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Baling Solid Waste to Conserve Sanitary Landfill Space

a feasibility study

San Diego City, California

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In addition to the purpose indicated by the title, the study was also designed to: (1) explore the possibilities of reducing direct haul distances; (2) study the use of solid waste bales as fill in reclaiming small canyons near residential areas; (3) compare the compaction obtained by baling with that achieved through conventional methods; (4) investigate baling as an integral feature of possible transfer station operations; (5) develop yardsticks, formulas, and techniques that might be useful to other communities in dealing with their solid waste collection and disposal problems.

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BALING SOLID WASTE TO CONSERVE SANITARY LANDFILL SPACE

A Feasibility Study

This publication (SW-44d) reports on work performed under Federal solid waste management demonstration grant no. G06-EC-00061 to the CITY OF SAN DIEGO, CALIFORNIA, *and is reproduced as received from the grantee.*

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PREFACE

Conserving sanitary landfill space and minimizing transport costs are two important objectives in the processing of solid waste materials. Processing--changing solid wastes in some fashion--may mean converting the wastes into a more stable form or into a different physical state by chemical, thermal, or biological means. Or it may mean mechanical alteration such as by size reduction and densification. Baling solid wastes, the subject of this report, is an example of the latter kind of processing.

The investigation performed by the City of San Diego, California, and described in this document has contributed significantly to advancing the state of the art in the solid waste processing field. This report, plus the recently published results of a Federal grant to the City of Chicago entitled High-Pressure Compaction and Baling of Solid Waste (SW-32d), constitute prime literature presently available on the subject of baling solid wastes.

In the present study the feasibility of baling solid wastes is examined to see if the technique could significantly prolong the life of both existing and future sanitary landfills. The effectiveness of solid waste baling under two circumstances is evaluated: (1) using unshredded solid waste at a local baling site; (2) using shredded solid waste baled offsite at a commercial facility. The densities achieved are compared to those obtained using conventional sanitary landfill techniques. In addition, the possibilities of using a baler transfer station are explored.

As a follow-up to this study a pilot baling plant is currently in operation in San Diego with the support of a solid waste demonstration grant from the U.S. Environmental Protection Agency (EPA). The facility has been active since the summer of 1971 and is presently processing approximately 100 tons of solid waste per day. A final report covering the operation of the pilot plant and evaluation of the complete baling-transport-disposal system is scheduled for completion in late 1973 and subsequent publication.

Eric Quartly served as Project Director for the City of San Diego while David Arella and Keith Grems served as EPA project engineers for the completed project reported herein.

--JOHN T. TALTY, *Director*
Processing and Disposal Division

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Project

Study and Investigation

Title

Investigate and Evaluate Feasibility of Refuse Baling as a Means of Conserving Sanitary Fill Space

Objectives

To investigate and analyze the physical and technical feasibility of baling municipal refuse and the economic feasibility of using this process in combination with the transfer station concept.

Procedures

Municipal refuse was actually baled in a local test program and in a demonstration by a baler manufacturer. Compaction thus obtained was compared with that obtained by present landfill methods. A preliminary design for a proposed pilot baling transfer station was prepared. Comparative costs were estimated for (1) longer direct haul to a more remote fill, (2) full-scale conventional transfer station operation, and (3) full-scale baling transfer station operation.

Findings

The process of baling municipal refuse is physically and technically feasible with presently available equipment and economically feasible when combined with the transfer station concept. Greater compaction can be achieved by baling than by the use of standard compaction methods (bulldozer or compactor) in sanitary landfills. Under certain frequently met conditions, baling transfer stations are more economical than longer direct hauls by collection vehicles. In the station capacity ranges studied, baling transfer stations are more economical than conventional transfer stations. Construction of a pilot baling station is recommended in order to test the findings and tentative conclusions of this study and investigation project.

CHAPTER I

INTRODUCTION

Increasing national concern about the serious and urgent problem of solid waste disposal is shared by the citizens of San Diego and by their municipal government. This concern has been the principal motivation for the city's undertaking, in cooperation with the United States Public Health Service,* the project described in this report.

San Diego has its own unique problems to face in this field and its own special complex of available resources to solve them. Although the project has been primarily oriented toward these local considerations, an important secondary motivation has been the hope that this city's investigations and findings may be helpful to other municipalities confronted by similar refuse disposal problems.

Nature of the Project

This study and investigation project, entitled "Investigate and Evaluate Feasibility of Refuse Baling as a Means of Conserving Sanitary Fill Space," was jointly financed by city funds and a grant from the Solid Wastes Program of the Public Health Service's National Center for Urban and Industrial Health. It represents the first year of a possible three-year project in which the initial study and investigation phase would be followed by a demonstration phase involving the construction and operation of a pilot baling transfer station.

The purposes of the first phase, reported herein, were not only (as the title indicates) to determine the feasibility of refuse baling as a means of conserving the life of sanitary fill sites but also (1) to explore the possibilities of reducing direct haul distances, (2) to study the utilization of refuse bales as fill in the reclamation of small canyons in close proximity to residential areas, (3) to compare compaction obtainable by baling with that obtained by conventional methods, (4) to investigate baling as an integral feature of possible transfer station operation, and (5) to develop yardsticks, formulas, and techniques that may be useful to other communities in dealing with refuse collection and disposal problems.

Locally the project received direction and leadership from the Public Works Director of the City of San Diego and was coordinated by the Senior Administrative Analyst of the Public Works Department. The full-time staff consisted of an Associate Civil Engineer (borrowed from the Engineering Department for the duration of the project) and, assisting him, an Administrative Analyst and an Administrative Trainee. Other professional members of the Engineering and Public Works Departments served part-time as consultants and resource people. Clerical workers, equipment operators, and laborers were provided either on a scheduled part-time basis or for temporary periods as required by the progress of the work.

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*Federal responsibility for this project now lies with the U.S. Environmental Protection Agency.

In a real sense, the city's Chollas Sanitary Landfill served as a practical laboratory for certain phases of the project - notably (1) an extensive study of refuse compaction by conventional methods based in part on sampling of the extent of refuse dumping at the fill by private contractors and citizens and (2) actual testing of refuse baling using a local baler leased for this purpose.

Methods of Procedure

In its investigation of various methods of refuse baling, the staff sent inquiries to a total of fifty baler manufacturers throughout the country to learn the types, characteristics, and capabilities of equipment available for or adaptable to the baling of refuse. Replies were received from twenty-five companies.

It was found that only a few firms manufacture equipment that can be readily adapted to the baling of municipal refuse. Still fewer have actually done research and development work leading toward the production of such equipment or the adaptation of existing models to this purpose. There is evidence, however, of increasing awareness on the part of manufacturers that there may be a potential market for balers specifically designed to process solid wastes. The special problems of baling municipal refuse economically on a large scale and the cooperative efforts that have been made by the City of San Diego and an interested baler manufacturer to solve those problems are discussed in Chapter III of this report.

The project staff also canvassed twenty-two local business firms to determine the types of balers being used commercially in this city and to locate balers that might be available and suitable for the initial testing of refuse baling. This search resulted in the city's finding and leasing a baler which, although it had relatively low compression capability as compared with modern, heavy-duty equipment, could be used for testing purposes on a systematic basis. A substantial number of bales were produced, their densities were calculated, and such characteristics as shape, ease of handling, and absence of odor were evaluated. A number of completed bales were stacked or "nested" in a simulated landfill situation in order to investigate the best equipment and procedures for this purpose and to discover the kinds of problems that might arise in the process. A description of these experiments and their results will also be found in Chapter III.

Both of these approaches--cooperation with a baler manufacturer and the local testing experiment--were found to be valuable in (1) exploration of the compaction potentialities and the technical feasibility of baling municipal refuse and (2) preliminary evaluation of various types of available baling and auxiliary equipment to determine which is most suitable for use in a possible pilot operation.

In order to evaluate the economic feasibility of refuse baling, the staff conducted sampling, engineering, and statistical studies of compaction obtained by present sanitary fill techniques and compiled data on costs of present methods.

These were compared with the estimated costs of possible alternative operations involving baling. Specifically, evaluations were made of the economics of a baling transfer station as compared with a conventional transfer station and also with direct haul to the fill site. These studies are presented in Chapter IV.

Also set forth in Chapter IV are (1) design concepts, preliminary drawings, specifications, and cost estimates for a prototype baling transfer station, (2) related equipment and manpower studies, and (3) survey studies to determine the optimum site location for such a station.

Evaluation of the Progess of the Project

Weekly staff meetings were held throughout the course of the project. These were attended regularly by the Project Director and the Project Coordinator and from time to time by other officials of the Public Works Department, the Sanitation Division, and the State of California. At these sessions the progress of the work was appraised, problems were discussed, and subsequent steps were planned. Detailed written progress reports were submitted to the Project Director once a week and once a month to the National Center for Urban and Industrial Health, Public Health Service. The Project Officer for the National Center made several trips to San Diego to discuss concepts and project plans and to review progress of the study.

Definitions of Terms Used in the Report

In general any technical terminology used in this report follows the usage and definitions of standard reference works in the literature of the field, particularly Refuse Collection Practice and Municipal Refuse Disposal prepared by the American Public Works Association with the assistance of the United States Public Health Service and published by the Public Administration Service. Terms that do not appear in these sources, or that are peculiar to San Diego, are defined as they appear in the context of the report.

General Description of the City

San Diego is a coastal southern California city of 694,000 population, third largest in the state and, according to the United States Bureau of the Census, eighteenth largest in the nation. It has experienced a rapid rate of growth in recent decades and this trend is expected to continue for the foreseeable future. It is not heavily industrialized. In 1960 it had, for each 100,000 people, only nineteen manufacturing establishments of twenty or more employees each as compared with 95 in Cincinnati and 63 in Seattle[1] Its central retail business area is comparable with that of other American cities of its size, and smaller shopping centers are scattered throughout the city. An extensive Naval establishment is clustered in and around its excellent harbor, and a large Naval air station is located in the northern section of the city. These installations together with Marine facilities in the city and its metropolitan area combine to give San Diego a strong military flavor.

[1] See Appendix 1 for a comparison of San Diego with six selected cities of comparable size, with respect to population, housing, industry, and climate.

The city's subtropical climate, natural points of interest, and varied recreational facilities attract large numbers of tourists and other visitors, particularly but by no means exclusively during the summer months. Perhaps for the same reasons there is a considerable segment of retired persons in the population.

Transient or relatively transient visitors to the city are a significant factor in shaping the special character of San Diego's refuse problem. The daily average number of visitors in the city is more than 85,000. According to a recent study by the local Economic Research Department of Copley Press, Inc., "the visitor industry is San Diego's third largest source of basic income. It ranks ahead of agriculture and behind manufacturing and Navy payrolls as a source of new money for San Diego." Military personnel living on board ships, in barracks or, often with dependents, in housing units at major military installations numbered about 60,000 in 1967. These more or less temporary residents, together with such smaller groups as college students living in dormitories, patients at hospitals, and institutional inmates or prisoners, total approximately 150,000 - in themselves the equivalent of a good-sized city - and while they are here they produce a substantial quantity of refuse.

Spread over an area of 310 square miles, San Diego has a population density of 2,180 persons to the square mile. In 1960 this density was 2,944 (the decrease since then is due to the annexation of additional outlying areas to the city), as compared with 15,157 in Boston and 3,966 in San Antonio. The city's Planning Department reported in October, 1967, that only 38 per cent of San Diego's land area is urbanized (this is the portion, incidentally, in which the city has established refuse collection routes), "with most of the remaining land devoted to agriculture and open livestock grazing." The Department went on to say that within the city limits "there are large acreages of completely vacant or unused land, much of it in steeply sloping hillsides and canyons." Even in those areas where there has been urbanized development the terrain is intersected by numerous canyons and there is, therefore, more than the usual proportion of dead-end streets.

Seventy per cent of the city's 215,000 housing units are single family dwellings. In 1960 this percentage was 71 as compared with 16 per cent in Boston and 56 per cent in Pittsburgh.

Brief History of Refuse Operation in San Diego

The year 1919 marked the first assumption by the city of responsibility for the solid waste problem in an organized way. At that time the Sanitation Division was created and took over the task of collecting refuse, which had previously been either burned on the householder's premises or hauled away by private contractors. Some of the policies initiated then have remained largely unchanged to the present day. The Sanitation Division has never had a major reorganization, although it was decentralized to a degree in 1952 when, due to growth of the city, its work could no longer be handled from a single operations station. Both the early-morning collection "sweep" through the downtown business area by a fleet of vehicles and the "daily route method" of collection in residential areas, in which a specific area is assigned to each crew each day, have been used throughout the intervening period. The Division has been greatly expanded in personnel, facilities, and budget over the years and many technical improvements have been introduced, but the basic principles of administrative organization and of scheduling collection that were found to be successful in the beginning are believed to be still valid today.

The physical and mechanical changes in sanitation service techniques that have been most apparent to the average citizen have been in the kinds of collection vehicles used. There has been a progressive adoption of improved transportation equipment, as it became available, for more efficient performance, more attractive appearance, and better protection of the public health. Horse-drawn wagons were replaced by motorized open-box trucks in 1926 and in turn by enclosed packer trucks in 1946. These were the cylindrical, side-loading type until 1955 when they were replaced by the box type with rear-loading hoppers. In 1965 the city began a transition from twenty-yard packer trucks with three-man crews to twenty-five yarders with two-man crews. This change is still in progress.

Until 1958 garbage was collected separately twice a week and sold to hog farms. Since that date it has been integrated with other refuse and collected once a week in residential areas. A requirement has been in effect since 1924 that garbage and, later, all refuse to be collected must be set out at the curb or (in sections of the city where they exist) in alleys.

Refuse other than garbage was disposed of by open burning at various dumps in the city before 1951 when the present "fill, compact, and cover" method was adopted. The Chollas sanitary landfill in the southeastern part of the city was opened in that year and is still in use. The other two existing facilities, Arizona landfill in the central section and Miramar landfill on the north side, were opened in 1952 and 1959 respectively. In the meantime the Mission Bay Fill was in operation from 1952 through 1959.

By 1958, when it was integrated with other refuse, garbage had become so small a proportion of the total bulk of solid waste materials that it posed no serious problems at the landfills except at the Miramar location. Since this facility is adjacent to the Naval Air Station, sea gulls attracted by the garbage constituted a hazard to aircraft and have had to be systematically frightened away by the noise of shotgun blasts and by amplifying on a public address system the recorded cries of gulls in distress. This system has been highly effective and successful for three years now.

In August, 1966, the city began to use a heavy compactor instead of a bulldozer to obtain increased compaction at the Arizona landfill. Aerial surveys have been utilized in studies of available volume and remaining life expectance of landfills since 1963.

CHAPTER II

SUMMARY AND CONCLUSIONS

The historical development and present character of the refuse collection and disposal services provided by the City of San Diego have been influenced to some degree by climate and topography. In all essential respects, however, this operation is comparable with those of many other municipalities. The findings of this study and investigation project, although based primarily on San Diego experience and conditions, are believed to have general applicability.

At the present time San Diego is generating more than a half million tons of refuse a year or about four and one-third pounds a person a day. Rapid population growth and gradual increases in the per capita generation of refuse are expected to double this tonnage by 1985. While this growing demand will in itself result in higher current expenditures for sanitation service, its impact will be compounded by the exhaustion of existing favorably located landfills, the necessity for acquiring new, more remote locations, and accelerated increases in costs due to longer direct hauls by collection vehicles. This situation, which is expected to become critical in San Diego within seven years, has already been or soon will be confronted by many another community.

For these reasons a number of new techniques and procedures that give promise of mitigating the problem are being explored here and elsewhere under the solid waste disposal program of the United States Public Health Service. Among these is the possibility investigated in this project and described in this report - the baling of refuse. Each of the findings and conclusions arrived at during the course of the project, summarized in this chapter, is more fully described and substantiated in the appropriate chapter of the report.

As part of the evaluation of the feasibility of refuse baling as a means of conserving sanitary landfill space, a major objective of this project, it was necessary to compare the compaction (1) now being obtained by conventional landfill methods with (2) that potentially obtainable by baling. The first of these was investigated by making a field survey at one of the city's landfills to determine the weight and compacted volume of refuse now being deposited, and the second by actually baling refuse in controlled test situations.

The tonnage of refuse brought to the landfill by private citizens and commercial contractors is not normally weighed. However, in the field survey, this tonnage was determined by counting and classifying all private vehicles entering the landfill during a fourteen-week test period, weighing a 23 per cent sample during the first six-week's phase of the test, and developing average weight factors for each vehicle classification. Estimates of private tonnage thus derived were added to the actual recorded tonnage brought in by city collection trucks. This combined tonnage was compared with the compacted volume of the materials as determined by aerial volumetric surveys. In three separate phases, the study examined differences in densities obtained by using different types of compacting equipment and by varying the amount of water added manually to the refuse during compaction.

It was found that compaction ranged between 1,189 and 1,383 pounds to the cubic yard, that better results were obtained with a compactor than with a bulldozer, and that the application of larger amounts of water to the refuse improved effectiveness.

The feasibility of baling refuse and the degree of compaction obtainable by this method were investigated at two levels: (1) an extended local test was conducted in which unprocessed refuse was baled in a leased light-duty baler installed at a test facility especially constructed for this purpose, and (2) arrangements were made for a demonstration of refuse baling by an interested baler manufacturer, using modern, heavy-duty equipment.

In the local baling test a total of 48.5 tons of typical city-collected refuse was processed during a five-week period into 162 bales averaging 599 pounds apiece in weight and 689 pounds to the cubic yard in density. These bales were classified as to composition of the refuse and were rated as to such characteristics as shape, handling ease, odor absence, fines retention, and liquid retention. As a second phase of this program, 64 additional bales were produced and "nested" in a simulated landfill situation.

On January 9, 1968, at its plant in Bellevue, Ohio, the American Baler Company conducted a demonstration of baling pre-shredded municipal refuse. The four complete bales that were produced ranged from 1,500 to 2,490 pounds in weight, from 0.92 to 1.56 cubic yards in volume, and from 1,466 to 1,593 pounds to the cubic yard in density. On the basis of this experience and its background of previous knowledge in the field, the company believes that densities close to 1,900 pounds to the cubic yard are practicable. Bale densities of this magnitude probably approach the maximum obtainable without resorting to relatively slow, cumbersome, and expensive multiple stage baling presses.

Findings in both the local test and the factory demonstration tended to supplement and reinforce each other. The balers used in both tests were of the same basic horizontal design which lends itself to more continuous, higher production than other types, Locally it was shown that ordinary city-collected refuse can be successfully processed, even without pre-shredding, into reasonably well-formed bales which generally maintain their integrity during transportation and disposal. Since the local test involved a larger quantity of materials (an estimated 65 tons in all as compared with perhaps five or six tons at Bellevue) and extended over a period of time, it established the feasibility of baling refuse which varies considerably in composition and moisture content from day to day and from one collection area to another. The Bellevue test provided persuasive evidence of the desirability of shredding the refuse before it is fed into the baler and of using baling equipment of high compression capability. The factory-produced bales were not only denser but better shaped, with sharp, well-defined corners and relatively smooth surfaces, and they maintained their integrity without appreciable distortion during handling.

Densities obtained locally are not competitive with the approximately 1,380 pounds to the cubic yard obtainable by efficient landfill methods, but the compaction obtained at the factory exceeds that level. Based on the compaction actually reached in that test (1,593 pounds to the cubic yard) and allowing five per cent of volume for voids between bales in place in a landfill, the space required per ton for refuse in bales would be 91 per cent of that required with our best present landfill methods. If the greater density (1,890 pounds to the cubic yard) predicted by the company were reached and the same allowance for voids made, the space required per ton would be 77 per cent of that required with conventional methods. It follows that the potential saving in landfill life that is realizable by baling can be expected to fall between 9 and 23 per cent.

It is felt that the potential economic benefits of baling refuse can be fully realized, however, only in the operational setting of a transfer station. The project staff made preliminary studies of the economic feasibility of a full-scale baling transfer station where the exhaustion of an existing favorably located landfill would require longer direct haul to a more remote landfill by collection vehicles. It was concluded that, under the San Diego conditions studied, when the additional round-trip distance required per truck by longer direct haul exceeds about 10.1 miles the baling transfer station would be more economical than direct hauling. It also appears that, in the station capacity ranges studied (300 to 350 tons a day), a net savings can be realized by baling despite the baling operating costs because of the reduction in the cost of land for the station site, in rehaul equipment, and in compaction equipment and labor at the landfill. This would make a baling transfer station (fully equipped with balers, a hogger, and conveyors) more economical than a conventional station in which refuse is simply transferred from collection to rehaul vehicles. However, it should be noted that this conclusion might not be valid if the comparison were made with a conventional transfer station of larger capacity and consequently greater efficiency.

A pilot baling transfer station is needed (1) to test these tentative conclusions under actual production conditions, (2) to refine baling techniques and routines, (3) to ascertain the optimum moisture content of the refuse being baled, (4) to compare the compaction obtainable with pre-shredded versus unprocessed refuse, (5) to determine and deal with any possible nuisance factors or health hazards (such as noise, dust, odor, and vector breeding) that may be encountered in the operation, (6) to develop effective practices in placing the bales in a landfill, (7) to explore the feasibility of other means of bale disposal, such as in the reclamation of small canyons near residential areas, and (8) to develop accurate cost comparisons. As a means of implementing and proving out the combined baling and transfer concepts, a pilot baling transfer station would in the long view be a potentially rewarding investment.

Recapitulation of Conclusions

1. The problem of disposing of solid waste materials, already formidable, is growing in magnitude and complexity as urban populations continue to increase and the per capital production of refuse continues to rise.

2. In many communities using sanitary landfills for refuse disposal this problem is compounded by the imminent exhaustion of favorably located landfill facilities and the prospect of longer direct hauls by collection vehicles.

3. The urgency of the situation has prompted investigation of a number of new approaches that might offer alternative solutions to the problem. Among these is the concept of baling refuse.

4. The process of baling refuse is physically and technically feasible with presently available equipment and economically feasible when combined with the transfer station concept.

5. Greater compaction can be achieved by baling than by use of standard compaction methods (bulldozer or compactor) in sanitary landfills.

6. Under certain frequently met conditions, baling transfer stations are more economical than longer direct hauls by collection vehicles.

7. In the station capacity ranges studied, baling transfer stations are more economical than conventional transfer stations.

8. A pilot baling station is needed to test the findings and tentative conclusions of this study and investigation project.

CHAPTER III

PHYSICAL FEASIBILITY OF BALING REFUSE

A review and appraisal has been made of the background, present status, and expected growth of the tasks of solid waste collection and disposal in San Diego. It is evident that both the magnitude and the cost of the city's already formidable task in performing these functions will increase in the future. San Diego is not unique in this respect. There are few if any municipalities using landfills for solid waste disposal that do not face to some degree the prospect of mounting quantities of refuse, dwindling space in favorably located disposal sites, and greater expenditures for sanitation operations.

This situation here and elsewhere has led to the exploration and consideration of a number of new techniques and procedures that may give promise of alleviating the solid waste disposal problem. Among these is the possibility investigated in this project and described in this report - the baling of refuse. The physical feasibility of applying this process in the solid waste field is discussed in this chapter. Its economic feasibility, particularly as related to the transfer station concept, is examined in Chapter IV.

The Baling Process

Baling may be defined as the process of applying pressure to loose, compressible materials within an enclosure and binding the compacted mass while it is in a confined condition. The resultant object is a bale.

Widely used for many years in industry and agriculture, the baling process is perhaps the simplest and most economical form of packaging. In essence no encasing or wrapping are required to maintain the integrity of the bale and the cohesion of its contents. The compaction inherent in the process contributes to the conservation of space and consequently to economies in storage and transportation. In the weights in which they are usually produced on the farm and in the factory, bales are readily handled by manual or mechanical means. Typically their surfaces are rectangular in shape and relatively smooth and they can be stacked and nested economically without excessive voids and waste space. For these reasons baling is often used in the packaging of certain types of raw materials, scrap, staple commodities, and manufactured products. The United States Department of Commerce has listed 53 different commodities that have been successfully baled for transit.[1] These range from excelsior to textiles and from feathers to tobacco.

[1]Quoted in Stern, W. The package engineering handbook. Rev. version. Chicago, Board Products Publishing Company, [1949]. p. 38.

In most applications in agriculture and industry, baling is used for the compressing and packaging of relatively homogeneous materials - cotton, hay, paper stock, and rags, for example. With such commodities the process is relatively standardized and more or less trouble free because the materials are relatively uniform in composition and in the size and shape of their constituent elements. They present few surprises. Foreign objects that might damage the mechanism or require frequent adjustments in the process are seldom encountered. Potential compressibility is known within reasonable limits.

A major complication in adapting the baling process to municipal refuse is that this material lacks such homogeneity and predictability. It is true that the composition and character of mixed solid wastes have been analyzed and described in a general way. On the average, its characteristics may be distinctive in different parts of the country, from city to city, and even from area to area within the same community. Nevertheless, any given batch fed into a baler hopper may differ markedly from that average, may present unusual problems, and in the completed bale may vary widely from the norm in density. These problems strongly indicate a requirement to investigate and evaluate the need for certain techniques and procedures preliminary to the actual baling process: (1) some means of controlling the composition of the input, such as by limiting it to city-collected refuse and by imposing certain restrictions on the kinds of materials that will be picked up, (2) sorting out non-balable items, and (3) pre-shredding the materials to reduce their heterogeneity.

Balers are manufactured in a number of different types and sizes to meet the special requirements imposed by the quantity and character of the materials to be baled. They may be stationary or portable. They range in size from small, manually operated balers that are suitable for small offices or plants to powerful briquetter presses that can reduce an automobile to a small cube of compacted metal.

Heavy, production type balers are hydraulically or electrically operated. They are generally classified into two major types depending on the direction of movement of the compressing ram: (1) vertical stroke balers, which are subclassified as down-stroke or up-stroke (so called "pit" type) balers and (2) horizontal stroke balers. In vertical stroke balers the materials are compressed between a moving ram (a piston with a flat faceplate or "platen" the size of one face of the bale) and the fixed floor or ceiling of the compression chamber. Vertical stroke balers have the disadvantage that time and effort are required to remove the completed bale before the chamber can be recharged and the production of a new bale begun. This type has the advantage, at least theoretically, of greater compaction for the same expenditure of energy. Compound or multiple stage balers, in which pressure is applied vertically and then horizontally or vice versa, produce still greater compaction but are even slower in operation. In the horizontal stroke baler the ram moves laterally against the end of the bale being formed and in the process not only compresses the materials but also pushes the bales (the one being formed and one or more already completed) toward ejection through an elongated chamber and out its open end. The completed bales still lodged in the chamber before ejection act as a plug and provide resistance to the ram in the production of a new bale. A tension adjustment at the perimeter of the open end of the chamber allows this resistance to be increased or decreased as needed. The process is continuous in that a completed bale need not be removed before starting a new one. A minor disadvantage of this type of baler is that it is harder to feed than a pit baler because the material must be elevated. The theoretical loss of compacting power inherent in this design is probably more than offset by the fact that the bale is automatically ejected. As a matter of fact the horizontal stroke baler appears to be the only type presently available that has a production rate high enough to handle the large quantities of material that are normally involved in a refuse operation.

In most applications, bales are customarily bound with wire or with flat metal straps. In the present state of the art, these must be tied or secured manually which is time-consuming and expensive for a high production operation. The chief obstacle in the way of automatic tying appears to be the expansibility of the material and the spring-back of the compacted bale when the pressure of the ram is relieved. Another difficulty arises from the clogging (with compacted material) of slots in the face of the platen, through which the wires or straps must be threaded. The solution of these problems - and they do not seem to be mechanically insurmountable - will be a major breakthrough. There are indications that one or more baler manufacturers are developing devices for this purpose and that there is a reasonable prospect of success in the near future.

