PRACTICAL MANUAL OF CHEMICAL PLANT EQUIPMENT
PRACTICAL MANUAL of CHEMICAL PLANT EQUIPMENT

by ROBERT G. SCHMIDT, P. E.
Columbia Nitrogen Corporation
Augusta, Georgia

CHEMICAL PUBLISHING COMPANY, INC.
New York
1967
Practical Manual of
Chemical Plant Equipment

© 2011 by Chemical Publishing Co., Inc. All rights reserved. This book is protected by copyright. No part of it may be reproduced, stored in a retrieval system or transmitted in any form or by any means; electronic, mechanical, photocopying, recording or otherwise, without the prior written permission of the publisher.

ISBN: 978-0-8206-0086-4

Chemical Publishing Company:
www.chemical-publishing.com
www.chemicalpublishing.net

First edition:
© Chemical Publishing Company, Inc. – New York, 1967
Second Impression:
© Chemical Publishing Company, Inc. · 2011

Printed in the United States of America
Preface

This complete manual of commonly used chemical plant equipment has been written for the chemist, engineer, operator, or mechanic entering the chemical industry. The manual is designed to explain the principles of operation; advantages and disadvantages of the different types of equipment; terminology used in the industry; and some of the important basic operating theories and practices.

When first viewed, most chemical plants are a confusing maze of pipe, valves, pumps, columns, tanks, and other equipment that appear to be impossible to understand. The language commonly used by the “old hands” is also very confusing to the new man. The purpose of this manual is to provide knowledge of the commonly used equipment and terminology so that the new man can be relieved of much of his initial mental confusion. He can thus devote his efforts to the study of the special equipment used and grasp the overall idea or sequence of operating steps so necessary to an understanding of the particular plant and the job to be accomplished.

March 1967

ROBERT G. SCHMIDT
Contents

1. **Solids—Storage And Handling**
   - General .......................................................... 1
   - Conveyors ..................................................... 1
     - Air Conveyors ............................................. 1
     - Belt Conveyor ............................................. 3
     - Vibrating Conveyor ...................................... 3
     - Zipper Conveyor ......................................... 4
     - En Masse Conveyor ...................................... 4
     - Screw Conveyor .......................................... 4
     - Bucket Elevators ....................................... 4
     - Feeders ................................................... 5
   - Drying .......................................................... 5
     - Flash Dryer ............................................... 5
     - Fluid Bed Dryer ......................................... 7
     - Rotary Dryer ............................................. 7
     - Tray Dryer ................................................ 8
     - Spray Dryer ............................................... 9

2. **Liquids—Storage And Handling**
   - Tanks .......................................................... 11
     - Pumps ....................................................... 14
     - Net Positive Suction Head .............................. 14
     - Centrifugal Pumps ..................................... 15
     - Turbine Pumps .......................................... 20
     - Canned Pumps .......................................... 21
     - Propeller Pumps ......................................... 22
     - Reciprocating Pumps ................................... 23
     - Diaphragm Pumps ....................................... 24
     - Gear Pumps ............................................... 25
     - Cam Pumps ............................................... 26
     - Lobe Pumps .............................................. 26
     - Vane Pumps ............................................... 26
     - Screw Pumps ............................................. 26
     - Steam-Driven Piston Pumps ............................ 28
     - Steam-Driven Plunger Pumps .......................... 29
     - Pump Drivers ........................................... 29
     - Packing for Pump Shaft ................................ 30
     - Mechanical Seals ..................................... 30
3. Gases—Storage and Handling
   General ................................................................. 33
   Handling Air ......................................................... 33
   Types of Apparatus
      Axial Compressors .............................................. 34
      Fans ................................................................. 34
      Reciprocal Compressors ...................................... 34
      Rotary Blowers and Compressors ............................ 35
   Vacuum Pumps ..................................................... 35
   Steam Jets ........................................................ 36

