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A State-of-the-Art Report on Systems Incorporating Highway Transportation

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This state-of-the-art report on highway transportation systems for solid waste traces their historical development in the United States, economic justification for their use, basic design and location considerations, and basic cost criteria for constructing, owning, and operating. The report deals only with truck-to-truck transfer systems--i.e., from route-collection vehicles to large-capacity transfer vehicles. Basically, two categories of these transfer systems are discussed: direct-dump and compaction. An extensive bibliography and specific appendixes are included.

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SOLID WASTE TRANSFER STATIONS

A State-of-the-Art Report on Systems Incorporating Highway Transportation

This report (SW-99) was written by TOBIAS A. HEGDAHL

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PREFACE

The rapid urbanization of the United States--71 percent of the Nation's 203 million people today are concentrated in urban areas--has perpetrated a crisis in locating suitable and unobjectionable sanitary landfill disposal sites. By the year 2000, 85 percent of a maximum estimated 320 million population will be concentrated in a few megalopoles. Even now, in terms of amounts of wastes generated and spatial concentration, cities are troubled most by disposal problems. Public officials in many of these communities are grappling with the same antithesis: the most accessible open acreage around the city is already consumed while the demand for disposal sites accelerates. So the sites are being located farther and farther from the urban area. Collection vehicles are forced to haul longer distances, and solid waste handling costs, that already must vie for the public dollar, rise.

The concept of transferring waste from many route-collection vehicles to large-capacity transfer vehicles can afford one solution to this increasingly intractable problem. This transfer of solid waste to large-payload haulers, to conserve the travel time of the whole collection vehicle force, is not a new practice. The transfer station itself is basically very simple, but it can be designed to incorporate several different types of transfer systems. And as its use has become more prevalent, particularly in the last decade, manufacturers have developed specialized equipment to meet the demand.

This report is devoted largely to a discussion of the design, operation, and economics of truck-to-truck transfer systems currently in use in the United States. The drop-box, or roll-on/roll-off type container transfer system, although a popular and effective method used by many industries, institutions, and smaller communities, has been excluded, because it has not yet been employed in a central transfer operation that serves as an unloading point for route collection vehicles.

The existing technology described here should be considered discerningly in solving local solid waste problems. The implicit question is this: Will use of a transfer station, as an intermediate handling step, represent an overall collection-transportation cost savings? No general rule of thumb can be formulated to determine this; no two areas are the same. Although basic economic criteria upon which to base the need for a transfer operation are presented, the numbers used in any specific analysis must be derived from a study of local conditions and variables.

Beyond the "short haul" transfer systems described, transfer modes for longer distances are gaining impetus as urban entities look to even more remote localities. A few communities have been transferring waste via barges, and the use of railroads has been under consideration for several years. Rail transfer operations undoubtedly will be employed if contract and political barriers can be overcome. As part of its interest in technology application in this area, the Office of Solid Waste Management Programs is seeking now to initiate a rail-haul demonstration project.

We hope that this information on current trends in solid waste transfer, compiled by the Office of Solid Waste Management Programs into a single source, will be helpful.

--Clyde J. Dial, *Director*
Systems Management Division
Office of Solid Waste Management Programs

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CHAPTER I

DEVELOPMENT IN THE UNITED STATES

Historical Review

The basic concept of transferring solid waste from a relatively small payload route-collection vehicle to a bulk hauler has been practiced for several decades. Reducing the travel distance of several collection vehicles by replacing them with one large payload vehicle going to the disposal site offers savings (Figures 1 and 2). The savings, however, must recover the cost of owning and operating the transfer station and transfer vehicles. The economics will be discussed later in this chapter.

New York City started a system of barge transfer in the 1930's, and Chicago utilized rail transfer to some extent during the 1930's and 1940's. Truck transfer systems began emerging on a significant scale in the 1950's and have developed into the major haul medium. The only significant barge transfer system currently in operation is in New York City where nine installations have been established between 1937 and 1965. Rail transfer is not utilized to any significant extent, but is receiving a great deal of study and consideration. With the tremendous volumes of solid waste concentrated in our urban areas, extensive rail haul may soon become a reality as contract, routing, disposal site, materials handling, and location difficulties are overcome. Indeed,

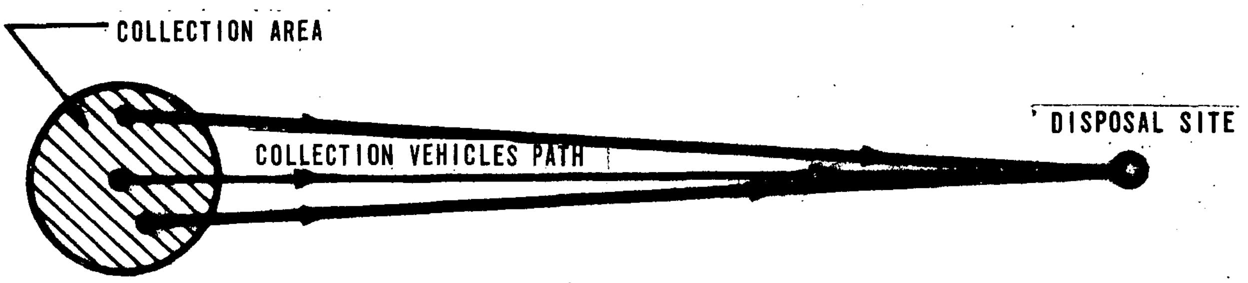

Figure 1. Direct haul to the disposal site by each collection vehicle may result in large hauling costs if a considerable distance is involved.

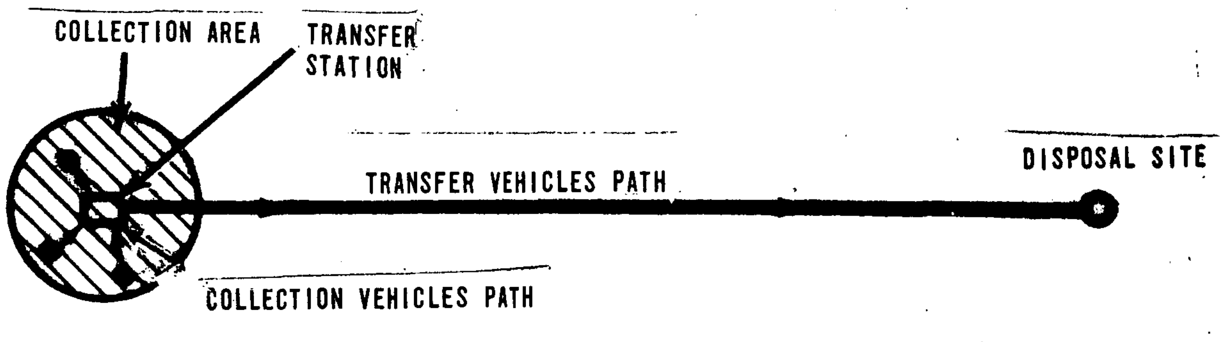

Figure 2. When the contents of several collection trucks are transferred to one large transfer vehicle, significant haul cost savings may result.

as the location of available disposal sites become increasingly distant, only the tremendous bulk hauling capabilities of a rail system appear economically feasible.

The location of disposal sites became an acute problem in the 1960's not only in the largest urban areas but in many intermediate and smaller-size cities. As a result there was a tenfold increase in the number of transfer stations over the previous decade as transfer became a necessary economic alternative to direct haul to distant disposal sites. To meet the increased demand, specialized highway bulk transport vehicles have been designed along with processing equipment to maximize payloads within legal highway weight restrictions. The efficiency of a transfer station depends largely on the speed with which transfer vehicles are loaded and unloaded. The city of Chicago pioneered the development of the large-capacity, van-type transfer trailers, but encountered difficulty in the unloading operation. Finally a decision was made to employ an endless belt type of moving floor unloader, but even this proved somewhat inefficient. Since the early 1950's when this system was used, many manufacturers have capitalized on the vast increase in demand and have developed trailers with telescoping hydraulic cylinders that move bulkheads from front to rear for rapid unloading. Various other unloading systems designed by operating authorities have also been developed for specialized use. More detailed equipment descriptions will be given later.

Transfer Station Locations

An inventory of nearly all the solid waste transfer stations in the United States as of 1971 was made with the aid of the states, equipment manufacturers, and the 1968 National Survey of Community Solid Waste Practices. A list of the locations, their ownership, miles to disposal site and annual tonnage are given in Appendix A. A few small installations may have been overlooked, but each location listed represents a facility that serves as a central transfer point utilizing a truck and trailer system (Figure 3). The fact that over 75 percent of the transfer stations have been placed in operation since 1965, clearly illustrates their relatively recent popularity (Figure 4).

Transfer stations have been employed in many large cities for a number of years and several areas have incorporated them as an integral part of their long-range plans. In some cases operating authorities have developed specialized equipment for processing and hauling. In recent years emphasis has been placed on the regional approach to solid waste management, and in some areas this has resulted in the construction of central transfer stations that haul to large regional landfill sites. The use of systems of this type will undoubtedly increase as the economy, efficiency and effectiveness of the regional approach is realized.

The potential savings in transfer station utilization has unfortunately misled some municipal officials. In attempting to justify a transfer station through the use of a rule of thumb for breakeven haul distance, some communities have constructed transfer facilities that

Figure 3. The solid waste transfer stations as of 1971 are located as indicated on the map.

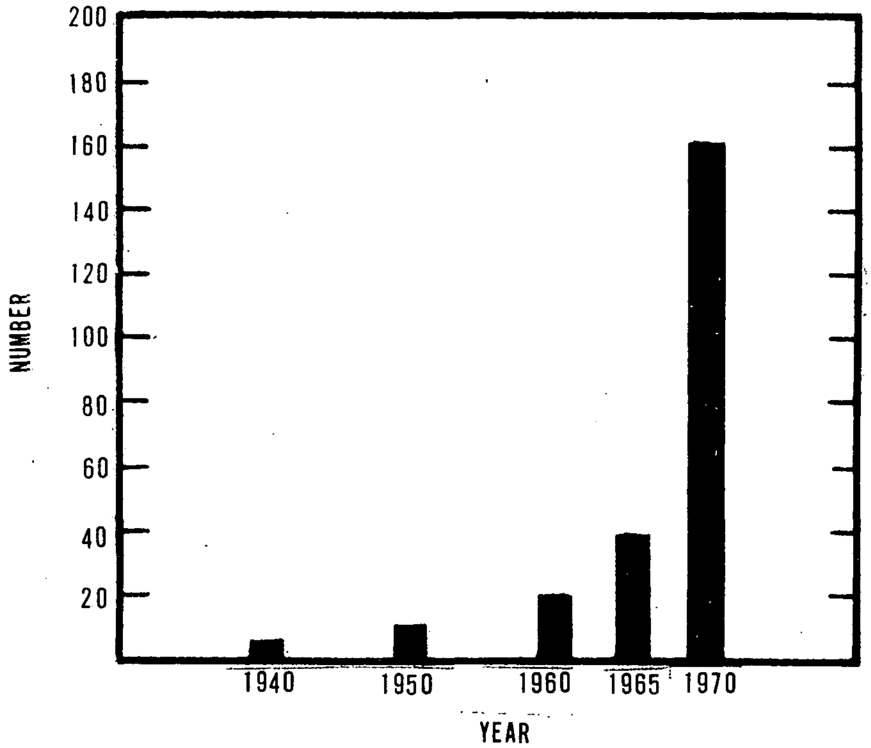

Figure 4. Over 75 percent of the transfer stations have been placed in operation since 1965

are unnecessary and even more costly than direct haul. City officials, beset by many other problems, and with insufficient time for necessary study, have been persuaded to construct a transfer station as a method of reducing costs in their rapidly increasing solid waste budget. In some cases transfer stations have been constructed without the location of disposal sites being firmly fixed, or at least not determined for more than a few years in the future. Careful planning for long range future needs is a must when capital expenditures for transfer stations are under consideration.

Economic Justification

The utilization of a transfer station can only be justified by the total cost reduction and convenience it offers to a given service area. These potential savings must relate directly to the needs within a service area whether the transfer station is intended to serve only the collection vehicle fleet of a municipality or to serve the general public on a free or user-fee basis. A transfer station will lower neither the door-to-door collection cost nor the disposal cost. Savings are realized only by reducing the haul distance from the collection zone to the unloading area. Because collection trucks travel only short distances to unload at a transfer station, they can be back on their routes while a transfer vehicle containing several collection truck loads is traveling to a distant disposal site.

Although a transfer operation offers potential savings it requires an extra materials-handling step and the construction of a transfer facility. The associated costs must be recovered or money will be lost in the transfer operation. The costs that are incurred are as follows:

(1) the capital expenditures for land, structures, and equipment;

(2) the labor, utilities, maintenance, operating, and overhead costs at the transfer plant;

(3) the labor, operating, maintenance and overhead costs incurred in the bulk hauling operation.

Costs are saved with the utilization of a transfer operation because:

(1) the non-productive labor time is cut since collectors no longer ride to and from the disposal site; therefore, the larger the collection crew the greater the savings;

(2) any reduction in mileage traveled by the collection trucks results in a savings in operating costs and in addition, it may be possible to reduce the number of collection crews needed because of increased productive collection time.

Anyone considering a transfer operation must therefore determine if the savings will exceed the costs. The primary variable is the distance to the disposal site. Attempting to apply a rule of thumb (i.e., a 10-mile haul distance justifies transfer) to this determination is unrealistic and mere guesswork unless a study is made of local conditions. A decisive distance in one area may be totally misleading in another. Factors such as wage rates, type of access roads, collection truck capacity, and size of collection crews (i.e., one man, two men, etc.) change the breakeven distance considerably.

Although distance to the disposal site is important in comparing direct haul with transfer and haul, a more realistic criteria is the time necessary to travel the distance. Variables such as routes taken, traffic conditions and speed limits could result in a time of 15 minutes to cover a 10 mile distance in one area and an hour in another area. Also the major item in total haul cost is labor which is directly related to time and not distance. For these reasons the usual cost per ton per mile unit of comparison will be replaced by the more realistic unit of cost per ton per minute in the following analysis.[1]

To determine whether a transfer system is economically feasible, it should be compared with direct haul. Such a comparison requires realistic data applicable to the particular service area in question. If a contractor or municipality has accurate figures for the hourly cost of owning and operating their collection trucks, this information can be utilized, and the detailed analysis that follows for determining hourly costs is not necessary. If, however, these costs are not available, the appropriate figures should be substituted into the example that follows. Costs applicable to a private collection contractor such as taxes, licenses, and insurance may not be applicable to a municipality, and should be deleted from the analysis.

Assume that a collection agency uses trucks that average five tons per load, that the crew consists of one driver and two collectors, and that all three men ride to the disposal site located 20 miles from a transfer station site under consideration. The haul cost analysis for the collection truck will be presented first followed by that for a transfer system. After the necessary figures from these analyses are obtained, a graphical comparison between direct haul and transfer and haul will be presented.

TABLE 1

CAPITAL COSTS OF COLLECTION TRUCK

Item	Cost ($)
Compactor truck (diesel)	$15,000
Tires:	
Rear: 4 @ $110.00	440
Front: 2 @ $110.00	220
Total	660
Truck cost less tires	$14,340

The capital costs for the collection truck, less tires, is $14,340 (Table 1). Annual owning and operating costs can conveniently be broken into those incurred on a time basis and those incurred on a usage basis.[2] Costs incurred on a time basis are depreciation, labor, insurance, licenses, and taxes (Table 2). Cost incurred because of usage are gas, oil, tires, repair, and maintenance (Table 3).

TABLE 2

ANNUAL TIME COST OF COLLECTION TRUCK

Item	Cost ($)
Depreciation on truck, less tires, over 6 years (straight line)	$ 2,390
Driver's salary	8,400
Collectors' salaries 2 @ $7200.00	14,400
Fringe benefits @ 25 percent of salaries	5,700
Interest on truck investment less tires @ 6%	860
Taxes and licenses	500
Insurance	500
Total annual time cost	$32,750

The cost per minute assuming 260 working days per year and 8 hours per day is:

$$\frac{\$32,750}{260 \text{ days} \times 8 \text{ hours} \times 60 \text{ minutes}} = \$0.260/\text{minute}$$

TABLE 3

USAGE COST PER MILE FOR COLLECTION TRUCK

Item	Cost ($/mile)
Fuel @ $0.20 per gallon and 4 miles per gallon	$0.0500
Oil @ $1.50 per gallon and 5,000 miles per gallon	0.0003
Tires:	
Rear: 4 @ 20,000 miles	0.0220
Front: 2 @ 30,000 miles	0.0073
Repair and maintenance	0.0500
Total	0.130

The transfer station site under consideration has been assumed to be located 20 miles from the disposal point, and it should be located centrally to the area it is intended to service. Although some collection trucks would have to travel less than 20 miles from their service area to the disposal point, others would have to travel more than 20 miles. An overall average distance of 20 miles will be assumed.

Both a time factor and a usage factor are available to analyze the round trip of a collection truck from the transfer station site to the disposal point. In the case of the collection vehicle only the actual driving time is included in the cost analysis. The unloading time is not considered because this step is always required regardless of whether the truck unloads at the transfer station or at the disposal point. With the transfer vehicle, however, the extra materials-handling time involved in loading and unloading must be considered. This will be discussed in more detail later. For this example assume that the actual driving time required for the 40-mile round trip is one hour. In a specific case this time can be determined by actually timing the vehicles. The time cost was previously determined to be $0.260 per minute. Ultimately the unit of cost per ton per minute is required so the usage cost must also be converted from a per-mile to a per-minute basis. The total usage cost involved in the 40-mile trip is: $0.13 per mile X 40 miles = $5.20. Since the trip requires one hour of driving time the per-minute usage cost is: $5.20 ÷ 60 min = $0.087 per min. The total cost per minute for the collection truck is the summation of time and usage costs which is $0.260 per min + $0.087 per min = $0.347 per min.

This figure is for a driver and two collectors riding to the disposal site. Identical calculations can be made for the driver and just one collector, and for the driver only by simply deleting their labor cost from the total time cost; usage cost will not change. The total costs become $0.276 per minute and $0.204 per minute, respectively. Labor therefore represents a substantial portion of transportation cost.

These cost per minute figures can easily be converted to the desired cost per ton per minute units by dividing them by the average payload of the truck which is assumed to be five tons (Table 4).

TABLE 4

FIVE-TON PAYLOAD COLLECTION TRUCK-UNIT HAUL COSTS

Crew Size	Cost ($/ton/min)
Driver only	0.041
Driver and one collector	0.055
Driver and two collectors	0.069

An identical procedure is used to calculate the cost per ton per minute for transfer vehicle haul. Assume that a 75-cu yd tandem axle trailer is pulled by a tandem axle diesel tractor and that a 20-ton payload can be carried. The capital cost, less tires, would total $34,520 (Table 5) and the annual time costs total $22,130 (Table 6). The usage cost per mile for the transfer vehicle is $0.196 (Table 7).

TABLE 5

CAPITAL COSTS OF TRANSFER VEHICLE

Item	Cost ($)
Transfer tractor (diesel)	$16,500
Transfer trailer (75 cu yd)	20,000
Tires:	
Tractor - 8 rear tires @ $110.00	880
2 front tires @ $110.00	220
Trailer - 8 @ $110.00	880
Total tire cost	1,980
Transfer vehicle cost less tires	$34,520

TABLE 6

ANNUAL TIME COSTS OF TRANSFER VEHICLE

Item	Cost ($)
Depreciation on tractor less tires over six years (straight line)	$2,570
Depreciation on trailer less tires over six years	3,190
Drivers salary	9,600
Fringe benefits @ 25 percent of salary	2,400
Interest on transfer vehicle investment less tires @ 6%	2,070
Taxes and licenses	800
Insurance	1,500
Total annual time cost	$22,130

The cost per minute assuming 260 days per year and 8 hours per day is:

$$\frac{\$22,130}{260 \text{ days} \times 8 \text{ hours} \times 60 \text{ minutes}} = \$0.177/\text{min}$$

TABLE 7

USAGE COST PER MILE FOR TRANSFER VEHICLE

Item	Cost ($/mile)
Fuel @ $0.20 per gallon and 4 miles per gallon	$0.0500
Oil @ $1.50 per gallon and 5000 miles per gallon	0.0003
Tires:	
Tractor - 8 rear tires @ 20,000 miles	0.0440
2 front tires @ 30,000 miles	0.0073
Trailer - 8 tires @ 20,000 miles	0.0440
Repair and Maintenance	0.0500
Total usage cost per mile	$0.196

A time factor and usage factor are now available for the analysis of the transfer vehicles 40-mile round trip to the disposal site. As mentioned previously, however, the time for a complete cycle of events including loading, travel time and unloading must be included because the transfer operation requires extra materials-handling steps. During the actual travel time, both time and usage costs will be incurred but during the loading and unloading time only time costs are involved.

Because the transfer vehicle is less maneuverable than the lighter collection vehicle assume the round-trip driving time is 1.25 hours but that each transfer vehicle and driver make four trips per day or that each complete cycle requires two hours. Therefore, each round trip requires 45 minutes (2.00 hr - 1.25 hr) of unproductive time in loading and unloading. The cost of this unproductive time is \$0.177 per min X 45 min = \$7.97. For the 20-ton payload the cost per ton is \$7.97 ÷ 20 tons = \$0.40 per ton. This cost will be plotted at zero travel time in the graphical cost comparison presented later. For the 1.25 hours (75 minutes) of driving time both time and usage costs are incurred. The time cost equals \$0.177 per minute. The usage cost must be converted to a per minute basis:

$$\frac{\$0.196/\text{mile} \times 40 \text{ miles}}{75 \text{ min}} = \$0.105/\text{min}$$

The total cost per minute while traveling is therefore:

$$\$0.177/\text{min} + \$0.105/\text{min} = \$0.282/\text{min}$$

This cost is simply divided by the 20 ton payload to get the desired cost per ton per minute:

$$\frac{\$0.287}{20 \text{ tons}} = \$0.014 \text{ per ton per minute.}$$

A transfer operation involves not only haul costs but the costs involved in owning and operating the transfer station. This cost includes all depreciation of buildings and equipment, labor, utilities, repair and maintenance, overhead and operating expenses of equipment kept permanently at the station. In this example, instead of attempting to determine the cost based on a hypothetical installation, a figure of \$1.50 per ton will be used. This is representative of what is experienced in typical transfer stations in the United States.

A graphical comparison between direct haul and transfer and haul can now be made (Figure 5). The slope of each haul cost line is equal to the cost-per-ton-per-minute figure determined for each case. For the transfer and haul operation, the unproductive costs of owning and operating the transfer station plus the unproductive costs of loading and unloading the transfer vehicles must be included. These costs ($1.50 + $0.40 = $1.90 per ton) are plotted at zero travel time in Figure 5. It should be emphasized that the abscissa of Figure 5 is the actual travel time involved and not the total-round trip time. The points where the collection vehicle lines intersect the transfer and haul lines are the breakeven points for each crew size. For the three-man collection truck, transfer becomes justifiable at round-trip travel times of over 35 minutes and with one and two man trucks at 71 and 46 minutes, respectively.

Transfer Station Systems and Equipment

The trend toward solid waste transfer has led to the development of equipment specifically suited to the need. Early transfer station operations relied completely on equipment built by various manufacturers to specifications of the operating authority. In the 1960's, however, as the popularity of transfer increased rapidly, solid waste equipment manufacturers developed specialized processing and haul equipment. At the present time those interested in a transfer operation have the option of either designing their own system and writing specifications for desired equipment or of buying specialized equipment from the manufacturers and designing the system around it.

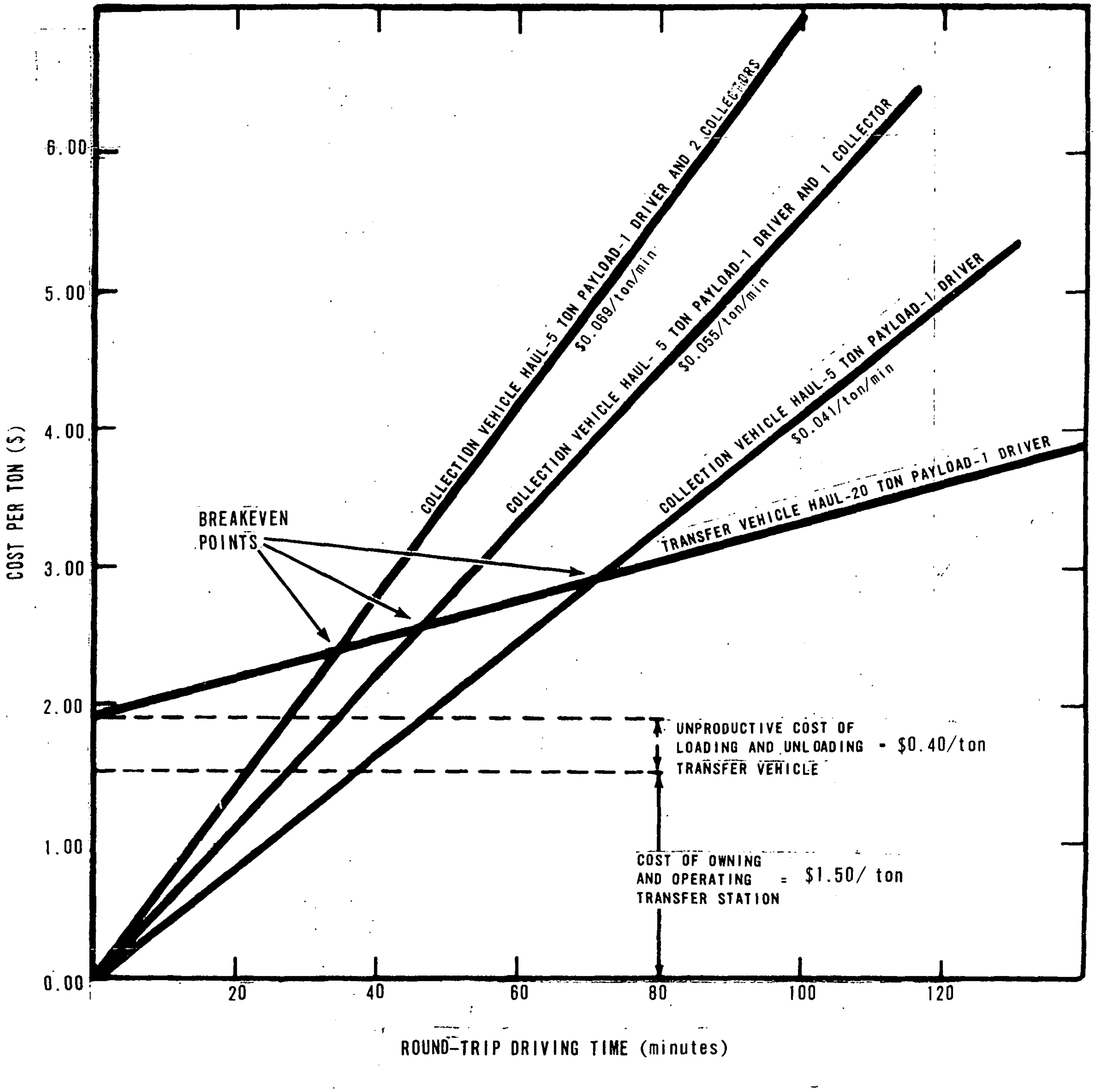

Figure 5. The round-trip driving time at which transfer and haul becomes justifiable is shown by the breakeven point for each crew size.

Two basic types of transfer systems have developed as a result of this option. The first is the basic direct-dump system where a collection truck dumps by gravity into a large open-top trailer. The trailer is located under a funnel shaped hopper to prevent spillage and a backhoe is usually used to compact and distribute the load after it has been placed in the trailer (Figure 6). An offshoot of this system utilizes a dumping pit where a crawler tractor crushes and compacts the waste before pushing it into the trailer via the hopper (Figure 7). Because of the densities achieved with the compaction tractors, a backhoe is usually required for load distribution only. The compaction pit system is used primarily in high-volume transfer stations because of the expense of incorporating the extra equipment whereas the basic direct dump system has been used in both small and large installations. All direct dump systems are characterized by the fact that open-top trailers are used and the equipment employed is usually not specifically predesigned for solid waste transfer. Some type of cable system is usually employed to pull the loads out of the rear of the trailer at the disposal site. The specifications for hoppers, trailers, and any other desired equipment are written and bids are let to various manufacturers.

The second basic transfer system utilizes hydraulic pressure to achieve horizontal compaction of the waste within the trailer. Two methods have been used to achieve compaction but both are characterized by the use of enclosed reinforced steel trailers specifically manufactured for solid waste transfer (Figure 8). The first compaction method

Figure 6. A direct-dump transfer station in which a backhoe is used to compact and distribute the load.

