REFUSE PIT STORAGE REQUIREMENTS
A Waste Density Study in Operating United States Resource Recovery Facilities

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ABSTRACT

This paper discusses and recommends design criteria that can be used to determine dimensions when designing the refuse pit in a resource recovery facility. It further lists results of a long term study done at three resource recovery facilities in the United States.

INTRODUCTION

A substantial number of large resource recovery facilities have been built in the last few years in this country. Even more are under construction or in development or implementation. Most of these facilities employ mass-burn technology. Solid waste is mainly delivered in bulk by packer truck or transfer trailer every working day during refuse collection time. The facilities process and combust the waste on a continuous 24 hr/day and 7 days/week basis. To match this steady-load processing of solid waste with the intermittent delivery, a buffer is needed. This buffer is generally provided in the form of a refuse pit. The refuse pit has to be sized to receive solid waste in excess of the average facility processing capability to store it during nights and weekends as well as to provide for storage during times of reduced processing capacity due to scheduled or unscheduled shutdowns of furnace/boiler units for maintenance.

These refuse pits are nearly always built from reinforced concrete. The large size and considerable wall thickness make these pits a costly part of the overall facility. Optimal sizing of the pit is therefore not only important to ensure reliable facility operation, but also to avoid excessive facility costs.

REFUSE PIT VOLUME AND DIMENSIONS

It has become standard practice to assume at least a three (3) day's storage capacity for the refuse pit. This means that the pit should be able to receive and store as much solid waste during a complete shutdown of the facility as the equipment could process at full capacity during 3 days (72 hr). If a later facility expansion is contemplated during the original design, it is common practice to design for a 3 day storage capacity based on the extended facility capacity to avoid at a later date a costly and difficult to carry out extension of the refuse pit.

To determine the pit volume that corresponds to storage requirements expressed in days of facility capacity, it is necessary to establish how much of the total volume of the pit can be used for storage and to estimate as accurately as possible the average solid waste density.

The part of the total volume of the pit that can be utilized for storage is generally assumed to be all of

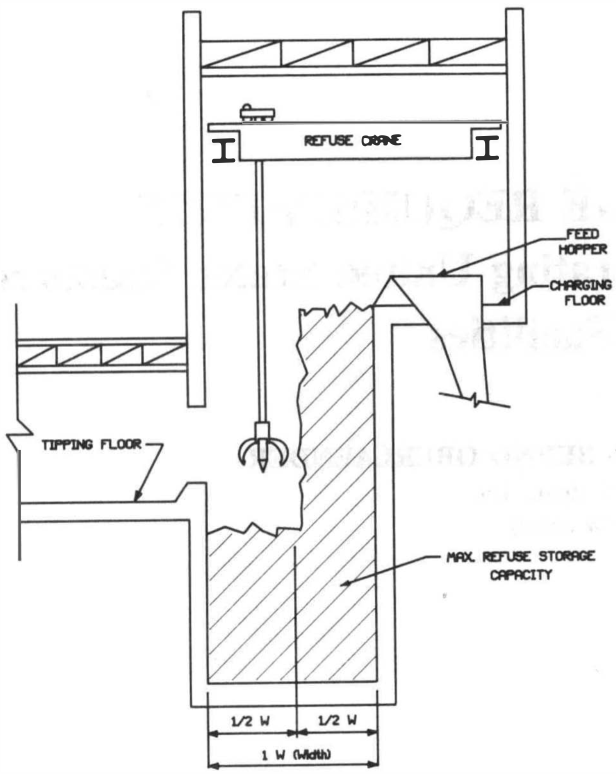

FIGURE 1

the volume that is below the tipping floor and some part of the volume above the tipping floor up to the charging floor level. To allow dumping of solid waste into the pit on an ongoing basis while the pit gets filled up, it is necessary to leave space for the unrestricted movement of the crane grapple.

The pit width should be designed at least two and a half to three times as wide as the space that an open grapple requires (see Figure 1). As a general rule 50% percent of the pit volume above the tipping floor level can be assumed to be available for storage. This will vary somewhat and it is not unusual to allow for more than 50 percent storage above the tipping floor in a large facility. In large facilities the pit can be substantially wider than twice the crane grapple, to save costs that would result from a very deep pit. Pit depth is kept at approximately 30–45 ft[1], measured from the tipping floor down to the bottom of the pit. This is sufficient to allow several vehicles to dump refuse before the crane needs to restock it to storage. The pit length is mostly determined by the space needed for the feed hoppers and the furnace boiler distances. Another criteria for designing pit length and size is by determining the number of tipping bays required for easy dumping by delivery vehicles. A rule of thumb to establish this criteria uses the following formula:

$$\text{Number of tipping bays} = \frac{\text{Maximum number of trucks/hour}}{6}$$

This will allow for an average 10 min turn-around time per truck.

