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February 18, 1970

TO: MEMBERS OF THE CAMBRIDGE CITY COUNCIL

ABOUT: RECOMMENDATIONS FOR SOLID-WASTE MANAGEMENT IN CAMBRIDGE

Please allow me to correct the erroneous report of my recommendations appearing in the Boston Globe of February 17 in case I was inarticulate enough to leave similar impressions of my suggestions with your goodselves.

My belief is that Cambridge has the following options. These are stated not necessarily in the order of preference.

1. Rely on the planned opening of the compactor plant being built by Reclamation Systems Inc. in the B & M yards. Should the plant not succeed in starting commercial operation, take steps legally to acquire the facility and to operate it through a bid-selected commercial group as a compaction plant as planned or as a reclamation + pulverization plant.

   Reliance on this plant without a contract on quantities and rates means depending on market forces to keep costs within bounds. At the last discussion in the City Manager's office to which I was invited RSI said that the projected rate was now $9 to $10 per tons, compared with $5 to $6 a year ago. If the opening of the plant led to the closing of the Saugus dump the rates might increase to whatever the market would bear, which might be $15 or more.

2. Join with neighboring communities and the DPW in searching for a site for a sanitary landfill which will:

   a. result in negligible ecological or esthetic damage
   b. have a capacity of 3 to 5 years as a minimum.

   Any agreement with the community in which the site is located should:

   a. guarantee ample financial recompense for the odium and unpleasantness of having a major trash-treatment and filling operation within its borders, and

   b. guarantee strict control over operations to ensure that the standards of cleanliness, dust, noise, insect and animal infestation, and truck traffic are far higher than those usually tolerated, and

   c. offer to finish the site with loam cover, landscaping and planting to an agreed-upon plan.

   Such a site could be used in conjunction with local 'transfer stations' within local communities and could also be a powerful bargaining factor in negotiations with RSI, which reportedly has no site of its own yet. (Dumping of Cambridge refuse at sea should not be countenanced;

virtually nothing is yet known about the ecological and other effects of dumping large quantities of baled municipal refuse on the ocean bottom. In the changing legal climate it is possible that large damages could be assessed against Cambridge if serious effects were experienced by shoreline communities, for instance).

3. Investigate the possibility of installing a reclamation and pulverization plant either on the present dump or at the incinerator, which should be shut down as soon as practicable (its costs must be as high as its air pollution, and there are better alternatives). I'm attaching a recent paper by Bill Johnson of Sanitary Refuse Collectors in Montreal, currently the only plant of this type in North America. (The MetroWaste plant in Houston is similar but produces compost in addition and can't sell it). If, as seems likely, we are faced with a per-ton disposal cost of from $9 to $15 or more when the dump is finally closed - the upper figure is the last quotation received by the City for a new incinerator - the economics of a refuse reclamation plus pulverization plant are far more favorable here than in Montreal, where SRC makes a profit, or in Houston, where MetroWaste makes a small loss (for obvious reasons). (I am currently writing a paper on the subject and would be happy to send it for your reference if it is of interest).

In any event the pulverization of refuse, which adds about $3.00 per ton to the processing cost, permits much less costly transportation, whether by pipe for distances of up to a mile or by truck or rail for longer distances. Pulverization also produces a truly sanitary landfill which is not subject to fires, insect or rat infestation, and which breaks down rapidly to give a stable and non-gassy site. Most new landfills in Europe, or at least in Britain, now require pulverization. Its use in Cambridge would be a great asset in obtaining the agreement of an outside community to be host to a landfill. It could also permit our present dump to be used for longer than seems possible at present, and, with suitable perimeter treatment, would be welcomed by local residents. I believe that Cambridge needs the open space which the future dump site offers more than it needs more industry or population. Pulverization would allow a hilly, landscaped area at low cost and low nuisance to be formed.

4. Contract as soon as possible with one or more private paper collectors to collect as much newspaper and cardboard as they can persuade citizens to put out. The contract should be on a bid basis whereby the contractors' trucks are weighed by the city and they are paid a suitable sum for each ton collected. The mean cost to the city to collect and dispose of all domestic trash is about $35, and will rise. Paper and cardboard is both the major portion by weight and the greatest nuisance, whether on the dump or in the incinerator. The contract should absolutely require that a reputable public-relations firm be part of the bid to undertake the vital advertising and promotion which will be required on a continuing basis if residents are to be motiviated to separate newspapers.

David Wilson

Attachments:

'Refuse-reduction plant, Montreal-Quebec' - W. J. Johnson, Engineering Journal June 1969

'Rethinking the solid-waste problem' - D. G. Wilson, Science Journal Sept 1969

'Large-elevation landfilling for refuse disposal' - R. K. Ham, Public Works, [illegible] 1970

Refuse Reduction Plant
Montreal-Quebec

D.G. Wilson

W. J. Johnson,
Disposal Manager,
Sanitary Refuse
Collectors, Montreal.

EIC-69-CIV 4

The Problem

The econimical disposal of solid waste is a problem which has been facing engineers in North America for some considerable time.

Because of the vastness of the North American continent, waste products have generally been discharged, with little consideration, into seemingly endless volumes of air, land and water at hand.

This condition is even more prevalent in Canada, where the abundance of natural lakes, seemingly unpopulated, and large areas of open land have led the engineer into thinking that he has a completely unlimited natural disposal system. Observations taken in recent years, together with a look at the acute problem which is now facing the U.S.A. can quickly dispel this type of thinking.

In Europe, the municipal engineer generally performs all the removal and the disposal of solid waste himself, and consequently has been aware of the total problem involved for some time. The public cleansing divisions of the larger municipalities are highly trained groups of engineers and supervisors who specialize in solid waste and associated problems. In North America, until very recently, solid waste engineering has been a part of the general municipal division, with very few specialists.

Existing Solutions:

Existing methods of disposal in North America fall into three main categories:
Dumping
Sanitary Landfill
Incineration

A brief description of each method is made to consider their advantages and limitations.

Dumping.

This is hardly a means of disposal, unless burning is employed. The objections: vermin, odor, air pollution are obvious. Some dumps upon completion are covered with earth and often misnamed landfills.

Sanitary Landfill.

Sanitary landfill is a method of disposing of refuse on land without creating a nuisance or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume and cover it with a layer of earth at the conclusion of each day's operation or at more frequent intervals as may be necessary. This well compacted cover will prevent the emergence of insects, minimize the escape of odors and gases, prevent rodent burrowing, prevent the fly of paper and dust, provide adequate bearing surface for vehicles and provide sufficient depth in the event of settlement or erosion.

Since the land that can be suitably used for landfill must be within economical hauling distance, have a suitable supply of cover material, and must generally be a low lying fill area (old borrow pits, etc.), it is extremely difficult to obtain suitable locations in urban areas. Almost all the major cities in North America have exhausted suitable landfill sites within economical trucking distance.

Incineration.

In the major cities of North America, incineration of garbage is the most widely used means of disposal. Existing incinerators burn from 20 tons to 1,000 tons of garbage per day with varying degrees of efficiency. The most efficient incinerators are, in general, the larger ones, obtaining a total reduction of 90% by weight; but generally speaking, normal results are 75%-80% reduction. The resulting residue is organically inert: glass, ash dust, trimmed cans, etc., can generally be used for a low grade fill. Some of these materials can sometimes be salvaged and used as by-products. Another feature of incineration is the manufacture of steam which can be used or sold for heating or industrial purposes if they exist in the area. Strategic location close to population centres can minimize trucking costs.

Incineration is probably the most positive form of disposal used today. Its disadvantages are those of cost, both of construction and operation. Capital cost can vary from $4,000.00 to $8,000.00 per ton of installed capacity. Operations cost, excluding depreciation, vary from $4.00 to $8.00 per ton of refuse destroyed. Large new incinerators are projected to provide 95% reduction at a cost of operation of $2.00 to $3.00 per ton, but these are likely to be limited to the super cities.

To find any other form of garbage disposal with proven history, it is necessary to journey to Europe where compost is being made from garbage. Should there be a market for this compost, it can prove to be an economical means of disposal. However, with European garbage it appears that only about 25% of the refuse can be made into acceptable compost.

A primary step in the production of compost is the grinding of pulverizing of the garbage by rasps, hoggers or hammer mills. An interesting feature of the grinding is the transformation of the garbage from a variety of waste materials into a relatively homogenous mass bearing little resemblance to the original material. Not only is the garbage reduced in volume by up to 70% but it is converted into a humus-like substance which is relatively odorless, unattractive to flies and vermin, relatively uncombustible and further compressible under load. This discovery opened a new concept of treatment by grinding with or without the production of compost.

The Montreal Plant

Sanitary Refuse Collectors, a private company providing collection and disposal for over 30 municipalities in the metropolitan Montreal area, were, like the municipalities themselves, searching for a lasting and economical means of disposal. Refuse reduction by grinding seemed to present enough advantages to make its application a serious consideration.

Design

(a) *Preliminary*. Although the crushing of garbage is originally a European idea, several plants have been built in North America, mainly with disappointing results. The crushed garbage in all of these instances was used to make compost; the economical feasibilities of these projects were usually unrealistic, with the result that most of the plants closed down after short durations.

The plant to be designed, therefore, was to have the economical value in reducing the haulage distance combined with the reduction in volume and transformation of the raw garbage from an undesirable waste product into a relatively clean and safe homogeneous material.

It was also acknowledged at the design stage that no disposal plant will successfully eliminate all of the refuse; items such as washing machines, refrigerators, hot water tanks, heavy plastics, highly inflammable items, etc., occur in domestic waste collected in North America with alarming regularity and are practically indestructible, or particularly dangerous. Therefore any disposal plant must be operated in conjunction with a landfill site.

These primary considerations, together with the fact that because of the transformed nature of the garbage, a landfill site could be found at a closer location, were the original basis of design.

(b) *Building*. The building design was to fall into three main structures according to function: the unloading building complete with storage pit; the salvage and baling buildings which also housed the administration offices; and the crushing and discharge buildings. The dumping building was to be linked to the salvage and crushing buildings by a conveyor gallery.

To keep the dumping building to a minimum structural size, seven entrance doors were installed to enable the trucks to reverse directly through them and discharge their load into the storage pits without any manoeuvering inside the building itself. To accommodate surge loading of 30 or more trucks, plus normal scheduled loads and breakdowns, an eventual storage capacity of 1,200 cubic yards was established as being practical.

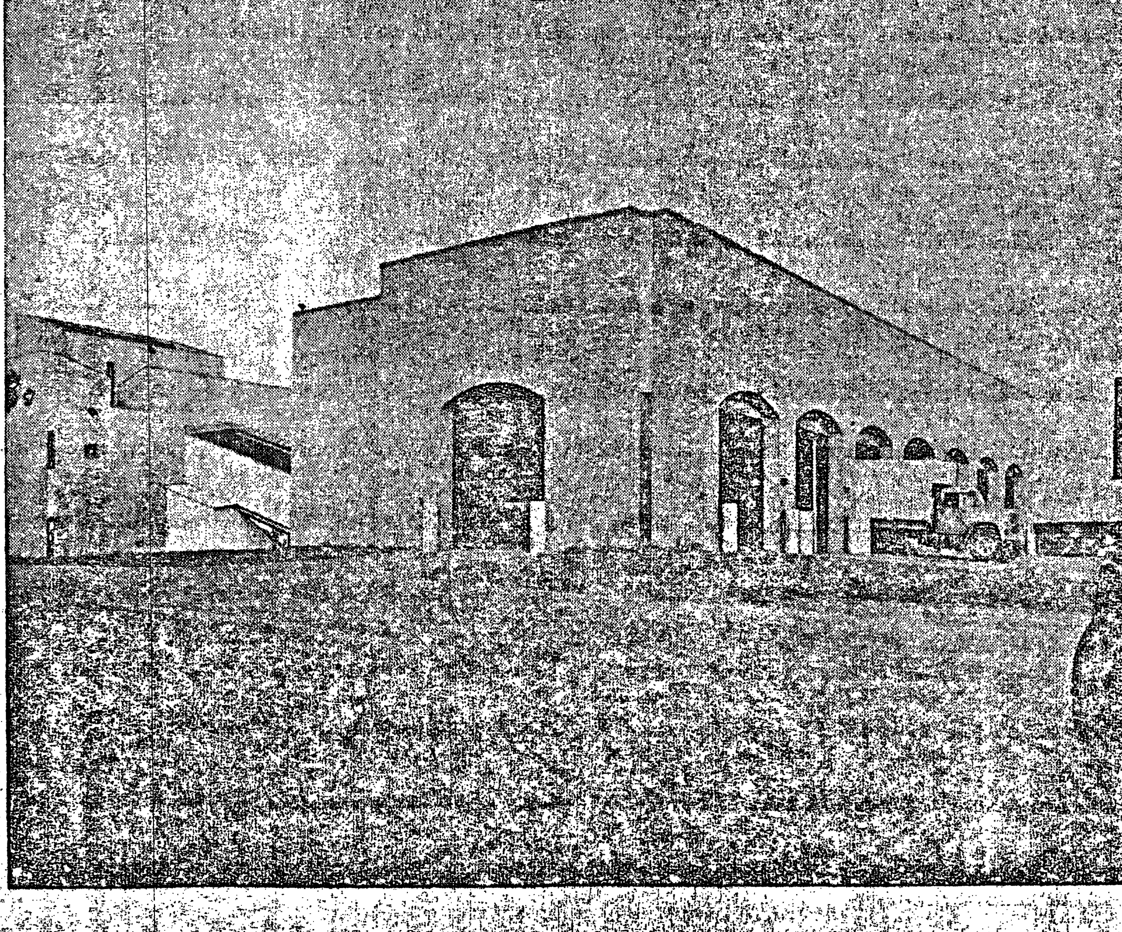
The capacity was also scaled to suit the capacity of the two crushers; working under normal conditions, the two pits would be completely emptied in a little over 12 hours. This arrangement gave greater fluidity to the trucking operations.

Studies on the local market showed that paper and rags would be salvageable items and six picking stations per belt were incorporated in the salvage room. The paper and rags were dropped down to the baling room to be fed into two balin[g] machines by a front-end loader.

The crushing building was designed merely to house the two crushing machines and drive-motor together with a reject metal hopper which the two machines rejected automatically.

The whole plant has a basic reinforced concrete frame with masonry cladding, much use being made of prestressed concrete for the roof beams. An interesting feature was the incorporation of

Figure 1
Overall view of the Montreal refuse reduction plant



inside tiled faces to provide cleanliness, easy maintenance and neat appearance. Excellent architectural treatment by Bland, Lemoyne, Shine resulted in a striking and pleasing appearance to the plant (Fig. 1) and the architectural high standard was confirmed when the plant was placed in the final group for the Massey Medal awards for 1964.

(c) *Machinery.* North American garbage varies considerably from that in Europe; also it is not separated in more easily manageable materials by the householder (i.e. waste paper and trash). Certainly in Montreal and the surrounding districts almost everything is picked up with the usual collection. Thus handling equipment had to be designed to transfer normal size boxes containing garbage to items as large as double mattresses.