Figure 7. In a compaction pit transfer system a backhoe is used to compact the waste before it is pushed into a transfer trailer.

Figure 8. Enclosed reinforced steel trailers are utilized in horizontal compaction transfer systems.

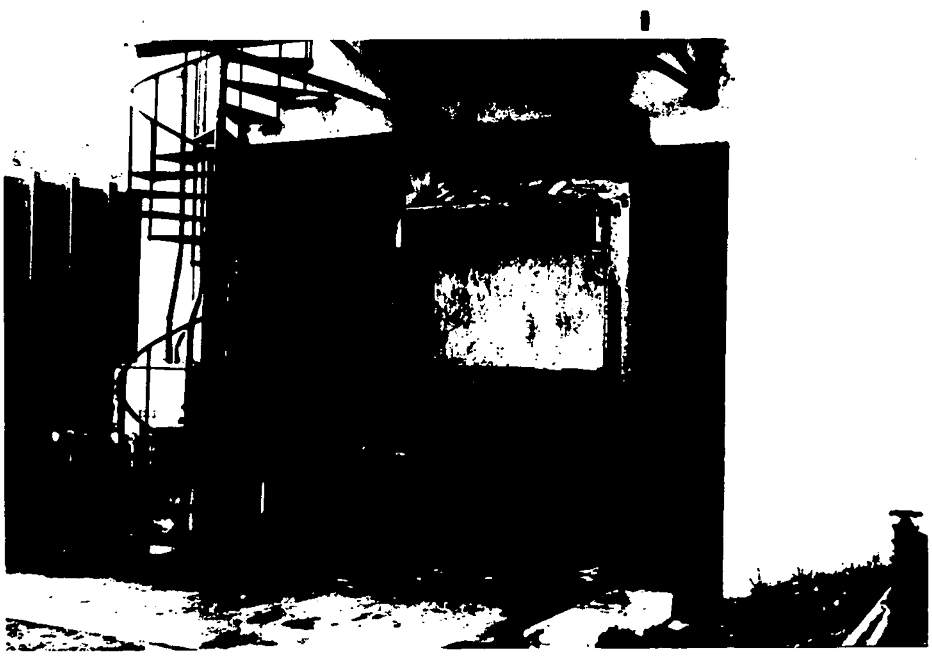

Figure 9. In some transfer systems stationary compactors are used for loading and compacting waste into the rear of a transfer trailer.

is partially a direct-dump operation in that waste is dumped directly into the trailer near the front. A hydraulic-powered bulkhead traverses the length of the trailer and compacts the waste against the rear doors. The entire compaction process is self-contained within the trailer body and the bulkhead also pushes the load through the rear doors at the disposal site. The second compaction method involves the use of a stationary compactor (Figure 9). The transfer vehicle is backed up and securely fastened to the compactor. Waste is fed by gravity into the compactor chamber from an overhead hopper located above. The compaction ram forces the waste forward through the rear doors of the trailer in horizontal reciprocating cycles. This trailer is also equipped with a hydraulic-powered bulkhead which traverses the length of the trailer for unloading at the disposal site. Either compaction method can easily produce maximum legal payloads. A list of the major manufacturers of transfer station equipment is given in Appendix B. This list includes only major manufacturers of total package, transfer-station equipment systems.

Either of the two basic transfer systems may be equipped with storage provisions if they are needed to prevent queuing problems with incoming vehicles during peak delivery periods. Some systems are more adaptable to the incorporation of storage than others. If the compaction pit direct-dump system is employed, a large storage area can be made available in the pit much the same as in incinerator operations. Direct dumping from one vehicle to another requires many dumping hoppers and trailers to accommodate heavy incoming traffic flow unless waste is stockpiled in the unloading area and later pushed into the hoppers with a front end loader. In compactor systems, front-end-loaders, conveyors, crane buckets, and specially designed hydraulic push-pits can be utilized to charge the compactors from a floor or pit storage area.

Any transfer system can be an enclosed or nonenclosed operation. A nonenclosed or open-air transfer station is cheaper to construct, of course, but aesthetic and public health problems will probably result unless the facility is well hidden or isolated. Open-air installations are used primarily in dry, year-round warm climates or in small direct dump operations. In many areas solid waste transfer operations are housed in very aesthetically designed structures resulting in very little neighborhood opposition and few citizens complaints.

One method of transfer not investigated as part of this study that has had application in reducing costs in rural areas, apartment complexes, commercial establishments, industries, and recreational areas is the drop box, the roll-on/roll-off, and the lift-on/lift-off container. In this system the full container is replaced with an empty one and then carried to the disposal site. These systems can be used in connection with compaction devices to achieve large payloads. Some manufacturers are conducting research of this system in connection with a large municipal transfer station as an alternative to the use of transfer trailers. One manufacturer is marketing a mobile transfer system. Solid waste picked up on the collection route is compacted into a seven cu-yd detachable container by a hydraulic apparatus on a small truck. This truck drops a full container off at a transfer yard, picks up an empty one, and then proceeds back to the collection route. The full containers are later picked up and emptied into a large compactor truck which hauls the solid waste to the disposal site.

Operation and Management

A transfer station may be designed to serve only as part of the collection system of a contractor or city or in addition to serve as a convenient solid waste unloading site for the general public. As the number and types of incoming vehicles increase, both the initial construction costs and the station operating costs rise. If only large packer trucks use a transfer station, less processing is required to produce legal payloads and less traffic congestion is encountered. On the other hand, if the general public has access to the site, much of the incoming waste will be uncompacted, additional unloading space must be provided, and more traffic flow regulation is required.

The simplest and most economical transfer operation is therefore one that has the sole purpose of providing haul cost savings to a fleet of contractor or city-owned collection trucks. Waste inputs are relatively predictable and record keeping is simple. Weighing of incoming vehicles may not be required if the outgoing transfer vehicles are weighed. The utilization of an inexpensive direct-dump system may be desirable because of the precompacted nature of the incoming waste.

A transfer station which is open to the general public is usually financed either by a system of user-fees or from some type of general fund. To break even with a user-fee system, the charge at the transfer station must cover both the cost of transfer and disposal. It must, therefore, be cheaper for the prospective user to pay the transfer fee than to haul directly and pay only the disposal fee. The cost per ton for a user-fee-financed transfer system will be higher because of necessary weighing and billing expenses. A transfer system financed from a general fund will be subjected to a heavy incoming traffic flow because no direct charges are made. This type of operation is often used in an effort to reduce indiscriminate dumping within the area.

In a transfer station utilized by only a fleet of city or private collection trucks, the hours per day and days per week of station operation are set to meet the needs of the collection schedule. Open access transfer stations, however, are sometimes operated a specified period of time, seven days per week for the convenience of customers. If storage is available, dumping may be permitted 24 hours a day with the transfer vehicles operating during a single daytime shift. To avoid excessive overtime costs, most transfer operations, operating six or seven days a week, utilize a rotating shift labor scheduling procedure.

In summary, transfer station design should not be attempted until a determination is made of who will use the facility and how the operation will be financed. Plant layout and the type of transfer system to be utilized are largely dictated by the type of incoming vehicles.

CHAPTER II

DESIGN AND LOCATION CONSIDERATIONS

A detailed economic analysis of transfer station feasibility cannot be made until a transfer system suited to the particular area is decided upon. Major design decisions concerning buildings, processing equipment and haul equipment for systems basically equivalent may have to be determined at the discretion and personal preference of the deciding authority. Basic criteria upon which to analyze different systems should not, however, be ignored. Primary considerations related to site selection are: (1) traffic accessibility; (2) type of neighborhood (zoning); (3) proximity to collection routes; (4) proximity to disposal site. Basic considerations related to the transfer system are: (1) volume handled; (2) haul vehicle restrictions; (3) type of wastes handled; (4) types of incoming vehicles; (5) processing equipment; (6) peak load allowances - storage; (7) traffic patterns.

Site Selection

Ideally a transfer station should be located so that costs are minimized in the tradeoff between the travel time of the route-collection vehicle to the transfer point and the travel time of the transfer vehicle to the disposal site. This may result in the need for several transfer stations within a service area. Operations research techniques have been used to develop mathematical optimization models for the number and location of transfer stations. In Mathematical Analysis of Solid Waste Collection by Marks and Liebman of Johns Hopkins University, one such example of this type of work is presented.[3]

A limited number of sites will usually be available, however, and often the acquisition of even one site may be difficult due to the reputation of "garbage" being a bad neighbor. If several sites are obtainable, the choice may be obvious because of proximity to waste-generation areas and uncongested streets and freeways.

The type of neighborhood can have a large influence on the cost of a transfer station. A residential section may be the ideal location from a waste concentration standpoint but considerable initial opposition by residents of the area should be expected. To be aesthetically acceptable, large capital costs in structures and landscaping may be necessary. If a residential location provides obvious advantages and neighborhood opposition is overcome, it is imperative to maintain a "good neighbor" standing. This usually requires that all waste be removed from the site at the end of each working day, and that the site be kept free of litter and well maintained.

It may prove advantageous to locate in an industrially or commercially zoned area even though a greater haul distance is involved. This will probably result in fewer citizen complaints, a smaller investment in buildings and landscaping, and fewer problems with access streets. This does not mean sloppy operations will be condoned, but in these areas the operation is less likely to be visible to the public.

Of prime importance in site location is accessibility to streets, highways, or freeways where fast moving traffic flows freely. Time savings resulting from the use of rapid moving access routes may easily offset additional distances resulting in usage of such routes. Indeed, an authority may be well ahead if efforts are initially made to start looking for a site in a centrally located industrially or commercially zoned area near existing primary roads.

Again, every area must deal with its own set of conditions concerning waste generation areas, zoning and access routes, but thorough consideration should be given to the above-mentioned points before commitment to a site location is made. Easy inflow and outflow of traffic combined with a location as near as possible to waste generation areas are of primary importance.

Design Considerations

Once a site has been selected a basic transfer system must be determined. A structure that is aesthetically acceptable to the surrounding neighborhood can then be chosen to house the operation. The following detailed discussion elaborates on the various considerations involved in building design, plant layout, and system selection. The basic systems briefly described in the previous chapter will be discussed in detail along with the advantages and disadvantages of each.

Building Design. Buildings for housing transfer stations range from none at all (open-air) to large concrete and steel structures that are very pleasing in appearance. An open-air transfer station works well only in a dry climate with year-round warm weather. In some areas, however, small transfer stations that employ a direct-dump system often utilize only a small shelter over the unloading area (Figure 10) or in some cases not at all (Figure 11). Unless open-air transfer stations are well hidden or in remote areas, such as one example located in Southern California (Figure 12), they often create aesthetic problems. These stations are also faced with wind problems and require constant policing to keep litter from accumulating. In many cases, operators of open-air transfer stations have converted to an enclosed operation or strongly recommend that only enclosed installations be considered in rainy or windy climates.

Conventional sheet metal, concrete, or brick construction is used in the majority of transfer station buildings (Figures 13-15). Any type of transfer system (direct-dump or compactor types) can be housed in any of the building enclosures above. Sheet metal buildings are usually cheaper to construct per square foot of space and can be erected the fastest; they may not, however, be as architecturally attractive as some concrete buildings. As mentioned earlier, the landscaping and architectural requirements will usually become greater, the closer the transfer station is to residential areas.

Transfer station buildings are usually equipped with water sprays and/or ventilation fans for dust control and enclosed with chain link fence to control litter and access. Buildings should also contain rest rooms and an office for communication and record keeping purposes. The foundation requirements and physical dimensions of the building cannot be determined until the plant capacity, layout, and type of

Figure 10. Small direct-dump transfer stations are sometimes constructed with only a small shelter covering the unloading area.

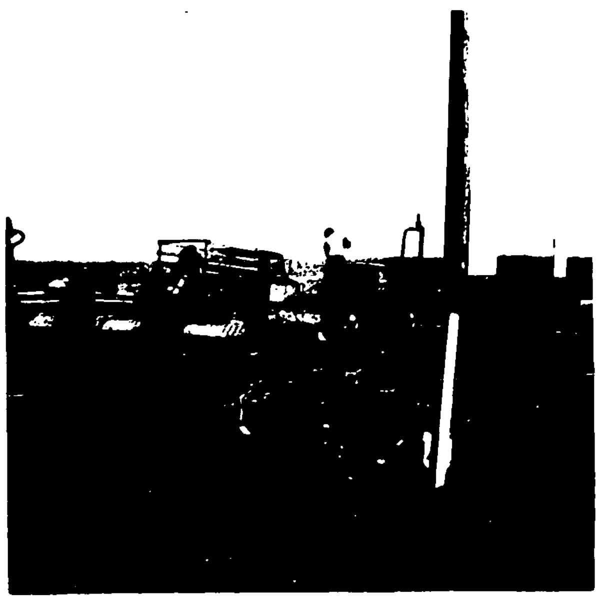

Figure 11. Although open-air, direct-dump transfer stations are usually aesthetically objectionable, they are sometimes used in small-volume operations.

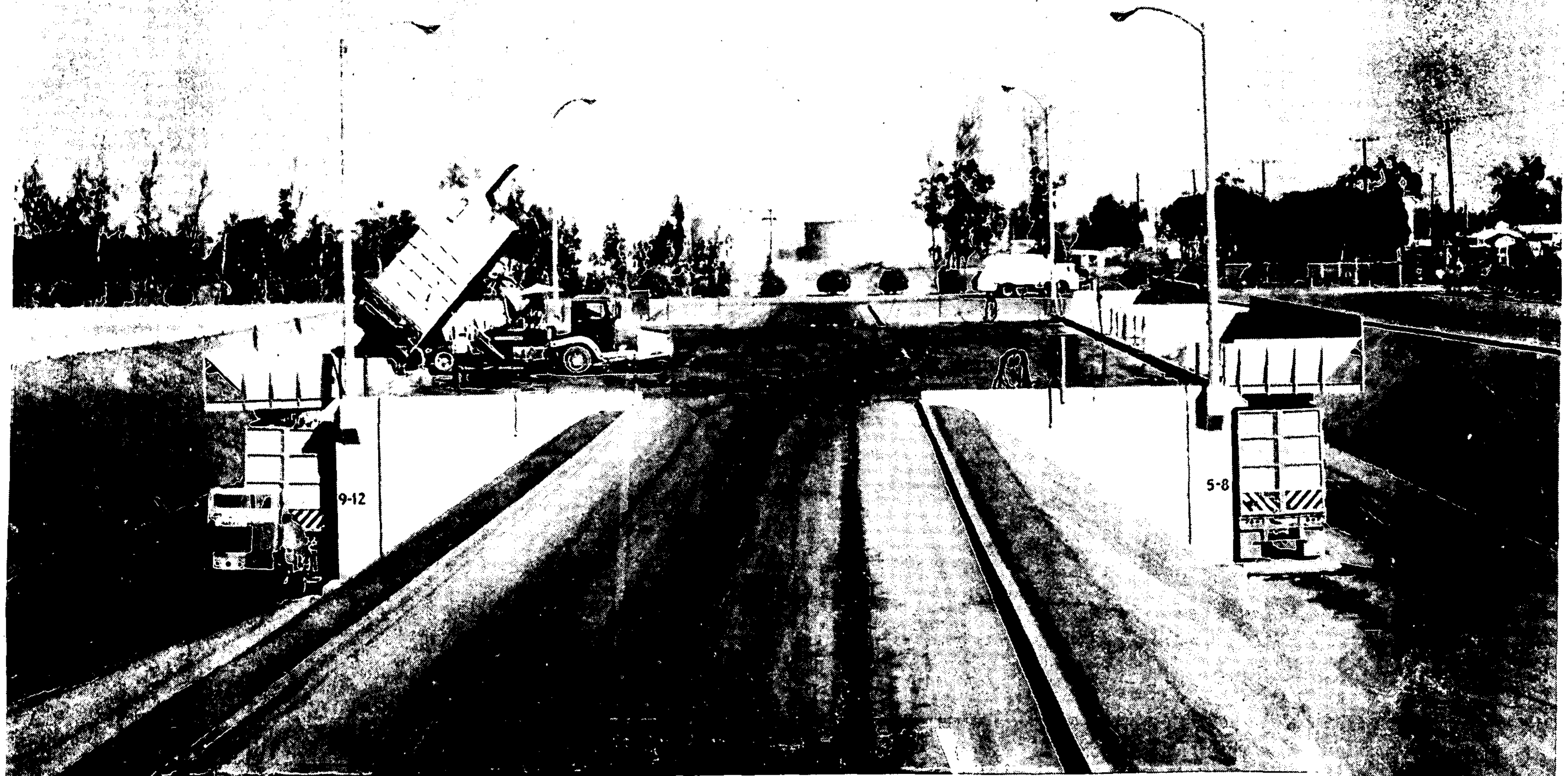

Figure 12. An open-air, direct-dump transfer station may be aesthetically acceptable when the operation is well hidden by careful landscaping.

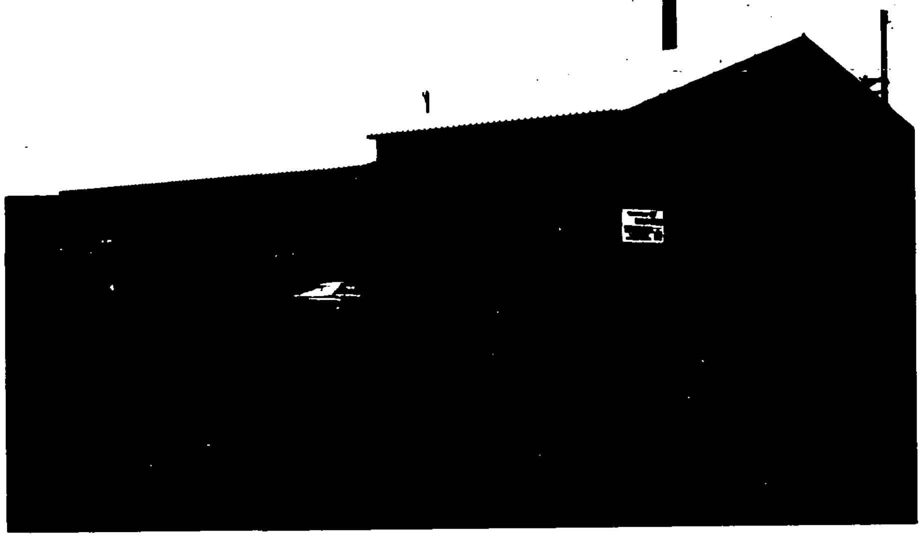

Figure 13. Sheet metal structures are often used to house transfer station operations.

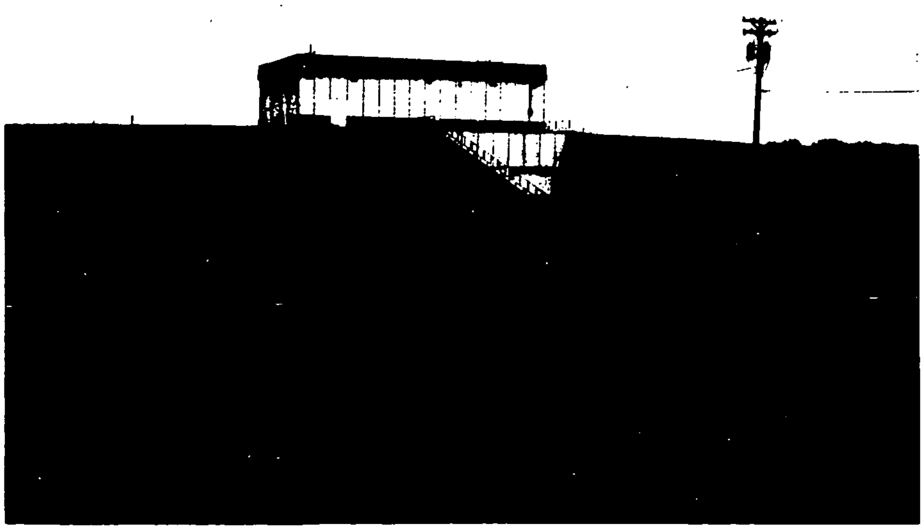

Figure 14. Transfer stations of concrete construction present a very pleasing appearance.

Figure 15. Brick structures are occasionally used to house transfer station operations.

transfer system are determined. Keep in mind, however, that considerable expense beyond that for the buildings proper is usually required in the form of excavation, access roads, utility provisions, fencing, and landscaping.

The transfer station should be equipped with a scale to weigh incoming vehicles especially if user-fees are levied. Estimation of fees on a volume basis can prove very inequitable. Accurate tonnage figures also provide valuable information needed for future planning. In addition, a record of incoming loads permits close estimates on outgoing transfer vehicle loads so legal highway weight restrictions are not exceeded. Of course, this estimate is not necessary if outgoing loads are weighed. Several large-volume transfer stations incorporate scales in the transfer vehicle loading platform so a continuous weight readout is available as the trailers fill up. In this way maximum payloads are always achieved without risking costly fines for overweight conditions. The expense of utilizing these scales, however, is seldom justified in low-volume operations so estimates are necessary.

The scale must be capable of handling the largest incoming trucks anticipated and a scale house should be provided for the scalemaster and his records (Figure 16). If user-fees are charged, considerable time can be saved by equipping the scale with a printer and calculator for determining fees (Figure 17). In some large transfer stations the scale is coordinated with a computer system so all weight data are received instantly at a central data processing point for record keeping and billing purposes.

Figure 16. When scales are utilized, a scale house should be provided for the scalemaster and his records.

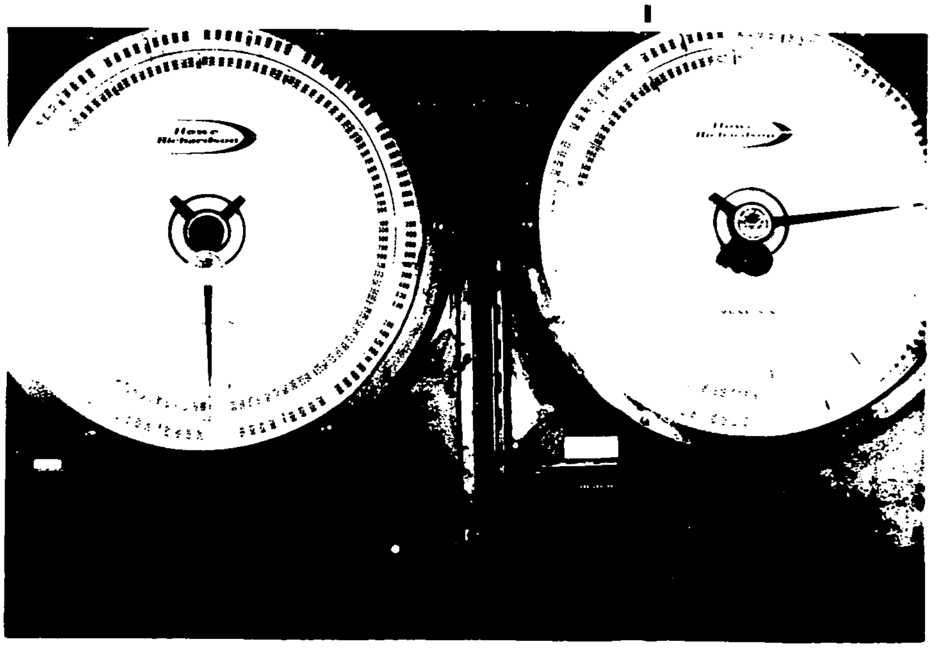

Figure 17. Scales incorporating a printer and calculator can speed up the weighing operations considerably.

Sanitation must be considered an integral part of any transfer station operation. Besides creating public health hazards, unsanitary conditions will quickly result in the loss of badly needed public support. Operations must be kept free of litter and transfer vehicles must be adequately covered during travel to the disposal site. High pressure hoses should be available at the transfer station for frequent washdown of storage areas, solid waste handling equipment, and transfer vehicles. A vehicle washing center has been incorporated into the design of some transfer stations. Frequent washdown of vehicles is a routine part of the haul operation and adds immeasurably to the public image of the overall solid waste management system.

Transfer Systems and Plant Layout. The basic transfer systems described briefly in Chapter I are those that are currently used in the United States. The system best suited to a specific area must be determined by considering local conditions. A system that has application in one area may not be flexible enough in another. The advantages and disadvantages of the various basic systems will be discussed as they relate to such considerations as: volume of solid waste handled; types of solid waste handled; transfer vehicle weight and size restrictions; types of vehicles using the facility.

The two basic transfer systems previously discussed were the direct-dump system characterized by the use of open-top trailers, and the compactor system characterized by the use of enclosed reinforced steel trailers. Each system can be subdivided into the following categories.

Direct dump-transfer systems: (1) Gravity dumping from one vehicle to another--no compaction; (2) Gravity dumping from one vehicle to another followed by load leveling and compaction with a backhoe; (3) Compaction pit method - waste is unloaded into a storage pit or onto a floor area and crushed under crawler tractor treads before being pushed over a ledge into an open trailer below. Load leveling is usually performed with a backhoe. When incoming traffic is heavy, the first and second methods may have an intermediate step whereby the waste is first dumped onto a storage floor before being pushed over a ledge into the open-top trailer.

Compaction transfer systems: (1) Internal compactor system - waste is placed in the trailer through a door located on top and near the front. Waste may be dumped directly from the collection vehicle through the door or it may be pushed over a ledge and into the trailer by a front-end loader working from a storage area. The internal hydraulic compactor compacts the waste toward the rear of the trailer in cycles. (2) Stationary compactor system - the trailer is backed up to the compactor which horizontally pushes the waste through a door in the rear of the trailer in reciprocating strokes. Waste can be fed to the compactor in different ways as will be discussed later.

The following basic information applicable to any transfer system is presented before each system is discussed in detail.

The primary purpose of the utilization of any transfer station is to reduce costs through reduction in haul time. It follows that maximizing the payload of each transfer vehicle is mandatory to fully utilize the costs savings of a transfer system. An upper limit, however, is placed on the payload obtainable with a given transfer vehicle because of gross weight and axle weight restrictions. In addition, State restrictions on maximum lengths, heights, and widths that limit total volume must be adherred to (Table 8). Maximum legal payloads for most State motor vehicle codes will result from a vehicle configuration in which the number of axles and their spacing allow an upper limit of combined dead load and live load to the maximum permissible gross vehicle weights.[4] Some States allow multitrailer rigs to be used within certain overall length restrictions, which will often be the vehicle configuration whereby maximum payloads can be achieved. They are not compatible, however, with some transfer systems and usually complicate the unloading operation. Trailer manufacturers are very familiar with vehicle configurations that give maximum payloads under different State motor vehicle codes.

State highway regulations should be carefully checked before the selection of a transfer vehicle is attempted. The designer is faced with the legal limitations and must work backward to determine optimum vehicle configuration. When a direct-dump operation with limited compaction is used, a large-volume vehicle is required to obtain maximum payloads. Compactor systems produce higher densities so smaller volume trailers can be used, but necessary strength reinforcement increases tare weights, thereby lowering payloads.

