CHEMICAL ENGINEERING SERIES

Chemical Engineers' Handbook

PREPARED BY A STAFF OF SPECIALISTS

JOHN H. PERRY, Ph.D., Editor

THIRD EDITION

New York, Toronto, and London
McGRAW-HILL BOOK COMPANY, INC.
1950

Table 23. Asbestos-cement Pressure Pipe*

Size, nominal inside diam., in.	Length, ft.	Class 50† Wall thickness, in.	Class 50† Outside diam., in.	Class 50† Weight per ft., lb.	Class 100† Wall thickness, in.	Class 100† Outside diam., in.	Class 100† Weight per ft., lb.	Class 150† Wall thickness, in.	Class 150† Outside diam., in.	Class 150† Weight per ft., lb.	Class 200† Wall thickness, in.	Class 200† Outside diam., in.	Class 200† Weight per ft., lb.
3	13	0 33	3 66	3 6	0 35	3 70	3 8	0 44	3 88	4 6	0 60	4 20	6 6
4	13	33	4 66	4 7	35	4 70	5 0	45	4 85	6 0	60	5 20	8.4
4½	13	36	6 72	7 6	.38	6 76	7 8	.55	6 95	10 7	75	7 50	15 4
6	13	42	8 84	11 7	44	8 88	11 9	65	9 15	16 8	88	9 76	23 7
8	13	44	10 88	15 2	.59	11 18	19 8	.85	11 70	28 0	1 10	12 20	37.0
10	13	48	12 96	19 8	68	13 36	27 6	98	13 96	38 6	1 24	14 48	49 6
12	13	52	15 04	24 8	78	15 56	36 6	1 13	16 26	51 6	1 44	16 88	67 0
14	13	56	17 12	30 6	88	17 76	47 0	1 25	18 50	65 0	1 65	19 30	87 8
16	13	59	19 18	35 9	97	19 94	58 2	1 39	20 78	81 2	1 87	21 74	112.0
18	13	63	21 26	42 5	1.07	22.14	71 2	1 53	23 06	99 5	2 09	24 18	139 5
20	13	69	25 38	55 5	1 25	26.50	99.3	1 82	27 64	141 5	2 48	28 96	199 0
24	13	90	31 80	89 2	1 54	33.08	150 6	2 29	34 58	221 0	3 12	36 24	310 0
30	13	1 09	38 18	126 3	1 83	39 66	211 0	2 80	41 60	318 0	3 74	43 48	435 0

† Weights given are exclusive of couplings and fittings.
* Johns-Manville Co.
† Class is equivalent to working pressure in pounds per square inch.
‡ Inside diameters for 4, 6, 8 in. Class 150 are 3.95, 5.85, 7.85 in., respectively.

Table 24. Asbestos-cement Sewer Pipe*

Size, nominal inside diam., in.	Class 1 Wall thickness, in.	Class 1 Outside diam., in.	Class 1 Weight per ft., lb.	Class 2 Wall thickness, in.	Class 2 Outside diam., in.	Class 2 Weight per ft., lb.	Class 3 Wall thickness, in.	Class 3 Outside diam., in.	Class 3 Weight per ft., lb.	Class 4 Wall thickness, in.	Class 4 Outside diam. in.,	Class 4 Weight per ft., lb.
4	0 39	4 78	4 9									
5	41	5 82	6 6									
6	42	6 84	7 9									
8	44	8 96	11 9									
10	50	11.00	15 3	0.56	11.12	17 7	0 65	11.30	21.0			
12	54	13 08	19 9	64	13 28	23 6	74	13 48	28 6			
14	58	15 16	24 6	73	15.46	31 0	84	15 68	37 0			
16	62	17.24	30 2	.82	17.64	40 6	94	17 88	47 8			
18	65	19 30	35 5	90	19.80	51 0	1 03	20 06	58 0	1.12	20 24	66 0
20	69	21 38	41.7	94	21.88	57 5	1 13	22 26	70 0	1 25	22 50	84 0
24	75	25 50	54.3	1 06	26 12	77 6	1 31	26 62	100 0	1 45	26 90	110 0
30	96	31 92	86 8	1 24	32.48	113 2	1 64	33.28	155 0	1 85	33 70	175 0
36	1 15	38 30	124.8	1 41	38 82	154 3	1 93	39 86	215 0	2 18	40.36	248 0

Laying length of all sizes of pipe is 13 ft.
* Johns-Manville Co.