Garbage itself behaves in an unusual way when handled because it contains so many numerous items, and yet bears none of the characteristics of the natural materials. It has an angle of repose of 90° and greater, and while this may lend itself to good application for stacking and digging, it presents many problems when moving any reasonably large mass.

North American garbage also has a very low weight bulk density. Experiments have shown that the average weight per cubic yard of raw garbage is 170 lb. However, this figure can vary considerably and in point of fact will rarely exceed it. Figures which involve tonnage can therefore be very misleading when related to volume.

The costliest of the individual machinery items in the plant was the overhead crane. It was carefully designed to produce the proper feed to the conveyor belts with extra capacity for stacking to take place. As it was the only single piece of equipment in an otherwise double flowline, great care was taken to safeguard against possible major breakdown. The crane was to be underslung from the overhead beams and controlled by a central type console. This latter system gives greater scope to the operator of the crane, enabling him complete control over the dumping building floor. Incorporated in his console were remote control for the doors to the dumping building. The crane operator thus became an important part of the plant and not an isolated unit.

The crane bucket dumped the garbage into a double central hopper, from which the pan feeders transferred the garbage to the two conveyor belts. The belts then carried the garbage up the conveyor gallery through the salvage room, to the crushers. After crushing, the material was transported, via a single conveyor, to the trucking facilities.

For normal handling machinery such as conveyors, pan feeders and overhead crane, Canadian manufacturers were chosen. As for the crushers, it was decided to use a European machine of proven ability. After careful consideration of different manufacturers, the Gondard machine of France was chosen.

All of the machinery was synchronized to prevent any back-up of operations due to malfunction of any particular part, and each portion of the operation, unloading, salvage and discharge, were all connected by intercommunication systems. At different points in the plant, special dust gathering equipment was incorporated. Figure 2 shows a typical cross-section through the plant giving some machinery details.

Operations

In late 1964, the first loads of garbage were processed through the plant with rather mixed results.

Control gates designed to govern the flow of garbage from the hoppers to the conveyor belts caused blockage and finally had to be removed.

The crushers were modified by our own forces in the field, and some of the modifications proved to be inaccurate. It did however show the vast difference between European and North American waste. The crushers rotate in an opposite direction to the entry of the garbage, thus breaking the garbage up and giving a more even rate of crushing (Fig. 3).

Uncrushable items such as tin cans are rejected up the reject chute and pass out through the top into the storage hopper, or after repeated hammering become small enough to pass between the hammers, and through the bottom grill, and are discharged with the crushed garbage. The application works well in Europe and the reject hoppers are usually full of a goodly collection of crushed tin cans. In North American garbage, however, there is also a fair collection of heavy plastics and rags; these latter items will tend to bind together with tin cans and are rejected with them; this results in the reject hopper containing an unsorted mass of hard rags, shredded plastics and battered cans. It so happened that no market existed for the metals and the problem was solved by removing the reject hopper and placing these uncrushable items back on the crushed garbage conveyor, via the reject chute.

The crushed material eventually weighed much less than original estimates, with the result that the volume of the payloads out of the plant had to be increased. After leaving the crushers, the original design called for the crushed material to be transported by a single conveyor to a reversible conveyor which fed one of the two stationary packers. The hopper capacity of the packers was only one cubic yard feeding into a 34 cubic yard box. The resulting payload was found to be too small, even though the crushed garbage did reduce again in volume under compression. The length of stroke of the packer cylinder tended to slow down production and this, together with the fact that special trucks were needed to haul away the stationary packer boxes, presented further problems. This latter item caused great economic troubles as any small down-time to the trucks (i.e. flats, broken haulage cable, normal electrical or hydraulic failures), meant that a standby would be needed as a safeguard. This item combined with the small payload resulted in a change to the haulage system.

Figure 2
Cross section of plant

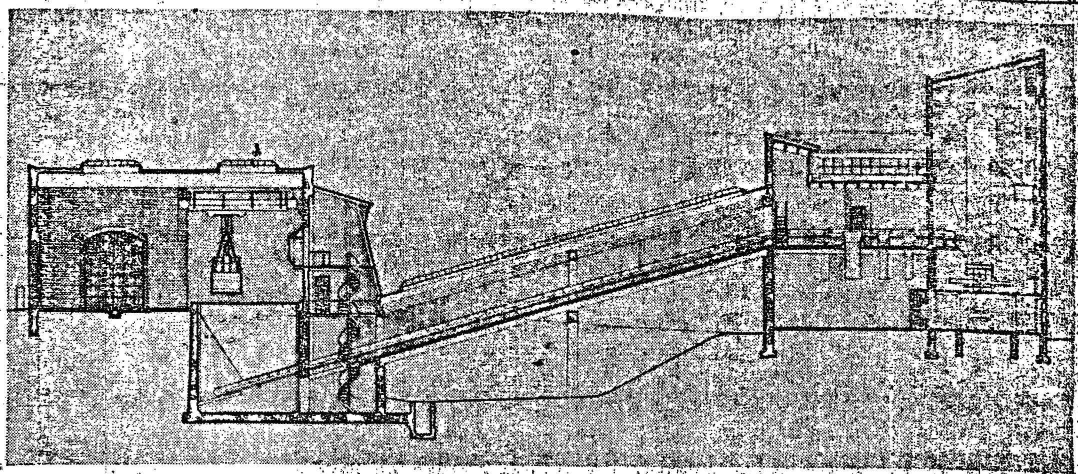


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Figure 3
Crusher cross section

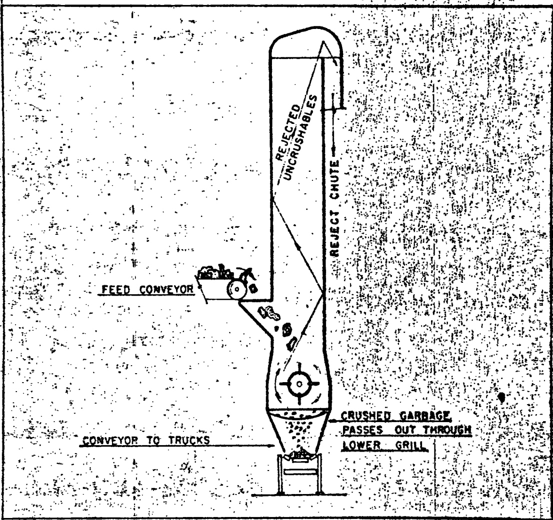

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Figure 4
At landfill, bulldozer hauls crushed material from trailer

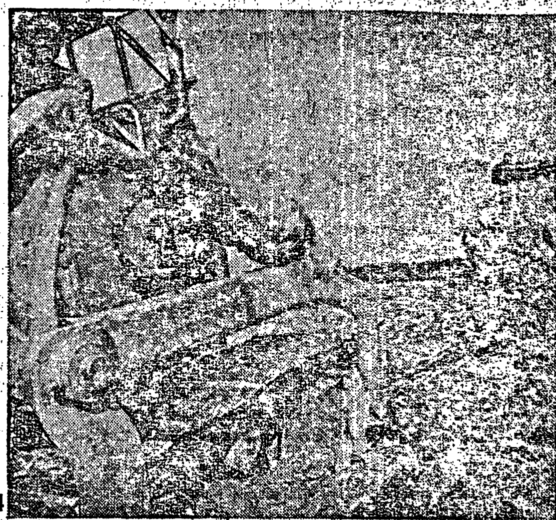

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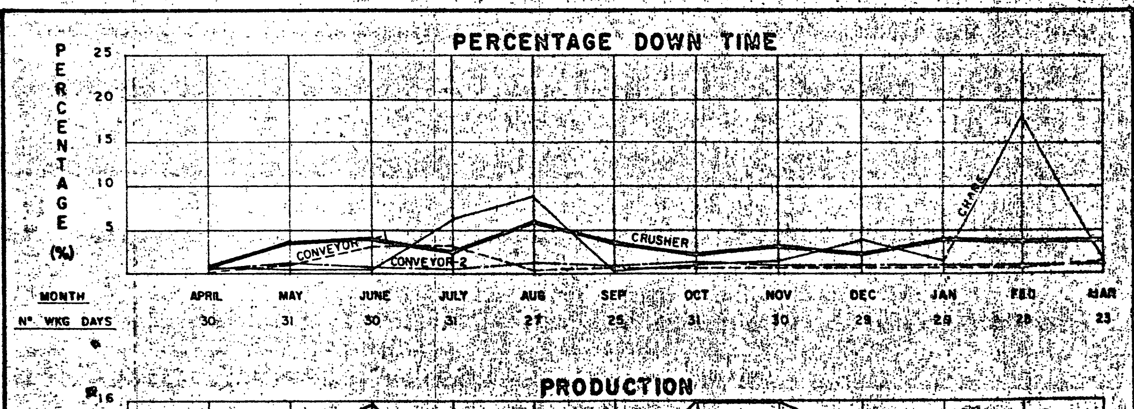
Figure 5
Plant operation 1967-68



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A normal trailer body was utilized with high built sides, and a plate was placed at the rear of the trailer with the cables running the length of the trailer body to the end. The crushed material was then placed in front of this plate, and, on arrival at the landfill, the bulldozer hauled the cables until the plate forced the material out of the rear doors. As the crushed material is extremely easy to handle, this arrangment proved much less troublesome than originally anticipated, although many revisions to the plate and sides were needed before the system was deemed satisfactory. The advantages, of course, were obvious: there was little maintenance to the trailer body and plate; and the new theoretical payload was now 90 cubic yards which gave a loading time of 50 minutes enabling less trucks to operate on the round trip. The distance from the reduction plant to the disposal site is 11 miles (22 miles round trip) and average travel time is approximately 70 minutes, which compared favorably with the loading time. An additional advantage was the fact that, should any accident or malfunction present itself on the tractor, a fifth wheel tractor could easily be hired from a nearby haulage company. Only one standby trailer was needed in the case of breakdown, reducing operational overhead. Figure 4 shows the trailer discharging at the landfill site.

Other changes were made to the feed arrangements, conveyor speeds and capacities, hopper sides and angles, until good working conditions were obtained.

Although the plant was working on two 10-hour shifts since January 1965, tonnage remained in the vicinity of 230 tons per day. The changeover to the larger trailers was made in February 1966 and resulted in an increase of over 150 tons per day, many days producing well over 400 tons.

The graphs in Figure 5 show a typical year's operation from April 1967 to April 1968.

The graph showing production is split into three figures: crushed material, scrap, and salvage, the combination of each item giving the total production.

The graph showing the down time gives the individual items of machinery with their percentage down time related to working hours per month.

It was found that the most economical method of performing maintenance was to close the plant completely twice per year for a period of one week. As the plant is run in conjunction with a landfill site, this could be done without any great problems and maintenance crews could work with much more efficiency in a completely closed plant. As July and February are the two months when pick-up of garbage is at its lowest, the plant was closed for a week at that time. Normally, three pickers are employed per belt on salvage, together with two men on baling operations. Salvage operations are kept separate from production operations and made to operate profitably at all times. Prices on the salvage market tend to vary considerably and it is advisable to keep a close control on this side of the operations.

igure 6
verage production
osts per month

AVERAGE PRODUCTION COST PER MONTH
APRIL 1967 – APRIL 1968

ITEM	COST / MONTH
MACHINERY, REPAIRS, HAMMERS ETC.	4,940.00
TRUCK REPAIRS, INCLUDING GAS, RUBBER.	1,900.00
* FOREMAN & PLANT OPERATION WAGES	6,000.00
* DRIVERS' WAGES	3,340.00
TOTAL FOR 7,642 TONS	16,180.00

* NUMBER OF PERSONEL ON OPERATIONS FOR THE PLANT, PER SHIFT IS, 1 SUPERINTENDENT, 1 FOREMAN, 1 CRANE OPERATOR, 1 CRUSHER OPERATOR, 2 BELT MEN, 5 DRIVERS AVERAGE $2.12 PER TON

Scrap amounts to approximately 3% of total material passing through the plant. Generally speaking, items which would be damaging to the crushers are removed, although very heavy rags and heavy wire are also removed as they tend to cause jamming. Although the percentage is low, it still represents approximately 50 cu yds per day, a figure which represents almost indestructible items.

It is also interesting to note the almost day-by-day fluctuations in the condition of the garbage, depending on weather, season, and pick-up conditions.

Regular production tonnage with so many variable conditions is difficult to maintain, and results in varying maintenance figures as far as hammer and crusher wear are concerned.

Depth and flexibility, therefore, are the prime requisites behind any disposal plant design.

Economics

Figure 6 shows a summary of the average costs per month spent in operating the plant for the period shown on the production graphs, from April 1967 to April 1968. The average production over this period was 7,642 tons per month. Therefore cost per ton was:

$$\text{Total operations cost } \frac{16{,}180}{7{,}642} = \$2.12 \text{ per ton.}$$

Salvage over this period showed a profit of	$0.57 per ton.
Total operation cost, with salvage	$1.57 per ton.

We must study what savings would be realized if instead of dumping their loads in the reduction plant, the packer trucks were forced to journey to the landfill site with their loads. As mentioned previously, distance to the landfill beyond the plant is 11 miles, necessitating a round trip of approximately 70 minutes.

Cost of Operations using Landfill

Cost of operation of one packer truck (3 man crew) on round trip to landfill site	$14.22
Disposal of one packer truck	3.50
	$17.72

Cost of Operations using Reduction Plant

Cost to process one packer truck (average 4.75 tons weight) through reduction plant without salvage $2.12 x 4.75	$10.07
Cost to process one packer truck through plant with salvage 1.57 x 4.75	$ 7.46

As the weight of the crushed material and the packed garbage entering the plant is approximately the same, four packer truck loads are contained in each trailer load leaving the plant.

Disposal of the crushed material at the landfill site is very easy, and the crushed material is held at a premium by the landfill operators as it keeps the working face in excellent condition, prevents flats and fires and gives an easier trucking surface. For these reasons, disposal of one trailer can be much more economical than raw garbage, and total price for one trailer is $4.00.

Therefore total cost of processing one packer truck through reduction plant, including disposal of crushed material at the landfill site.

Without salvage:

$$10.07 + \text{disposal } \left(\frac{\$4.00}{4} = \$1.00\right) = \$11.07$$

With salvage:

$$7.64 + \quad \$1.00 \quad = \$\ 8.46$$

A good saving in disposal is thus realized at the moment, with the landfill in the present location. Obviously, as trucking distances to the landfill grow longer the plant will show increased savings. As with incineration, the closer location which the reduction plant can be situated to collection areas means that round pick-up trips by the packer trucks can be substantially reduced, resulting in less packer trucks operating in any given area.

Capital cost of the plant and machinery amounted to approximately $700,000. Because of differing financial arrangements, amortization charges will vary with each locality and hence have not been shown on a per ton basis. The municipal engineer will, however, be able to relate the capital amount to his own interest rates and appropriate accordingly. It is possible that the capital cost could be reduced as the plant, being an original design, did have areas where savings could be realized in the future.

Landfill

Owing to a large total volume, the plant is run in conjunction with a normal sanitary landfill site.

The crushed material acts as an excellent temporary cover over the raw garbage and keeps the working face of the landfill in good condition. It is virtually fireproof and almost eliminates flats to the trucks manoeuvering on the landfill site.