To determine the maximum number of trucks per hour, available records from an existing facility (e.g., landfill) should be consulted, or in lack of such data, one can conservatively assume that all solid waste will be delivered in 5 ton packer trucks, delivering 7 days worth of plant capacity in a 5 day period. One should further assume that half of this delivery takes place in two rush-hour periods per day of a duration of 90 min each.

Example:

Facility size:	2000 tons per day
Daily delivery:	2000 tons × 7 days per 5 days = 2800 tons
Number of trucks per day:	2800 tons/5 tons per truck = 560 trucks
Number of trucks during each 90 min rush-hour period:	560/2/2 = 140
Maximum number of trucks per hour:	140/90 × 60 = 93.3
Number of tipping bays:	93/6= 15.5, say 16

This approach requires one tipping bay for every 125 tons of daily processing capacity.

To allow for adequate maneuvering and space between unloading vehicles, a tipping bay should not be less than 13.5 ft wide. If building columns of 3 ft are considered between every two to three tipping bays, the above example would require a pit length of 231 ft:

$$\text{Pit length} = (16 \times 13.5 \text{ ft}) + (5 \times 3 \text{ ft}) = 231 \text{ ft}$$

Table 1 lists several refuse pit dimensions of operating resource recovery facilities in different parts of the United States. The differences in elevation of the

[1] For conversion factors into SI units see Appendix A

TABLE 1 REFUSE PIT DIMENSIONS

Facility Name	Capacity (Assumes expanded Facility size) (tons per day)	Elevation of Tipping Floor Above Grade (ft)	Pit Length (ft)	Pit Width (ft)	Pit Depth from Tipping Floor (ft)	Number of Tipping Bays
Alexandria, VA	975	11.8	180	38	34	13
Babylon, NY	1,125	15	122	41	25	9
Bristol, CT	975	0	129	33	40	9
Fairfax County, VA	3,750	15	360	50	40	24
Haverhill, MA	1,650	-8	180	52	37	12
Hillsborough County, FL	1,600	28	192	45	35	12
Indianapolis, IN	3,150	7	264	50	42	18
Kent County, MI	937	0.5	142	49	36.3	9
Marion County, OR	825	11	90	35	34	6
Stanislaus County, CA	800	7	120	40	35	8
Tulsa, OK	1,125	17	130	47	27	8

tipping floor to grade are caused by site specific conditions such as ground water level, cost and complexity of excavation versus cost and space availability of ramps and elevated tipping floors, aesthetics, etc.

REFUSE DENSITY

To translate storage requirements into actual pit dimensions, it is necessary to know the density of the stored refuse. Only a few studies have been done on this subject in the past. One of them was presented by Scott and Holmes in the *Proceedings of the 1974 ASME National Incinerator Conference* [1]. Since then not much useful information has been systematically collected, evaluated and published in this country. In the United States, mass-burn resource recovery facilities have been built in larger numbers and substantial size only since the late seventies and early 1980s. Several major contractors and consultants to communities have used varying refuse density assumptions to specify the sizing of the refuse pits. A widely used assumption was that refuse stored below the tipping floor level would weigh on average 650 lb/yd^3 and refuse stored above the tipping floor level would have an average density of 450 lb/yd^3. The difference in density is established to take to some degree into account that the lower the refuse is in the pile, the denser it will be due to compaction caused by the weight of the material above. Most facilities that have refuse pits built based on these density assumptions work quite well and have no serious storage problems.

To either confirm the validity of these assumptions or to find more accurate numbers to help in the optimization of the pit sizing in respect to waste density and give designers and consultants a better tool to establish pit dimensions, a long-term study was undertaken at several operating facilities. To avoid upsetting interruptions in the mode of operation of the plant, a simple system had to be conceived that allowed for data collection over a considerable length of time with minimal requirements for time and manpower.

The method that was chosen to establish the refuse density on an ongoing basis requires the following data acquisition:

W_{rec} = Mass of refuse as weighed at the scalehouse determined with an accuracy of ±5%.

W_{pro} = Mass of refuse as processed in the furnace units, arrived at through weighing of the refuse in the crane grapple with a load cell. For each grapple load a weight reading with an accuracy of approximately ±7.5% is recorded.