Flexible Metal Hose

Various metals such as brass, bronze, monel, aluminum, and steel are used in manufacturing flexible hose which may be had with metal or fabric coverings and with male-female and flanged joints. Threads are usually cut to standard "iron pipe sizes." Inside diameters range from ⅛ to 12 in. The maximum recommended temperature for bronze hose is approximately 450°F., or 230°C.

NON-METALLIC PIPE AND TUBING

A large number of non-metallic materials are manufactured into pipe and tubing. No general size standardization exists. Some materials and dimensions are given below; for further details the manufacturers' catalogues should be consulted. In many cases, fittings and valves are available.

Asbestos-cement Pipe

Asbestos and Portland cement are used to make a seamless pipe, generally with plain ends. Pipe of this material is corrosion-resistant and finds especial application in the conveyance of relatively corrosive fluids. It has a smooth interior surface and, being non-metallic, is free from tuberculation. The joints are usually made with sleeves, sealed with rubber or other elastic rings, or with cement or asphalt. Ends are sometimes machined or tapered for use with metal couplings. A variety of fittings is made. This material can withstand temperatures to 370°C., or 700°F., and has a low thermal conductivity.

Pressure pipe is made in four classes, corresponding to working pressures of 50, 100, 150, and 200 lb./sq. in. See Table 23.

Sewer pipe, as shown in Table 24, is made in four classes, which, in wall thickness, lie between classes 50 and 150 for pressure pipe.

Ducts, as shown in Table 25, are made with wall thicknesses slightly less than class 50 pressure pipe.

Table 25. Asbestos-cement Ducts*

Inside diam., in.	Length, ft.	Wall thickness, in.	Outside diam., in.	Weight† per ft., lb.
3	10	0 32	3.64	3 5
4	10	32	4 64	4 5
5	10	35	5 70	5 9
6	10	35	6 70	7 3
7	10	40	7 80	8 6
8	13	40	8 80	11 2
10	13	40	10 80	13 9
12	13	45	12 90	18 4
14	13	45	14 90	18 8
16	13	50	17 00	23.6
18	13	50	19 00	26 6
20	13	55	21.10	32 6
24	13	60	25 20	42 7
30	13	67	31.34	59 4
36	13	75	37 50	79 5

* Johns-Manville Co.
† Weights given are exclusive of couplings and fittings.

Carbon, Graphite, and "Karbate" Pipe and Fittings

These materials are resistant to practically all acids (including hydrofluoric), alkalies, salt solutions, and organic compounds except those of a highly oxidising

Favorable Conditions of Temperature and Humidity Artificially Created and Maintained in Manufacturing Processes*

Industry and product	Process	t °C.	Relative humidity, %
	Carding	20–23	50
	Combing	20–23	60–65
	Roving	20–23	50–60
	Spinning	20–23	60–65
	Spooling, twisting	20–23	65
	Warping	20–23	65
	Weaving	20–23	75–80
	Carding	23–25	65–70
	Spinning	23–25	55–60
	Weaving	20–23	50–55
	Storage for shipping	20–23	55–60
	Dressing	21–25	60–65
	Spinning	21–25	65–70
	Throwing	21–25	65–70
	Weaving	21–25	60–70
	Chocolate covering	18	>55
	Hard-candy making	21	>50
	Storage	− 1	>70
		+15†	>55
	Softening	29	85
	Cigar and cigarette making	21–23	55–70
	Lithographing	21	45
	Relief and offset	25	45
	Folding	25	65
	Binding	21	45
	Dough fermentation	27	65
	Proofing	32–35	80–90
	Loaf cooling	21	65
	Winding insulation	>40	> 5
	Application	24	>20
	Fuse loading	21	55
	Seal packing prepared, crisp cereals	23	45–50

* "International Critical Tables," vol. 2, p. 322, McGraw-Hill
† Divergence in practice.

