportant which symbols are used as long as the necessary information is conveyed, and the symbols are used consistently.

Notations for the process and control equipment instrumentation has been taken primarily from the Instrument Society of America (ISA).[1,2] We have made changes and additions to update the terminology.

The presence of an instrument is symbolized by a circle (e.g., PI in Example 8) and a line pointing to the general location in the system. The type of instrument is identified by the notations listed below. Please note the two classes of notations: those ending in R and those ending in I. The letter "I" specifies that the instrument is an indicator only, while the letter "R" states that it is equipped with a recorder (stripchart, maganetic tape, etc.).

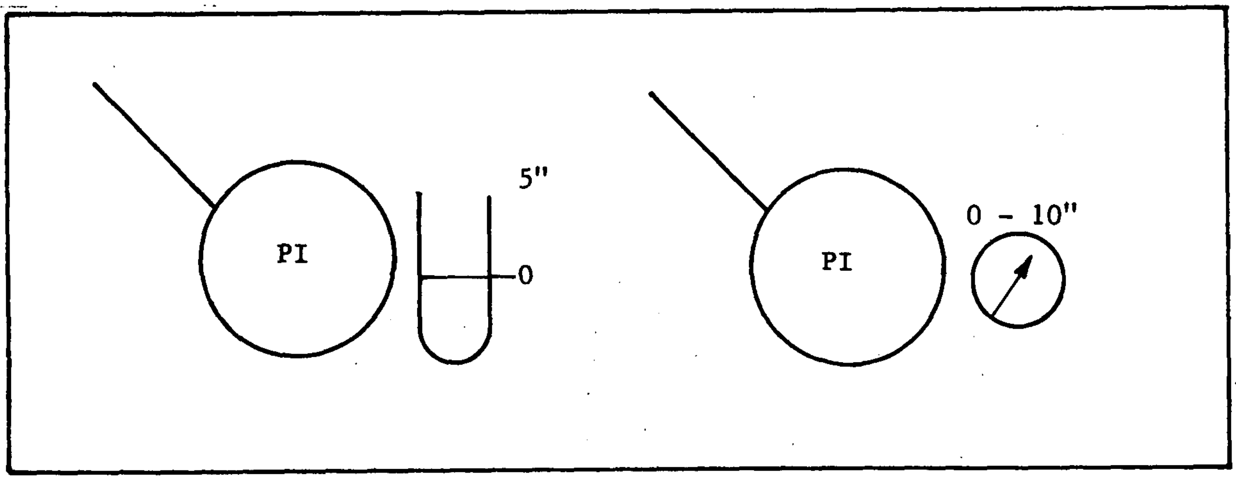
Instrument Notations

FI - Flow Indicator
FR - Flow Recorder
LG - Gage Glass
LCI - Level Control Indicator
PCI - Pressure Control Indicator
PR - Pressure Recorder
TI - Temperature Recorder Indicator
DPI - Differential Pressure Indicator
DPR - Differential Pressure Recorder

PWI - Power Indicator
CMI - Continuous Monitor Indicator
CMR - Continuous Monitor Recorder

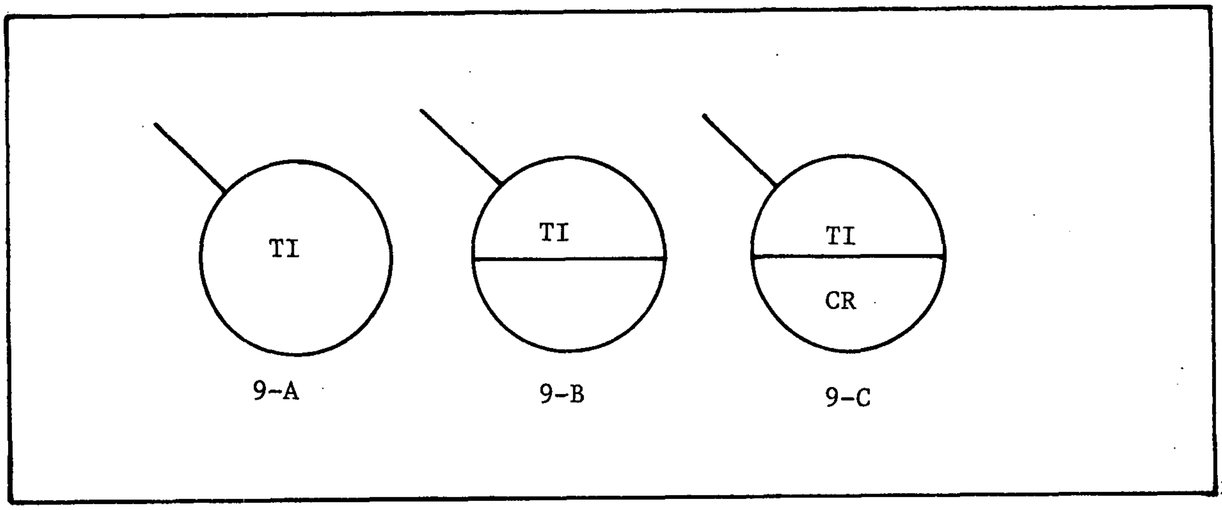
V - Voltage
A - Current (AC)
PV - Primary Voltage
PA - Primary Current (AC)
SC - Secondary Current (DC)
SPK - Spark Rate

It is generally not necessary to identify the type; however, this may be done within the circle, as shown in Example 8.



