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OFFICE OF RESEARCH AND DEVELOPMENT
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CINCINNATI, OHIO 45268

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SUBJECT: Particle Loss Data for MHF Incinerators from the 10-City Study

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In response to your request, available data from our attached report, "Air Pollutional Discharges from Ten Sewage Sludge Incinerators," by J. B. Farrell and H. Wall, have been reviewed and are presented in a more direct manner than in the original report.

UNCONTROLLED EMISSIONS

Uncontrolled emissions from the six MHF sludge incinerators for which usable data were available are shown in Figures 1-4. Log of the relative metal loss (Metal loss/metal input in the feed) is plotted against log of the relative ash loss (particles emitted/ash input in the feed). For all of the metals examined, correlations are reasonably good. When it is considered that the incinerators were selected to give a range of sludge compositions and that no control was exercised in operating conditions, the degree of correlation obtained is surprising.

Figure 5 shows the expected shape of the relationship between metals loss and particle loss, assuming that the concentration of metal in any increment of ash being suspended into the gas stream is proportional to the concentration of the metal in the total mass of ash not yet suspended in the gas stream. For metals showing little classification into the particulate phase (k close to 1) the slope is close to 45° until very high losses are reached; for metals with a high degree of classification (k >> 1), the curves have a lower slope, particularly at high losses. This general behavior is followed in our experimental results.

Note that on Figure 5 all curves pass through the point, 1000 g/kg metals loss-1000 g/kg ash loss. Obviously when all the ash is lost, all the metals must be lost too. For Figures 1 to 4, the curves have been drawn as straight lines and extrapolate to figures greater than 1000 g/kg for the metals loss. From Figure 5, one can conclude that these lines should be concave downward as they near 1000 g/kg on the abscissa (dotted lines in Figure 3 conform to the model). Nevertheless, it appears that the metals losses are all high, perhaps by as much as a factor of 2. We have no explanation for this discrepancy which indicates that our data overestimate metals losses.

CONTROLLED EMISSIONS

Metal emissions leaving the scrubber relative to total emissions leaving the scrubber are shown in Figures 6-9. Relative metal losses are spread out more than for uncontrolled emissions as indicated below:

Losses: Cd > Pb > Zn > Cr, Cu > Ni > Mn > Fe

The losses of metals relative to losses of ash, particularly for Cd and Pb, are now far greater than for the uncontrolled emissions. Evidently, a further classification occurs at the scrubber. As the report explains, the primary reason is that Cd and Pb are concentrated in the finer aerodynamics particle size fractions.

The correlations are not as good as were obtained for the uncontrolled emissions. This is an anticipated result because loss of particles through a scrubber is primarily a function of aerodynamic particle size. Aerodynamic particle size doubtlessly varied from run to run because it depends on fraction of particles stripped out of the ash which was an uncontrolled variable.

The data in Figures 5-9 are particularly useful for estimating metal losses from MHF incinerators. If the scrubber meets EPA standards (0.65 g/kg), then on a volatile-solids free basis, this will amount to a range of ash loss of 0.11 to 0.22 percent ash loss for a typical VS range of 40 to 70 percent. Losses estimated have been read from Figures 6-9 and are shown below:

Metal	% Loss	% Loss/2
Cd	18 - 32	9 - 16
Pb	7 - 13	3.5 - 7
Zn	0.8 - 3.2	0.4 - 1.6
Cu	0.4 - 1.4	0.4 - 0.7
Cr	0.24 - 0.6	0.1 - 0.3
Ni	0.15 - 0.6	0.07 - 0.3
Mn	0.06 - 0.02	0.03 - 0.1
Fe	0.03 - 0.11	0.02 - 0.05

The central column above shows the losses predicted from the figures. In the right-hand column, losses have been adjusted downward to take into account a possible overestimation of losses as indicated by results for uncontrolled emissions.

The results point to two simple ways to run MHF incinerators to reduce emissions: (1) use a scrubber that keeps losses comfortably below the EPA limits. This will make it very unlikely that loss of Cd and Pb will be excessive (see Figures 6 and 7), and (2) reduce the furnace throughput. This will reduce flow of gaseous combustion products and reduce particulate carryover (of uncontrolled emissions) to the scrubber. Carryover will have a lower average particle size but quantity will be reduced. The net effort will be a reduction in the mass of particles escaping the scrubber, although the reduction will not be in the same proportion as the reduction in uncontrolled emissions.

There is a third way to reduce emissions and that is to use an APC (air pollution control) device whose performance does not deteriorate when particle size is fine. Both electrostatic precipitators and baghouses would reduce losses of fine particles.

Particle Size Leaving the Scrubber

Table A-2 from the 10-City report, which is attached, shows the particle size distributions before and after the scrubbers. The O-runs are after the scrubbers. Excluding Run K, the median fraction in the $> 10\ \mu m$ size range was 25 percent. Table 3, also attached, shows the pressure drops across the scrubbers. Maximum pressure drop was 20 inches of water (51 cm).