Air-conditioning Equipment.

1. Apparatus for the addition to, or removal from, the room being conditioned, of heat and moisture.
2. Automatic controls for the apparatus, so that the temperature and humidity may be controlled within the desired limits.

Apparatus for accomplishing the necessary changes in moisture content are generally known as humidifiers and dehumidifiers.

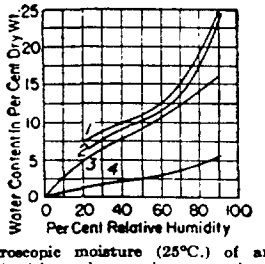


FIG. 15. Hygroscopic moisture (25°C.) of artificial textile fibers compared with crude constituents and natural silk. 1. Viscose rayon (artificial silk). 2. Natural silk, new yellow. 3. Nitrocellulose. 4. Cellulose acetate. ("*International Critical Tables*," vol. 2, p. 323.)

Humidifiers may be divided into the following general types, depending upon the method of operation:

1. Indirect system which introduces moistened air into the room.
2. Direct system which sprays water directly into the room.
3. Combined system which is a combination of the first two.

Indirect Humidifiers. These humidifiers are similar in operation to spray-type air washers except that the water is sprayed directly against the incoming air. Such humidifiers comprise a chamber, usually from 6 to 8 ft. in length, through which the air is drawn at a velocity

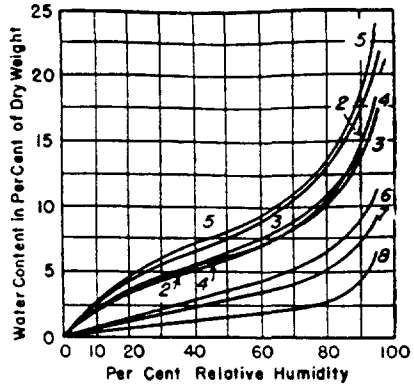


FIG. 16. Hygroscopic moisture of various fibrous materials prepared for electrical insulation. 1. Manila paper. 2. Red rope paper. 3. Pressboard. 4. Leatheroid paper. 5. Silk. 6. Red rope paper (varnished). 7. Empire cloth. 8. Asbestos paper. ("*International Critical Tables*," vol. 2, p. 323.)

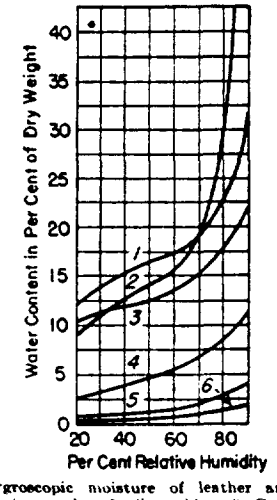


FIG. 17. Hygroscopic moisture of leather and rubber. 1. Leather (sole oak tanned). 2. Sheepskin. 3. Gold's beater skin. 4. Latex, dipped cord. 5. Reclaimed rubber. 6. Smoked, crepe sheet. ("*International Critical Tables*," vol. 2, p. 324.)

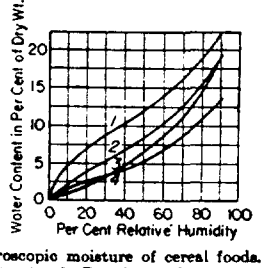


FIG. 18. Hygroscopic moisture of cereal foods. 1. Macaroni. 2. Flour (patent). 3. Bread. 4. Crackers. ("*International Critical Tables*," vol. 2, p. 324.)

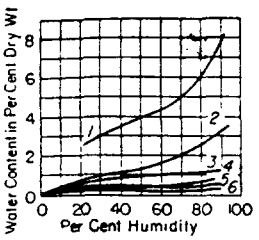


FIG. 19. Hygroscopic moisture of some inorganic substances. 1. English ball clay 2 Kieselguhr. 3 Kaolin. 4 Asbestos fiber. 5 Zinc oxide 6. Glass wool. ("*International Critical Tables*," vol. 2, p. 324.)