The Baling of Refuse

As part of the evaluation of the feasibility of refuse baling as a means of conserving sanitary landfill space, a major objective of this project, it is necessary to appraise and compare the effectiveness of two methods of compaction: (1) by conventional landfill techniques and (2) by baling. The first of these was investigated by making field surveys to determine the weight and compacted volume of refuse now being deposited, and the second by actually baling refuse in controlled test situations. Other objectives of the tests were to investigate the mechanical feasibility of baling refuse and to determine what problems might be encountered with the disposal of completed bales in a simulated landfill situation.

The feasibility of baling solid waste materials and the degree of compaction obtainable by this method were investigated at two levels: (1) an extensive local test was conducted using a leased light-duty baler installed at a test facility especially constructed for this purpose, and (2) arrangements were made for a demonstration of refuse baling by an interested baler manufacturer, using modern, heavy-duty equipment.

Local Refuse Baling Tests

Early in the project, local San Diego business firms having balers were surveyed so that arrangements could be made to conduct actual testing of the feasibility of baling refuse. Originally it was contemplated that this testing would be done on the baler owner's premises on week-ends or at other odd times when he was not using the equipment. When it was found that a baler could be leased outright for a period of time, however, it was decided to install it on city property and thus create a test situation that would be better controlled, more comprehensive, and more realistic than would have been possible under the original plan. Accordingly, a test facility was designed and constructed on city property near the Chollas sanitary landfill. The criteria for the selection of a baling test site were accessibility, proximity to a disposal site, suitable topography, and availability of power and water. As constructed the test facility had, at an upper level, a paved dump area adjacent to a wooden ramp and chute designed for feeding refuse into the leased "Balemaster" horizontal stroke baler mounted on a concrete pad at a lower level. It was equipped with a hoist for handling completed bales, was provided with an access road and a paved area for the maneuvering of mobile service equipment (refuse packer truck, dump truck, and a leased skip loader), and was completely enclosed by a chain link fence. Power and water were brought in from nearby sources. Views showing the design and operation of the test facility appear in Plates 1 to 4 on pages 15 to 18.

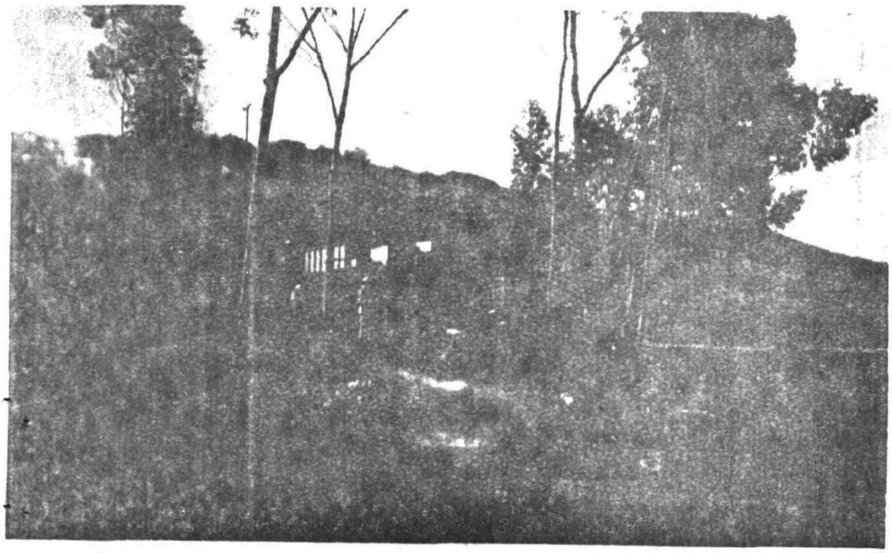
The local baler test program began on December 11, 1967, and ended on January 19, 1968. It was conducted on an experimental rather than a production basis. On a typical day, three to four tons of refuse were handled and from twelve to fourteen bales were produced. They were measured and weighed, their densities were computed, they were classified as to composition, and a number of bale characteristics such as shape, ease of handling, and absence of odors were evaluated.

The nucleus of the four-man crew consisted of an equipment operator and a laborer from the Public Works Department. One full-time member of the project staff was assigned regularly to the test program crew and the other two full-time members served alternately in this capacity, so that all three became thoroughly conversant with the process through active participation in the work.

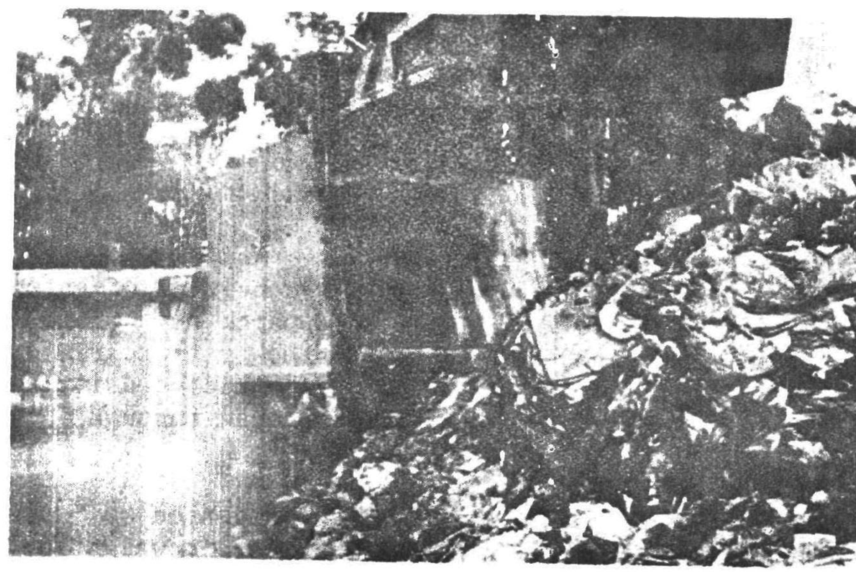
During the test period this crew processed 48.5 tons city-collected refuse into 162 bales averaging 599 pounds apiece in weight and 689 pounds to the cubic yard in density. The bales ranged in weight from 335 to 900 pounds, in volume from 0.3 to 1.4 cubic yards, and in density from 370 to 905 pounds to the cubic yard. A day-by-day summary of weights and densities recorded is shown in Table 1 on page 19 and the distributions of weights, volumes, and densities of all the bales produced during the test period are shown graphically in Plate 5 on page 20.

The composition of the refuse baled was classified by visual inspection and found to be about 21 per cent "typical San Diego refuse," about 17 per cent "excessive garbage," about 60 per cent "excessive paper," and about two per cent "excessive prunings." None of the bales were judged to fall in the other two composition categories that had been set up for the test - "excessive fines" and "excessive water."

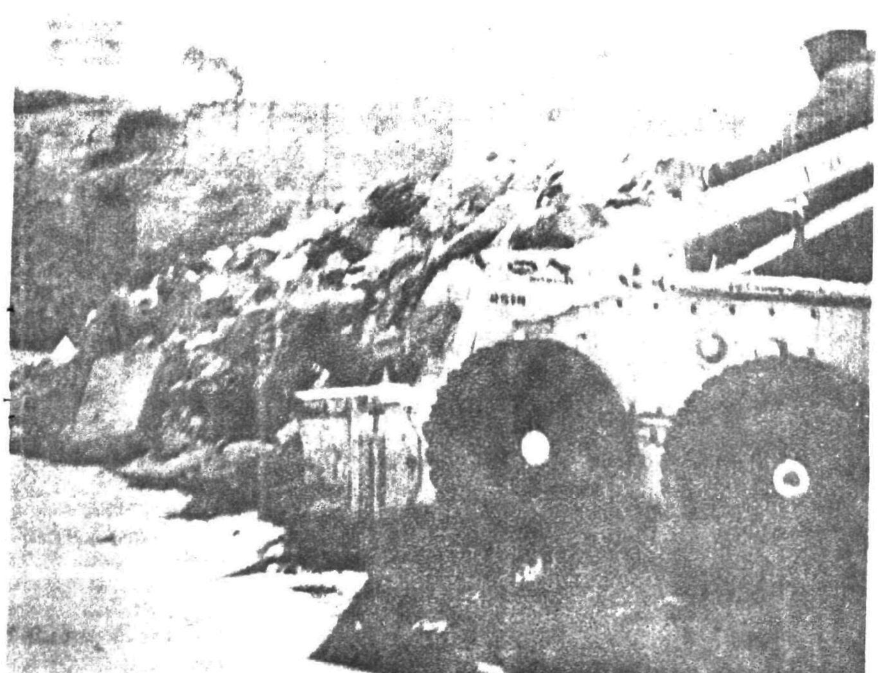
It was found that there were substantial differences in the average densities of bales in each of the three leading categories described above (omitting "excessive prunings" as having too few cases to support a valid comparison). The average density of those bales judged to be composed of "typical San Diego



General view of test facility during construction



Refuse is dumped at the upper level



A skip loader cuts into the pile of refuse

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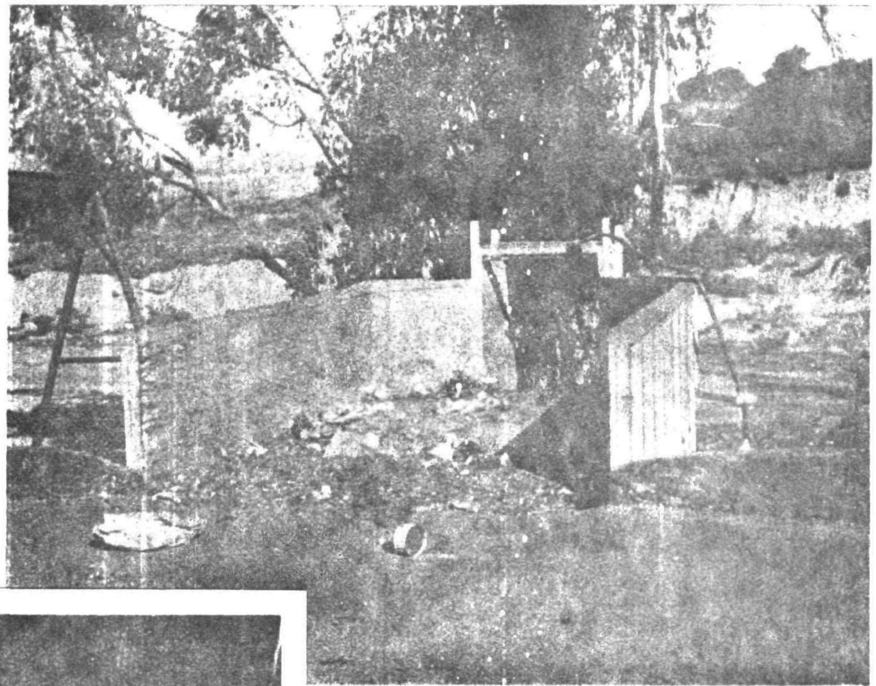
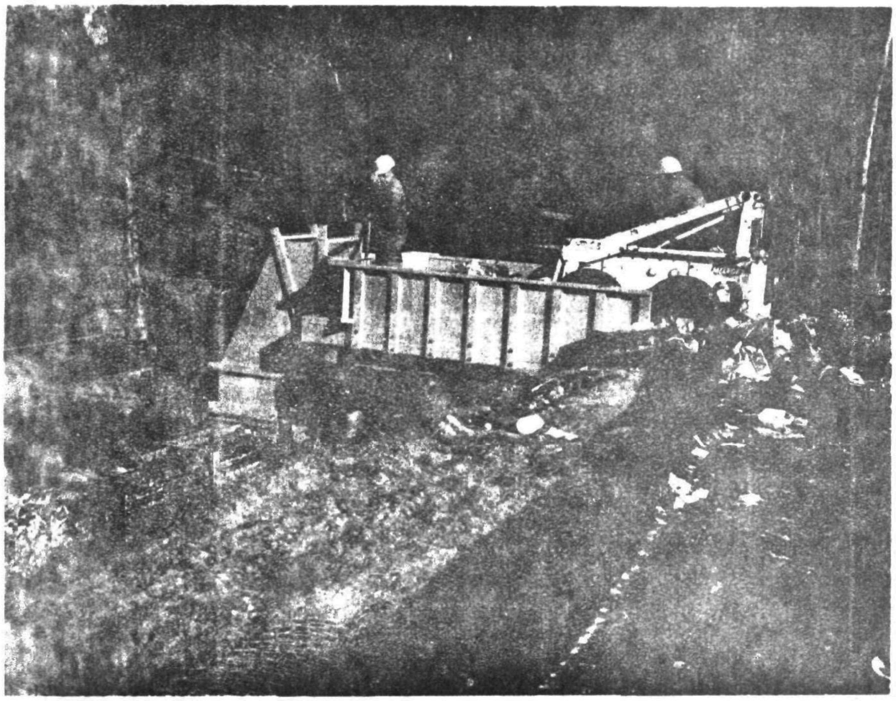
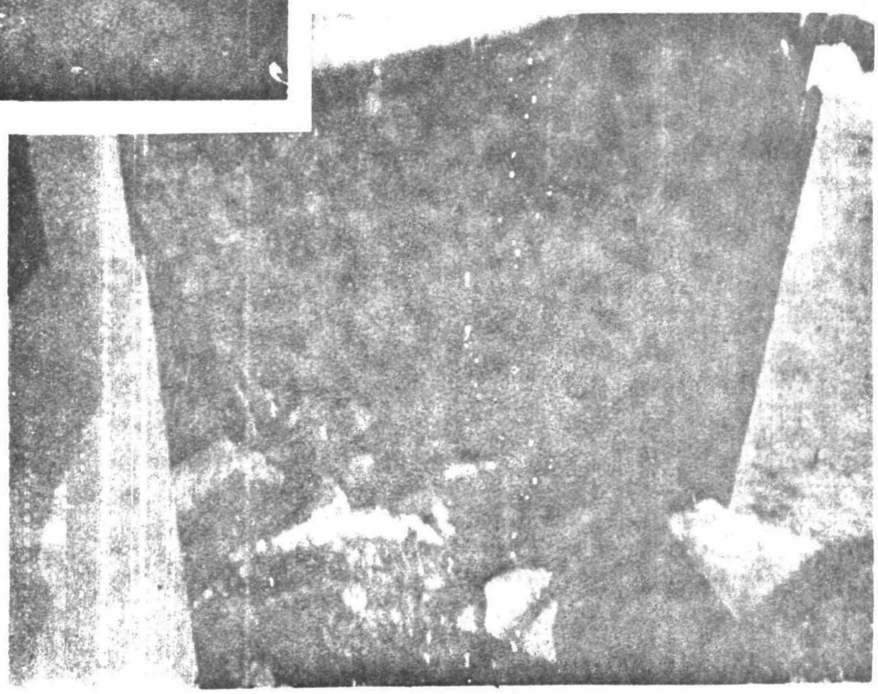
End view of upper ramp leading to baler hopper

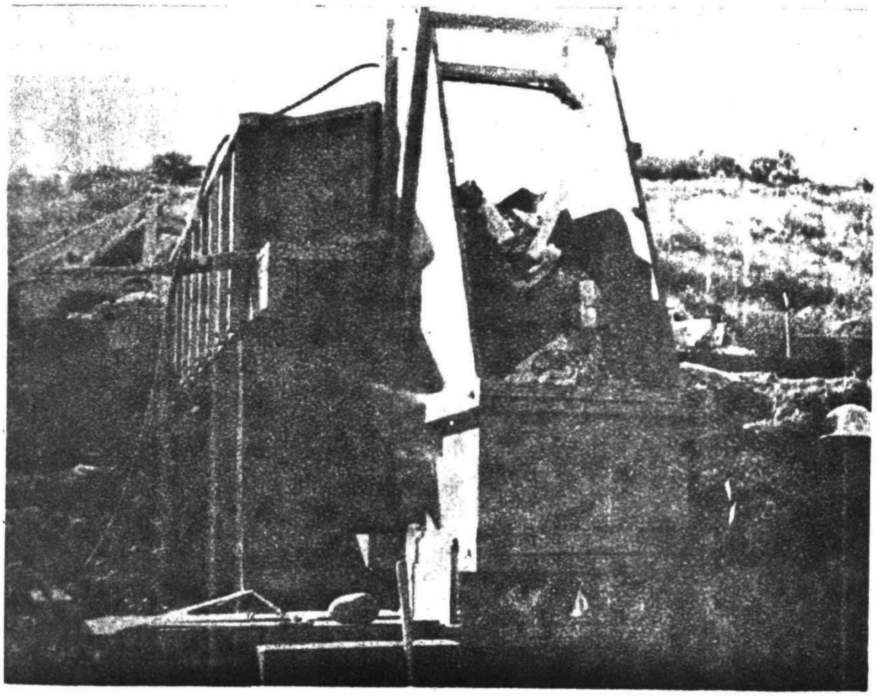




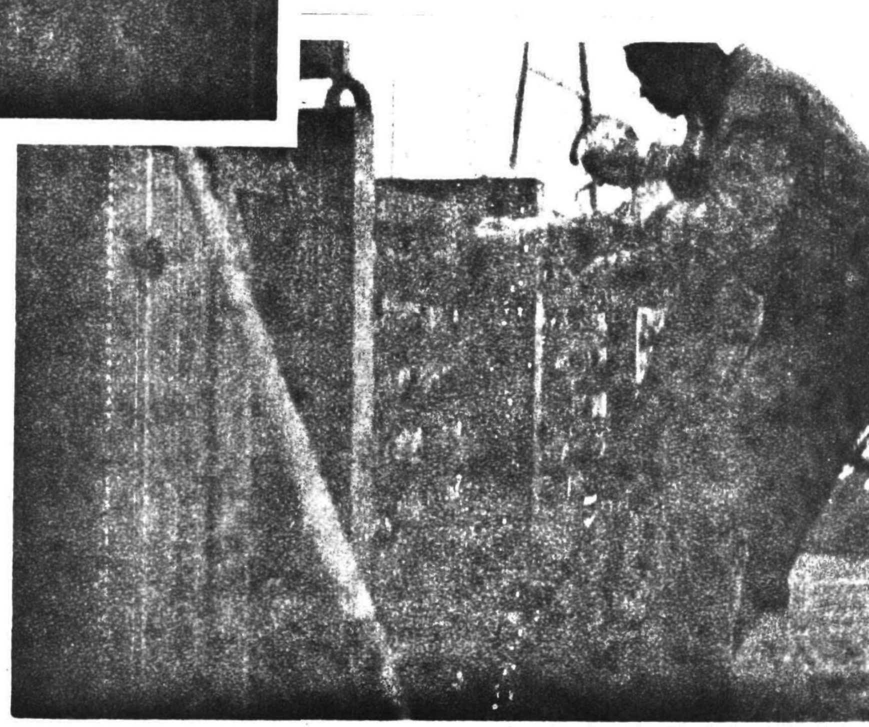
Refuse "bridging" at throat of chute has tc be manually dislodged



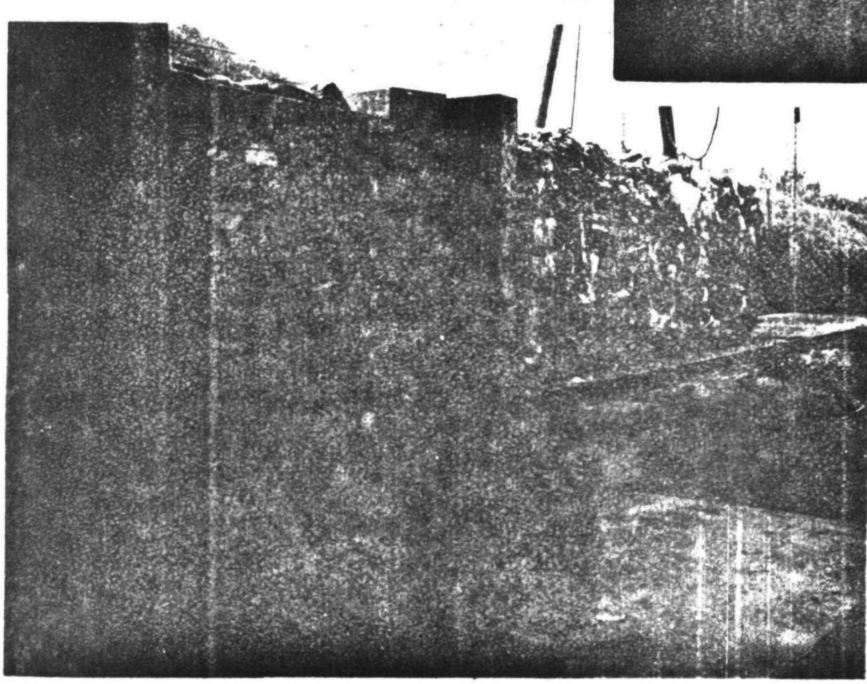
Water is applied to refuse as it enters chute



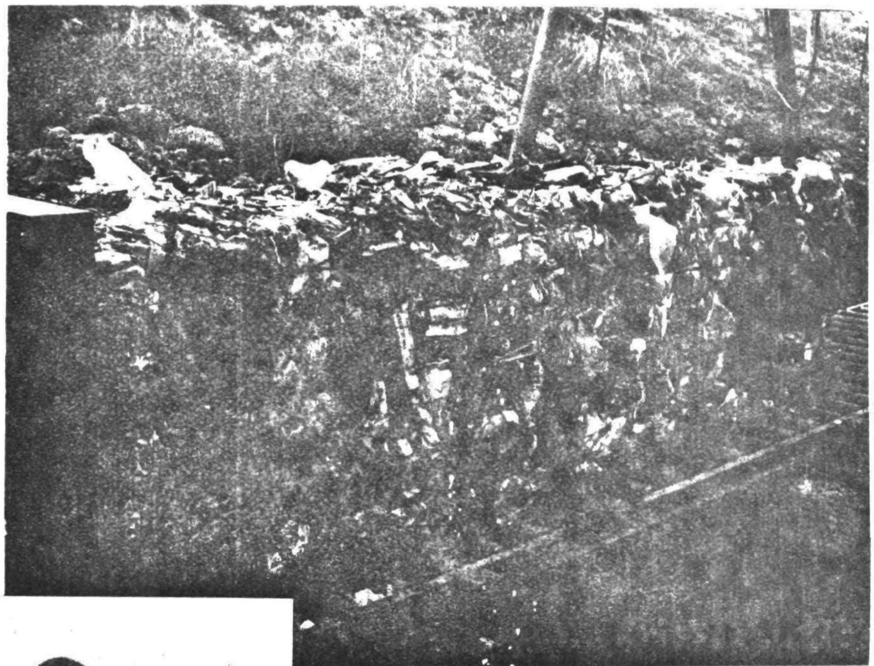
Refuse descending chute into baler chamber



Baling wires are tied manually

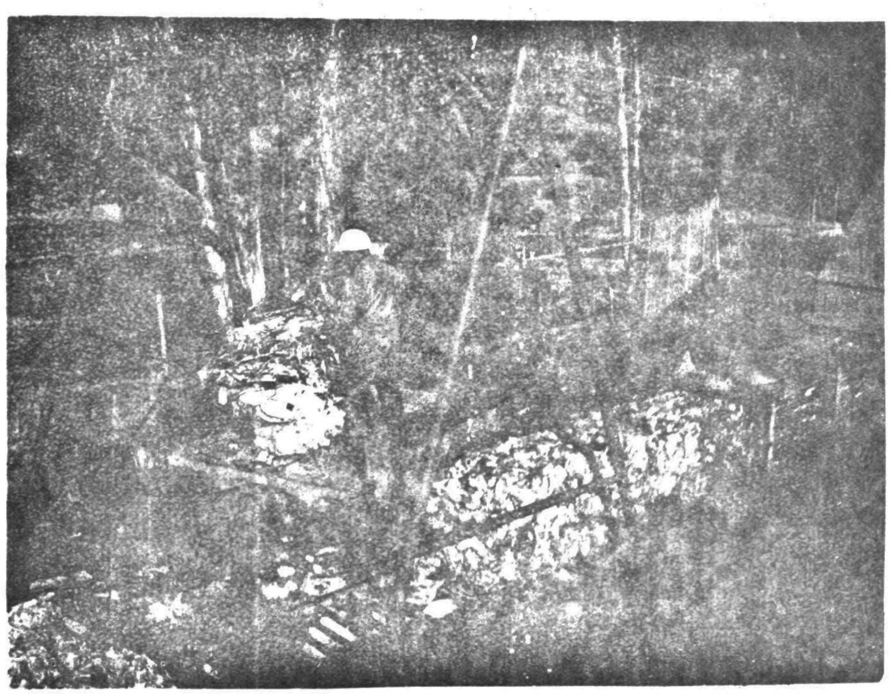


Bales emerging from extension of baler chamber



Bales are pushed along roller conveyor

Hoisting bale from conveyor



Bales are placed in dump truck for transportation to the fill

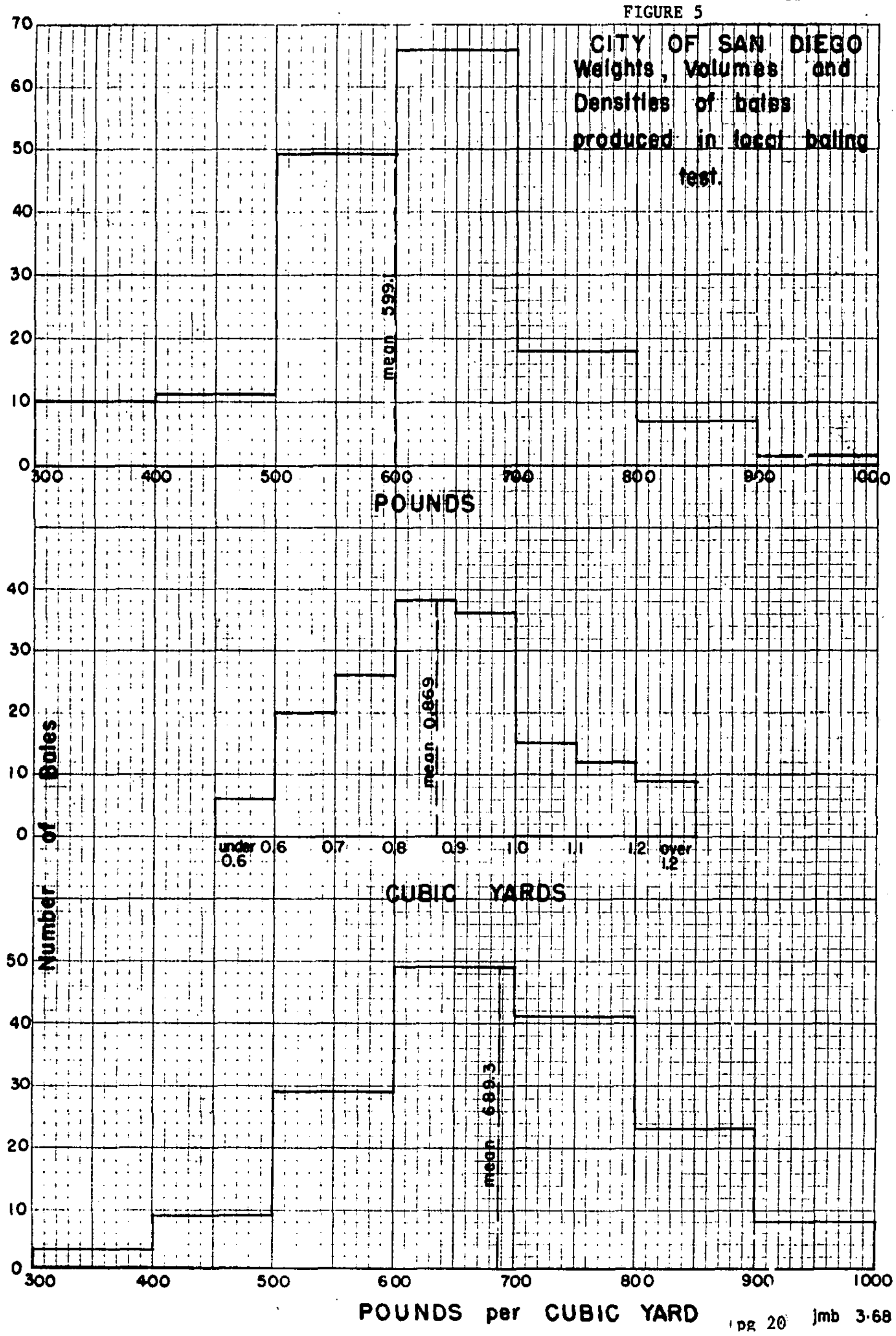
TABLE 1

SUMMARY OF LOCAL BALING TEST RESULTS
(WEIGHTS AND DENSITIES ROUNDED TO NEAREST FIVE POUNDS)

Weeks	Days	Tons of Refuse	No. of Bales	Weight of Bales (Lbs) Max.	Min.	Ave.	Density of Bales (Lb/Cu.Yd) Max.	Min.	Ave.
1	Dec. 11	.800	3	575	450	535	600	475	555
	12	1.775	6	600	550	575	835	680	760
	13	4.200	13	750	575	645	675	590	630
	14	3.700	13	800	335	570	830	575	730
	15	1.225	7	350	350	350	405	370	390
Sub-total		11.700	42	800	335	555	835	370	635
2	Dec. 20	2.025	7	615	550	580	700	620	665
	21	1.125	3	750	750	750	780	780	780
Sub-total		3.150	10	750	550	630	780	620	700
3	Dec. 26	4.925	13	780	735	760	850	700	775
	27	2.150	7	665	575	615	630	575	600
	29	5.100	20	600	450	520	600	495	450
Sub-total		12.175	40	780	450	610	850	495	615
4	Jan. 3	5.075	16	750	600	635	895	560	735
	4	4.075	13	900	575	630	900	620	785
	5	2.500	8	650	625	640	780	770	775
Sub-total		11.700	37	900	575	630	900	560	760
5	Jan. 8	3.650	13	650	500	560	740	625	670
	9	2.250	8	590	540	565	670	670	670
	10	3.900	12	690	625	650	905	795	860
Sub-total		9.800	33	690	500	595	905	625	735
TOTALS AND AVERAGES		48.525	162	900	335	600	905	370	690

Note: Bale volumes were determined by individually measuring each bale. Bales were weighed in groups of four and averaged. This average was used in determining density.