Enclosures

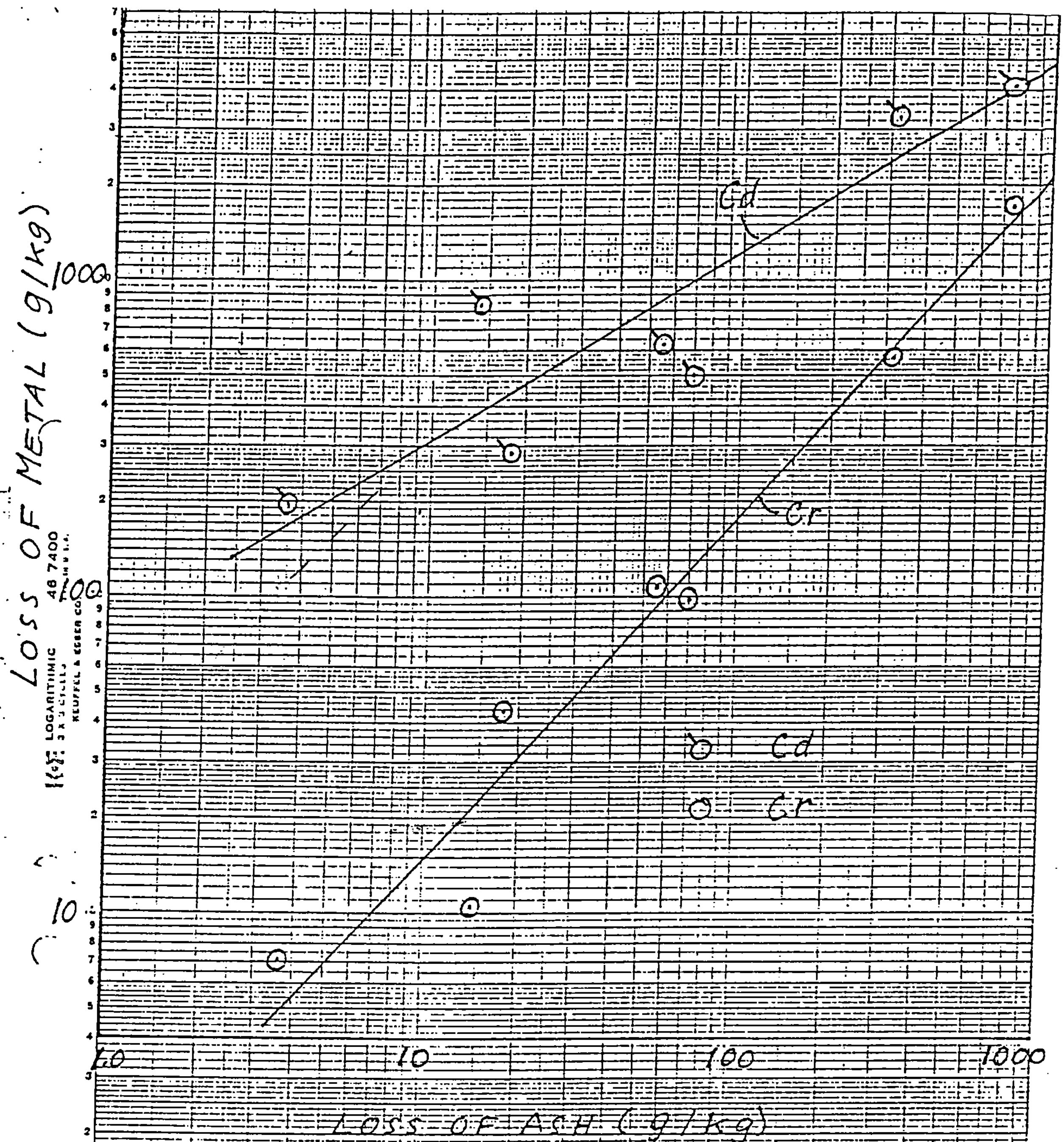

FIGURE 1

Metals Loss vs. Particle Loss in Uncontrolled Emissions from MHF Sludge Incinerators (Metal / Metal in feed vs Particles / Ash in feed): Cr and Cd