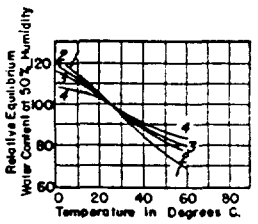


FIG. 20. Effect of varying temperature on equilibrium water content at constant relative humidity of 50 per cent. 1 Wood 2. Silk. 3. Wool. 4 Cotton. ("*International Critical Tables*," vol. 2, p. 324.)

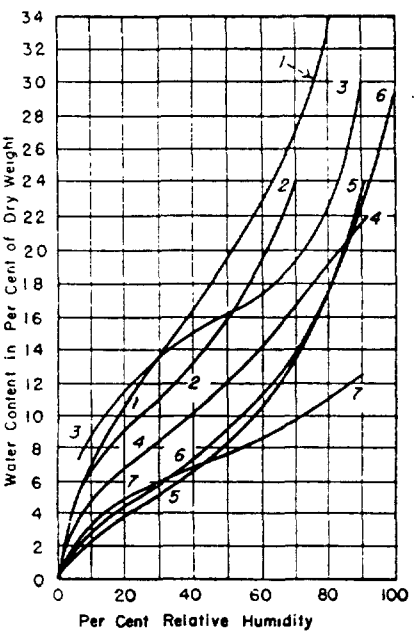


FIG. 21. Hygroscopic moisture of some organic substances. 1. North Carolina leaf tobacco. 2. Cigarette tobacco (Fatima). 3. Sole leather (oak tanned). 4. Catgut. 5. Soap (Ivory). 6. Lumber. 7. Glue (hide, first grade). ("*International Critical Tables*," vol 2, p. 325.)

from 500 to 700 ft./min. Inside the chamber are [illegible] one or more banks of spray nozzles distributed [illegible] over the cross-sectional area of the chamber. These nozzles create a finely divided spray through centrifugal action and require water pressures for effective [illegible] fication of from 35 to 45 lb./sq. in. At the intake of the humidifying chamber, a set of baffles distributes the air and prevents the spray from escaping from the chamber, and at the outlet of the humidifier chamber an eliminator is provided. This eliminator, consisting of a series of metal baffles, is so designed as to separate all the free unevaporated moisture from the humidified air. The air leaving the humidifier is completely saturated but without any entrainment or unevaporated water particles. The general construction of this type of humidifier is shown in Fig 24.

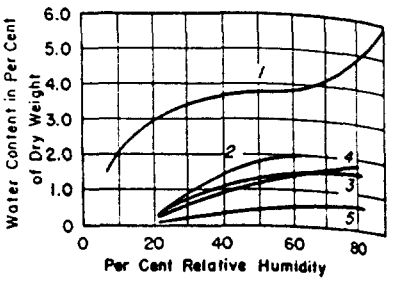
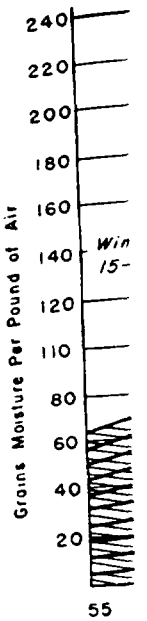


FIG 22 Hygroscopic moisture of carbon products 1. Carbon black, for rubber trade 2 By-product furnace coke (Franklin Co., Illinois coal) 3. By-product coke, domestic size (Pittsburgh bed coal) 4 By-product coke (domestic size) 5 Connellsville, 72-hr. beehive foundry coke ("*International Critical Tables*," vol. 2, p. 325.)

