The results given in Table 2 are shown plotted in Fig. 4.

For convenience, Fig. 5 illustrates the distance to which different sized particles are carried for different wind velocities: If the chimney is 100 ft high, the chimney velocity is 20 ft per sec, the average flue-gas temperature is 300 F, and the outside air temperature is 70 F. Other data used are the same as in Table 1.

The distance a particle is carried is determined by multiplying the wind velocity in ft per sec by the falling time (obtained from Fig. 4) in seconds for the proper particle size and chimney height.

Application of the Results

A practical problem will now be solved by the use of the foregoing plotted data, showing the methods of approach.

The following data assumed are in no way to be considered an accurate representation of the performances of the different types of firing, or dust-separating equipment. These data are used merely to demonstrate a method of attack.

The assumed data are: Chimney height = 100 ft; chimney velocity = 20 ft per sec; chimney-gas temperature = 300 F; average wind velocity = 5 mph or 10 mph; size of unit = 50,000 kw; lb of coal per kwhr = 1.7; carry-over for stoker = 5 per cent of the coal fired; and carry-over for pulverized fuel = 6 per cent of the coal fired.

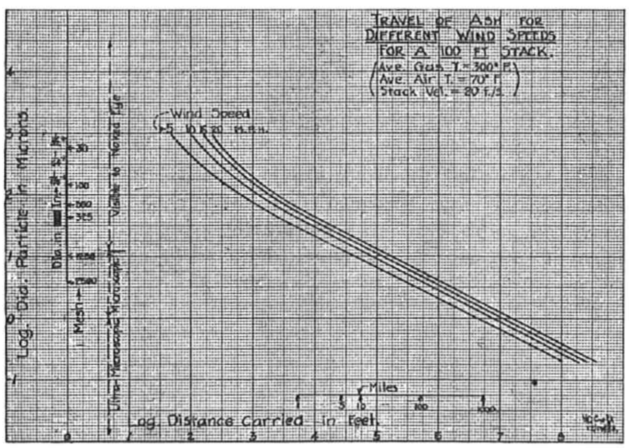

Fig. 5 Travel of Ash for Different Wind Speeds for a 100-Ft Stack

(Avg gas temp = 300 F. Avg air temp = 70 F. Stack velocity = 20 fps.)

The assumption is also made that all of this carry-over will be discharged by the chimney in order to calculate the worst condition of loading, although some of the larger sizes would probably be deposited in the breeching and chimney, especially if no induced-draft fan is used and low breeching velocities exist.

The assumed percentage by weight of the various sizes of the carry-over and the assumed efficiency of the separator for each size as well as the resulting calculated yearly loading at different distances are given in Table 3.

The distance that the particle is carried was obtained from Fig. 5.

The dust loading per square foot per year given in Table 3 was obtained by using the distance carried for the largest particle as a radius with the chimney at the center and assuming an equal distribution of the dust for that size over the area of the circle formed.

The distribution of the dust for the next larger size was determined by using the distance carried for this sized particle as a radius of a circle with the chimney at the center, subtracting the area covered by the next larger size, and dividing the total weight of ash for that size by the annular area so formed.

TABLE 3 DISTRIBUTION AND YEARLY DUST LOADING BY CARRYING OVER FROM A 100-FT CHIMNEY

Particle Diameter		Distance Carried by Wind—in ft.		Sep. Eff. %	Stoker—Carry Over = 5% of Coal.						Pul. Coal—Carry Over = 6% of Coal					
					Carry Over		Dust Loading in lb. per sq ft. per yr.				Carry Over		Dust Loading in lb per sq. ft per yr.			
							5 M.p.h.		10 M.p.h.				5 M.p.h.		10 M.p.h.	
Mesh	Microns	5 M.p.h.	10 M.p.h.		%	Lb/hr.	No Sep.	with Sep.	No Sep.	with Sep.	%	Lb/hr	No Sep.	with Sep.	No Sep.	with Sep.
20	832	56	112	99.9	1.0	42.3	37.6	.038	9.4	.009	0	0	0	0	0	0
50	294	144	288	98.0	4.0	170	26.9	0.54	6.73	.135	1.0	51	8.08	.162	2.02	.040
70	208	220	440	93.0	5.0	213	20.1	1.49	5.57	.390	1.0	51	4.82	.337	1.32	.092
140	104	560	1120	81.0	15.0	228	12.6	2.94	3.12	.580	3.0	153	8.45	1.6	2.05	.39
270	53	1410	2820	70.0	25.0	1325	6.94	2.07	1.73	.518	5.0	255	1.34	.401	.331	.0994
	30	5000	10,000	61.0	20.0	1133	0.431	0.168	.108	.0421	25	1275	.486	.190	.0122	.0476
	20	11,200	22,000	55.0	15.0	637	.0056	.0025	.0139	.0063	35	1785	0.157	.0706	.039	.0175
1250	10	44,700	88,400	42.0	15.0	637	.003	.0017	.0007	.0004	30	1530	.007	.0041	.001	.00058

50,000 kw. Unit; 1.7 lb. coal/kw-hr. Chimney Velocity = 20 ft./sec.