FIGURE 5



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refuse" was highest at 747 pounds to the cubic yard, of those with "excessive garbage" next at 700 pounds to the cubic yard, and of those with "excessive paper" lowest at 656 pounds to the cubic yard. By statistical (standard error) analysis, the probabilities that differences between these averages are significant were found to be 90 per cent as between "San Diego refuse" and excessive garbage," 99 per cent as between "San Diego refuse" and "excessive paper," and 95 per cent as between "excessive garbage" and "excessive paper." It is virtually certain, therefore, assuming that the judgments as to appropriate classification were accurate, that the superior compactibility of "San Diego refuse" as compared with "excessive paper" is significant and not due to chance. The odds are nine to one that it is also superior to "excessive garbage" in compactibility.

It was noted above that "typical San Diego refuse" constituted only about one-fifth of all of the solid wastes processed during the test. The reason that the composition of solid waste materials processed in the test was not representative is probably that it was conducted during the Christmas season when the incidence of paper in the refuse is higher than at other times of the year. These considerations suggest that if the baling test program had been conducted throughout the year, or at a more representative season, average densities would have been closer to the 747 pounds per cubic yard found for "San Diego refuse" than to the 689 pounds per cubic yard actually obtained in the test.

Certain characteristics of the bales were evaluated by a member of the project staff, using a scale from 10 (excellent) to 0 (totally unsatisfactory). These appraisals are summarized in Table 2 on page 22. "Shape of bales" and "fines retention" were judged to be fair to good, and "handling ease," "liquid retention," and "odor absence" were rated good to excellent.

In the later stages of the test considerable pre-sorting of non-baleable materials was necessary. A large number of Christmas trees, received during the two weeks following the holidays, and also a number of other bulky or excessively long items had to be separated out manually because they could not be fed into the baler. On some days these rejected materials constituted as much as ten per cent of the volume of the refuse processed. This difficulty would be minimized by hogging or shredding the refuse ahead of the baling operation.

Attempts to determine the effect on compaction of adding water to the refuse during the baling process were inconclusive. It was found to be virtually impossible to apply water with any degree of uniformity to raw, unshredded refuse. Densities obtained during the first seven days of the test, when no water was added, were almost identical to those obtained during the next nine days, when water was added. A more significant factor appeared to be the water content of the refuse as it arrived from the collection route. If it was relatively wet, as after rainfall, compaction was increased and the shape of the bales was improved. The effect of adding water to the refuse during baling might well be the subject of future study under better controlled conditions.

Two other serious problems were encountered: (1) tying the bale wires manually was rather time-consuming and constituted a real bottle-neck in the operation (this can probably be cured by the development of a workable automatic

Table 2

SUMMARY OF RATINGS OF BALE CHARACTERISTICS

LOCAL BALER TEST

Judgment Scale	Shape of Bale No.	Shape of Bale %	Handling Ease No.	Handling Ease %	Liquid Retention No.	Liquid Retention %	Fines Retention No.	Fines Retention %	Odor Absence No.	Odor Absence %
10	0	0.0	34	21.0	58	48.3	10	6.2	36	22.7
9	18	11.1	40	24.6	28	23.3	31	19.1	27	17.0
8	44	27.2	32	19.8	24	20.0	44	27.2	38	23.9
7	46	28.4	19	11.7	8	6.7	33	20.4	36	22.7
6	24	14.8	13	8.0	2	1.7	13	8.0	16	10.0
5	10	6.2	11	6.8	0	0.0	16	9.9	5	3.1
4	13	8.0	3	1.9	0	0.0	9	5.6	1	.6
3	4	2.5	1	.6	0	0.0	2	1.2	0	0.0
2	1	.6	6	3.7	0	0.0	1	.6	0	0.0
1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
0	2	1.2	3	1.9	0	0.0	3	1.8	0	0.0
Total	162	100.0	162	100.0	120[a]	100.0	162	100.0	159[b]	100.0
Q_3	8.5		9.8		10.0		9.0		9.9	
Median	7.6		8.8		9.9		8.1		8.6	
Q_1	6.4		7.2		8.9		6.7		7.5	

Note a - 42 bales were not judged on this characteristic.

b - 3 bales were not judged on this characteristic.

tying device) and (2) jams due to "bridging" of the refuse as it was conveyed toward and fed into the baler frequently caused stoppages and had to be broken up by positive manual disloging of the material (this problem would be minimized by pre-shredding).

After the conclusion of the initial phase of the baler testing program described above, 64 additional bales were produced and "nested" in a hillside shelf dug out for this purpose. A fork lift was used to stack the bales to a height of three tiers. Approximately 55 cubic yards of baled refuse were disposed of in this manner and covered with earth. Voids between the bales were estimated at 15 per cent of their aggregate volume, so that a total of approximately 63 cubic yards of space were required to accommodate the 55 cubic yards of refuse. These voids resulted from the impossibility of nesting the bales as close together as desired, partly because of their somewhat uneven surfaces and partly because a fork lift is not an appropriate device for this purpose. To some extent the operator's view of his work is obstructed by the bale itself. Placing the bales vertically from above would be more effective than moving them laterally from the tines of a fork lift. Future experiments may show that a better machine for this purpose would be a crane of the clamshell type but with flat jaws. Bales of higher compaction and consequently of better shape, such as those produced with pre-shredded refuse at the American Baler Company's demonstration (see the next section of this chapter), could undoubtedly be stacked more successfully.

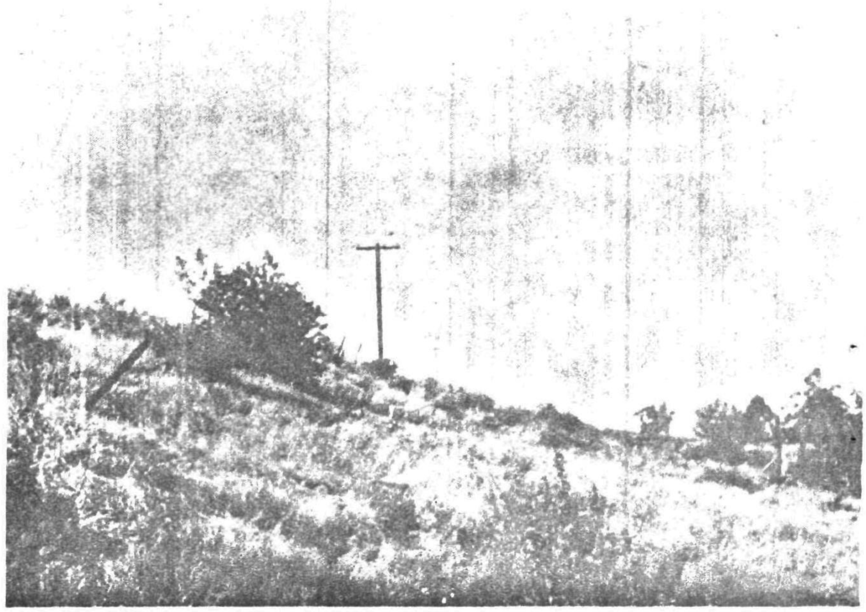
Pictures of the disposal experiment described above are shown in Plates 6 to 9 on pages 24 to 27.

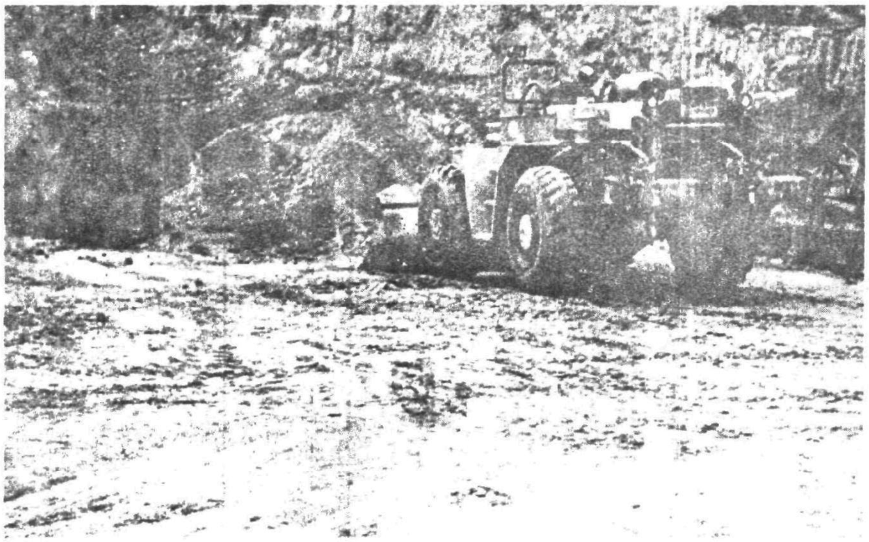
Manufacturer's Refuse Baling Demonstration

Early in the course of the project, the staff sent a total of fifty letters of inquiry to all known baler manufacturers in this country as listed in MacRae's Blue Book. Copies of this inquiry and the mailing list to which it was sent appear in Appendix 2 of this report. The letter described the purpose and scope of the project, requested brochures and information about the manufacturer's baling equipment, and invited comment and suggestions on the potential adaptability of such equipment to the baling of municipal refuse. Twenty-five responses were received. Four companies were out of business or their forwarding addresses were reported unknown. Of the number responding, ten do not manufacture any equipment suitable for baling municipal refuse at all and eleven manufacture only conventional balers designed for small applications where continuous, high-capacity production is not required. The remaining four appeared to be promising in that they stated they planned to start or in some cases had already started to engineer and construct balers specifically designed for use with municipal refuse.

Follow-up letters were sent to these four firms affirming our interest and suggesting meetings to discuss the equipment they now have or plan to develop. In some cases these invitations were reaffirmed by long distance telephone calls. Only one baler firm, the American Baler Company of Bellevue, Ohio, responded to the extent of sending representatives to discuss detailed possibilities and problems.

Hillside before being cut to create simulated landfill





Fill cutting job approaches completion

Some of the bales are dumped on the ground for pick-up by the fork lift

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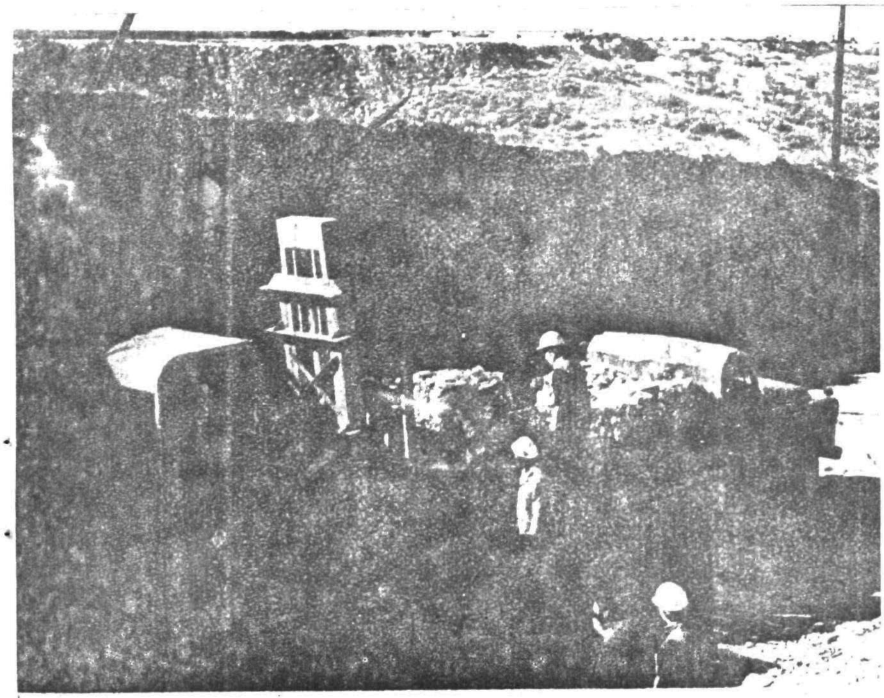
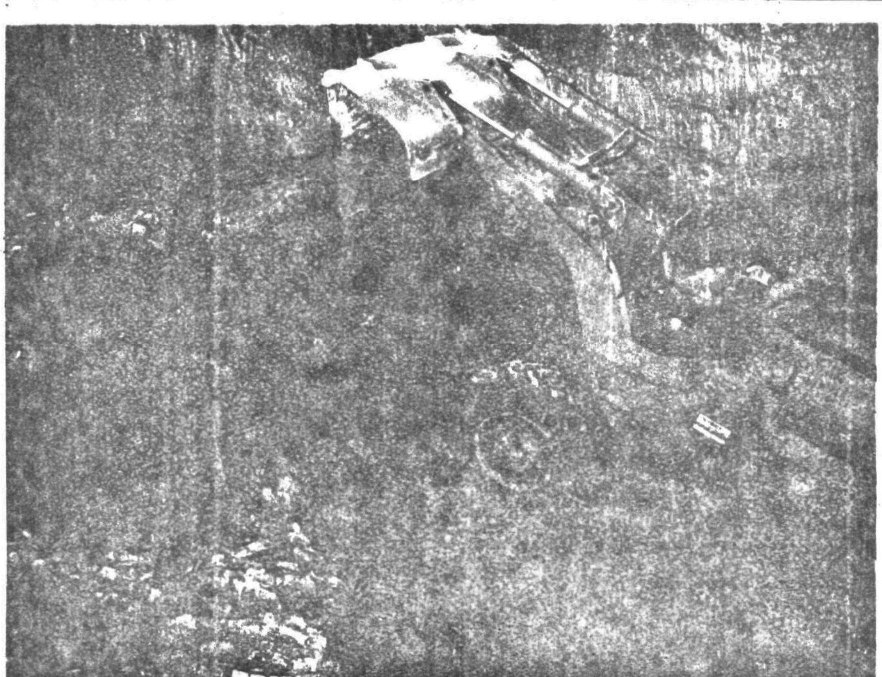
VIEWS OF LOCAL BALE DISPOSAL EXPERIMENT



Other bales are transferred directly from the truck to the fork lift

Fork lift stacks the bales in the simulated fill



Stacked bales are covered with earth

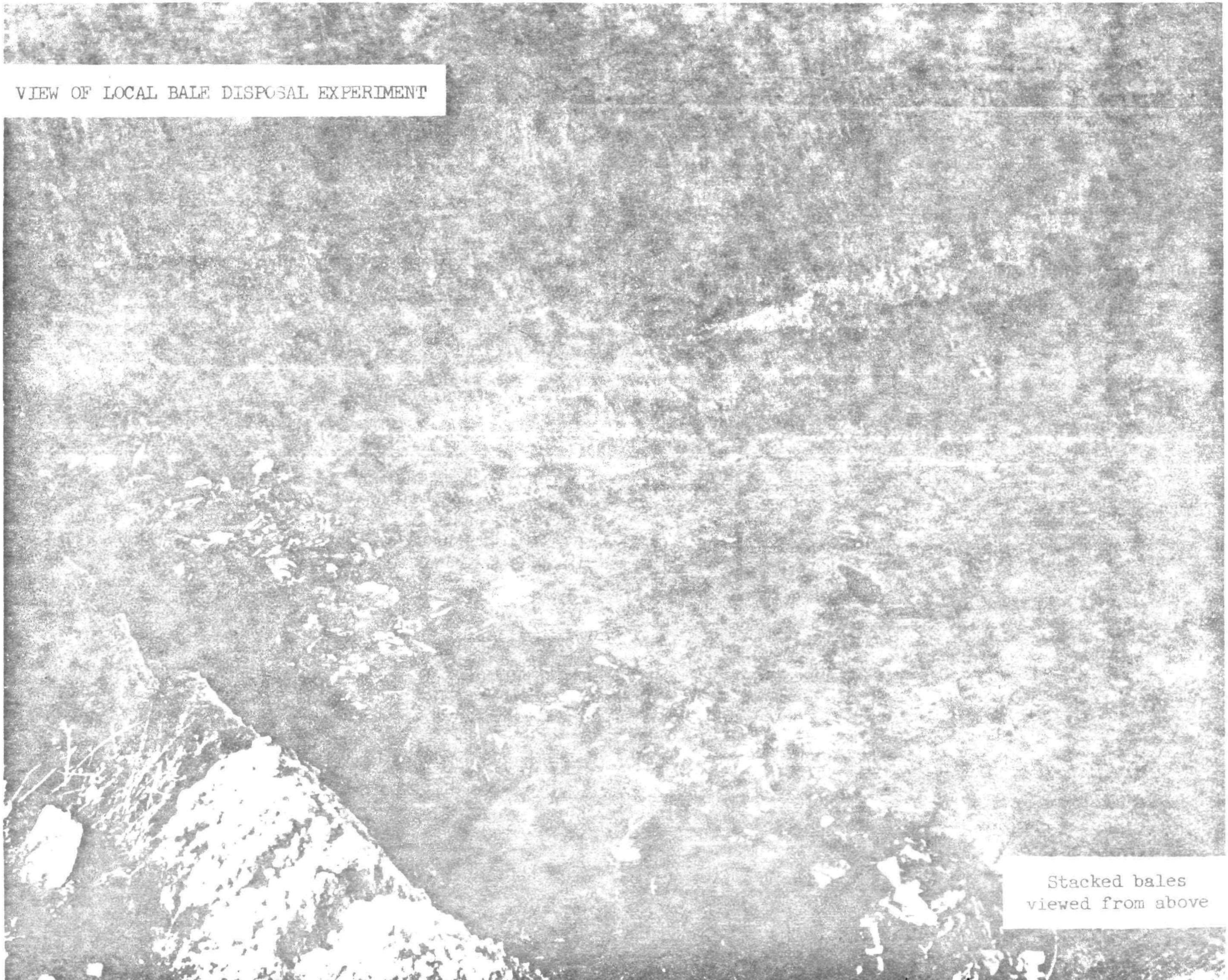


FIGURE 8

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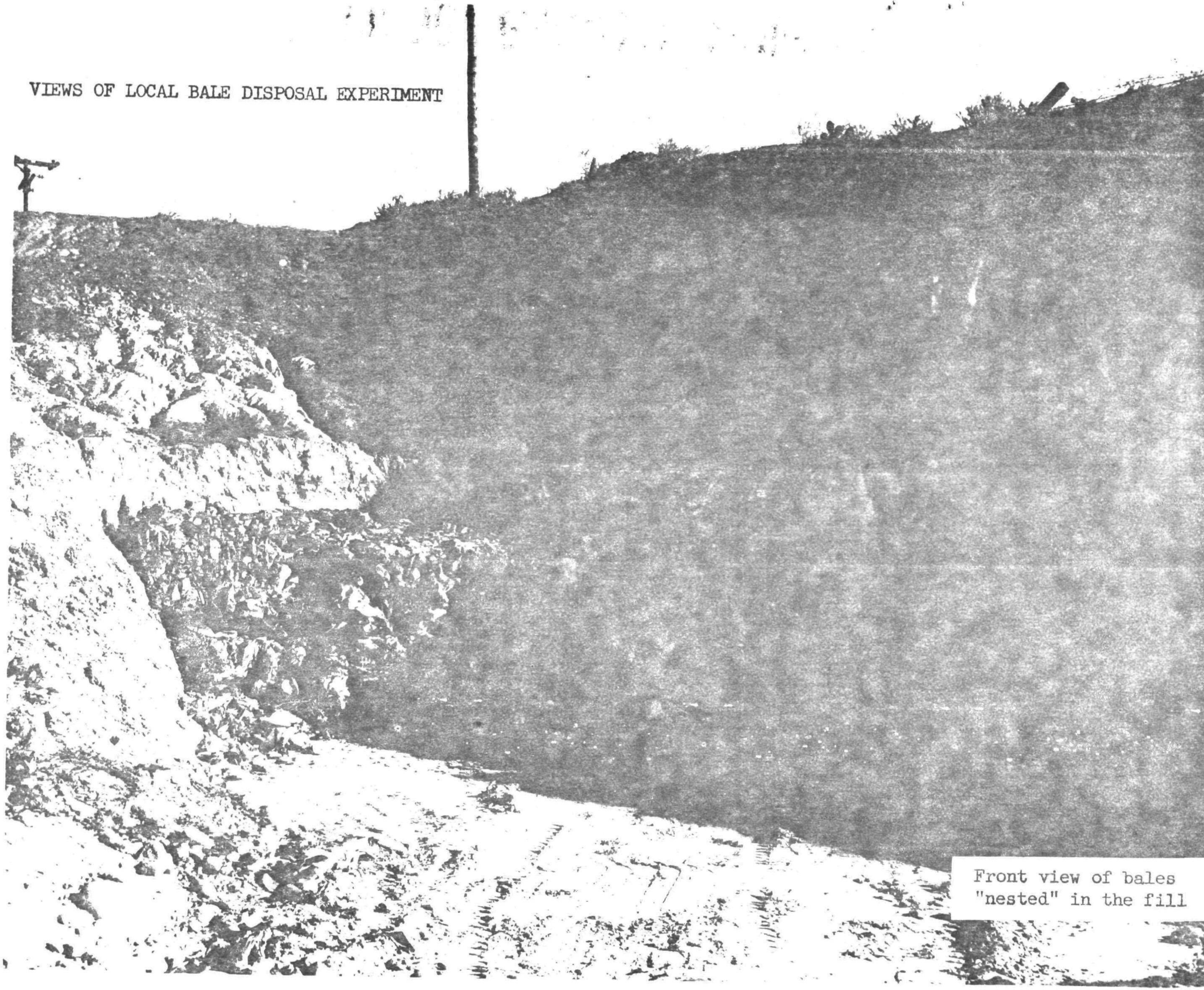
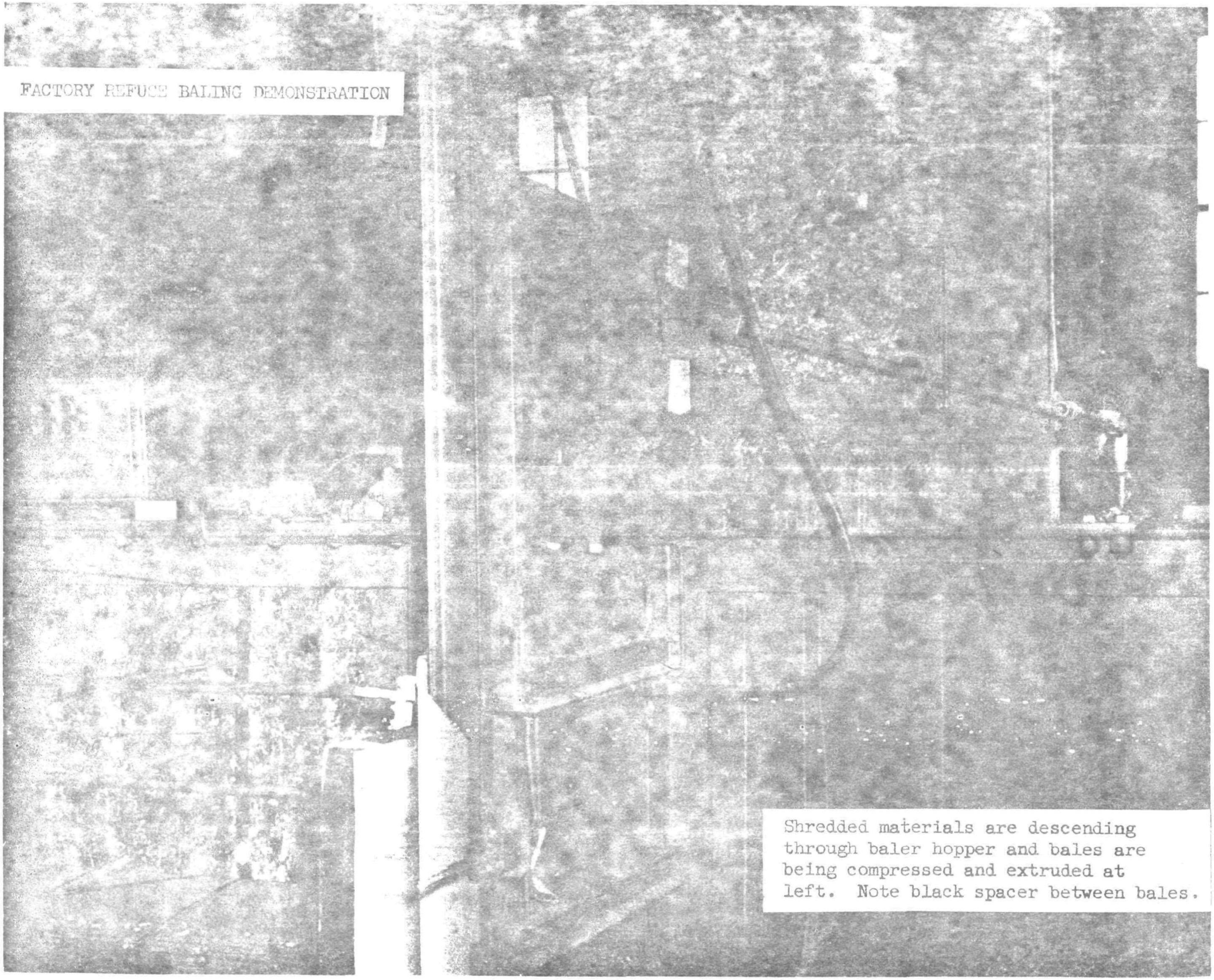
VIEWS OF LOCAL BALE DISPOSAL EXPERIMENT



Front view of bales "nested" in the fill

FIGURE 9

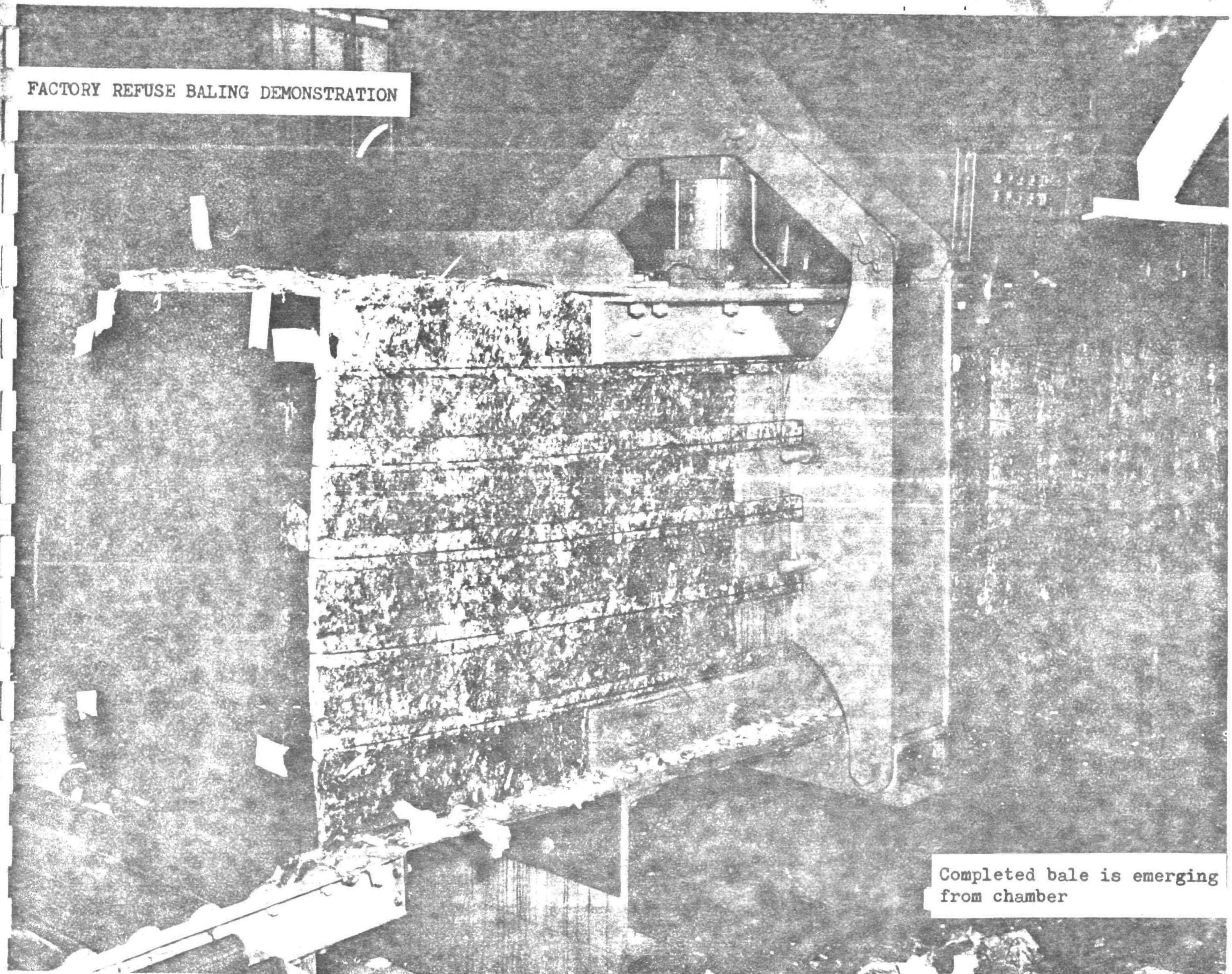


FACTORY REFUSE BALING DEMONSTRATION

Shredded materials are descending through baler hopper and bales are being compressed and extruded at left. Note black spacer between bales.