Such humidifiers are used only in connection with ventilating systems. They are practically always placed on the inlet side of the ventilating fan. In the winter, provision is made for maintaining a constant dew point by means of a thermostat placed in the path of the saturated air leaving the humidifier and controlling the outside and return air dampers. In some cases, where high humidities are to be maintained, requiring dew points higher than obtainable by the mixture of outside and return air, the dew-point thermostat also controls the quantity of steam being used to heat the spray water either indirectly by a water heater or directly by introducing the steam into the water. Where all outside air must be employed, it is usual to provide in front of the air washer certain preheater coils of sufficient capacity to bring the air to a temperature slightly above the freezing point. In summer operation, whenever the outside wet-bulb temperature is above the minimum dew point desired in the building, all outside air is taken and, it will be remembered from the psychrometric principles previously discussed, that the air issuing from the humidifier will have been cooled to the wet-bulb temperature of the entering air, provided of course that the water is neither heated nor cooled during recirculation, which is usually the case in such installations.

In order to calculate the quantity of air that must be supplied with this fan-type system, it is necessary to compute all the heat that will be dissipated in the space to be conditioned by such sources as the sun; transmission of heat through walls; heat given up by people; and other sources such as lights, motors, etc The cubic feet per minute then required may be obtained from

$$\text{Cu. ft /min.} = \frac{\text{B.t.u.} \times 56}{\text{temperature rise}}$$



55

FIG. 23. T

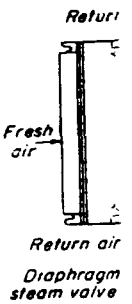


FIG. 24. Hum

The factor 56 is th
of air raised 1°F. by
from the dew point
leaving the humidifi
perature must rise to
will give the required
from the dew point
the heat given up
absorbed. This tem
psychrometric chart
tions to be maintain

Example. Assume
85°F. dry bulb and 64°
humidifier it will sat
temperature of 64°F.

...to pulverize. This material is often calcined and ...pulverized in the same manner as lime. Dead-burned ...magnesite is treated as cement clinker.

Fluorspar. A No. 4237 Raymond ring-roller mill ...grinding fluorspar had a capacity of 3700 lb./hr., 95 per ...sent through No. 200 sieve, with a power consumption ...of 23 hp. on the mill and 23 hp. on the fan, a total of ...1.1 hp.-hr./ton. Magnesite generally the most difficult ...of the carbonates to pulverize, grinds similarly to fluor-...spar. When calcined it is ground in the same manner as ...quicklime. Dead-burned magnesite is handled like ...cement clinker. Table 33 gives the results obtained in a ...Hardinge mill, wet-grinding barytes and limestone to be ...used as a paint filler.

Table 33. Wet Grinding of Barytes and Limestone in Hardinge Mill

	Limestone	Barytes
Size of mill	8' × 48"	7' × 36"
Size of feed	1½"	1½"
Fineness of product, sieve No.	325	325
Capacity, tons/hr.	¾	2
Mill speed, r.p.m.	18	22
Power for mill, hp.	40	25
Classifier system	Cone	Drag
Moisture in mill, %	30	28
Type of mill lining	Flint	Flint
Grinding medium	Coarse limestone	Lump barytes

Asbestos and Mica. The choice of crusher for asbestos depends on whether a long or a short fiber is desired. Crushing is done in slow stages to preserve as much as possible of the fiber length. Primary crushers employed are usually of the jaw type with secondary crushers of the smaller jaw type. Small gyratories and corrugated rolls are also used. With some grades a third reduction may be required. After drying and crushing to about 2 in. the asbestos rock goes to the so-called fiberizing machines, which reduce the rock, liberate the fiber, and grade it into fine and coarse fiber. There are different types of fiberisers, the swing hammer mill, the Jumbo, and the Laurie and Pharo cyclones. The *Jumbo* consists of a cylindrical shell surrounding a shaft with six pairs of arms placed at 6-in. intervals and disposed crosswise to each other. The arms are of heavy steel bars with rolled iron beaters, the faces of which are constructed on an angle. The *Laurie* cyclone consists of two beaters of the screw-propeller type, driven in opposite directions at 1700 to 2000 r.p.m., in a cast-iron chamber. The Pharo cyclone was designed to overcome the tearing effect on the fiber, one of the objections to the Laurie. It is of the same general type, but the hood above the fiberizing end is cut off immediately above the latter, and the crushing blades, or beaters, of which the paddles are one right and the other left, rotate in the same direction.