The primary goal is to determine an inexpensive and reliable method of obtaining maximum payloads. Obviously the lighter the transfer

TABLE 8

MAXIMUM MOTOR VEHICLE MEASUREMENTS FOR EACH STATE*

State	Height (in)	Width (in)	Length		Axle weights		Gross comb. weight (lb)
			Single trailer (ft)	Double trailer (ft)	Single (lb)	Tandem (lb)	
Alabama	162	96	55	N.P.	18,000	36,000	73,280
Alaska	162	96	60	65	20,000	34,000	100,000
Arizona	162	96	65	65	18,000	32,000	76,800
Arkansas	162	96	55	65	18,000	32,000	73,280
California	162	96	60	65	18,000	32,000	76,800
Colorado	162	96	65	65	18,000	36,000	74,600
Connecticut	162	102	55	N.P.	22,400	36,000	73,000
Delaware	162	96	55	65	20,000	36,000	73,280
Dist. of Columbia	150	96	50	N.P.	22,000	38,000	70,000
Florida+	162	96	55	N.P.	20,000	40,000	66,610
Georgia	162	96	55	55	20,340	40,680	73,280
Hawaii	156	108	55	65	24,000	32,000	73,280
Idaho	168	96	60	65	18,000	32,000	76,800
Illinois	162	96	55	65	18,000	32,000	73,280
Indiana+	162	96	55	65	18,000	32,000	72,000
Iowa	162	96	55	60	18,000	32,000	73,280
Kansas+	162	96	55	65	18,000	32,000	73,280
Kentucky	162	96	55	65	18,000	32,000	73,280
Louisiana	162	96	60	N.P.	18,000	32,000	73,280
Maine	162	102	55	N.P.	22,000	36,000	73,280
Maryland	162	96	55	65	22,400	40,000	73,280
Massachusetts+	162	96	65	N.P.	22,400	36,000	73,000
Michigan+	162	96	55	65	18,000	26,000	143,000
Minnesota	162	96	55	N.P.	18,000	32,000	73,280

TABLE 8 (Cont'd)

Mississippi	162	96	55	55	18,000	32,000	73,280
Missouri	162	96	55	65	18,000	32,000	73,280
Montana+	162	96	60	65	18,000	32,000	76,800
Nebraska	162	96	60	65	18,000	32,000	71,146
Nevada*	N.S.	96	70	70	18,000	32,000	76,800
New Hampshire	162	96	55	55	22,400	36,000	73,280
New Jersey	162	96	55	55	22,400	32,000	73,280
New Mexico	162	96	65	65	21,600	34,320	86,400
New York*	162	96	55	N.P.	22,400	36,000	85,000
North Carolina	162	96	55	N.P.	18,000	36,000	73,280
North Dakota	162	96	60	65	18,000	32,000	73,280
Ohio+	162	96	55	65	19,000	32,000	78,000
Oklahoma	162	96	55	65	18,000	32,000	73,280
Oregon+	162	96	60	75	18,000	34,000	76,000
Pennsylvania	162	96	55	N.P.	22,400	36,000	71,145
Rhode Island	162	102	55	N.P.	22,400	36,000	73,280
South Carolina	162	96	55	N.P.	20,000	36,000	73,280
South Dakota	162	96	65	65	18,000	32,000	73,280
Tennessee	162	96	55	N.P.	18,000	32,000	73,820
Texas	162	96	55	65	18,000	32,000	72,000
Utah+	168	96	60	65	18,000	33,000	79,900
Vermont	162	96	55	N.P.	22,400	36,000	73,280
Virginia	162	96	55	N.P.	18,000	32,000	70,000
Washington+	162	96	60	65	18,000	32,000	76,000
West Virginia	162	96	55	N.P.	18,000	32,000	73,280
Wisconsin	162	96	55	N.P.	19,500	32,000	73,000
Wyoming	162	96	65	65	18,000	36,000	73,950

*These figures should serve only as a rough guide because they are subject to change and certain limitations.

+Greater length and gross weights allowed on designated highways

N.P. - not permitted

vehicle, the larger the payload. Controversy develops as to whether this goal can be best accomplished with an open-top direct-dump trailer or an enclosed compactor loaded trailer. Open-top, tractor-trailer rigs have empty weights ranging from about 26,000 to 33,000 lb and the initial purchase price is usually lower than the heavier compactor trailer rigs which weigh from about 39,000 to 42,000 lb. Assuming a gross vehicle weight limit of 72,000 lb, the open-top vehicles can carry a maximum payload of about 19.5 to 23 tons while the enclosed compactor rigs are limited to about 15 to 16.5 tons. Graphical comparisons of trailer characteristics versus allowable densities and payloads clearly illustrate the hauling restrictions placed on transfer systems by legal weight limits (Figures 18 to 20). Enclosed compactor trailers, however, have definite time saving advantages in unloading and in their ability to handle various bulky wastes. In addition, maximum payloads may be difficult to obtain with certain types of wastes when using open-top trucks. These points will be discussed in more detail later.

To obtain an idea of the sensitivity of total haul cost to payload, assume that a transfer station handles 100,000 tons per year and that the approximate total cost per transfer vehicle trip is $30, which is a realistic figure. If each trip averages a 16-ton payload, 6,250 trips are required while a 20-ton payload requires only 5,000 trips. Thus, 1,250 trips are eliminated giving a total annual savings of $37,500 (Figure 21). The total annual haul cost can therefore be reduced substantially by maximizing the payload each trip. The cost per trip is nearly constant regardless of payload so transporting less than maximum payloads increases the cost per ton per minute accordingly.

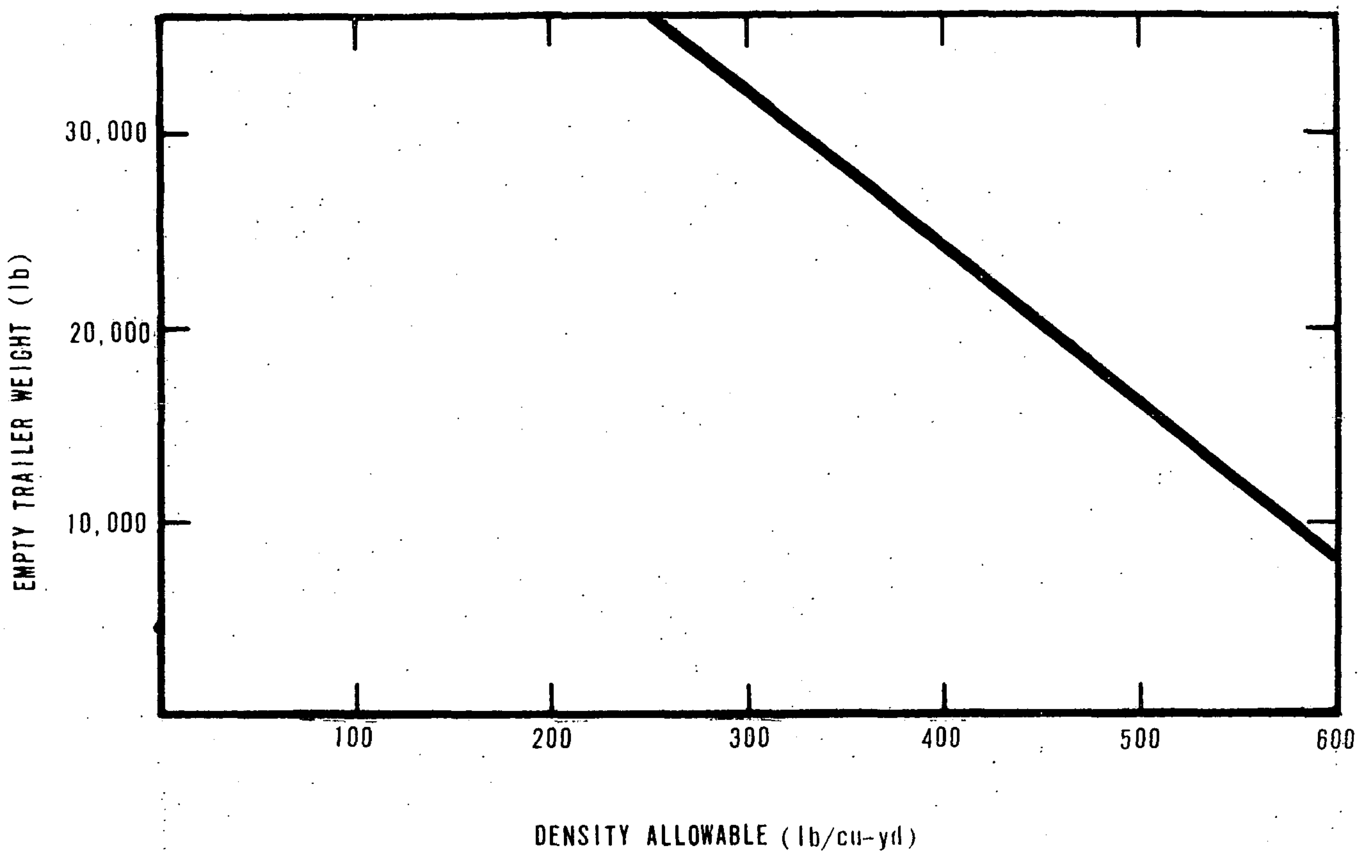

Figure 18. The maximum densities allowable in an 80 cu-yd trailer are shown at various empty trailer weights when a 16,000-lb tractor is used and a 72,000-lb legal gross weight limit exists.

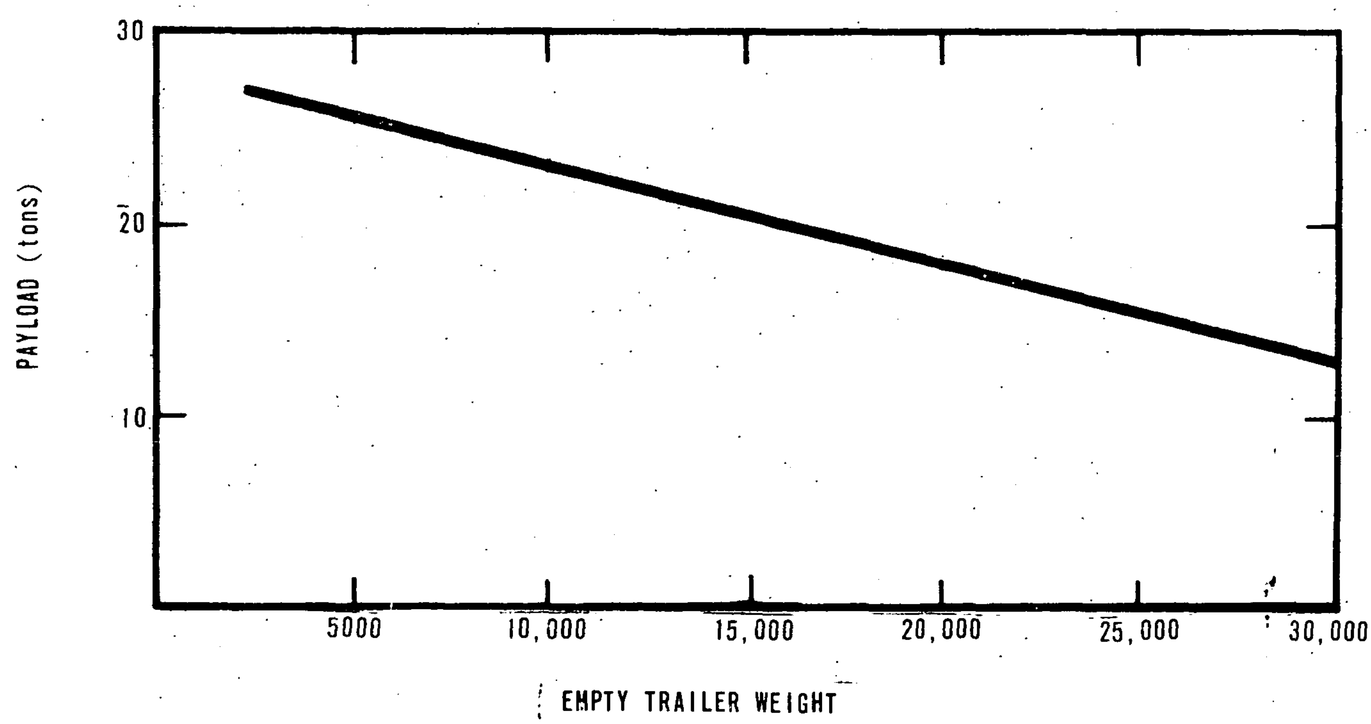

Figure 19. The maximum payloads allowable in an 80 cu-yd trailer are shown at various empty trailer weights when a 16,000-lb tractor is used and a 72,000-lb legal gross weight limit exists.

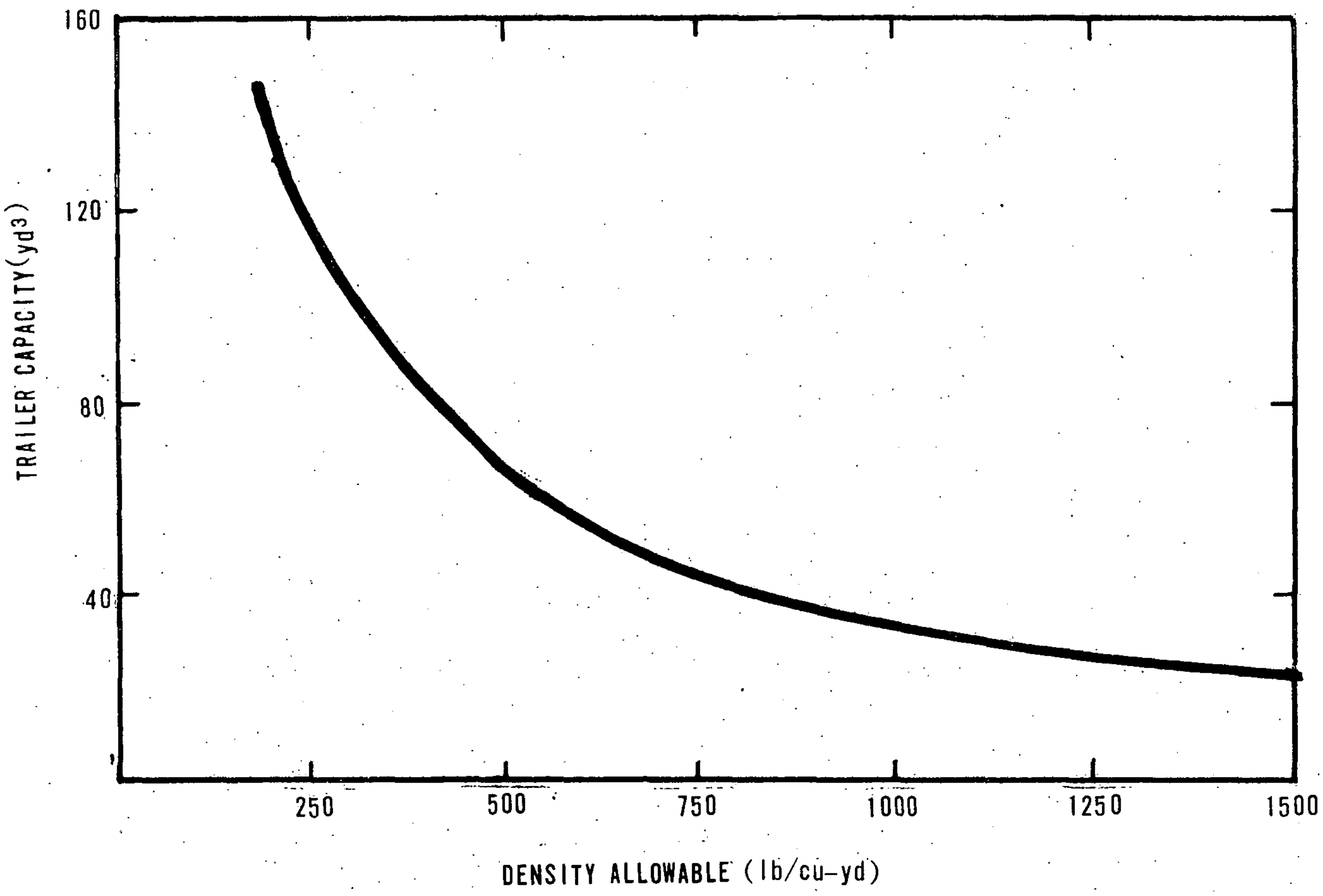

Figure 20. The maximum densities allowable are shown at various trailer capacities when the empty weight of the tractor-trailer rig is 40,000-lb and a 72,000-lb legal gross weight limit exists.

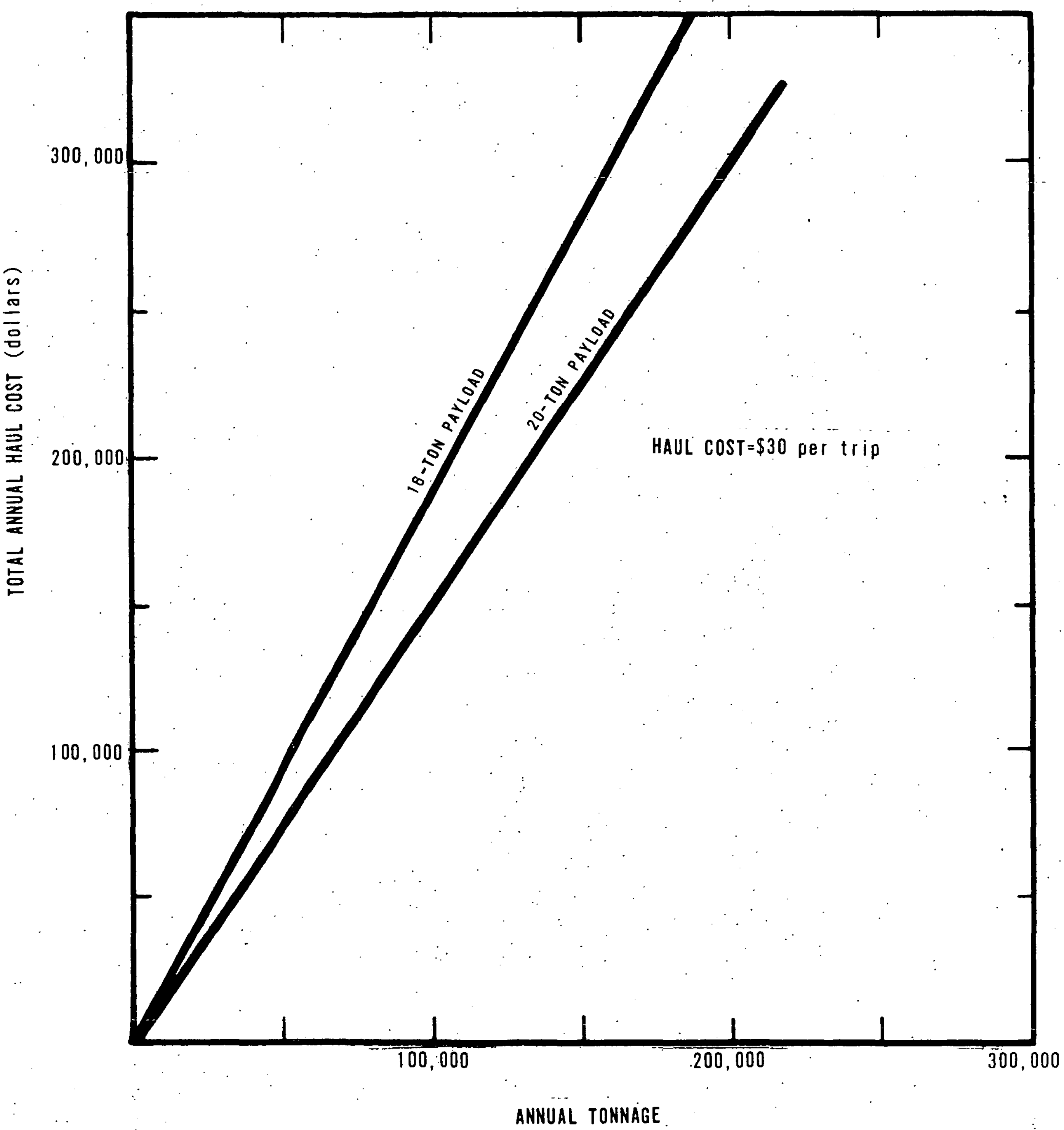

Figure 21. The total annual hauling cost from a transfer station can be significantly reduced by maximizing the average payload per trip.

Planning the size of a transfer station requires that expected future solid waste quantities be estimated. To allow for future expansion, necessary land must be available and provisions for easy additions to initial buildings should be provided. Foundation work for future expansion can usually be most easily done during initial construction. Hauling and handling equipment for expanded operations should be acquired as needed to prevent operation slowdowns. If a transfer station is constructed in a well-developed area, it may never be necessary for the station to draw upon a larger population area unless a more distant disposal site is used. An increase in volume, however, should be expected over the years as the per capita waste generated increases.

Planning the size of a transfer system can only be attempted after a study of local conditions is made. The choice of a system must first be made to meet the needs and desires of the service area. The choice should be based on consideration of the advantages and disadvantages of each system as they relate to the specifics of the area. Such factors as who will use the facility and the type of neighborhood in which it is to be located may have a great influence on the decision. Several systems may appear basically equivalent. Hence, the preference of the operating authority may have to determine which system best meets the aesthetic or economical requirements of the area.

Once selected, the size of the transfer system must first be determined so that the actual physical dimensions of the structure and traffic areas can be planned. The expected daily waste quantities and the round-trip time to the disposal site are the most important variables in planning the size of the system for the number of trailers, unloading stalls, compactors, etc. After the daily waste volume and round-trip travel time are known, it is relatively easy to determine the number of trailers needed to handle the load. At least one trailer must always be in loading position and an old tractor or other vehicle should be available for moving the trailers into and out of loading position. A fewer number of tractors than trailers is necessary since tractors should not be idle at the transfer station. Storage provisions based on peak load periods are necessary to prevent queuing problems with incoming collection vehicles. The capacity of a transfer station depends on the capacity of its least efficient element. For example, a sufficient number of trailers may be available but a small storage area may substantially slow down the operation.

In summary, planning the size of a transfer station is not a difficult problem once a transfer system has been selected and the important variables have been determined from a study of the area. A rule of thumb is not available for planning the size of various elements of a transfer system because a wide variation of conditions will exist in different communities.

In the following paragraphs, each of the transfer systems within the direct-dump and compaction categories will be discussed in detail.

Gravity Dumping from One Vehicle to Another - No Compaction. This is the most basic and simple form of transfer and has been practiced for many years in small operations, especially in the once widely practiced hog-feeding operations. This system is employed where small volumes are handled and usually consists of an earthen or asphalt ramp from which the unloading vehicles dump into a trailer located below. This system is inadequate for most purposes and should not be considered except possibly in rural locations where less than one transfer load per day is expected. Unless a hopper is utilized, problems with spillage will probably arise. With special types of high-density waste such as might be produced in an industrial process, this method may be entirely adequate, however, because compaction would not be required to obtain maximum legal payloads.

Gravity Dumping from One Vehicle to Another Followed by Load Leveling and Compaction With a Backhoe. This method has become quite popular and has been used in both small and large transfer stations. Basically this method is the same as that above except that backhoes provide the necessary leveling and compaction to obtain maximum payloads. This system works well where most of the incoming waste comes from compactor collection vehicles because little additional compaction is usually required to obtain maximum legal payloads. The backhoes used in this system can be mounted either stationarily above the trailers or be self-propelled vehicles that move from trailer to trailer (Figures 22 and 23).

This type of system has been used both in open-air operations and enclosed operations (Figures 12 and 24). Incoming vehicles back up and unload directly into the funnel-shaped hoppers located above the trailers (Figure 25). The hoppers are designed large enough to prevent spillage. The backhoe then distributes, compacts, and levels the transfer trailer load as required. Backhoes are capable of exerting up to 10,000 lbs

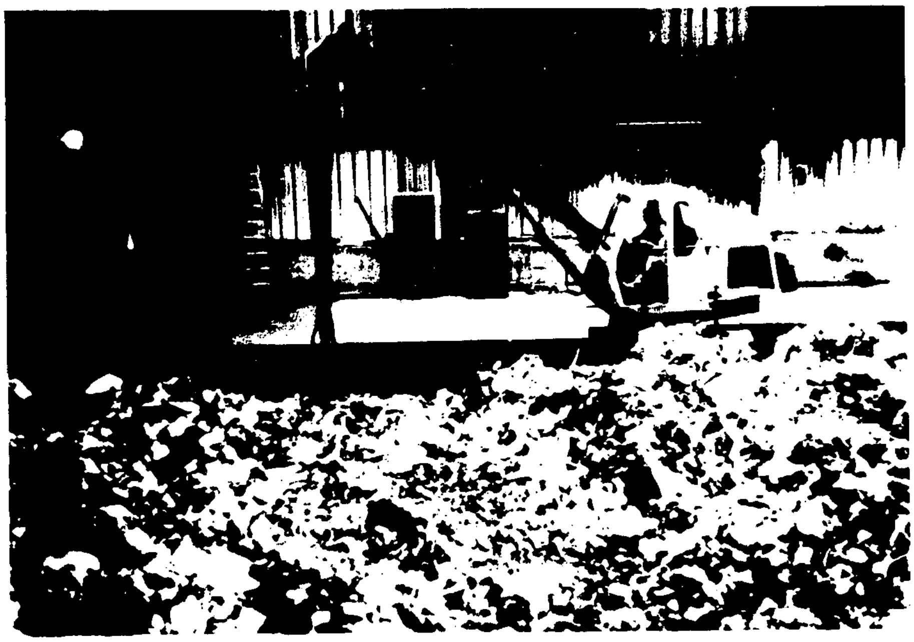

Figure 22. The stationary backhoe used in many direct-dump transfer systems is permanently mounted and serves only a few loading hoppers.

Figure 23. The self-propelled backhoe used in many direct-dump transfer systems moves from hopper to hopper.

Figure 24. The direct-dump transfer stations in King County, Washington, are attractively housed under a steel roof.

Figure 25. The loading hoppers utilized in direct-dump transfer stations are used to funnel the waste into open top trailers located one level below.

of downward force on the waste depending upon size and can easily achieve maximum payloads if most of the incoming material is precompacted in collection trucks.

To avoid the problem of backing and maneuvering the transfer vehicles into position under the hoppers, a drive-through arrangement is usually employed. The unloading area can be at ground level with the transfer vehicle loading positions excavated at a lower level; or the unloading areas can be elevated with the transfer vehicles loading at ground level. The existing terrain at the site may easily determine which method requires the least construction. A typical traffic flow and plant layout diagram is shown (Figure 26). Simultaneous loading of two transfer vehicles and unloading of eight collection vehicles can be performed at this facility.

To prevent queuing problems, the facility must be designed to have a sufficient number of hoppers and trailers available to accept peak incoming waste loads since storage is not easily incorporated into this system. In special circumstances waste can be stockpiled on the loading floor and later be placed into the empty trailers when the heavy incoming waste load subsides.

Many methods have been used to unload open-top trailers. The cable pullout method is popular but somewhat inefficient. Cables are crossed and positioned before loading at the front of the trailer and run along the sides all the way to the rear door. A tractor at the landfill is attached to the ends of the cables and pulls the load out, but unless care is taken to place bulky material near the front of the

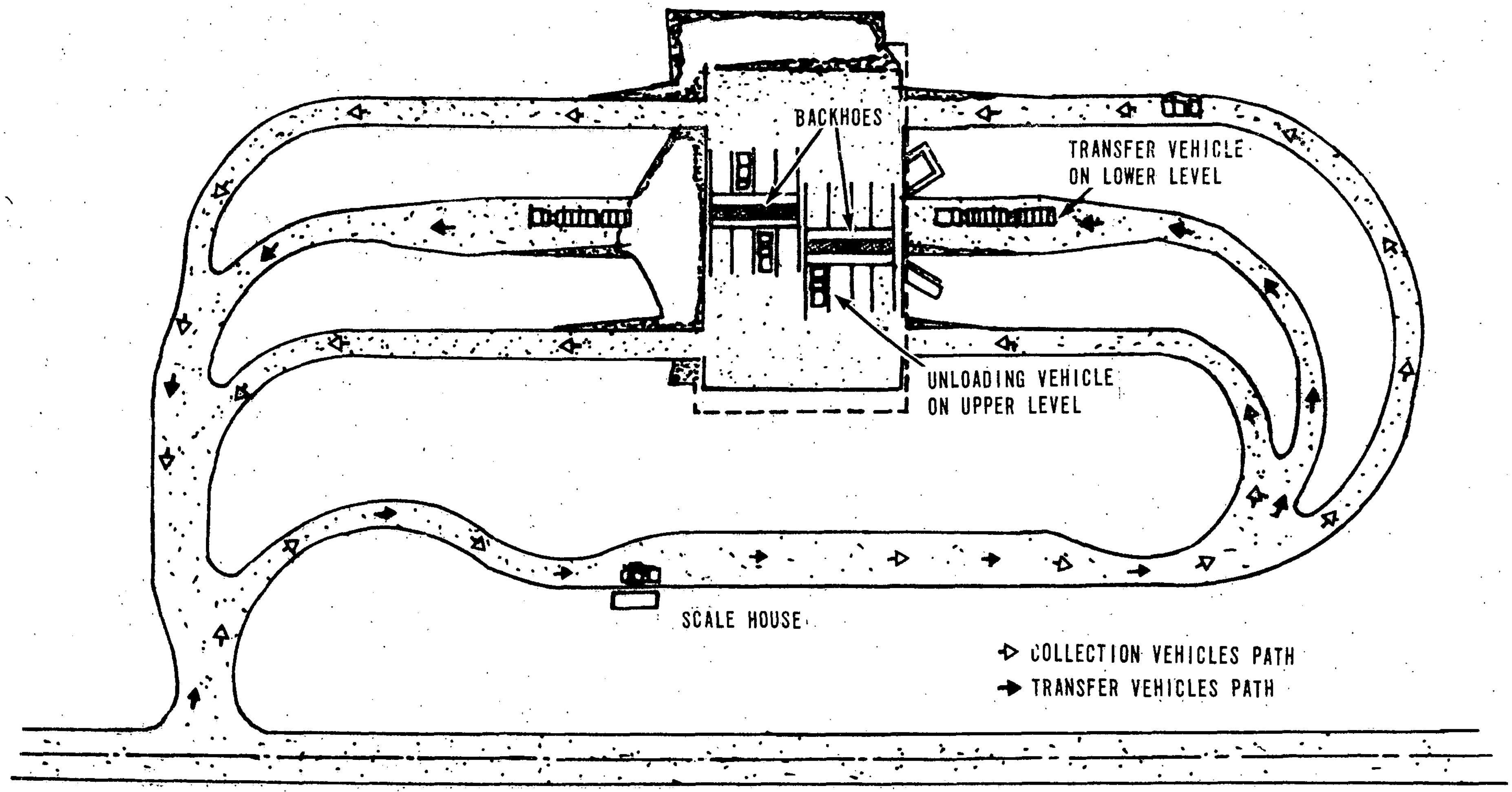

Figure 26. The traffic flow and plant layout of a typical direct-dump transfer station in which backhoes are used for compaction.

trailer to provide a sweeping action, waste is often left in the trailer. The cables must also be manually repositioned in the trailer before it can be reloaded. A similar but more efficient unloading method utilizes a steel cargo net that ejects the load by being pulled from the front to the rear of the trailer. The same tractor and cable procedure provides the ejection power. After unloading, the cargo net is repositioned in the front of the trailer with electric winches and small cables.