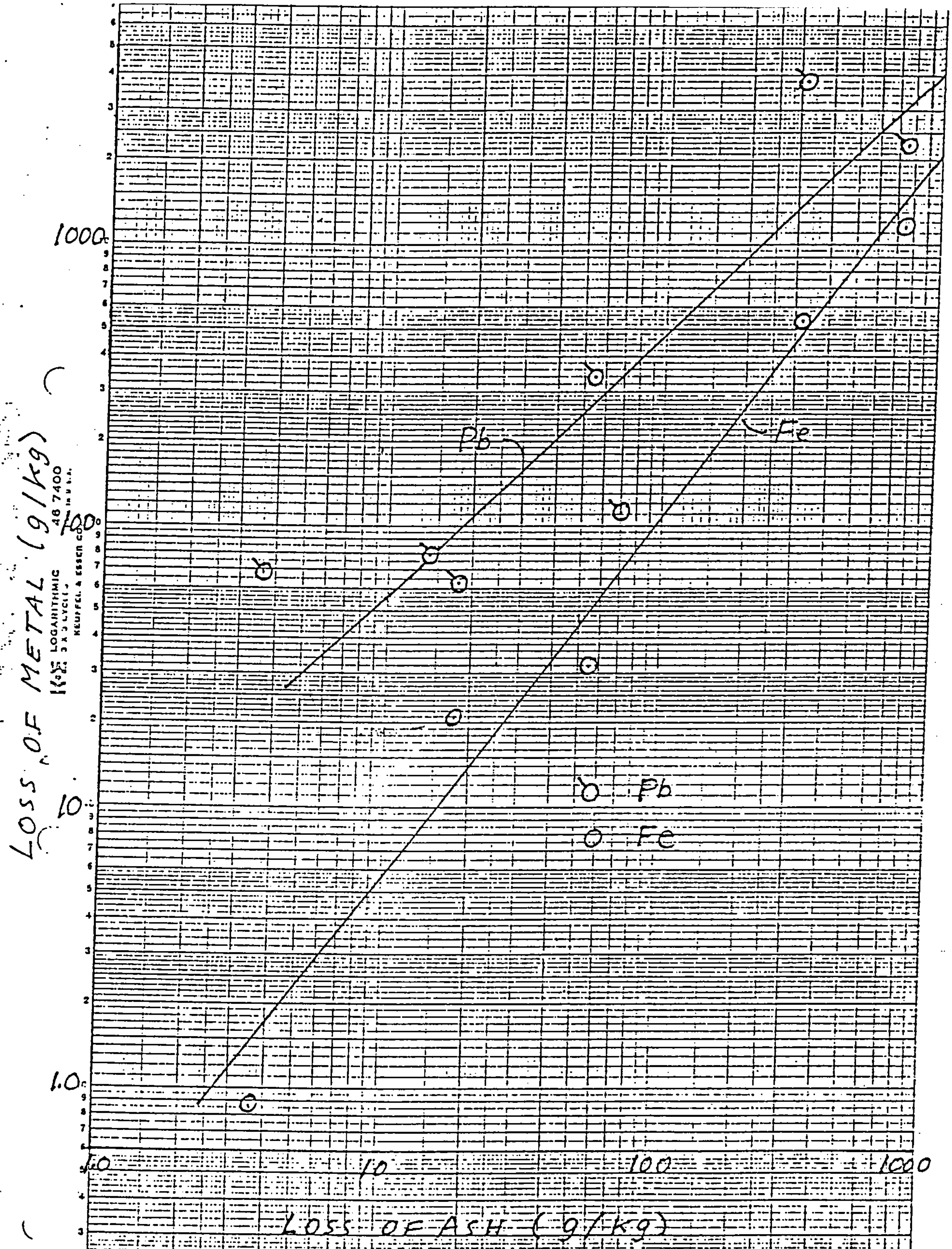

FIGURE 2

Metals Loss vs. Total Particle Loss in Uncontrolled Emissions from MHF Sludge Incinerators (Metal/total Metal fed vs. total Particles/Total Ash in feed); Fe and Pb

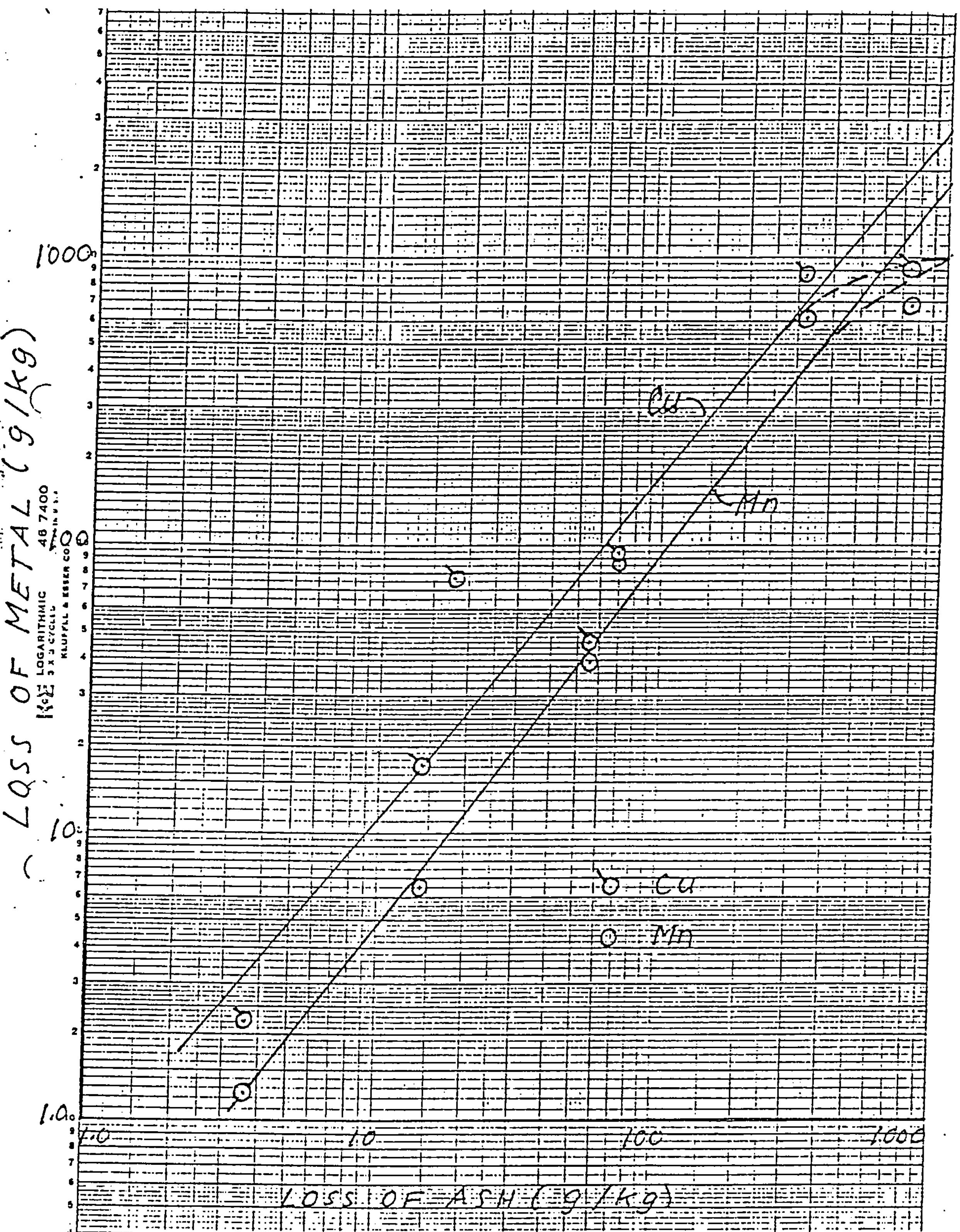

FIGURE 3

Metal Loss vs. Total Particle Loss in Uncontrolled Emissions from MHF Sludge Incinerators (Metal in Particles / Metal in feed vs. Particles / Ash in feed): Mn and Cu