4. Pipe, Fittings, Valves
   Pipe ................................................................. 41
      Steel .............................................................. 41
      Stainless Steel ................................................ 42
      Copper ........................................................... 42
      Glass and Lined Steel ....................................... 42
      Plastic .......................................................... 43
   Fittings .................................................................. 43
      Iron ................................................................. 43
      Stainless Steel ................................................ 43
      Copper ........................................................... 45
      Glass ............................................................... 46
      Plastic ............................................................ 46
      Lined Pipe Fittings ............................................ 47
   Pointers on Piping ................................................ 47
   Screwwed Pipe .................................................... 47
   Wrenches ............................................................. 48
   Flanged Pipe ........................................................ 49
   Valves .................................................................. 49
      Gate Valves ........................................................ 49
      Globe Valves ..................................................... 51
      Needle Valves .................................................... 51
      Plug-Cock or Ball Valves ..................................... 51
      Butterfly Valves ................................................ 52
      Check Valves ....................................................... 54
      Diaphragm Valves ................................................ 55
      Flush-Bottom Valves .......................................... 56
      Safety Valves ..................................................... 56
      Steam Traps ........................................................ 57

5. Mixing of Materials
   Blending of Solids ................................................ 61
   Ribbon Blender ...................................................... 61
   Twin Shell Blender ................................................ 61
   Paddle Mixers ..................................................... 62
   Mixing of Fluids ................................................... 63
   Flow Mixers ........................................................ 63
   Propeller Mixers .................................................. 64
CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine Mixers</td>
<td>65</td>
</tr>
<tr>
<td>Shaft Seals</td>
<td>65</td>
</tr>
<tr>
<td>Operating Notes</td>
<td>65</td>
</tr>
<tr>
<td>6. Heating and Cooling</td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>67</td>
</tr>
<tr>
<td>Heat Exchangers</td>
<td>68</td>
</tr>
<tr>
<td>Open or Atmospheric Exchangers</td>
<td>68</td>
</tr>
<tr>
<td>Jackets</td>
<td>69</td>
</tr>
<tr>
<td>Internal Coils</td>
<td>69</td>
</tr>
<tr>
<td>Reboilers</td>
<td>69</td>
</tr>
<tr>
<td>Condensers</td>
<td>70</td>
</tr>
<tr>
<td>Double-Pipe Exchangers</td>
<td>70</td>
</tr>
<tr>
<td>Shell-and-Tube Exchangers</td>
<td>70</td>
</tr>
<tr>
<td>Interchangers</td>
<td>71</td>
</tr>
<tr>
<td>Suggestions for Operation</td>
<td>71</td>
</tr>
<tr>
<td>7. Separation of Materials</td>
<td></td>
</tr>
<tr>
<td>Solids from Solids</td>
<td>73</td>
</tr>
<tr>
<td>Rotary Screen</td>
<td>73</td>
</tr>
<tr>
<td>Solids from Liquids</td>
<td>73</td>
</tr>
<tr>
<td>Plate-and-Frame Filter</td>
<td>73</td>
</tr>
<tr>
<td>Batch Centrifugal Filter</td>
<td>75</td>
</tr>
<tr>
<td>Continuous Centrifugal Filters</td>
<td>75</td>
</tr>
<tr>
<td>Centrifuges</td>
<td>76</td>
</tr>
<tr>
<td>Rotary Vacuum Filter</td>
<td>78</td>
</tr>
<tr>
<td>Liquids from Liquids</td>
<td>80</td>
</tr>
<tr>
<td>Non-Miscible Liquids</td>
<td>80</td>
</tr>
<tr>
<td>Miscible Liquids</td>
<td>80</td>
</tr>
<tr>
<td>Fractional Distillation</td>
<td>81</td>
</tr>
<tr>
<td>Refluxing</td>
<td>83</td>
</tr>
<tr>
<td>Types of Distillation Tray</td>
<td>84</td>
</tr>
<tr>
<td>Packed Columns</td>
<td>84</td>
</tr>
<tr>
<td>Strippers</td>
<td>86</td>
</tr>
<tr>
<td>Gases from Gases</td>
<td>87</td>
</tr>
<tr>
<td>Absorption</td>
<td>87</td>
</tr>
<tr>
<td>Cooling</td>
<td>87</td>
</tr>
<tr>
<td>Molecular Sieve</td>
<td>87</td>
</tr>
<tr>
<td>8. Utilities</td>
<td></td>
</tr>
<tr>
<td>Heating Systems</td>
<td>89</td>
</tr>
<tr>
<td>Steam</td>
<td>89</td>
</tr>
<tr>
<td>Hot Oil and Other Heaters</td>
<td>91</td>
</tr>
<tr>
<td>Cooling Systems</td>
<td>92</td>
</tr>
<tr>
<td>Cooling Tower</td>
<td>92</td>
</tr>
<tr>
<td>Operating Suggestions</td>
<td>92</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>94</td>
</tr>
<tr>
<td>Process Water</td>
<td>94</td>
</tr>
<tr>
<td>Electrical Systems</td>
<td>95</td>
</tr>
<tr>
<td>Air Systems</td>
<td>96</td>
</tr>
</tbody>
</table>
9. INSTRUMENTS FOR PRESSURE
   General .......................................................................................... 99
   Indicators .......................................................................................... 100
   Manometers ..................................................................................... 100
   Bellows Pressure Gauges ................................................................. 102
   Bourdon Tubes: Spiral and Helix ..................................................... 103
   Diaphragm Seal ................................................................................. 104
   Transmitters ..................................................................................... 104
   Pneumatic Transmitters ................................................................. 106
   Electric Transmitters ..................................................................... 106
   Electronic Transmitters ................................................................. 107
   Regulators ....................................................................................... 108