Example 8

The use of a line across the diameter of the circle demonstrates that the instrument panel is probably located in a substation (SS) or a control room (CR). (This is not standard ISA notation.) The location can be specified by adding SS or CR to the bottom half of the circle as illustrated in Example 9.

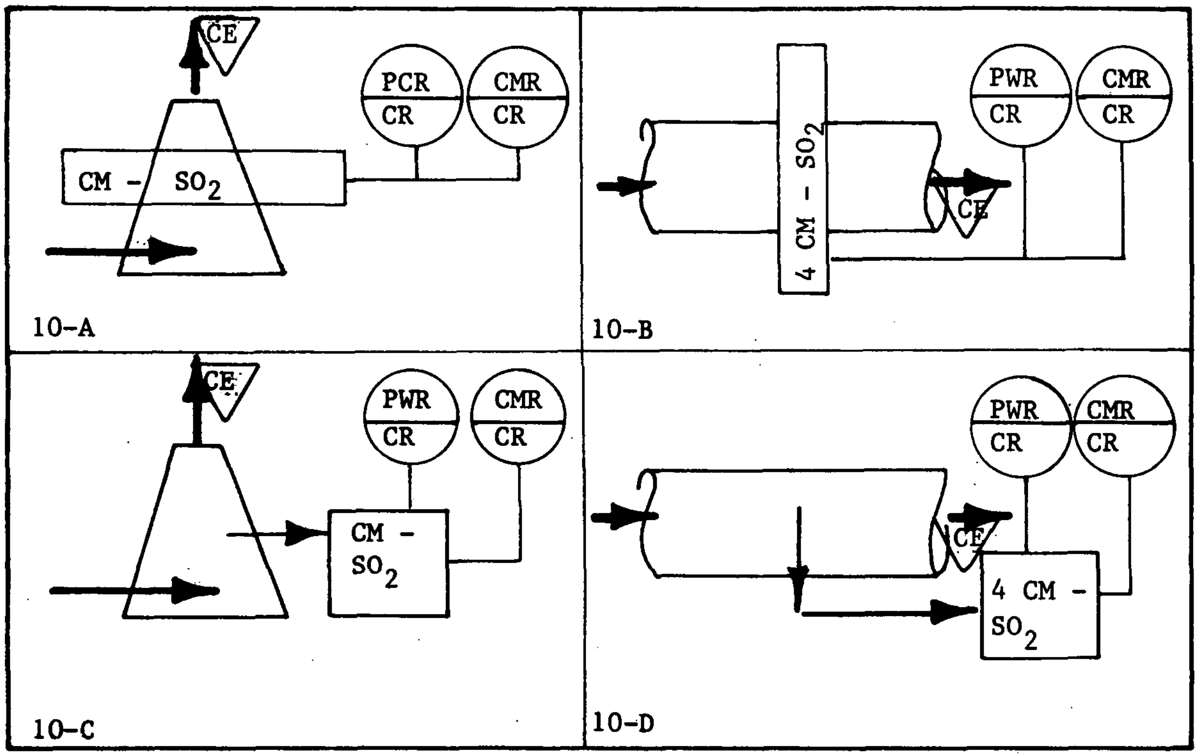


Example 9

The symbol for 9-A means that a temperature-indicating monitor is mounted in the vicinity of the control device. The horizontal line of 9-B states that the monitor is on a control panel. The 9-C with its CR shows that the temperature can be checked in the main control room.

The distinction which should be made is whether the continuous monitor is in-situ or extractive. The latter extracts a small sample stream from the breeching or stack, but the former is mounted inside of the stack. The in-situ monitor is subjected to substances in the exhaust ducts and thus requires regular cleaning and maintenance of the protective blowers. The extractive monitor is free of the stack problems, but experiences some sample deterioration and probe corrosion. In-situ monitors are denoted by a long, narrow rectangle spanning the stack or exhaust duct; the extractive monitors are identified by a square and a distinct sampling line. Both monitors are illustrated in Example 10. The symbol CMR denotes a continuous monitor recorder. The substance being measured (e.g., SO_2) identified in the rectangle; other possibilities include NO_x, O_2, TRS, Opacity. The 10-A states that an SO_2 in-situ monitor is mounted in the stack with power and continuous monitor indicators (PMI and CMI) located in the control room (CR).

The 10-B also illustrates an in-situ monitor; however, it is in the exhaust ducts. The #4 in 10-B shows that there are four parallel ducts, each with an opacity montitor. The 10-C indicates an extractive monitor with the sampling probe located in the stack; there is no information on the location of the instruments. Similar to 10-B is 10-D except that an extractive monitor is indicated.