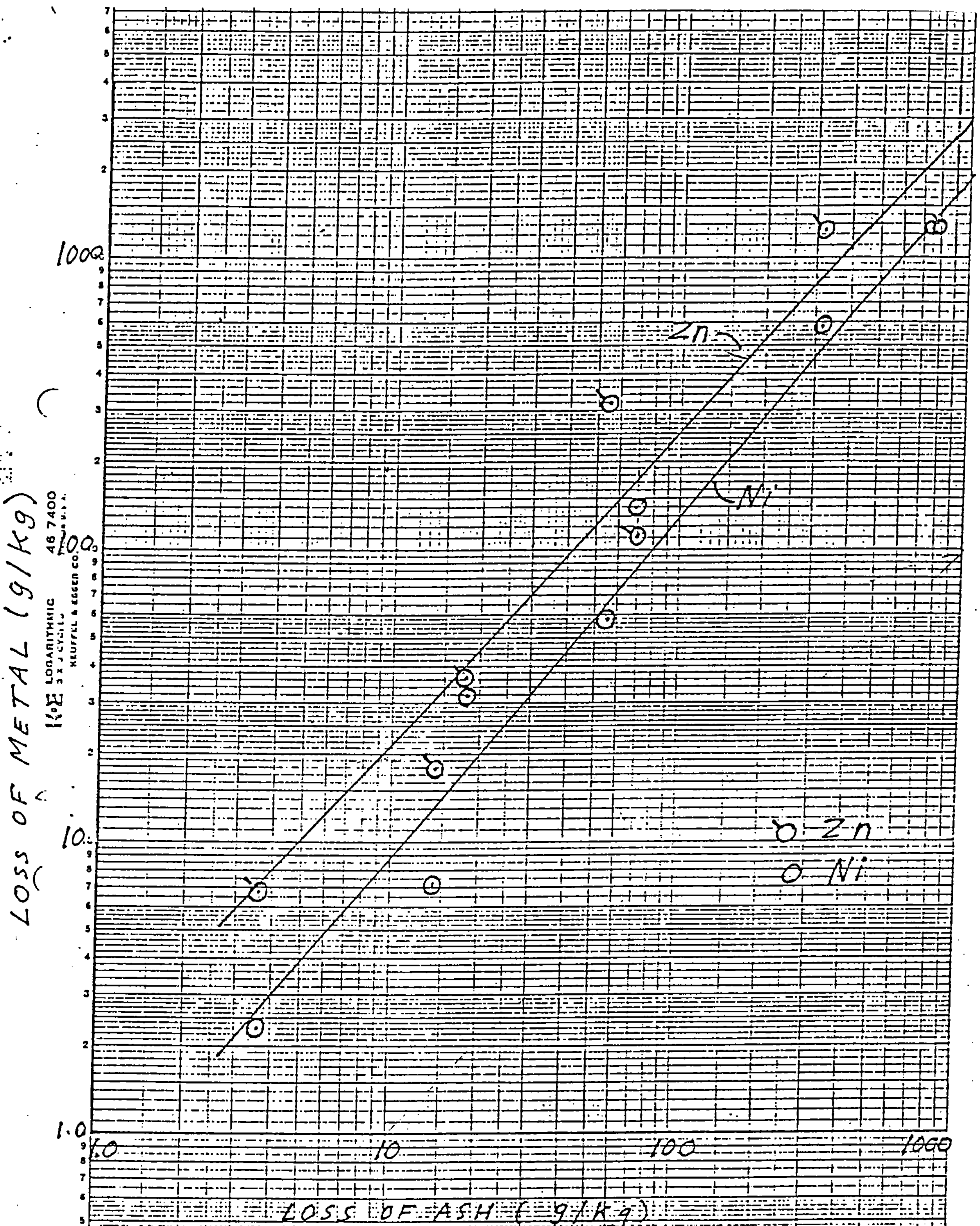

FIGURE 4

Metals Loss vs. Total Particle Loss in Uncontrolled Emissions from MHF Sludge Incinerators (Metal / Total Metal in feed vs Particles / Total Ash in feed):