Two unique methods for unloading open-top trailers are used on the West Coast. The new transfer station in San Francisco utilizes a transfer vehicle configuration consisting of a 73-cu-yd trailer in tow of a 70-cu-yd body truck. Self-propelled hydraulic tippers capable of tilting the trailers to a maximum of 70 degrees from the horizontal are utilized in the unloading operation (Figure 27). The trailer is first backed onto one tipper and unhooked, and the truck is then backed onto the other tipper. After both are unloaded the truck drives off the tipper, rehooks to the trailer, and proceeds back to the transfer station. The tippers can move to any desired location on the landfill under their own power. Unloading can be accomplished in six minutes. The tippers are expensive ($72,000 each), however, and are not warranted unless a large volume is handled.

King County, Washington, utilizes a unique transfer trailer configuration made up of a flatbed truck carrying two 42-cu-yd containers. At the landfill, a self-propelled hydraulic scooper fitted with specially designed arms picks up the containers and flips them for emptying (Figure 28). The transfer vehicle stops on the road with the hydraulic

Figure 27. Self-propelled hydraulic tippers are used for open-top transfer vehicles in San Francisco.

Figure 28. A hydraulic scooper is used to unload transfer vehicles in King County, Washington.

scooper moving to the designed location for unloading the containers. Unloading is accomplished in a matter of a few minutes. Once again, a large volume is required to justify the use of this expensive ($130,000) specialized machine.

This type of direct-dump transfer system has the following advantages: (1) open-top trailers are lighter and capable of carrying larger payloads than enclosed compactor trailers with their heavy reinforced steel bodies and hydraulic equipment; (2) the simple loading method prevents the possibility of having to completely halt operations as would be required in a compactor system with enclosed trailers if a breakdown occurred; (3) open-top trailers are usually cheaper in initial cost and require less maintenance than enclosed compactor trailers; (4) if incoming waste is precompacted in collection trucks, this method will usually produce maximum payloads with the minimum amount of processing; (5) drive-through provisions for loading transfer vehicles can easily be incorporated into the design.

This type of transfer system has the following disadvantages: (1) maximum payloads may be difficult to obtain when large amounts of uncompacted waste are received; (2) unloading of open-top trucks is more difficult and usually takes more time than required with enclosed compactor transfer trailers and investment in expensive disposal site unloading equipment may be required; (3) bulky items are not as easily handled as in an enclosed compactor trailer system where considerable hydraulic crushing force is available; (4) time is wasted in the placement and removal of canvas or metal tops that are required to prevent littering during transportation.

Compaction Pit System. Other than utilizing an intermediate compaction operation, this method is very similar to the preceding one. It offers the advantage of providing storage as a routine part of the operation. Waste is dumped from the collection truck directly into a storage pit. Here a crawler tractor crushes the waste before pushing it over a ledge and into the hoppers located over the open-top trailers (Figure 7). Backhoes then distribute and level the load but are not usually needed to provide additional compaction.

This system is usually utilized when much of the incoming waste is not precompacted in collection vehicles and when heavy traffic inflows are experienced. The crawler tractor crushes and compacts the waste and can quickly load large volumes of waste into the open-top trailers. The storage pit allows many vehicles to unload simultaneously thus eliminating long waiting lines. The preceding system, however, can accomplish the same task more economically if most of the incoming waste is from compactor collection trucks and if a large amount of storage is not required to handle peak loads.

The new transfer station in San Francisco, with its well designed plant layout and traffic flow patterns, is the best example of the compaction pit system (Figures 29 and 30). Currently about 2,000 tons per day are being handled in a one-shift operation. Two transfer vehicles are loaded simultaneously from the compaction pit with one crawler tractor. The transfer vehicles rest on scales and as they fill up their weights are instantly visible on a readout device, ensuring maximum payloads without exceeding highway weight restrictions. The lightweight

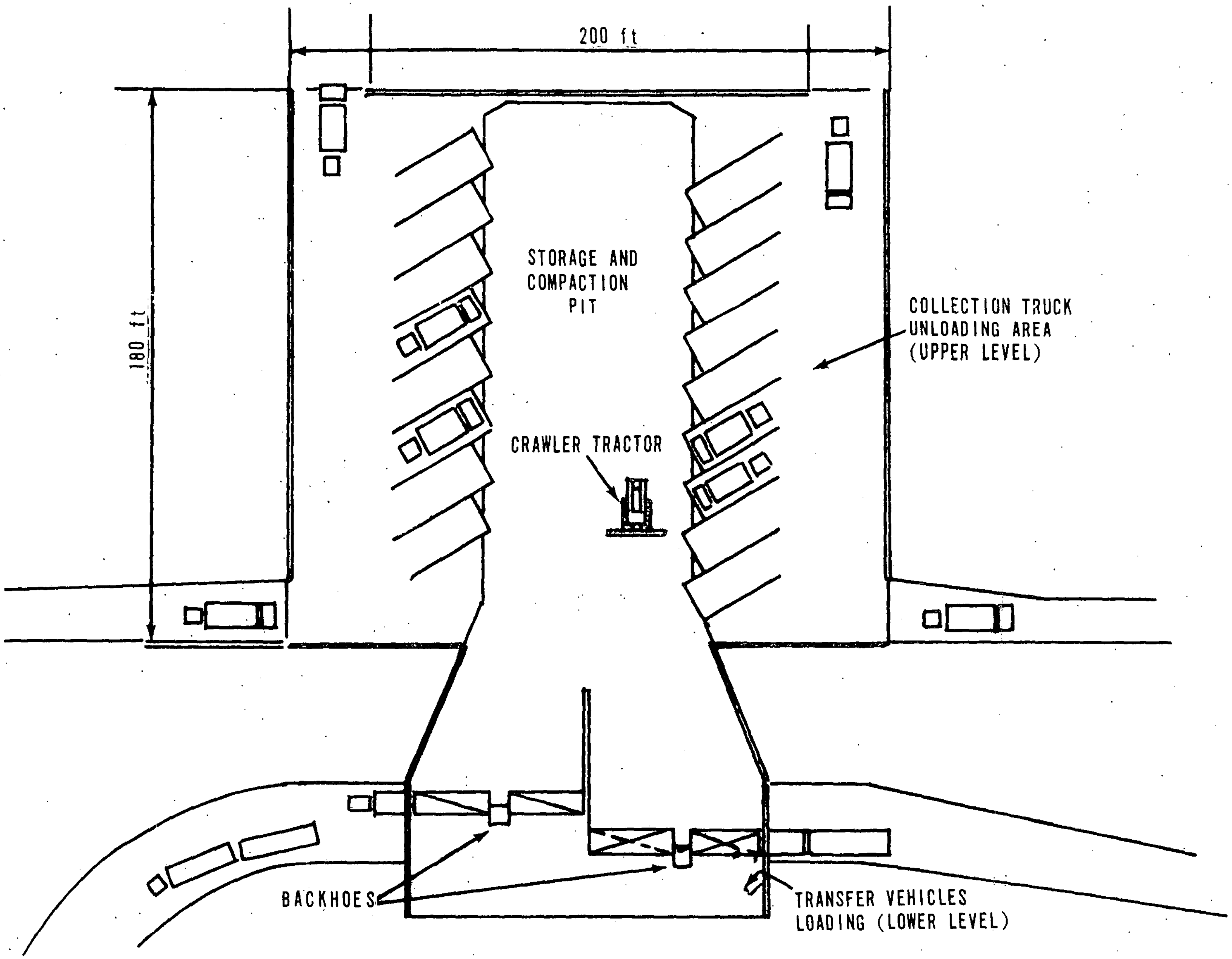

Figure 29. As indicated in this floor plan of the compaction pit transfer station in San Francisco, simultaneous loading of two transfer vehicles and unloading of 17 collection trucks can be performed.

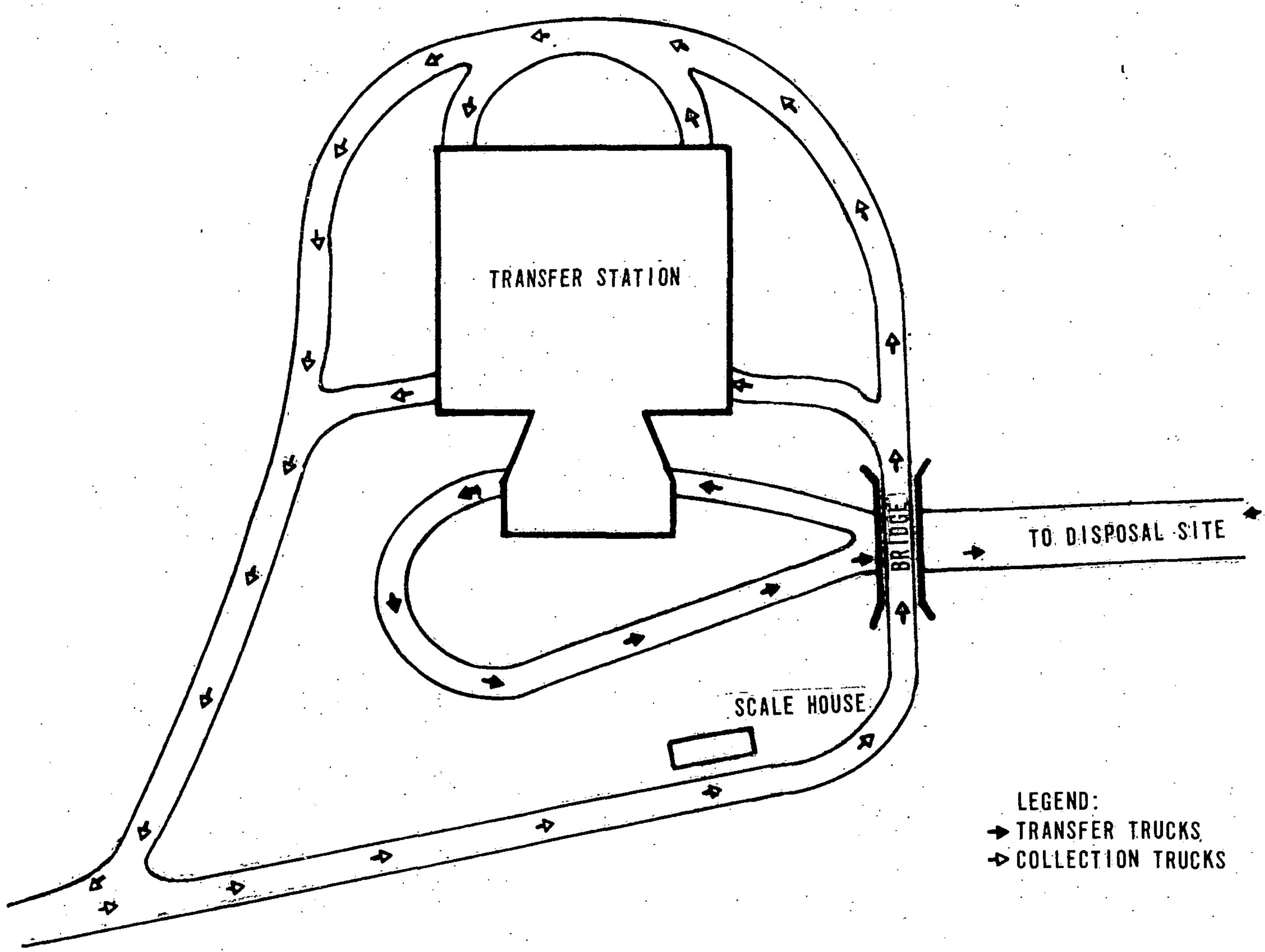

Figure 30. As indicated in this plot plan of the compaction pit transfer station in San Francisco, traffic flows smoothly with no interference between collection trucks and transfer vehicles.

aluminum open-top transfer vehicles discussed previously are capable of carrying 25.5-ton payloads. Seventeen incoming collection trucks can unload simultaneously. Incoming and outgoing traffic flow is smooth and uninterrupted by bottlenecks because collection trucks and transfer trucks have independent circulation patterns. The transfer vehicles are not required to back into position as drive-through provisions are incorporated into the three-level design. The trailers can be loaded in about six minutes. Several smaller compaction pit systems are also operated on the West Coast. The San Francisco operation is described in more detail in Appendix E.

The advantages of the compaction pit system are as follows: (1) a convenient and efficient storage area is available that does not clutter the unloading area; (2) uncompacted material is crushed in the pit making maximum payloads obtainable without further processing; (3) the open-top transfer trailers are lighter and capable of carrying larger payloads than the enclosed compactor trailers with their heavy reinforced steel bodies and hydraulic equipment; (4) the open-top trailers are usually less expensive initially and require less maintenance than the enclosed compactor trailers; (5) large volumes of waste can be handled very quickly and many incoming vehicles can be unloaded simultaneously; (6) drive through loading provisions for transfer vehicles can easily be incorporated into the design.

The compaction pit system has the following disadvantages: (1) considerable capital investment is required to construct the compaction pit and to purchase the crawler tractor; (2) unloading of open-top trucks is more difficult and usually takes more time than required with enclosed compactor transfer trailers and investment in disposal site unloading equipment may be required; (3) time is wasted in placement and removal of canvas or metal tops that are required to prevent littering during transportation.

Internal Compaction Trailer System. In this system the transfer trailer serves as both the compactor and the bulk hauler. A traveling bulkhead powered by a telescoping hydraulic cylinder is initially positioned at the front of the trailer to start the cycle. Waste drops through a door located on top and near the front of the trailer to a position immediately forward of the bulkhead (Figure 31). The bulkhead then pushes the waste horizontally toward the rear of the trailer and compacts it against the rear doors. The bulkhead is then repositioned in the front of the trailer to receive a new charge of material. At the disposal site the rear doors are opened and the bulkhead traverses the trailer length and ejects the load (Figure 32).

This system can be set up in a variety of ways. For a small operation, the incoming vehicle simply backs into position and dumps its load through a hopper and into the trailer (Figure 33). To eliminate the need for backing into position, a drive-through operation is sometimes used. The incoming vehicle drives over a door above the hopper and stops. The hopper door is then hydraulically opened to receive the waste from the collection vehicle (Figure 34). Holding hoppers can be used so that the flow of waste into the trailer can be controlled. Often the load from a collection vehicle may be larger than the volume the bulkhead can

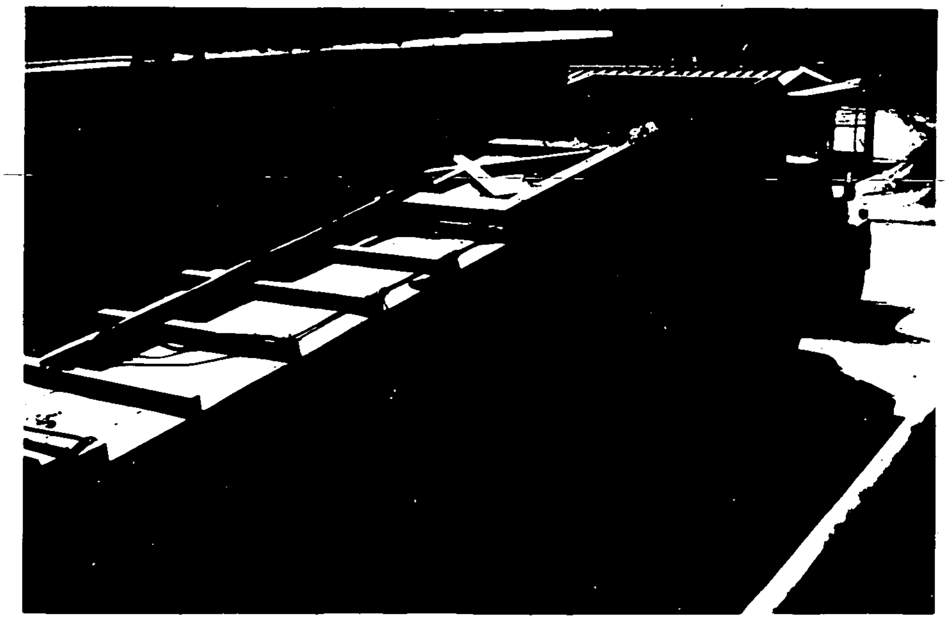

Figure 31. In a transfer trailer utilized in an internal compaction trailer system, the waste is loaded through the top sliding door via a hopper.

Figure 32. Horizontal compaction transfer trailers utilize hydraulically powered bulkheads to eject the load out the rear doors.

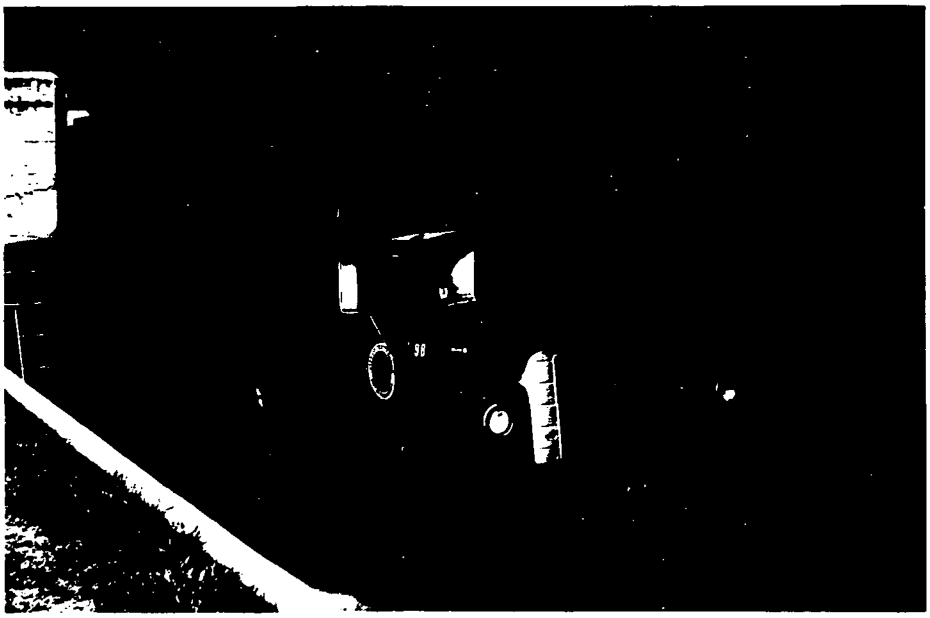

Figure 33. The internal trailer compaction system is best suited for low volume operations.

Figure 34. A drive-through system for unloading incoming vehicles is sometimes utilized in some internal compaction trailer systems.

handle in one cycle. The holding hopper must therefore be capable of receiving the entire load but must discharge only a portion into the trailer.

Queuing problems with incoming vehicles can easily result with the two operations above because only one incoming vehicle can be unloaded at a time for each transfer trailer available. Therefore, in large-volume operations this system requires that storage provisions be provided. The overflow of incoming waste can be stockpiled on the unloading floor and later pushed into the hoppers with a front-end loader. Attempts at utilizing this system in a large-volume operation with only a few unloading hoppers and no storage area will result in inefficiency.

Several methods for powering the hydraulic bulkhead system on the trailers can be used. At the transfer station the hydraulic pump can be located on a stationary unit along with an electric power source (Figure 35). Quick-connect couplings are attached to the telescoping hydraulic cylinder of the trailer which moves the bulkhead during the compaction process. The hydraulic pump along with a gasoline engine power source can be mounted permanently on the trailer itself (Figure 36). This method is sometimes required in a small open-air operation when no protection for a stationary unit would be available. Each trailer, however, must be fitted with a pump and gasoline engine, and this extra dead weight must be carried on each trip to the disposal site. The gasoline engine also supplies the power for ejecting the load at the disposal site.

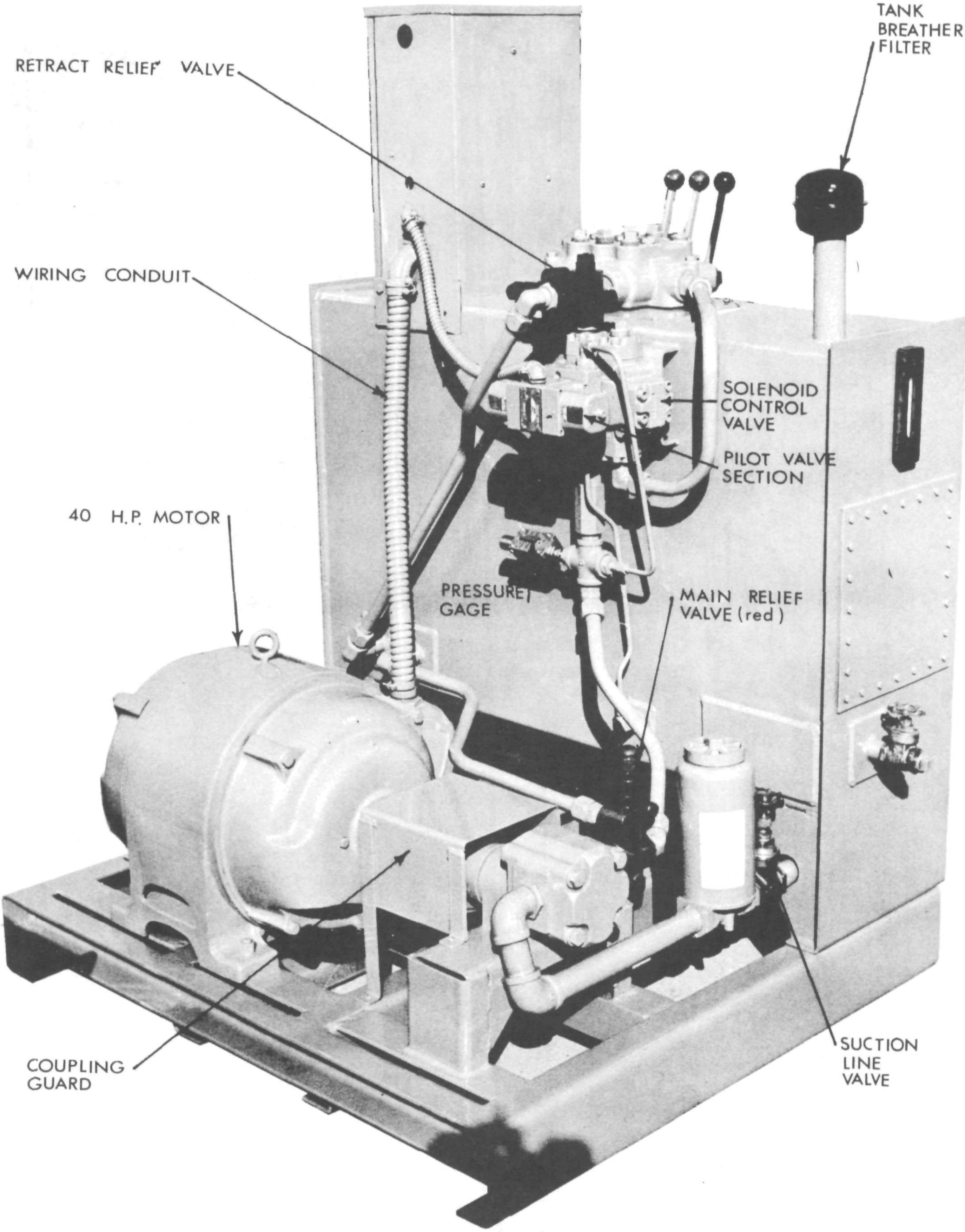

Figure 35. At the transfer station, there can be a stationary power source for operating the hydraulic system on an internal compaction transfer trailer.

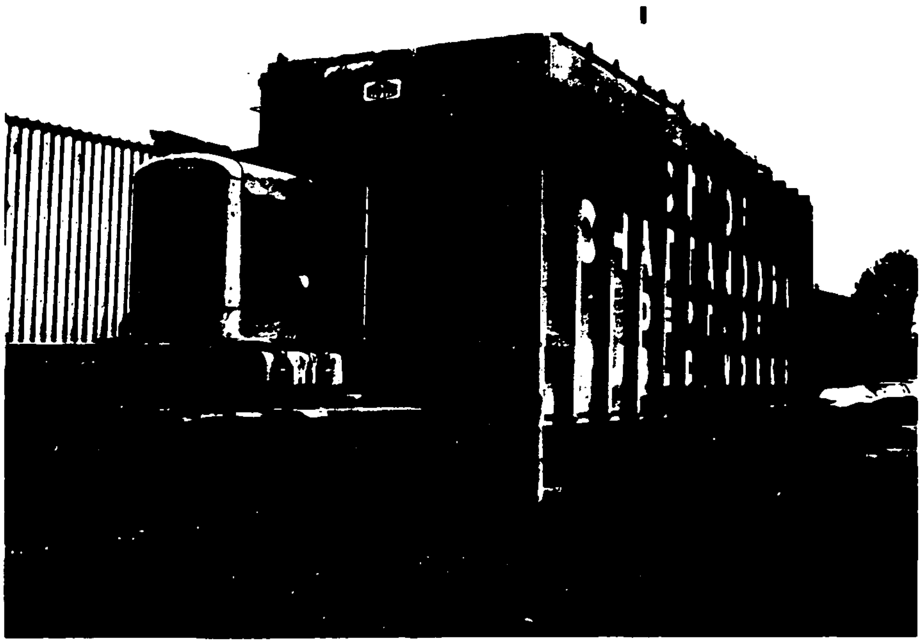

Figure 36. An internal compaction trailer may be equipped with a gasoline-engine-powered hydraulic system.

If each trailer is not equipped with a gasoline motor, load ejection at the disposal site can be accomplished in several ways. Each haul tractor can be equipped with a wet-line kit which is powered by the tractor engine through a power take-off system. At the disposal site, quick-connect hoses are attached from the power take-off unit to the hydraulic cylinder of the trailer for load ejection. Load ejection can also be performed with a trailer mounted mobile power unit located at the disposal site (Figure 37). This unit consists of a hydraulic pump powered by a gasoline engine. The power unit is moved to the desired unloading point and attached with quick-connect hoses to the hydraulic cylinder on each trailer. The one power unit therefore takes the place of the wet-line kits that would be required on each tractor, but unless access to the disposal site is well controlled the risk of vandalism or theft is apparent.

At any transfer station, drive-through access for transfer vehicles is preferable to avoid the problem of backing and maneuvering the large rigs into loading position. If a drive-through operation is not possible because of peculiarities in site topography or location, sufficient turnaround space must be provided to avoid wasted time in positioning.