If the crushed material would be used by itself, it is likely that no daily cover would be needed. Indeed, in Europe, crushed material sites are operated with only a final earth cover.

Initial compaction of the crushed material is greater than that of raw garbage by approximately one-third.

Experiments conducted on compaction of landfills tend to vary and are greatly effected by depth of landfill site and added moisture content. The figure of one-third was obtained by using two trial pits, one for raw and one for crushed garbage, to compare the results objectively.

This greater initial compaction is accompanied by a good rate of decomposition once the material is in place, and gives a better final settlement. Experiments on landfill sites have shown that in many instances some raw refuse still remains in the fill after many years of initial dumping.

Thus the landfill site can be kept in excellent condition for minimum cost and utilized for a much longer period.

Conclusion

It is not the purpose of this paper to prove the superiority of this type of operation over any other. As mentioned previously, special circumstances which occur in any one locality would make one system of disposal more applicable than another, and careful preliminary study must be undertaken before any decisions are reached. In recent years transfer stations using larger stationary packer type of trucking have become more common due primarily to the lower operating cost of this type of operation. Larger installations such as incineration normally require a fair size storage volume to accommodate for surge loading. The extra cost involved in this storage volume (storage pits, overhead cranes, etc.) makes a smaller installation, which the stationary packer type of system usually services, hardly comparable with a larger system with its necessary heavier equipment.

This operation, then, is tailored to meet the needs presented by conditions in the local area.

Because of the low operating cost and initial capital expense, the plant is an economical disposal system which performs the disposal of solid waste in a clean and hygienic manner, making it more attractive to limited budgets.

The end product of the plant is a relatively clean and safe homogeneous material.

There is no air pollution associated with the operation, an item of increasing importance in modern plant engineering.

Because of the transformed nature of the garbage after crushing, landfill sites can be found at closer locations. This becomes more politically important every day as municipalities increase in size and final disposal areas become more difficult to find. Many small rural communities object to their land being used as a garbage dump for an adjacent town or city, often with justifiable reason. The crushed material can eliminate many of the objections associated with raw refuse as such and becomes a much more presentable proposition.

Should an area for compost present itself, even in limited demand, it is a relatively simple operation to form an experimental station to test the available market. Private operators in the Montreal area have shown interest in the compost field and have performed experiments, which have shown that a good class compost can be obtained by further crushing to reduce particle size, and aerating afterwards. Attemps will be made shortly to market the compost locally.

If the crushed material was fed to an incinerator, it is possible that a more efficient burining rate would be produced owing to the even particle size. Savings could also be realized on repairs, due to longer life on refractory linings and easily controlled temperatures. It is difficult to state at this stage whether the increased cost of crushing would be offset by savings in incinerator efficiency, and controlled experiments will have to be performed before any definite statements can be made. Some experiments have been tried in North America but did not result in complete combustion of the crushed material. This could be due to the type of grate involved, as it would appear that the material needs activation to obtain a good rate of burning. The future in this field, however, holds excellent possibilities.

The plant was the first of its type in North America, and although many problems presented themselves initially, the economical feasibility is good and the original concept correct.

The plant presents a new form of waste disposal on this continent which will give greater scope to the municipal engineer when problems involving solid waste present themselves.

Large Elevation Landfilling for Refuse Disposal

ROBERT K. HAM
Assistant Professor of Civil Engineering, University of Wisconsin, Madison, Wisconsin

THE PROBLEMS associated with solid waste disposal have led to consideration of modifying present practices. One such concept is that of large elevation landfilling or building hills of refuse.

Many of the modern problems of refuse disposal are due to increasing amounts of refuse generated per person plus a general population increase; migration of people to urban areas; and decreasing availability of landfill sites. Although the costs of disposal are high, they will continue to increase as citizens become more concerned with the effect of disposal on the environment, the wastefulness of many disposal practices and the possibility of having a disposal operation located near them.

By concentrating refuse disposal into one area over a fairly long period of time, large elevation landfilling makes it economically possible to provide a well engineered operation, to lower nuisance levels, to reduce insults to the environment and to transform the city dump from a detriment to a potentially useful attraction for the community. The proposed method involves the construction of large hills with refuse—a concept which is not new, for it has been used and is being used at several locations around the world. The method offered herein is somewhat different than those used elsewhere, however, in that special site preparations and operating procedures are proposed. It is suggested that the best final use of the hill would be a public recreation area where skiing, tobogganing and sledding might take place during the winter, and picnicking, hiking and the viewing of flower gardens and the surrounding area could occur during the rest of the year. It is certainly possible that other final uses may be more appropriate in some localities.

Site Selection and Preparation

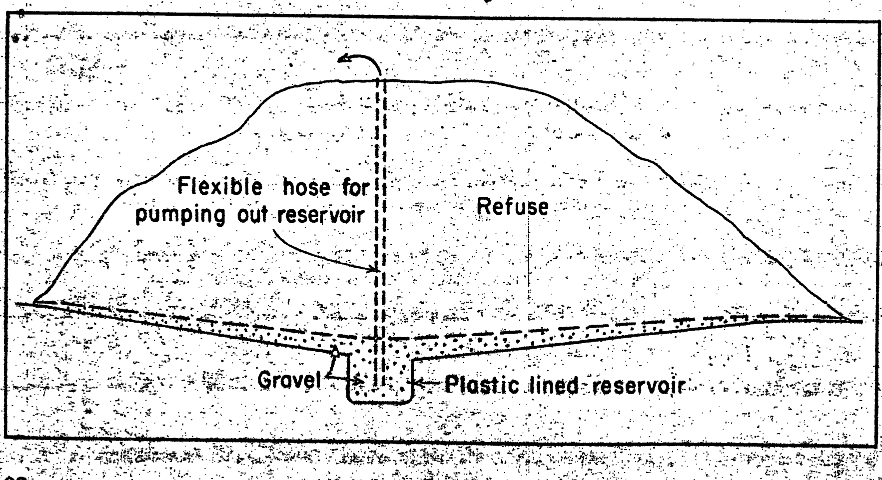
Proper site preparation can greatly diminish one of the major areas of concern brought about by concentrating such large amounts of refuse—the potential water pollution problem. It is suggested that the provision of a water-carrying layer of sand or gravel under the hill, properly sloped to carry water from the refuse, would collect water flowing downward from the refuse, as well as water flowing upward if the site should be one of ground water discharge. These waters would intercept the "aquifer" layer and flow laterally in it to a collection system for controlled discharge and/or treatment.

An estimate of the flow rate from ground water discharge may be obtained by drilling several wells of different depths and measuring the pressure acting on the water at each depth. If the pressure above datum increases with depth, there is a net ground water flow upward which, even though the surface may be dry before landfilling, may result in discharge into the refuse and the build-up of a water mound. Knowing the pressure gradient, standard hydrogeological methods can be used to calculate the rate of ground water discharge. An estimate of the maximum probable amount of leachate is next obtained to give the total amount of water the aquifer must carry. Knowing the permeability of the aquifer layer, the required thickness and the slope of the layer necessary to provide adequate flow rates can be calculated readily. It is suggested that a sizable margin for error be allowed by providing excess aquifer thickness. This would assure adequate capacity even if part of the water carrying ability of the aquifer were removed due to clogging by extraneous matter or to aging processes.

The prepared site is shown schematically as Figure 2. It is prepared by first contouring the ground to the slope required for aquifer drainage. A trough is placed around the periphery of the site and then a layer of water-carrying sand or gravel is placed over the entire area, possibly varying in thickness from 6 inches near the center (where the flow capacity is less critical) to 2 feet near the periphery.

Load bearing measurements should be made to indicate whether the site is sufficiently strong to support the hill without settling. If settling is likely to occur, it may be useful to have the sand-gravel layer slope towards the center of the hill as shown on Figure 1. Settling, in this case, would simply add to the slope, causing increased flow rates to occur. The collection reservoir at

☐ **FIGURE 1. Profile of a refuse hill designed for use on an unstable foundation. Subsequent settling would increase the slope of the drainage system to the reservoir.**



the center of the hill could be filled with gravel and lined with heavy plastic sheets to avoid leakage. Pumping could be done through flexible plastic tubes which run through the hill itself in such a manner that settling of the hill will cause the least chance of tube blockage or breakage. For safety reasons, several such tubes should be installed.

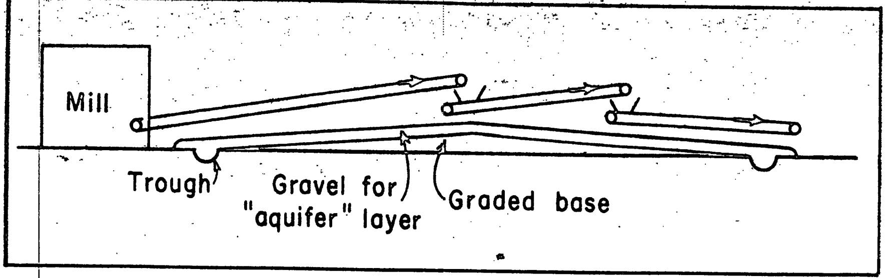


FIGURE 2. Where foundation conditions are suitable, a permanent drainage system would collect water and allow it to flow through a gravel layer to a peripheral trough. Conveyors transport refuse from the mill to all areas of the disposal site.

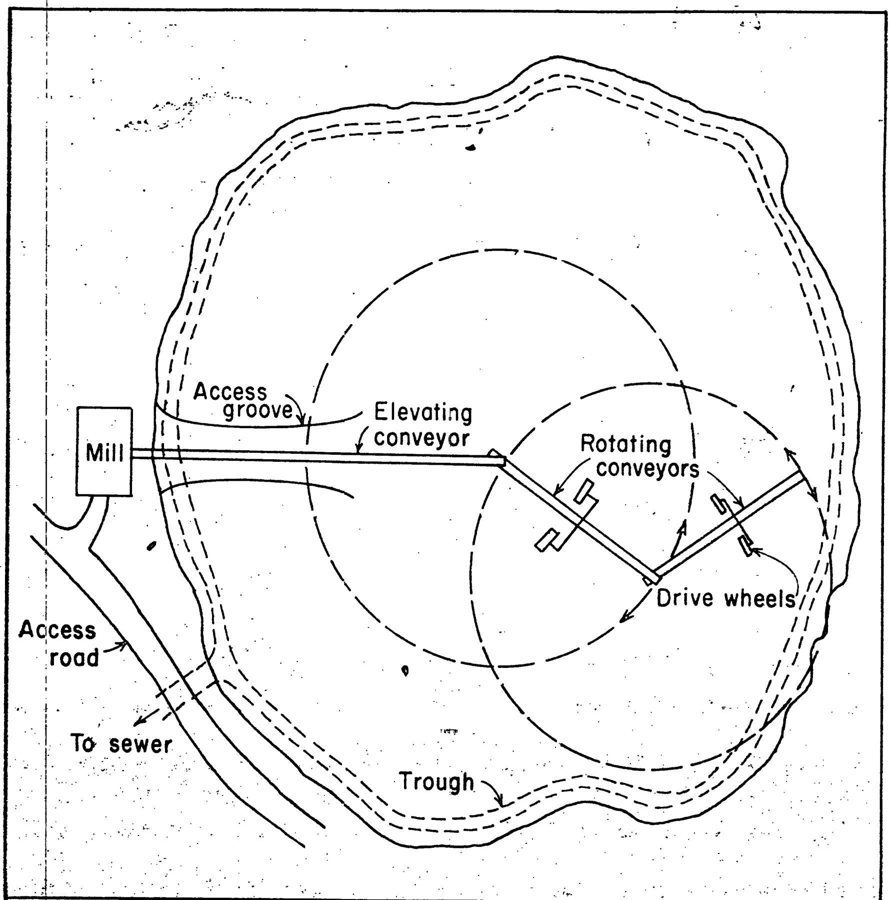


FIGURE 3. Plan view shows initial layout for construction of a hill of refuse.

Equipment Requirements

The major pieces of equipment are the mill and the conveyor system. It is felt that milling is particularly useful for hill construction because, relative to nonmilled refuse, milled material is easier to handle, does not require periodic cover, attains higher densities, reduces nuisances such as blowing paper and has a relatively unobnoxious appearance and odor. Additional comments on these points will be presented later. It is suggested that a conveyor system be used to transport milled refuse up the hill for disposal. This process will result in an apparent low level of activity at the site, a smooth all-weather operation, a reasonable cost for a system of the scale discussed herein, and it should be acceptable to the public and to concerned officials.

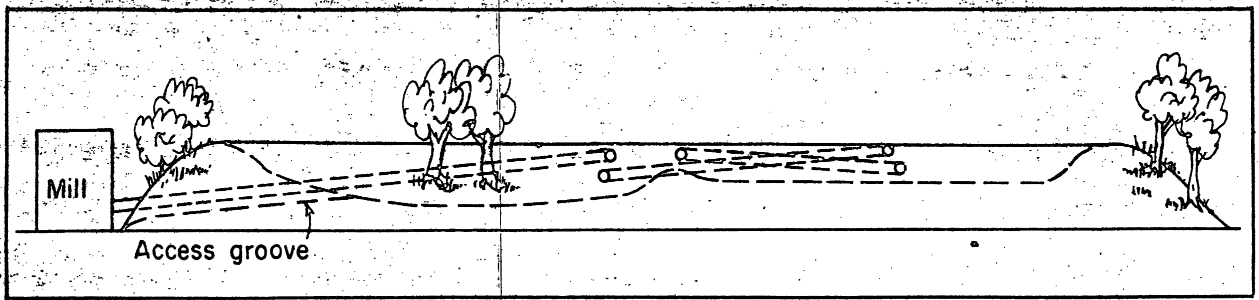
The mill is located next to the base of the hill. Well built, all-weather roads should be provided from the nearest main road to the mill. The roads are flanked by the access area, which should be designed such that it will enhance the area during hill construction and yet become a pleasing entrance area for the park after the hill has been completed. The access area should be planted with grass, shrubs and trees to bring about a park-like atmosphere and to conceal the milling and construction operation. The mill and an adequate dumping area should both be enclosed in a building of pleasing appearance. This will mean that nonmilled refuse will not be observed at the site; in fact, the only clue to the presence of refuse will be the trucks which frequent the mill. Milled refuse looks much like shredded paper and should not present an offensive sight during conveyance and disposal.

The conveyor system carries the milled refuse from the mill to the disposal site. One possible configuration for the system is shown in Figures 2 and 3. This system allows all portions of the hill to be reached quickly and with a minimum of effort. The use of conveyors to transport and distribute the refuse rather than trucks or tractors, for example, avoids any problems associated with road building and trucking up steep inclines, reduces labor requirements and greatly reduces the apparent level of activity during hill construction. The non-rotating elevating conveyors should have provision for elevation adjustment as the hill grows and, depending on the final contour of the hill, they may or may not be extensible. The rotating or distribution conveyors should be provided with a mechanism for easy rotation from one dumping area to the next.