Ni and Zn

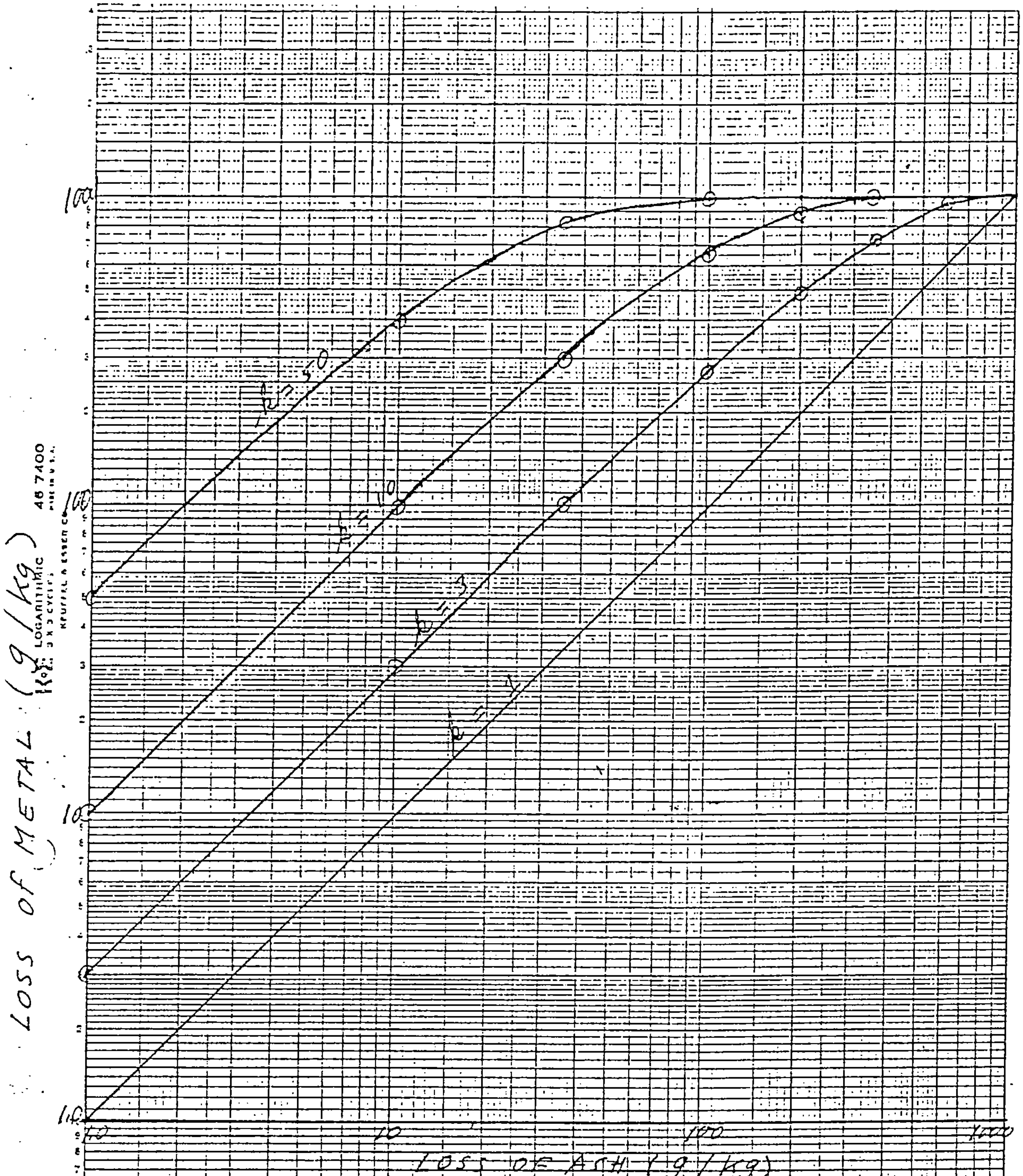

FIGURE 5

Expected Relationship Between Metals Loss and Particle Loss Assuming Metal Concentration in Any Increment of Particle Lost is Proportional to The Concentration of Metal in the Total Mass of the Ash Remaining