The advantages of the internal compaction trailer systems are as follows: (1) the system is easily adaptable to small operations where incoming waste requires considerable compaction to achieve maximum payloads because only a ramp and hopper are needed to transfer the load to the trailer; (2) unloading of the trailers is very fast and efficient; (3) the enclosed nature of the trailer does not require that canvas or

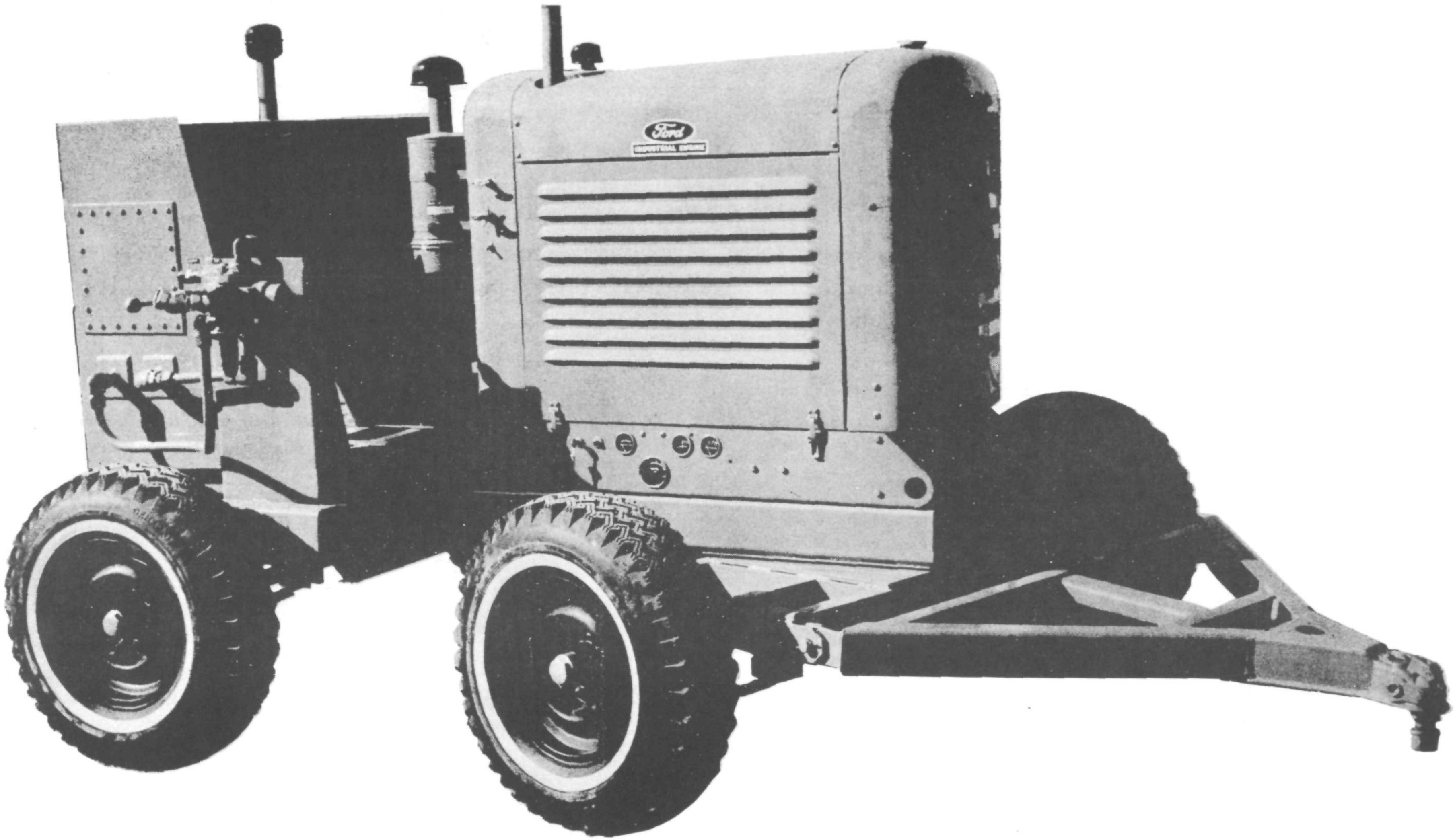

Figure 37. A mobile hydraulic power source may be used for unloading compaction transfer trailers at the disposal site.

metal tops be handled with each loading and unloading; (4) maximum payloads are easily and quickly obtained whether the incoming waste is in a compacted or uncompacted state.

The disadvantages of the internal compaction trailer system are as follows: (1) should the hydraulic bulkhead system fail, the trailer is out of commission since there is no way of placing waste in the trailer; (2) the extra dead weight of the hydraulic bulkhead system and required reinforcement steel effectively reduce maximum payloads; (3) the initial cost of compaction trailers is higher than that of open-top trailers and they usually require more maintenance; (4) if the majority of incoming waste is precompacted in collection trucks, the heavier enclosed trailer offers little advantage as maximum payloads can easily be achieved in lighter open-top trucks with top tamping.

Stationary Compactor Transfer Systems. This system has gained wide popularity since it was introduced in 1961 and is the predominant transfer system in use today. A transfer trailer is backed into position and locked to a stationary compactor that is firmly anchored in a concrete foundation (Figure 38). The hydraulically powered reciprocating ram of the compactor forces the waste horizontally through a door in the rear of the trailer.

Nearly all recent transfer station installations of this type utilize an equipment package consisting of the trailers, compactors, hoppers and sometimes the compactor feed equipment, all of which are purchased from one manufacturer. The building foundation specifications and floor plan layout are dictated largely by the particular equipment package being utilized.

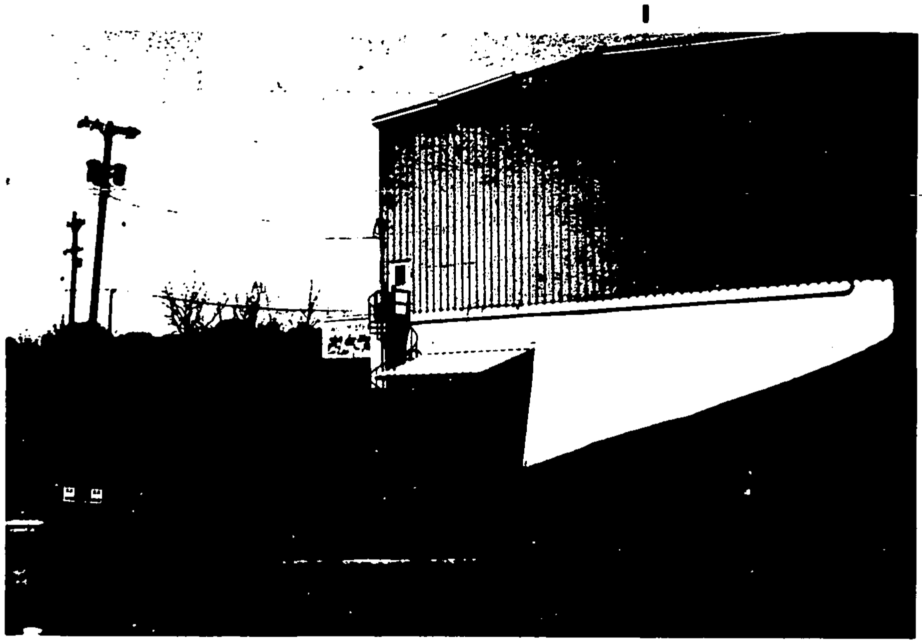

Figure 38. In a stationary compactor transfer system, transfer trailers are locked to the stationary compactor for loading.

Figure 39. The stationary compactor transfer system has become very popular in small-volume operations.

The stationary compactor system has been used in a variety of different-sized installations ranging from small open-air single compactor stations to large enclosed multi-compactor plants. Small enclosed operations have become very popular in many communities throughout the country (Figure 39). The compactor chambers are always fed by gravity from a hopper arrangement but the movement of waste from the incoming trucks to the hoppers is accomplished in a variety of ways. In small operations a storage area may not be required and incoming waste is dumped directly into the hopper above the compactor (Figure 40). In operations requiring storage the compactor can be fed with crane buckets, conveyors, front-end loaders, and hydraulic push pits, alone or in combinations.

The front-end-loader charging method is a simple and inexpensive method of providing storage. Waste is stockpiled on the floor and later pushed into the compactor hopper with the front-end loader (Figure 41).

The conveyor feed method offers advantages of simpler one-level building design and can be housed in a standard modular steel building. Some incinerators have been converted to transfer stations by simply placing a conveyor on the charging floor and utilizing the old furnace-charging buckets as the conveyor feed (Figure 42). In other plants one section of the conveyor is placed at floor level and the incoming trucks dump directly onto it (Figure 43). During peak delivery period, the waste can also be dumped on the floor adjacent to the conveyor and pushed onto the belt with front-end loaders.

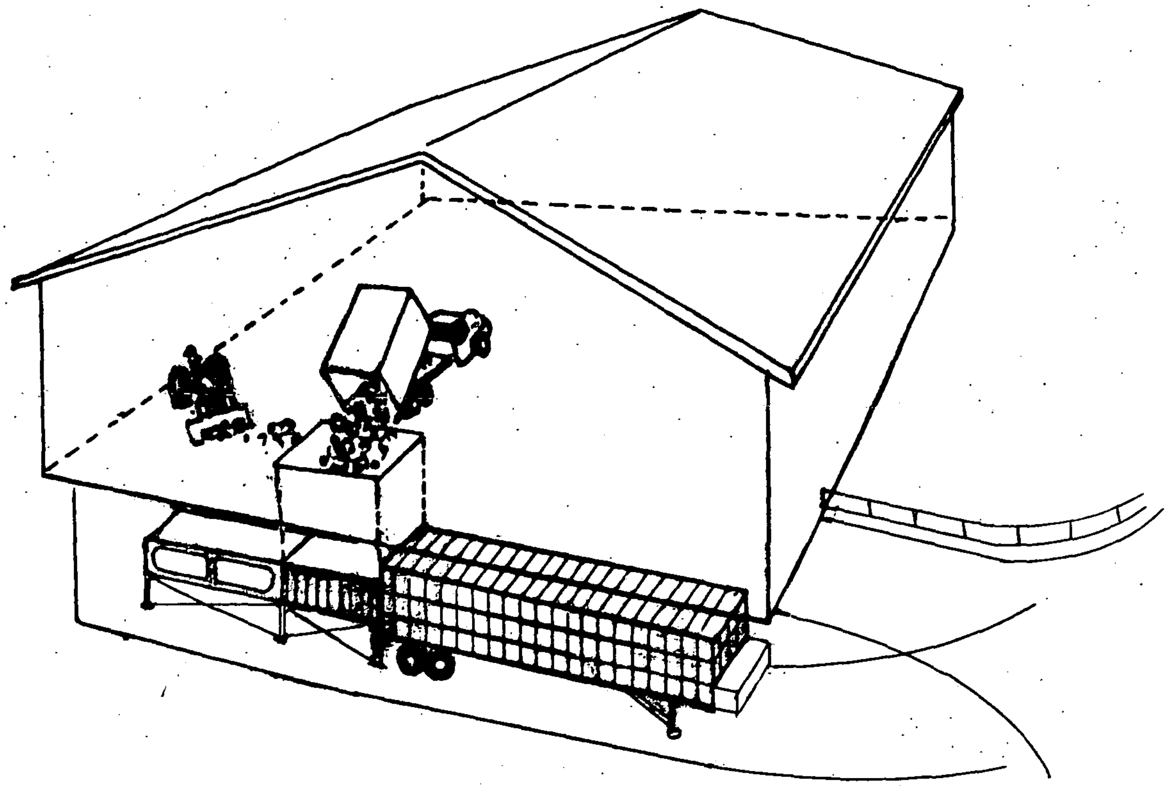

Figure 40. In this type of small volume transfer station, incoming solid waste is dumped directly into the stationary compactor hopper.

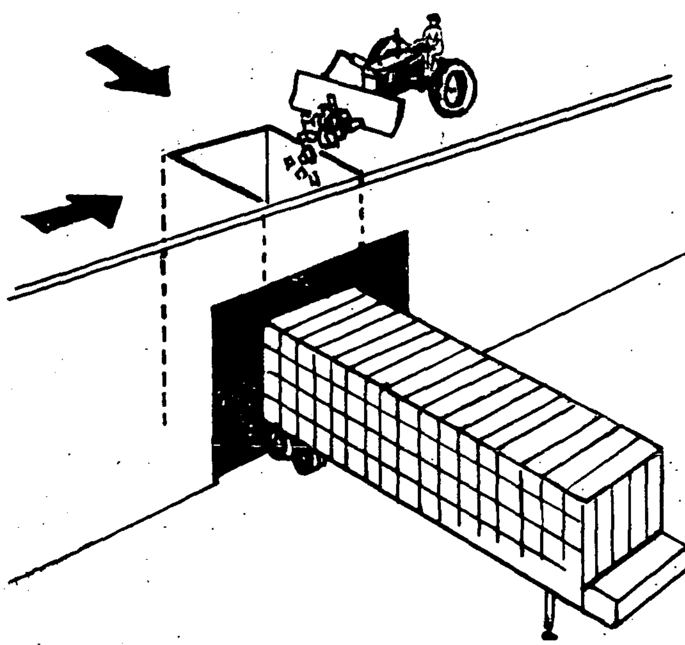

Figure 41. In this type of transfer station, incoming solid waste is stockpiled on the floor during peak delivery periods and is then loaded into the stationary compactor hopper with a front-end loader.

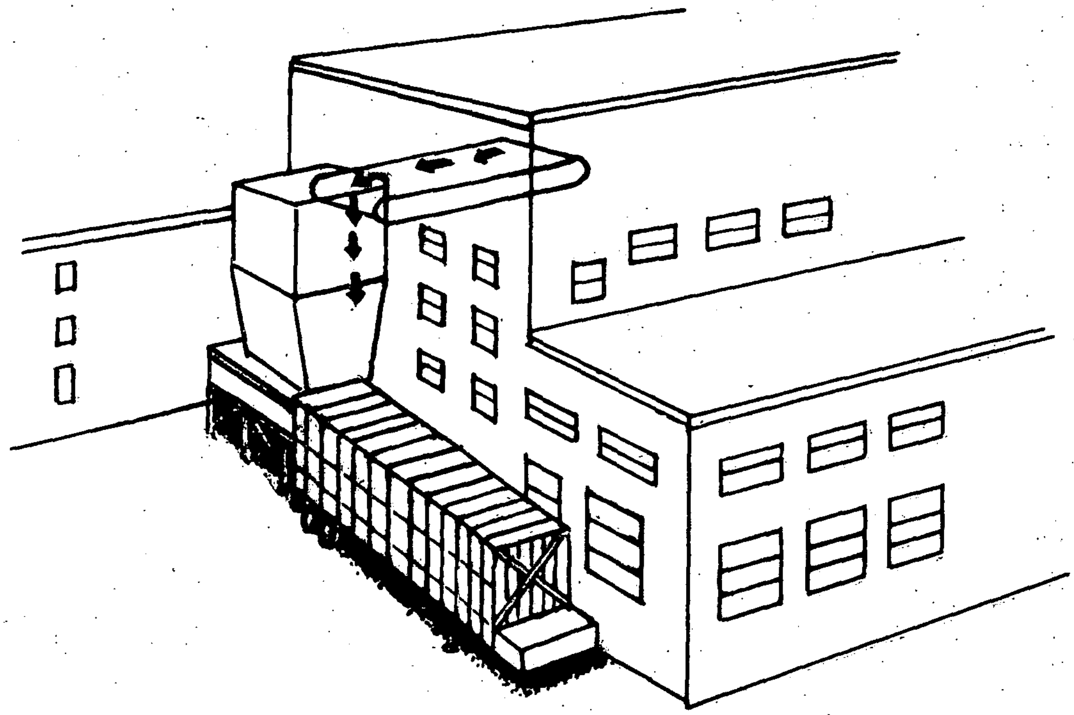

Figure 42. In this incinerator that was converted to a stationary compactor transfer station, the crane bucket is used to charge the conveyor from the storage pit.

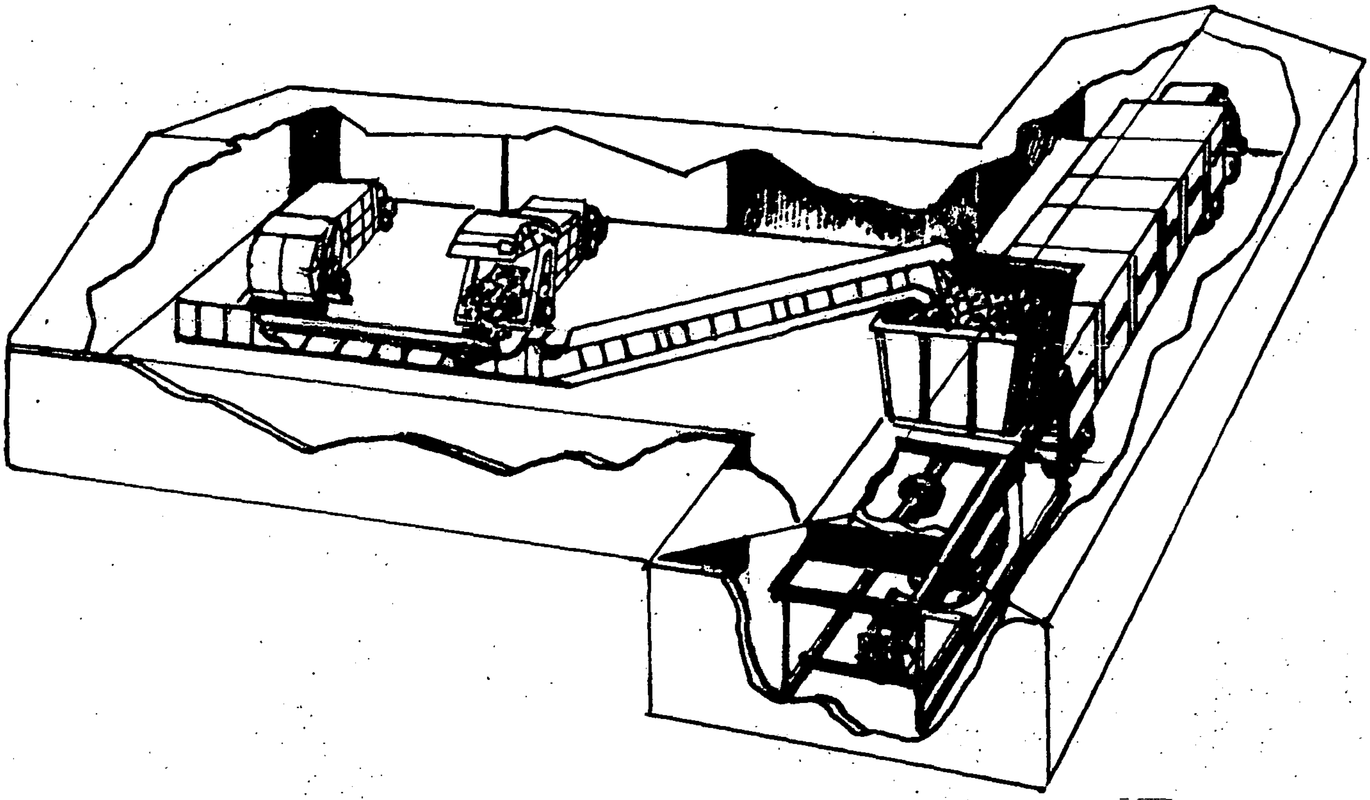

Figure 43. When an inclined conveyor is used to charge the stationary compactor hopper, a simple single level building design can be utilized.

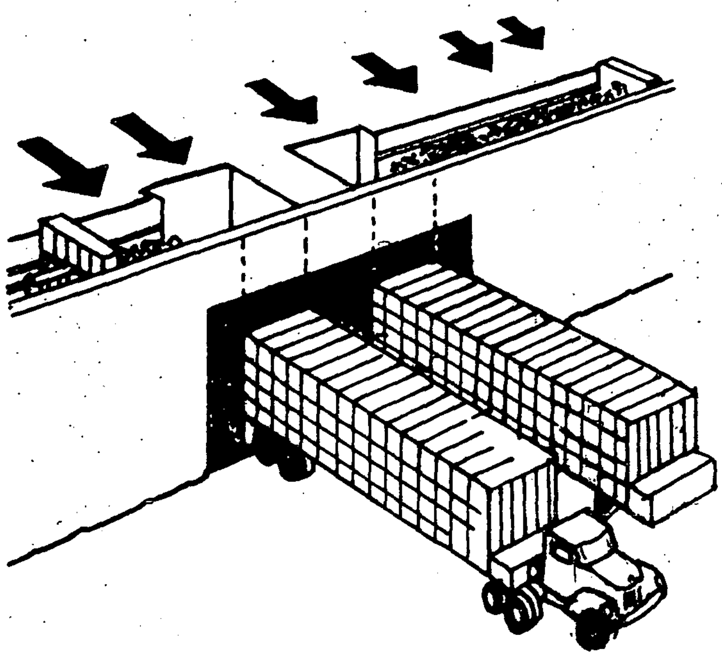

Figure 44. In some transfer stations, hydraulic push-pits are used as both a means of storage and as a means of loading the stationary compactor hopper.

The hydraulic push-pit is another method developed to provide storage capacity. Solid waste is fed automatically to the compactor by means of a hydraulically actuated bulkhead (Figure 44). The incoming trucks back up and dump into the pit, and when required, the bulkhead traverses the pit horizontally and loads the compactor hopper. A central control panel is used to actuate both the stationary compactor cycle and push-pit bulkhead cycle. Two types of pits are used with the push-pit bulkhead. The first is a concrete pit that is initially poured into the floor foundation (Figure 45). The second type is a steel pit constructed integral with the stationary compactor unit (Figure 46). The steel pit is more flexible in that it can be moved to a new location if required and requires only that an unloading level equal in height with the top of the pit be available.

The stationary compactors used in this type of transfer system are large heavy-duty units that can handle almost any material placed in them (Figure 9). The range of specifications for transfer compactors are included in Appendix C. The compactors are capable of easily producing in place densities necessary to obtain maximum legal payloads but care must be exercised to prevent overloading. Because of the large forces produced by the compactor ram the trailers must be firmly anchored to the compactor. Chains were formerly used to secure the trailers but most new units utilize an automatic locking device that is released manually. The large pressures also require that the walls of the trailers be heavily reinforced to prevent splitting. This adds considerable weight to the unit. The compactor does not force solid waste through the entire

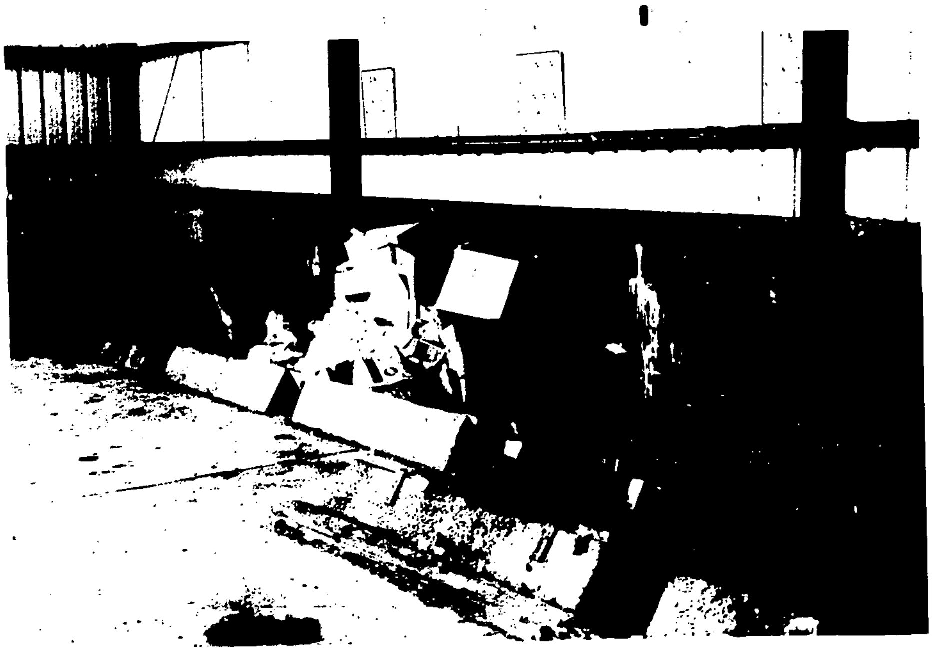

Figure 45. A permanent concrete push-pit system is sometimes used for charging solid waste into a stationary compactor hopper.

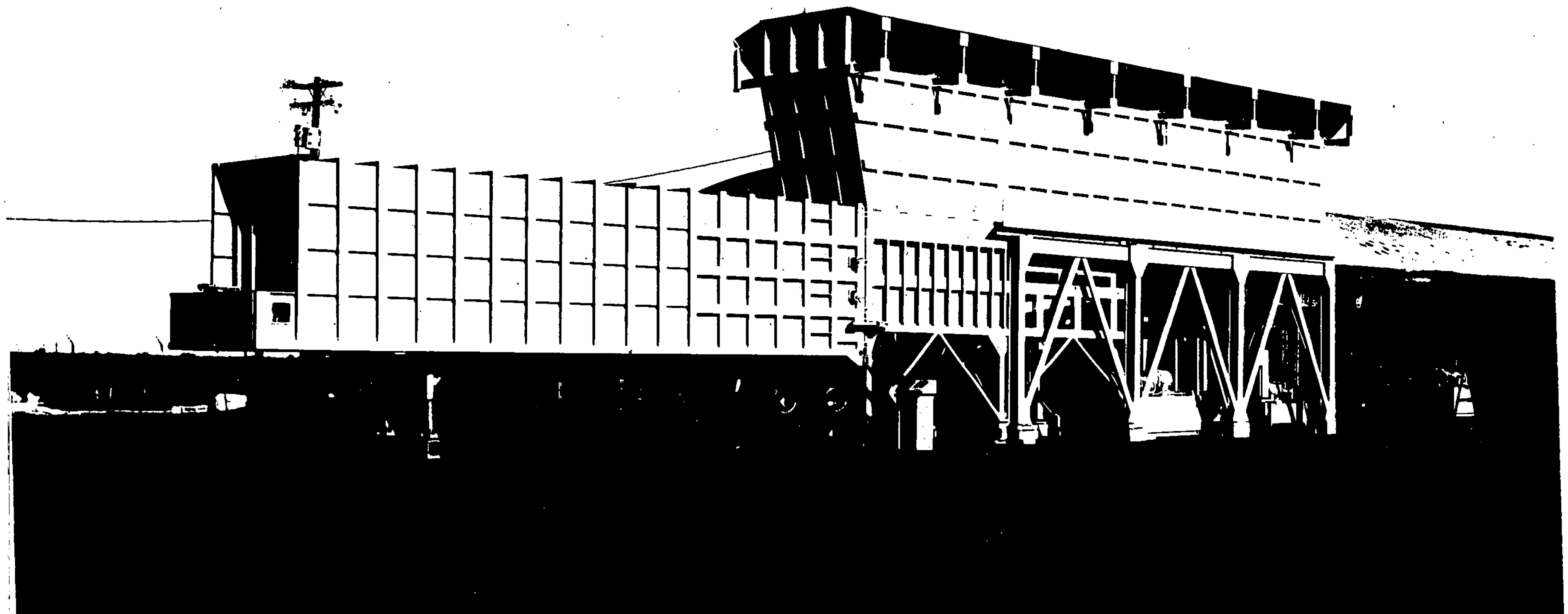

Figure 46. This portable steel push-pit system for charging solid waste into a stationary compactor hopper is shown independent of the transfer station to illustrate the construction.

rear door of the trailer but through a smaller area equipped with double dutch doors. At the disposal site the entire rear section is opened and the ejection bulkhead pushes out the load (Figure 47).

Some trailers utilize the load-ejection bulkhead as a packing plate during loading. The waste forced in by the compactor is compressed against the bulkhead until enough pressure is obtained to force the bulkhead slowly to the rear. In other systems, the bulkhead is not used but remains in the front part of the trailer. Compaction is obtained only when the trailer is nearly full and the last several cycles of waste are forced against the preceding ones. Because nearly all the compaction is obtained at the rear of the trailer with this system, horizontal as well as vertical reinforcing of the walls is required to handle the pressures produced. Most stationary compactor systems utilize a light on the control panel to indicate when a preset resistance is met by the reciprocating ram. This warns the operator as to when the trailer is nearly full. A booster cycle can then be switched on which increases the hydraulic pressure several hundred lb per sq in. The increased pressure is used to force in the last compactor charge of waste. Operators of stationary compactor systems have indicated that care is required in loading the trailers because fine material tends to drop from the lip of the compactor at the rear of the trailer and cause overweight conditions on the rear axle.