Construction of the Hill

To make the disposal operation as unobvious as possible, the following method of construction, as illustrated in Figures 4 and 5, is proposed. As each new layer or rise of the hill is begun, a pile of refuse should be placed around the periphery of that layer, thereby screening the operation from view until the next layer is begun. As soon as the outer slope of each layer is completed it should be covered with earth, and vegetation should be planted. Note that the earth may be placed by the conveyor system, but that some machinery for compaction and contouring the surface will probably be necessary at this point. Note also that as people get closer to the hill, where the operation could be seen more clearly, more of the operation will be hidden from view. No fences or other eyesores would be necessary. The elevating conveyors are located in an area called the access groove. The groove screens the elevating conveyor from side views and

NOTE: I believe that a pipeline conveyor would be cheaper & more effective than a belt conveyor.



□ FIGURE 4. Initial phases of construction would concentrate on building, covering and landscaping the outer slope.

has utility as access to the hill during and after construction, as will be discussed later. Prompt planting of trees and shrubs will further shield the conveyor from view.

There are several matters of concern as the hill nears completion. It is expected that the top of the hill will be skewed and/or relatively flat. A skewed hill not only provides a more interesting and imaginative profile, but requires less conveyor adjustment during the latter phases of construction. It is not necessary to fill the access groove, for the relatively low and uniform slope would, for example, make an ideal toboggan run in the winter and provide access to the summit throughout the year. Another advantage of leaving the access groove is that it would provide a means for relatively simple removal of the conveyors from the site. If, however, it is desired to fill in the access groove, incorporation of this fact into the design of the conveyor system will be necessary.

A potential problem during construction is the disposal of large objects. Anything which can be transported by conveyor to disposal will offer no problem, as it will be quickly covered with milled refuse. Large bulky objects which cannot be milled or readily conveyed must be handled separately. Depending on the number of such objects, it is suggested that they can be trucked on a road in the access groove (note that it is relatively easy to make good all-weather roads with milled refuse, as shown by experience in Europe and experiments in Madison) and placed on the hill at such locations that they can be readily covered with milled refuse. When the hill is sufficiently large that trucking becomes difficult, such materials can be placed in a specific location at the foot of the hill, next to the mill, where proper fencing and periodic covering with milled refuse will make disposal as unobnoxious as possible. Note that if large amounts of bulky refuse are received, rather than have many trucks going up and down the hill it may be useful to provide a special process for grinding such objects for disposal, or to provide an auxiliary conveyor system to transport milled refuse cover to a special disposal site for these objects adjacent to the main hill.

Discussion

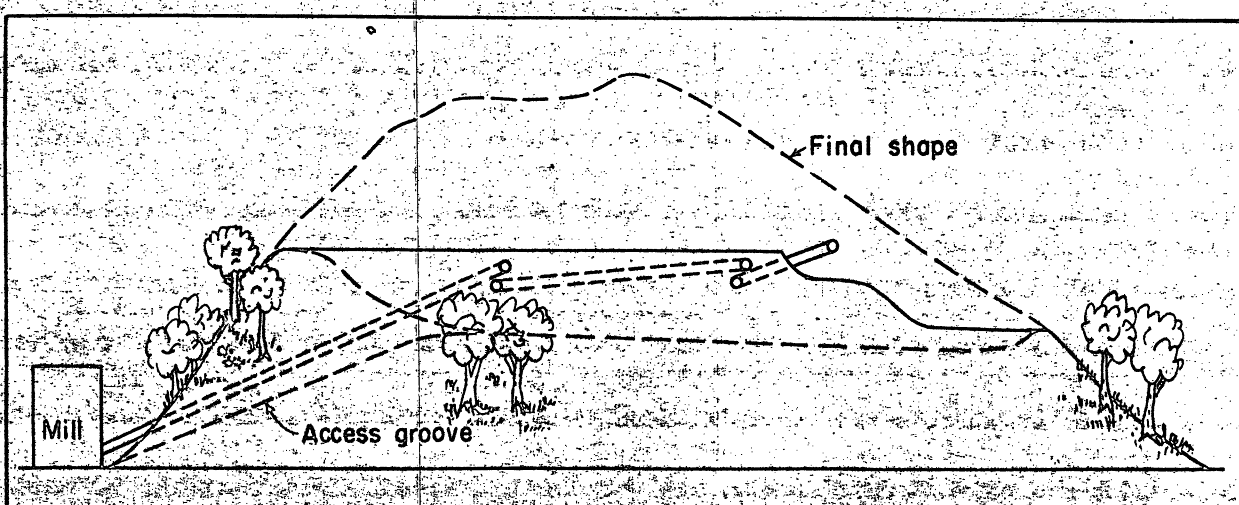
As has been emphasized throughout this article, the construction of a large elevation landfill must be done in such a manner that at no time will the public find the process obnoxious, nor will health and safety considerations be jeopardized. It is felt that the milling process is particularly useful to meet these criteria, and to provide a sound long-term, low-cost operation. This opinion is based on experience gained during the Heil-Gondard, City of Madison demonstration project, in which the feasibility of landfill construction with milled refuse but without daily cover was studied. Items of special interest include the following:

▷ Results from the demonstration project have suggested that daily cover is not necessary; the milled material provides its own cover. The costs, noise levels, and amount of activity associated with bringing in huge quantities of cover material, elevating it to the active area of the hill, spreading it, and compacting it are thereby avoided.

▷ Milled refuse piles, not covered, have resulted in no more, and probably less, fly or rodent problems than non-milled refuse piles covered with 1 to 2 feet of dirt. Vector problems appear unlikely even for a large-scale operation. (PUBLIC WORKS, July, 1969).

▷ It has not been found necessary to cover milled refuse due to odor problems; odor levels have been well below those normally associated with sanitary landfill operations.

□ FIGURE 5. Middle phases of construction and the final profile. Note that the elevating conveyor has been raised.



▷ Blowing papers are not a problem with milled refuse; probably because paper is ground and then mixed with other matter to form a matrix which restrains any blowing.

▷ Milled refuse can be handled easily on a continuous basis; therefore, conveyors can be used, resulting in less gross activity at the site, lower labor requirements, and smoother all-weather operation.

▷ Milled refuse compacts easily and uniformly to densities of 1000 lbs. per cu. yd. (based on a six foot rise compacted with a Caterpillar D-7 tractor) or more. This means that less landfill volume is required than would be necessary for a conventional non-milled operation where daily cover is applied.

▷ Milled refuse is significantly less obnoxious in appearance than is raw refuse.

▷ Milled refuse settles more uniformly than does non-milled refuse.

▷ Milled refuse does not burn as readily as raw refuse; however, to assure safe operation, it is suggested that the site be provided with appropriate fire-fighting equipment until more experience has been acquired with milled refuse. Note that the milling process itself will tend to dissipate hot ashes or other similar fire hazards.

Water Contamination and Gas Production

It is obvious that the accumulation of large amounts of refuse represents a major potential source of water contamination. For a large-elevation landfill, with elevations of 100-300 feet or more, it is doubtful that any leachate will pass through the refuse to the base in many parts of the country. For cells constructed of milled refuse up to one year old, not covered with dirt, and six feet deep, data collected under the Heil-Gondard project at Madison indicated that a maximum of 0.18 percent of rainfall reached the bottom. This amounted to 0.073 liter per square foot for a seven-month period, over which 17.31 inches of precipitation was received. The maximum amount of leachate collected in any 30 day period was about 0.028 liter per square foot. It should be emphasized that these cells were not covered and were level; therefore, there was essentially no surface runoff and the water soaked in readily. These amounts are expected to be far in excess of the actual amounts of leachate which would be collected from a refuse hill of depths much greater than six feet and with sides that are sloped, covered with dirt, and planted with vegetation. In addition to direct leaching, the formation of a water mound over a period of time would provide a transfer mechanism to carry contaminants to ground or surface waters. In order to avoid such contamination problems, whether due to leaching or the formation of a water mound, provision for drainage of the hill, such as the aquifer layer described previously, may be used.

The water that is collected by the aquifer may be highly polluted. That collected from milled refuse cells during the Heil-Gondard project has reached more than once a BOD of 14,000 mg/L, COD of 30,000 mg/L, total nitrogen of 600 mg/L, and ammonia nitrogen of 400 mg/L. The pH ranged from 5.1 to 7.8. Using these concentrations and assuming a leachate flow rate of 0.021 gallon per square foot per 30 days, the pollutional load from a hill with base dimensions ½ mile by ¼ mile (or approximately 1,000 feet in radius for a conical hill) would be approximately 100 pounds of BOD and 4.4 pounds of nitrogen in a flow of 870 gallons per day. It is expected that the amounts of pollutants produced in an actual hill would be considerably less than these estimates. It is likely, therefore, that the leachate will have no effect on a sewage treatment plant of reasonable size, and that disposal in a sewer, if available, would be desirable. Work is underway at the University of Wisconsin, and additional work is being planned, to estimate more accurately the amounts, composition, and treatability of leachate. Note that runoff from the surface of the hill will run harmlessly down the slope and will not enter the collection system.

Little is known about gas production within a large landfill. Since gas production is known to be very dependent on moisture content, the provision for adequate drainage of the refuse hill should lower the rate of production markedly; nevertheless, studies are planned at the University of Wisconsin to determine more accurately whether special precautions for gas discharge should be taken.

Some Additional Benefits

To the public official who is finding site acquisition more and more difficult, the main benefit brought about by a large-elevation landfill may be the extended period of time a relatively small site can be used. For example, assuming a cone shaped hill with a base radius of 1000 feet and a height of 330 feet, and assuming that the rate of refuse generation is 4.5 pounds per person per day and the density of refuse in the hill is 1000 pounds per cubic yard (this is a conservative figure), approximately 7.8×10^6 man-years of refuse will be required to complete the hill. For a municipality of 500,000 population equivalents, this would take 15.6 years. In a day when many cities are hard-pressed to acquire sufficient land to assure operation two years hence, the use of a small site for over 15 years is a most desirable prospect. Aside from needing fewer sites, another aid to new site acquisition may be the increased number of potential sites available because smaller sites are acceptable and because one need not be as concerned with proper drainage and possible water contamination problems.

An important benefit to the municipality, and to future site acquisition should arise from increased public acceptance. This would be due to nuisance-free construction methods, such as those described previously, and a carefully developed master plan for ultimate use of the hill which takes the needs of the community into account. It is suggested that the hill be designed and constructed in collaboration with the Parks Department or some similar agency, if it is to be used for recreational purposes. By careful planning. the hill could have ski slopes of various degrees of difficulty and toboggan runs for winter use. During the summer a well designed system of paths, along with imaginative planting of vegetation, can provide the municipality with a major scenic and recreational attraction. It is not difficult to imagine that parts of the hill could be used for flower gardens, picnicking, scenic views, etc. Research is underway at the University of Wisconsin to determine the suitability of milled refuse for supporting various types of vegetation. Goals of this effort include the identification of species both suitable and not suitable for growth on refuse, methods for improving the ability of refuse to support growth (if necessary), and any peculiar characteristics of milled refuse which might be used to advantage by planting distinctive vegetation.

It is felt that proper design of a large elevation landfill operation can gain public acceptance, be reasonable in cost, enhance rather than detract from the environment, and turn one of the most offensive aspects of modern living — the dump — into a major municipal attraction. □□□

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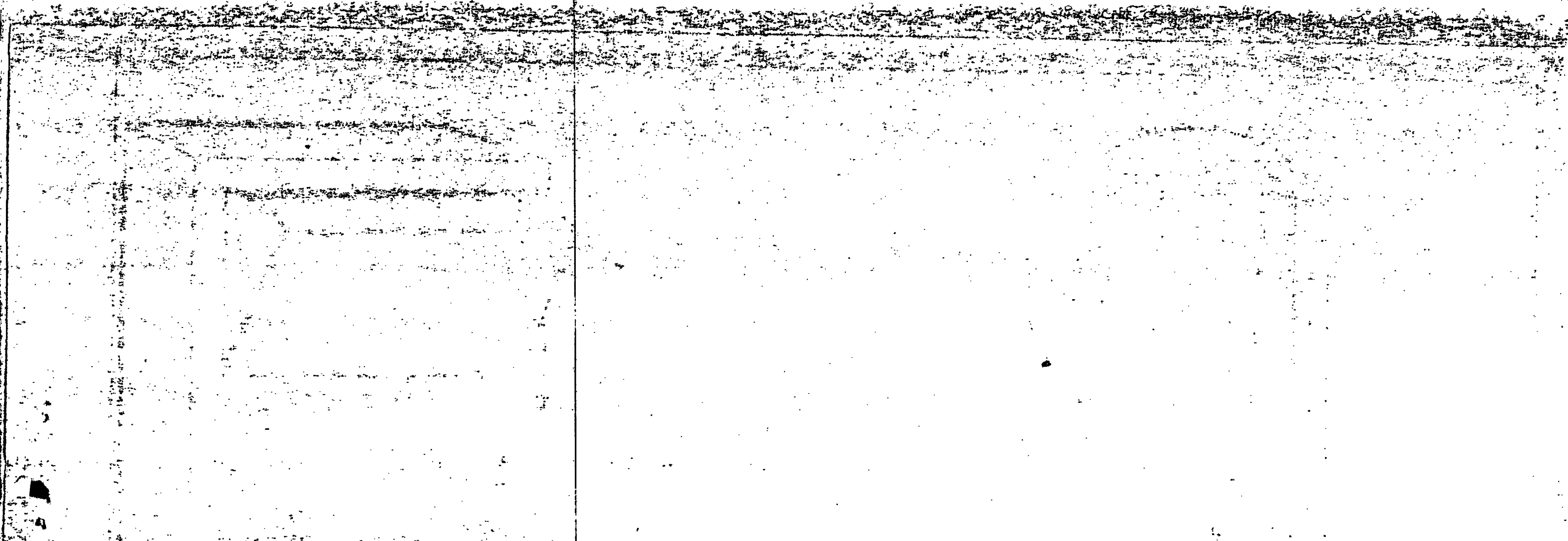
RETHINKING THE SOLID WASTE PROBLEM

by

D. G. Wilson

Department of Mechanical Engineering

September, 1969



D. G. Wilson

Rethinking the solid waste problem

Today people throw rubbish away to be collected and disposed of in ways virtually untouched by modern technology. But the picture must change for reasons of public health, social amenity and hard cash.

THE ECONOMICS of our society are such that it is becoming cheaper to make new products but more expensive to recondition or even clean them. The trend is strongest in the United States where, every year, people throw away seven million cars, 30 million tonnes of paper and 48,000 million tin cans. And man's solid wastes are changing from wood, paper and iron to unrustable alloys, glasses and plastics which neither rot nor burn. In the US domestic waste is being generated at the rate of some 2.5 kg per head per day. Adding industrial waste results in a figure much more than doubled. Agriculture likewise generates wastes on a prodigious scale. Over 100 million head of American cattle each produce almost 30 kg of manure daily and soil a quantity of straw, adding 15 kg to the daily per capita figure.