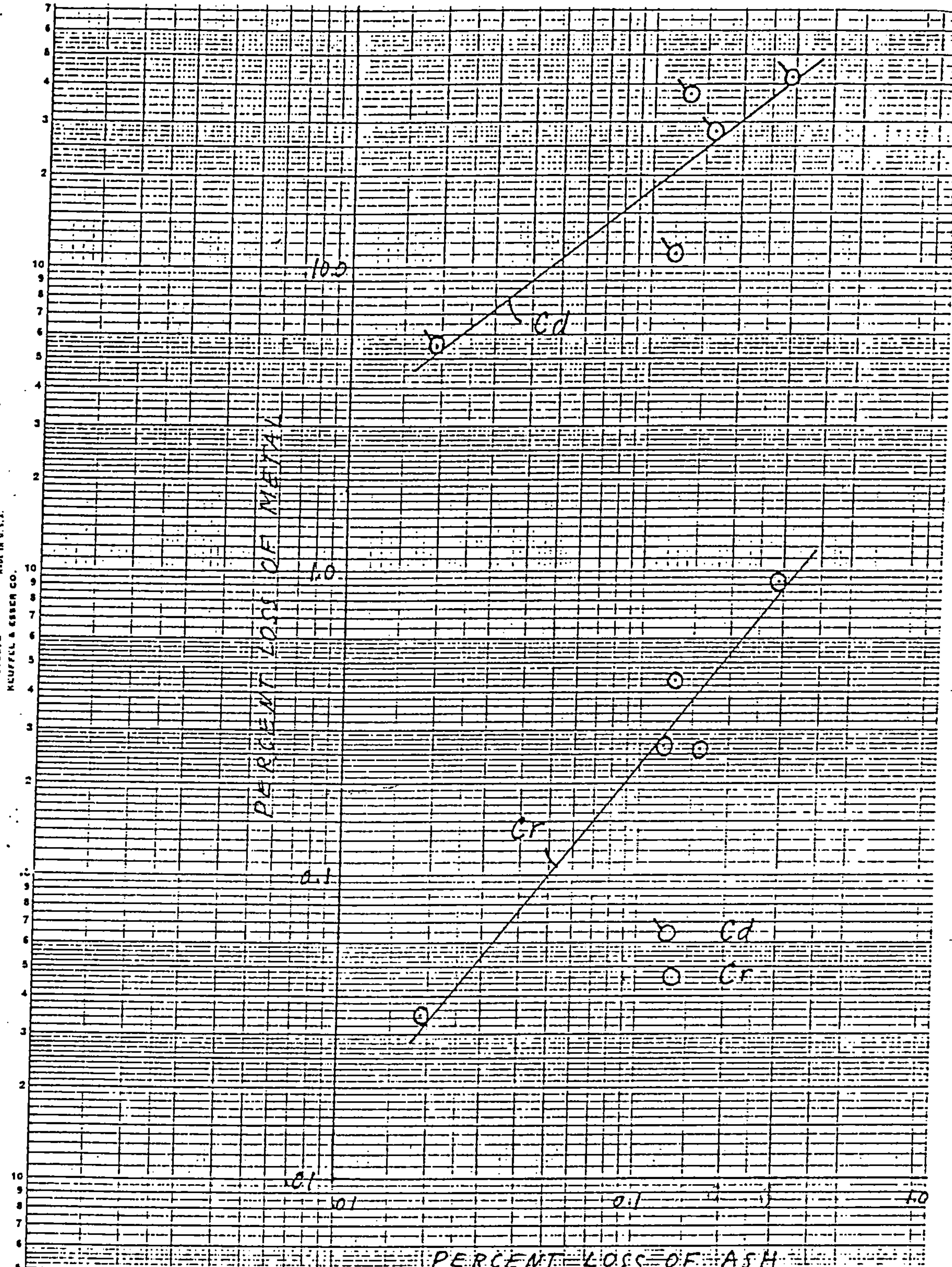

FIGURE 6

Loss of Metals and Ash in Controlled Emissions from MHF Sludge Incinerators with Wet Scrubbers (metal in particles/metal in feed vs particles/ash in feed): Cr and Cd

.06
$\frac{.6 \times 100}{1000}$
= .06

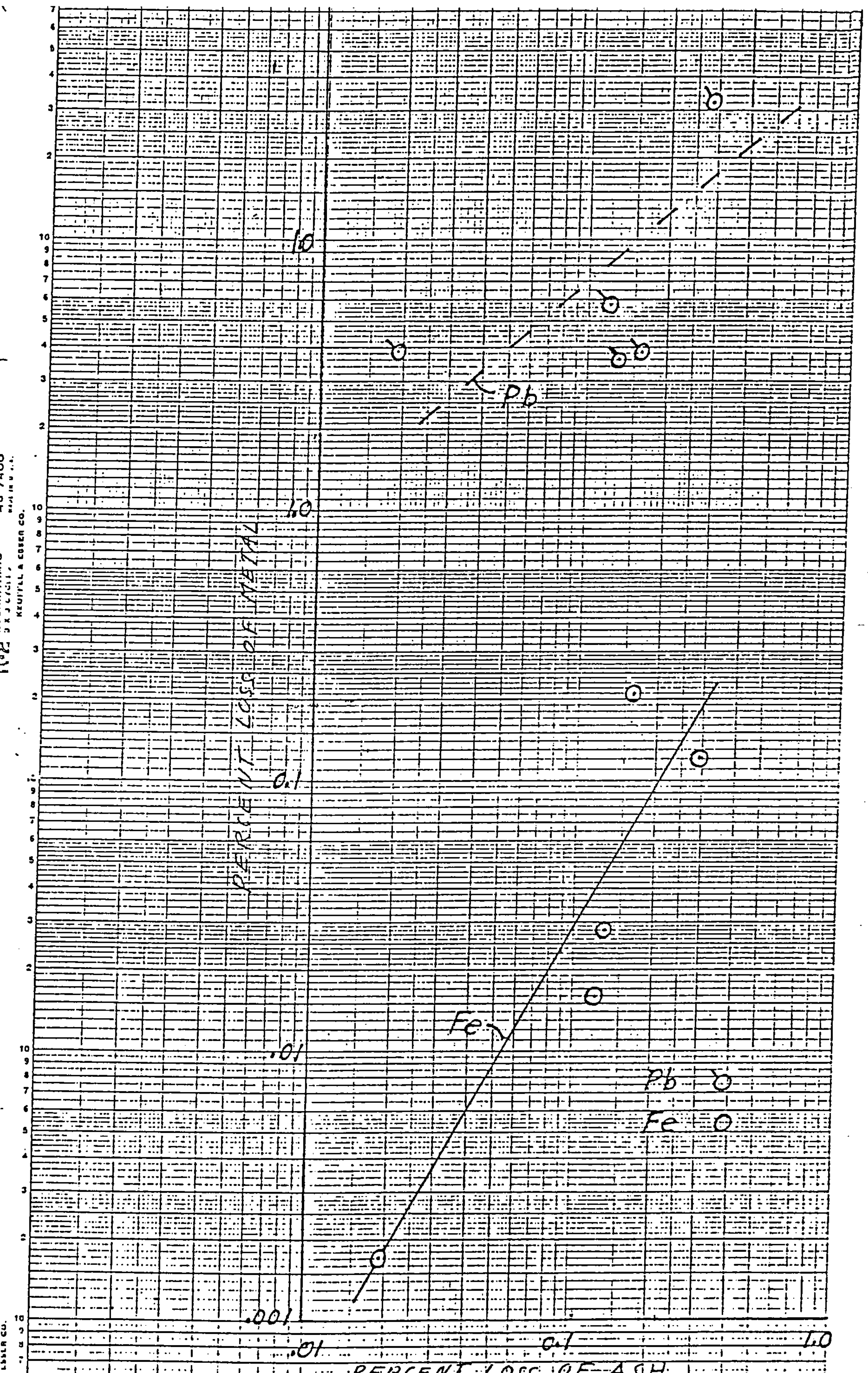

FIGURE 7
Loss of Metals and Ash in Controlled Emissions from
MHF Sludge Incinerators with Wet Scrubbers
(metal in particles / metal in feed vs. particles / ash in feed): Fe & Pb

