could be done it was necessary to ascertain what chemical and physical properties of flours were capable of measurement. Whilst fully aware that different races of yeasts possess varying fermentative energies, the authors thought it desirable to use the ordinary baker's yeast. The same yeast had been used in all their experiments and its constancy of fermentative energy had been checked and verified. The baking marks were apportioned by Mr. Humphries some time before the gas production experiments were carried out. It had not been possible to have them redetermined except in one case and in this the value was unaltered. This point would be borne in mind in the continuation of their work. The laboratory behaviour of blends of flours had not been studied although the authors were quite aware that the bakehouse results when working with mixtures did not agree with the mean values that might be expected. They submitted that so far from this being against the enzyme theory, it was a result that was only explicable by assuming the truth of that theory. Mere physical qualities of mixed flours would average out to a mean resultant, but, taking into consideration the characteristic nature of enzymes, what was to be expected would be the great modification of one flour by a mere trace of a suitable enzyme contained in another.

New York Section.

Meeting held at Chemists' Club on March 20, 1908.

MR. GEORGE O. STONE IN THE CHAIR.

CITY REFUSE AND ITS DISPOSAL.

BY H. DE B. PARSONS.

City-waste materials may be divided into three parts: sewage; city refuse; and trade refuse. These may be further subdivided as in Table I.

TABLE I.
Classification of city wastes.

Sewage	{	Liquid and Semi-liquid Refuse	{	House sewage. Street, roof, and area drainage. Night-soil.				
City Refuse	{	Household Refuse	{	Garbage	{	Animal matter. Vegetable matter. Meat and bones. Fruit.		
				Ashes	{	Steam ashes. Household ashes.		
			{	Rubbish	{	Paper. Wood. Rags and bedding. Leather and rubber. Metals. Bottles, glass, and crockery. Sweepings from buildings.		
			{	Street Refuse	{	Street Sweepings	{	Animal manure. Pavement dirt. Droppings from carts. Materials from building construction. Rubbish and leaves.
						Dead Animals		
						Snow		
			Trade Refuse	{		{	Cellar excavations. Materials from building construction. Stable manure. Market offal Slaughter-house offal. Dead animals.	

The total refuse, excluding snow and dead animals, collected in the year 1906 by city and permit carts from the five boroughs of Greater New York amounted to 3,159,182 tons. The average quantities of refuse collected yearly per capita in Greater New York are given in Table II.

TABLE II.
Average yearly collection of refuse per capita.

	Pounds.	Yards.	Percentages.	
			By weight.	By volume.
Garbage	181	0.163	12.31	8.45
Ashes	936	0.862	63.68	44.64
Rubbish	93	0.650	6.33	33.65
Street-sweepings ..	260	0.256	17.68	13.26
Total refuse .	1470	1.931	100.00	100.00

The average weights of the different classes of refuse, as collected in the Boroughs of Manhattan and the Bronx, City of New York, are: Garbage, 1110 lb. per cubic yard; ashes, 1086 lb. per cubic yard; rubbish, 143 lb. per cubic yard; street-sweepings, 1016 lb. per cubic yard. The weights per cubic yard of these materials as collected in the other boroughs vary to some extent. The greatest difference is noted in the unit weight of street-sweepings, which from macadam roads are heavier than those from asphalt or stone block pavements.

Methods of disposal.—There are six generally recognised ways for disposal of refuse, some of which are limited to one or more of the subdivisions of Table I. These are:—

Methods.	Applicable to
1. Dumping on land.	All subdivisions.
2. Dumping into water.	All subdivisions.
3. Ploughing into soil.	Garbage and street-sweepings.
4. Feeding to swine.	Garbage.
5. Reduction process.	Garbage.
6. Incineration.	All subdivisions (except steam ashes).

1. *Dumping on land.*—Where primary separation is in force, ashes, with or without street-sweepings, can be used to reclaim land where a combined collection would be decidedly objectionable. In such case, the garbage, rubbish, and sweepings have to be dealt with separately.