V_{pit} = Volume of refuse in the pit. This is established on a daily basis by a person determining the average height of the refuse to calculate the volume occupied by the stored refuse. This is always done at the same hour of the day, e.g., midnight. To improve the height estimation, the pit is divided into approximately 25 equal rectangles. If available, painted marks are used for this task, but marks in the pit walls from concrete forms used during construction are also very useful for this purpose.

Rho_e = Assumed refuse density. A refuse density is estimated and used together with the volume determination (V_{pit}) to calculate the daily pit inventory.

There are two ways used to determine the pit inventory (W_p) in tons:

Method 1 = W_{P1}: = $V_{pit} \times Rho_e$ (tons)

Method 2 = W_{P2}: = $W_{rec} - W_{pro} + W_{P1}$ (from previous day) [tons]

Rho_e is kept constant within one full month

Method 1 is based on the refuse height/volume determination and the estimated density (Rho_e).

Method 2 takes the pit inventory per Method 1 of the day before as a given number and adds the received refuse minus the processed refuse during the last 24 hr period.

ΔW = Method 1 and Method 2 lead to slightly different pit inventory tonnage values.

$|\Delta W|$ = For a statistical sufficient number of observations (e.g., 30 days), we can create an average for the total values of the difference between Method 1 and Method 2.

min.$|\Delta W|$ = For a certain assumed refuse density, a minimum for the total value of the average difference $|\Delta W|$ exists. This minimum can be found by iteration.

Rho_m = The minimum $|\Delta W|$ exists only for a definite refuse density. This refuse density (Rho_m) is the most likely average density for each monthly period, because it is creating the lowest possible difference between the two pit inventory determination methods.

To find the actual average refuse density, daily data over a monthly period are processed. During this time period the assumed refused density (Rho_e) has to be held constant to find a definite minimum.

Regular data collection has been started during 1989 in the mass-burn resource recovery facilities in Indianapolis, Indiana; Marion County, Oregon and Tulsa, Oklahoma. These facilities are in different parts of the country and in different local settings from large city to a more rural area. The wastes processed in these facilities include mainly household refuse and to varying degrees commercial waste. It is not possible to establish a firm number for waste density, since refuse is such a nonhomogeneous commodity that constantly changes its composition. It is the intent, however, to determine how reasonable the assumed densities mentioned earlier are (650/450 lb/yd^3 below/above tipping floor level).

The results of this testing up to and including November 1989 are presented in Tables 2, 3, and 4 and Fig 2. As expected, the results vary widely, but stay well within the design range. No clear seasonal pattern is recognizable. Marion County and Tulsa experienced generally lower densities during the Fall months and two plausible explanations were given. Tulsa had a large amount of leaves brought to the plant. Marion County went through the annually scheduled maintenance outages and a resulting full pit did not allow for good pit management. Also, an indication of increased density with increased height of the refuse pile is not well established (see Fig. 3).

A possible reason for this phenomenon is the vast variety of refuse composition (e.g., a study undertaken in West Germany shows for paper content in refuse a variation depending on the season between 13% and 20% in weight) [2]. It is also known that in the United States grass clippings provide up to 20% of the waste stream during summer time.

Another fact is that the higher refuse has to be piled up in the pit, the more refuse has to be moved by the crane operator. The purpose of this mixing is homogenization of the refuse to avoid generation of methane and bad odors in the pit. This handling of the refuse seems to diminish the compaction caused by its own weight.

For comparison, a curve published by Scott and Holmes [1] is included in Fig. 3. This curve presents the function between increasing refuse density and depth of refuse based on experiments undertaken by the London Council during 21 days. It should be noted that the test conditions:

(a) constant refuse composition

(b) long time period for refuse compaction

on which the curve is based are not comparable with current operating conditions of actively operated resource recovery facilities.

Therefore, no close coincidence between the curve and actual density determination exists.