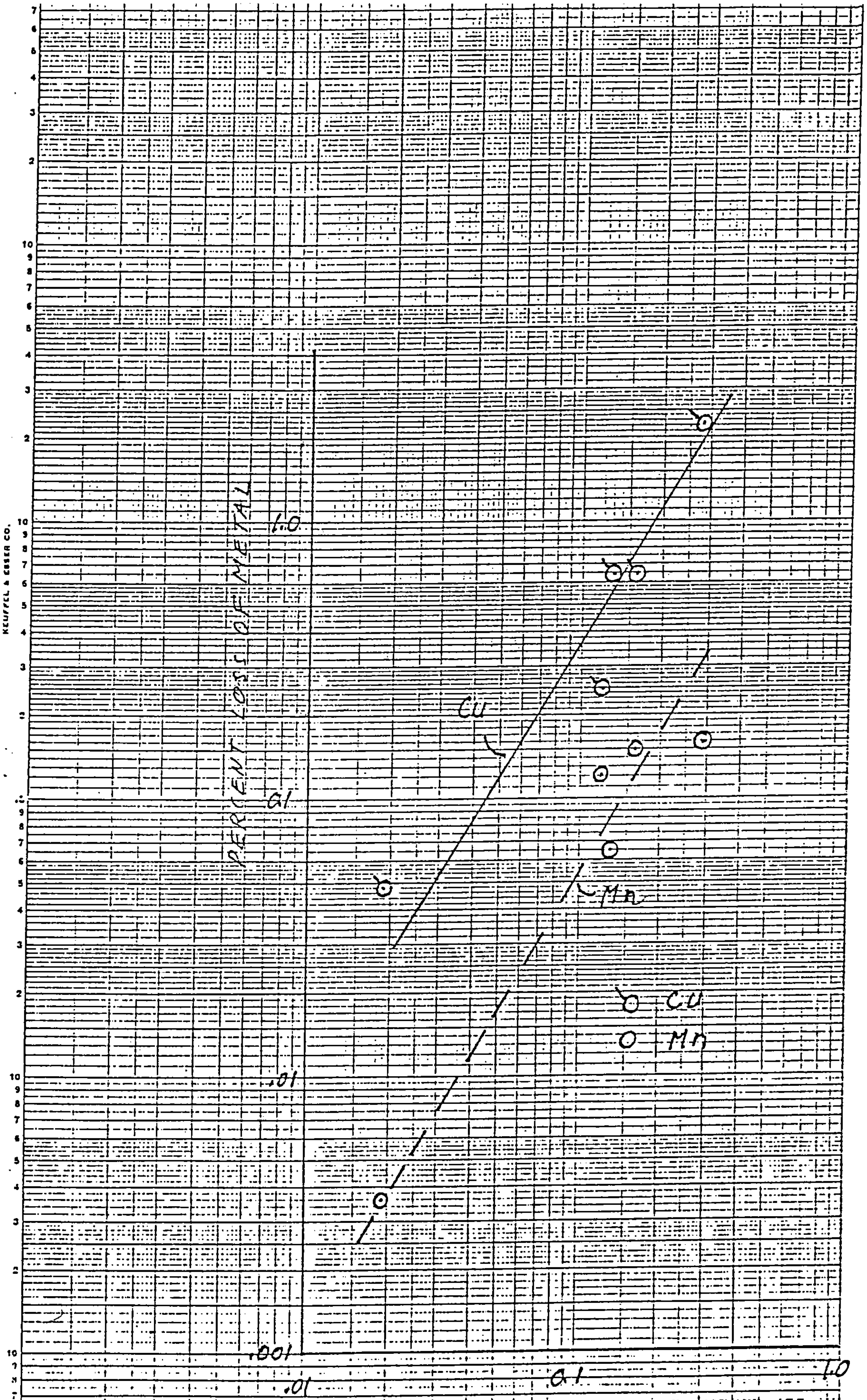

FIG 8 PERCENT LOSS OF ASH

Loss of Metals and Ash in Controlled Emissions from MHF Sludge Incinerators with Wet Scrubber (metal in particles / metal in feed vs. particles / ash in feed): Mn & Cu