Example 10

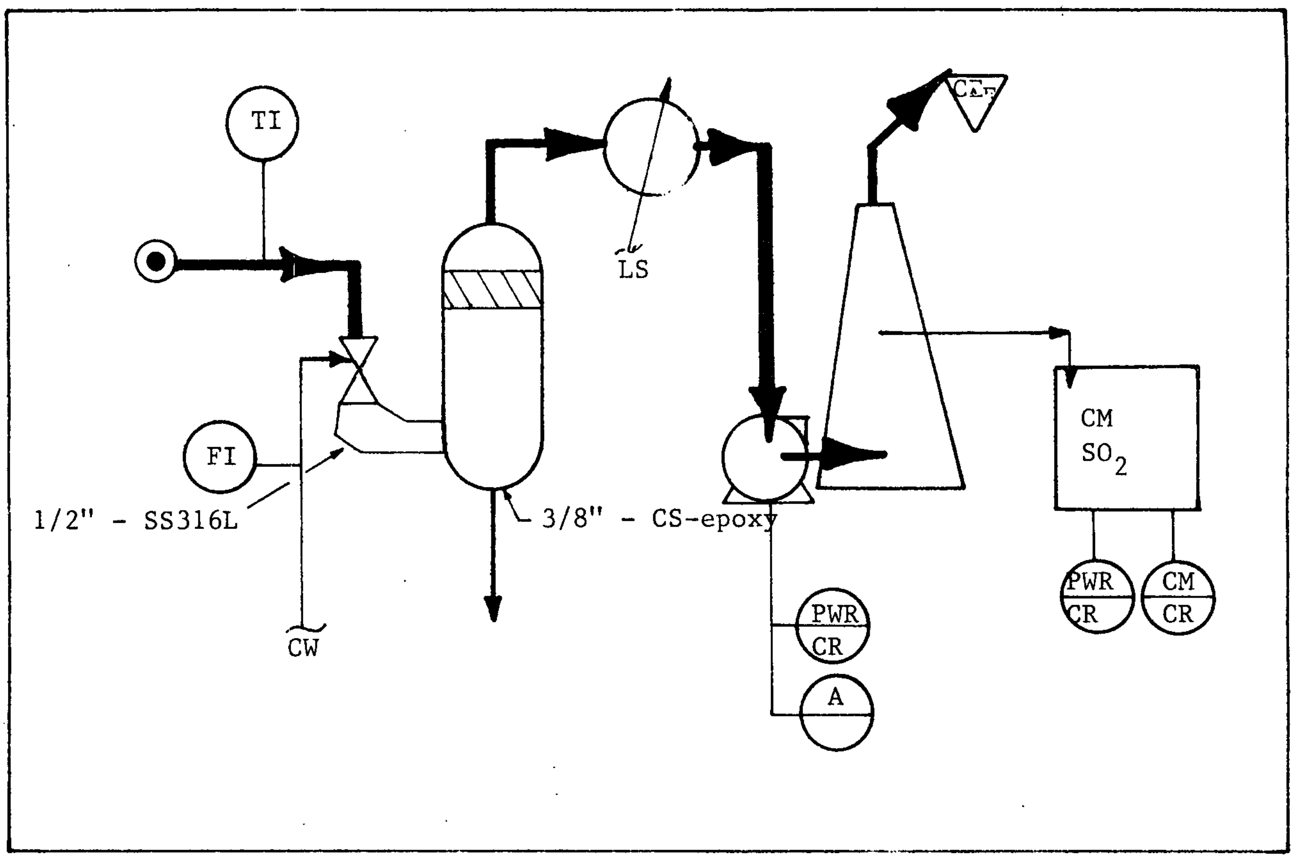
5.0 MATERIAL OF CONSTRUCTION

Some of the main causes of control system failures are corrosion and erosion. If these problems are likely, it may be helpful to indicate the materials of construction on the flowchart to remind the field inspector of potential problems or process changes that could cause rapid equipment deterioration. We suggest a three-part code identifying the material thickness, the basic material of construction, and the coatings or liners present. The thickness and the coatings/liners need not be coded unless they are deemed important. For the basic material, the symbols or words listed below are suggested.

Symbol	Material
SS	Stainless Steel
FRP	Fiberglass Reinforced Plastic
CS	Carbon Steel
Hastalloy	Hastalloy
Inconel	Inconel
Aluminum	Aluminum
Titanium	Titanium
Wood	Wood

We have chosen <u>not</u> to abbreviate the material name as this could lead to confusion. The user may select any codes that are appropriate.

A three-part code of thickness, the basic material, and surface protection for 1/4" thick stainless steel with a rubber liner would be denoted as 1/4-SS304-rubber. A #1 indicator line should be used to connect the code with the equipment as illustrated in Example 11.