2. *Dumping into water.*—All classes of refuse could be dumped into water provided that the water is large enough in volume to dilute and scatter those portions which float, and deep enough to permit the heavier portions to sink without interfering with channels or navigation. Unless there be an almost uniform current away from the neighbouring shores, this method cannot be recommended, and, where in use, efforts are made to abandon it in favour of some other.

3. *Ploughing into soil.*—This method is only applicable to garbage, and possibly to street-sweepings. The soil should be sandy and the farm area large. The hauls will be necessarily long, and it requires the primary separation system for collection. It is inapplicable to cold climates where the ground freezes.

4. *Feeding to swine.*—This is a method only applicable to fresh garbage, unmixed with other refuse. It is seldom considered for large cities.

5. *Reduction.*—These processes consist of some method of "rendering" the garbage, by which the oil and grease are extracted, leaving a residue called "tankage." It is only applicable to garbage practically freed from rubbish, and can only be adopted by large cities, for, unless there be sufficient garbage, the first cost is prohibitive. Furthermore, it is only profitable when the garbage is rich in grease, which is one reason why it has not been more generally adopted by the southern cities of the United States. The best known systems are the Arnold, using live steam for melting and cooking; the Merz and the Simonin, using a solvent like naphtha and benzene.

The oil and grease are sold at a price varying from 2 to 4½ cents per pound. The crude oil is refined by the purchasers and used for commercial purposes. Its chief constituents are glycerin, stearine, and red oil.

The tankage, when dried and ground, is odourless and dark brown in colour. It is sold as a base for the

manufacture of commercial fertilizers, and the principal market is in the Southern States. The price is based on the "units" of ammonia which it contains and its freedom from grease, and is variable. The tailings, or discarded tankage, are generally burned in the plant for fuel.

An approximate average working analysis of a reduction works is:—

	Per cent. by weight.
Water and factory losses	85
Grease (and oil)	3
Tankage	9
Tailings	3
	100

The first cost of a reduction plant is large, on account of the expensive machinery required; and the cost of operation and maintenance is high, because of the labour, fuel, wear and tear on the machinery and the corrosive action of the acetic and other acids produced during certain stages of the process. In general, reduction plants are not self-supporting, even if the garbage is delivered free at the works. In Cleveland, Ohio, a reduction plant is used by the municipality, and it is the only plant for which the financial details are available. The works are about self-supporting when the garbage is delivered to the plant without charge and when grease can be sold for at least 4 cents per pound. In cities where such works are successfully worked by contract, a bonus is paid for the reduction.

The advantages of reduction are:—

1. The organic or putrescible matter of the garbage is converted into grease and tankage, which are harmless. Therefore, the garbage can be cared for in a sanitary manner.

2. It saves components which have a commercial value.

3. With a properly designed and carefully worked plant, the process need not be a nuisance, and its adoption adds a manufacturing industry to the city.

The disadvantages are:—

1. Expensive machinery and apparatus with large costs for renewals and repairs.

2. The offensive odours that are apt to be given off require expense to prevent an annoyance.

3. As the works have to be situated at some distance from the city, haulage is an important factor.

4. Requiring skilled labour, there is some danger of strikes.

5. The garbage must be separately collected. There will always be some foreign material, tin cans and the like, which requires sorting out at the works.

6. There is usually but one plant, as a number of small plants would not pay. The whole system, therefore, would be crippled by fire or by any other cause that would stop the plant.

7. The process provides for the garbage only, leaving the remaining refuse to be treated otherwise.

Incineration.—Garbage cannot be incinerated alone unless previously dried or unless a fuel is used. It requires about one pound of average coal (10,000 B.t.u.) to incinerate eight pounds of raw New York garbage. There is no advantage in incinerating ash collections alone, as the expense would probably exceed the gain. It may be practicable at some future time to separate the coal and cinders, and such a process has been proposed but not tried on a sufficiently large scale to warrant any predictions as to success. Rubbish burns readily and produces great heat. Some difficulties have been experienced by the production of slag. Street-sweepings from the better paved and centrally located streets will burn, as ordinarily collected, without the addition of other fuel, particularly as they contain a large amount of rubbish. When different classes of refuse are mixed, the aggregate is self-combustible, the coal and cinder in the ashes and the rubbish supplying the fuel required to dry the garbage and street-sweepings.