10. INSTRUMENTS FOR TEMPERATURE
    Primary Elements ............................................................................... 111
   Expansion Type—Thermometers .................................................. 111
   Thermocouples ................................................................................. 111
   Resistance Elements ....................................................................... 113
   Radiation Elements ......................................................................... 113
   Transmitters .................................................................................... 113
   Pneumatic Transmitters .................................................................. 114
   Electronic Transmitters .................................................................. 114
   Regulators ....................................................................................... 115

11. INSTRUMENTS FOR FLOW AND LIQUID LEVEL
    Indicators ........................................................................................ 117
    Bulls Eye ......................................................................................... 117
    Pitot Tube ..................................................................................... 117
    Venturi .......................................................................................... 118
    Dall Tube ..................................................................................... 119
    Nozzle ........................................................................................... 119
    Orifice ............................................................................................ 120
    Area Meter: Rotometer .................................................................. 121
    Flow Transmitters ......................................................................... 122
    Pneumatic ..................................................................................... 122
    DP Cells ....................................................................................... 123
    Electronic ..................................................................................... 124
    Liquid Level Indicators and Transmitters .................................... 124
    Glass ............................................................................................. 124
    Bubbler ......................................................................................... 125
    Floats ............................................................................................ 125
    DP Cells ....................................................................................... 126

12. INSTRUMENTS FOR CONTROL
    Recorders and Integrators ............................................................ 129
    Controllers .................................................................................... 129
    Proportional Action ....................................................................... 130
    Reset Action .................................................................................. 134
    Rate Action .................................................................................... 136
CONTENTS

Controller, Fully Equipped ..............................................138
Operating Pointers .......................................................139
Control Valves .............................................................139
Miscellaneous ..............................................................140
Valve Positioners ..........................................................140
Manual Stations ............................................................141
1. SOLIDS—STORAGE AND HANDLING

GENERAL

It is still quite common to find solids being received, stored, and handled in bags or fiber drums. For large quantities of solids, however, the hopper car, some type of conveyor, and bins or silos are more economical. In many places in the process, the solids might be present with sufficient liquid as a slurry that can be pumped. (Generally less than 25 percent solids by weight can be pumped successfully.) This section of the manual will deal with solids where there is insufficient liquid present to use a pump.

CONVEYORS

Air Conveyor

The air conveyor has become extremely popular and it can be used on almost all but wet sticky materials, although some breakage will occur in the material being conveyed.

There are four general types:

A suction or negative system sucks the material up, much as does a vacuum cleaner; this system is used especially where material must be picked up from a number of points and deposited at one or more points. Only one operation can be performed at a time.

The pressure or positive system moves the material by direct pressure created by a blower located ahead of the intake of material. This system is used where there is one intake place and several delivery points.

The third system is a combination of the two, shown in Figure 1:1. Note that the blower can suck the material from the hopper car to the storage bin and can also blow the material from the bottom discharge of the silo to another point.

The fourth system, called fluidizing, is accomplished by mixing
Fig. 1:1. Combination suction and pressure air conveying system.

each particle in a thin envelope of air. This system moves a great deal of material with a minimum of air and minimum of degradation or breakage. For example, 20 to 30 standard cubic feet per minute (SCFM) of air moves about 1,000 lb. an hour through a one-inch pipe. Actually, the quantity of air would depend upon the length, number of bends, nature of material being conveyed, and height to which it is to be conveyed.

Fig. 1:2. Fluidizing type air-conveying system.