FIGURE 10

FIGURE 11



Completed bale is emerging from chamber

As a result of these conversations, this firm offered to conduct, at its own plant and at its own expense, preliminary tests of the feasibility of baling refuse. This demonstration took place on January 9, 1968. It was witnessed by San Diego's Project Coordinator, by the Reviewing Officer of the United States Public Health Service's Office of Solid Wastes, co-sponsor of the project described in this report, and by other interested observers. Appendix 3 is a verbatim copy of the company's notes on this demonstration.

The material baled in the Bellevue test was pre-shredded rather than raw refuse. On the basis of its long experience with designing balers for a variety of materials the company is convinced that the baling of refuse can not be accomplished effectively without pre-shredding. They believe that unless this is done bale densities will be lower, it will be impossible to add necessary moisture to the materials with any degree of uniformity, an excessive amount of fines will be lost, more pre-sorting will be necessary, and the tendency of raw refuse to "bridge" will create serious stoppage problems in conveying the materials through the system and feeding them into the baler hopper. All of these contentions are corroborated by San Diego's experience in its local test of baling refuse that had not been pre-processed. For these reasons the company made arrangements to secure pre-shredded municipal refuse from the City of Louisville, Kentucky, which has a shredder of the type recommended by the company for refuse, and transported it to Bellevue for the test.

This material was processed through a heavy-duty horizontal stroke baler (of the company's 10,000 Series) equipped with a larger than normal main hydraulic cylinder to increase pressure. The four complete bales that were produced ranged from 1,500 to 2,490 pounds apiece in weight, from 0.92 to 1.56 cubic yards in volume, and from 1,466 to 1,593 pounds to the cubic yard in density. The bales were judged to be excellent in shape with sharp, well-formed corners and relatively smooth surfaces. They appeared to maintain their integrity without appreciable distortion during handling. Two pictures taken during the course of the demonstration are shown in Plates 10 and 11 on pages 28 and 29

On the basis of this experience and its background of previous knowledge of the field, the company is prepared to guarantee that its new Model 12,375 baler, which is designed specifically for municipal refuse, will produce densities from 1,755 to 1,890 pounds to the cubic yard with properly shredded material having a moisture content of approximately 30 per cent, at the rate of 25 tons an hour even with manual tying.

Comparison of the Local and Factory Tests

In general, observations made and conclusions reached in both the local testing program and the Bellevue demonstration tended to supplement and reinforce each other. The balers used in each case were of the same basic horizontal stroke design which lends itself to more continuous, higher production operation than other types. Although the San Diego test baler was light-duty and somewhat antiquated, it successfully processed ordinary city-collected refuse, even without pre-shredding, into reasonably well-formed bales which generally maintained their integrity despite rather rough handling during transportation and disposal. An important feature of the local test was that, since it involved a larger quantity of materials (an estimated 65 tons as compared with perhaps five or six tons at Bellevue) and extended over a period of time, it established the consistent and sustained feasibility of baling refuse which may vary considerably in composition and moisture content from day to day and from one collection area to another.

The average compaction obtained in the local test, 689 pounds per cubic yard, was only about half as much as would be required to match the approximately 1,380 pounds per cubic yard obtainable by conventional landfill methods. However, densities exceeding that level were attained at Bellevue with modern, heavy-duty equipment. Based on the compaction actually obtained in the factory test and allowing five per cent of volume for voids between bales in place in a landfill, the volume required per ton for baled refuse is 91 per cent of that required with conventional landfill methods. If the greater density guaranteed by the company were reached (and the same allowance for voids made), the volume needed per ton would be 77 per cent of that required with conventional methods. It follows that the potential saving in fill life that is realizable by baling can be expected to fall between 9 and 23 per cent.

The marked difference in bale densities obtained in the two tests - more than twice as great at the factory as in the local test - was primarily due to (1) the amount of pressure applied (approximately 140 as against approximately 20 pounds to the square inch respectively), (2) the moisture content of the refuse, and (3) the pre-shredding of the material. Pictorial evidence of the importance of pre-shredding is shown in Plates 12 through 15 on pages 32 through 35.

One of the important functions that could be served by a pilot baling transfer station such as that described in Chapter IV of this report would be a determination, under controlled conditions, of the relative contributions of each of these three factors to the high densities attained at Bellevue. A limited amount of experimental evidence has already been built up on the effect of the first two factors (pressure and moisture) on the compaction of refuse. Densities obtained by increased compressive loads up to 100 pounds to the square inch were studied at Chandler, Arizona, as early as 1954.[2] Los Angeles County has conducted similar tests and arrived at comparable findings. Neither of these investigations involved baling directly, and both of them dealt with refuse that had not been pre-shredded. The American Baler Company has assembled data on the relationship of pressure to density based on the baling demonstration described above and also on some earlier tests made in 1963, applying pressures up to 760 pounds to the square inch to pre-shredded refuse, and has derived the parameter curves shown in Plate 16 on page 36. The curves in all of these studies show a characteristic pattern of continued but diminishing increments of density as pressure is increased. A point is eventually reached at which further application of energy is no longer economically feasible because of the minimal improvement of density and because the strain such pressures impose upon the machine leads to excessive maintenance costs. Where this point falls is still a matter of practical judgment rather than of scientific determination because up to now experience in the baling of refuse has been extremely limited. Evidence of the efficacy of increased moisture

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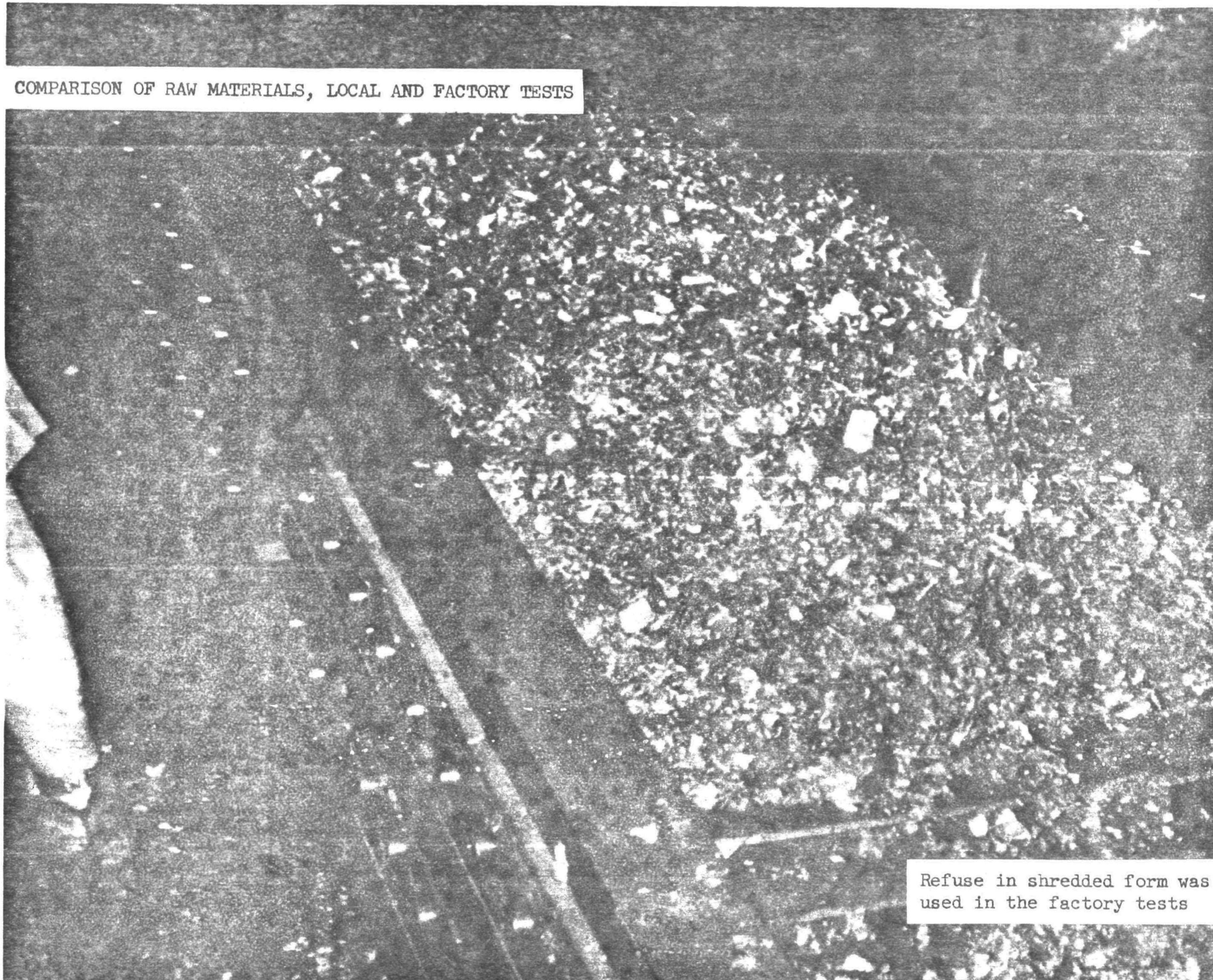
[2] Quoted and shown graphically in American Public Works Association. Municipal refuse disposal. 2d ed. Chicago, Public Administration Service, 1966. p. 53-54.

COMPARISON OF RAW MATERIALS, LOCAL AND FACTORY TESTS

Unprocessed refuse was used in the local baling tests

FIGURE 12

COMPARISON OF RAW MATERIALS, LOCAL AND FACTORY TESTS



Refuse in shredded form was used in the factory tests

FIGURE 13

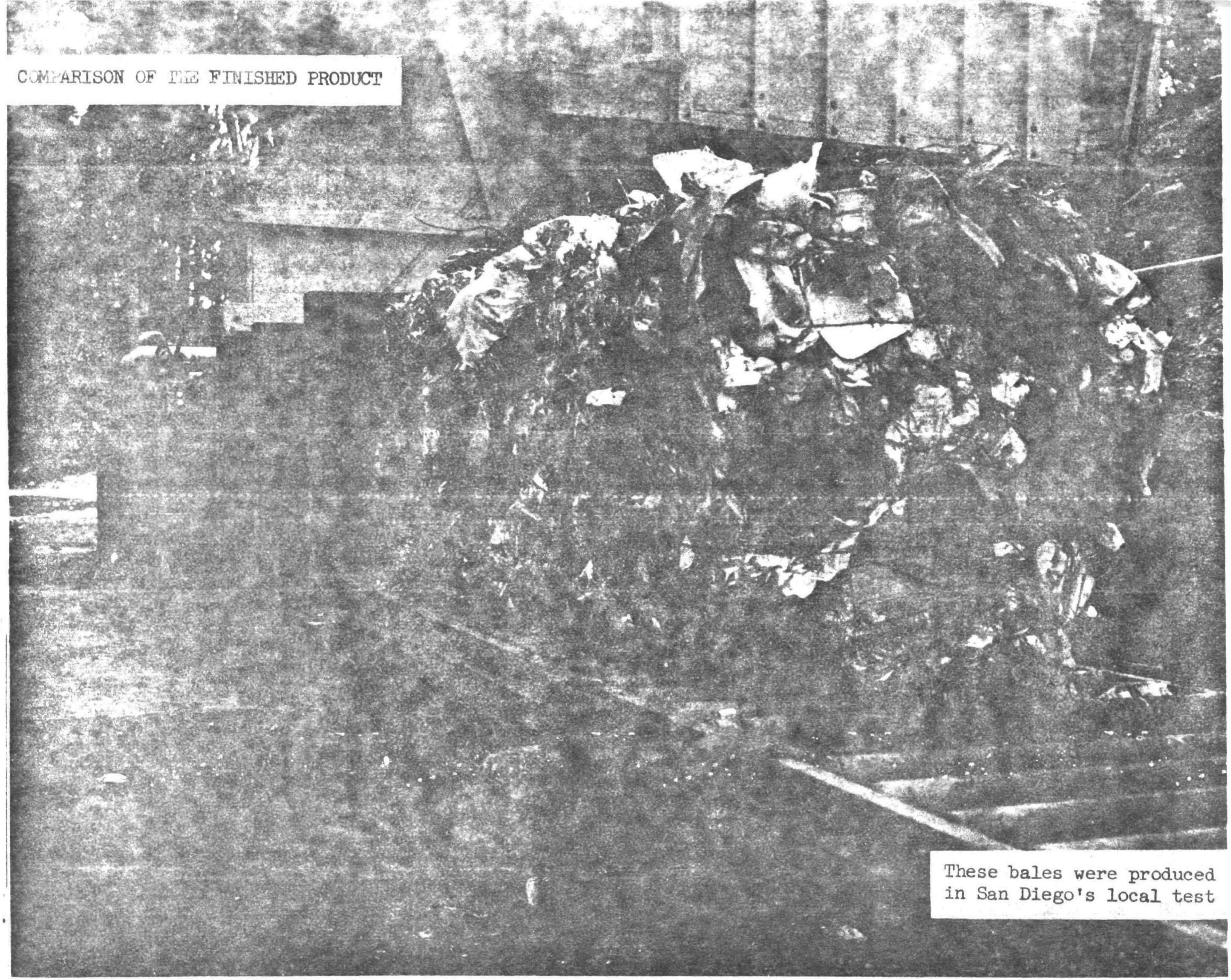
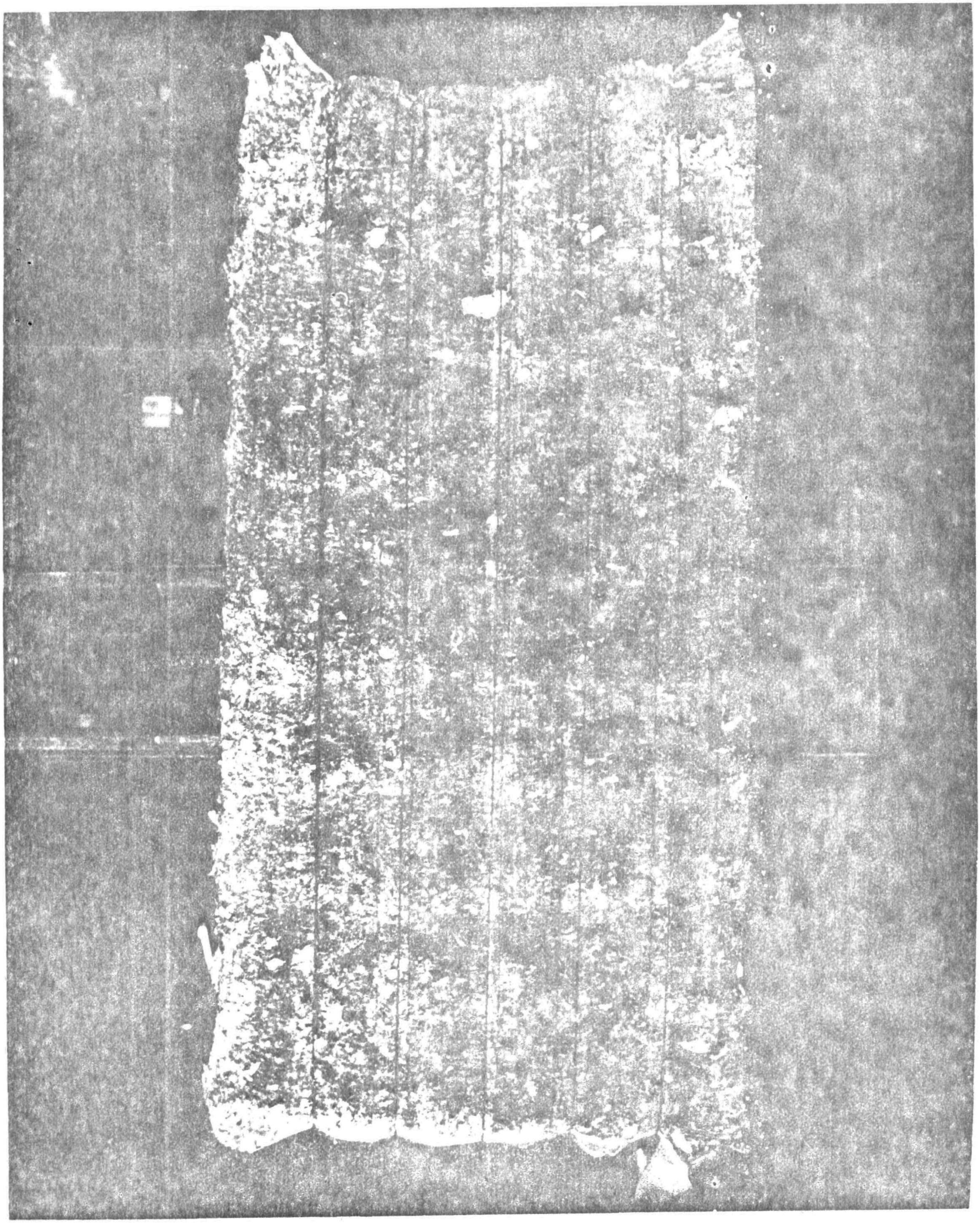
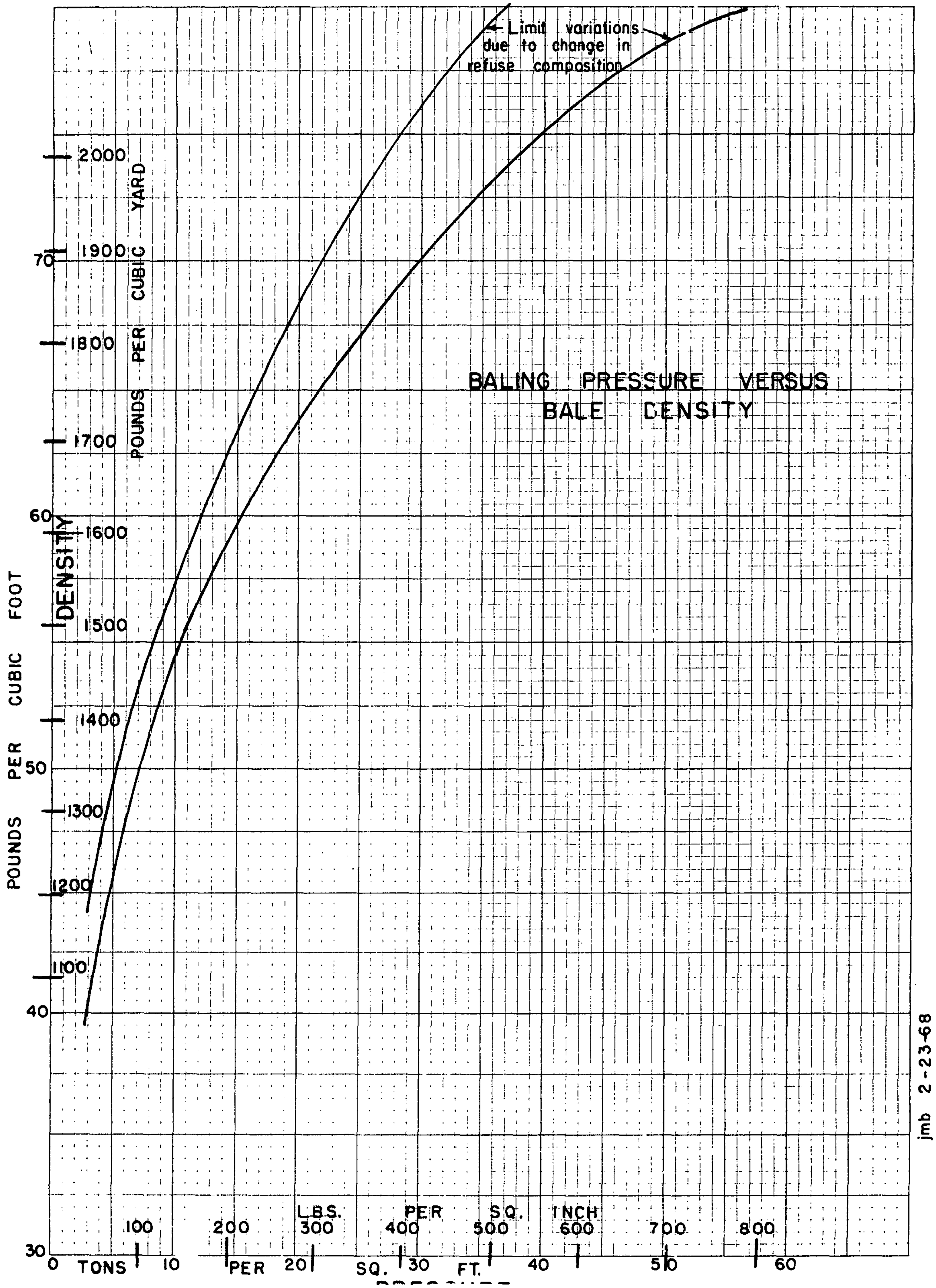

COMPARISON OF THE FINISHED PRODUCT
These bales were produced
in San Diego's local test

FIGURE 14

FIGURE 15




Limit variations due to change in refuse composition
BALING PRESSURE VERSUS BALE DENSITY
DENSITY
POUNDS PER CUBIC YARD
POUNDS PER CUBIC FOOT
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
70
60
50
40
30
LBS. PER SQ. INCH
100
200
300
400
500
600
700
800
TONS PER SQ. FT.
0
10
20
30
40
50
60
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content in improving the density of compressed refuse was found in the compaction tests in a landfill situation (but presumably also applicable to baling). It was noted earlier in this chapter that the American Baler Company's guarantee of high density with their equipment is conditioned in part on a 30 per cent content of moisture in the material. Further study of the optimum percentage of moisture is needed.

The pre-shredding of refuse is also a condition of the company's guarantee. It is felt that this requirement is not arbitrary or capricious. It is based on the company's own experience and the opinions of three private firms now investigating the baling of refuse who are convinced that pre-shredding is essential for the reasons stated in the preceding section of this chapter. One of these firms, the Southern Railway Company, is reported to have estimated that shredding costs will be approximately 50 cents a ton. This figure is consistent with the findings of preliminary cost studies made by the project staff in connection with its investigation of the economic feasibility of baling transfer stations. This aspect of the project is discussed in Chapter IV of this report.

Summary of the Chapter

Although the baling process has long been used for packaging a wide variety of agricultural and industrial commodities, the concept of applying it to the solid waste field is relatively new and presents some technical difficulties.

The physical feasibility of this application and the degree of compaction obtainable by this method were investigated by actually baling refuse in an extensive local test (162 bales) and in a baler factory demonstration. The findings of the two tests tended to corroborate each other. In the local test a large quantity and variety of raw, unprocessed refuse was successfully baled over a period of time, but the average density obtained was slightly less than 700 pounds to the cubic yard. Although the factory demonstration was more limited in scope, the four bales that were produced averaged about 1,500 pounds to the cubic yard in density and were superior in shape and integrity.

Densities obtained locally are not competitive with the approximately 1,380 pounds to the cubic yard obtainable by our best landfill methods. The fact that compaction obtained at the factory exceeds that level is attributable to greater pressure, high moisture content, and the pre-shredding of the material before it was baled. The tests indicate that baling refuse not only is physically and technically feasible but also has great potential as a means of conserving landfill space in San Diego and elsewhere.

CHAPTER IV

ECONOMIC FEASIBILITY OF BALER TRANSFER STATIONS

It was established in Chapter III of this report that it is physically and technically feasible to bale city-collected refuse with presently available baling equipment. It was shown further that when this equipment has high compression capability and when the refuse materials are pre-shredded, it is possible to obtain significantly greater compaction by this means than has been obtained by our best present landfill methods.

It is believed that the potential economic benefits of baling refuse can be fully realized, however, only in the operational setting of a transfer station. It will be shown in this chapter of the report that a functional integration of the baling and transfer concepts is the key to substantial savings when the exhaustion of favorably located facilities requires longer direct hauls by collection vehicles to a more remote landfill.

The essential requirements of the refuse baling process, as described in Chapter III, virtually dictate that it be performed at an intermediate point in the collection-disposal sequence. To produce the degree of compaction necessary to prove out economically the baling press must have high compression capability and must therefore be heavy, massive, and stationary. Since the most effective compaction can probably not be achieved without pre-shredding, another heavy piece of equipment for this purpose is also needed. These technical requirements make impracticable, at this time, some of the ideas that have occasionally been advanced: (1) balers in residences and shops (so-called point of origin processing analogous to the garbage-grinding disposal units now in widespread use), (2) installation of baling devices in refuse collection vehicles, and (3) separate portable balers that might be transported from one collection area to another.