Table 5 presents refuse density design data for the facilities presented in Table 1. The average refuse waste density is an average of the storage capacity below

TABLE 2 WASTE DENSITY TESTING IN INDIANAPOLIS, INDIANA

1989	Average Density Rho_m(lb/yd^3)	Average Height of Pit Inventory (ft)	Average Daily Refuse Received W_{rec}(tons)	Average Daily Refuse Processed W_{pro} (tons)	Average Daily Pit Inventory Based on Method 1 W_{p1} (tons)	Method 2 W_{p2} (tons)	Difference %
January	484	34.5	1471	1813*	4088	3831	-6.3
February	436	28.3	1389	1440*	3015	2885	-4.3
March	470	28.7	1556	1588	3297	3278	-0.6
April	672	36.7	1627	1638	6027	6130	1.7
May	774	22.1	1972	1855	4176	4237	1.5
June	495	41.7	1925	1806	4923	4979	1.1
July	540	21.4	1712	2037	3344	3290	-1.6
August	711	22.1	1939	1789	3833	3924	2.4
September	470	19.4	1935	1934	2234	2212	-0.1
October	654	29.5	1800	1865	4711	4661	-1.1
November	467	33.3	1919	2130	3808	3654	-4.0
December							
Average	561	28.9	1750	1809	3951	3916	-1.0

*Temporary problems with crane weigh cells

TABLE 3 WASTE DENSITY TESTING MARION COUNTY, OREGON

1989	Average Density Rho_m (lb/yd^3)	Average Height of Pit Inventory (ft)	Average Daily Refuse Received W_{rec} (tons)	Average Daily Refuse Processed W_{pro} (tons)	Average Daily Pit Inventory Based on Method 1 W_{p1} (tons)	Method 2 W_{p2} (tons)	Difference %
January	793	17	526	516	788	860	9.1
February	498	19.3	450	425	560	639	14.1
March	693	28.9	517	510	1166	1243	6.6
April	Insufficient Data						
May	639	35.5	505	524	1324	1315	-0.7
June	561	37.1	534	517	1213	1226	1.1
July	654	30.8	515	524	1175	1159	-1.4
August	661	45.9	481	418	1768	1767	-0.1
September	348	60.1	445	438	1219	1244	2.1
October	382	45.8	461	513	1020	984	-3.5
November	524	23.6	503	494	721	732	1.5
December							
Average	575	34.4	494	488	1095	1117	2.9

TABLE 4 WASTE DENSITY TESTING TULSA, OKLAHOMA

1989	Average Density Rho_m (lb/yd^3)	Average Height of Pit Inventory (ft)	Average Daily Refuse Received W_{rec} (tons)	Average Daily Refuse Processed W_{pro} (tons)	Average Daily Pit Inventory Based on Method 1 W_{p1} (tons)	Method 2 W_{p2} (tons)	Difference %
January	Insufficient Data						
February	Insufficient Data						
March	Insufficient Data						
April	Insufficient Data						
May	Insufficient Data						
June	606	42.7	1124	1107	2897	2940	1.5
July	582	40.9	1030	1006	2665	2965	11.3
August	529	33.2	1074	1062	1966	1972	0.3
September	568	27.0	988	1012	1720	1710	-0.6
October	431	40.7	851	790	1963	1981	0.9
November	380	51.0	822	861	2168	2130	-1.7
December							
Average	516	39.3	982	973	2230	2283	2.0