Figure 1:2 is a simplified diagram of the fluidizing portion of a fluidizing system. The blower supplies air to a rotary air-lock valve. The rotating blades can regulate the rate of solids being fed into the system, mix the solids and air, and take them over to the discharge
pipe. A fluidizing valve is needed at each point of pickup of solids. As with the other air conveyors, the pipe discharges into a cyclone separator and through a rotary air-lock as shown in Figure 1:3. The cyclone separator is a vessel or piece of pipe of large diameter and the conveying pipe discharges into the cyclone in a tangential way to give the air and solids a circular motion. The air then rises at a slow velocity because of the large diameter of the cyclone, thus allowing the solids to drop down into the rotary air-lock. The rotary air-lock lets the solids drop into the silo or bin and keeps the air from entering.

![Diagram of cyclone separator]

**Fig. 1:3.** Cyclone separator.

As a cyclone is not 100 percent efficient, the air will contain about one percent of the solids fed into it originally. This air is frequently taken to a second cyclone, bag filter, or other type of collector or scrubber to recover these solids.

**Belt Conveyor**

One of the most economical types of conveyor is the belt conveyor; however, their use is limited to reasonably level straight runs. The angle at which a belt conveyor may be run depends upon the material to be conveyed.

**Vibrating Conveyor**

In the vibrating conveyor the solids lie in a trough, which is vibrated
in such a way as to make the particles move along in short jumps. It is not good for wet sticky materials and is generally used only for short, straight, horizontal, or downhill runs. A spiral, elevating, vibrating conveyor is available but it is rather expensive.

**Zipper Conveyor**
A zipper conveyor moves with the solids as a belt conveyor does, but it has the advantage of being able to elevate material and change direction. The maintenance costs are relatively high compared with other types and fine rubber particles gradually created by wear could cause contamination of certain materials.

**En Masse Conveyor**
The *en masse* conveyor consists of a chain holding a succession, of solid paddles, or vanes, often called *flights*, that move with the material being conveyed. It is so called because it is designed to run completely filled, and the chain, the flight of paddles, and the solids move together. In a newer type, called a *modified flight*, the vanes or paddles are not solid, but have a large slot in each. This type uses less power and is less noisy than the other form, but it can carry only solids that can interlock with one another—nothing that might fall through the openings.

The major advantages of *en masse* conveyors, with both solid and modified flights, are that they can operate under positive pressure, they can elevate solids, and they can change direction. They are, however, generally a little more expensive than other types of conveyor.

**Screw Conveyor**
This well-known screw type of conveyor is satisfactory for most materials but it is generally noisy and limited to straight short runs.

**Bucket Elevators**
The bucket elevator is used where elevation of the solids is the only requirement. There are three major types:

1. A *centrifugal discharge elevator*, which must operate at a relatively high speed.
2. The *continuous bucket elevator* in which, at the discharge point, each bucket drops its content on the sloping bottom of the bucket below, deflecting the solids into a discharge chute.
3. The *positive discharge elevator* in which the chain passes over the upper sprocket and then passes two snub sprockets so that the bucket is turned through more than 180 degrees.

A major problem of bucket elevators is the slow rate of movement
of solids and the relatively large height needed at the loading and discharge ends of the conveyor.

**Feeders**

Where it is necessary to supply solids to a process at a controlled rate, a *volumetric* feeder (which delivers a certain volume of solids), or a *gravimetric* feeder (which delivers solids by weight) is used.

Most of the conveyors previously listed can serve for volumetric feeding. A rotary valve, sometimes called a *star feeder* is an economical model to use and is shown in Figure 1:4.

![Typical star feeder](image)

**Fig. 1:4.** Typical star feeder. (*Sprout Waldron*).

Gravimetric feeders are used where the rate of flow by weight must be accurately controlled. Generally, these consist of a belt moving over a weighing scale and the speed of the belt, or the amount of solids fed to the belt, is adjusted to obtain the desired weight of solids delivered.

**DRYING**

The most economical method of removing liquids from solids is by mechanical means, such as the use of filters and centrifuges. These mechanical methods generally leave from 2% to 50% liquid with the solids, which must be removed by some type of dryer.

**Flash Dryer**

The flash dryer is one of the most popular dryers where a powdered product is desired. As it employs air-conveying and short residence time it is not too satisfactory for large crystals or where breakage is to be avoided. Some of the variations are the *air-stream flash dryer*,
the cage mill, and the recycle. Figure 1:5 shows an air-stream type in which a relatively dry material is to be fed to the flash dryer and breakage of the product is to be minimized.