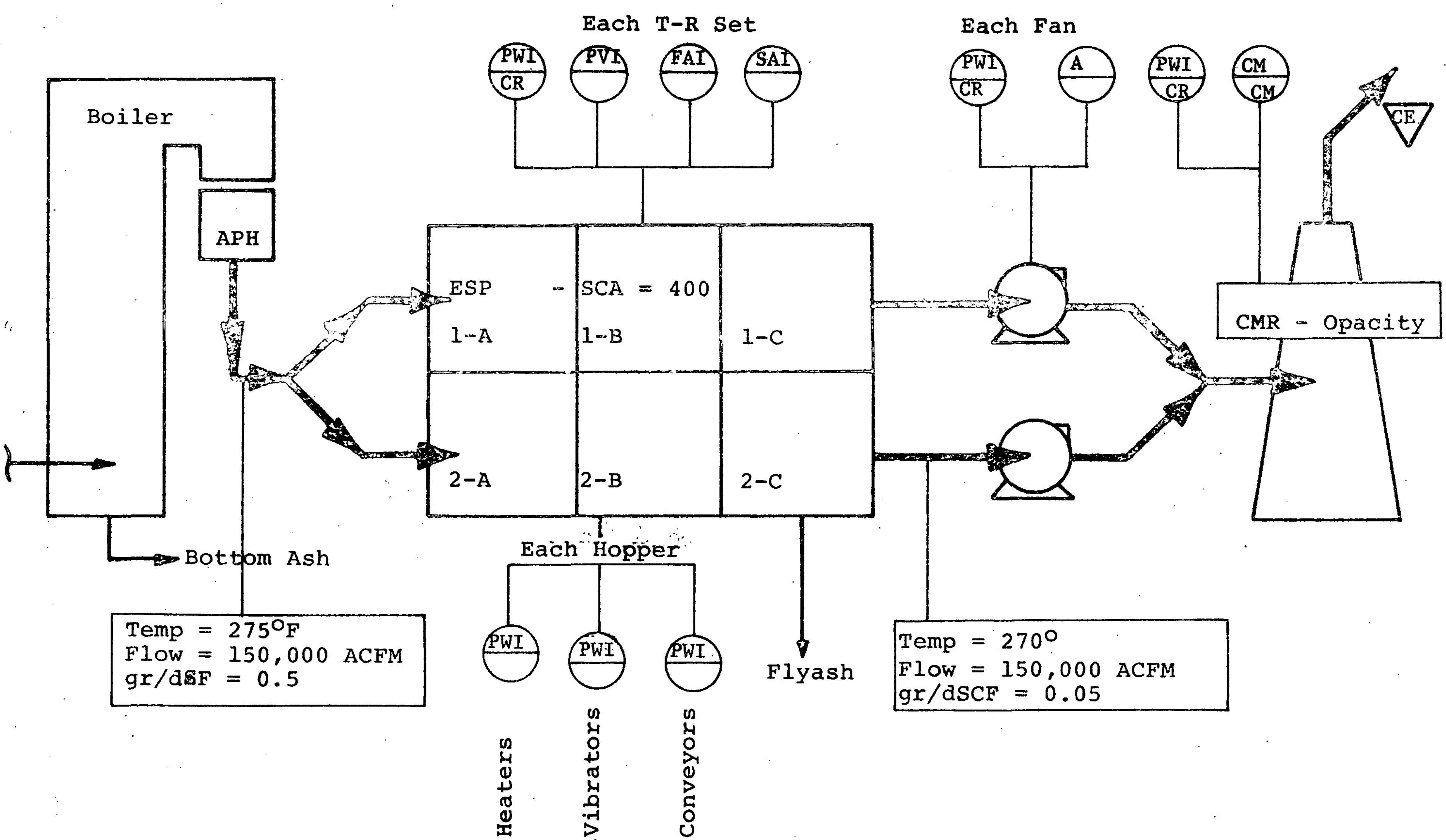


Example 11 illustrates a venturi scrubber (boxes 48 and 50, page 19) used for the control of SO_2 from a combustion source. The venturi itself is made of 1/2" thick 316L stainless steel, and the cyclonic separator is composed of 3/8" thick carbon steel with an epoxy coating. There are temperature and flow indicators (TI and FI) mounted in the general vicinity of the control equipment. A continuous extractive monitor type with a probe in the main stack is used for the measurement of SO_2, and the output of the monitor is located in the control room (CR). The ID fan power indicator light is in the main control room; however, the current (A) is monitored by a panel meter mounted on the plant gounds.

6.0 EXAMPLE OF A COMPLETE FLOWCHART

A complete flowchart for a coal-fired utility boiler is shown in Example 12. This is a combination and extension of Examples 5 and 10. Most of the important components of a flowchart are included in this example.

Example 12. Coal-Fired Utility Boiler
Controlled by a "Cold-Side"
Electrostatic Precipitator