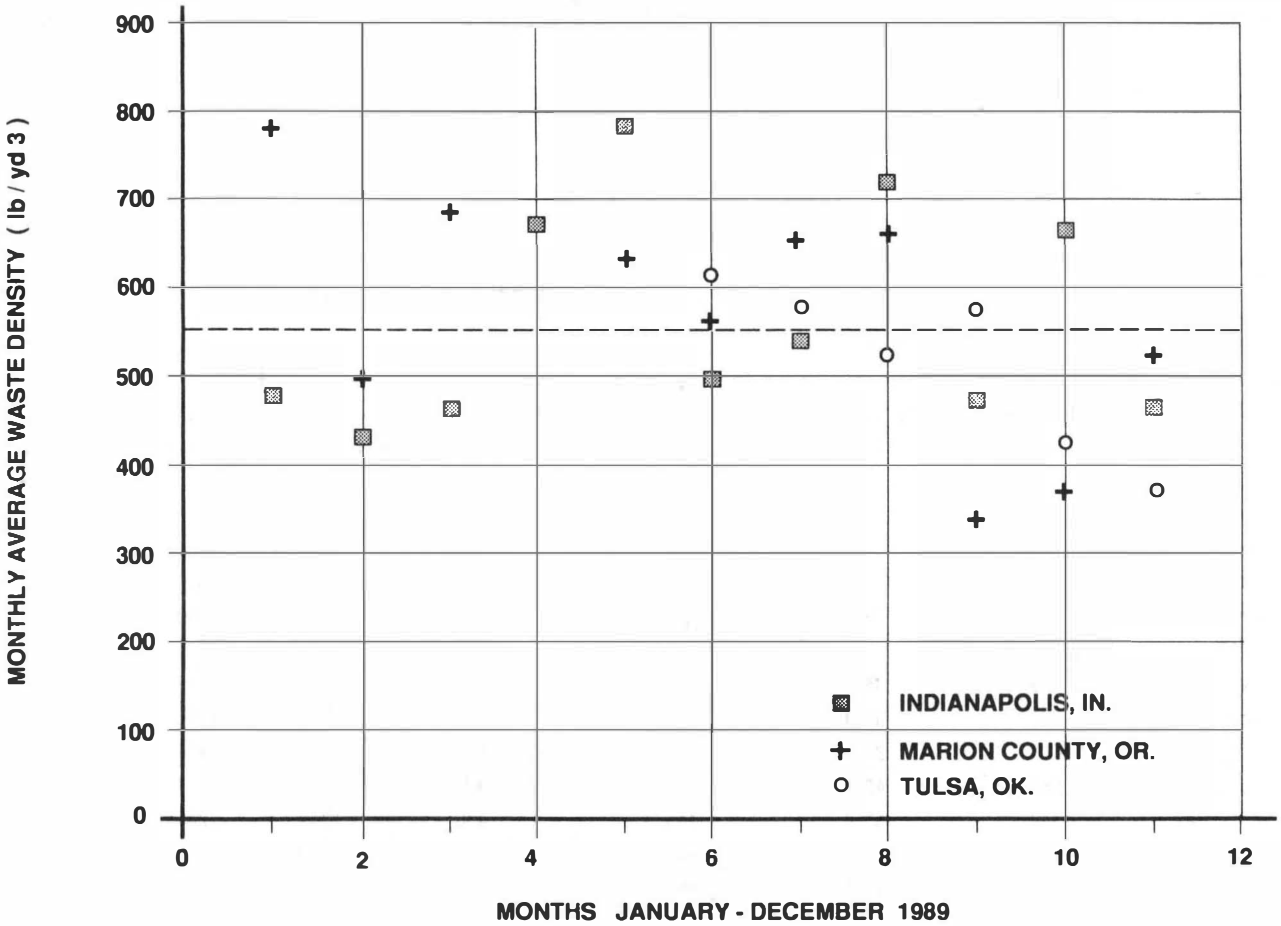

FIG. 2 AVERAGE MONTHLY WASTE DENSITY
(Resource Recovery Facilities: Indianapolis–Marion County–Tulsa)

TABLE 5 REFUSE PIT DESIGN DENSITIES

Facility Name	Average Design Density (lb/yd^3)
Alexandria, VA	574
Babylon, NY	552
Bristol, CT	562
Fairfax County, VA	562
Haverhill, MA	576
Hillsborough County, FL	583
Indianapolis, IN	571
Kent County, MI	530
Marion County, OR	560
Stanislaus County, CA	559
Tulsa, OK	558
Average	562