The other possible alternative - placing the baling operation at the landfill - reduces flexibility (the plant may not be well located for subsequent use when the fill is completed) and eliminates the possible savings that might be realized by the strategic location of a baling transfer station near the center of a collection area. It is axiomatic that to the extent that more time must be spent in hauling refuse, as the distance increases between the area of origin and the point of disposal, less time is available for actual collection. Therefore, additional vehicles and crews must be placed in service to complete the route. Formulas developed by the project staff for determining the number and cost of such replacement vehicles are described in a subsequent section of this chapter.

Conventional Transfer Stations

In an earlier period of sanitation service history, horse drawn wagons were used to collect and haul refuse to the disposal site. In those times, this method worked well for relatively short hauls. Four miles was the usual maximum distance beyond which it was more economical to use the transfer concept.[1] In early transfer operations, refuse was removed from the collection wagons at central locations and placed in larger wagons for re-haul to the landfill. The system had the advantages of decreasing the time, distance, and cost of hauling by collection vehicles and increasing the time available for collection.

The motorized vehicles that replaced horse drawn wagons had sufficient speed to overcome the problems of additional haul time. The economics of direct haul became more favorable and the advantages of transfer diminished or disappeared. As urban areas continued to expand, however, problems of additional haul time began to reappear with increasing frequency as the distances between collection areas and disposal sites increased. This new cycle is resulting in a revival of and economic justification for the old transfer idea, but in terms of modern equipment and practices.

Although there is considerable variation in the designs of individual transfer stations now in use, the basic concept of removing refuse from collection vehicles to supplementary transportation vehicles remains unchanged. Most conventional transfer stations can be categorized as either direct dump stations or storage-type stations.[2] In direct-dump stations, collection vehicles at an upper level empty refuse into re-haul vehicles positioned at a lower level. In the transfer stations of this type operated by the Sanitation Districts, Los Angeles County and by Orange County, California, a loader equipped with a "clamshell" type bucket distributes solid waste materials in the re-haul vehicle and effects some compaction by tamping the refuse.[3] New York City operates a water-side station where collection vehicles dump their loads into barges which are then towed to the disposal site.[4] Storage-type stations involve various methods of rehandling the material. Cranes or derricks are sometimes used for transferring an accumulation of dumped refuse to the re-haul vehicles. Another arrangement utilizes a conveyor belt and hopper system. "The material is dumped from the collection trucks into pits so shaped that the refuse falls by gravity to the conveyor. The hopper is constructed high enough to permit the transfer vehicles to drive underneath to be loaded."[5] In other variations of this type, workers pick salvageable materials off a slowly moving conveyor belt or electromagnetic devices remove the ferrous metals.

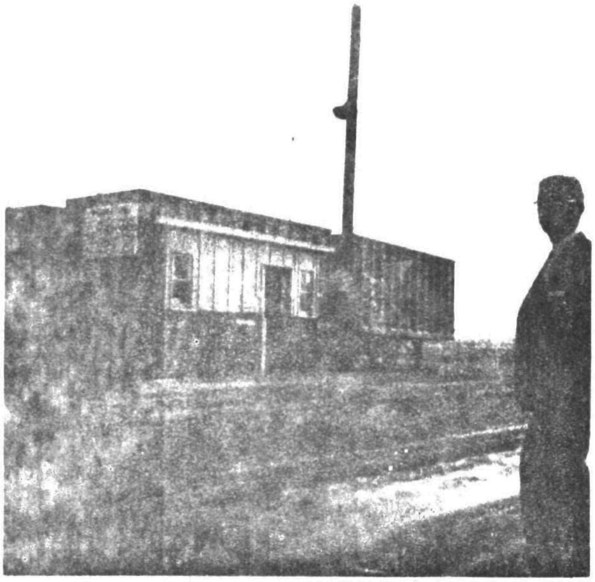
[1]American Public Works Association. Refuse collection practice. 3d ed. Chicago, Public Administration Service, 1966. p. 203.

[2]Ibid., pp. 213-215.

[3]Pictures of the transfer station operated by the Sanitation Districts of Los Angeles County appear in Plate 17 on page 40.

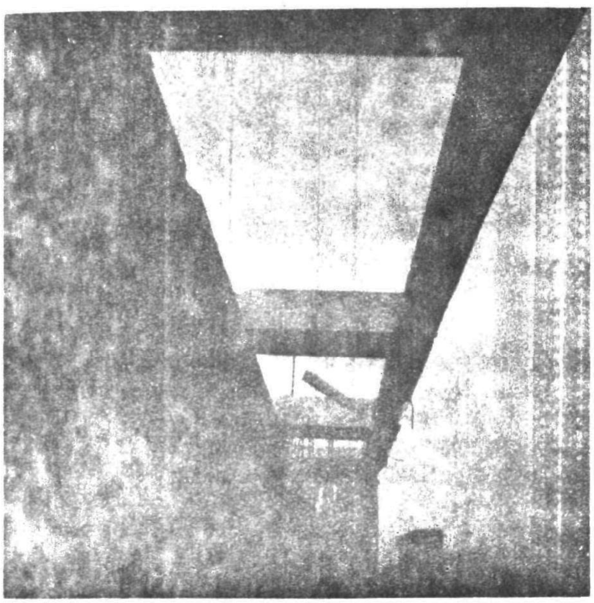
[4]Ibid., pp. 214-215.

[5]Ibid., p. 214.



Refuse vehicles weigh in at the scale house

They proceed to the upper level of the station



Loads are dumped into re-haul vehicles stationed below

This loader is used to spread and tamp refuse in the trailer

(Courtesy of Sanitation Districts, Los Angeles County, California)

The simplicity of the design of these transfer stations makes for easy, expeditious operation with relatively few stoppages due to equipment failure. They have the disadvantage that in the transfer process much of the compaction obtained in modern collection vehicles is lost due to fluffing and spring-back of the materials when they are extruded from the packers. Greater volume per unit of weight is thus required in the re-haul vehicles than would be needed if the refuse had the same density as in the packer truck. For this reason it is usually necessary to use both a semi-trailer and a full trailer in order to haul efficiently with tonnages approaching legal load limits, thus increasing costs and reducing maneuverability. This is a major inherent weakness and it can be eliminated only by introducing into the transfer station some more effective form of compaction process than simple tamping.

The net savings realizable by conventional transfer stations are limited to those related to collection and haul costs. Operations at the disposal site receive no direct economic benefit. The compacting methods that must be used there are identical whether the refuse is received from re-haul vehicles or from packer trucks. The incorporation of baling in the transfer station operation, on the other hand, is a promising means of realizing additional net savings not only by effecting significant reductions in disposal costs but by reducing the number of trailers needed for re-haul. With baling, the legal load can be carried in one trailer instead of two.

The Proposed Pilot Baling Transfer Station

A pilot baling transfer station is needed (1) to test the baling process under actual production conditions, (2) to refine baling techniques and routines, (3) to compare the compaction obtainable with pre-shredded versus unprocessed refuse, (4) to ascertain the optimum moisture content of the refuse being baled, (5) to determine and deal with any possible nuisance factors or health hazards (such as noise, dust, odor, and vector breeding) that may be encountered in the operation, (6) to develop effective practices in placing the bales in a landfill, (7) to explore the feasibility of other means of bale disposal, such as in the reclamation of small canyons near residential areas, and (8) to develop accurate cost comparison under actual operating conditions.

Certain preliminary comments are necessary, however, before the pilot baling transfer station which has been proposed to serve these purposes is described. The fact that the proposed station is a prototype has a number of specific implications:

A. Since some of the mechanical procedures involved have not been validated for the purposes contemplated, the station layout described in this chapter was based on the design theory of staff engineers and the opinions of consultants familiar with the individual items of mechanical equipment.

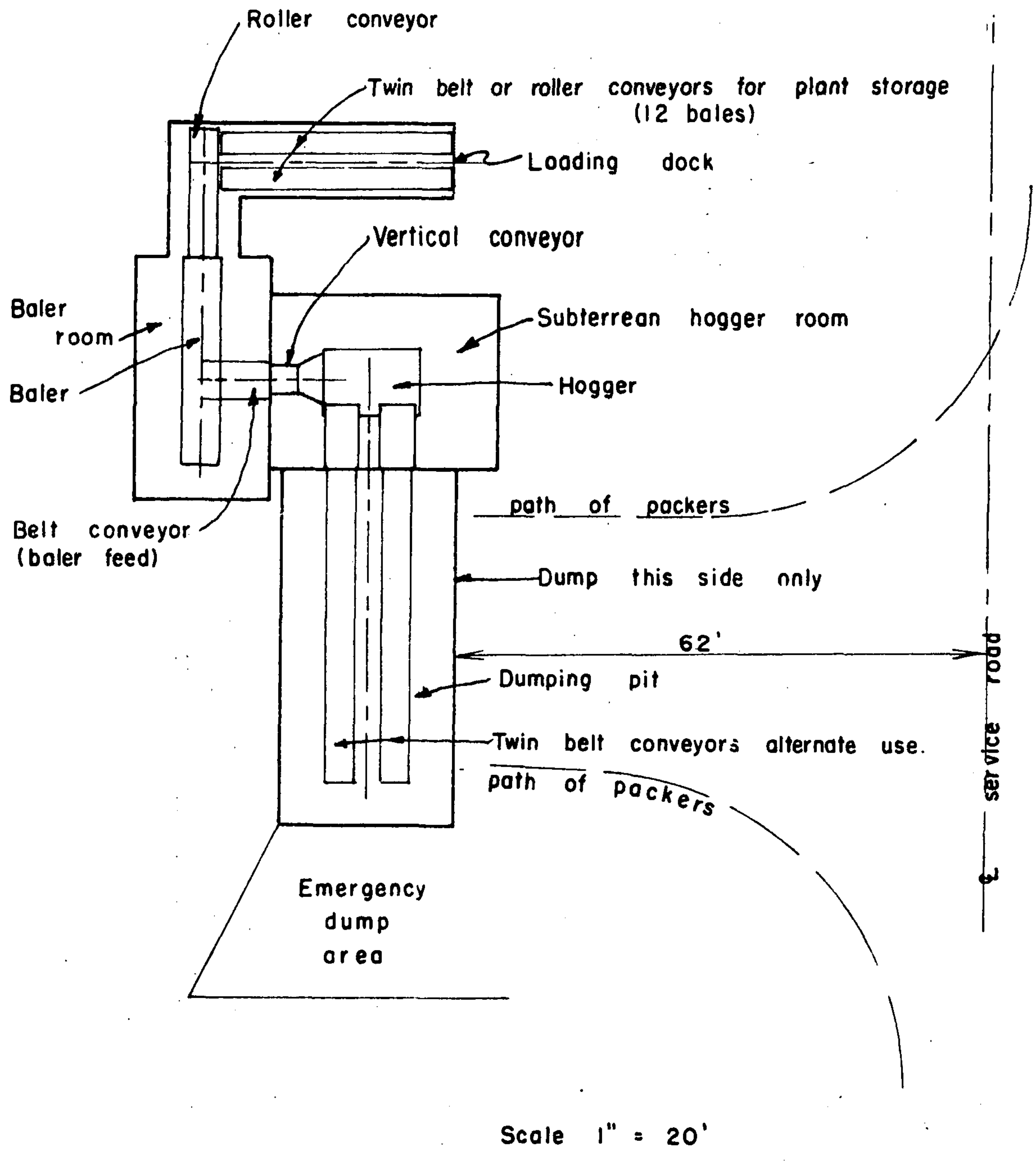
B. The designs and sketches presented herein describe a pilot baling transfer station rather than a full-scale plant. This is the prudent approach to any new operational procedure, however promising, that involves a substantial capital outlay. In previous experience, baling municipal refuse (as discussed in Chapter III) has been experimental in nature and limited in scope. It should be thoroughly tested and evaluated on a reasonably large scale under actual operational conditions. Because of its specialized purpose and smaller capacity, however, a pilot plant is somewhat at a disadvantage in economic comparisons with (1) present methods of landfill operations (because it would disrupt present large-scale operations), (2) a conventional transfer station, and (3) a full-scale baling transfer station.

C. The pilot station design should be realistic. It should include not only all of the basic essential elements but also, if possible, some of the desirable features that will - if the pilot operation is successful - be incorporated in a subsequent full-scale plant. The purpose is to reduce labor cost, which in any such undertaking constitutes the major portion of estimated annual expenditures, and to minimize possible problems that might be associated with human error during the operation.

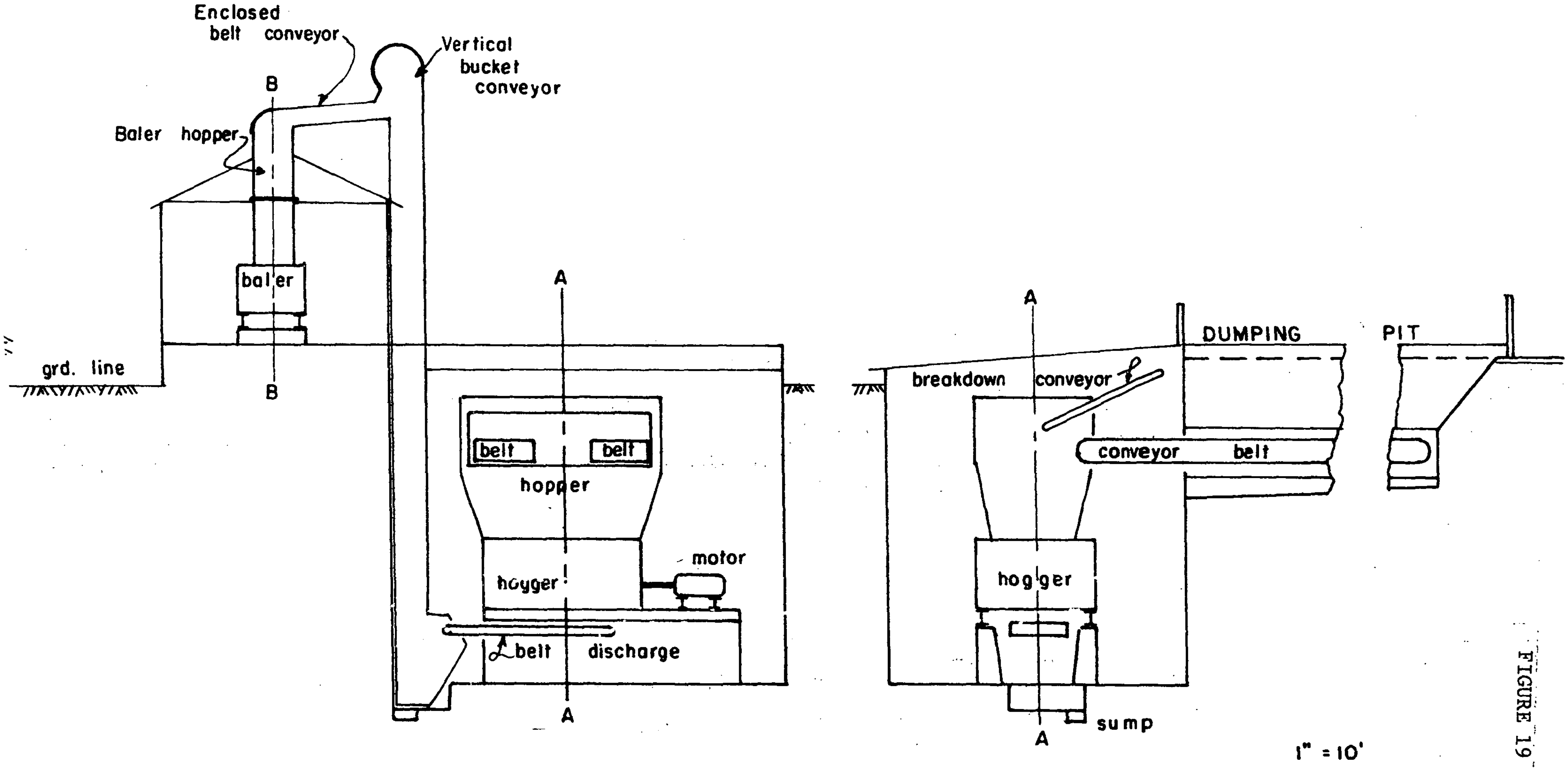
In general, the refuse baling transfer station differs from the conventional transfer station in three distinctive respects: (1) the presence of specialized processing equipment, (2) a more sophisticated system of conveying the materials from one stage to the next, and (3) the state of the refuse at the completion of the operation.

A plan drawing of the proposed pilot baling station, which would be capable of processing 150 tons of refuse a day, appears in Plate 18 on page 43 and elevations are shown in Plates 19 and 20 on pages 44 and 45. As designed, the functional point of refuse entry into the actual plant operation is a dumping pit large enough to accept up to four packer trucks at a time which will also serve as temporary storage space for up to 100 cubic yards of refuse. Two belt type conveyors in the bottom of the pit, each four feet wide, transport the refuse into the plant. Since these belts are designed to be operated independently and at either simultaneous or differing speeds by remote control within the station, they can be manipulated to break up bridging of refuse that might occur in the storage pit. For purposes of safety, hand-operated trip mechanisms would also be installed at strategic locations.

At the inbound ends of the twin belt conveyors, refuse is fed into a rectangular hopper leading to the hogger (shredder) for the first phase of refuse processing. Immediately above the hopper near the ends of the pit belt conveyors, a separate breakdown conveyor operates to expedite and meter the flow of refuse into the hopper (see Plate 19 on page 44). It is expected that this device will tend to feed refuse into the hogger at a uniform rate and prevent surges in the operation.



PILOT REFUSE BALING TRANSFER STATION
Design Capacity 150 tons/day



ELEVATIONS OF PILOT BALING STATION

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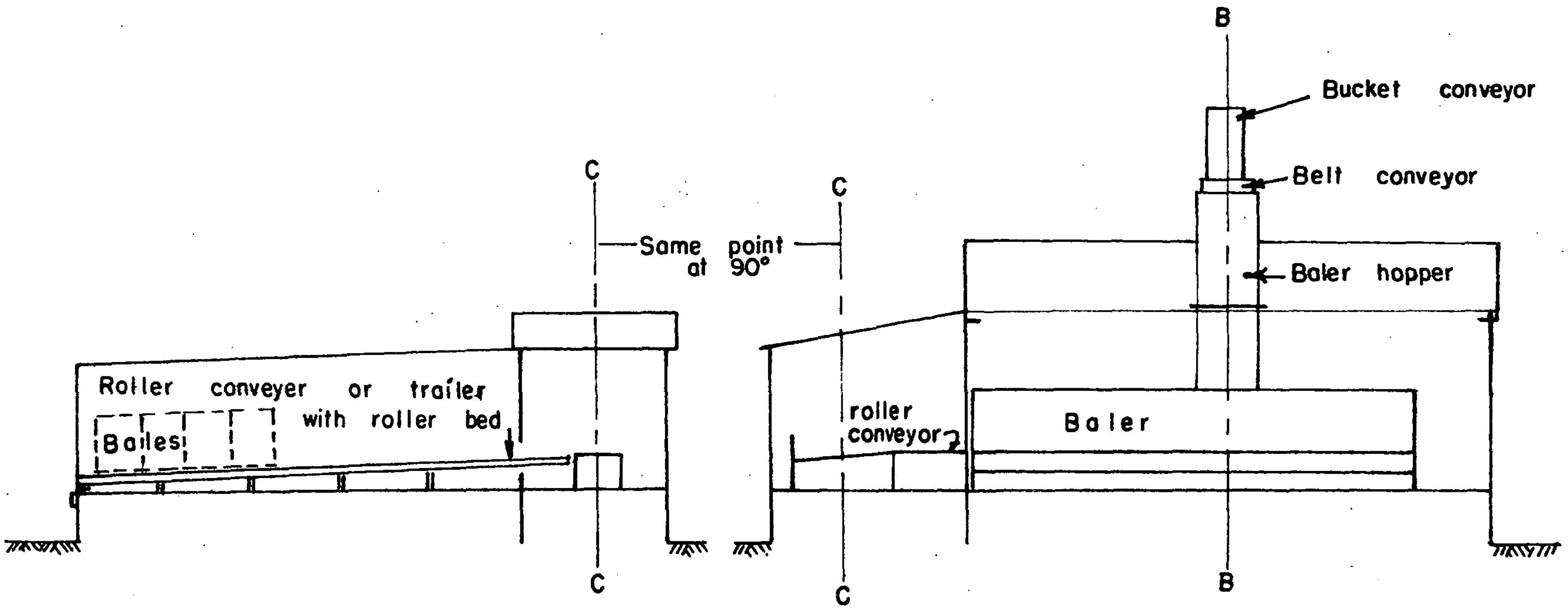
FIGURE 19



1" = 10'

FIGURE 20

ELEVATIONS OF PILOT BALING STATION

Sheet 2 of 2

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The subterranean location of the concrete building housing the hogger and its hopper has the advantage of tending to contain dust and "fly" refuse from the hogger and to suppress the noise of the operation.

After being processed through the hogger the refuse materials, now in fragments no larger than from four to six inches, fall onto a belt type conveyor, are transported to an enclosed vertical bucket type conveyor, elevated therein to a height of fifty feet, fall onto another short belt conveyor, and finally drop into the baler hopper for the second phase of processing (see Plate 20 on page 45).

The baling press, housed in an enclosed structure to permit operation during inclement weather, produces uniform bales at an estimated potential rate of one every three minutes. Experience in this field shows that this interval is long enough for two men to hand-tie the bales (if automatic tying devices become available some of this labor cost could be saved). The bales emerge from the press onto a roller conveyor and are then mechanically pushed 90 degrees onto twin roller conveyors. They move on these to the end of the loading dock and directly onto the re-haul vehicle, the bed of which is itself equipped with rollers. This vehicle (a semi-trailer) is positioned on an incline, so that the bales roll into place by the force of gravity. As soon as one vehicle is fully loaded and departs for the disposal site, another is parked at the dock and the loading process continues.

Cost of the Proposed Pilot Station

It is estimated that the proposed pilot baling transfer station described in the preceding section of this chapter can be built on city owned land and completely equipped, including the hogger, baler and all necessary appurtenances, for $201,000. An itemized breakdown of capital investment costs is presented in Table 3 on page 47.

Estimated current operating costs for one year, totaling $127,200, are given in Table 4 on page 48. The estimated cost of hauling completed bales to the landfill is shown as part of plant expense, and the cost of equipment and labor for the actual disposal of the bales at the fill is shown separately. Because of the specialized, evaluative purpose of the pilot plant and its presumably short life expectancy, computation of annual costs of amortization would not be appropriate.

Conventional versus Baling Transfer Stations

Conventional Transfer Station

The chief advantages of a conventional transfer station are: (1) it is relatively easy to plan and construct, (2) its basic operating procedures are simple and direct, (3) it can accept a wide variety of refuse materials including certain problem items that normally can not be shredded or baled, (4) transfer of the refuse is accomplished quickly, and (5) the absence of complex machinery minimizes the possibility of a complete station shutdown due to equipment failure.

TABLE 3

ESTIMATED CAPITAL EXPENDITURES FOR PILOT BALING TRANSFER STATION

Item		Amount
1. Site Preparation		
Site Grading		$ 600
Paving (8,000 sq. ft.)		2,880
10% Contingencies		320
	Sub-total	3,800
2. Dumping Pit		
Structural Excavation		300
Concrete Pit (34 cu. yd.)		4,000
Hardware		3,000
Pit Conveyors w/motors		28,000
10% Contingencies		3,500
	Sub-total	$ 38,300
3. Hogger Pit Building		
Concrete Building		$ 8,000
Structural Excavation and Backfill		800
Breakdown Conveyors (2)		3,000
Hammer Mill		32,000
Coupler, Hopper, Motor and Starter for Hammer Mill		21,475
Bucket Conveyor for 50' Lift		10,000
Sump Pump and Drain Line		1,500
Air Blower with Conduit		1,000
Ladder		450
Lighting		1,000
10% Contingencies*		2,575
	Sub-total	$ 81,800
4. Baler Building		
525 sq. ft. Building		$ 5,250
Earthwork		600
Truck Dock 340 sq. ft.		2,800
Baler		35,500
10' Belt Conveyor		2,000
60' Roller Conveyor		6,000
Lighting		1,000
Electrical Service and Power Panel		18,000
Water Service (by City Forces)		1,800
10% Contingencies*		3,750
	Sub-total	$ 76,700
	TOTAL CAPITAL INVESTMENT	$201,100

*Contingencies not computed on heavy machinery.

TABLE 4

ESTIMATED CURRENT OPERATING EXPENSES OF PILOT BALING TRANSFER STATION FOR ONE YEAR

Item		
Plant Operation Costs		
1. Re-haul equipment		$ 15,560
2. Plant Labor		
2 heavy truck drivers	$ 17,740	
1 utility foreman	10,267	
2 laborers	15,322	$ 43,329
3. Maintenance and repair		6,476
4. Electrical power and water costs		7,000
5. Bale ties and supplies		10,000
Bale Disposal Costs		
1. Crane rental		10,200
2. Labor (equipment operator and laborer)		15,450
3. Bulldozer for covering (1,000 hrs @ $14/hr)		14,000
4. Bulldozer operator (1,000 hrs)		5,185
TOTAL ANNUAL OPERATING COSTS		$127,200

As compared with a full-scale baling transfer station, the disadvantages associated with the conventional station include: (1) higher station total operating costs (including re-haul costs), (2) larger land area required, (3) loss of much of the compaction obtained in the collection packer truck, (4) larger number of re-haul vehicles for comparable tonnages of refuse transferred, and (5) higher cost of disposing of raw refuse at the landfill (see Table 9 on page 64).

Baling Transfer Station

In the main, the disadvantages and advantages of the baling transfer station are the converse of those set forth above. Disadvantages of the baling transfer station include: (1) more difficult to plan and construct, (2) greater complexity in operating procedures, (3) greater vulnerability to stoppages due to equipment failure, (4) slower process at transfer station although offset by less time required at fill site, (5) greater possibility of public objection to the noise of the machinery, and (6) the character of the refuse must be controlled due to technical limitations of the hogger.[6]

As compared with the conventional transfer station, the baling transfer station offers the advantages of: (1) lower annual operating costs (including re-haul costs), (2) smaller land area required, (3) fewer re-haul vehicles needed, (4) lower cost of disposing of bales at the landfill, as compared to raw refuse, (5) extension of fill life through greater compaction, and (6) utility of refuse in baled form for constructive purposes such as small canyon reclamation.[7]

Transfer Station Location

Regardless of type, the transfer station "should: (1) be located as near as possible to the center of production of the collection area which it serves, (2) be convenient to the secondary or supplementary means of transportation, (3) be so placed that there will be a minimum of public objection to the transfer operations, and (4) be located at points where the construction and operation will be most economical."[8]

These and other criteria for the choice of a location for a transfer station are set forth in Table 5 on page 50 which was developed by the project staff. These considerations are chiefly oriented to permanent, full-scale stations

[6] For this reason, the proposed pilot baling transfer station would process only city-collected refuse. Installing heavier-duty hoggers in subsequent full-scale stations might permit acceptance of privately transported materials which, although they are more heterogeneous in character, constitute 60 per cent of the city's refuse. In any case, convenient close-in landfills would be available to such private transporters for a longer period because of the extended fill life resulting from baling city-collected refuse.

[7] As pointed out in Chapter I, San Diego has many such canyons which can be surveyed and evaluated for conversion by this means into useful and attractive park and recreational areas. See Chapter V for a discussion of small canyon reclamation.