In the past manure was a valuable commodity. But today's cattle are raised in places bearing more resemblance to a mass production factory than to a farm, and the economic value of manure is no longer high enough for it to be transported and sold as cheaply as synthetic fertilizers. Thus it can be seen that solid wastes are often valuable materials in the wrong place; so the problem of what to do with them is in consequence largely one of efficient transport and handling. Moreover, the high concentration of wastes near animal 'factories' typifies the common situation in which land management, air pollution and water pollution are interlinked. Wastes dumped on or in the ground may cause water pollution. Wastes burnt may pollute the air—unless the incinerator has water washing equipment in which case the pollution may merely be transferred to the water. It is not unduly pessimistic to claim that in most countries there is little or no coordination between the agencies responsible for air and water pollution and land management. And poor waste management can bring other evils. The insects and vermin that breed on untreated waste cause disease, and the unsightliness of most of our wastes—for example, a car wrecker's yard—may well be one of the causes, as well as one of the effects, of a neighbourhood becoming 'run down'.

A summer study we held at MIT in 1968 showed the difficulties to stem largely from poor appreciation by town officials and others of the economic factors, to a fast changing economic balance caused by the increasing cost of labour and to a lack of knowledge of existing methods of treatment. Such large savings could be realized by the integrated application of the best techniques already available that the cry for new ones must be regarded at least partly as response to a false scent. I therefore intend to review some of the trends in the US scene which appear contrary to the public interest, and then to discuss some of the more promising developments in the solid wastes picture generally.

THE UNITED STATES displays litter in the streets, poorly run dumps, and incinerators—where they are to be found at all—which usually foul the atmosphere and produce only partly burned residue. Having an abundance of space and natural resources, Americans have not on the whole tried to conserve their environment. They moreover prize that individualism and independence which rejects the authority of government. The result of these attitudes is that, whereas in industry rules requiring great self denial are scrupulously observed in order to attain amazing levels of efficiency and productivity, in local or federal government the economic incentives do not operate and

CARS provide perhaps the most evocative scenes in the field of man's waste matter. This unsightly dump is actually in central London, where land values are high, yet little of the value of the original materials can be recovered. In thermodynamic language, the entropy of the waste is high.

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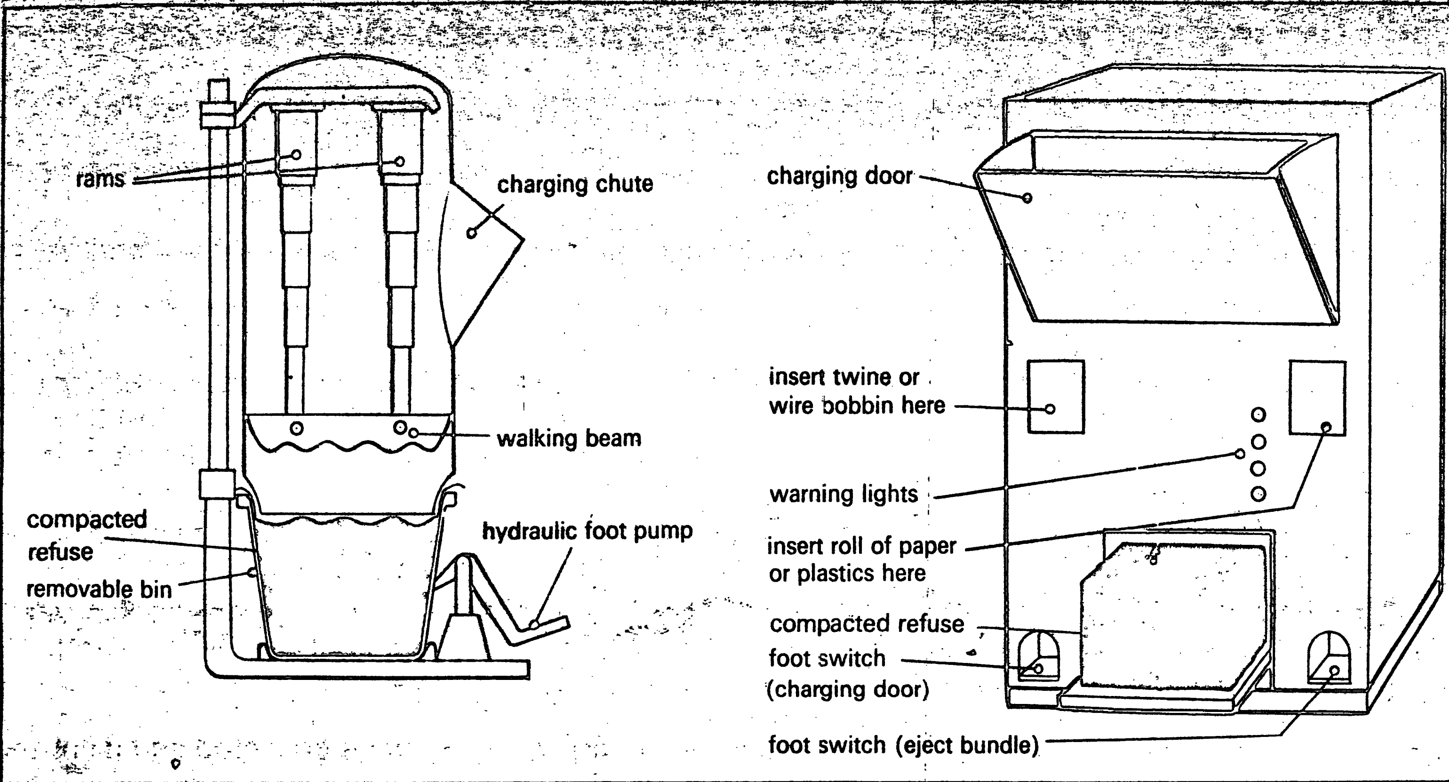


DOMESTIC REFUSE has for many years contained an increasing proportion of paper and paper products, so that its overall volume can be greatly reduced by compacting in a press. Left, above, is suggested a simple manually operated compactor which might be economically acceptable to larger homes; it has a hydraulic circuit energized by a foot pedal. Right is a more elaborate powered compactor which automatically compresses and wraps the waste.

the result can be equally startling inefficiency. The MIT study found that, whereas in US manufacturing industry the costs of almost every operation were known to a fraction of a cent, few city managers or engineers were even aware that the costs of household refuse collection lie between $17-35 per tonne and constitute 60-80 per cent of the total costs of waste management.

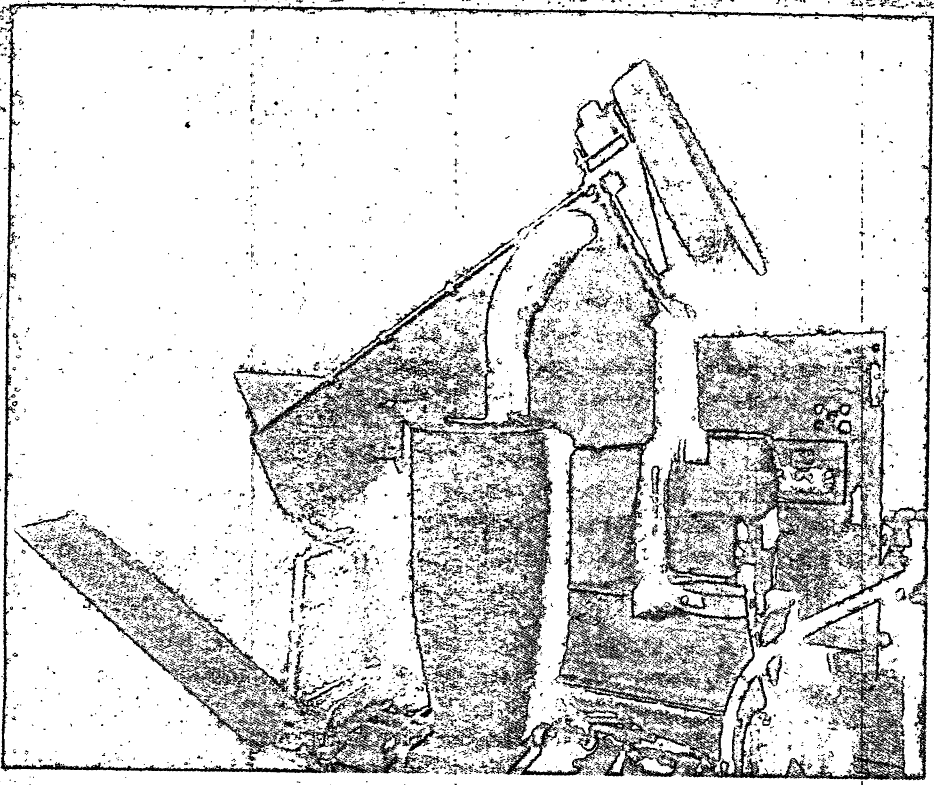
The predominant concern is usually with solid waste treatment, the cost for which might range from $2 per tonne for a poorly operated dump to $17 per tonne for a small incinerator. When a town dump becomes filled the only available alternative is often incineration, which involves a large capital expenditure. The actual costs then become highly visible, whereas the costs of collection are often submerged. As the tendency has been to cut down on the visible costs, the US has a legacy of some of the worst incinerators in the world—underdesigned, undersized and, in general, poorly operated. No US incinerator has electrostatic precipitation, although one has now been ordered. In these circumstances, the incinerator manufacturers have been able to afford little or no research, and operating problems are frequent.

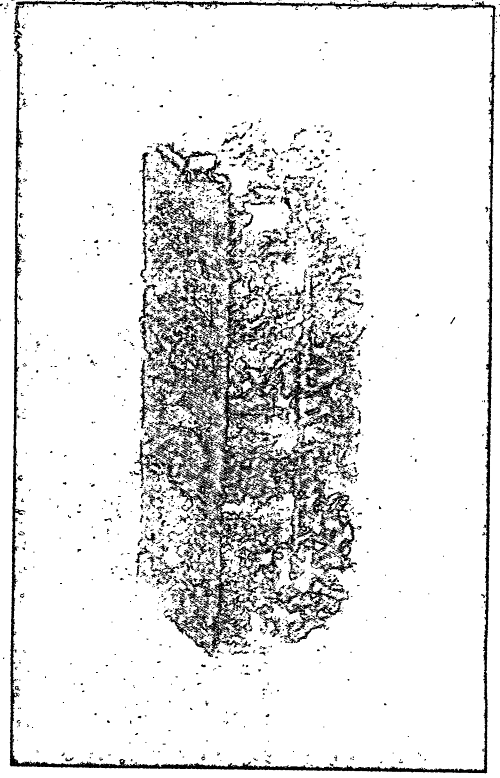
This situation is accentuated by the US form of local government. At its best it produces a fierce local pride; at its worst a refusal by a town to co-operate with its neighbours. Many towns have ordinances (by-laws) which specifically prohibit the movement of the wastes of another municipality through its own territory. Accordingly, many towns unwittingly pay the penalties of independence and smallness. One obvious penalty is that any method of treatment, particularly incineration, drops in unit costs as the size increases. The second is that smallness diminishes bargaining power. A group of municipalities whose aggregate solid wastes total 1000 tonnes per day is not only assured of greater competition among bidders for the privilege of supplying treatment but is also likely to be able to consider alternative methods not available or viable on a small scale. These alternatives now include long distance hauling and salvage and reclamation plants, as well as incineration; and pyrolysis (heating in the absence of oxygen) is a possible competitor.

THERMODYNAMICS is a very useful concept to apply to the treatment of solid wastes. In the form that they are produced in home, farm and factory, wastes have properties that give them 'availability'—strictly a measure of the maximum energy, in the form of work, obtainable by allowing matter to react with its environment and come into equilibrium with it. Most wastes have an enthalpy of combustion and, if maximum work is to be produced, should be burned at the highest practicable temperature and the energy liberated absorbed in an engine working between the widest possible temperature limits.

Solid wastes may also sometimes be used again. Some have a market value for reprocessing back into their original form (in the case of glass and metals), or to a slightly changed form (clean newspaper and cardboard), or a completely new one (wood).

As soon as the solid wastes are mixed together—aluminium with steel, glass with plastics or clean paper with dirty paper—the entropy increases greatly and the availability decreases. To bring mixed wastes back into a separated condition requires the expenditure of work. This work may merely be that of sorting, but if the mixing is accompanied by contamination or reaction it is very much greater. Obviously it is desirable to prevent wastes becoming mixed, and there are continual attempts to devise methods whereby refuse is sorted at the point of production. Householders may be asked to use separate containers for clean newspapers, steel cans, bottles, garbage (kitchen refuse) and whatever is left. As such procedures are susceptible to human fallibility, and also increase the cost of collection, they tend to be of value only in large establishments. The alternative is to do the sorting after mixing has taken place, and later I shall describe experiments on processes intended to overcome the penalties of mixing.





LARGE SCALE compaction of solid wastes calls for a correspondingly large and elaborate plant. This example, the MIL-PAC unveiled at a 'garbage-in' held at the Plaza Hotel in New York by the makers, SFM Corporation, first pulverizes waste material and then compacts it to a volume down to one fifteenth of the original. The resulting briquette (right) is 'an odourless block which can be used for landfilling, organic fertilizer or for salvageable materials'

A thermodynamic viewpoint also helps to define a pollutant as "any matter not at equilibrium with its environment". This definition encompasses all forms of pollution: material, thermal and acoustic. Preserving the availability of refuse, in order either to produce power or to reprocess it for re-use, automatically reduces the overall pollution of the environment. Furthermore, the amount of availability destroyed is a direct measure of the amount of pollution caused. Incineration is therefore a greater polluter of the environment than is a landfill where the availability of the waste material might be preserved for future generations. Of course, if the material in the landfill were to be allowed to continue the mixing process—say with water going to an aquifier—the pollution may be more noxious, even though less in magnitude, than if the waste were burned.

In some cases the change in availability in bringing material into equilibrium with the environment is small, so there is no great sacrifice in destroying the availability. For example, ground glass has virtually all the characteristics of sand, which indicates that efforts to preserve the availability of glass might sometimes be misguided.

THE COLLECTION of domestic solid wastes has scarcely changed since the days of the horse and cart. The carts have been covered and fitted with doors and, as our domestic refuse contains a rising proportion of paper and paper products, with load compaction devices. Automatic 'dustless' loading, particularly by the Zoller system, has become widespread in Europe, although the rapid reduction in the use of dust-producing solid fuels is diminishing the need for it. The high cost of collection is due mainly to the large labour force required. In England it is not uncommon for a crew of seven to be needed for each collection vehicle. In the US it is usual for the householder to have to bring his bins to the roadside and return them afterwards, so that some of these costs are not borne by the municipality. However, the challenge to cut the high labour component is clear.

Use of paper sacks, which started in Scandinavia, has been one step in this direction. Apart from the obvious advantage of cleanliness, paper sacks do not have to be returned; and, as the weight of the bin is eliminated, the loader's job can be greatly speeded up. Paper sacks have often enabled the crew to be reduced to one loader and one driver. Indeed, in parts of the US, and doubtless also in Europe, one-man operation of the vehicle has been achieved. With an open cab and the capability for front-end loading, the driver can reach out and grab a bundle or paper sack—sometimes without even stopping the vehicle. Plastic bags may also achieve success but many of those on the market are flimsy and easily torn, and those made of polyvinyl chloride can corrode incinerators.