![Air-stream type of flash dryer diagram]

**Fig. 1:5.** Air-stream type of flash dryer.

Air and natural gas are burned in a furnace to provide hot air around 1300 degrees F. Air could also be blown over steam coils but the higher the temperature of the air, the more efficient the system. A feeder, such as a screw-feeder, supplies the wet product at a uniform rate. The product is carried by the stream of warm air up to the hot cyclone and may be at a temperature around 300 degrees F (more, or less, as desired). If the product is then to be cooled, it may be passed into a cyclone system shown in Figure 1:6, where cool air is mixed with the hot product.

If the final product is to be very fine or in powdered form, a cage mill can be added. The cage mill consists of rods fastened to a rotating disc which break up the particles of product. Other types of mills are also used—for example, an impulse mill.

If the product is wet enough to be like paste, a recycle system can be added in which a percentage of the dry product from the hot cyclone is mixed in a paddle-blade mixer with the incoming wet material. A complete system using a cage mill, a recycle, and a cooling cyclone is shown in Figure 1:6.
Index

A
Absorption, 87
Amix, 78
Adsorption, 81
Aftercooler, 34
Air conveyor, 1
  handling, 33
  locking, 19
  stream flash dryer, 5
  supply, 97
Ambient temperature, 97
Anionic, 95
Area meter, 121
A.S.A., 56
Atmospheric heat exchanger, 68
  pressure, 14
  tower, 92
Axial, compressor, 34
  flow impeller, 22

B
Back-up wrench, 48
Ball valves, 51
Barometric leg, 39
Batch centrifugal filter, 75
Bellows pressure gauge, 102
Belt conveyor, 3
Black iron pipe, 41
Blind, 79
Blowback filter, 78
Blow down, 90
Bonnet, 55
Bourdon tube, 103
Breathing, 11
Bucket elevator, 4
Bubble cap, 82, 84
Bubbler, 125
Bull's eye, 117
Butt weld, 44
Butterfly valve, 52

C
Cage mill, 6
Cam pump, 25
Canned pump, 21
Carbon steel pipe, 41
Cationic, 95
Centrifugal, decanter, 75
  discharge elevator, 4
  filters, 75
  impeller mixer, 65
  pumps, 15
Centrifuge, 76
Check valves, 54
Chemical gauge, 104
Circuit breakers, 95
Coalescer, 80
Coefficient of heat transfer, 68
Compound gauge, 104
Compression, fittings, 45
  roll, 78
Compressors, 33
Condensate, 90
Condenser, 70
Cone centrifuge, 76
Continuous, bucket elevator, 4
  centrifugal filter, 75
  conical filter, 76
Control, point, 129
  relay, 138
  valves, 139
  manual stations for, 141
  positioner, 140
Controller, 129, 138
Cooling, systems, 92
  tower, 92
Corner taps, 121
Conveyors, 1
Cyclone, 3, 6

D
Dall tube, 119
Deionized water, 95
Derivative control, 136
Deviation, 129
Diaphragm, pump, 24
   seal, 104
   valve, 55
Differential pressure cell, 121
Disc-bowl centrifuge, 77
Distance velocity, 130
Distillation, 80
Doctor knife, 78
Double-pipe heat exchanger, 70
Down time, 30
D. P. cell, 121
Draft tube, 64
Drying, 5
Duplex, 23, 29
Dynaformer transducer, 107

E
Eills, 45
Electric systems, 95
En masse conveyor, 94
Endless belt filter, 78
Ejector, 37
Extraction, liquid-liquid, 81

F
Fans, 34
Feet of head, 15
Filter, 78
   aid, 78
Fittings, pipe, 43
Flapper, 106
Flange, 44
   tap, 121
Flared fittings, 45
Flash dryer, 5
Flexible couplings, 17
Flights, 4
Floating head, 71
Flow, meters, 117
   mixer, 63
Fluid bed dryer, 7
Fluidizing, 1
Flush bottom valve, 56
Fouling, 68
Fractional distillation, 81