[8] Ibid., p. 210

TABLE 5

FACTORS FOR CONSIDERATION IN LOCATION OF TRANSFER STATIONS

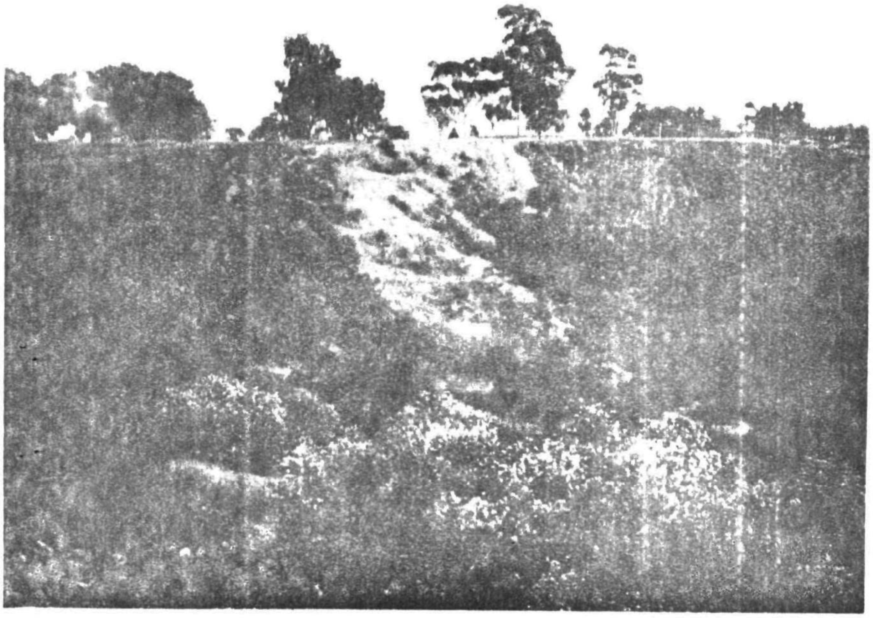
I. GENERAL LOCALE OF SITE(S)

A. Proximity to theoretical center of the collection areas served.
B. Proximity to population movements as they affect collection areas.
   1. Probability of present routes served being reduced.
   2. Probability of new collection routes being added to the transfer operation.
   3. Location of future transfer stations.
C. Character of the area in relation to possible public objection to a transfer station.
   1. Residential development.
   2. Commercial development.
   3. Industrial development.
   4. Miscellaneous (recreational, hospitals, etc.)
D. Accessibility from collection routes and availability of exit routes for re-haul vehicles.
   1. Expressways.
   2. Major and minor streets.
E. Present and possible zoning ordinances governing land use in the area (to avoid conflict).

II. SPECIFIC AREA OF SITE(S)

A. Location should be at points where the construction and operation will be most economical.
   1. Capital outlay for land.
   2. Site preparation needed before construction.
   3. Proximity to utility services (e.g., gas, power, water, etc.).
B. Character of area (zoning) bordering site in relation to possible public objection.
C. Accessibility to the specific site.
   1. Major and minor streets (e.g., street widths, pavement thickness, traffic).
D. Zoning ordinance governing land usage at the site.
E. Specific characteristics of site.
   1. Spacial dimensions.
   2. Existing structures.
   3. Other improvements.
F. Proximity to supplementary means of transportation.
   1. Water-ways.
   2. Railroads.

THREE VIEWS OF A SMALL CANYON PROPOSED FOR RECLAMATION FIGURE 21



This canyon is too small and too near a residential area for a conventional fill operation

But it could be box-cut and filled with nested bales of refuse and covered with earth

Making possible a valuable extension of a city golf course's present cramped parking lot

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rather than pilot stations which by definition are temporary arrangements designed primarily for evaluation rather than for production purposes. The criteria for the selection of a site for the proposed pilot baling transfer station that appear to be most relevant to this testing and validation function are: (1) avoidance of land costs by location on property presently owned by the city, (2) minimal site preparation, (3) suitability of site for construction, (4) proximity to existing utility services, (5) possibility of obtaining adequate supply of refuse materials without undue disruption of regular collection routes and routines, (6) ease of access, and (7) proximity to a small canyon which can be filled with bales for reclamation purposes. Plate 21 on page 51 shows a canyon that could be used for this purpose. The possibility of future expansion of the pilot station into a full-scale station was not overlooked, but this was not a major factor in site selection.

Two areas were considered for the location of the proposed pilot baling transfer station: (1) the general area of San Diego known as Old Town and (2) the specific area within the boundaries of the city's Central Operations Station at 20th and B Streets.

The Old Town area is strategically located not only in relation to the Central collection district now served by the Arizona landfill (approximately 50 per cent of the district's collection mileage is in that area) but also in relation to some of the Rose Canyon operations district now served by the Miramar landfill. In field surveys of the area several possible sites were identified and evaluated. The project staff concluded, however, that in the light of the criteria described above, this locale is probably better situated for a possible future full-scale baling transfer station than for a pilot station.

The specific site, selected on city-owned property at the Central Operations Station, is pictured in Plate 22 on page 53. Located at the foot of a steep earth bank to the east, this site would not be visible from residential area or from a municipal golf course to the north. Its visibility from a Naval hospital located about a third of a mile away and at a higher elevation might require landscape screening. It will be recalled that the suppression of noise was one of the important considerations in the design of the station.

Access to the proposed site is excellent. Three major highways radiating through heavily populated areas of the city converge near the operations station. Access to the specific site is by a road within the station. Proximity to the Arizona landfill would permit easy re-routing of collection vehicles in the event of emergency breakdowns at the pilot plant. Existing water, sewer, and power lines are nearby, while lavatories and shower facilities are within easy walking distance.

FIGURE 22

Aerial view of small canyon proposed for reclamation (upper arrow) and proposed site for pilot station at the Central Operations Center (lower arrow)

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These advantages, together with the site's proximity to a small canyon which could be filled with baled refuse as a model reclamation project (perhaps leading to further exploitation of this idea in the future), appear to make this location the best and most economical choice as a site for the proposed pilot baling transfer station.

Basis for the Economic Feasibility Study

Actual experience with a pilot baling transfer station would undoubtedly contribute to a better appraisal of the economic feasibility of a full-scale baling transfer station operation than is now possible. Nevertheless it is prudent to make the best possible estimate, on the basis of information presently available, of the cost of this approach to a refuse disposal problem that is becoming critical in San Diego and elsewhere, as compared with other available alternative solutions. For a municipality that is committed to the landfill method of refuse disposal, the basic alternatives are either longer direct hauls to more remote landfills or the operation of transfer stations with or without an element of refuse processing, such as baling. The refuse baling process is technically feasible and can produce greater compaction than normal landfill methods. In combination with the transfer concept it appears to offer great promise of substantial savings. It would be futile, however, to make the necessarily large investment in such a system if careful and objective preliminary analysis revealed that savings could not actually be realized in a specific situation.

The economic feasibility analysis described in the remainder of this chapter was based on data derived from a study of this city's Central Operations Station at 20th and B Streets. This location was chosen for this purpose primarily for three reasons: (1) its collection area is probably comparable to those of the typical American city, (2) it produces substantially larger tonnages of city-collected refuse than do either of the other two major collection areas, (3) the exhaustion of its Arizona landfill, situated as it is in the heart of the city, will present a more critical and costly situation than will the completion of the other existing or available landfills. In the course of the study, although it was based on localized data, certain generalized concepts and techniques were developed which can be used to advantage in future investigations of this kind here and elsewhere. Estimated comparative costs were determined for (1) longer direct haul to the disposal site, (2) conventional transfer station operation, and (3) baling transfer station operation.

Data for Direct Haul Cost Study

It will be recalled that the present collection fleet at the Central Operations Station consists of twenty-three packer trucks having twenty cubic yard capacities and three-man crews each and one sixteen-yard, three-man packer truck which operates in the beach areas. At its other two operations stations the city has replaced all twenty-yard, three-man packers with twenty-five-yard, two-man trucks and plans to do so at the Central Station within a few years. The sixteen-yard vehicle will remain in service because of the restricted street widths in the beach areas. For purposes of this study it is assumed that these larger capacity vehicles will be in operation by the time a full-scale baling transfer station could be constructed and put into operation.

The factors which determine the cost of direct haul are: (1) the average hourly cost of operating, staffing, and supervising each collection packer, (2) the average amount of refuse transported per packer during direct haul, (3) the average mileage traveled per packer in the direct haul, (4) the average round trip speed of a packer while hauling, and (5) the average time it takes to complete the direct haul and return to the collection route.

Hourly Cost

As computed by the Equipment Division of the Public Works Department, cost of operating a collection vehicle reflects depreciation, overhead, repairs, tow calls, minor modifications, painting, fuel, overtime pay when necessary, and standby packer trucks as needed. Normally shown as per mile unit charges in the city's cost accounting practice, these costs were converted to charges per hour for purposes of this study. The average equipment cost of operating a twenty-five cubic yard packer truck for one hour was found to be $4.64.

San Diego's Sanitation Division has three classifications of collection personnel: Crewmen I, II, and III. All of these classifications perform collection duties but only Crewmen II and III are authorized to drive packer trucks. Therefore, in the twenty-five cubic yard, two-man crew arrangement, in which the men alternate in collecting and driving, only Crewmen II and III are assigned. To obtain the present average hourly labor cost, it was necessary to determine the average pay steps that Crewmen II and III have actually reached. Average hourly base pay rates at these points were found to be $4.47 and $4.72 respectively, including fringe benefits.

The hourly cost of collection supervision at the foreman level was found to be $ 0.82 per packer including fringe benefits.

Based on these elements, the total hourly cost of operating a packer truck may be summarized as follows:

Item	Hourly Cost
Equipment - 25-yard packer	$ 4.64
Labor - Crewmen II and III, including fringe benefits	9.19
Supervision - foreman level, per packer	.82
Total	$14.65

Average Mileage and Tonnage

Average mileage traveled per packer during direct haul is the quotient of the total mileage traveled by all packers divided by the number of packers operating. Since the present fleet of twenty-yard, three-man crew packers will be replaced by twenty-five-yard, two-man crew trucks at the Central Operations Station, it was necessary to determine the number of the larger vehicles that would be needed to replace the present fleet. Records show that at the Central Station the average amount of refuse collected and hauled is approximately fourteen tons per day per packer, normally requiring three trips to the landfill (occasionally four trips are necessary when the refuse contains large proportions of bulky items which occupy more volume in the packer). The average load on the basis of fourteen tons and three trips is 4.65 tons per packer. On the other hand, study of collection records at the Chollas Operations Station showed that on the average a twenty-five-yard packer transports 6.5 to 7 tons of refuse per trip. This average has been increasing and Sanitation officials feel that ultimately 7.5 tons per packer can be reached. For purposes of determining the tonnage transported during direct haul with the twenty-five-yard packer, it is assumed that seven tons per load is a good average and that the amount of refuse collected per truck per day could vary between thirteen and fifteen tons. On this basis, the twenty-yard packers at the Central Station can be replaced with twenty-five-yard packers on a one-to-one basis.

In order to obtain the total round trip mileage to be traveled during future direct haul, it was necessary to determine the mileages between individual collection routes and the proposed Murphy-Shepherd landfill to which it is assumed Central Station packers would haul at the completion of the Arizona landfill in 1975. For this purpose the approximate center (centroid) of each route and the most direct haul route from that point to the landfill were determined. Mileages were found by map measurements, checked by driving the route by automobile. Combined daily and weekly mileages were computed for the entire fleet. A similar procedure was used to establish the round trip mileage for present direct haul to the Arizona landfill. The difference in mileage between the haul to the proposed Murphy-Shepherd site and that to the Arizona landfill is the base from which the additional cost of longer direct haul was calculated (see Table 6 on page 57 for a summary of these mileages). The average mileage increase in the round trip to the more remote landfill was found to be 9.9 miles per packer.[9]

Average Speed and Haul Time

As part of a three-week study to determine the average speed of a packer during direct haul, collection crews reported time and odometer readings for (1) departure from the collection route, (2) arrival at the landfill, (3) departure from the landfill, and (4) arrival at the collection route. The complete round trip was recorded to take into account the difference in speed between a loaded and an empty packer. Average speed during a complete round trip was found to be twenty-two miles an hour.

Average increase in haul time per packer for one round trip to the proposed Murphy-Shepherd landfill was found to be twenty-seven minutes (by dividing the average round trip increase of 9.9 miles by the average packer speed of twenty-two miles an hour and multiplying this quotient by sixty minutes).

[9] The project staff's studies showed that, in the specific San Diego situation examined, the break-even extra distance at which the costs of direct haul and of a full-scale baling transfer station would be equal was about 10.1 miles.

TABLE 6

WEEKLY ROUNDTRIP MILEAGE INCREASE
DIRECT HAUL TO MURPHY-SHEPHERD LANDFILL VERSUS ARIZONA LANDFILL

Route Collection Day	Route Collected[a]	Number of Packers Required[b]	Mileage to Murphy-Shepherd[c]	Mileage to Arizona	Total Mileage to Murphy-Shepherd[d]	Total Mileage to Arizona[d]	Total Mileage Increase to Murphy-Shepherd
Mon.	LA PLAYA	14	26.0	16.8	364.0	235.2	128.8
Tues.	OCEAN BEACH	6	25.4	19.8	152.4	118.8	33.6
Tues.	LOMA PORTAL	7	23.8	15.0	166.6	105.0	61.6
Tues.	OLD TOWN	8	17.6	9.2	140.8	73.6	67.2
Wed.	SO. CENTER CITY	8	21.2	6.8	169.6	54.4	115.2
Wed.	SOUTH PARK	8	19.2	4.6	153.6	36.8	116.8
Wed.	WEST LOGAN HTS.	6	20.2	8.6	121.2	51.6	69.6
Thurs.	HILLCREST	9	16.4	5.6	147.6	51.3	96.3
Thurs.	WEST NO. PARK	7	13.6	4.0	95.2	28.7	66.5
Thurs.	MIDDLETOWN	6	23.0	9.4	138.0	56.4	81.6
Fri.	NO. NORMAL HTS.	8	11.0	6.6	88.0	53.6	34.2
Fri.	SO. NORMAL HTS.	7	12.4	5.4	86.8	37.8	49.0
Fri.	EAST NO. PARK	6	12.8	3.2	88.8	19.2	69.6
		100			1912.6	922.4	990.2[e]

a. Four of the station's twenty-four trucks (including the 16 cubic yard packer) have special schedules that vary from day-to-day during the week, but this does not appreciably affect the mileage figures.
b. Twenty-five cubic yard vehicle.
c. One round trip, collection route to landfill and return to route.
d. Number of packers times mileage for one round trip.
e. Average increase per packer: 990.2 ÷ 100 = 9.9 miles.

The Economics of Direct Haul

In standard practice, estimates of the cost of transporting quantities of materials have been based on unit costs calculated from actual experience. These units are usually expressed as cost per ton mile if the emphasis is on the distance to be traveled or as cost per ton minute if the duration of the trip is of primary importance. The distance basis is the older and more common concept and is suitable for use when conditions of travel are relatively uniform and constant. Under modern urban travel conditions encountered in transporting municipal refuse in trucks, however, the time concept is more appropriate. Travel to and from the disposal site may be on fast expressways, on congested city streets, or on a combination of both. It is quite conceivable that the travel time of a refuse truck from a distant collection area to the landfill could be less, if the route is on an expressway, than that of a packer hauling from a closer area over city streets. Moreover, all or most of the expense of operating refuse vehicles, consisting largely of labor costs, is normally accounted for on a time basis or can readily be converted to it.

The standard method of computing cost per ton minute is to divide the average total hourly cost of operating the vehicle by the average payload in tons and to convert this quotient (cost per ton hour) into minutes by dividing by sixty.

Cost estimates based on the ton minute unit (or on the ton mile unit) are valid only in static situations where changes in haul time (or distance) are not involved. Gross errors result when this approach is used, as it sometimes has been, to estimate the cost of the additional direct haul time (or distance) required by the closing of a favorably situated landfill and the consequent necessity of transporting to a more remote location. This common fallacy arises from attempting to apply to a changing situation a cost unit that is inherently a constant, and overlooking the fact that the extra time spent on the longer haul occurs at the expense of time available for route collection.

This point can be illustrated by a local example based on the data contained in the preceding section of this chapter: the situation that will exist when the Arizona landfill is completed and longer direct haul to the proposed Murphy-Shepherd landfill becomes necessary.

In this illustration, the basic starting point is the following "standard" allocation of time during the working day of the collection forces:

340	minutes for actual collection (productive)
80	minutes for hauling (subsidiary)
60	minutes for early morning preparation, driving to the route, lunch and rest breaks, and return to the station (subsidiary)
480	minutes or eight hours

During the actual productive time of 340 minutes the packer crew now collects an average of fourteen tons of refuse. The collection rate is therefore 24.3 minutes per ton (340 minutes divided by 14 tons) and the total daily weight of refuse collected by a fleet of twenty-four packers is 336 tons. In the new conditions imposed by the closing of the Arizona landfill, however, each round trip haul would increase in distance by 9.9 miles and, in time required, by twenty-seven minutes. With two such trips a day, the total time lost would be fifty-four minutes, and the time available for collection would drop from 340 to 286 minutes (assuming that time for preparation and rest breaks would remain constant).

At the collection rate of 24.3 minutes per ton, a packer crew would now collect only 11.8 tons per day and the fleet would collect 283 tons per day instead of the normal 336 tons. The deficit of fifty-three tons which could not be collected in the time available would require either that the crews work overtime or that additional packers and crews be placed in service. Since a policy of requiring continual overtime work (in effect a permanent lengthening of the working day) would not be a practical alternative, an enlargement of the fleet would be required.

In these circumstances the number of additional packers required depends on the tonnage to be collected and the daily rate of collection per packer. In the example being considered, the addition of 4.5 packers to the fleet would be needed (53 tons divided by 11.8 tons daily rate) or actually, since the operation of half a truck would not be practicable, five additional packers. The expanded fleet of twenty-nine packers would be needed to collect the required tonnage and haul it to the new Murphy-Shepherd landfill.

In this specific case, failure to take into account the factor of lost collection time would result in an error of $ 0.03 in the ton minute unit cost and an underestimate of $70,000 in annual expenditures. The mathematics of these serious discrepancies is shown below:

Cost Estimates Without Lost Time Correction

In the standard formula for computing ton minute unit haul costs -

$$\text{Cost per Ton Minute} = \frac{\text{Total Hourly Packer Operating Cost}}{\text{60 minutes x Average Payload (tons)}}$$

substitute the appropriate data for a twenty-five cubic yard packer: $14.65 hourly cost, seven-ton payload:

$$\text{Cost per Ton Minute} = \frac{\$14.65}{60 \times 7} = \$\ 0.0348$$

The estimated annual cost for direct haul is then obtained by multiplying the above unit cost by the annual tonnage hauled and this product by the extra haul time in minutes. The annual tonnage figure is 87,360 (336 daily tonnage times 260 working days in the year). By this estimate, therefore -

Annual Increased Cost = \$ 0.0348 x 87,360 tons x 27 minutes = \$ 82,083.46

Cost Estimate With Lost Time Correction

On the basis of \$14.65 per hour for operating a twenty-five cubic yard, two-man-crew packer, the daily cost of operating (eight hour day) is \$117.20 per packer and the five additional packers required would thus cost \$586. a day. It follows that -

True Annual Increased Cost = \$586. x 260 working days = \$152,360

This estimated annual cost, approximately \$70,000 higher than that found by the other method, reflects the true increased cost due to increased haul time (subsidiary work) at the expense of collection time (productive work).

The true cost per ton minute in terms of this specific situation can now be calculated as follows:

$$\text{True Cost per Ton Minute} = \frac{\$152{,}360 \text{ annual cost increase}}{87{,}360 \text{ annual tons} \times 27 \text{ minutes}}$$

$$= \$\ 0.065 \text{ for 27 minutes extra haul time for this size fleet}$$

It is important to note that this unit cost per ton minute is not constant. It will vary with any changes in fleet size and minutes per round trip. Although this method of estimating costs has general applicability, the amount shown relates only to the specific direct haul situation described and also involves the assumption that the problem would be met by adding packers to the fleet rather than by continual overtime work, which would probably be even more costly.

To summarize, the "standard" procedure often used for determining cost per ton minute reflects only cost "on the road" and involves the erroneous assumption that all other conditions will remain constant. It does not take into account the additional costs resulting from lost collection time. In the true cost shown above for a specific San Diego situation, this important factor has been included in the computations.[10] The annual extra cost of direct haul found in that situation, \$152,360. will be compared with the costs of two alternative solutions of this particular problem: (1) operation of a conventional transfer station and (2) operation of a baling transfer station.

[10] See Appendix 4 for a presentation of the development of mathematical formulae with general applicability to direct haul studies.

Comparative Costs of Convention and Baling Transfer Stations

Conventional Transfer Stations

It is estimated that the cost of building a conventional transfer station having a nominal capacity of 350 tons of refuse a day (the approximate weight of refuse now being received by the Arizona Fill) would be $95,750 and the cost of land for the site would be $42,360. The annual costs of amortizing these outlays are estimated at $6,858 and $2,118 respectively. It is expected that annual current expenses of operation, including re-haul to the landfill, would be $196,630 and that the total cost for one year, including amortization of land and capital improvements, would be $205,606. Details of the estimates are shown in Table 7 on page 62.

The unit cost of this operation would be $2.26 a ton on the basis of an annual nominal plant capacity of 91,000 tons (350 tons a day for 260 days). It should be noted that 350 tons a day is not the optimum capacity for a conventional transfer station and that this unit cost would undoubtedly be lower in a larger station.

Baling Transfer Stations

The cost of building and equipping a baling transfer station (see Table 8 on page 63) is estimated at $298,100 - three times as much as the capital outlay for construction required for a conventional transfer station. Only a little more than a third as much land is required, however, and this cost is estimated at $15,000 for the baling station. Current operating expenses are expected to be $166,698 for one year (as compared with a conventional station, it will be noted by comparing Tables 7 and 8, plant labor and supplies and services are higher, re-haul labor and equipment are lower, and certain types of "housekeeping" plant equipment needed in the conventional transfer station are not required in the baling station). As a result, current operating expenses are almost $30,000 a year lower in the baling station than in the conventional station. The $192,996 total cost for a year, including amortization, is about $13,000 lower.

On the basis of 91,000 tons nominal capacity (the same as for the conventional transfer station), the gross unit cost of the baling transfer station operation would be $2.12 a ton.

Cost Comparisons

Before a legitimate comparison can be made between the estimated annual costs of the conventional transfer station and the baling transfer station (and between both of these and the extra cost of longer direct haul to the landfill), it is necessary to examine the substantial savings that can be effected at the fill when the refuse is brought there in baled form. As shown in Table 9 on page 64, these estimated savings amount to $35,672 in the specific San Diego example being considered in this chapter.

TABLE 7

ESTIMATED ANNUAL COST OF A FULL-SCALE CONVENTIONAL TRANSFER STATION
(350 TONS NOMINAL DAILY CAPACITY)

Item	Amount Total	Amount Annual*
Capital Investment Costs		
1. Plant construction		
300 lin. ft. 14' high concrete retaining wall @ $125/ft.	$ 41,250	$ 2,163
4,800 cu. yd. embankment @ $2/yd.	9,600	480
5,000 sq. ft. 5" concrete pavement @ $.70/sq.ft.	3,500	175
30,000 sq. ft. 6" A.C. pavement @ $.60/sq. ft.	18,000	1,800
1 each 40' truck scale	12,000	1,200
950 lin. ft. 8' chain-link fence @ $12/ft	11,400	1,140
	$ 95,750	$ 6,858
2. Land - 42,360 sq.ft. @ $1/sq.ft. value	42,360	2,118
TOTAL CAPITAL INVESTMENT COSTS	$138,110	$ 8,976
Current Operating Expenses		
3. Plant labor		
1 equipment operator III	$ 10,786	
1 equipment operator I	6,500	
1/2 utility foreman	5,134	$22,420
4. Plant equipment		
1 sweeper ($3/hr)	6,240	
2 crane booms ($5/hr. - 1 standby)	20,800	27,040
5. Re-haul labor and equipment		
3 heavy truck drivers	26,610	
3 truck-tractor diesels ($5/hr)	31,200	
6 sets gondola trailers ($7/hr. set)	87,360	145,170
6. Supplies and services		2,000
TOTAL CURRENT OPERATING EXPENSES		$196,630
Amortization (Items 1 and 2 above)		8,976
TOTAL ANNUAL COST		$205,606

*Amortization computed on the basis of twenty years for land, buildings, and earthwork and seven years for mobile equipment.

TABLE 8

ESTIMATED ANNUAL COSTS OF A FULL-SCALE BALING TRANSFER STATION

(350 TONS NOMINAL DAILY CAPACITY)

	Amount	
Item	Total	Annual*
Capital Investment Costs		
1. Site preparation	$ 3,800	$ 350
2. Dumping pit with equipment	73,800	6,866
3. Hogger with equipment	81,800	6,551
4. Baler building with equipment	126,700	10,581
5. One 40' truck scale	12,000	1,200
	$298,100	$25,548
6. Land - 15,000 sq. ft. @ $1/sq. ft. value	15,000	750
TOTAL CAPITAL INVESTMENT COSTS	$313,100	$26,298
Current Operating Expenses		
7. Plant labor		
1 utility foreman	$ 10,268	
5 laborers	38,300	
1 electrician (25% time)	2,600	$51,168
8. Re-haul labor and equipment		
3 truck drivers	$ 26,610	
3 truck-tractors ($5/hr.)	31,200	
6 trailers ($1.50/hr.)	18,720	$76,530
9. Supplies and services		
Wire ties	$ 20,000	
Electrical power	15,000	
Water	2,000	
Miscellaneous	2,000	$39,000
TOTAL CURRENT OPERATING EXPENSES		$166,698
Amortization (Items 1-6 above)		26,298
TOTAL ANNUAL COST		$192,996

*Amortization computed on the basis of twenty years for building and earthwork, fifteen years for the hogger, ten years for major machinery (including the baler) and paving, and seven years for mobile equipment.

TABLE 9

ANNUAL SAVINGS IN DISPOSAL COSTS

1. Present methods of landfill operations cost an average of $0.842 a ton.*

2. Estimated annual cost of bale disposal:

1 mobile crane @ $5/hr	$ 10,400
1 equipment operator III	10,786
1 equipment operator III (30%)	3,236
1 bulldozer @ $14/hr (30%)	8,736
1 laborer	7,661
Total	$ 40,819

3. Cost per ton for bale disposal = $\frac{\$40,819}{91,000 \text{ nominal tonnage**}}$ = $0.448

4. Present disposal cost ($0.842) minus estimated bale disposal cost ($0.448) = $0.394 savings per ton, or $35,854 per year.

**350 tons per day for 260 working days in the year.

TABLE 10

COMPARATIVE ANNUAL COSTS OF CONVENTIONAL AND BALING TRANSFER STATIONS

Cost Item	Conventional Station	Baling Station
1. Amortization of station	$ 6,858	$ 25,548
2. Amortization of land	2,118	750
3. Plant costs (labor and equipment)	49,460	51,168
4. Supplies and services	2,000	39,000
5. Re-haul (labor and equipment)	145,170	76,530
Total	$205,606	$192,996
Disposal savings at $0.39/ton (see Table 9)		35,672
Total annual net costs	$205,606	$157,324

When these savings are taken into account the estimated net annual cost of the baling transfer station operation is reduced to $147,964, which is $57,654 a year lower than the cost of the conventional transfer station and $4,396 less than the cost of direct haul (see Table 10 on page 64). The estimated unit costs per ton are $1.63 (baling station), $2.26 (conventional station), and $1.67 (direct haul), under these specific conditions.

Summary of the Chapter

The potential economic benefits of baling refuse can probably be fully realized only in the operational setting of a transfer station. The transfer concept, although not new, is receiving increasing attention as a means of avoiding the expense of longer direct hauls by refuse collection vehicles to more remote landfills when favorably located fills are exhausted. A baling transfer station would differ from a conventional transfer station chiefly in (1) the presence of specialized processing equipment, (2) a more sophisticated system of conveying the materials from one stage to the next, and (3) the state of the refuse at the completion of the operation.