It is partly the favourable response to paper sacks that has initiated research on both the compaction of refuse and on vehicles which are quicker loading without being excessively noisy. Most compaction trucks operate either with a reciprocating piston compactor or a rotary arrangement resembling a meat mincer. A flurry of excitement was caused in the US last year by demonstration of a traditional European rotary screw truck because of its faster loading, quietness and ability to 'chew up' refrigerators, stoves and oil drums. Normally a special collection must be made for large items, which therefore incur a disproportionate expense that is often passed on to the householder. These rotary packers also pulverize the refuse to a degree which gives considerable advantages in incinerator operation and landfilling. The vehicle has been found so quiet that it can collect paper sacks at night without residents complaining, so that three-shift operation becomes possible. In addition to the obvious additional utilization of capital equipment, such a truck can average a higher speed during the night hours when the streets are free of traffic.

The possibilities of one-man collection opened up by the use of paper sacks has led to several proposals for collection trucks having a mechanical pick-up controlled from the cab.

INVENTORS have been intrigued by the possibility of extending compaction to the home, and various electric, hydraulic and manual compactors have been suggested and developed. It would obviously be attractive to throw one's trash into an under-counter unit yielding one or two small and dense bundles to take out for collection, with nothing to be brought back. And it is easy to devise simple means whereby the compacted blocks—perhaps wrapped in paper or plastic or impregnated with a plastic resin—may be carried to the pick-up point on the street without too great a capital investment. One device freezes the compacted waste in ice. Collection could then be made as infrequently as once a month, but obviously a system is needed to transfer the cube direct from the storage container to a special vehicle. If all houses in a community had compactors the collection vehicles could be simplified for one-man pickup and their speed of operation increased.

Since much of the cost of refuse collection is absorbed in wages it is natural that attention has been given to the development of multi-purpose vehicles, the driver of which might perform several tasks. One such proposal is for a one-man vehicle to collect refuse and sweep the road at the same time. The only problem seems to be that existing vacuum units are bulky and inefficient, but improved aerodynamics should reduce noise and erosion. Two methods of air cleaning are illustrated on these pages. In one a travelling screen with automatic blow down is intended to remove leaves and litter before any can enter the fan. The second is a radial inflow turbine directly coupled to a centrifugal fan. The intense vortex downstream of the turbine nozzles prevents any but micron sized particles from passing through the fan. The turbine thus acts as an efficient vortex separator with energy recovery.

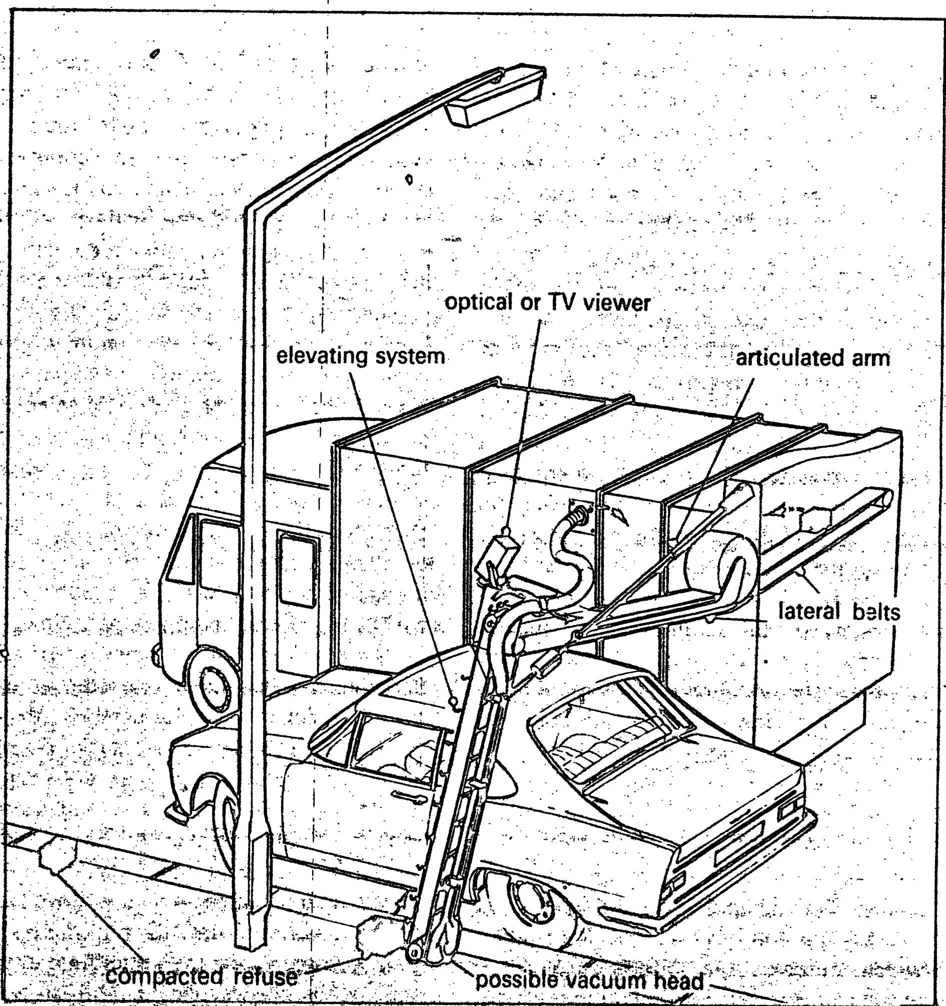
A perennial problem in street cleaning is parked cars. If the citizenry were law abiding it would be possible to specify that cars should be parked on alternate sides of the road on alternate dates. It might be better to face reality and design a collecting and cleaning vehicle which operates over and under parked cars.

If refuse can be cleanly compacted and bundled it might be preferable to devise a "universal" collection and delivery vehicle. Town dwellers are today faced with reductions in mail deliveries, elimination of many food and milk rounds and the abandonment by many stores of home delivery. These services, as in the case of refuse collection, have been essentially untouched by technology. The application of computer routing systems and computer operated delivery and collection of several commodities from a single vehicle should naturally lead to the concept of a universal vehicle which could visit every house in a municipality once or twice a day. Refuse could be kept as separate from food or mail as the petrol and oil used in the engine.

A further step in automatic collection is the use of tube systems. A Scandinavian pneumatic system is being used in new blocks of British flats. A French hydraulic system is working in Paris. Such systems are attractive for large new buildings and perhaps new towns but are not economic for whole cities unless existing facilities can be used. There have been many proposals to have solid wastes ground up and injected into the sewers. Alternatively, the ground-up refuse could be packaged—typically in plastic skins—adjusted to neutral buoyancy and then passed into the sewers. The sewage treatment facilities could then be combined with means for extracting and treating solid wastes. One drawback to the idea is that most existing sewers, although farsightedly constructed oversize, have now after decades and sometimes centuries become overloaded. Moreover, many old sewers are combined with storm water conduits. On the other hand a report by the US Public Health Service shows that the additional load on sewers due to the use of the domestic refuse grinders already in use is negligible.

TRANSPORTING refuse to some distant area is always very attractive to the refuse producers. Unfortunately, although it is considered better to give than to receive, such a proposal is not normally welcomed by residents near the receiving end of other people's wastes. But the proposal has obvious merit.

Since the law of conservation of matter still generally holds, and since we are an urban civilization engaged in building and producing, there must be an increasing volume of holes in the ground from which all this matter has been removed. Quarries, deep and surface mines and other excavations have always been natural candidates for the disposal of our wastes. Almost the only new component in the proposals for long distance shipment of wastes is that the technology



COLLECTOR TRUCKS for picking up solid wastes from the roadside could for urban use be designed to work over or under parked cars. This proposal by the author suggests a vehicle having a guided arm for collecting paper sacks of refuse and possibly vacuum sweeping also. It would have a closed circuit TV or optical system for steering the boom past cars and lamps that study allows us economically to use resources hundreds of kilometres away can equally well be applied to shipment of refuse back. To fill up a hole in the ground with wastes in a well controlled manner can be a beneficial action on all sides. Indeed, property values in San Francisco have been known to rise when it has become known that an area of waste land nearby is to be used for landfill. The reputation of the public works department is apparently high enough for residents to be confident that the waste land will be turned into a park or golf course with the minimum of pollution and disturbance during the filling operation.

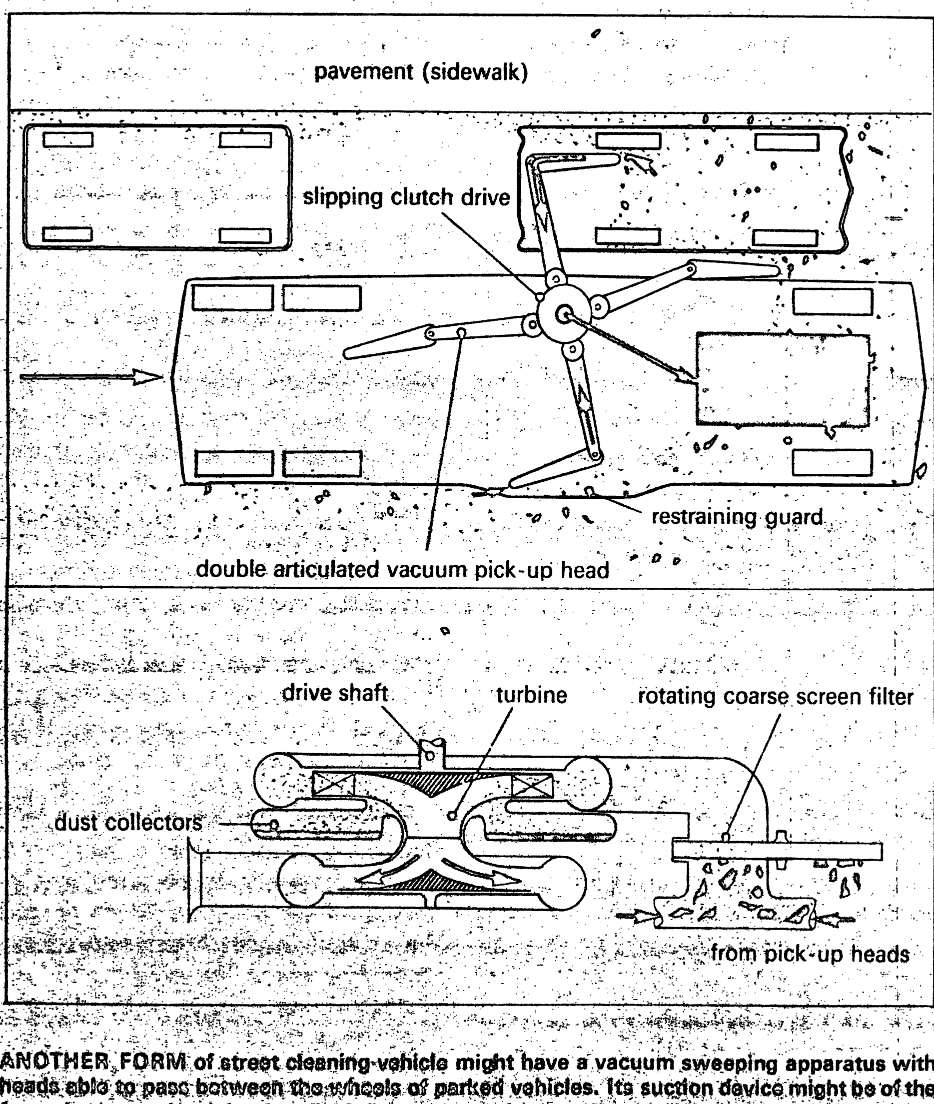
Proposals for long distance refuse shipment generally follow the same pattern. Transfer stations would be sited at appropriate points, determined by operational research studies, in the community to be served. The wastes would be brought to these by standard collection vehicles. Large hydraulic presses would take the trash in the delivered condition (some proposals call for shredding, but this adds considerably to the expense) and compress it into 1.2 metre cubes having a density of some 900–1200kg/m³. Typically, the bales would then be banded, wrapped in polythene sheets and loaded on to railway flat cars for shipment up to 800 km away. Proposals of this kind are under study in several places in the US. The plans of the Reading Railroad and Eastern Land Reclamation Inc to dispose of Philadelphia's wastes in abandoned coal mines have been held up because of supposed concern for the effects of water pollution deep underground. The contract to ship San Francisco's rubbish into the Nevada Desert has gone through several on-again, off-again cycles and its future continues indefinite. But one contract that seems about to be signed is between the city of Milwaukee and the Milwaukee railroad. Many hope this operation will meet with success sufficient to encourage the many communities at present wondering whether to take the plunge.

INCINERATION has for many years been a standard treatment in many parts of Europe, but in the US the greater availability of dumping sites has confined the need for incinerators to a few large urban areas. Consequently there is a marked difference between the design and performance of European and US incinerators; few of the latter are operating satisfactorily, even though ordinances regarding air pollution are much less stringent than in Europe.

Although rubbish has been described by at least one enthusiast as "the sweetest fuel this side of natural gas" it is in fact so highly heterogeneous that incinerator design rests on rule of thumb rather than on analytical techniques; and the problems of control—for example, to provide low excess air when desired—are severe. The heterogeneity has a marked effect in determining the residence time. A sheet of polythene may enter the furnace with a bundle of telephone books and a balk of timber. The first burns out in a few milliseconds; the others may take two hours. To burn out the books the burning mass must be stirred or tumbled every few minutes, but too much agitation results in excessive carry-over of particles. And to increase the burning rate by restricting the air supply and thus raising the mean combustion temperature can cause serious attack on normal fire-brick when certain materials are present in the refuse.

Plastics, particularly polyvinyl chlorides, are increasing in proportion and causing corrosion, clogging and even explosions. This situation seems likely to get worse. In the past five years a Syracuse, NY, hospital—presumably typical of many—increased its output of solid wastes from 12 to over 60 cubic metres per day. Much of this is due to the enormous growth in the use of "disposables" in hospital care, from sheets to hyperdermics (one chemical firm has the courage to point out in their sales literature that there is at present no good way to dispose of such disposables).

These problems are not yet resolved, although claims have been made that corrosion and thermal cracking can be prevented by proper control of the air flow. The problems are particularly severe in incinerators where heat recovery is attempted by the use of "water wall" furnaces or other heat exchange methods for raising steam. This casts further doubt on the already uncertain proposition that it is worth while recovering thermal energy from refuse. But energy recovery seems to win on many counts. Obviously it reduces thermal pollution of the atmosphere. Secondly, the energy produced might eliminate the need for some other source of energy, further reducing thermal and material pollution. Thirdly, by removing heat from the furnace the amount of excess air needed for cooling can be reduced to no more than about 60



ANOTHER FORM of street cleaning vehicle might have a vacuum sweeping apparatus with heads able to pass between the wheels of parked vehicles. Its suction device might be of the form shown on the right. A radial inflow turbine and centrifugal fan are mounted back to back on the same shaft, creating an [illegible] vortex which arrests all dust larger than micron size per cent above stoichiometric, greatly diminishing the volume of gas to be treated by the air cleaning equipment and thus reducing the capital cost. If an electrostatic precipitator is fitted, this saving can be considerable.