G
Gas, bulb for temperature, 111
   cylinders, 33
Gate valves, 49
Gauge, chemical, 104
   bellows, 102
   Bourdon, 103
   chemical, 104
   compound, 104
   diaphragm seal for, 104
   helix, 103
   reflex, 125
   spiral, 103
Gear pumps, 25
Glass, pipe, 42
   lined pipe, 42
   pipe fittings, 46
Globe valves, 51
Gravimetric feeder, 5

H
Head, 15, 21
Header, 99
Heat, exchangers, 68
   transfer, 67
Helix, 103
Holding time, 64
Horizontal centrifugal filter, 75
Horsepower, 95
Hunting, 131

I
Impeller, 15, 16, 19, 61, 65
Impulse, mill, 6
   steam trap, 58
Induced draft tower, 92
In-line mixer, 63
Intalox saddles, 86
Interchanger, 71
INDEX

Inverted bucket steam trap, 57
Ion exchange resin, 95

J
Jacket, 69

K
Kettle type reboiler, 69

L
Lantern ring, 30
Liquid level instruments, 124
Liquid–liquid extraction, 81
Load, 129
Lobe pumps, 26
Lockout, 96

M
Magnetic starters, 95
Manifold, 33
Manometer, 100
Manual stations, 141
Mechanical, draft tower, 92
seals, 30, 65
Mercury pressure, 104
switches, 107
Miscible, 80
Mixed flow impeller, 23
Mixing, 61
Modified flight, 4
Molecular sieve, 81, 87
Mother liquor, 78
Motor control center, 96

N
Net positive suction head, 11, 14
Needle valves, 51
N. E. M. A., 96
Nipples, 43
Nozzle, 119
N. P. S. H., 11

O
Offset, 129
Oil bubbler, 12

On-off controller, 130
Orifice, 120

P
Packing, for columns, 84
glands, 30
pumps, 30
Paddle mixer, 62
Pall rings, 86
Pipe, 41
dope for, 42
fittings, 43
schedule numbers, 41
tap, 121
Piping pointers, 47
Pitot tube, 117
Plate cooler, 68
Plate and frame filter, 73
Plastic pipe, 43
Plow, 75
Plug-cock valves, 51
Positive, discharge elevator, 4
displacement, 23
Poppet valve, 36
Precoat, 78
Pressure, air conveyor, 1
gauges, 102
measurement, 99
regulators, 108
switch, mercury, 107
vapor, 11, 15
Primary element, 99
Process water, 94
Propeller, mixers, 64
pumps, 22
Proportional, action, 130
band, 130
p.s.i.a., 15
p.s.i.g., 12
Pug mill, 63
Pump(s), 14
curves, 18, 19
drivers, 29
size, 19, 29

R
Radiation element, 113
Radius tap, 121
INDEX

Stainless steel, 41
Star feeder, 5
Static tube, 117
Steam, driven piston pump, 28
driven plunger pump, 29
generation, 89
traps, 57
jets, 36
Strainer, 17, 57
String filter, 79
Stripper, 69, 86
Stripping section, 82
Stuffing box, 30
Suction air conveyor, 1
Surge tank, 33
Suspended basket filter, 75

T
Tees, 45
Telescoping gas holder, 33
Temperature, instruments, 111
regulator, 115
Thermocouple, 111
Thermometer, 111
Thermopile, 113
Thermostatic steam trap, 57
Thermowell, 113
Thermosyphon, 69
Tray, distillation, 82, 84
dryer, 8
Transmitters, 99, 104
Transport lag time, 130
Triplex, 24
Trouble-shooting pumps, 18
Turbine, mixer, 65
pump, 20
Twin shell blender, 61

U
Under-driven filter, 75
Unions, 45

V
Vacuum pumps, 35
Valves, ball, 51
butterfly, 52
check, 54
INDEX

control, 139
diaphragm, 55
flush bottom, 56
gate, 49
globe, 51
needle, 51
packless, 55
plug-cock, 51
poppet, 36
positioner, 140
relief, 57
safety, 56
tray, 84
W. O. G., 51
Vane pump, 26
Vanels, 20, 77
Vapor locking, 17, 19
Vapor pressure, 11, 15
Vena contracta tap, 121
Vent, 11, 17, 19

Vertical centrifuge, 76
Venturi, 118
Vibrating conveyor, 3
Volumetric feeder, 5

W
W. O. G., 51
Water, cooling, 92
deionized, 95
ion exchange resin for, 95
process, 94
soft, 95
Weir, 55
Wrenches, 48

Z
Zeroing, 124
Zipper conveyor, 4