As the material reaching the mill contains a large amount of freed asbestos, classification of the fiber begins immediately. It is first put through a screening trommel, the fines are discharged on a shaking screen, and the oversize—all above 1½ in.—falls into one of the fiberising devices which discharges on the same screen. The latter is slightly inclined and is made from wire or perforated plates. It has an oscillating movement which, apart from the sizing of the rock and eliminating the dust, causes the fiberised asbestos to rise to the top. The liberated fiber is taken up by a fan, while the overflow falls on a second fiberizing machine, which discharges, like the first, on a screen, where the asbestos is again lifted by a fan, and so on until the rock is practically entirely fiberized. Tailings free from asbestos go to the dump.

Asbestos is often pulverized. This is the case when it is used for molded products. The pulverising is usually accomplished by passing the material through a series of buhrstones or by using a high-speed screen mill with air-transport system. A mill with a 1/64-in. screen pulverized 400 lb./hr. with 13-hp. power consumption. Certain impurities, such as sand, gravel, and hard fiber, may be removed by using an air-classification pulverizer with automatic throwout (see p. 1120).

The micas, as a class, are difficult to grind to a fine powder; one exception is disintegrated schist, in which the mica occurs in minute flakes. The material pulverized is generally the waste from production of sheets and scrap from punching and trimming. Arranged in order of increasing resistance to grinding to a fine powder, micas from various sources may be classified as follows: Madagascar, Ontario, Quebec, Manchuria, India, New Hampshire, North Carolina, South Africa, Russia, Brazil.

Mica is pulverised wet or dry; the wet-ground product is the more desirable, as it retains its luster to a high degree. When ground wet, it is first passed through revolving screens with a constant stream of water; it is then ground in wooden chaser mills at a slow rate and graded after drying, by passing through a series of bolting reels, the finest reel being about 200 mesh. A modification of this process is used in certain European countries, where the mica is ground in chaser mills and buhrstone mills. The water with the ground mica is passed over screens and thus graded. After pressing out the water, the solids are dried and disintegrated in a double-cage mill. Table 34 gives data obtained in wet-grinding a Manchurian mica.

For dry grinding, hammer mills equipped with an air transport system are generally used. The material, after dropping through a perforated screen into the intake of an exhauster, is collected in a cyclone followed by bolting reels. Table 35 gives the operating characteristics grinding North Carolina mica in a high-speed hammer mill.

Table 34. Wet Grinding Manchurian Mica

Amount passed through mill, lb./hr.	400
Total power consumption, including pumps, screens, mill elevators, and conveyor, kw.	60
Power consumption, kw.-hr./ton product	300
Screen analysis, feed to bolting reels:	
% on No. 20 sieve	5
% on No. 50 sieve	18
% on No. 80 sieve	17
% on No. 100 sieve	12
% on No. 200 sieve	19
Through No. 200 sieve	29

Table 35. Grinding Mica in High-speed Hammer Mill

Size of motor (direct-connected), hp.	60
Size of feed	Scrap
Production, lb./hr.	950
Screen analysis of discharge, % on sieve:	

No. 20	No. 40	No. 60	No. 80	No. 100	No. 150	through No. 150
1%	15%	22%	16%	10%	11%	25%

The Fertilizer Industry. Many of the materials used in the fertilizer industry are pulverised, such as those serving as sources for calcium, phosphorus, potassium, and nitrogen. The most commonly used for their lime content are limestone, oyster shells, marls, lime, and, to a small extent, gypsum. Limestone is generally ground in hammer mills, ring-roller mills, and ball mills. Fineness required varies greatly from No. 10 sieve to 75 per cent through No. 100 sieve.

Oyster Shells and Lime Rock. Operating characteristics for hammer mills grinding oyster shells and burned lime for agricultural purposes are given in Table 36.

Phosphates. Phosphate rock is generally pulverized for one of two major purposes: for direct application to the soil, or for acidulation with sulfuric acid in the manufacture of acid or superphosphate, phosphoric acid, and