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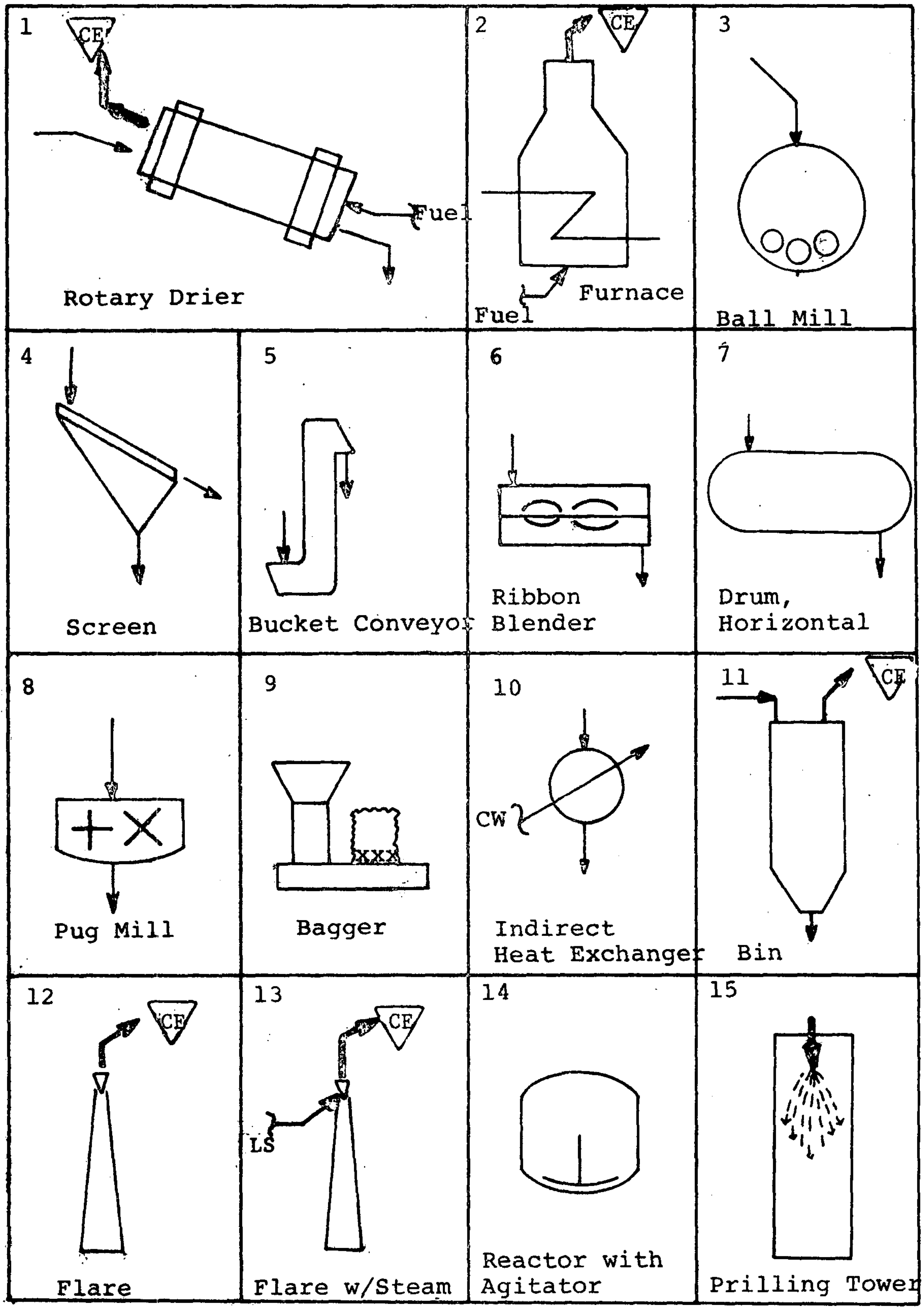
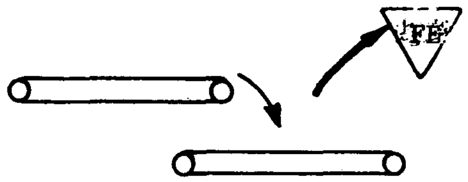
1. Hill, R.G. Drawing Effective Flowsheet Symbols. Chemical Engineering, January 1,1968, Pages 84-92.

2. O'Donnell, J.P. How Flowsheets Communicate Engineering Information. Chemical Engineering Report,September 1957, Pages 249-266.