IN THE FACE of all these advantages the inability of many steam-raising incinerators to prove themselves is surprising. The reasons lie in the corrosion problems, in failures due to fatigue resulting from the variability of furnace temperature and in the difficulties in finding uses for a steam supply which normally has inadequate pressure, temperature or flow to make a turbine and generator, with its special personnel and control systems, worth while. Electricité de France does use an incinerator in Paris for power production, but its economics are uncertain. An installation on Long Island, NY, has been designed to produce some power but to take much of the steam to run a multiple effect sea-water desalination plant. As the fresh water produced can be stored, this use could accept a more variable steam supply than power generation alone, but the plant has been plagued by tube failures since its commissioning.

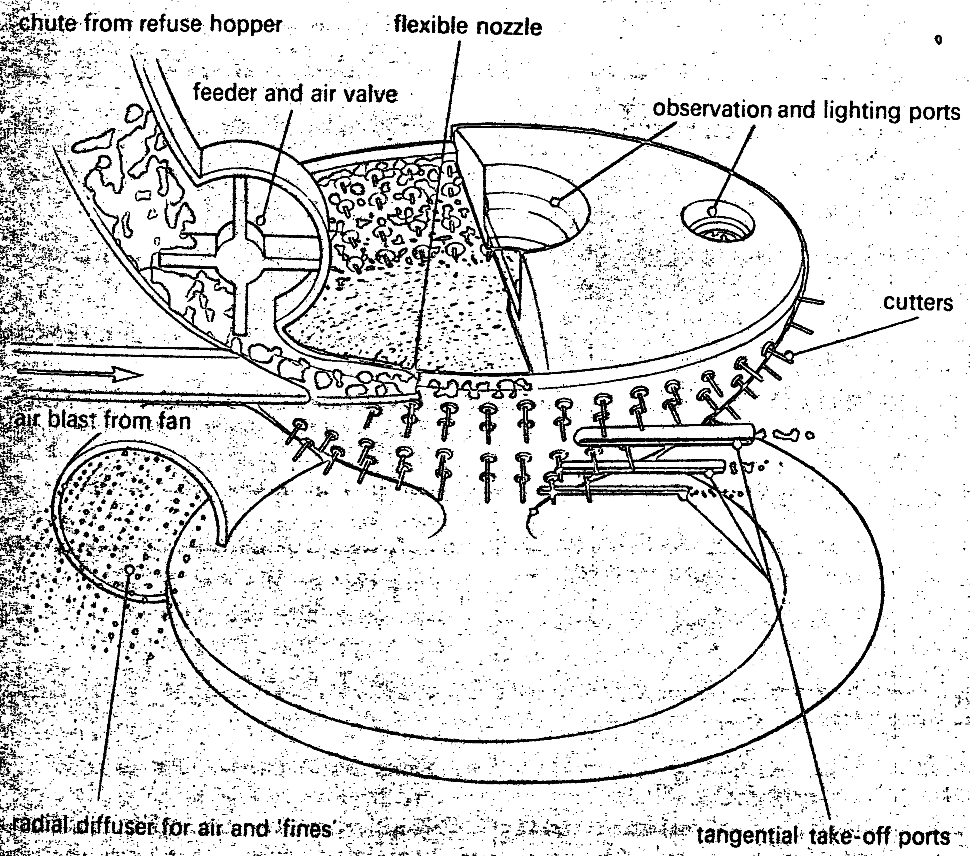
Several proposals are now being made to pulverise refuse before feeding it to an incinerator. This should result in a more uniform residence time and flame temperature. But the added expense and noise (serious in a residential neighbourhood) and the high power needed for pulverization might well outweigh the claimed advantages, and I know of no incinerator actually being operated in this way. Other proposals have been made for pulverized refuse to be burned in a fluidized bed or other form of suspended combustion, and various experiments are in hand.

A radical development is to employ temperatures above the fusion point of most refuse materials. One "slagging incinerator" has been in use in Germany for two years, although few details on its behaviour have been divulged. The American Design and Development Corporation of Whitman, Massachusetts, has built a prototype vertical shaft furnace fuelled periodically by coke burnt at some 1650°C to produce a molten slag (it bears an obvious resemblance to a blast furnace). The black slag, when run into a water quench tank, turns into a sand which seems suitable for road building. The report of a test subsidized by the US Public Health Service has just been issued. It indicates that the high viscosity of the slag, and local severe attack on the refractories, are immediate technical problems which must be overcome. The cost of coke fuel and limestone flux is also very high (over $4 per tonne of refuse) in the small prototype tested.

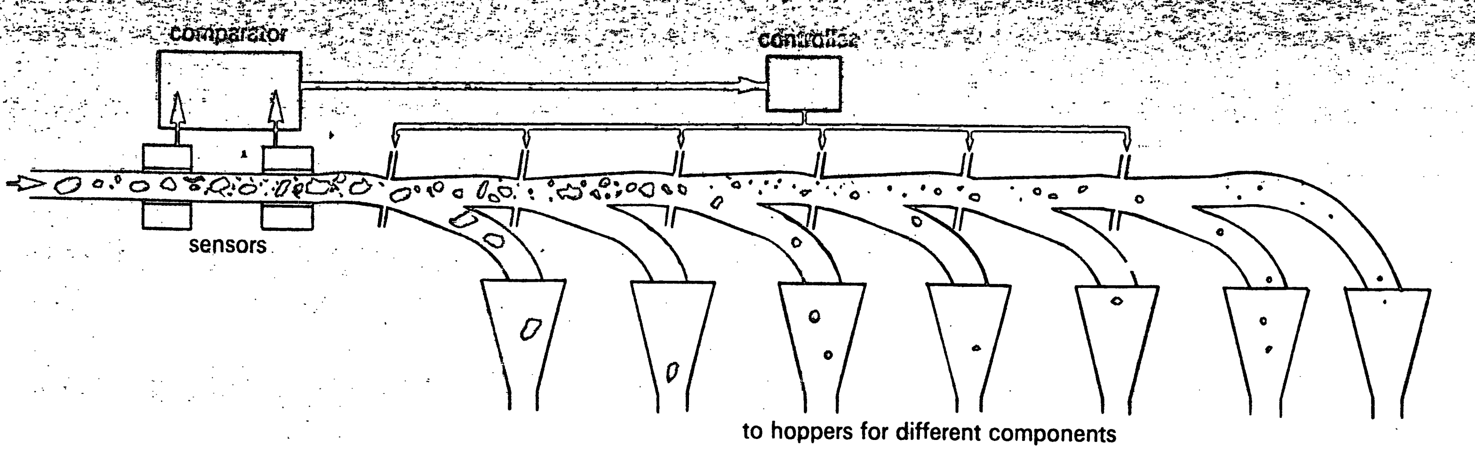
Another approach to increasing the availability of the energy from wastes is to heat all cellulosic materials in the presence of insufficient air for combustion and thus produce gaseous and liquid fuels ranging from gases to tars plus a charcoal residue. On the face of it such pyrolysis is another process which would seem to yield very large gains. Some of the liquid fuels could be used to heat the retorts and so make the operation self-supporting. One unit, the Lantz converter, is produced by Pan American Resources Inc on the US West Coast. These operate on a continuous basis; preliminary reports indicate successful operation on lumber but I have no knowledge of their ability to handle mixed refuse. At present it is the practice on the East Coast to load barges with waste lumber, tow them out to sea and set fire to them. Almost any change would be an improvement on such a barbaric practice.

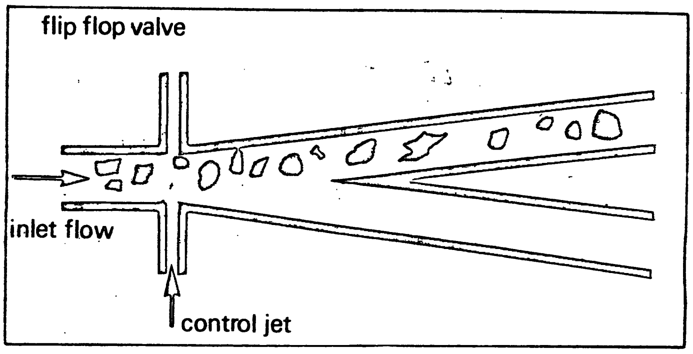
RECLAMATION is always an attractive concept. Although man's use of tools broke nature's cycle of decay and rebirth he has for centuries tried to re-use as many of his materials as possible. But his recent accession to vast resources of power has led to the incongruous situation where, for instance, it is often cheaper to make glass from sand than to clean an existing bottle and use it again. The relative increase in labour costs bears the major responsibility.

Many European incinerators and compost plants have traditionally incorporated salvage as part of their operation. For instance, the refuse is sometimes distributed on moving belts from which saleable materials are removed by men stationed by hoppers. Such an arrangement has been installed in the Houston, Texas, plant of Metropolitan Waste Conversion Corporation. This is a remarkable development in a country where wage rates are the highest in the world. The plant approaches, but has not attained, economic viability partly because of its size—it handles about 350 tonnes per day and receives a steady income from the sale of waste paper and ferrous materials (which are easy to recover with revolving magnets). Although this particular unit is generally regarded as a compost plant, compost is essentially a by-product from the recovery of paper and steel. Plans are in hand and experiments are being undertaken to remove paper automatically, whereupon the income of the plant should increase greatly; the running cost should decrease and the quality of the compost, which normally has only a small food waste content, should increase. At present 100,000 tonnes of waste paper are being re-used each week in the US and, should greater quantities be salvaged, there seems no danger that the selling price of paper, cardboard, metal or glass "cullet" re-



VORTEX MILL of this general form might be used to shred refuse and separate the result into classified grades according to size and density. The waste products would be fed by a powerful air blast into a high velocity vortex chamber equipped with sharp cutters projecting from its wall. The shredded waste would escape from the appropriate outlet port for all particles of that particular range of size and density. The air and 'fines' would leave through the bottom.





SORTING of solid wastes might be accomplished automatically by a system of the general form illustrated here. The refuse is transported through a duct by a high velocity air stream (conceivably, a liquid flow) and automatically assessed for size, density or type of material by a built-in system surrounding the duct. This would then provide signals controlling fluid logic flip-flop gates to divert each type of waste particle to its own appropriate channel. Such a system would make economic sense only if worked hard for 24 hours a day.

covered from wastes will fall drastically because of the inability of the market to absorb them. Metropolitan Waste Conversion Corporation has demonstrated a bulk use for compost called "hydromulching". This involves spraying an aqueous slurry of compost and grass seed, or other ground cover, to impart soil holding qualities to denuded areas.

Although the Houston plant differs little in essentials from many European plants, I believe it points the way hopefully to the future. It was set up by private enterprise to serve a city, and the need for large corporations to see profits in the urban field is considerable. It is the first major reclamation plant installed in the US for many years and has stimulated proposals for more advanced methods of refuse separation.

One such method, on which work is just starting at MIT, is illustrated on page 74. Refuse is fed to a high velocity vortex chamber with walls bearing cutters which can be advanced inwards as they wear. If this "size reducer" works as planned it will be a considerable advance because existing pulverizers have to be stopped frequently to replace worn cutters and so suffer from very high maintenance costs. The vortex has the further advantage that particles will not pass out of the central outlet until they have been reduced in size sufficiently for their aerodynamic drag to overcome the centrifugal force and give them the required inward acceleration.

Some classifications by size or density might therefore be possible in a vortex. Hopefully the outlet duct will carry nothing but discrete particles of matter in suspension. Can the major component material of each particle be identified, so that it may be switched down an appropriate branch into a storage hopper? One suggestion is for a laser beam to vaporize a small quantity of the material for almost instantaneous spectographic analysis. A single test may not suffice to identify each particle, but three properties determined by three different methods would give virtually positive identification of all particles composed of a sufficiently high proportion of a single component or mixture for reclamation to be worthwhile.

TOTAL RECOVERY of our solid wastes is the most exciting goal in the whole field. If it were considered as important to a major manufacturer as developing a new shaving cream, the problems would soon be solved. At least the passing of the 1955 US Solid Wastes Act has enabled federal support to be given to many projects that were otherwise only marginally attractive to private industry.

As I have mentioned, plastics, which have contributed so much to our lives, are causing serious problems in incineration. To my considerable surprise no one in three major US petrochemical corporations has been able to suggest methods of re-use or even satisfactory methods of disposal of the plastics which they themselves produce. Indeed our large plastics firms seem to be finding difficulty in disposing of their own trimmings.

I believe we must revise our values: future society should charge producers of materials with the responsibility either to develop economic and acceptable methods of reclamation or disposal or to accept such materials back when users have finished with them. The trend is shown by the proposal that motor vehicles should bear a sales tax to finance the cost of disposing of abandoned cars. It indicates a growing dissatisfaction with the present role of the supplier in our modern society. This trend would be reversed if our major corporations joined in an effort to ensure that their products do not foul our environment. There is reason to hope that they are in fact planning such an effort.

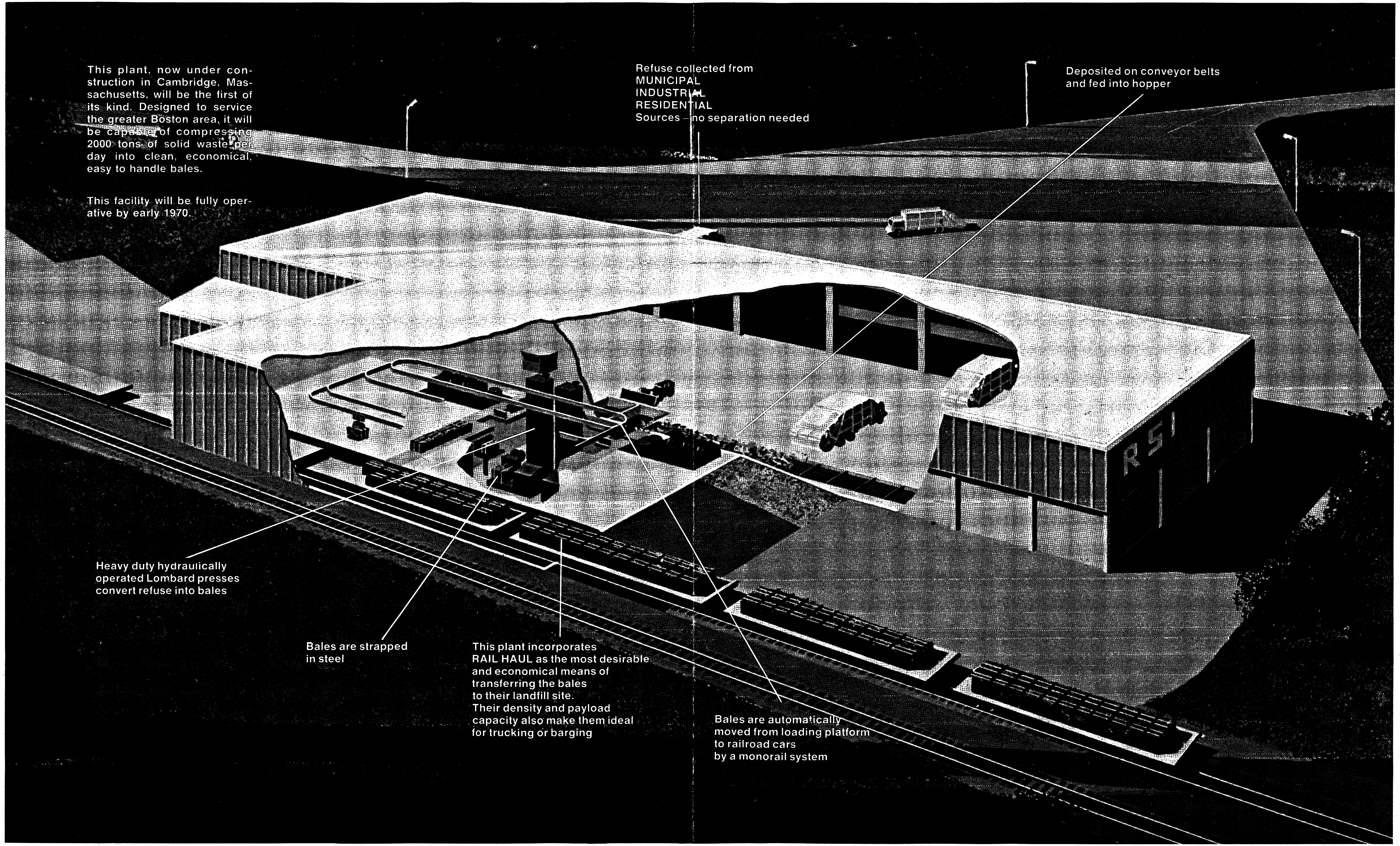
FURTHER READING:

SOLID WASTE RESEARCH & DEVELOPMENT, Proceedings of the Engineering Foundation Research Conference *(Wayland Academy, Beaver Dam, Wisconsin, July 22-26, 1968)*

COMPREHENSIVE STUDIES OF SOLID WASTES MANAGEMENT, first Annual Report, by C. G. Solueke and P. H. McGauhey. *(College of Engineering, University of California, Berkeley, May 1967).*

THE MANAGEMENT OF SOLID WASTES, Summer Study Report edited by D. G. Wilson *(Urban Systems Laboratory, MIT, Cambridge, Massachusetts, September 1968)*

PROCEEDINGS of the 1964, 1966 and 1968 National Incinerator Conferences, *(American Society of Mechanical Engineers, New York)*



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- Because no separation of collection is needed. Rubbish and garbage can be combined
- Because it reduces air pollution
- Because it reduces fire hazard
- Because the bales produced have the payload capacity to make them ideal for rail haul, trucking, or barging
- Because the life of landfill sites will be extended and more useable land will result
- Because Reclamation Systems is DOING something about the solid waste crisis

By early 1970 Reclamation Systems will, through the use of heavy duty, hydraulically operated presses, commercially compact solid waste into high density bales.

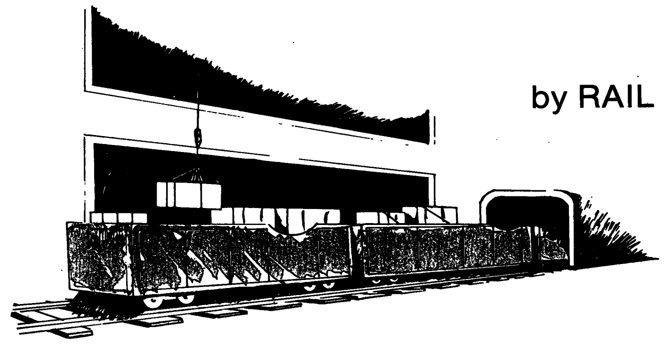
The bales will measure 4′ x 4′ x 4′ and weigh from 4000 to 6000 pounds, depending on the type of material used.

Total compaction will be as much as 30 to 1.

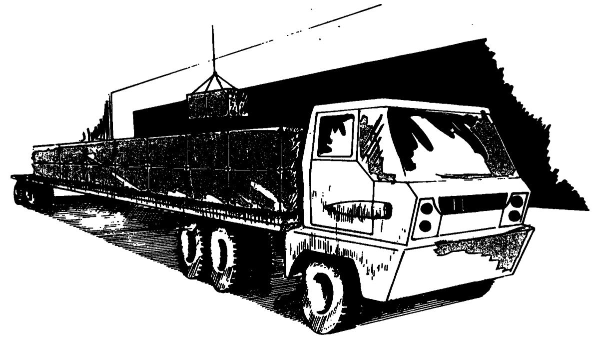
Reclamation Systems, as part of its total systems concept, will FINANCE and CONSTRUCT facilities for municipalities.

THIS MEANS THAT CITIES AND TOWNS WILL NOT HAVE TO MAKE LARGE INITIAL CAPITAL OUTLAYS WHICH DRIVE TAX RATES UP.

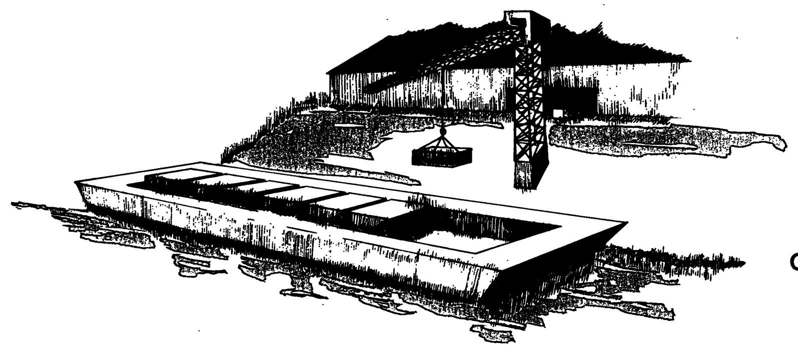
In addition, Reclamation Systems will coordinate TRANSFER after compaction . . .



by RAIL

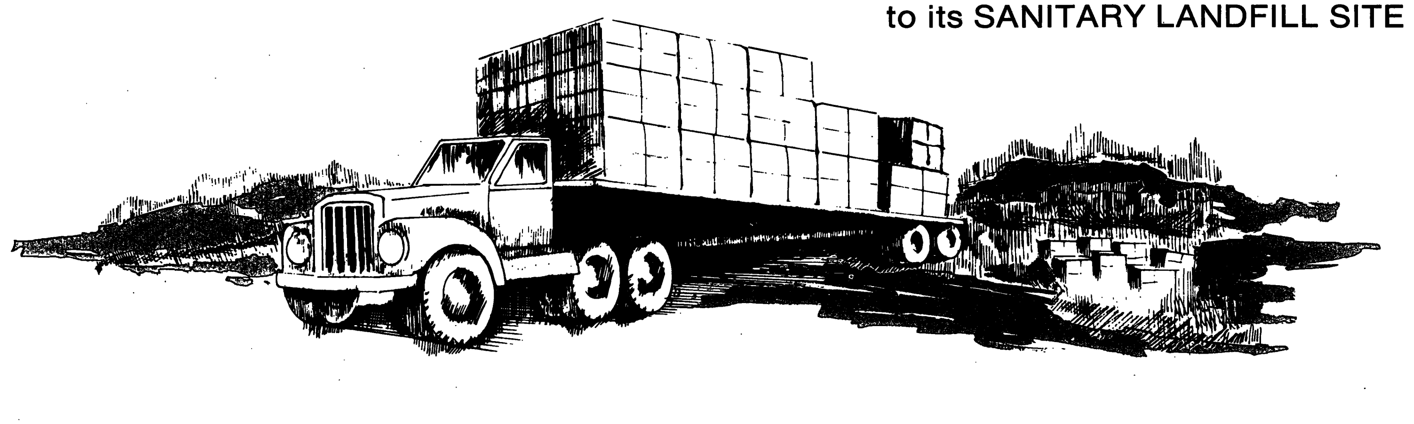


by TRUCK



or by BARGE

to its SANITARY LANDFILL SITE



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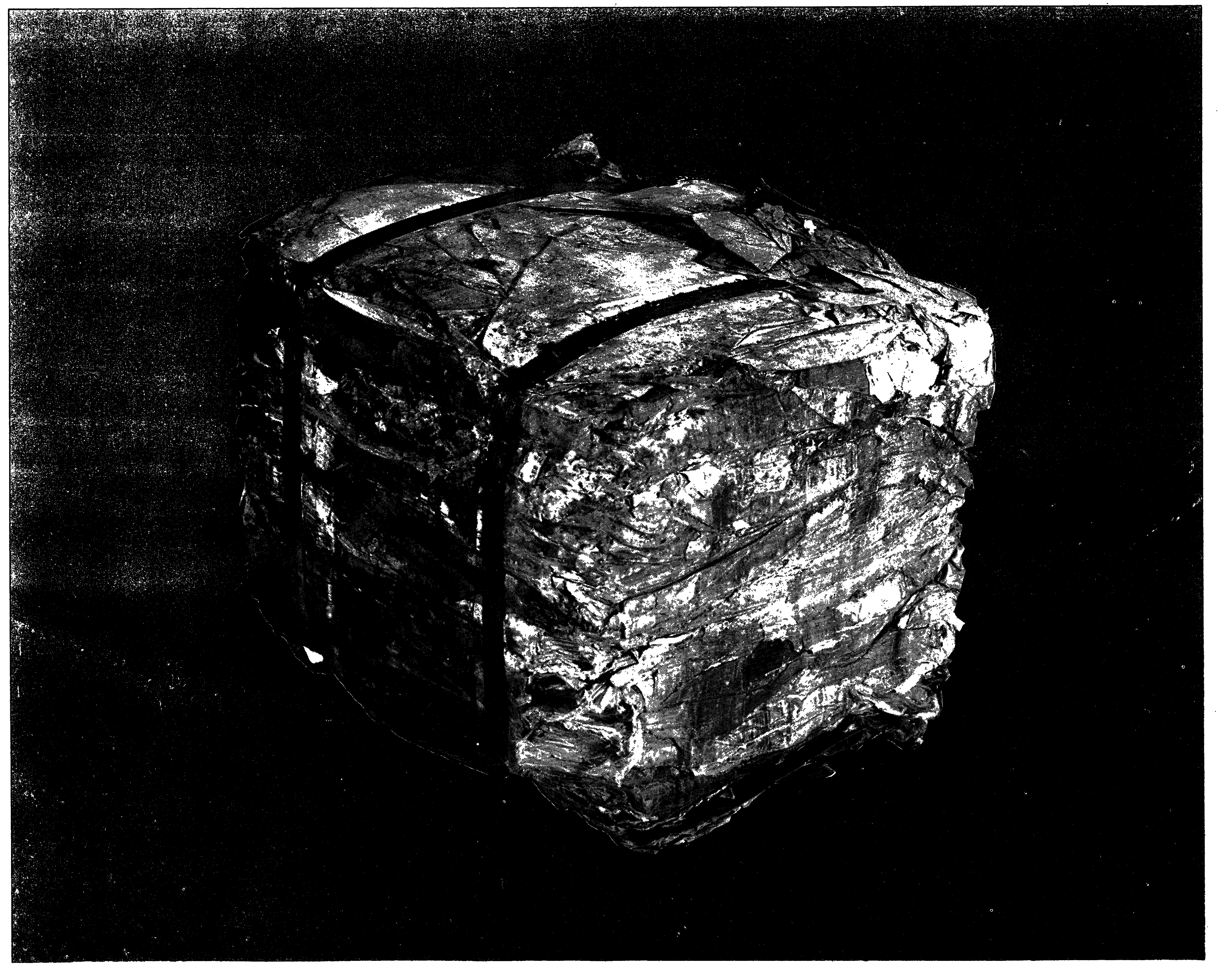

DAVID GORDON WILSON
42 WINSLOW STREET
CAMBRIDGE, MASSACHUSETTS 02138
(617) 876-6326

February 19, 1970

TO: MEMBERS OF THE CAMBRIDGE CITY COUNCIL

ABOUT: FORTHCOMING PROPOSAL BY THE CAMBRIDGE BICYCLE-SAFETY COMMITTEE

The members of the Cambridge Bicycling Subcommittee of the Traffic--Safety Committee want to let you know in advance something about a comprehensive proposal which we are preparing and hope to present to you within a month. We have been alarmed equally by the increase in bicycle-related accidents and by the lack of concern for the law or the rights of other road users displayed by many bicyclists as well as by motorists. We believe that bicycling can make a substantial beneficial contribution to reducing street congestion, parking problems, and air pollution in Cambridge, but both bicyclists and motorists need education about the law and about respect for other road users.

Briefly the program, which we have developed in coordination with the Police, Traffic and School departments, consists of:

The printing of a large number of posters, leaflet brochures for bicyclists and other brochures for motorists;

The designation and posting of certain quieter streets as 'Bikeways', which bicyclists would be encouraged to use in preference to heavily trafficked routes, and in which motorists would be warned to take especial care. No changes in legal status is required. Such Bikeways are being endorsed with great enthusiasm all over the USA.

The location of bicycle stands in certain places throughout the city where at present bicycle parking can cause a nuisance

The designation of the week of April 18-25, 1970, as Cambridge Bicycle Week, during which a number of events organized jointly with the Parks and Recreation Department will bring bicycling and bicycle safety to public attention.

The financial support for which we shall be asking amounts to $8,500, principally for the Bureau of Public Roads approved bikeway signs. Although this is a considerable sum, it is small when compared with the community cost of a single fatal accident or with any of the continual measures used to keep automobiles in our streets, and we hope that you will feel able to approve it. As soon as we have our draft leaflets ready individual members of the committee will be offering to explain our proposal to each of you.

David Wilson

CITY OF CAMBRIDGE

CAMBRIDGE, MASSACHUSETTS 02139
Tel. 876-6800

EXECUTIVE DEPARTMENT
James L. Sullivan
City Manager
John H. Corcoran
Assistant City Manager

February 23, 1970

To the Honorable, the City Council:

I would like to take this occasion to transmit to your Honorable Body material that has been received from Professor David Wilson as it relates to matters discussed by him upon the occasion of the inspection of the City Dump, Saturday, February 14, 1970.

Appended hereto please find -

1. Communication dated February 18, 1970, entitled "Recommendations for Solid Waste Management in Cambridge".

2. Paper entitled "Refuse Reduction Plant, Montreal, Quebec" by W. J. Johnson.

3. Paper entitled "Large Elevation Landfilling for Refuse Disposal" by Robert K. Ham, Assistant Professor of Civil Engineering, University of Wisconsin.

4. Paper entitled "Rethinking the Solid Waste Problem" by Professor David G. Wilson of Massachusetts Institute of Technology.

5. A brochure entitled "Reclamation Systems, Inc." which has been forwarded to this office by Reclamation Systems, Inc. and which information we believe to be self-explanatory and submitted for informational value that we think it may have at this particular time.

Another paper by Professor David G. Wilson dated February 19, 1970, unrelated to the aforementioned matter but nevertheless a concern that Professor Wilson has as it relates to bicycle safety here in Cambridge, is also enclosed. I am submitting all of the foregoing material to your Honorable Body for your information.

Very truly yours,

James L. Sullivan
City Manager

JLS/b

(10) 56

COMMUNICATION

from the City Manager transmitting ~~one from~~

material received from Professor David Wilson as it relates to matters discussed by him upon the occasion of the inspection of the City Dump on February 14, 1970.

February 23, 1970

2/23/70
Referred to the
City Mgr -
2 Reports Requested