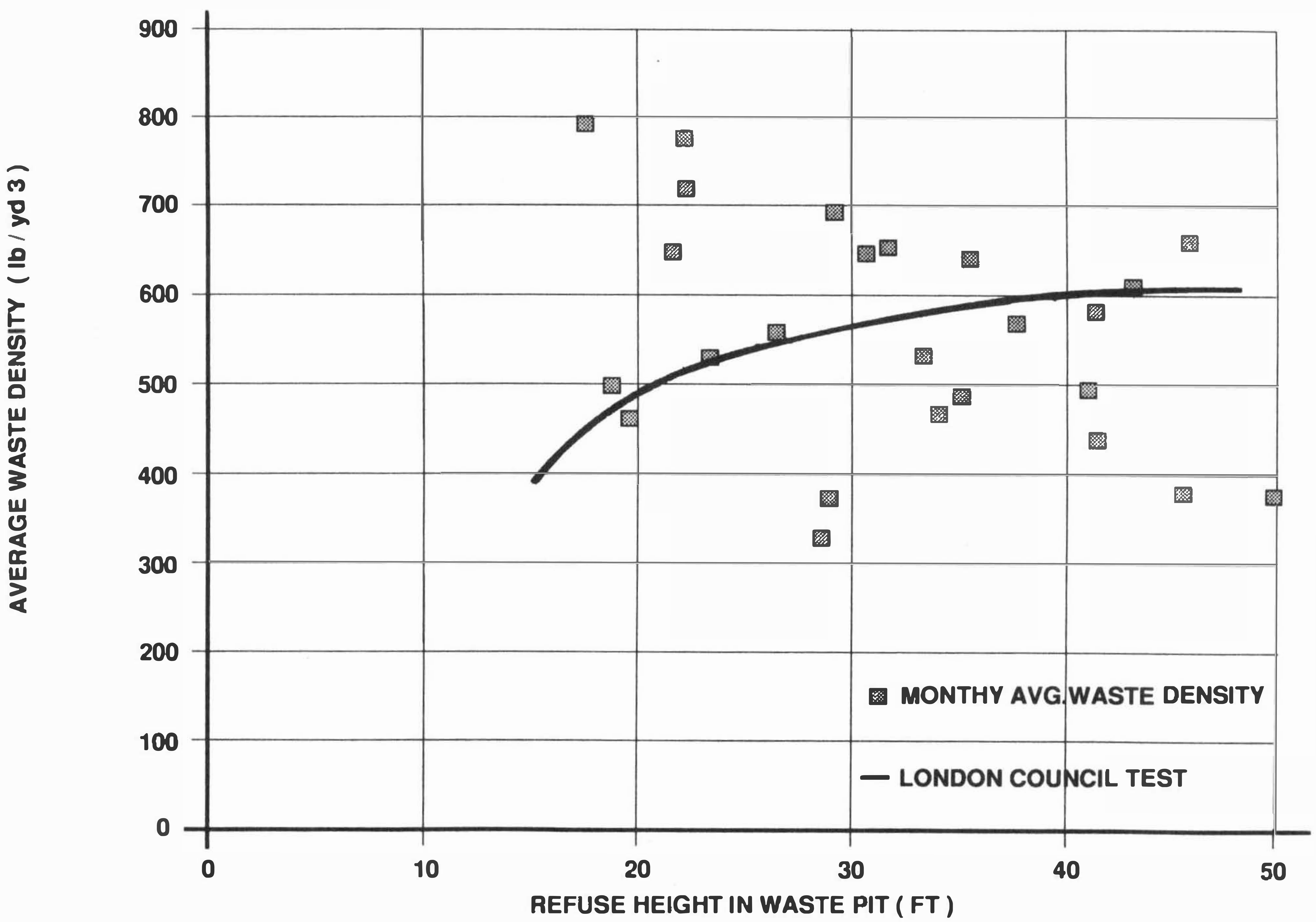

FIG. 3 REFUSE DENSITY AND HEIGHT IN REFUSE PITS
[Indianapolis-Marion County-Tulsa (1989) and London Council Test (1974)]

(650 lb/yd^3) and above (450 lb/yd^3) the tipping floor level divided by the available volume (all of the volume below and 50% of the volume above the tipping floor).

CONCLUSION

The refuse density testing over an extended period (January–November 1989) has shown that previous assumptions about refuse densities are valid and well within the range of actually determined densities. It also shows that the height of the stocked refuse in an actively operated facility has no significant influence on average refuse density. Based on the average density of 562 lb/yd^3 used for the facilities in Table 5 (most of which are in operation) and the average density of the study of 550 lb/yd^3, the authors recommend to use for the design of new refuse pits a refuse density of 550 lb/yd^3 for all of the available storage volume.

REFERENCES

[1] Scott, Peter J., and Holmes, John R., "The Capacity and Principal Dimensions of Refuse Storage Bunkers in Modern Incineration Plant." In *Proceedings of the ASME National Incinerator Conference.* New York: The American Society of Mechanical Engineers, 1974.

[2] Goessele, P., and Dobberstein, J., "Planung, Durchfuehrung and Auswertung von Hausmuellanalysen auf Stichproben Basis." ("Design, Execution and Evaluation of Municipal Refuse Composition Analysis on the Basis of Random Sampling"). Abfallwirtschaftsseminar an der TU-Berlin, Band 4, Hg: B. Jager, Thome-Kozmiensky, M. Ferber, West Germany, 1979.

Key Words: Data; Density; Design; Dimensions; Pits; Storage; Testing

APPENDIX A ENGINEERING UNITS

Physical Quantity	English Unit	SI Unit
Length	Foot: 1 ft	= 0.30480 m
Area	Square Foot: 1 ft^2	= 0.09290 m^2
Volume	Cubic Foot: 1ft^3	= 0.00283 m^3
	Cubic Yard: 1yd^3 = 27 ft^3	= 0.76455 m^3
Mass	Pound: 1 lb	= 0.45359 kg
	Ton (short): 1 ton	= 907.18 kg
Density	1 lb/ft^3	= 16.018 kg/m^3
	1 lb/yd^3	= 0.59328 kg/m^3