It is proposed that a pilot baling transfer station be built and operated under realistic production conditions in order to evaluate technical and economic aspects of the operation. This station would cost $201,100 to build and $127,200 to operate for a period of one year.

Economic feasibility studies based on information presently available indicate that where the exhaustion of an existing favorably located landfill requires longer direct haul to a more remote landfill, and when the additional round-trip distance required per truck exceeds about 9.5 miles, a full-scale baling transfer station would be more economical than direct hauling. In the station capacity range studied (350 tons a day), a baling transfer station would be substantially more economical than a conventional transfer station.

CHAPTER V

A LOOK AHEAD

The purposes of this chapter are to place in a larger frame of reference the one-year study and investigation project which is described in the preceding chapters of this report and to sketch briefly the follow-up study and possible eventual action that are envisaged for the future.

As was pointed out in Chapter I, it was planned that this study would represent the first year of a possible three-year project in which the initial study and investigation phase would be followed by a demonstration phase involving the construction and operation of a pilot baling transfer station. This in turn, if it proves successful, is expected to lead to practical changes in refuse disposal practice and procedures - in effect, to a realization of the potential benefits of refuse baling that now seem to be promised by the initial studies.

It is believed that the two major objectives of the first phase have been met. In the first place, as outlined in Chapter III of this report, baling municipal refuse is physically and technically feasible in experimental situations. This was true even when (as in the local baling operation described in that chapter) conditions are not ideal. A pilot baling station is needed, however, to test that feasibility under actual day-by-day production conditions with large quantities of material. Secondly, Chapter IV provides theoretical evidence of the economic feasibility of using this process in combination with the transfer station concept. Here again, the experience that can be gained with a pilot station is needed as a basis for confirming or revising present tentative conclusions.

Beyond these major objectives the first phase of the study had certain subsidiary purposes (set forth at the beginning of Chapter I) which were met with varying degrees of comprehensiveness during the course of the project. Limitations imposed by the time available and by the size of the staff prevented the exploration of some of these in the depth that might have been desirable or that was originally planned for the total three-year project. In other cases the conclusions reached were tentative in nature because of the theoretical and experimental basis for the investigation. It may be noted that when this study was undertaken the baling of municipal refuse was a new and unexplored field with virtually no basis of previous experience. Some of these areas which have not yet been fully investigated are discussed in a later section of this chapter.

The Proposed Demonstration Project

Based on the tentative conclusions set forth in the body of this report, construction of a pilot refuse baling transfer station is proposed in order to demonstrate the technical and economic feasibility of the process. Preparation of design plans and specifications and construction of the facility are scheduled for completion within nine months. During the remaining three months of the first demonstration year and throughout the second year primary emphasis will be directed toward gathering data for evaluating the operational and environmental effects of baling refuse.

Objectives of the Project

During the first year of demonstration and investigation, staff work will be directed toward developing final plans and specifications for construction of the test facility. Additional work will include preparation for plant operational procedures and staffing and development of techniques for data evaluation and for investigation of environmental effects of bale disposal in conjunction with efficient methods of bale landfill operations.

Objectives during the second year will relate to the implementation of plans and procedures developed in the first year. The main emphasis will be: (1) to develop and evaluate data on economics and techniques of pilot operation, (2) to develop and evaluate techniques for efficient and effective disposal of refuse bales, and (3) to evaluate operational and environmental effects of baling refuse and to develop standards for comparison with conventional transfer station and landfill operations.

Method of Procedure

Final plans and specifications for the proposed 150-tons-a-day facility will be the responsibility of technical personnel assigned to the staff. Additional personnel from the City of San Diego's Engineering Department will be available for special tasks as required. These special tasks will include obtaining the engineering survey of the pilot station site, preparation of design plans, advertising of construction bids, awarding the contract, and supervision of plant construction and installation of equipment. The Public Works and Purchasing Departments will also provide personnel for plant staffing and for purchase of necessary equipment.

At the completion of station construction, tentative operational procedures established during the design phase will be initiated. Preliminary plant staffing will require the services of a foreman, two laborers, and a heavy truck driver. Prior to full-capacity operation, initial trials will be conducted to develop experience and, if required, effect correction of equipment performance. Time schedules will be developed for delivery of incoming refuse, processing of the refuse, and delivery to the disposal site. Stress will be placed on the analysis and correction of operating problems (e.g., breakdowns, procedures, noise factor, dust, sanitary methods) and the development of effective and efficient rehaul techniques (e.g., equipment, scheduling, loading and unloading).

Continuing operation will provide data for developing and evaluating the economics and techniques of the pilot operation. Emphasis will be placed on the establishment of record keeping procedures (weights, densities, time and motion studies, equipment performance, costs, etc.). Data will be used for comparing the economics of a baling transfer station with direct haul and with other transfer stations.

Further investigation is planned in the area of developing and evaluating techniques for effective disposal of refuse bales. Experimentation with different types of landfill equipment and bale handling procedures will be conducted at a selected test site. This investigation will be concerned with the determination of landfill preparation, cover dirt and finished slope requirements, and the feasibility of small canyon bale disposal. Supportive cost data for evaluation purposes will be maintained.

Operational investigation will include: (1) comparing densities obtained with shredded and unshredded refuse and with varying sizes of shredded particles, (2) determination of optimum water content to be added during baling, (3) experimentation to find optimum length of bales, and (4) procedures for separating ferrous metals. Technical data will be gathered for comparing and evaluating the baling landfill environment with that of conventional landfills. The areas of investigation will include: (1) extent of gas production, (2) odor production at the transfer station and in the landfill, (3) degree of settlement or expansion, (4) extent of temperature rise, (5) control of vector breeding both at the transfer station and at the landfill, and (6) extent of water percolation. It is expected that technical data will be compiled over a period of several years in order to determine the long range effects of landfilling with baled refuse.

Evaluating the Project

Plans and specifications will be reviewed and approved, construction will be supervised during progress, and all work done and equipment furnished will be inspected and checked against specifications, with testing where appropriate before acceptance. Performance of the heavy equipment (hogger, baler, and conveyors) during the operation phase of the project will be judged on the basis of direct observation and production and maintenance records.

The project will be evaluated on the basis of costs, compaction achieved, dust, odor, handling and disposal problems, and on technological problems and procedures required in the refuse baling process. Special studies will be designed (to be conducted insofar as is feasible during the course of the project and to be followed up in the future) to evaluate the characteristics of baled refuse in the landfill as compared to raw refuse compacted by standard methods, with respect to decomposition, settlement, gas production, odor, and vector breeding. The advice of professional consultants in the field of sanitary engineering will be utilized in setting up these studies.

During the course of the study on solid waste disposal by the refuse baling method, the necessary information and technology will be developed and included as part of appropriate preliminary and final reports. Conferences will be held periodically with Federal and State officials and with private authorities in the field to evaluate the effectiveness of the project and for mutual exchange of information.

Areas of Special Interest

During the course of the first phase of the project certain ramifications of the study were opened up which could not be fully explored due to limitations of time, staff, or financial resources. Although resolution of these problem areas was not essential to the accomplishment of the study's two major objectives (determination of technical and economic feasibility), they are of sufficient interest and importance to justify special consideration in this chapter and special plans for follow-up studies in the second phase of the project.

Factors Contributing to Bale Compaction

In Chapter III it was reported that bales of refuse produced in the factory demonstration had markedly greater density than those produced in the local baling test (see page 31). In the absence of pertinent experimental evidence, the staff theorized that this difference could be attributed primarily to the amount of pressure applied by the two balers, to the moisture content of the refuse, and to pre-shredding of the material used in the factory demonstration. The known factors were the relative amounts of pressure exerted by the two balers and a reasonable assurance that the composition of the refuse materials baled at the two locations was not dissimilar. It was not possible, however, either to process raw refuse in the factory baler or shredded refuse in the local baler. At the factory, moisture content was judged (on the basis of one sample) to be 30.0 per cent. In the local test it was not feasible to make accurate field measurement of moisture content. It was therefore suggested in the report that the contribution of variable factors to compaction be determined under controlled conditions in the second phase of the study.

It should be emphasized that these uncertainties in no way invalidate the study's basic conclusion that by baling refuse under favorable conditions it is feasible to obtain considerably greater compaction than is obtainable by conventional landfill methods. This was accomplished in the factory demonstration. The point is that accurate evaluation of all of the major contributory factors can help assure consistent realization of favorable results and perhaps even improve them at minimum cost.

The two factors which will be emphasized in the tests during the proposed pilot operation will be moisture content and pre-shredding, rather than composition of the refuse or pressure applied by the baler. Composition of the refuse is expected to be reasonably constant (see Chapter II of this report). If necessary, uniform batches will be prepared to insure uniformity for test purposes. Baler pressure will be held constant from bale to bale. Plate 16 on page 36 of the report shows the general relationship between pressure and compaction.

Moisture content of the incoming refuse varies with the season and depending on the amount of garbage and other wet material present. Preliminary investigation indicates that the optimum moisture content is about 30 per cent and that additional water will generally have to be applied to reach this level. The staff believes that pre-shredding of refuse is needed to prepare the material for more uniform absorption of the added moisture, to facilitate the movement of refuse on conveyor systems (by reducing bridging) and to present a mechanically more homogeneous material to the baler. Pre-shredding breaks long, tough fibers into shorter lengths and reduces paper to small pieces which when pressed together hold the fines within the formed bale.

It is expected that in the controlled tests contemplated, with refuse composition and baler pressure held constant, optimum moisture content parameters can be established for both raw and pre-shredded refuse. With refuse composition, baler pressure, and water content held constant, the effect of pre-shredding or density can be determined.

Limiting the Pilot Plant to City-collected Refuse

It was noted on page 49 of this report that the character of refuse to be processed in the proposed baling pilot station "must be controlled due to technical limitations of the hogger." For this reason it was planned to process only City-collected refuse at this stage.

This approach applies only to the pilot station and not necessarily to a possible future full-scale baling transfer station. It is recognized that local government has the responsibility of insuring that adequate disposal facilities are available for commercially and privately transported refuse. Whether these are publicly or privately operated and whether the facilities are identical with, or as favorably located as, disposal sites for City-collected refuse are matters of municipal policy. This need could conceivably be met by insuring the continued availability of sanitary landfills for commercial and private use, by setting up dual type transfer stations, by installing heavier-duty (and considerably more expensive) hoggers in subsequent full-scale baling stations, or by other means.

Neither the present report nor the detailed proposals for a pilot baling station (described in a preceding section of this chapter) are intended either to espouse or to prejudice any particular eventual solution to the problem of adequate refuse disposal sites for commercial and private carriers. The operational conception of a transfer station may be internal (jurisdictional vehicles only) or external (both jurisdictional and public) or combinations thereof (i.e., jurisdictional and large commercial haulers). Local conditions in any City would determine the necessity of the type of transfer station service to be provided.

Neither are the report's cost comparisons between a full-scale baling transfer station and a conventional transfer station of the same size intended to imply a permanent policy of restriction of input to City vehicles (see pages 61-65). Direct haul costs were figured in terms of available cost data. Private haulers will find different cost values for direct haul, as will other cities, when they compute their costs. The intent of the report was to show method rather than constant unchanging values.

In addition to the cost, however, there were certain definite considerations that led the staff to propose limiting the pilot plant to City-collected refuse.

First, as previously stated in the report, there is control over the type of refuse coming in.

Second, during initial operation, breakdowns and mechanical difficulties can be expected to halt production for varying lengths of time. With the proposed location of the pilot station and with limitation to City collection vehicles, a plant breakdown would require only a short detour to our nearby Arizona Landfill. Since Arizona Landfill is open only to City collection forces, however, any private truck arriving at the baling station during a halt in operations would have to be detoured to Chollas or Miramar Landfills which are approximately nine miles away.

Third, it will be possible to schedule City collection vehicles so as to insure a smooth flow of materials, while private trucks arriving at unscheduled times could create a supply of materials far in excess of the input storage capacity of the plant.

Reclamation of Small Canyons

In this report the feasibility of utilizing small canyons as disposal sites for baled refuse was examined in a preliminary way. It was pointed out that the baling process may open up this intriguing and potentially rewarding possibility because (1) it would permit the use of canyons which are too small for conventional, large-scale landfill operations and (2) it would be more acceptable to nearby householders since with refuse in baled form the operation would be cleaner, quieter, and less odorous.

Limited experimentation was conducted in the stacking or "nesting" of bales in a simulated landfill situation by means of a forklift (see discussion on page 23 and pictures on pages 24-27). These tests were inconclusive because (1) relatively few bales were disposed of in this manner, (2) since the locally fabricated bales were not well-shaped, it was impossible to "nest" them close together and consequently there were excessive voids between them, and (3) the forklift was found to be an inappropriate tool for this purpose. A small canyon site has been selected for bale disposal during the proposed demonstration phase of the project on a larger scale and under more realistic conditions than were possible during the study and investigation phase just completed. This canyon is located on City park land near the proposed pilot baling transfer station (see picture on page 53).

The basic operating procedure in the disposal of baled refuse in small canyons will consist of four steps: (1) bulldozers will "brush-off" the disposal area, (2) bulldozers will "bench" the initial area and stockpile all earth removed, (3) a traveling crane will pick up bales deposited from the re-haul vehicle and nest them in one or more layers on the levelled area, and (4) a bulldozer will cover the nested bales with earth as required. Alternative procedures for cover will also be investigated during the project. The basic steps outlined above do not include compaction since that will have been accomplished by the baler.

It was pointed out in Chapter I of this report that the topography of San Diego is characterized by the presence of many large and small canyons. Most of the larger canyons have been preempted for freeways, arterial streets, or major drainage channels. Many of the smaller canyons are located in close proximity to residential districts. Not all of them are suitable or available for baled refuse disposal sites, however, because of (1) a lack of accessibility to the canyon by disposal equipment, (2) an excessive number of drainage structures emptying into the canyon, (3) a lack of adequate streets feeding the area, (4) the desirability of completing neighborhood fills of this type in a reasonably short period of time, and (5) a multiplicity of ownerships within the canyon, making satisfactory lease or purchase negotiations impractical.

Nevertheless, the staff's survey indicates that approximately fifty small canyons would meet all of the criteria implied by these limitations and probably could successfully be negotiated for and put into operation. All of these fifty canyons considered suitable and available for this type of development have certain features in common. All of them have fairly steep sides and are in the order of eighty feet deep. Variations occur chiefly in the bottom slope and in the width between sides. Due to these differences, they range from 70,000 to 350,000 cubic yards in total capacity. In almost all cases a reasonable amount of earth cover is available from the top of the canyon sides.

Preliminary studies indicate that, because of these differences in capacity and depending on quantities, unit disposal costs may vary markedly from canyon to canyon and could probably range from an estimated $0.45 to $2.00 a ton. It should be noted that this may be considerably more than the cost of bale disposal in a large landfill operation (see Table 9 on page 64) because of the different conditions that would be encountered in the small canyon operation and the increases in unit costs that are inherent in a small operation. However, the potential advantages of filling the close-in sites as well as possible transportation savings should justify the increased costs. Firmer estimates can be made after a basis of experience is built up during the demonstration phase of the project.

It is estimated that the fifty suitable canyons would average about 200,000 cubic yards in capacity. The total potential capacity that could be made available by disposing of baled refuse in small canyons, therefore, is estimated at approximately 10,000,000 cubic yards - most of it favorably located with respect to collection area centroids. Moreover, the finished fills would create a total of approximately five hundred acres of attractive "green belt" areas at precisely the points where they could contribute most to the enhancement of urban living. The need for small "green areas" throughout the City has long been recognized by planning groups, but the cost of developing them by conventional earthfill methods has usually been prohibitive. "The fact should not be overlooked that great benefit to the community would result from a planned program for acquiring and developing many such areas. The small spaces of a city are equally important, if not more so, to the people of a community, as they are in constant everyday contact with these areas."[1]

[1] The general plan for San Diego--1985; presented by the Citizens' Advisory Committee on the General Plan.

The speed of filling these small canyons would depend on the number of baling transfer stations in operation. A 150-tons-a-day station would fill approximately 45,000 cubic yards a year.

Summary of the Chapter

In reviewing this report and in looking ahead to the future it should be borne in mind that the economic feasibility of baling as tentatively developed in the study and investigation project is by no means the only or, in the long view, the most compelling reason for constructing and operating a pilot baling transfer station. As long as the economics appear reasonable, economics should be considered secondary to technology. It is important, for example, to test and evaluate, under realistic conditions, such technical aspects of refuse baling as (1) compaction obtainable, (2) optimum moisture content for effective baling, and (3) possible hazards in bale disposal, such as gas production and vector breeding.

It is also important to explore, under realistic conditions, the feasibility of using bale disposal to reclaim small canyons near residential areas, where full-scale landfill operations or the disposal of raw, unbaled refuse would not be acceptable because of odor, dirt and noise. There are many such canyons in San Diego, some of them situated near the centroids of refuse collection areas.

It is believed that this new and yet untried technique may be found to have great potential not only in conserving sanitary landfill space and reducing direct haul distances, but also in contributing to the beautification of the community and creating usable land for park, recreational and similar purposes. Some of these benefits are intangible but they are no less worthwhile because precise monetary values cannot be assigned to them.

APPENDIX

CHARACTERISTICS OF SAN DIEGO

AND SIX SELECTED CITIES OF COMPARABLE SIZE, 1960

Items	San Diego	Boston	Buffalo	Cincinnati	Pittsburgh	San Antonio	Seattle
Population and Housing							
Total population	573,224	697,197	532,759	502,550	604,332	587,718	557,087
Population density per square mile	2,944	15,157	12,869	6,569	10,968	3,966	6,810
Percentage of housing in one-family units	71.1	16.4	28.3	37.4	56.1	83.7	63.3
Industry							
Number manufacturing establishments of 20 or more employees per 100,000	19.2	106.0	66.4	95.1	57.1	32.2	63.2
Number hotels, motels, tourist courts, camps, per 100,000	45.2	7.2	11.4	11.7	9.3	32.7	53.1
Climate							
Mean temperatures							
January	55.5	29.9	23.5	33.7	28.9	52.0	41.2
July	69.6	73.7	69.8	76.9	72.1	84.0	65.6
Mean annual precipitation	10.4	42.8	35.7	39.5	36.1	27.8	34.1
Percentage possible sunshine	67	60	53	58	55	62	N.A.

Source: United States Bureau of the Census Reports, 1960

LETTER OF INQUIRY TO BALER MANUFACTURERS

THE CITY OF
SAN DIEGO CITY ADMINISTRATION BUILDING • COMMUNITY CONCOURSE • SAN DIEGO • CALIFORNIA 92101

PUBLIC WORKS
DEPARTMENT

ERIC QUARTLY
DIRECTOR

213/990

August 21, 1967

Gentlemen:

Under a Federal Grant, the City of San Diego is undertaking a rather thorough investigation of the feasibility of baling refuse as a means of preserving our critical sanitary fill space. Refuse disposal is recognized as a nation-wide problem and accordingly our project is being jointly sponsored by the City of San Diego and the U. S. Department of Health, Education and Welfare under the Solid Waste Disposal Act. At the conclusion of our study, a detailed written report will be prepared and printed for distribution to the Department of Health, Education and Welfare and other cities and counties in the nation.

San Diego, like many other cities, has undergone a period of rapid growth which is expected to continue for some time. Our present population of over 670,000 currently generates an estimated 350,000 tons of solid waste refuse for disposal at our sanitary fills each year. Over half of this refuse is municipally collected by our fleet of 65 packer trucks. Based on current projections, it is estimated that our annual tonnage generated will have doubled to about 700,000 tons per year by 1985. We estimate that we shall have to dispose of a total of some 48 million tons of solid waste refuse in the next thirty year period. The problem of finding adequate space for disposal of this refuse by sanitary fill method is becoming an increasingly critical one.

Our first year of study will be primarily devoted to an investigation of the feasibility and economics of baling municipal refuse and will include some preliminary testing of balers. For this preliminary testing, we anticipate limiting our baling to refuse collected in our City packer trucks (25 yard capacity), therefore no salvaging or sorting is planned. If baling appears to be practical, we intend to proceed with our plans to construct a pilot baling plant for more intensive testing during the second year of our project.

We foresee several possible advantages in baling refuse:

A. Extending the life of our sanitary fills by obtaining greater compaction.

B. Shortening or eliminating the mid-day haul to the sanitary fill site with construction of baling/transfer stations.

C. Possible cost reduction in handling refuse by bales.

To our knowledge, there has been very little if any experimentation in the baling of refuse. Since this is a new and as yet unproven application of baling equipment, we are anxious to evaluate as many different types of balers as possible. We would appreciate any brochures and information you may have on your baling equipment as well as your comments or suggestions on the potential adaptability of your equipment to the baling of municipal refuse.

Thanks in advance for your prompt attention.

Yours very truly,

Eric Quartly
Project Director

MAILING LIST OF BALER MANUFACTURERS

Adamson United Co.
730 Carroll Street
Akron, Ohio

Adco Manufacturing Co.
726 Gay Street
Columbus, Ohio

American Baler Co.
2640 Ohio Street
Bellevue, Ohio

American Baler Machines Co.
839 39th Street
Brooklyn, New York

Apex Foundary Division
of Comet Industries Corp.
6111 South Eastern
Los Angeles, California

Apex Steel Corporation, Ltd.
6920 E. Slauson Avenue
Los Angeles, California

Arnold Hughes Co., Inc.
6600 Mt. Elliott Avenue
Detroit, Michigan

Baldwin-Lima-Hamilton Corp.
Eddystone Division
Philadelphia, Pennsylvania

Balemaster Division
East Chicago Machine Tool Corp.
4811 Railroad Avenue
East Chicago, Indiana

Bemis Company, Inc.
850-M Northstar Center
Minneapolis, Minnesota

Boland Machine & Mfg. Co.
1000 Tchoupitoulas Street
New Orleans, Louisiana

Bolling & Co., Inc.
3200 E. 65th Street
Cleveland, Ohio

M. E. Canfield Co.
419 East 3rd
Los Angeles, California

J. I. Case Co.
700 State Street
Racine, Wisconsin

Cardwell Machine Co.
19th & Franklin Streets
Richmond, Virginia

Chattanooga Welding & Machine Co.
Chestnut & 13th Streets
Chattanooga, Tennessee

Consolidated Baling Machine Co.
406 Third Avenue
Brooklyn, New York

Consolidated Baling Machines
3690 South Santa Fe
Vernon, California

Cox & Sons Co.
Water & Hampton Streets
Bridgetown, New Jersey

Dempster Bros., Inc.
Springdale Ave. & South R.R.
Knoxville, Tennessee

Dover Corporation
Elevator Division
P. O. Box 2177
Memphis, Tennessee

Dunning & Boschert Press Co.
379 W. Water Street
Syracuse, New York

Economy Baler Co.
1032 McDonald Street
Ann Arbor, Michigan

Galland-Henning Mfg. Co.
2761 South 31st Street
Milwaukee, Wisconsin

General Hydraulics of Calif., Inc.
411 South Flower
Burbank, California

Jules D. Gratiot Co.
3423 Verdugo Road
Los Angeles, California

H-P-M Division, Koehring Co.
840 Marion Road
Mt. Gilead, Ohio

T. W. Hall Co.
59 Sunnyside Avenue
Stamford, Connecticut

Harris Press & Shear Corp.
Simmons Building
Cordele, Georgia

Harris Waste Paper Baler
4551 East Gage
Bell, California

Johnson Manufacturing Co.
P. O. Box 311
Chippawa Falls, Wisconsin

Lake Engineering Co.
310 Gostlin Street
Hammond, Indiana

E. W. Loeser Co.
1355 Genesee Street
Buffalo, New York

Logemann Brothers Co.
3225 North Pierce Street
Milwaukee, Wisconsin

Maren Engineering Corp.
16246 School Street
South Holland, Illinois

Minnich Machine Works
1607 Ridgely Street
Baltimore, Maryland

National Balers
1071 E. 48th Street
Brooklyn, New York

Nichols Baling Presses
2646 Downey Road
Los Angeles, California

Rapids Machinery Co., Inc.
875 11th Street
Marion, Iowa

Salem-Brosius, Inc.
P. O. Box 2222
Pittsburgh, Pennsylvania

Schick Baler Corp.
433 York Avenue
Philadelphia, Pennsylvania

Steel Equipment Co.
P. O. Box 737-M
Cleveland, Ohio

Tamaker Corp.
6411 Ventura Boulevard
Ventura, California

Taylor-Wilson Mfg. Co.
1603 Keenan Building
Pittsburgh, Pennsylvania

Ther Electric & Machine Works
17 South Jefferson Street
Chicago, Illinois

Tonawanda Engineering Co.
Tonawanda, New York

Turner Manufacturing Co.
Statesville, North Carolina

Watson-Stillman Press Division
Farrel-Birmingham, Inc.
565 Blossom Road
Rochester, New York

Wenzelman Manufacturing Co.
1172 North Broad Street
Galesburg, Illinois

West Engineering Co., Inc.
Dill Road & Vawter
Richmond, Virginia

THE AMERICAN BALER COMPANY

TELEPHONE AREA 419, 483-5790

BELLEVUE, OHIO

January 12, 1968

NOTES ON BALING TEST RUN
BY THE AMERICAN BALER CO. AT ITS PLANT
IN BELLEVUE, OHIO, TUESDAY, JANUARY 9, 1968

In view of the size of the current problem in handling solid wastes, and particularly the transportation and disposition of such materials, it seems important to analyze what can be done with existing techniques, and to inquire into the possibility of improving these techniques either as to capacity or results.

We arranged to send a packer truck to Louisville, Kentucky, where Mr. Charles Bennett at the Department of Sanitation, Incinerator Plant, graciously took the time to prepare two packer loads of typical refuse. He reports that one load was brought in from a fairly affluent section of the town and another one from a less affluent, where the percentage of garbage was relatively high. Both samples contained significant amounts of bottles, cans and plastic containers. Measured free density of the stock as fed to the baler was 11.4 p.c.f. In 1956, the City of Louisville had installed a Williams Model 445 No-Knife Hog for reducing large pieces of lumber and automobile and truck tires, etc. and the above two loads were processed through this hog and loaded into our chartered packer truck and brought to the plant in Bellevue. The effects of being in the packer truck were removed by running through our shredder and air system. At this plant we maintain a demonstration system including a standard model continuous heavy duty horizontal baler. This baler, however, is equipped with a larger main hydraulic cylinder so that tests can be run at greater pressures than normally used in collection of secondary fibers for return to the paper mills. Plans were made for adding water to this material. However, this proved unnecessary as the moisture content of one sample taken at about the middle of the test was 30.0%. Four complete bales were made and measured as follows:

1.	26" x 36" x 75"	2,210#	54.3 pcf
2.	26" x 36" x 78"	2,490#	59.0 pcf
3.	26" x 36" x 48"	1,500#	57.7 pcf
4.	26" x 36" x 71"	2,125#	55.3 pcf

Then, two smaller bales were made, one of which was taken back to the United States Public Health Service in Cincinnati by Mr. Donald A. Oberacker, and the other was opened for inspection. A section of this was dropped into a tank of water, and predictably floated about 92% submerged. These densities were then checked on the pressure density curve made in connection with some earlier tests in 1963, indicating the final densities were as great or greater than the more favorable of the two curves plotted at that time. A copy is attached marked Figure 1. One possible explanation of this is that moisture content had been lower on the earlier test. Figures 2A and 2B show respectively the particle size of the loose material (this can be compared with the 10-foot rule illustrated in the circle). Figure 2B is a view of the discharge end of the baler showing the nature of the continuous operation. Figure 3 is a picture of the above Bale #1. Note: Corrugated end pads were used during part of the test, but in our opinion would not be necessary in actual practice on a production basis with this product.