An electrically driven hydraulic system is used to power the stationary compactors. If hydraulic push-pits are used they are usually driven by a separate electric motor. The hydraulic ejection bulkhead

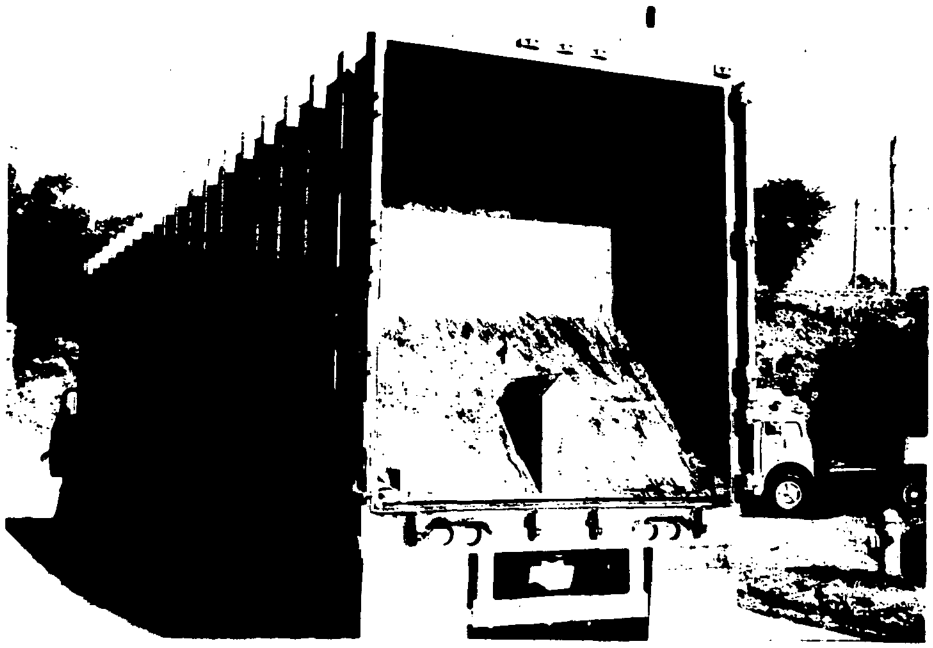

Figure 47. An ejection bulkhead utilized on a compaction transfer trailer pushes the waste out through the rear doors.

of the trailer is driven either by a wet-line kit to the power take-off of the tractor or by a stationary gasoline motor mounted on each trailer.

The stationary compactor transfer system requires that the trailers be backed into position to be attached to the compactors. Therefore ample turnaround space must be provided. Incoming vehicles must also back into position to unload into the compactor hopper or into the storage area.

In large stationary compactor transfer stations, traffic flow is sometimes controlled with a colored lighting system. The compactor operator flashes a light to signal incoming trucks to a dumping stall. In addition, transfer vehicle positioning is often done with tractors specially designed only to move trailers around the yard (Figure 48). The yard tractors move the full trailers to a pick-up area and replace them with an empty trailer. The haul tractors can then spend all their time moving between the station and the disposal site (Figure 49). They leave their empty trailer in the designated area and pick up a full trailer and drive directly back to the disposal site.

The advantages of the stationary compactor transfer system are as follows: (1) maximum payloads can easily be obtained with uncompacted or compacted solid waste; (2) unloading of the trailers is very fast and efficient; (3) the enclosed nature of the trailer does not require that canvas or metal tops be handled with each loading and unloading; (4) the compactor can handle nearly all bulky material that can be placed in the hopper because of the large hydraulic force available; (5) the incoming waste usually receives minimum exposure because it is rapidly pushed into the sealed trailers.

Figure 48. Small yard tractors are often utilized for moving trailers into and out of loading position.

Figure 49. Conventional tractors are used for hauling transfer trailers to and from the disposal site.

The disadvantages of the system are as follows: (1) should the compactor fail, there is no other way of loading the trailer; (2) the extra dead weight of the ejection bulkhead system and required steel reinforcement effectively reduce maximum payloads; (3) the initial cost of the trailers is higher than open-top types and they usually require more maintenance; (4) a drive-through system for transfer trailer loading is not possible with current compaction systems; (5) if the majority of incoming waste is precompacted in collection trucks, the heavier enclosed trailer offers little advantage as maximum payloads can be achieved in lighter open top trailers with top tamping.

CHAPTER III

TRANSFER STATION COSTS

The basic logic for economically justifying a solid waste transfer operation was presented in Chapter I. In the present chapter some representative construction and operating costs will be presented based on information gathered in a field survey of several transfer stations throughout the United States. Unfortunately, in many cases data on the owning and operating costs were nearly impossible to extract from the existing accounting system. Various costs were interwoven and combined with costs incurred in solid waste collection and disposal activities. The importance of accurate cost accounting cannot be overemphasized as the existence of the transfer station is based solely on economics. A cost accounting system is presented in Appendix D. The two direct cost centers, namely, the Transfer Operations Cost Center and the Waste Transport Cost Center, developed in this accounting system will be used in the following discussions of owning and operating costs.

Construction Costs

Construction costs vary widely depending on locality, design and site improvement requirements. Any conventional type of building construction can be used to house the transfer facility once the desired transfer system and size is determined. In addition to the building itself, considerable expense for excavation and filling, foundations, utility provisions, access roads, fencing and landscaping is incurred. Some types of transfer operations such as stationary compactor or compaction pit systems require more detailed foundation work thereby increasing construction costs. If a site is not already owned, considerable cash outlay for land may be required.

A wide variety of building types was encountered during the survey ranging from none at all (open-air) to well-landscaped, aesthetically designed concrete and steel structures (Table 9). It is difficult to correlate initial cost to handling capacity. Although many of these transfer stations are underutilized, a definite design capacity is hard to place on any transfer station for several reasons. First, a major concern in designing for size is to minimize the time expended in unloading each incoming vehicle. Thus a sufficient number of unloading spaces must be provided, but each vehicle requires one stall whether it will unload 1 ton or 10 tons. If the facility is restricted to use by a fleet of standard-sized packer trucks, the capacity can be determined more easily. Second, it is not necessary for the waste to be loaded as fast as it is brought in when storage is available. A peak input period usually occurs in both the morning and afternoon, but during slack periods the peak loads can be quickly reduced. In addition, most transfer stations are seldom operated more than one shift per day but are flexible in that overtime can be scheduled when necessary to handle unusually heavy loads. Ultimately, of course, the maximum capacity of a transfer station is limited by the maximum rate with which the transfer vehicles can be loaded. For example, if

TABLE 9

CONSTRUCTION COSTS OF TRANSFER STATIONS EXCLUSIVE OF LAND AND EQUIPMENT

Location	Type	Year Constructed	Building material	Yearly tonnage handled	Cost*
Detroit, Michigan	Stationary compactor	1970	Brick and concrete	350,000	$ 863,420
Hamilton, Ohio	Stationary compactor	1970	Steel	3,800	115,000
Lancaster, Pennsylvania	Stationary compactor	1968	Steel	120,000	160,000
King County, Washington					
Algona	Direct dump-backhoe tamping	1968	Steel roof, no sides	29,000	177,000
Bow Lake	"	1960	Open-air	57,900	65,000
Factoria	"	1966	Steel roof, no sides	57,800	102,000
Houghton	"	1966	Steel roof, no sides	44,200	100,000
Kent	"	1960	Open-air	21,700	31,000
Northeast	"	1969	Steel roof, no sides	66,800	173,000
Renton	"	1964	Steel roof, no sides	42,300	124,000
Orange County, California					
Stanton	Direct dump-backhoe tamping	1961	Open-air	181,195	347,000
Huntington Beach	"	1963	Open-air	136,022	212,000
Anaheim	"	1966	Open-air	206,996	350,000
San Francisco, California	Compaction pit	1970	Steel	550,000	900,000
Seattle, Washington	Compaction pit				
North		1968	Concrete	190,000	900,000
South		1966	Concrete	160,000	700,000
S.E. Oakland Co., Michigan+	Direct dump	1971	Brick and concrete	160,000	1,500,000
Topeka, Kansas	Stationary compactor	1968	Steel	26,000	160,000

*All costs are indicative of the year in which the facility was constructed.

+To be opened in August 1971.

a stationary compactor can displace 10-cu-yd every 45 seconds, it could theoretically handle 800-cu-yd per hour but only if a transfer trailer is always in position and if the compactor can be fed continuously at the rate of 800-cu-yd per hour. This ultimate capacity is more difficult to determine in a direct-dump and compaction pit system.

In trying to estimate the cost of a transfer station per ton of handling capacity, difficulty is also encountered because of varying aesthetic requirements. Considerable extra construction cost will usually result from building in a residential neighborhood.

In summary, the desired transfer system must first be selected. This is followed by an estimation of the number of unloading stalls required to handle the anticipated peak incoming traffic flow. Then the necessary processing equipment to load the daily waste volume should be determined. Finally, a building aesthetically acceptable to the neighborhood and of dimensions suitable to house the operation should be determined so construction and site development costs can be estimated.

Construction cost figures for the type of transfer stations built in King County, Washington show that many other costs in addition to those for the structure itself are involved (Table 10). This station, which is typical of the seven in King County, can accommodate about 12 vehicles unloading simultaneously and is covered entirely by a roof but not completely enclosed (Figure 24). Backhoes are used for compaction in the two-level, direct-dump operation.

TABLE 10

CONSTRUCTION COSTS OF A

KING COUNTY, WASHINGTON, TRANSFER STATION

Item	Cost
Supervision, bond, insurance	$ 3,700.00
Excavation and filling	13,000.00
Asphaltic roads	12,500.00
Fencing	9,700.00
Steel guard rails	2,800.00
Concrete walls	17,000.00
Concrete slabs	10,200.00
Reinforcing steel	8,800.00
Steel building	29,800.00
Roofing and sheet metal	12,500.00
Painting	2,500.00
Plumbing, sewer, drainage	14,700.00
Electrical wiring and lighting	3,000.00
Landscaping	12,600.00
Miscellaneous items	1,000.00
State taxes	6,800.00
Architects and engineers fees	12,500.00
Total cost (except land)	$173,100.00

Equipment Costs

The equipment used in transfer stations falls into two major categories. The first is processing equipment which includes every device utilized in the transfer process and varies from system to system. The second is haul equipment which includes trailers, tractors, and unloading equipment.

Processing Equipment. Processing equipment requirements vary from none at all in the very simplest direct-dump systems to stationary compactors used in an enclosed trailer system. Each system will be listed below along with the processing equipment utilized.

Gravity Dumping from One Vehicle to Another - No Compaction. This system usually requires the use of a hopper to avoid spillage. The hopper should encompass the length of the open top transfer vehicle. No actual mechanical equipment is required, but maximum payloads are not obtained unless very dense waste is being handled.

Gravity Dumping from One Vehicle to Another Followed by Compaction with a Backhoe. In addition to the hopper used in the preceding method a mobile or permanently mounted backhoe is used. Small, permanently mounted, electrically powered backhoes cost from $5,000 to $10,000 but are seldom capable of producing the necessary compaction to achieve maximum payloads and serve mainly as load leveling devices. Larger electric stationary backhoes capable of producing up to 8,000 lb. of downward force cost between $20,000 and $30,000. Diesel or gasoline-powered mobile backhoes capable of exerting 8,000 to 10,000 lb. of downward force cost about $40,000. If a floor storage area is used in conjunction with the transfer system to handle peak loads the waste is pushed into the hoppers with ordinary rubber-tired, front-end loaders.

Compaction Pit System. This system requires a crawler tractor to compact the waste in the storage pit and push it into the open-top trailers. The compaction pit system requires the use of crawler tractors ranging in price from $30,000 to $70,000 depending on the size of the operation. A backhoe similar to those listed above is also used to distribute the loads but is seldom needed for compaction purposes.

Internal Compaction Trailer System. This system requires only a hopper over the opening in the front of the trailer. The compaction is achieved entirely within the trailer. These trailers cost from $23,000 to $26,000. If floor storage is used with the system the hoppers are loaded with ordinary rubber-tired, front loaders.

Stationary Compactor Systems. The compactors are usually sold as a package with various-sized hoppers available. With hoppers and all accessories, the compactor units range in cost from $20,000 to $24,000. The compactors can be fed in various ways as discussed in the previous chapter. The cost of push pits starts at about $8,000, and the cost of conveyor feed systems varies considerably depending upon such specifications as length, width, and feed rate.

The cost of scales which might be used in any type of transfer station varies widely with such specifications as length, capacity and automatic features. As an example, the cost of a 30 ton capacity scale that could be used for weighing incoming vehicles would be about $10,000.

Haul Equipment. Two basic types of haul vehicles are utilized in truck-transfer operations. The first is the open-top trailer associated with direct-dump and compaction pit systems; the second is the enclosed trailer manufactured specifically for use with either an internal compaction system or a stationary compactor system. Both types of trailers can be pulled by any conventional haul tractor.

Unlike the enclosed trailer with its built-in hydraulic bulkhead unloading system, the open-top trailer requires that some unloading system be designed to fit the operation. The simple crossed cable or cargo net pullout systems require little capital expenditure but are somewhat inefficient, and landfill tractors must leave their spreading and compaction tasks to pull the loads from the transfer trailers.

As discussed in the preceding chapter, the unique unloading systems used in San Francisco and in King County, Washington require expenditures for auxiliary machines. The hydraulic tippers used in San Francisco cost approximately $72,000 each while the modified hydraulic scooper of King County costs about $130,000.

Single, open-top trailers of 90 to 110 cu yd capacity cost $12,000 to $18,000 depending on construction material (i.e., stainless or ordinary steel). Double trailer units with a combined capacity of 120 to 145 cu yd cost $12,000 to $20,000. The San Francisco aluminum transfer vehicles consisting of a truck with a body of 70-cu-yd pulling a 73-cu-yd trailer cost about $43,000 each. The flat-bed trailers used in King County cost approximately $5,000 and each container about $3,000, giving a total cost of about $11,000 for the 84-cu yd configuration.

Enclosed trailers utilizing internal compaction list for $23,000 to $26,000 depending on capacity and the hydraulic power system used (i.e., auxiliary gasoline engine or power take-off kit). Enclosed trailers utilized with stationary compactors cost $18,000 to $22,000. Trailers range in size from 60 to 80-cu yd. When several units are purchased, bid prices are usually several thousand dollars less than list prices.

Diesel haul tractors usually cost $16,000 to $17,000 each. All transfer station authorities advised against the use of gasoline tractors because of excessive fuel costs and maintenance problems.

Owning and Operating Costs

Total costs per ton for transfer and haul vary widely depending primarily on wage rates, efficiency of operations and haul distances. The range of costs for operations surveyed was $2.25 to $4.50 per ton. This includes all costs incurred both in the transfer station operation and in the long-haul operation (Table 11). Total costs were broken down into transfer station operation and haul operation cost centers when existing data permitted. It must be kept in mind, however, that haul cost varies directly with the haul distance. No cost data were obtained at several of the transfer stations surveyed because of inadequate accounting procedures.

The cost of operating a transfer station varies with the degree of service rendered and the type of financing used for the operation. If the station is open to the general public and user charges are levied, additional billing, accounting and weighing expenses are incurred. The

TABLE 11

OWNING AND OPERATING COSTS OF TRANSFER STATIONS*

Location	Transfer Station Cost ($/ton)	Haul Cost ($/ton)	Total Cost ($/ton)
Hamilton, Ohio	-	-	$3.40 (est.)
Lancaster, Pennsylvania	-	-	2.23
King County, Washington+ (average of 7 stations)	$2.19	$2.38	4.57
Orange County, California			
Stanton	-	-	2.93
Huntington Beach	-	-	2.91
Anaheim	-	-	2.82
San Francisco, California	1.88	1.76	3.64
Seattle, Washington (both stations)	1.23	1.55	2.88

*These cost figures were obtained from interviews with the respective operating authority.

+1968 figures.

most efficient and economical type of transfer station is that which is run only as part of the collection operation of a city or contractor. Waste loads and incoming traffic flow are relatively predictable and billing services are not required.

As was discussed in the previous chapter, the efficiency of operation from the standpoint of carrying maximum payloads on each trip can affect total costs substantially. Scales for weighing transfer vehicles can therefore be a valuable tool in reducing haul costs because both light loads and possible delays and fines resulting from overweight conditions are eliminated.

From records available, a further breakdown of the costs proved very difficult, but interesting information was gleaned from various sources. For the seven transfer stations operated by King County, Washington, some complete data for 1968 were obtained (Table 12). The rather high costs can be explained in part by the fact that all seven stations render a great deal of service as they are open to the public seven days per week and are financed by user charges. Solid waste from all seven stations is hauled to one landfill resulting in a long travel distance from several of the installations. For all seven stations the average round-trip hauling time is 89.2 minutes of which 73 percent is in travel time, 12 percent is unloading time and 15 percent is loading time at the station.

The following costs pertaining to transfer vehicles were obtained from Orange County, California, where open-top, double-trailer diesel rigs are utilized in an open direct-dump system. For vehicles with

TABLE 12

1968 COST BREAKDOWN FOR SEVEN TRANSFER STATIONS IN KING COUNTY, WASHINGTON

Transfer station operation cost center

Item	Cost/ton ($)
Operation	$1.67
Depreciation	0.12
Construction and modification	0.02
Overhead	
Administrative	0.18
Facilities and equipment	0.20
Total	2.19

Waste transport cost center

Item	Cost/ton	Cost/mile	Cost/ton/mile	Cost/ton/minute
Wages, salaries and benefits	$1.12	$0.41	$0.025	$0.013
Equipment operation	0.26	0.09	0.006	0.003
Equipment maintenance	0.19	0.07	0.004	0.002
Depreciation	0.42	0.15	0.009	0.005
Overhead				
Administrative	0.18	0.06	0.003	0.002
Facilities and equipment	0.21	0.07	0.004	0.002
Total	2.38	0.85	0.052	0.027

Extracted from King County Solid Waste Disposal For 20/20 Vision Volume II, December 1970.

less than 24,000 miles the fuel cost is $0.040 per mile; the depreciation is $0.070 per mile; and the maintenance, including tires, is $0.110 per mile. For vehicles with over 180,000 miles the fuel cost is $0.042 per mile, the depreciation cost is $0.048 per mile, and the maintenance cost including tires is $0.160 per mile. These figures are based on averages for the entire fleet. Transfer-vehicle fuel consumption for all operations surveyed ranged between four and six miles per gallon. The vehicles are usually amortized over a 6 to 8-year period.

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APPENDIX A

LOCATION AND OTHER CHARACTERISTICS OF TRANSFER STATIONS IN THE UNITED STATES*

State	City or region	Year operation began and ownership	Miles to disposal site	Annual tonnage
Alabama	Decatur	1969, public	-	-
California	Alhambra	- private	8	2,000
	Beverly Hills	- public	11	27,000
	Chico	Under construction	-	-
	Colusa	1970, public	-	-
	Dominguez	1970, private	-	-
	Fresno	1968, private	-	33,000
	Hollywood	- private	-	500
	Los Angeles			
		1950, private	40	600
		1950, private	40	600
		1950, private	30	1,250
		- private	-	500
		- private	-	500
		- municipal	-	14,000
		1969, private	-	-
	Lovelace	1963, private	-	11,000
	Lynwood	1966, private	25	3,600
	Orange County			
	Anaheim	1966, public	13	207,000
	Huntington Beach	1963, public	15	136,000
	Stanton	1961, public	25	181,000
	Oroville	1969, private	-	15,000
	Sacramento	1959, private	23	31,000
	San Francisco	1970, private	32	730,000
	Santa Barbara Co.	1967, public	22	146,000
	Santa Monica	1959, public	10	52,000
	South Gate	1959, public	20	68,000
	South Lake Tahoe	Under construction	-	-
	So. San Francisco	Under construction	-	-
	Wilmington	1967, private	8	6,250
Colorado	Colorado Springs	- private	12	400
	Denver	1965, municipal	13	30,000

State	City or region	Year operation began and ownership	Miles to disposal site	Annual tonnage
Connecticut	Middlebury	1966, private	-	4,000
	Orange	1970, private	-	7,000
	Westport	- public	-	20,000
Delaware	Kent County	- public	-	-
Florida	Delray Beach	- public	22	-
	Fort Lauderdale	- -	-	-
	Hollywood	- public	-	-
	New Smyrna Beach	1970, public	24	15,000
	Orange Co.	Under construction	-	220,000
	Palm Beach	- public	10	-
	Pompano Beach	- private	-	-
	West Palm Beach	- public	7	-
	Winter Park	1961, public	-	-
Georgia	Chamblee	1966, public	16	11,000
	Doraville	1966, industrial	12	-
	Forrest Park	- -	-	-
Illinois	Chicago	- private	-	-
	Chicago	- private	-	-
	Rosemont	1970, private	-	-
	Wilmette	1965, public	8	20,000
Indiana	Fort Wayne	1970, private	-	-
	Kokomo	1969, private	-	-
	Muncie	1970, private	-	-
Kansas	Kansas City	1970, private	-	-
	Topeka	1969, public	11	18,000
Kentucky	Bellevue	1969, public	-	-
	Louisville	1968, private	-	-
Louisiana	Gretna	Under construction	-	20,000
	Metairie	1970, private	-	40,000
Maryland	Baltimore			
		1969, private	-	37,000
		1971, private	-	15,000
Massachusetts	Arlington	1969, public	-	39,000
	Bedford	1969, public	14	-
	Boston	1969, private	-	-
	Medford	1969, private	15	31,000
Michigan	Birmingham	1971, public	12 1/2	200,000
	Dearborn	1966, public	26	50,000
	Detroit			
	State Fair	- public	-	-
	Southfield	1970, public	30	400,000
		- private	-	-
		- private	-	-
	Flint	1970, private	-	-

State	City or region	Year operation began and ownership	Miles to disposal site	Annual tonnage
	Highland Park	- -	-	-
	Lincoln Park	1966, public	25	20,000
	Monroe	1970, private	-	-
	Redford Township	1969, private	15	-
	Trenton	- public	-	-
	Wyandotte	1964, public	25	40,000
Minnesota	Blaine	1971, private	-	-
	Grant Township	1971, private	-	-
	Minneapolis			
		1968, private	15	80,000
		1971, private	-	-
	Minnetonka	1969, private	23	-
	New Brighton	1968, private	-	-
	Osseo	1969, private	17	-
	So. St. Paul	- private	-	-
Missouri	Jefferson City	1969, private	6	16,000
	North Kansas City	1967, private	25	5,000
	University City	1970, public	15	24,000
Nevada	Reno	1963, private	11	-
New Jersey	Bloomingdale	1968, public	-	-
	Bound Brook	1966, public	-	-
	Englewood	1967, public	-	-
	Kenilworth	1969, public	-	-
	Park Ridge	1969, public	-	-
	Piscataway Tnwp.	1966, public	14	100
New York	Harrison	1970, public	-	-
	Hempstead	1969, public	12	-
	Larchmont	1969, public	-	-
	Mamaroneck	1969, public	-	-
	Millford	1965, public	-	-
	Mt. Vernon	1969, public	-	-
	New Rochelle	- -	-	-
	New York City			
	(9 Marine)	1937, public	13	272,000
		1939, public	22	333,000
		1939, public	20	90,000
		1950, public	17	294,000
		1954, public	27	355,000
		1955, public	23	343,000
		1955, public	20	355,000
		1958, public	25	170,000
		1965, public	16	225,000
	Port Chester	1966, public	27	-
	Rochester	Under construction	-	-
	West Seneca	1967, public	-	-
	Yonkers	1969, public	-	-

State	City or region	Year operation began and ownership	Miles to disposal site	Annual tonnage
North Carolina	Kannapolis	1970, private	-	-
Ohio	East Cleveland	1963, public	-	-
	Euclid	1967, public	-	13,000
	Girard	1962, private	-	7,000
	Hamilton	1970, public	10	36,000
	Lakewood	1931, public	12	31,000
	Madison Twnp.	- public	-	-
	Parma	1956, public	-	15,000
	Pepper Pike	- public	-	-
	Rocky River	1967, public	30	18,000
	Shaker Heights	- public	-	-
	Warren	1967, private	-	31,000
	Youngstown	Under construction	-	-
Pennsylvania	Erie			
		1970, private	-	-
		1970, industrial	16	-
	Lancaster	1968, public	17	100,000
	Pittsburgh	1966, private	18	62,000
	Norristown	1967, private	22	-
	Washington Twnp.	1969, public	-	-
Tennessee	Chattanooga			
		1964, public	18	27,000
		1964 public	24	5,200
	Johnson City	1960, public	5	156,000
Texas	Abilene	1961, public	7	94,000
	Arlington	1963, private	5	12,000
	Dallas	1969, public	29	36,000
	El Paso	1962, public	14	-
	McAllen	- -	-	-
	Sherman	1968, public	-	-
	Tyler	1967, public	7	-
Washington	King County			
	Algona	1968, public	21	30,000
	Bow Lake	1960, public	17	60,000
	Factoria	1966, public	16	55,000
	Houghton	1966, public	25	45,000
	Kent	1960, public	20	13,000
	N.E. Seattle	1960, public	36	68,000
	Renton	1964, public	12	44,000
	Seattle			
	Seattle North	1968, public	22	190,000
	Seattle South	1966, public	13	160,000
West Virginia	Huntington	- -	7	-
Wisconsin	Marshfield	1970, private	22	-
	Milwaukee			
		1971, private	-	-
		1971, private	-	-

*This list of locations is nearly complete; however a few installations may be omitted, especially those that might have gone into operation in late 1971.

APPENDIX B

MANUFACTURERS OF TRANSFER STATION EQUIPMENT SYSTEMS*

American Solid Waste Systems
63 South Robert Street
St. Paul, Minnesota 55107

Atlas Hoist and Body, Inc.
7600 Cote de Liesse Road
Montreal 376, Quebec

S. Vincen Bowles, Inc.
12039 Branford Street
Sun Valley, California 91352

Dempster Brothers, Inc.
P.O. Box 3127
Knoxville, Tennessee 37917

Elgin Leach Corporation
222 West Adams Street
Chicago, Illinois 60606

E-Z Pack Company
Division of Peabody Galion
Galion, Ohio 44833

The Heil Company
3000 West Montana Street
Milwaukee, Wisconsin 53201

Hobbs Trailers
609 North Main
Fort Worth, Texas 76106

Industrial Services of America
Tri-Pak Division
P.O. Box 21-070
7100 Grade Lane
Louisville, Kentucky 40221

Pak-Mor Manufacturing Co.
1123 S.E. Military Drive
P.O. Box 14147
San Antonio, Texas 78214

*Inclusion or exclusion of any manufacturer does not mean endorsement or lack of endorsement by the Office of Solid Waste Management Programs, EPA.

APPENDIX C

SPECIFICATIONS FOR STATIONARY COMPACTORS AND ENCLOSED TRANSFER TRAILERS

The following figures give a range of values found on currently manufactured equipment.

Stationary Compactors

Capacity	9-11 (cu-yd/cycle)
Cycle time	28-48 (sec)
Total ram force	90,000-120,800 (lb)
Hydraulic pump capacity	65-150 (gal/min)
Electric power unit	40-60 (hp)
Distance ram travels into trailer	13-50 (in.)
Hydraulic cylinder stroke	8-10 (in.)
Hydraulic cylinder diameter	30 ft long x 10 ft wide x 5 ft high
Dimension	

Transfer Trailers

Capacity	60-75 (cu-yd)
Empty weight	22,500-27,500 (lb)
Length	32-40 (ft)
Width	8 (ft)
Height	145-162 (in.)
Axle capacity	20,000-25,000 (lb)
Ejection thrust	78,000-100,000 (lb)
Ejection cylinder diameter	7-8 1/2 (in.)
Ejection cylinder stroke	trailer length

APPENDIX D

AN ACCOUNTING SYSTEM for transfer station operations

Eric R. Zausner*

The increasing costs and complexities of solid waste handling require new, more sophisticated management techniques. Data on performance and the costs of operation and ownership are essential for the use of these management tools. A good information system is, therefore, a prerequisite to effective management. Although cost accounting represents only one part of the total information system, its design, installation, and utilization can represent the most significant step in the development of an effective solid waste management program.

Present information on transfer stations activities and associated costs is both inadequate and nonstandardized. Furthermore, the use of transfer stations will continue to expand as urbanization causes increased concentrations of solid wastes and a scarcity of proximate disposal sites. The proposed system provides a guide to the type and quantity of information to be gathered, its classification, and the method of collection. It is intended to be of use to municipal or private personnel involved in transfer station operation and ownership.

* Formerly Chief, Management Sciences Section, Operational Analysis Branch, Division of Technical Operations.

Installation of a cost accounting system can help the transfer station manager control the costs and performance of operation and also plan for the future. The system can be implemented as presented or modified to meet the specific needs and problems of the potential user.

The relationship of the transfer station to the total solid waste management system is shown in Diagram I. The accounting procedure can be utilized with all types of transfer operations: compaction and noncompaction, truck transfer, and hauling by railroad cars or barges. In the last two cases, some provision may be needed to account for disposal charges.

System Benefits

Some of the more important advantages are:

1. The system facilitates the orderly and efficient collection and transmission of all relevant data. In fact, most of the data to be recorded are probably being collected already, although perhaps only sporadically and inefficiently. Hence, the added cost of installing the proposed system is minimal.

2. Reports are clear and concise and present only the amount of data required for effective control and analysis. They can be understood and completed easily by station personnel.