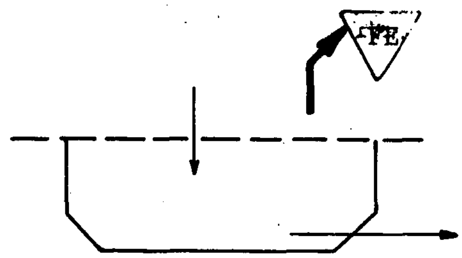
PROCESS EQUIPMENT

16-NEW



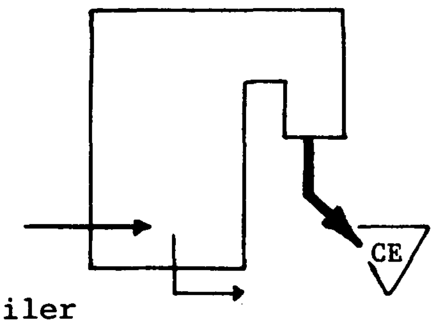
Conveyor, Transfer Point

17-NEW



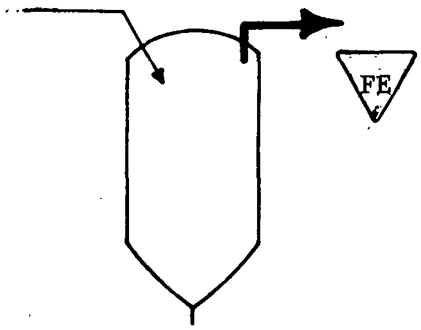
Truck/Rail Unloading Hopper

18-NEW



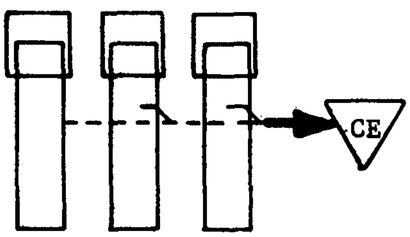
Boiler

19



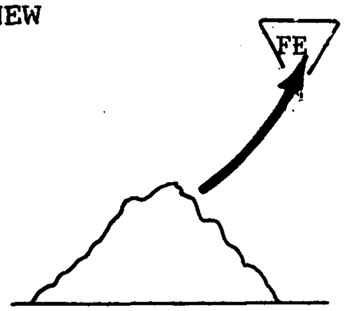
Hopper

20-NEW



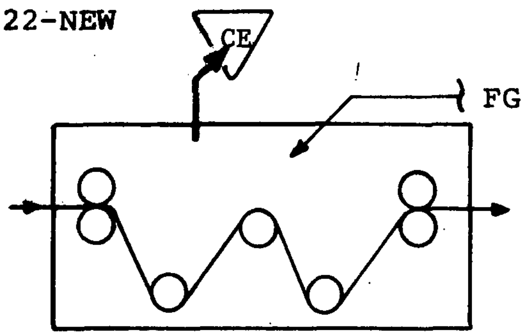
Multiple Effect
Evaporators

21-NEW



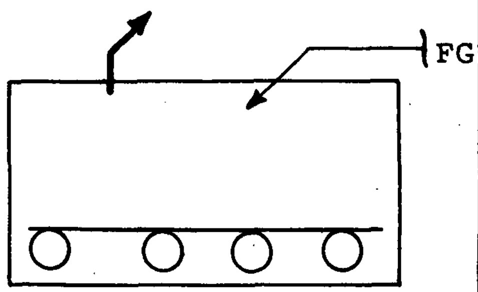
Storage Pile

22-NEW



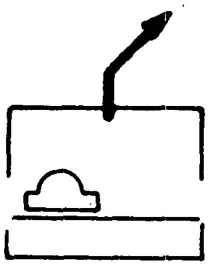
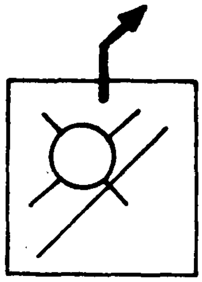
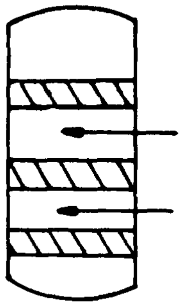
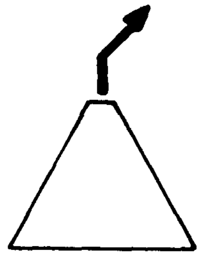
Tenter Frame

23-NEW



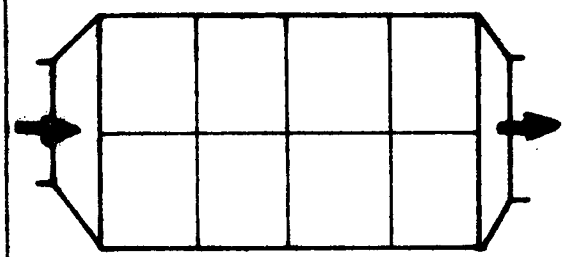
Curing Oven

PROCESS EQUIPMENT

24-NEW  Sander	25-NEW  Cotton Gin	26-NEW  H_2SO_4 Absorber	27-NEW  onical Burner

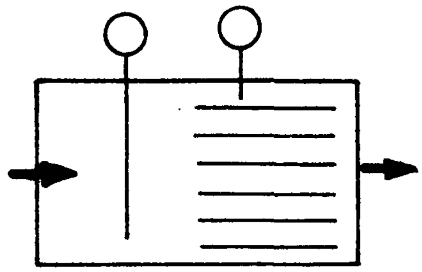
PROCESS EQUIPMENT

28-NEW



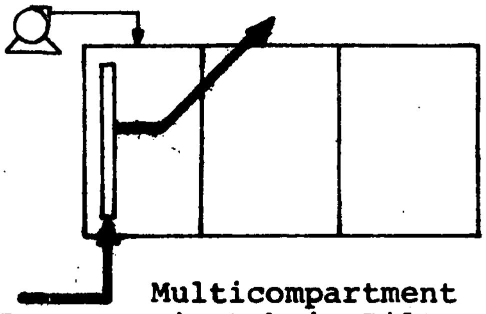
Electrostatic Precipitator

29-NEW



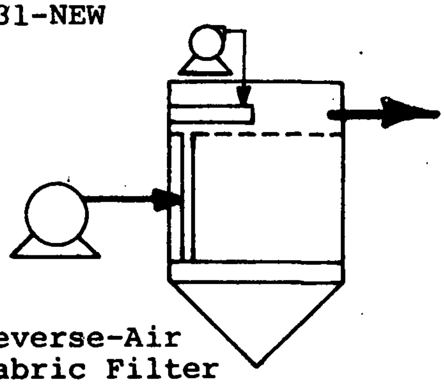
Positive Corona
Electrostatic Precipitator

30-NEW



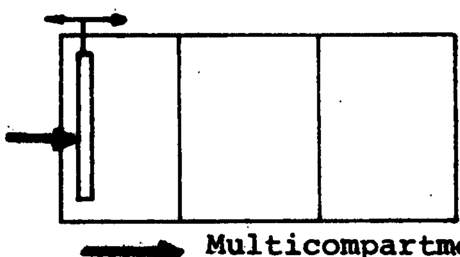
Multicompartment
Reverse Air Fabric Filter