It should be noted that doubling the chimney height has approximately the same effect as doubling the wind velocity. Therefore, in Table 3 (for a 100-ft chimney), the column headed "10 mph" indicates what might be expected with a 5-mph wind with a 200-ft chimney.

In considering the yearly dust loading indicated by Table 3, it is interesting to note that the yearly rate of erosion is approximately 0.03 lb of earth per sq ft (9).

Conclusions

(1) An equation for the resistance of particles is derived (Equation [11]) which is useful over the entire range of particle sizes usually found in cinders and fly-ash.

(2) A method is demonstrated for calculating the distance an ash particle of a given size may be carried from the top of a chimney with a given wind velocity.

(3) By making certain assumptions, a method of calculating the yearly dust loading at different distances from a chimney is advanced.

References

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(6) *Fuel*, 1931, vol. 10, p. 196.
(7) *Zeit. V.D.I.*, 1933, vol. 77, p. 319.
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Discussion

T. A. Marsh.[4] The Department of Smoke Abatement of the City of Chicago has given much attention to atmospheric conditions, not only in the matter of visible smoke, but also of fly-ash and dust, over a period of years and has thereby been able to draw conclusions and to submit some very definite facts.

It has been our observation that many dust-fall determinations have been unreliable and often misleading, due sometimes to the method of making these observations, and at other times to such factors as increasing or decreasing amounts of coal burned within the district during the period of observation. It must, of course, be recognized that not all of the dust fall is chargeable to fuel burning although dust samples indicate that fuel is the major source.

During 1934, the Department of Smoke Abatement, under Civil Works Administration Project No. 1504 which pertains to

[4] Member, Advisory Board of Engineers, Chicago Department of Smoke Abatement, and Central Division Engineer, Iron Fireman Mfg. Company. Mem. A.S.M.E.

smoke observation and abatement, had allocated to it 175 men, some of whom are engineers of national reputation and of wide experience in this work. The writer is authorized, by the Department, to present to the Society any of the facts or figures from the report compiled by these men.

One of the significant figures of the report is that the tonnage of coal burned in the Chicago district has doubled between 1911 and 1933, yet the amount of smoke in 1933 was only 95 per cent of that of 1911, and the density of the smoke only 49 per cent.

Over this period of time, the changes in smoke produced by classifications are as follows:

Railroads	93 per cent decrease
Power plants	15 per cent decrease
Metallurgical furnaces	61 per cent decrease
Manufacturing plants	1 per cent decrease
Boats	2 per cent decrease
Apartment buildings	1620 per cent increase
Domestic (residences)	900 per cent increase

It is evident that we have mastered the situation in the larger plants, but in the meantime the great increase in the number of apartment buildings and residences has so increased the tonnage of coal burned that these two classes of chimneys have become responsible for a very large proportion of our smoke.

An analysis shows the sources of Chicago smoke to be as follows, in order of importance:

Apartments and large heating plants	43.0 per cent
Power plants	25.4 per cent
Domestic	20.4 per cent
Manufacturing	5.1 per cent
Railroad locomotives	2.8 per cent
Metallurgical and special processes	2.4 per cent
Boats	0.9 per cent

We have therefore logically centered our attention on the apartment buildings and heating plants.

Until the development of small automatic stokers for this field we had no reliable and economically sound weapon with which to attack this increasing source of half the smoke. The small stoker offers a definite solution. Four years ago we therefore wrote into our ordinance that all new plants of 1200 sq ft of steam radiation and over must use automatic firing of some kind, i.e., stokers, oil, or gas. At the present time there are approximately 6000 stokers installed in Chicago, each serving 1200 sq ft of radiating surface or more.

The dust fall in Chicago in tons per square mile per month for every year 1926 to 1932, inclusive, is as follows: 326.41, 390.28, 384.81, 355.02, 323.52, 268.52, and 230.33.

We have thus, due to our active campaign, not only reduced the volume and density of smoke in the City of Chicago, but have reduced the dust fall from a high figure of 390.28 in 1927, to 230.33 in 1932, the reduction being 41 per cent. These figures must, however, be considered in the light of the decrease of industrial coal burned in 1933 as compared to 1928. We are encouraged by the improvement, and, inasmuch as apartment buildings are very rapidly installing stokers purely for economic reasons, we feel that within a few years we shall make a measurable reduction in smoke from that particular group which is the worst offender. The improvements in stoker designs as now being made will further decrease the fly-ash.

The current research work and reports of the Department of Smoke Abatement of the City of Chicago are available to all who are interested in this work and our department will be glad to cooperate to the maximum with other cities or engineers toward improvement of atmospheric conditions.

There has never been any question as to whether stokers abated smoke. There has been a question, however, as to whether stokers actually decrease dust and fly-ash from chimneys. Our surveys indicate that stokers do decrease the dust and fly-ash emission because of decreased tonnage and maintenance of a uniform fuel bed.

Fuel and air distribution are the vital factors in fly-ash emission. Stokers with improper distribution and improper air regulation increase fly-ash. During the past three years sufficient advancement has been made in the art to make as much as a 75 per cent reduction in fly-ash from grates.