3. The data are grouped in standard accounting classifications. This simplifies interpretation of results and comparison with data from previous years or other operations. This, in turn, allows analysis of relative performance and operational changes.

4. The system accounts for **all** relevant costs of operations.

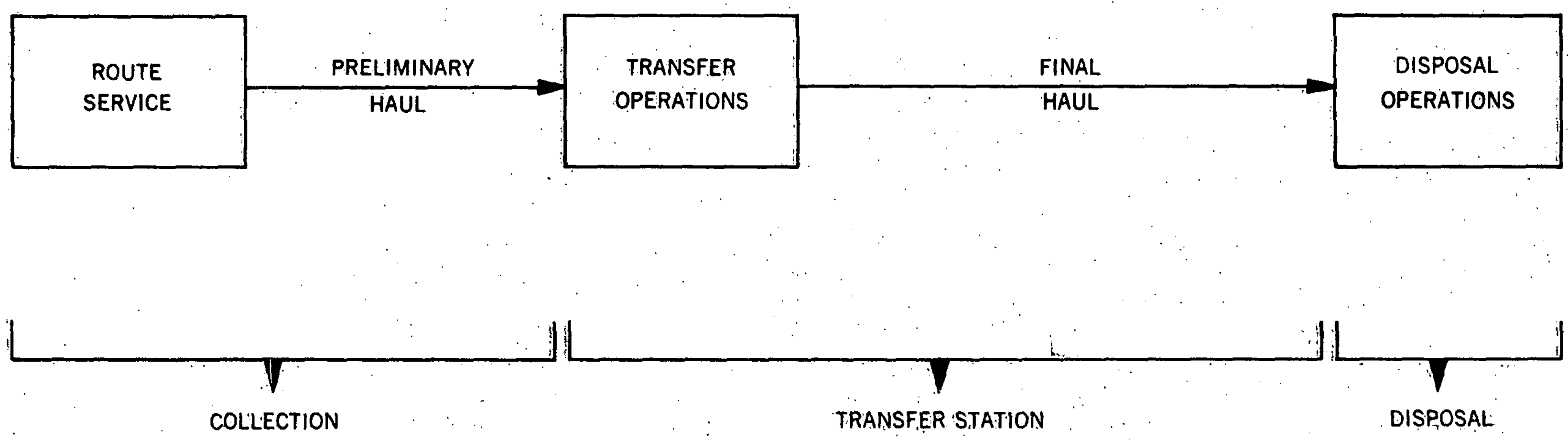
5. Because the system detects high costs and identifies their underlying causes, the supervisor can control expenses more effectively. Similarly, performance and efficiency may be monitored and controlled.

6. Accountability is superimposed on the system to indicate who or what is responsible for the increased costs.

7. The data provided are in a form that aids in the short- and long-range forecasting of operating and capital budgets. Requirements for equipment, manpower, cash, etc., can be

DIAGRAM I

SOLID WASTE MANAGEMENT SYSTEM



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estimated to aid budgeting and planning at all levels of management. The data are also available for later evaluation and analysis using operations research techniques.

8. The system, with only minor modifications, is flexible enough to meet the varying requirements of different sizes of transfer stations.

Cost Centers and Cost Allocation

The complexity of transfer station operations requires a breakdown and description of operations to facilitate analysis. In this presentation, the transfer station is assumed to consist of several interrelated suboperations, each of which is analyzed separately. These suboperations are called cost centers because expenses are accumulated separately for each of these functional activities (Diagram II). Analysis and control are simplified if excessive costs or inefficiencies can be traced to a functional activity or area of the facility.

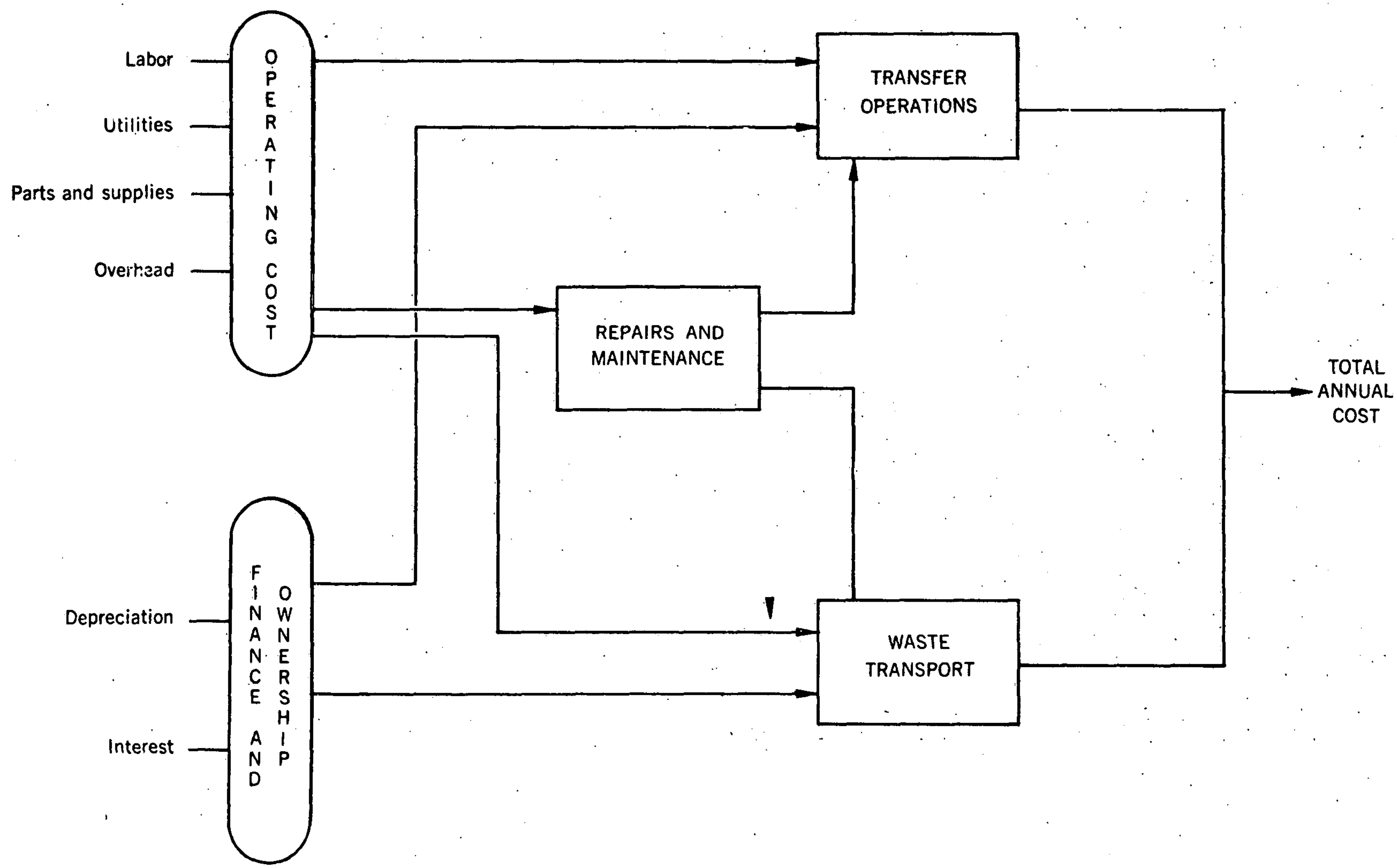
The number of cost centers required increases as the size and complexity of operations increase. Additional cost centers, however, require the collection of more data, and this increases costs. In most cases, transfer operations would include activities at the transfer station as well as the final haul to the disposal site. In this event, three cost centers would probably be able to gather adequate information without incurring excessive data collection costs. The Transfer Operations cost center and the Waste Transport cost center are called direct cost centers because they are directly associated with transfer and haul operations. Repairs and Maintenance is an indirect cost center. All repairs and maintenance expenses are accumulated in it and then allocated to the other centers based on the amount they have incurred. Because repairs and maintenance costs can be a large percentage of total expenses, the use of a separate center focuses attention on this critical area.

If railroad cars or barges are used, the cost of the final haul may not be included in a separate center but be accounted for as a total charge for both final haul and disposal.

The centers classify costs by one of two functions—operations and financing and ownership. Operating costs include

DIAGRAM II

COST CENTERS AND COST ALLOCATION



labor, parts and supplies, utilities, external charges, and overhead. Financing and ownership costs consist of depreciation and interest. Table I summarizes these costs and presents brief definitions of each.

There are many alternatives for actually allocating operating costs. A straightforward method for each type of expense will be outlined. Labor charges should be allocated to the cost centers based on the number of hours employees worked in each and on their respective wage rates. Parts and supplies include oil and gasoline as well as any materials used for repairs and maintenance. Oil and gasoline costs are assigned directly to the Waste Transport cost center because they are incurred by its vehicles. All other parts and supplies are allocated to each direct cost center after being recorded in the Repairs and Maintenance cost center. Repair charges levied by other municipal departments or private firms are also allocated to the direct cost centers after being recorded in the indirect cost center. Utility costs are incurred by the Repairs and Maintenance and the Transfer Operations cost centers. These expenses can be divided between them on the basis of an engineering estimate or, for simplicity, they can be assigned completely to the Transfer Operations cost center. General overhead, which includes supervision, administration and charges from other departments (payroll, accounting) can be allocated equally to each cost center or on the basis of the number of employees each has.

Finally, costs accumulated in the Repairs and Maintenance cost center are allocated to the two direct cost centers based on the expenses each has incurred. Their sum is the total operating cost.

Capital costs are easily associated with each of the direct cost centers. For instance, the capital cost of transfer vehicles can be associated with the Waste Transport center, while the purchase of scales can be included in the Transfer Operations cost center. Depreciation for each center can be calculated with these capital costs and estimates of their expected useful lives. Total interest cost can be allocated based on the proportions of capital utilized in each center.

These allocation procedures are illustrated in Diagram II.

TABLE I
SUMMARY OF COST TYPES

Labor (1)	________	
Parts and supplies (2)	________	
Utilities (3)	________	
Overhead (4)	________	
TOTAL OPERATING COSTS		________
Depreciation (5)	________	
Interest (6)	________	
TOTAL FINANCING AND OWNERSHIP COSTS		________
TOTAL COSTS		________

(1) Labor includes all direct wages, overtime pay and fringe benefits. Fringe benefits include the costs of group insurance, social security, pensions, vacation benefits, etc.

(2) Parts and supplies include oil, gas, grease, repair parts, miscellaneous supplies, etc.

(3) Utilities include electric, natural gas, water, etc.

(4) Overhead includes supervision, payroll and accounting services by other departments, liability and property insurance, taxes, and external charges. External charges include audits, contractual services, etc., when they are performed by other municipal departments, private contractors or consultants.

(5) Depreciation may be calculated using either straight line or accelerated methods.

(6) Interest should represent actual costs of funds.

The actual system is designed to facilitate the accumulation and allocation of costs to the centers.

Forms and Reports

Information flows through the cost system by way of eight reports (Diagram III). They transmit data collected in the field for use at various levels of supervision and management.

The reports are most easily grouped into those that are primarily used to collect data on operations and those that are used to reduce and analyze for decision making and control.

Reduction and presentation cannot be accomplished unless all pertinent activities and cost information are recorded daily. If this is not done, the data cannot be retrieved later. Transfer station personnel, supervisors, and others involved in operations primarily use Forms 1 through 4 to record the data required.

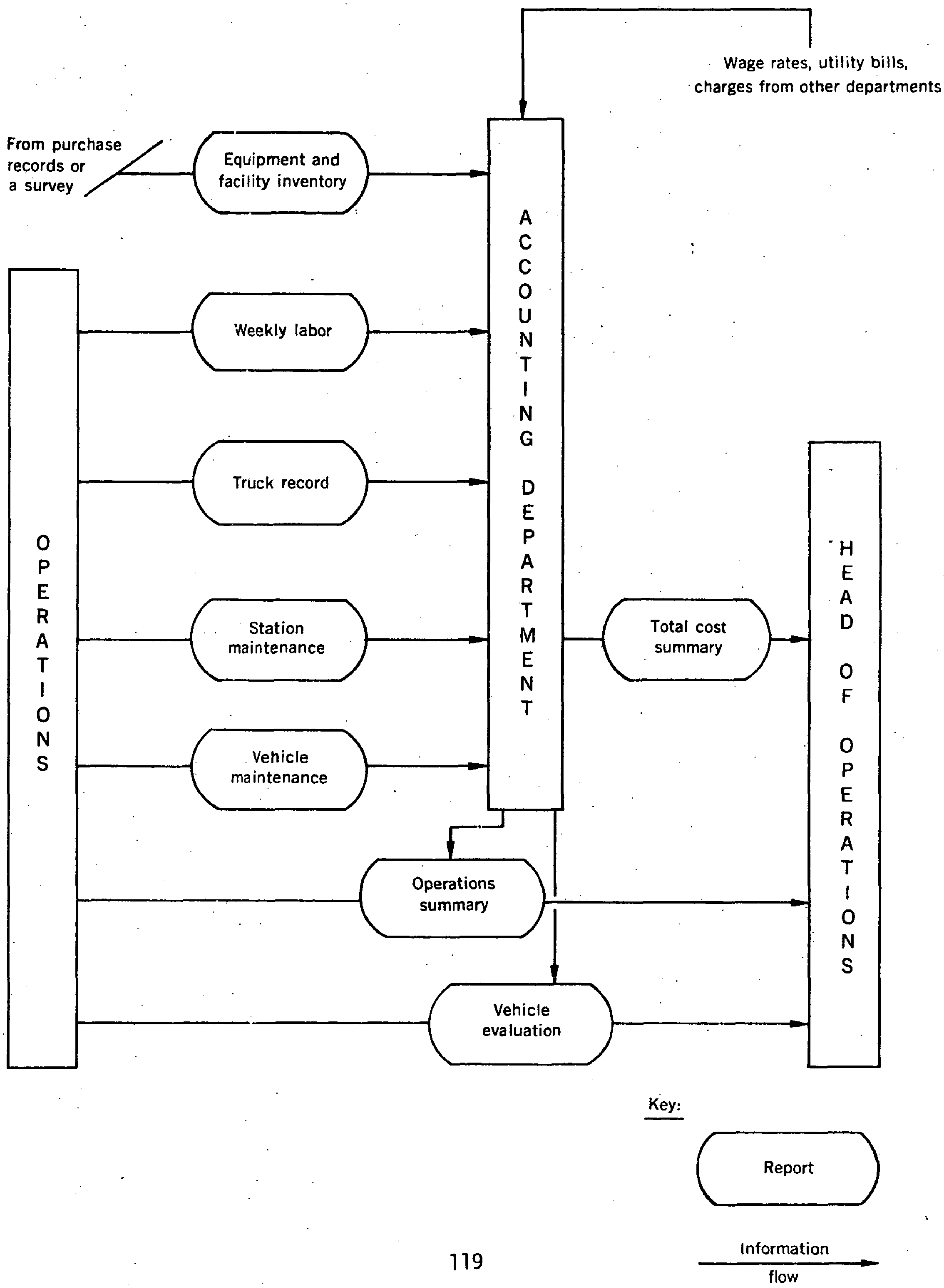
Weekly labor report (Form 1). Daily entries of labor activity are recorded in duplicate at the site by the foreman or supervisor. One copy is forwarded to the payroll department for determining weekly wages. The supervisor or the accounting department uses the other copy to compute the total hours worked and to assign the time and associated costs to the cost centers.

Daily truck record (Form 2). This form shows the quantities, sources, and types of solid waste delivered to the transfer station. The number, identification, and net weight of outgoing transfer vehicles are also recorded. Each delivery or departure is entered by the weighmaster. The form is forwarded to the accounting department at the end of each month. In addition to using recorded weight data to bill public and private users later, the sources and types of waste data are useful in special analyses of trends, compositions, and distributions of solid wastes in the community.

Transfer station maintenance record (Form 3). This form accumulates the activities and associated costs of repairing and maintaining the transfer station. Entries are made only when repairs are undertaken. These data are particularly useful in anlyzing maintenance department performance,

DIAGRAM III

REPORTS AND INFORMATION FLOW



FORM 1

WEEKLY LABOR REPORT

TRANSFER STATION
IDENTIFICATION ______________________________

DATE: ______________________

Employee ident.	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Individual totals	Note causes and hrs. of absence, etc.
	Cost center*	Hrs.	Cost center	Hrs.	Cost center	Hrs.	Cost center	Hrs.	Cost center	Hrs.	Cost center	Hrs.	Cost center	Hrs.		
TOTALS	X		X		X		X		X		X		X			XXXXXXXXXXXX

Instructions: Transfer station supervisor to complete this form daily. List all employees separately, including temporary help. "Hrs." refers to hours worked daily. At the end of the week forward one copy to the payroll department and retain the original for further use.

*For this column TO, WT, or R&M could be used to indicate the cost center in which each employee is working. For more accuracy, the following classifications are suggested:

D (driver), VM (vehicle maintenance), SM (station maintenance), W (weighmaster), F (foreman), S (supervisor), O (compacting equipment operator), C (clerk).

FORM 2

DAILY TRUCK RECORD

TRANSFER STATION ____________________ DATE: ___/___/___

SIGNATURE ____________________

No.	Truck ident.*	Time	Incoming wastes		Weighted load	Weight empty or tare wt.	Net amount of wastes	
			Source	Type			Incoming	Outgoing
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
TOTALS		X	X	X	X	X		

Instructions: To be completed by weighmaster for each delivery of wastes or departure of transfer vehicle.

Symbols:

Source: R (residential), C (commercial), I (industrial)

Type: T (tires), G (garbage), etc.

*Truck ident. is # of public truck; if private vehicle list name of company for billing purposes. Also identify transfer vehicles by number, driver's name, and type (barge, railroad car, etc.).

FORM 3

STATION MAINTENANCE RECORD

STATION IDENTIFICATION ______________________________ For Period ______________________

Date	Equipment or part of facility repaired	Type repair	Hrs. station was down	Labor hrs.	Parts description	Labor cost	Parts cost	External charges	Overhead cost	Total

equipment availability, and equipment repair costs in the Transfer Operations cost center.

Vehicle maintenance record (Form 4). This form accumulates the activities and associated costs incurred in maintaining the transfer vehicles. A separate sheet is kept for each vehicle, and entries are made only when maintenance or repairs are undertaken. These data are useful in analyzing individual truck efficiencies and repair costs in the Waste Transport cost center. The data on this form and those on Form 3 represent the overall activity and costs in the Repairs and Maintenance cost center.

Equipment and facility inventory (Form 5). This form is completed when construction is finished or when the cost system is first implemented. It is updated only when improvements or new equipment are constructed, purchased, or sold. In addition to collecting the data required to calculate depreciation for the period and allocating it to cost centers, the form also summarizes the bond and interest information needed to arrive at total costs of financing and ownership.

Forms 6 through 8 are completed less frequently; these intervals depend on the type of information transmitted. To be effective, certain types of control and analysis require more frequent feedback than others. Forms 6 through 8 reduce the data contained in the first five as well as other information available to the accounting department.

Operations summary (Form 6.) This report summarizes system operations and its associated operating costs. The report can be for the whole system or for individual stations, since it is a critical cost control mechanism. The report should be prepared monthly. The accounting department compiles it and forwards copies to the supervisor and the head of the sanitation department. The total unit costs presented, as well as unit costs for the various centers, indicate where excessive expenses were incurred. In addition, various measures of efficiency are shown to isolate the cause or causes of high operating costs. For instance, "tons/number of trips to the disposal site" adequately measures truck utilization in the Waste Transport cost center. This measure can help improve scheduling and reduce costs.

FORM 4

VEHICLE MAINTENANCE RECORD

TRUCK IDENTIFICATION ______________________ For Period ______________

DATE	Odometer reading	Type of service or repair	Hrs. down	Labor hrs.	Description parts and supplies	Labor cost	Parts cost	External charges	Overhead (rate hrs.)	Total cost
TOTALS	X	X			X					

FORM 5

FACILITY AND EQUIPMENT INVENTORY

Date ____/____/____

Equipment description	Capacity (cu. yd.)	Model No.	Model year	Manufacturer's name	Date of purchase	Purchase price	Estimated life	Annual depreciation	Monthly depreciation
TOTAL	X	X	X	X	X		X		

Facility description	Description (quantity, size, etc.)	Date put in use	New cost	Estimated total life	Other comments	Annual depreciation	Monthly depreciation
Land						X	X
Buildings							
Equipment							
Site improvement							
Other							
TOTALS	X	X		X	X		

Financing Data

Bond type	Face value	Premium or discount	Interest rate	Yearly interest*	Monthly interest

*Interest must account for effect of premium or discount on bond sale.

FORM 6

OPERATIONS SUMMARY

For period ____________ to ____________

	Factor	Amount for this period	Percent variance from Budget	Percent variance from Budget last period
TOTALS	Tons received			
	Average tons/day operated			
	Total operating cost			
	Total operating cost/ton			
	Labor cost/ton			
	Parts and supplies cost/ton			
	Utilities cost/ton			
	External charges cost/ton			
	Overhead cost/ton			
TRANSFER OPERATIONS COST CENTER	"Cost center" cost/ton			
	Tons/hr. of operation			
	Percent volume reduction			
WASTE TRANSPORT COST CENTER	"Cost center" cost/ton			
	Tons/number of trips to disposal site			
	Labor hrs./ton			
REPAIRS AND MAINTENANCE COST CENTER	"Cost center" cost/ton			
	Repair and maintenance cost/hr. of operation			
	Waste transport percent			
	Transfer operations percent			
	Percent time vehicles down			
	Percent time station down			

Vehicle evaluation report (Form 7). This form is optional. It is not needed if barges or railroad cars are used because transport costs are incurred on a contract basis.

The data accumulated on this form represent the total and individual costs of operating the transfer vehicles. Statistics are accumulated separately for each piece of equipment, and this allows efficiency and cost to be evaluated. The data may also be used to determine when to sell or trade a vehicle. Since this decision involves long-term assets, only quarterly or semiannual reports are necessary. More frequent preparation would not substantially improve decision making that would minimize operating costs. It may be desirable, however, to prepare reports on a truck if it exceeds a given level of repair charges. For instance, each vehicle's repair expenses can be compared with the average for all the vehicles; when a vehicle exceeds this average by 25 percent or 50 percent, it can be singled out for further analysis. The accounting department, which prepares this form, sends a copy to the operational supervisor and the head of the sanitation department.

Total cost summary (Form 8). All the activities and costs associated with transfer system operations for a selected period are compiled on this report from data available in the Transfer System Operations Summaries and on the Facility and Equipment Inventory forms. The combined operating expenses and the depreciation and interest figures represent the total cost of operations for the period. The report also summarizes the sources and amounts of revenues associated with the system's operation. The accounting department can complete this form quarterly or semiannually and send it to the head of the sanitation department or his equivalent.

Report Flow Summary

A brief summary may help to put the system in perspective. The personnel directly engaged in transfer activities complete data accumulation forms daily and transmit them periodically to the accounting department. The latter collates the information and adds additional data it has on file to complete summary reports on performance, activity, and costs. These forms are then sent back to the supervisor for

FORM 7

VEHICLE EVALUATION

GARAGE ______________________________ For period __________ to __________

Equipment identification	Total miles	Hrs. down	Hrs. down/total hrs.	Repairs and maintenance cost	Fuel cost	Repairs and maintenance cost/hr.	Fuel cost/hr.	Total cost/hr.	Total cost
TOTALS	X		X			X	X	X	
AVERAGES	X								
BUDGET									

FORM 8

TOTAL COST SUMMARY

DISTRICT ______________________________ For period __________ to __________

DATA	FOR THIS PERIOD	BUDGET THIS PERIOD	CUMULATIVE (YEAR TO DATE)	BUDGET (YEAR TO DATE)
Tons of waste received				
Total operating cost				
Total financing and ownership cost				
TOTAL COST				
Operating cost per ton				
Financing and ownership cost per ton				
TOTAL COST PER TON				
Public revenues (participating communities)				
Private revenues (industry, etc.)				
Miscellaneous revenues				
TOTAL REVENUES				
TOTAL REVENUES PER TON				
NET COST (PROFIT)				
NET COST (PROFIT) PER TON				

control purposes. In addition, selected summary reports on total cost and equipment performance are compiled and forwarded to the supervisor and to his immediate superior.

System Utilization

Only with efficient and intensive utilization of the information generated by the accounting system and its forms can the additional time, effort, and money required to implement and maintain it be justified. The system's intensive use promotes two major objectives—quality control and cost control. Reduce costs must be accomplished without degrading operating quality. Similarly, quality is interrelated with the costs of obtaining it.

All the factors that affect the quality and effectiveness of transfer system operations can be translated into costs. Cost control does not call for economizing at the expense of quality. On the contrary, once an acceptable level of operations and costs has been achieved, the system can help the supervisor maintain it.

Effective control requires timely recognition and assignment of responsibility for any increased costs. Comparing unit costs (cost per ton of waste transferred) with the current budget and that for the corresponding period of the preceding year helps pinpoint excessive expenses. This approach facilitates the analysis of costs, independent of changes in the level of activity. Cost center breakdowns help single out the factor or person responsible for increased expenditures, and this allows corrective action to be initiated.

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APPENDIX E

SITE SURVEYS

Several selected transfer stations were surveyed during the study to observe the operation of the various types of transfer systems. Interviews with operating personnel were conducted and all available information on buildings, equipment and costs was gathered. As mentioned previously, very little cost information was obtained from some of the facilities because of poor cost accounting and record-keeping. A general description and summary of information follows for each site visited.

San Francisco, California

This privately owned transfer station was opened in November, 1970 to reduce the haul costs to a sanitary landfill site located 32 miles south of San Francisco near the community of Mountain View. A solid waste disposal crisis had developed when rail haul contract negotiations for transport to a remote desert landfill site had broken down. Mountain View needed tremendous volumes of fill material to continue development of its 550 acre recreational park adjacent to San Francisco Bay, and made a proposal to accept all of the solid waste of San Francisco for approximately five years. In light of its pressing needs, San Francisco accepted the offer as an interim measure to permit exploration of other options for a permanent solution.

The new transfer station was designed to handle approximately 5,000 tons per day over a 24-hour period. Currently, however, it is averaging about 2,000 tons operating 9 to 11 hours per day. The two largest collection contractors in San Francisco haul nearly all the residential solid waste and have joint ownership of the transfer station with a landfill company and an equipment company under the name of Solid Waste Engineering and Transfer Systems (SWETS). The facility is not open to the general public but serves only compactor trucks and various industrial vehicles. Users pay a fee of $6.55 per ton to cover all costs associated with transfer and disposal.

The transfer station utilizes a compaction pit system and has a storage capacity of about 4,000 tons in the pit. Seventeen incoming trucks can unload simultaneously, and an entrance and exit door is available on each side of the pit for smooth traffic flow (Figures 29 and 30). Unloading requires five to eight minutes from the time the vehicle enters the site until the time it leaves. A peak traffic load of about 100 vehicles per hour is easily handled without excessive delay.

A 200 x 180 ft clear span steel building equipped with a ventilation and sprinkling system encloses the unloading area. Two transfer vehicles are filled simultaneously in the loading area attached to one side of the building. The transfer vehicles have drive-through access and can be loaded in about five minutes; an unloading level, a storage level and a transfer vehicle loading level are utilized (Figure 29).

A D8 Caterpillar tractor is used in the storage pit to compact the waste and push it into the hoppers where it then falls into the open-top trailers. Originally, it was thought that two tractors would be necessary, but one tractor has been handling the 2,000-ton-per-day load in about 10 hours. An electric-powered hydraulic backhoe is mounted stationarily above each trailer to distribute and level the load. Maximum legal payloads have been obtained without utilizing the backhoes for compaction. Each transfer vehicle rests on an electronic recording scale while being loaded. This enables the backhoe operator to see exactly how much weight is in each vehicle at all times.

The transfer vehicles are specially designed aluminum body units; each consists of a truck with a 70-cu-yd body towing a 73-cu-yd trailer. The total weight of the rig is about 26,000 lb allowing 25.5-ton payloads to be carried on the five axles. This is the largest payload carried by any transfer vehicle in the United States. Fuel pumps are located in the loading area to permit refueling of the transfer vehicles while they are loading. About 2 hours are required to cover the 64-mile, round-trip distance to the disposal site. This includes unloading time which requires a minimum of 6 minutes. Most of the route involves travel on the Bayshore Freeway.

Two self-propelled tippers are located at the landfill for unloading the truck-trailer combinations. The trailer is backed onto one tipper and the truck uses the other. The waste slides out the rear doors as the truck or trailer is hydraulically raised to a near vertical position (Figure 27). Each of the 17 transfer vehicles makes about four trips per day to the disposal site.