31-NEW



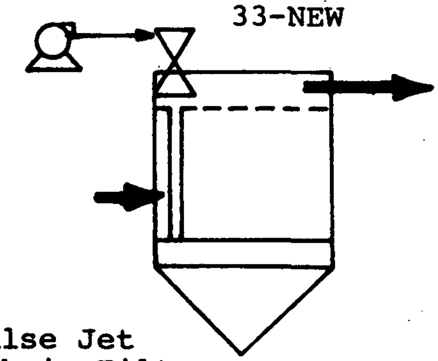
Reverse-Air
Fabric Filter

32-NEW



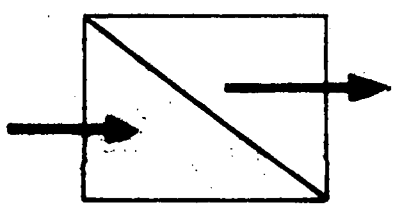
Multicompartment
Shaker Fabric Filter

33-NEW



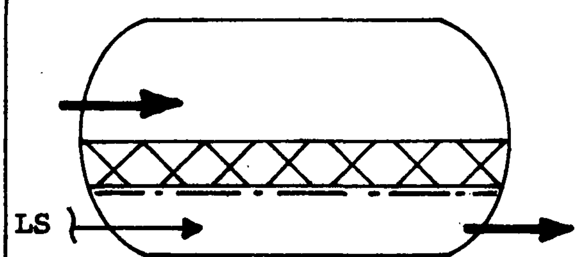
Pulse Jet
Fabric Filter

34-NEW



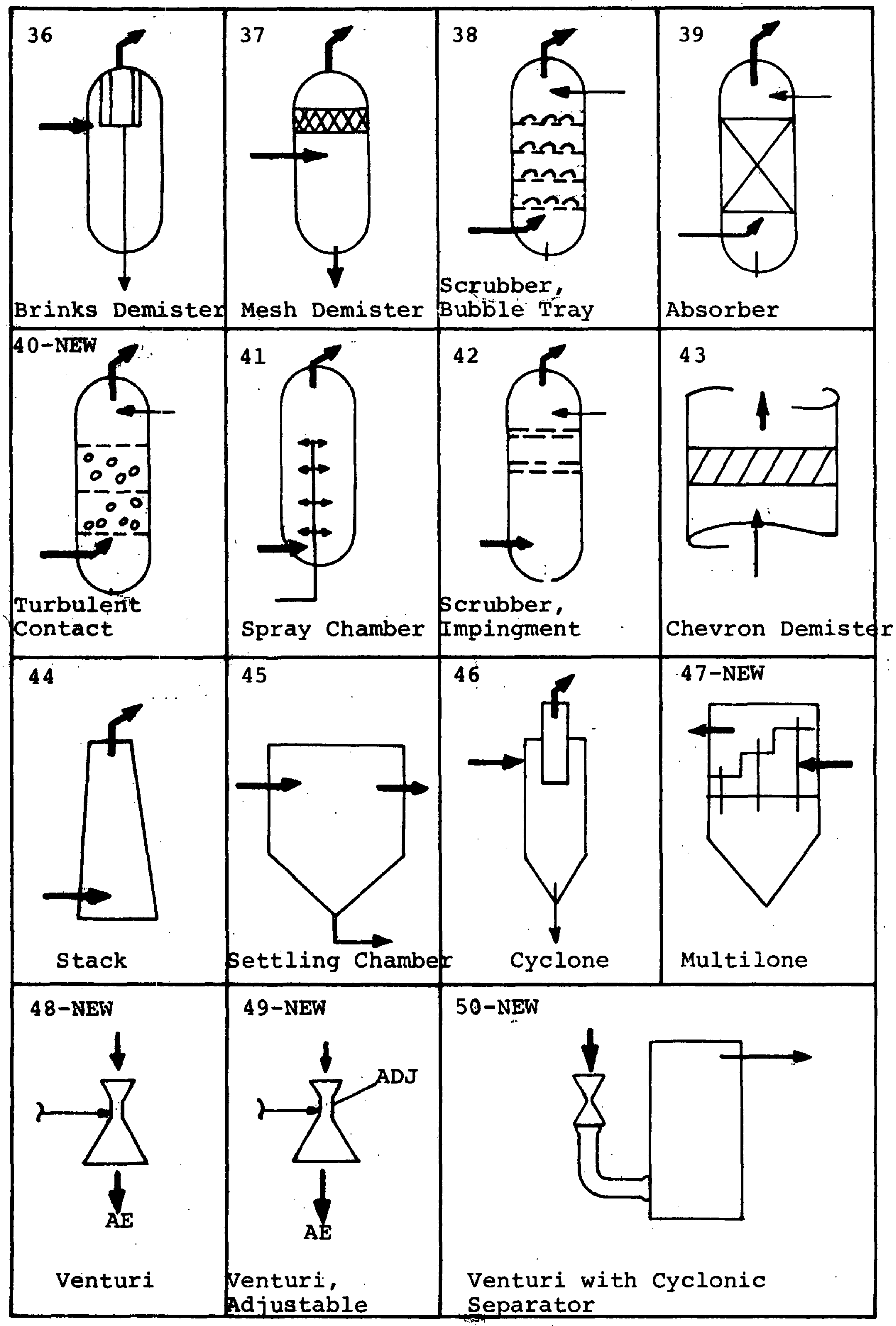
Panel Filter

35



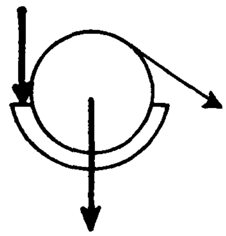
Adsorber

AIR POLLUTION CONTROL EQUIPMENT



AIR POLLUTION CONTROL EQUIPMENT

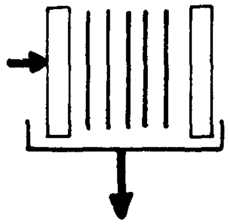
51



WE

Rotary Vacumn Filter

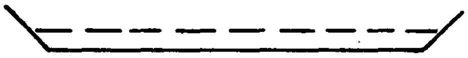