Sanitary incineration requires a high temperature not only to destroy offensive matter but to make the escaping gases innocuous. The average temperature in the combustion chamber should be at least 1,500° F.

The residue from incineration of mixed refuse amounts on an average to about 33 per cent. by weight, or 60 per cent. by volume. The volume at the destructor is large on account of the spaces between the clinkers, but when placed in a dump the volume is less, as the fine ash and dust work into the spaces. The heat may be utilised for power, and the clinker and ashes for brick-making, concrete-mixing, and for filling. It would be possible to press crude garbage and drain off some 15 per cent. of the water beforehand, but this would add complications and might not pay in some places. On the other hand, it might render incineration possible in places where the other classes of refuse are not fully collected or not found in quantity. In order to obtain high temperatures in the furnace, artificial draught should be used. One of the advantages of the plenum system for artificial draught over any form of induced or vacuum draught is the preventing of an inrush of cold air to chill the furnace when the doors are opened for firing, and the use of loose-fitting fire doors, which are more easy to operate than tight-fitting doors required for the induced systems. The draught pressure varies from $\frac{1}{4}$ -inch to 3 inches of water pressure, but should not be too great, as holes are apt to be burned in the fuel-bed and the stoking requires too constant attention. Probably a 1 or $1\frac{1}{2}$ inch pressure is sufficient, but the best pressure should be determined by experience for each locality. The air supply in the blast should be about 46 cubic feet, or $3\frac{1}{2}$ pounds per pound of average mixed refuse.* Many furnace designers prefer a steam jet to an air blast, and both systems have their advantages.

In America the failures have been chiefly due to incorrect designs of furnaces, large grates, slow combustion, low temperatures, too much reliance on stoking, and inexperienced firemen. Unless high temperatures are generated in the furnace cell, the garbage mass will be subjected to frying rather than to cremation, and odours are sure to be discharged from the stack. The furnace should be designed only after careful study of successful plants. Owing to the high temperatures maintained, the fire-brick work should be laid up with freedom for expansion. The fire-bricks, according to the experience of George Watson,* should be laid with very close joints, and consist of from 60 to 70 per cent. of silica, with 30 to 40 per cent. of alumina. While a little iron is harmless, potash and soda tend to act as a flux, and should be present only in small quantities.

The advantages of incineration are:—

1. When properly worked, it destroys all organic matter and offensive gases and reduces to ash all garbage, ashes, rubbish and street-sweepings.

2. The collections of ashes, rubbish and street-sweepings furnish the fuel. Garbage will also burn after drying.

3. Some revenue can be obtained from the heat generated through its conversion into power.

4. The system is sanitary, as fire is a sure destroyer of all germ life.

5. The hauls can be short, as a number of incinerators can be built and worked to advantage.

6. Civic authorities can work these plants better than reduction works, as they are more simple and less commercial.

7. No necessity for separate collections.

8. As a number of plants can be built, the risk of interference by fire or other causes of stoppage is reduced.

The disadvantages are:—

1. The necessity of having expert firemen, and of exercising great care to make the incineration satisfactory.
2. When not properly designed or worked, incineration plants emit objectionable odours and dust.

Fuel values.—Table III. gives approximate calorific values for the different classes of refuse, as collected in New York, and may be taken as representative of a large American city in the Northern States.

* George Watson, Trans. Amer. Soc. M. E., 25, 1904.

TABLE III.

Approximate calorific values of refuse in B. t. u. per pound.

	Dry material.	Material as collected including water.
Garbage	8,700	1,800
Ashes	3,000	1,800
Rubbish	7,500	6,500
Street-sweepings	7,000	3,600

In a mixed collection, these classes are found in about the following proportion, so that the combined calorific value would be approximately determined by the following calculation.