All incoming vehicles are weighed on a 35-ft scale located in front of the plant. Both this scale and the two 65-ft scales on which the transfer vehicles are weighed are automatically tied into an IBM system for recordkeeping and billing purposes. A 6,000-sq-ft maintenance building for minor repair work and servicing is also located on the site. The following building and equipment cost figures were obtained in an interview with the general manager of SWETS.

Building proper		$550,000
Maintenance building & scale house		40,000
Site development		300,000
Scales		65,000
Total building cost		$955,000
Transfer vehicles	17 @ $43,000	$731,000
Landfill tippers	2 @ 72,000	144,000
Compaction tractors	1 @ 65,000	65,000
Backhoe	2 @ 21,000	42,000
Total equipment cost		$982,000

Of the $6.55 per ton charged for incoming solid waste, $3.64 is allocated for the transfer operation. They estimate that $1.88 per ton goes for transfer station operation and $1.76 goes for the haul operation. The remainder of the $6.55 per ton goes to the disposal operation.

A total of 23 men are employed in the operation; 16 are drivers and the remainder work at the transfer station. Labor rates are high in the area and with fringe benefits annual labor costs are roughly $400,000 for a 45-hour week.

The entire operation has been running smoothly. The open-top trailer and compaction system was chosen over a stationary compactor system because of the speed with which the compaction tractor can load the waste and because the lighter trucks can carry larger payloads. The one compaction tractor and two backhoes effectively replace the six to eight stationary compactors that would be required with that type of system. The additional investment in landfill unloading equipment, however, was required. A comparison between a large-volume compaction pit system and large-volume stationary compactor system is included in Appendix F.

Seattle, Washington

Seattle opened its South Transfer Station (STS) in 1966 and added the North Transfer Station (NTS) in 1968. Both stations utilize the same design and incorporate a user fee system. Solid waste disposal is operated as a self-supporting utility in Seattle but private haulers handle all collection. The Solid Waste Utility owns and operates the transfer stations and the sanitary landfill. Transfer station fees which also cover disposal are as follows: Loads from passenger cars without trailers are free for city residents and $0.50 per load for non-city residents. The minimum load charge for cars with trailers and all other vehicles is $1.25; bulk solid waste from private collectors and industry is charged at $4.50 per ton.

The transfer stations of the city of Seattle are unique in that separate provisions for unloading and processing have been made for incoming compacted and uncompacted wastes. Eight compactor collection trucks can simultaneously unload directly into the open-top transfer vehicles via a hopper, and a rubber-tired mobile backhoe is used to provide any necessary compaction and load leveling. Uncompacted waste is unloaded into a compaction pit where it is compacted by a track dozer and then pushed into an open-top transfer vehicle. About 10 vehicles can unload simultaneously in this area. Two trailers are loaded simultaneously from the direct-dump operation and one trailer is loaded from the compaction pit area. One backhoe serves all three trailers. The trailers are backed into position by small yard tractors to prevent the long-haul tractors from being tied up in the switching operation. No particular transfer vehicles are permanently assigned to either station but the haul operation is well coordinated to provide dispatching efficiency.

A total of 38 open-top 95-cu-yd transfer trailers and 18 haul tractors serve the two stations. The rigs travel about 44 miles round trip from the NTS and 25 miles round trip from the STS. Approximate round-trip times are 2 hours and 1.5 hour respectively including unloading. Pneumatically-operated steel lids cover the load during transit and the waste is pulled out through the rear with a cargo net and cable system. A landfill tractor provides the ejection power and the cables and net are repositioned with two small electrical winches. The maximum legal weight limit is 73,280 lb so the rigs which weigh about 32,700 lb can carry slightly more than 20-ton payloads.

In 1970 both stations handled a total of 17,704 loads, each weighing approximately 20 tons for a total of 354,000 tons. Falling economic conditions in the Seattle area have reduced this from a high of 19,164 loads in 1969. The best day for the NTS in 1970 was 760 tons and for the STS, 708 tons. Currently the NTS averages 700 tons (35 loads) per day and the STS averages about 600 tons (30 loads per day) Monday through Friday. Approximately 200 to 250 tons (10 to 12 loads) come out of both stations on weekends. Each station was designed with an ultimate capacity of 300,000 tons per year.

Both transfer stations are well landscaped and fenced, and incorporate an attractive concrete building design. The NTS is located on about 4-1/2 acres of land and the STS occupies about 7 acres, but the city feels that 4-1/2 acres is too small to permit easy maneuvering. The NTS is located in a residential area and presents a completely unoffensive appearance; one condition of its operation, however, is that all waste must be removed from the site at the close of each day. The NTS is open 9 hours per day on weekdays and 10 hours on Saturday; the STS is open 24 hours per day Monday through Friday, 17 hours on Saturday and 15 hours on Sunday. Hauling takes place 6 days per week with storage on Sunday. Because of the stipulation that waste be removed from the NTS at the end of each day, all storage must take place at the STS.

Approximate capital costs associated with buildings and equipment are:

North Transfer Station building and development cost exclusive of land	$900,000
South Transfer Station building and site development exclusive of land	$700,000
Vehicle washing center at South Transfer Station	$ 80,000
Transfer trailers	$ 10,000 each
Haul tractors	$ 17,500 each
Compaction pit tractors	$ 65,000 each
Compaction backhoes	$ 31,000 each
Yard tractors	$ 13,800 each

A detailed analysis of owning and operating costs was not possible because of the complex accounting system used. The city presented the following total cost breakdown:

Total haul cost for both stations	$1.55 per ton
Transfer cost at North Transfer Station	$1.23 per ton
Transfer cost at South Transfer Station	$1.95 per ton

The higher cost at the STS can be attributed at least partially to the cost of the vehicle-washing center and the lower total tonnage handled.

The entire Seattle operation was impressive. The problem of providing service to all types of incoming vehicles was overcome by incorporating both the compaction pit and the backhoe direct-dump transfer systems. In addition, the NTS has been located in a residential area with few complaints. Considering the very attractive design and the extra expense of incorporating a user fee system, the operating costs are very reasonable.

King County, Washington

The King County transfer station system was started in 1960 to handle wastes generated in King County outside the city limits of Seattle. Three open-air, direct-dump, two-level stations were initially constructed. The last four were constructed during the 1960's and incorporate an aesthetic design with gable roof steel construction (Figure 24). The buildings are not entirely enclosed but can be very acceptably located near residential neighborhoods. In 1968, the N.E. transfer station was converted to the newer design leaving only Bow Lake and Kent with open-air installations. In all, the seven transfer stations have eliminated 15 previously used open dumps.

All seven stations utilize a direct-dump and backhoe transfer system. The four new stations and the modernized N.E. station have permanently mounted backhoes while the open-air installations utilize rubber-tired mobile backhoes. Before the incorporation of the backhoes for compaction, payloads were considerably less than what the 73,280-lb gross vehicle weight permitted. Within 120 days after installation, the cost of the backhoes was amortized because of savings realized from hauling fewer loads. User fees have been instituted to partially finance the operations, but fees are assessed on an estimated yardage basis since no scales are available.

Transfer vehicle design has undergone a number of changes since operations began in 1960. Initially, open-top trailers of 90-cu-yd capacity were used. They were unloaded by a hydraulically operated conveyor chain device which proved inefficient as 20 to 25 minutes were required to unload each trailer. An open-top 88-cu-yd side dumping trailer was then adopted. It could be unloaded in 3 to 5 minutes, but high maintenance costs and tire-wear rates were incurred because it had to be pulled across the waste it discharged. Currently a very satisfactory container concept is being used which consists of two 42-cu-yd steel containers carried on a flat-bed trailer. At the landfill, a hydraulic scooper lifts, empties, and replaces the containers in about three minutes and the transfer rig never leaves the temporary roads on the landfill site (Figure 28). The container flat bed trailer configuration is considerably cheaper ($10,000) than most other types of transfer trailers; the hydraulic scooper for unloading, however, is priced at about $130,000 and a large transfer operation is required to offset this cost. King County operates 48 transfer trailers and 14 tractors.

The only problem encountered at the newer stations is the stationary backhoe size. The authority plans to replace the small $5000 units with a heavier design to obtain better compaction. All waste is hauled to the Cedar Hills sanitary landfill site where a complete maintenance facility is located for immediate repair and servicing of all rolling stock.

A breakdown of operating costs for King County operations was presented in Chapter III along with a listing of each of the seven stations, their initial cost, year constructed, and volume handled. A breakdown of construction and site development costs for a typical facility was given in Table 11.

King County transfer and haul operations are incurring relatively high costs. The system was designed, however, to eliminate open dumps and provide county residents with convenient disposal points. The added expense of their user fee system combined with the high haul cost from some of the distant transfer stations are largely responsible for the high overall cost. The authority plans to streamline the operations and improve the efficiency of the entire seven transfer station systems.

Lancaster, Pennsylvania

The Lancaster transfer station is an example of a stationary compactor system incorporating a package design of a manufacturer which consists of trailers, compactors and hydraulic compactor feed equipment. The transfer station, which opened in 1968, serves 150,000 people in Lancaster and six surrounding townships and operates on a user-fee basis. The transfer fees are:

Automobiles	$0.75
up to 500 lbs	1.00
500-750	1.25
750-1000	1.65

1000-1250	2.05
1250-1500	2.45
1500-1750	2.85
1750-2000	3.20
16¢ per 100 lb over 1 ton	

The operation consists of two stationary compactors which are fed by two hydraulic push pits, each having a storage capacity of 100-cu-yd. Large trucks usually dump directly into the two compactor hoppers while small vehicles dump into the push-pits from one of six other unloading stalls. During peak periods, trucks can be handled at the rate of about 2-1/2 minutes each. The movement of material from each push pit to the compactor hopper is regulated by an operator who also regulates the stationary compactor operation. The control booth for the two operators is located between the two pits. These operators also regulate a water-spray dust control system and application of deodorizer and insecticides.

Two of the 65-cu-yd trailers are backed up to the compactors and loaded simultaneously. Compaction does not occur within the trailer until it is nearly filled. Communication between upper and lower levels is by a buzzer system. The transfer trailer rigs weigh 39,000 lbs so that with the 72,200-lb legal load limit, a payload of approximately 17 tons is carried. Once at the sanitary landfill located 17 miles away, the trailers are unloaded with a hydraulic push-out blade powered from the power takeoff on the tractor. The total round trip requires about 1-1/2 hours.

A total of seven enclosed trailers and four tractors are used in the hauling operation. Two open-top trailers are also used to haul bulky noncompactable material. The bulky waste is dumped directly in the trailers from a ramp. A total of nine people are employed to handle the station and hauling duties: one weighmaster, two compactor operators, two laborers, three drivers and one foreman. The station is usually open 9-1/2 hours per day 6 days per week.

The main building is 100 ft long, 40 ft wide, and 20 ft high and is located on 2.6 acres. A scale house and an air-conditioned office are also located at the site. The following capital cost information was obtained from the supervisor:

Land		$ 17,500
Buildings and scale house		160,000
Equipment		
Scale	1 @ $9,500	9,500
Compactors	2 @ 17,500	35,000
Push pits	2 @ 7,500	15,000
Closed trailers	7 @ 17,500	122,500
Open trailers	2 @ 5,000	10,000
Tractors	4 @ 16,500	66,000
	Equipment subtotal	$258,000
	Total	$435,500

The station is currently handling about 400 tons per day. From July 1969 to July 1970 a total of approximately 100,000 tons was handled through the station. The total transfer and haul cost was $2.23 per ton with no further breakdown available. The haul cost is estimated to be, however, under $1.00 per ton.

The overall operation is run very efficiently and the equipment has presented no major maintenance problems. The supervisor indicated the only change he would make if he could redesign the plant would be to incorporate a larger storage volume.

Hamilton, Ohio

The transfer system in Hamilton, Ohio, is identical to the system utilized in Lancaster, Pennsylvania, except for size. The same type of equipment is used but only one compactor and a push pit arrangement have been installed. The footings, however, have already been laid for future expansion to a two-compactor system.

A population of about 80,000 is serviced by the new transfer station. Most of the eight 20-cu-yd compactor trucks owned by the city unload at the facility twice a day. Operating hours are 8 a.m. to 6 p.m., Monday through Saturday. During the first few months of operation daily tonnages have ranged between 100 and 140 tons.

Work is staggered so that seven different employees work a 40-hour week. In addition to the foreman, two laborers and four drivers are employed. Four 75-cu-yd trailers and three tractors are used in the haul operation. One of the tractors is used as a spare and to move trailers around the yard. The round-trip, 20-mile haul distance usually required about two hours with unloading time. Approximately 19 ton payloads are legally carried on the five-axle rig.

A 40 x 60 ft steel building houses the operation (Figure 39). Other than the small room for the compactor controls, no office is available. Total land area is about 1-1/4 acres. The approximate capital costs are:

Building	
Steel structure	$20,000
Concrete	70,000
Miscellaneous	25,000
	$115,000
Equipment	
Stationary compactor and hopper	$38,800
Push pit	15,000
3 tractors	45,000
4 trailers	75,200
2 PTO's	2,000
Portable hydraulic power source	4,000
	$126,200
Total	$280,000

At the time of the interview, data on owning or operating costs were not available. Based on a rough estimate, the total cost would be about $3.40 per ton. The city is very pleased with the operation and no significant problems have been encountered.

Denver, Colorado

The Denver transfer station was opened in 1965 to handle the waste from three of the 11 districts of the city. After 1969 it was determined that wastes could be handled more cheaply by hauling directly to smaller landfill sites operated by suburban communities instead of transferring and hauling to the Lowry disposal site located 18 miles from the transfer station. The transfer station will be reopened when nearby landfill sites are filled and more transfer stations may be built.

The internal compaction trailer system incorporated a drive through design so backing incoming collection trucks into unloading position was not required. After a truck drove over the hopper trap door, the door opened and the load was discharged into the hopper located over the trailer (Figure 34). Once in the trailer, the hydraulic bulkhead compacted the waste against the rear doors in cycles. Two unloading hoppers were available but the city was dissatisfied with the system because of queuing problems that developed with incoming trucks. The city feels that storage provisions will definitely be incorporated into any future transfer station designs.

The facility was open 8 hours per day, 5 days per week and was used only by Denver's residential compactor trucks. A total of seven men were employed at the station: three drivers, one shuttleman, one clean-up man, one machine operator, and one foreman.

A fleet of six 60-cu-yd trailers and three tractors were utilized. The hydraulic compacting bulkhead system in the trailer was powered by a stationary electric source during the loading operation and by the power take-off of the tractor during unloading. The five-axle empty rigs weighed 37,500 lbs and 15-ton payloads were carried, which made the operation somewhat inefficient. In 1969 a total of 191,000-cu-yd was processed, which was estimated to amount to 38,200 tons.

An attractive concrete building housed the operation with office and restrooms available (Figure 14). The entire area is fenced and presents a very pleasing appearance.

Cost information was very sketchy because depreciation was not routinely figured into the overall costs, and repair and maintenance were contracted out. No estimate on cost per ton was available. A total capital cost of $650,000 was incurred but this includes a vehicle maintenance center located at the site. The three tractors cost $17,000 each and the trailers were $15,000 each. Other capital cost breakdowns were not available.

Topeka, Kansas

A transfer station was opened in Topeka in 1968 in an effort to reduce the overall solid waste budget of the city. The transfer station is located only a few miles west of the city limits, and hence the station is not utilized on days when route collection is on the west side.

The transfer station is used only by city trucks and has no weighing system available.

The two-level, single stationary compactor system is housed in a steel building. Each incoming vehicle must back up and dump directly into the compactor hopper as no storage space is available. Three 75-cu-yd enclosed trailers and three tractors are used in the operation. The round-trip distance to the landfill is approximately 20 miles and requires about one hour including unloading time. The five-axle rig weighs 39,000 lbs and with the 73,280 lb legal load limit, 17-ton payloads are obtainable.

Six men are employed at the transfer station: three drivers plus one relief, one laborer and the supervisor. The station is open only four days a week and from 6 to 12 hours per day as required. From 100 to 120 tons per day are hauled from the transfer station giving a yearly total of approximately 25,000 tons. No accurate tonnage records are kept.

Very little cost information was obtained. The following approximate capital cost breakdown was given.

Equipment	
3 tractors	$43,400
3 trailers	65,300
1 compactor and hopper	23,200
	$131,900
Building and site development	168,000
Total	$300,000

No owning or operating costs were obtained as they are not broken down in the total collection and disposal accounting system of the city. Considering the initial investment, the low overall tonnage handled and the close proximity of the landfill site, it is questionable whether this transfer station can be justified economically.

Orange County, California

In 1959, Orange County adopted a master plan for solid waste disposal which established the concept of solid waste transfer combined with sanitary landfill disposal as the most economical means of meeting the areas long-term needs. Since then, three transfer stations have been constructed as required by the utilization of new landfill sites. The transfer stations are operated by the Orange County Road Department.

All of the transfer stations in Orange County employ an open-air direct dump and backhoe transfer system (Figure 12). The waste is dumped directly into the open-top trailers via hoppers located one level above. A mobile backhoe moves from hopper to hopper to compact and distribute the loads as needed. The large backhoe allows a considerable amount of compaction to be obtained and payloads are easily achieved. Only municipal and commercial collection trucks are allowed to use the facility and no user fees are levied. The double trailer units have a capacity of 130-cu-yd and have averaged hauling 20.6 tons per load. The total empty rig weight is 34,200 lb. A crossed cable arrangement is used to unload the trailers and the cables must be repositioned manually after the landfill tractor pulls the load out of the trailer.

All incoming vehicles are weighed at each transfer station and accurate records are kept on each operation. Information concerning each of these stations, extracted from the annual report of the Orange County Road Department to the Board of Supervisors, is given below.

Transfer Station No. 1
Stanton

Year constructed	1961
Site size	10.8 acres
Hours of operation	7:00 a.m.--4:00 p.m., Mon-Fri.
Number of employees	22
Round trip distance to disposal site	42.5 miles
Waste transferred (July 1969--June 1970)	
Total yearly tonnage	181,195
Average weekly tonnage	3,485
Average daily tonnage	724
Total number of delivery vehicles	30,529
Average tons per delivery vehicle	6.0
Total number of transfer trips to disposal	8,812
Average tons per transfer truck trip	20.6
Equipment	**Cost each**
14 tractors	$18,000
19 double trailer sets	18,000
2 backhoes	44,000
2 sweepers	18,000
Initial construction and site development cost	$346,578
Equipment replacement cost at current prices	699,000
Costs (July 1969--June 1970)	
Labor	$196,656.92
Equipment	217,578.95
Materials and supplies	15,073.56
Overhead	82,387.88
Land, buildings, capital projects	18,746.43
Total cost	$530,443.74
Total cost per ton	$2.93

Transfer Station No. II
Huntington Beach

Year constructed	1963
Site size	7.4 acres
Hours of operation	7:00 a.m.--4:00 p.m., Mon.-Sat.
Number of employees	19
Round trip distance to disposal site	30.5 miles

Waste transferred (July 1969--June 1970)

Total yearly tonnage	136,022
Average weekly tonnage	2,616
Average daily tonnage	449
Total number of delivery vehicles	27,282
Average tons per delivery vehicle	5.0
Total number of transfer trips to disposal	6,411
Average tons per transfer truck trip	21.2

Equipment	Cost each
9 tractors	$18,000
12 double trailer sets	18,000
1 backhoe	44,000
1 sweeper	18,000

Initial construction and site development cost	$212,034
Equipment replacement cost at current prices	481,420

Costs (July 1969--June 1970)

Labor	$160,950.30
Equipment	137,512.16
Material and supplies	13,478.40
Overhead	66,436.15
Land, buildings, capital projects	17,202.59
Total cost	$395,579.60
Total cost per ton	$2.91

Transfer Station No. III
Anaheim

Year constructed	1966
Site size	7.5 acres
Hours of operation	7:00 a.m.--4:00 p.m., Mon.--Sat.
Number of employees	23
Round trip distance to disposal site	36.3 miles

Waste transferred (July 1969--June 1970)

Total yearly tonnage	206,996
Average weekly tonnage	3,981
Average daily tonnage	741
Total number of delivery vehicles	32,031
Average tons per delivery vehicle	6.5
Total number of transfer trips to disposal	9,824
Average tons per transfer truck trip	21.1

Equipment	Cost each
14 tractors	$18,000
18 double trailer sets	$18,000
2 backhoes	$44,000
1 sweeper	$18,000

Initial construction and site development cost	$350,042
Equipment replacement cost at current prices	681,420

Costs (July 1969--June 1970)

Labor	$215,961.57
Equipment	225,486.29
Material and supplies	3,877.73
Overhead	87,391.32
Land, buildings, capital projects	52,071.70
Total cost	$584,788.61
Total cost per ton	$2.82

In addition to the specific information on each station, the following vehicle costs were given.

	Fuel ($/mile)	Depreciation ($/mile)	Maintenance ($/mile)
Vehicle with less than 24,000 miles	0.040	0.070	0.110
Vehicles with 180,000 to 270,000 miles	0.042	0.048	0.160

The transfer stations in Orange County are examples of open-air operations that have worked well because of the dry, warm climate and the landscaping work that was done to conceal them. The purpose of the stations is to reduce transportation costs for route-collection vehicles. As a result operating costs are kept low (for this area of the country) because lightweight vehicle traffic is prohibited and user-fee systems are not utilized.

South Gate, California

The Los Angeles County Sanitation Districts have operated the South Gate transfer station since 1957 and in addition currently operate five major sanitary landfills. The transfer station is open to all types of vehicles and a user-fee system is used. Originally a direct-dump and backhoe compaction system was utilized, but recently the operation has been remodeled to incorporate a compaction pit system because of the increase in the amount of incoming uncompacted waste. The following user fees are levied:

	$ per ton
Solid waste	5.00
Hard-to-handle bulky material	7.00
Minimum charge	2.00

The facility is an open-air installation and consists of a storage pit where a crawler tractor compacts the incoming solid waste. The pit is inclined so the tractor can push the waste to the high end and into a hopper located above an open-top trailer. A stationary backhoe is used to distribute the loads after they have been placed in the trailer.

Each transfer rig is composed of a tractor and a set of two trailers. Each trailer has a 60-cu-yd capacity and the entire rig weighs about 32,800 lb. With California's 76,800 lb gross legal weight limit, 22 ton payloads can be carried. The round-trip distance to the disposal site is 35 miles and requires about 1-1/2 hour including 25 minutes for unloading. The trailers are unloaded with a crossed cable pullout system. Although slower than a self-unloading compactor trailer system, the authority feels the positive assurance that each trailer will be unloaded promptly, and that the larger payloads the lighter trailers can legally carry, compensate for the quick automatic unloading system with its possibility of hydraulic breakdown.

The facility is open from 6:00 a.m. to 5:00 p.m. Monday through Saturday and all incoming vehicles are weighed. Unloading vehicles simply back up and dump into the storage pit. The transfer vehicles have drive-through access to the loading hoppers and can be loaded in five to seven minutes. An average of eight employees are used to operate the facility. Fifteen sets of trailers and four tractors handle all the hauling duties.

Very little cost information was obtained. With the modifications to convert the compaction pit system, the total cost was roughly $600,000 exclusive of equipment. The approximate equipment costs are as follows:

Tractors	$16,000 each
Pairs of stainless steel trailers	15,000 each
Backhoes	30,000 each

The facility currently has been handling approximately 200 tons per day. The opening of a district landfill in the area has resulted in a decline from 300 tons per day handled in 1969. Cost per ton figures have, of course, increased with the decreased volume. No current figures were available; from previous years, however, the cost of operating the station itself ranges from $1.25 to $1.50 per ton and the haul cost is approximately $16.00 per hour per transfer vehicle.

The Sanitation Districts have long-range plans for constructing many more transfer stations as new landfill sites are acquired and the economy of transfer is justified. Any new transfer operations will be housed in an aesthetically designed building and will probably utilize the compaction pit transfer system.

Santa Monica, California

In 1961, Santa Monica, California started the first stationary compactor transfer system in the United States. The single compactor open-air system is open to all types of vehicles except commercial contract haulers. A user fee of $4.00 per ton is being charged. The station is open Monday through Saturday from 8:00 a.m. to 3:30 p.m.

Waste from incoming vehicles is unloaded on the ground near the compactor hopper. A front-end loader is used to charge the waste into the hopper, and an automatically cycling compactor then pushes the waste into the rear of an 84-cu-yd enclosed trailer. The trailer is backed down a ramp and attached to the compactor located at ground level. This older system utilizes chains to fasten the trailer to the compactor instead of the automatic latch used on newer systems.

The round-trip distance to the landfill is 21 miles and requires about one hour to complete. A unique type of bulkhead unloading system is used. An air-cooled gasoline engine mounted on the trailer is used to power a hydraulic winch which is attached to the unloading bulkhead with a cable. A cable runs from the winch, which is located in the front of the trailer, over a sheave located in the rear of the trailer and back to bulkhead. As the cable is wound, the bulkhead traverses the length of the trailer and ejects the load. The unloading bulkhead also serves as a packing plate during loading by moving from the rear to the front as the trailer is filled. A resistance to its movement is applied by regulating a by-pass value on the hydraulic system.

The empty weight of the transfer vehicle is 42,000 lb; thus with California have a gross legal weight limit of 76,800 lb, approximately 17-ton payloads are possible. Overall the payloads have been averaging 16.4 tons. The station is currently handling about 225 tons per day with a fleet consisting of three tractors and three trailers. Six employees including drivers are employed at the facility.

Cost figures for equipment replacement were not available and initial purchase price has little meaning in that the equipment was obtained 10 years ago. Current transfer station and haul costs are estimated at about $2.00 per ton.

APPENDIX F

COMPARISON OF TWO LARGE-VOLUME TRANSFER STATIONS

Typically, it is very difficult to compare two transfer systems located in different areas of the country solely on a total cost per ton basis because wage rates, aesthetic requirements and types of vehicles handled vary. A basic comparison of buildings, equipment, and labor requirements, however, as related to daily output, is presented below to provide an idea of what can be expected from two different large-volume transfer systems: a compaction pit system used in San Francisco, California and a stationary compaction system used in Detroit, Michigan. Both facilities were placed in operation in 1970. Information on the San Francisco operation was gathered during a site survey while the Detroit data were gathered by a telephone conversation with the operating authority.

This comparison shows the higher output potential of the compaction pit system and also the greater capacity for handling incoming vehicles. The stationary compactor system, however, utilizes a very fast and efficient unloading system that does not require additional expenditures for auxiliary landfill unloading equipment. Two transfer vehicles load simultaneously in the San Francisco system in a drive-through operation while five vehicles load simultaneously at Detroit and are required to back into position. The sixth compactor is used for a spare in Detroit. Detroit officials stated that they selected the stationary compactor

COMPARISON DATA ON TWO LARGE-VOLUME TRANSFER STATIONS

Item	San Francisco	Detroit
Type of transfer system	Compaction pit	Stationary compactor
Current one shift handling capacity (tons/day)	2,000	1,250
Number of vehicles that can unload simultaneously	17	6
Number of employees		
At transfer station	7	11
Drivers	16	20

Equipment

San Francisco Items	Cost each	Detroit Items	Cost each
17 truck and trailer rigs	$43,000	32 trailers	$18,000
		16 tractors	16,500
2 stationary backhoes	21,000	6 stationary compactors and hoppers	22,000
1 crawler compaction tractor	65,000		
2 landfill transfer vehicle unloaders	72,000		

Total Costs

Item	San Francisco	Detroit
Buildings, scales and site development	$895,000	$863,420
Total equipment cost	982,000	972,000

system not necessarily as the cheapest method, but as the most sanitary. The high output at San Francisco, however, requires rapid processing, and therefore exposure of solid waste in the pit is minimal, and the operation presents little health hazard.

Michigan allows a large legal gross vehicle weight; thus the seven-axle transfer vehicles can transport 23 ton payloads. Because of the lightweight aluminum vehicles used in San Francisco, 25.5 ton payloads are legally carried even though smaller gross vehicles weights apply. Overall, the San Francisco operation is faster, eliminates queuing problems because of the large storage volumes available and is less likely to be interrupted by hydraulic equipment breakdown. The Detroit operation has its advantages in the sealed nature of the transfer trailers and in the fast, efficient trailer unloading method.

THE FOLLOWING PAGES ARE DUPLICATES OF ILLUSTRATIONS APPEARING ELSEWHERE IN THIS REPORT. THEY HAVE BEEN REPRODUCED BY A DIFFERENT METHOD SO AS TO FURNISH THE BEST POSSIBLE DETAIL TO THE USER.