After seeing the above results and comparing these densities, it can be safely predicted that the method can be used to produce bales of 65 to 70 p. c. f. A baler of this type is feasible to run at a rate of up to 25 tons per hour. Baler capacity might be pushed somewhat beyond this, but it is probable that two men tying the bales would find the above figure a comfortable operating rate.

On checking the extension produced without tying the bale, the resultant density was 45 p. c. f. If these "pads" were removed by conveyor to trucks or railroad cars, and loaded random, we would estimate load density at about 35 p. c. f. By 1500 Friday, January 12, a probe thermometer in Bale #4 read 98^{0} F. in 70^{0} room temperature.

After the baling tests, a general discussion was held about the nature of the equipment. The shredder actually used for this test has been in service 11 years and questions regarding maintenance cost, if any, could be obtained directly from Mr. Bennett. Similar shredders have been used in paper stock processing plants for over 15 years, and the current trend in such plants is to convert to the shredder-continuous baler method.

Preliminary discussions as to the general cost of this type of system indicate the equipment cost for a plant to run at 50 tons an hour might run between $125,000 to $140,000. However, no absolute predictions are possible because of local conditions, the distance to proposed landfills, the possibility of requiring the extra density to insure the bale will sink in saltwater, and the question of how much overdesign should be provided in the shredder to reduce the discipline required in eliminating particularly bothersome items, for instance, heavy water heaters. All will effect the final result. The above estimate was based on a heavy duty shredder that would accommodate most of the usual metallic items, but should be protected from heavy water heaters. The resultant discipline required for this type of equipment would not be onerous in any well-organized system.

Here at American Baler we came to the conclusion that this method is completely feasible and offers a high probability of economic success. This conclusion is backed up by our decision to proceed with the manufacture of a Model 12375 Baler, which we are prepared to guarantee to produce 25 gross tons per hour on properly shredded material run at a moisture rate of approximately 30%. Density will run 65 to 70 p.c.f. -- bale weight 3200# to 3500#.

THE AMERICAN BALER CO.

R. E. Seltzer
President

THE AMERICAN BALER CO.

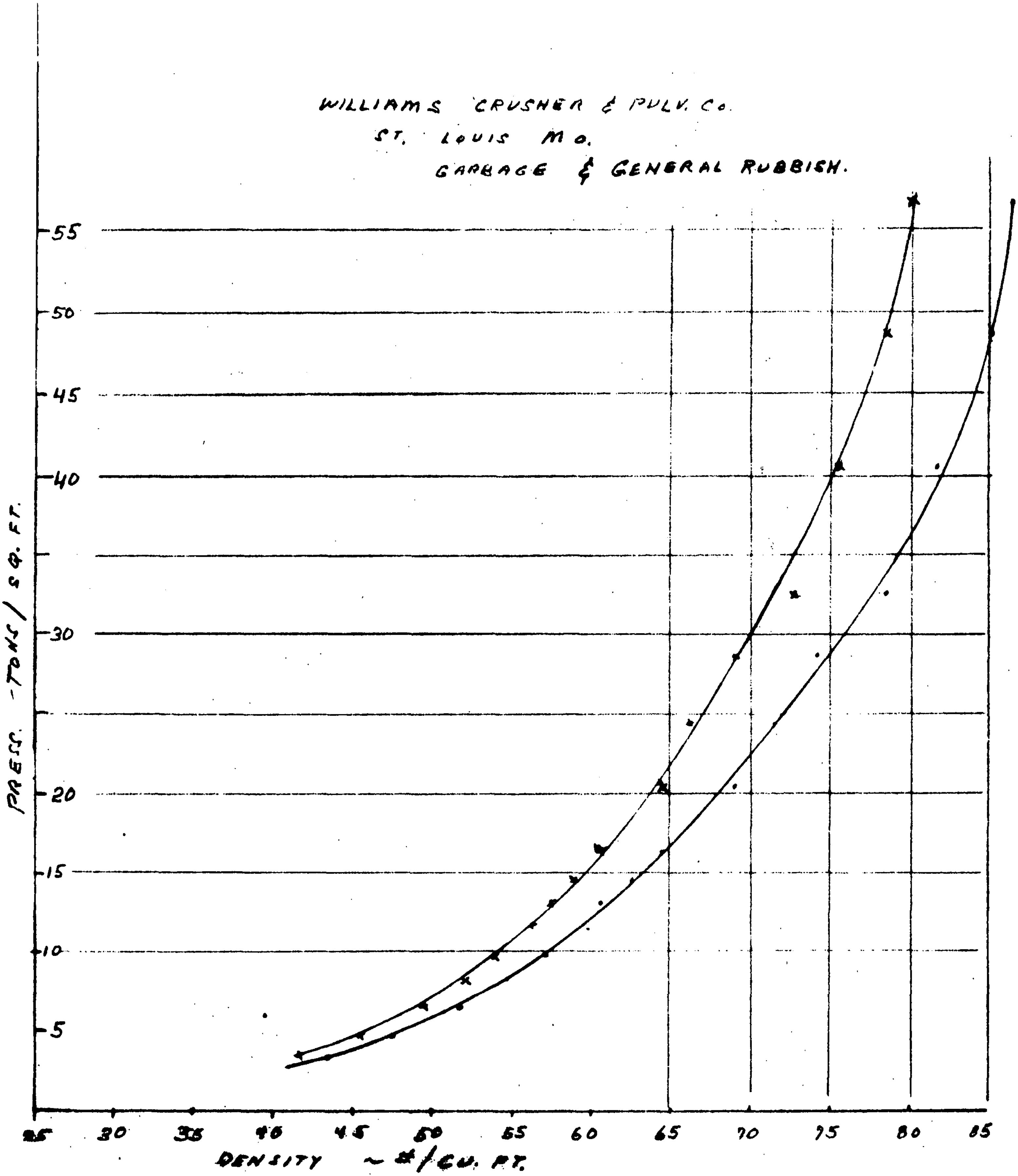

Figure 1

2-16-63
PSH

MATHEMATICS OF DIRECT HAUL COSTS

In Chapter IV of this report it was shown that the true cost of the extra distance to a more remote location that refuse collection vehicles must travel when close-in landfills are exhausted must reflect the reduction in collection time resulting from extra time on the road (see page 60). Since it is usually not practicable to compensate for this lost collection time by constant overtime (in effect a permanent lengthening of the working day), the number of collection vehicles must be increased.

The purpose of this appendix is to describe the mathematics of determining the necessary fleet size (and thus the true additional cost) under the new conditions.

First, certain constants were developed in general terms:

1. $$\text{Daily collection minutes per ton} = \frac{\text{Present collection minutes per day per truck}}{\text{Present average tons per day per truck}}$$

2. $$\text{Daily fleet tonnage} = \left(\text{Present number of trucks}\right)\ \underline{\text{times}}\ \left(\text{Average daily tons per truck}\right)$$

3. $$\text{Daily reduced collection time} = \left(\text{Present collection minutes}\right)\ \underline{\text{minus}}\ \left(\text{Extra minutes of daily haul}\right)$$

4. $$\text{Long haul tons collection ability per truck} = \frac{\text{Daily reduced collection time}}{\text{Daily collection minutes per ton}}$$

5. $$\text{Long haul fleet size} = \frac{\text{Daily total fleet tons (No. 2 above)}}{\text{Long haul tons per truck (No. 4 above)}}$$

Substituting in No. 5 with original values, it is found that:

Long haul fleet size <u>equals</u> (present number of trucks) <u>times</u> (average daily tons per truck) <u>divided by</u> the quantity (present collection minutes <u>minus</u> extra minutes of daily haul <u>divided by</u> the quantity [present collection minutes per day per truck <u>divided by</u> average daily tons per truck])

Or:

$$\frac{\text{(Present number of trucks)}\ \underline{\text{times}}\ \text{(Average daily tons per truck)}}{\left(\dfrac{\text{Present collection minutes}\ \underline{\text{minus}}\ \text{Extra minutes of daily haul}}{\left[\dfrac{\text{Present collection minutes per day per truck}}{\text{Average daily tons per truck}}\right]}\right)}$$

Collecting the terms, it is found:

$$\frac{\left(\text{Present number of trucks}\right) \underline{\text{times}} \left(\text{Average daily tons per truck}\right) \underline{\text{times}} \left(\text{Present collection minutes per day per truck}\right)}{\left(\text{Present collection minutes } \underline{\text{minus}} \text{ extra minutes of daily haul}\right) \underline{\text{times}} \left(\text{Average daily tons per truck}\right)}$$

Canceling (Average daily tons per truck) the formula becomes:

$$\text{Long haul fleet size} = \text{Present number of trucks} \ \underline{\text{times}} \ \frac{\text{Present collection minutes per day per truck}}{(\text{Present collection minutes}) \ \underline{\text{minus}} \ (\text{Extra minutes of daily haul})}$$

If the number of trucks factor is omitted, a simple ratio develops by which the present fleet size may be multiplied to determine the size of the new longer haul fleet size. Whether to round up or round down to the next higher or lower whole truck, when a fractional truck results from the formula, is a practical administrative decision which must take into account such factors as fleet size, labor conditions, overtime rates, and "swing crew" policy.

To determine the true cost of the longer direct haul, multiply the annual cost of a truck with crew by the number of extra trucks needed.

Example:

Assumptions:
30-truck present fleet carrying 15 tons per day each
7.5 tons collected per truck per trip
340 minutes collection time
18 miles addition per round trip
22 miles per hour travel speed
$30,000 annual cost per truck with crew

Computation:
18 miles @ 22 M.P.H. equals 49 minutes per trip
or 98 minutes per day lost from collection time

$$(30) \frac{340}{340 - 98} = 42.15 \text{ (say 42) trucks needed for the longer haul}$$

42 - 30 = 12 additional trucks

12 ($30,000) = $360,000 extra annual cost of long haul

30 (15) 260 = 117,000 annual tons to be handled

$$\frac{\$360,000}{117,000\ (49)} = \$0.0628 \text{ cost per ton/minute}$$

COST OF PRE-SHREDDING MUNICIPAL REFUSE

The estimated pre-shredding costs presented in this Appendix include (1) depreciation on the plant and equipment, (2) power, and (3) maintenance on the hogger (shredder). Other elements of cost are considered to be negligible.

Estimates of maintenance costs for the hogger being considered for the proposed pilot baling station are based on the experience of a present user of the same equipment (same manufacturer and same model) for the same purpose (shredding municipal refuse). An excerpt from a letter written on March 25, 1968, by Mr. Gerald T. Vaughn, Sr., Plant Manager of Lone Star Organics, Inc., Houston, Texas, in response to our inquiry, appears below:

> We are grinding our total intake of 330 tons or more per day with this shredder. It is being powered by a 500 H.P. motor at 900 R.P.M. with a capaicty of up to 50 tons per hour.
>
> The hammers are removed and resurfaced every 1200 to 1500 tons, or every fourth day. There does not appear to be a great deal of wear on the shredder itself. Removal of the hammers and replacing with rebuilt ones requires an average of 6 man hours - we use a 3 man crew for an average time of 2 hours - this was somewhat higher before the crew learned the proper procedure. The average resurfacing time is about 10-12 man hours. You should be able to arrive at some cost factors with this information using your labor rates in the San Diego area.

Multiplying the total of 18 man hours required per 1,500 tons (6 hours to remove and replace and 12 hours to resurface hammers) by San Diego's hourly cost of $6.10 for this kind of work yields $109.80. Adding $40.20 to this for necessary materials and overhead brings the total maintenance cost to $150 per 1,500 tons or $0.10 a ton.

In the table on page 87 this unit cost is added to depreciation and power costs to arrive at a total cost for pre-shredding in a pilot baling transfer station and in a full-scale station. The only difference in capital investment needed for a full-scale station versus a pilot station is in the size of the hogger motor, estimated to cost an additional $100 per year. The full-scale station requires a 500 H.P. motor to process 50 tons an hour and the pilot plant a 300 H.P. motor for a capacity of 30 tons an hour.

PRE-SHREDDING COSTS IN PILOT AND FULL-SCALE BALING STATIONS

Items	Costs Per Year	Costs Per Day	Costs Per Ton
Pilot Baling Station (150 tons per day)			
Depreciation			
- on $50,000 for hogger, motor, and appurtenances @ 10 years	$ 5,000		
- on $25,000 for building and conveyors @ 20 years	1,250		
Power	7,000		
Total	$13,250	$51.00[a]	$ 0.34[b]
Maintenance (see page 86)			0.10
Total			$ 0.44
Full-scale Station (350 tons per day)			
Depreciation			
- on $51,000 for hogger, motor, and appurtences @ 10 years	$ 5,100		
- on $25,000 for building and conveyors @ 20 years	1,250		
Power	12,000		
Total	$18,350	$70.58[c]	$ 0.20[d]
Maintenance (see page 86)			0.10
Total			$ 0.30

a - $13,250 divided by 260 working days in the year.

b - $ 51 divided by 150 tons.

c - $18,350 divided by 260 working days in the year.

d - $ 70.58 divided by 350 tons.

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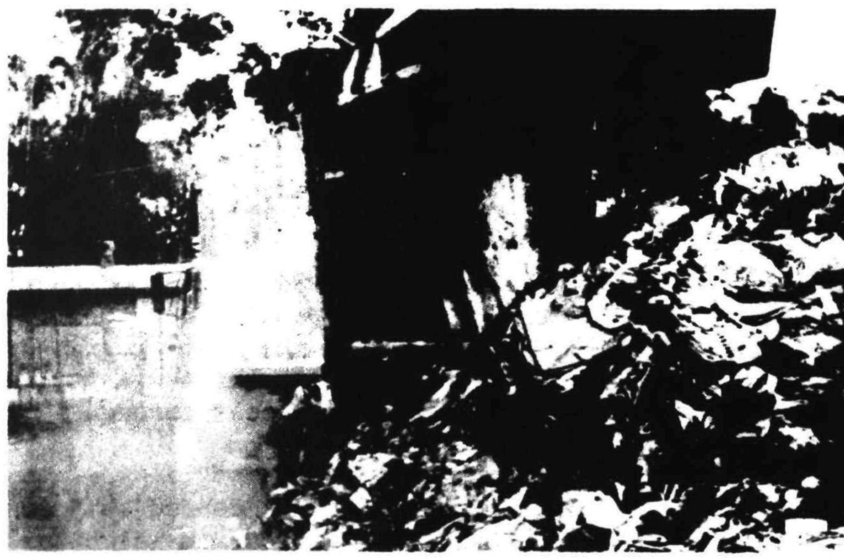
THE FOLLOWING PAGES ARE DUPLICATES OF ILLUSTRATIONS APPEARING ELSEWHERE IN THIS REPORT. THEY HAVE BEEN REPRODUCED HERE BY A DIFFERENT METHOD TO PROVIDE BETTER DETAIL.

General view of
test facility
during construction



Refuse is dumped
at the upper level

A skip loader cuts
into the pile of
refuse

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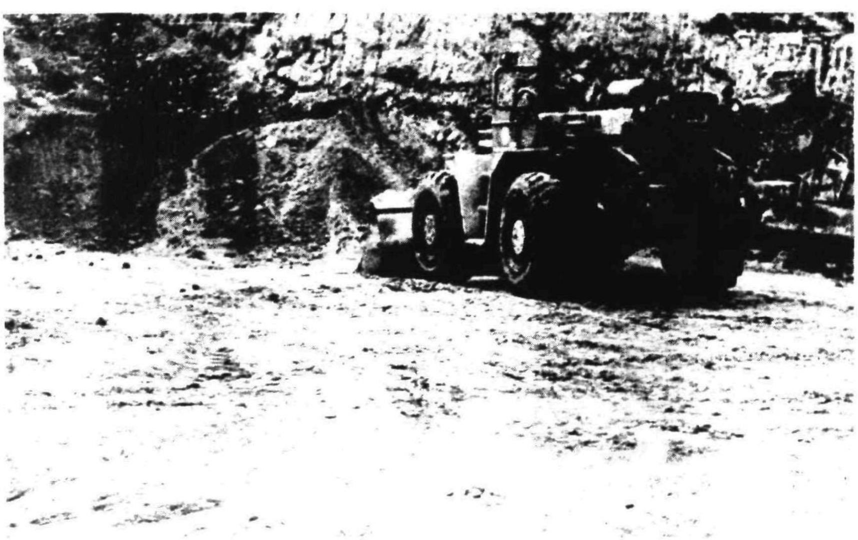
VIEWS OF LOCAL BALE DISPOSAL EXPERIMENT FIGURE 6

Hillside before being cut to create simulated landfill



Fill cutting job approaches completion

Some of the bales are dumped on the ground for pick-up by the fork lift

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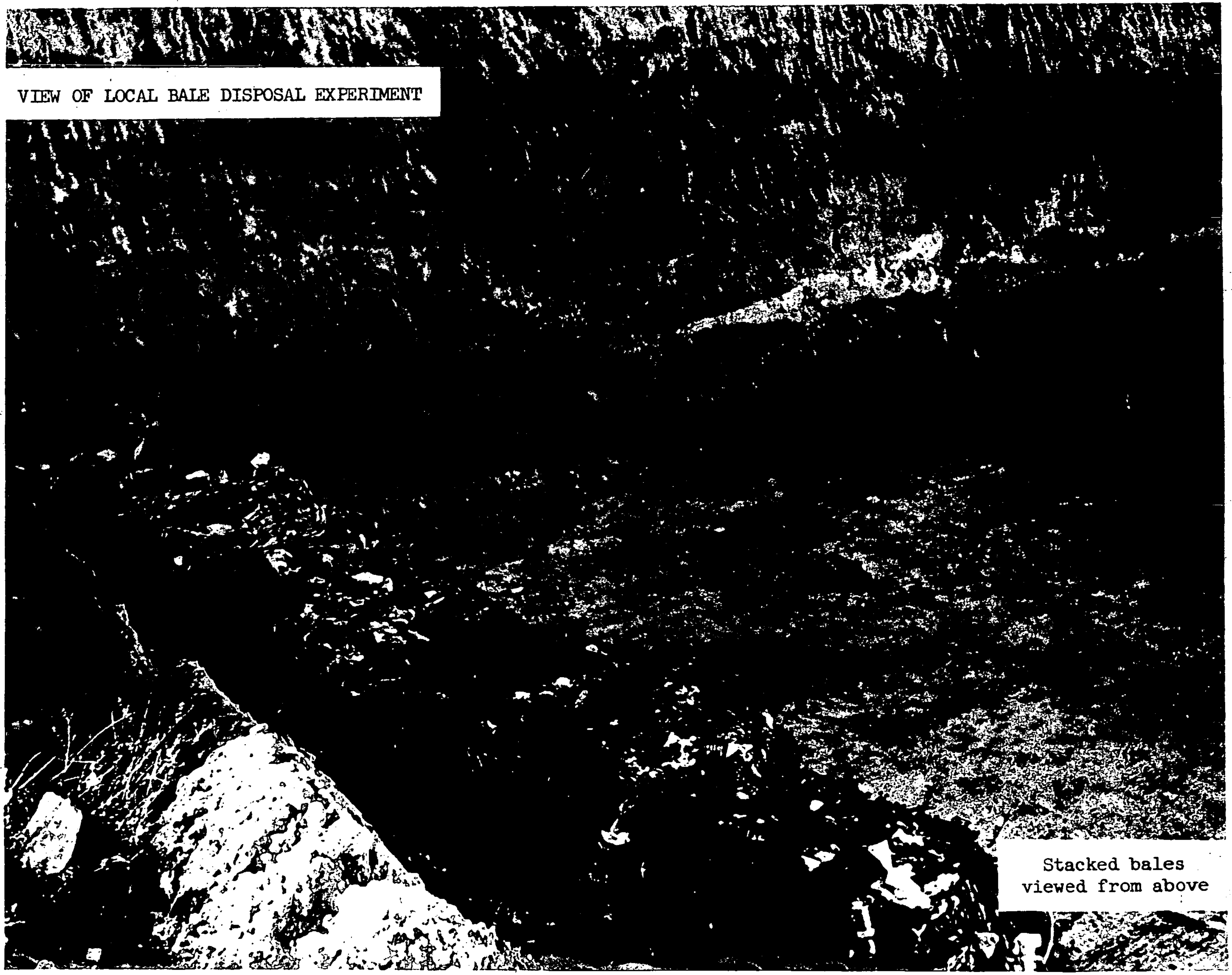

FIGURE 8

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FIGURE 12

COMPARISON OF RAW MATERIALS, LOCAL AND FACTORY TESTS

Unprocessed refuse was used in the local baling tests

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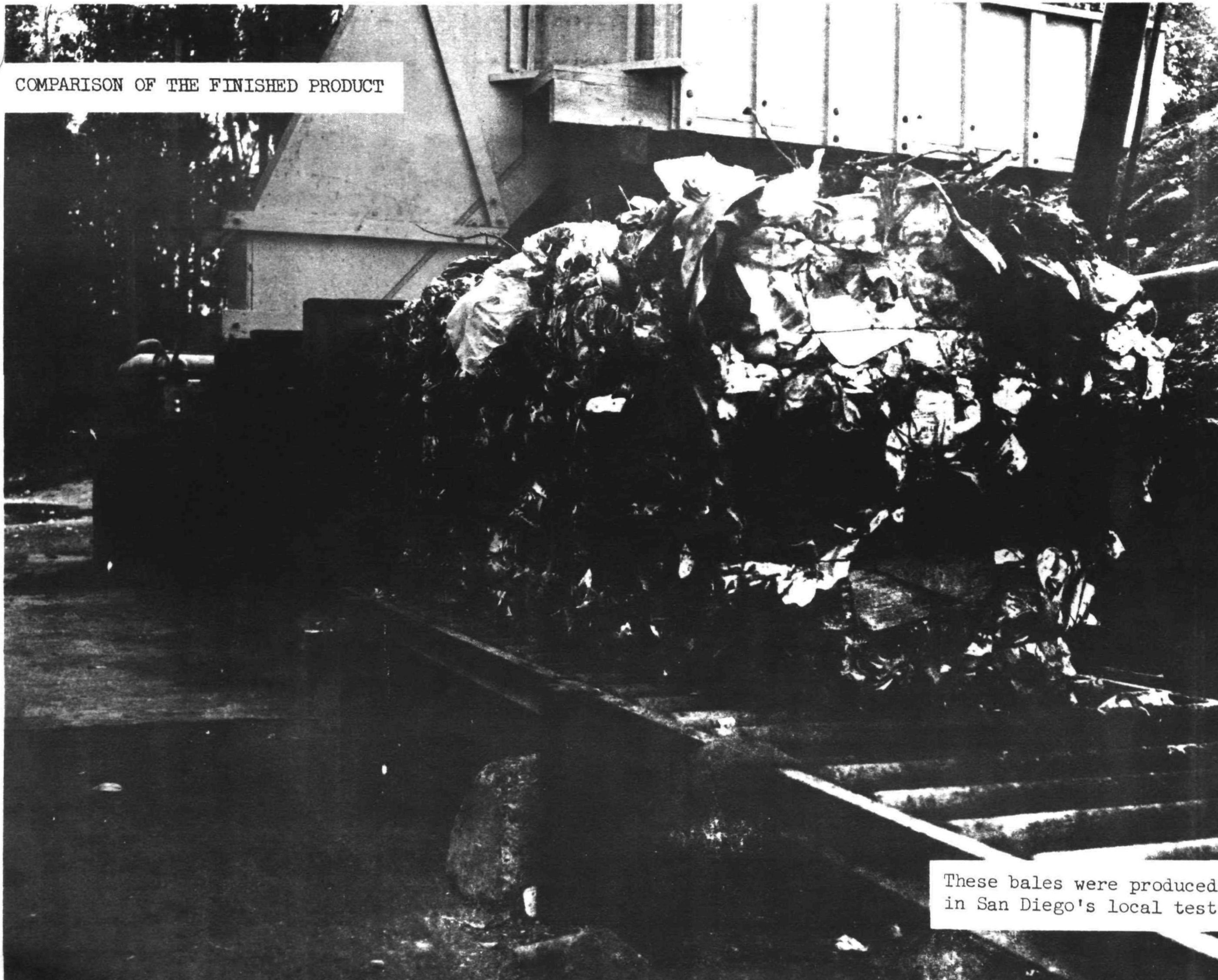

FIGURE 14

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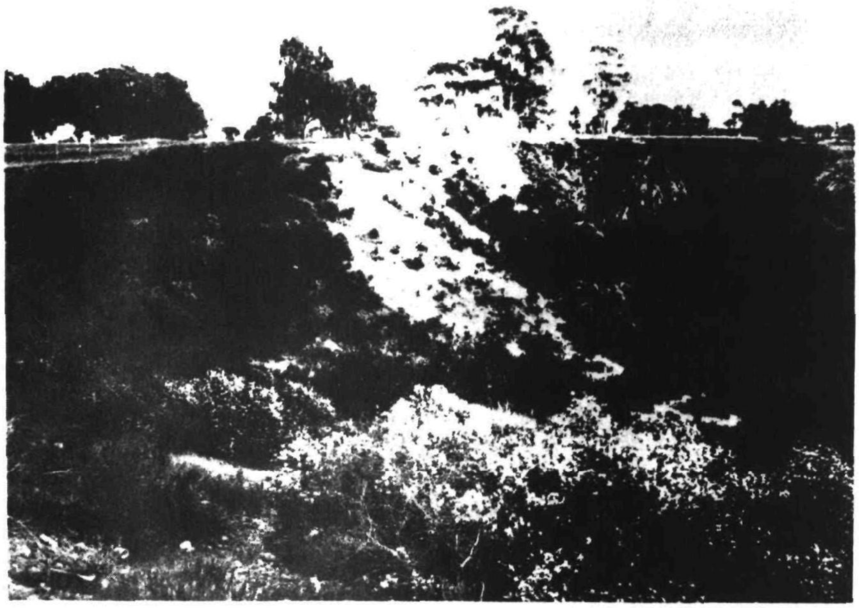
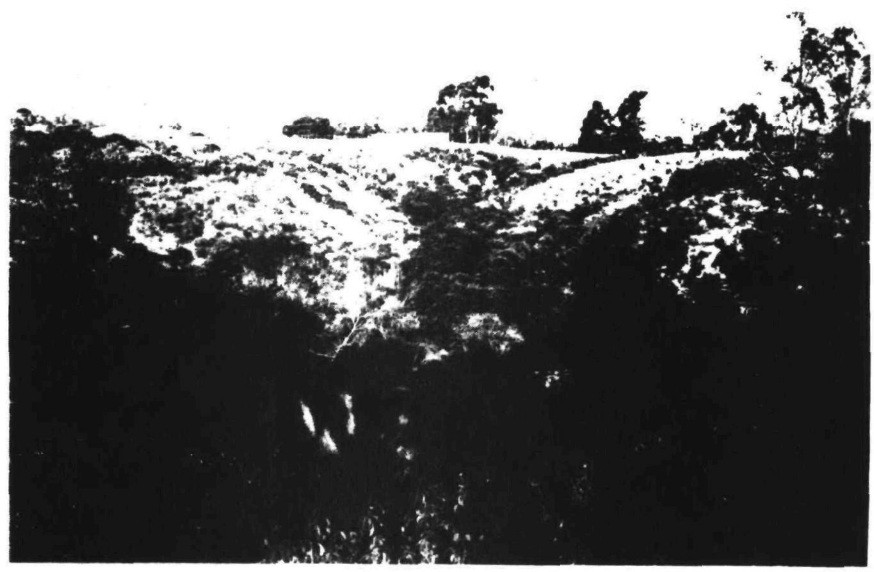
THREE VIEWS OF A SMALL CANYON PROPOSED FOR RECLAMATION FIGURE 21



This canyon is too small and too near a residential area for a conventional fill operation



But it could be box-cut and filled with nested bales of refuse and covered with earth

Making possible a valuable extension of a city golf course's present cramped parking lot

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FIGURE 22

Aerial view of small canyon proposed for reclamation (upper arrow) and proposed site for pilot station at the Central Operations Center (lower arrow)

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