	Percentage collected by weight.	Calorific value. B.t.u.
Garbage	12.3	221
Ashes	63.7	1646
Rubbish	6.3	409
Street-sweepings	17.7	637
Total	100.0	2013

This calorific value is about one quarter of that of coal. If a ton of coal is worth, say, \$3.00, then the mixed refuse would be worth about \$0.75 per ton, less the additional cost of the handling of the refuse. One cubic yard of mixed refuse weighs about 960 pounds and of coal about 1300 pounds, that is, the bulk of the refuse is about one-third more than that of coal for equal weights. In the same way the efficiency of the furnace for burning refuse is less than that for coal, when considered as a heat generator. Rubbish collections in New York have been burned on a large scale and accurate data obtained. (See Transactions, American Society of Civil Engineers, 57, 1906.) Trials were made in December, 1905, to determine the rate of evaporation of water per pound of rubbish burned, and the results were an equivalent from and at 212° F. of 1.64 pounds and 2.16 pounds. Subsequently, other trials were made by different observers, which gave equivalent water evaporations of 2.28 pounds, 2.29 pounds and 2.17 pounds, respectively, per pound of rubbish.

The Borough of Westmount, Canada, has a mixed refuse destructor plant, which is worked in connection with the municipal electric lighting station. The average result, extending over a period of eight months, was that 2,000 pounds of refuse were equivalent to 283 pounds of coal. An evaporation trial, made in May, 1906, gave an average equivalent evaporation of 1.36 pounds of water per pound of refuse. The equivalent evaporation as reported by J. T. Fetherston for eighteen European destructor plants, were, maximum 2.66 pounds, minimum 0.88 pounds, and average 1.62 pounds of water per pound of refuse. These are gross evaporations, and in order to obtain the net useful steam produced for power purposes it is necessary to deduct that used for the forced draught apparatus.

Disposal.—The costs of incineration are not easily obtainable, because the figures are not always reported, and when reported are not on the same basis and are, therefore, not comparable. Furthermore, there are very few high temperature incinerating plants in America. The heat generated is unquestionably a valuable asset, but it should always be treated as a by-product. The object of an incinerating plant should be primarily to destroy the combustible portion of the refuse, and to reduce the several kinds to ash, thus leaving but one grade of material to be handled for final disposition, which is suitable for land filling and other purposes.

Closely associated with economy is the question of haulage. If the collection carts have long hauls to the central receiving stations, it means the maintenance of a large staff of men, horses and carts. The hauls, therefore,

should be as short as possible, which can be secured by dividing the municipality into districts and placing in each district a receiving station. The ideal system would treat the material in these receiving stations, simply leaving the removal of the residue to the place for final disposition.

Garbage could not be treated by the reduction process in this way, as the reduction plants are not economical in small units, and are liable to be offensive. Where the reduction process is adopted, a system of primary separation allows the garbage alone to have the long haul to the reduction works, while other refuse could be delivered to the central stations and have the benefit of the short haul.

In comparing methods on a basis of costs of maintenance and working, it is proper to include in the costs the disposal of all the city refuse. Some methods can treat one, two, or more of the subdivisions, while other can handle but one.

The following items of cost will be found of interest.

Cost of collection, City of New York, 1906.

Garbage, ashes, rubbish and street sweepings.

	Manhattan and The Bronx.	Brooklyn.
Total cost	\$1,744,300	\$772,900
City cart loads	1,747,871	630,000
Cost per cart load	\$0.990	\$1.225

Cost of final disposition, City of New York., 1906.

Garbage, ashes, rubbish and street-sweepings.

	Manhattan and The Bronx.	Brooklyn.
Total cost	\$815,300	\$468,800
Cart loads	2,313,286	738,056
Cost per cart load	\$0.352	\$0.635

Manhattan and The Bronx.

	Garbage.	Ashes, rubbish and street-sweepings.
Total cost	\$218,300	\$582,200
Cart loads	250,260	2,043,724
Cost per cart load	\$0.873	\$0.285

Cost of incineration, mixed refuse, Westmount, Canada. Including operation, repairs, rents and taxes, 1907.

	Sinking Fund and Depreciation.	
	Without.	With.
Incineration, one ton	\$ 1.08	\$ 1.34
Revenue from steam	0.58	0.58
Net cost of incineration .	0.50	0.70

COLLECTION AND FINAL DISPOSITION OF CITY WASTES BY THE NEW YORK DEPARTMENT OF STREET CLEANING.

BY EDWARD D. VERY.

The work of the Department of Street Cleaning, so far as it applies to the wastes of the city, is described in