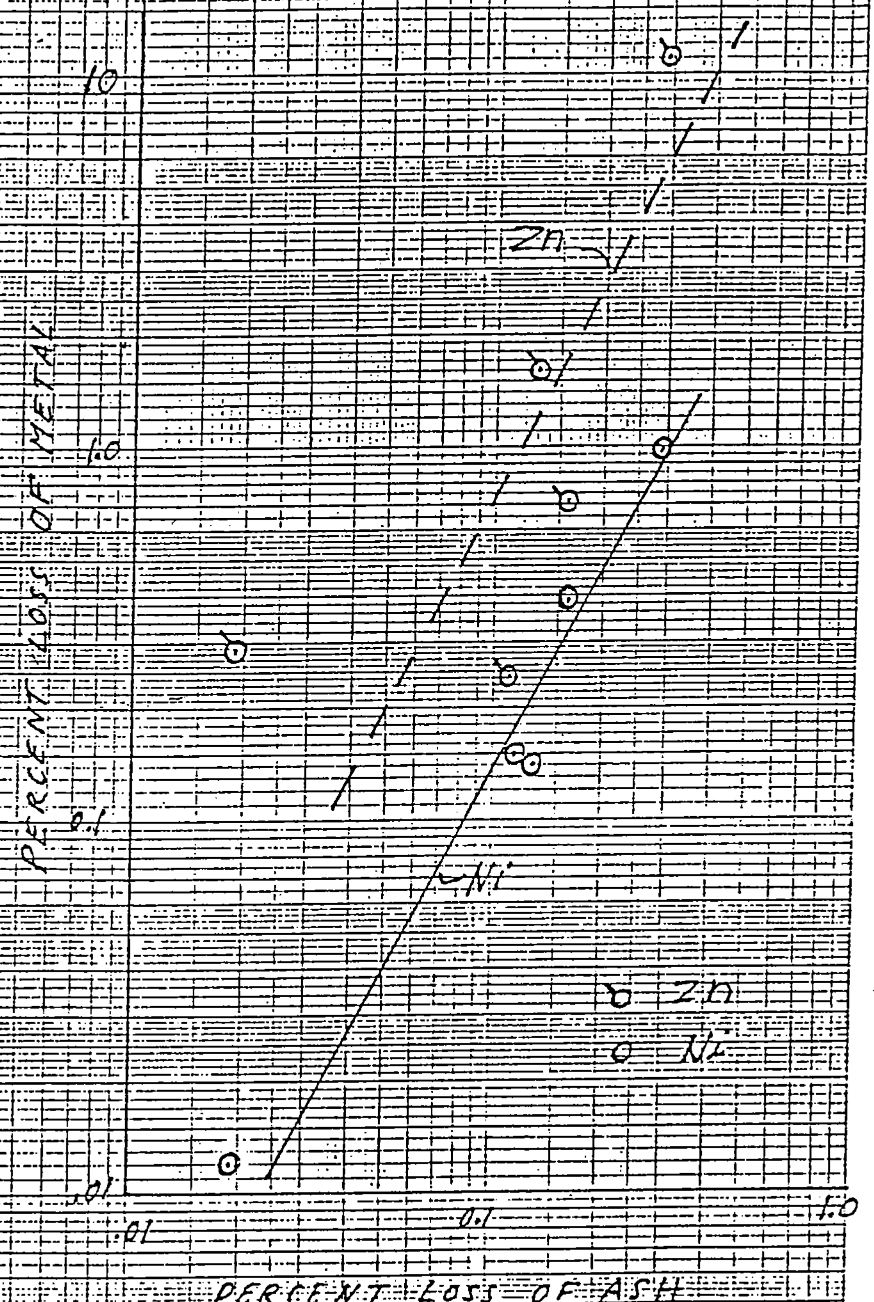

FIGURE 9

Loss of Metals and Ash in Controlled Emissions from MHF Sludge Incinerators with Wet Scrubbers (metal in particles/metal in feed vs. particles/ash in feed): Ni and Zn

TABLE A-2

DISTRIBUTION OF MASS IN VARIOUS PARTICLE SIZE FRACTIONS AT SCRUBBER INLET AND OUTLET IN SLUDGE INCINERATOR TEST (Weight Percents)*

Run	Size Fractions (μm) > 10	3.5-10	1.0-3.5	0.1-10	Wt. Percent of Scrubber Input That Left at Outlet
A-I	68.42	9.19	12.18	10.21	
A-O	30.06	7.20	8.41	54.33	1.8
C-I	34.93	31.48	8.06	25.53	
C-O	3.81	0.61	1.36	94.22	7.7
D-I	72.61	19.25	6.22	1.92	
D-O	3.98	1.88	2.28	91.86	0.8
E-I	80.77	1.86	1.92	15.45	
E-O	45.83	2.63	3.13	48.40	5.3
F-I	49.61	41.65	3.39	5.35	
F-O	24.53	15.81	6.63	53.03	10.5
G-I	98.28	1.39	0.13	0.20	
G-O	27.13	2.68	14.84	55.35	0.1
J-I	67.88	26.09	5.71	0.32	
J-O	16.26	33.36	8.03	42.35	0.4
K-I	39.46	34.86	21.23	4.45	
K-O	35.13	0.06	2.04	62.77	14.9 (wet cyclo)

* Mass in probe wash not included.

TABLE 3. Scrubber Efficiencies and Possible Significant Variables

Site	Incinerator Type	Scrubber Efficiency(%)	Type	Scrubber Δ P (cm H_2O)	Loading (g/kg)	Percent CO_2 in Exhaust (water-free basis)*	Percent Fines** (0.1-1.0 μm)
G	FB	99.9	V+I	--	769	10.9	0.2
J	FB	99.6	V+I	41	9.5	12.8	0.3
D	MH	99.2	I	15	225	6.3	1.9
A	MH	98.2	I	25	40.2	2.9	9.8
E	MH	94.7	V+I	51	2.4	8.5	15.4
C	MH	92.3	I	42	8.7	3.2	24.8
B	MH	92.0	I	48	5.1	16.9	-
F	MH	89.5	V+I	51	5.6	3.6	5.4
K	MH	85.1	WC	--	226	7.0	4.4

* Percent CO_2 is related to excess air. A low value indicates a high percent excess air. For a given sludge input rate, high percent excess air means higher gas velocity and probably higher entrainment of solids.

** Percent fines in the particles entering the scrubber