52



WE

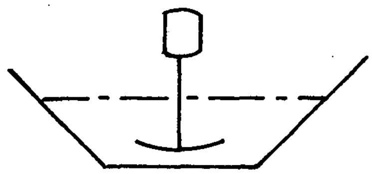
Filter Press

53



Pond

54

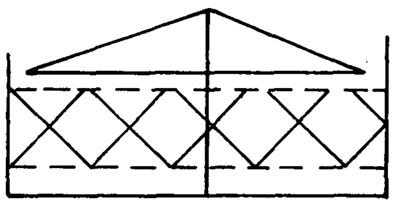


Activated Sludge Basin

55

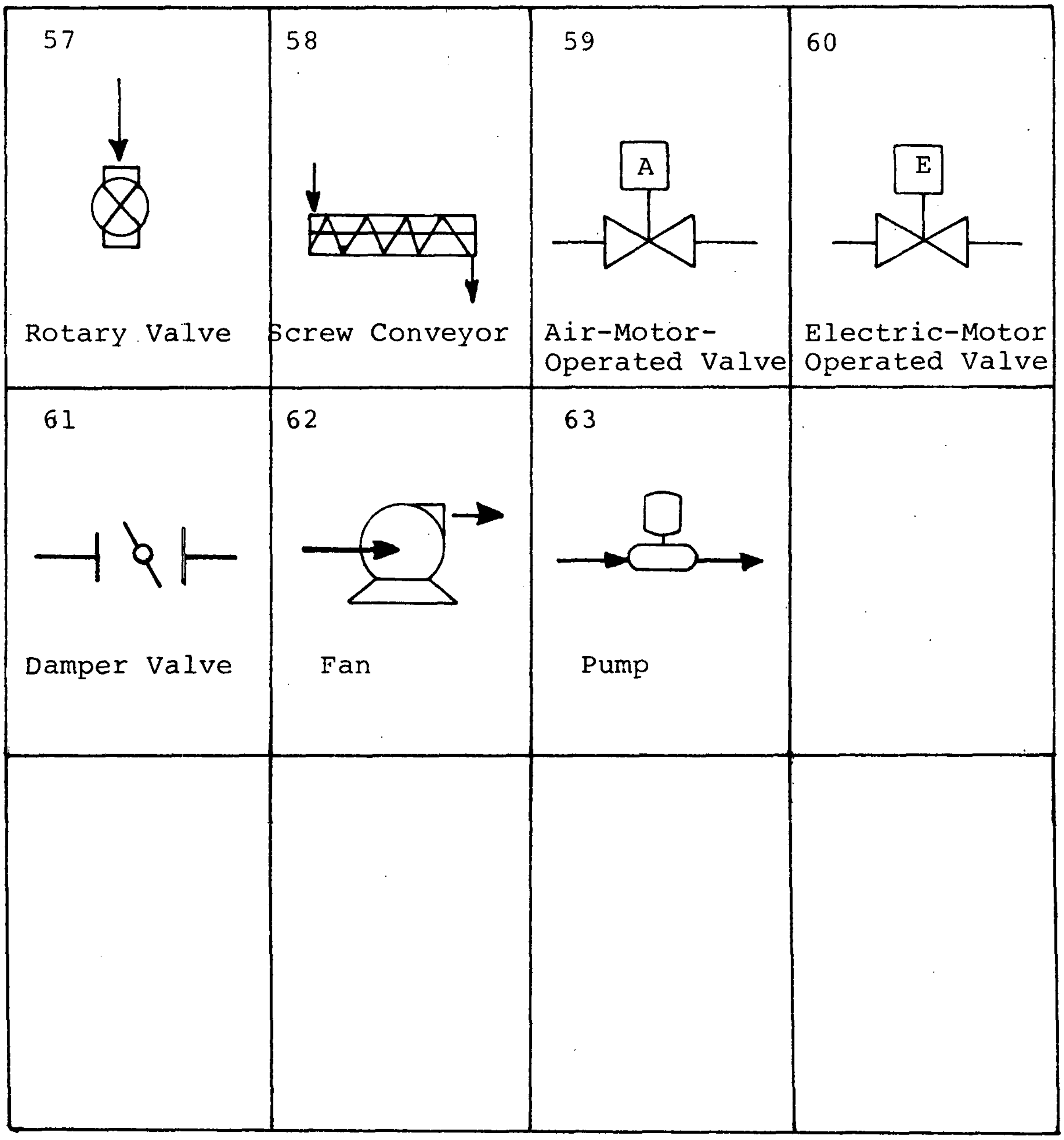
Clarifier

56

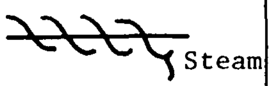
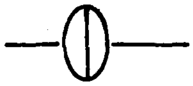
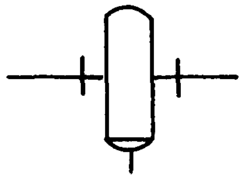
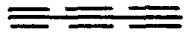


Trickling Bed

WATER AND WASTEWATER



ACCESSORIES

64  Pipe, Steam Traced	65  In-Line Filter	66  Separator, Oil, Water	67  Pipe, Jacketed

FLOW LINES AND PIPING