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OPERATION BREAKTHROUGH SITE MANAGEMENT SYSTEMS AND PNEUMATIC TRASH COLLECTION

Executive Summary

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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Executive Summary

Contract No. 68-03-0094

Project Officer

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Cincinnati, Ohio 45268

This study was conducted
in cooperation with
Office of Policy Development and Research
Division of Energy, Building Technology, and Standards
U.S. Department of Housing and Urban Development

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DISCLAIMER

FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the projects of that research; a most vital communications link between the research and the user community.

This report is a summary of the major findings from a comprehensive study of solid waste management systems at the housing complexes operated by the Department of Housing and Urban Development and under that Department's Operation Breakthrough program. The information synopsized in this document will aid planners in deciding that they have a need to obtain the complete series of reports dealing with the Operation Breakthrough solid waste management systems. Further details on the PTC system can be found in a complete test report entitled, "Evaluation of the Refuse Management System at the Jersey City Operation Breakthrough Site."

Francis T. Mayo
Director
Municipal Environmental Research Laboratory

ABSTRACT

The Department of Housing and Urban Development Operation Breakthrough programs demonstrate quieter, more sanitary, more convenient, and more economical waste collection systems within buildings, complexes, and municipalities. In the study summarized here, nine Operation Breakthrough sites were analyzed and compared as to economics, effectiveness, environmental factors, efficiency of operation, and acceptance by residents.

Eight of the sites used various trash collection methods ranging from conventional curbside pickup to centralized compaction and pickup. The sites were in:

- Indianapolis, Indiana;
- Kalamazoo, Michigan;
- Macon, Georgia;
- Memphis, Tennessee;
- St. Louis, Missouri;
- Seattle, Washington;
- Sacramento, California; and
- King County, Washington.

The ninth site, Jersey City, New Jersey, used a pneumatic trash collection (PTC) system, the first installation of its kind in a residential complex in the United States. This report summarizes the evaluation of the refuse management systems at Operation Breakthrough sites, particularly the PTC system evaluation and the refuse system user acceptance surveys at eight of the nine sites.

The report is submitted in partial fulfillment of Contract Number 68-03-0094 by Hittman Associates, Inc. The work was performed for the Environmental Protection Agency and was sponsored by the Office of Policy Development and Research, Division of Energy, Building Technology, and Standards, Department of Housing and Urban Development. The program was performed from December 1971 through May 1977.

CONTENTS

TABLES

ABBREVIATIONS

SFA	=	single-family attached dwelling units
SFD	=	single-family detached dwelling units
MFLR	=	multifamily low-rise dwelling units
MFMR	=	multifamily medium-rise dwelling units
MFHR	=	multifamily high-rise dwelling units
MFM/HR	=	multifamily medium and high-rise dwelling units
PTC	=	pneumatic trash collection
CEB	=	Central Equipment Building
OSHA	=	Occupational Safety and Health Administration
container	=	an enclosed container of the type designed for being emptied by a packer truck
can	=	a standard garbage can of usually 30 to 40 gallons capacity which can be manually emptied

CONVERSION UNITS

1 cubic foot	=	0.0283 cubic meters
1 cubic yard	=	0.7646 cubic meters
1 ton	=	907.2 kilograms

ACKNOWLEDGMENTS

The cooperation of Envirogenics, Inc., AVAC Systems, Inc., the design firm of the pneumatic trash collection system; site management; municipal employees; private refuse service contractors; and site residents is greatly appreciated. Without their help and enthusiastic support, this project could not have been completed as thoroughly at each site within the limited resources available.

Special thanks are extended to Mr. Jerome Rothenberg of HUD for his guidance and assistance and to the project personnel of EPA who include Messrs. Leland Daniels, Patrick Tobin, and Robert A. Olexsey.

SECTION 1

INTRODUCTION

One aspect of the Department of Housing and Urban Development Operation Breakthrough Program concerns the demonstration of experimental and innovative building and design concepts for residential construction. A provision of this program is to evaluate the refuse collection methods in the program in order to: (1) determine the most practical, convenient, quiet, sanitary, and economical waste collection systems, and (2) guide development of solid waste management systems for future projects. The various collection schemes are being demonstrated and tested at the nine Operation Breakthrough sites. Eight sites use various trash collection methods ranging from conventional curbside pickup to centralized compaction and pickup. The ninth site, Jersey City, has a PTC (pneumatic trash collection) system. These sites and a description of their refuse management systems are presented in Table 1.

The overall objective of this study is to evaluate the economics, effectiveness, and feasibility of using improved solid waste collection systems in new communities. The results include evaluation and comparative analyses of economy, effectiveness, technical design and performance, reliability, maintainability, environmental factors, and user acceptance and will be used to guide the development of larger scale projects in the future.

It should be noted that the major emphasis of the contractor's work effort was placed upon evaluating the PTC system at the Jersey City site. It is of particular importance since this was the first time a PTC system has been installed in a residential complex in the United States. Similar systems have been installed in hospitals and other non-residential complexes.

A pneumatic trash collection (PTC) system is a solid waste management system that automatically collects all the solid waste generated at a site, with the exception of bulky waste, and compacts this refuse into sealed containers. It is designed to be a quieter, more sanitary, and odorless service as well as to be convenient for users. The system is ultimately designed to reduce operating costs, manual labor, and energy requirements and thereby to provide for a more effective and efficient refuse collection service than conventional systems.

TABLE 1. OPERATION BREAKTHROUGH SITES REFUSE MANAGEMENT SYSTEMS

Site	Type of Housing	No. Units	Collection	Storage	Pickup Freq.	Transport	Disposal	Remarks
	On-site Parameters				Off-site Parameters			
Indianapolis, IN	SFA	140	Manual	Pens	1/wk	Packer Truck	Land Fill	Municipal service
	SFD	103	Manual	Pens	1/wk	Packer Truck	Land Fill	Municipal service
	MFLR	16	Manual	Container	3/wk	Packer Truck	Land Fill	Private service
	MFMR	36	Chute	Container	3/wk	Packer Truck	Land Fill	Private service
Kalamazoo, MI	SFA	127	Manual	Compactor	Daily	Packer Truck	Land Fill	Transport on-site by site
	SFD	14	Manual	Compactor	Daily	Packer Truck	Land Fill	owned dump truck. Off-site
	MFLR	52	Manual	Compactor	Daily	Packer Truck	Land Fill	transport by private service
	MFMR	52	Chute	Compactor	Daily	Packer Truck	Land Fill	twice each week.
Macon, GA	SFA	159	Packer Truck	Container	2/wk	Packer Truck	Land Fill	Transport on-site and off-
	SFD	6	Packer Truck	Container	2/wk	Packer Truck	Land Fill	site by private service.
	MFLR	42	Packer Truck	Container	2/wk	Packer Truck	Land Fill	
	MFM/HR	80	Packer Truck	Compactor & Container	3/wk	Packer Truck	Land Fill	
Memphis, TN	SFA	69	Packer Truck	Container	3/wk	Packer Truck	Land Fill	Transport on-site and off-
	MFLR	99	Packer Truck	Container	3/wk	Packer Truck	Land Fill	site by private service.
	MFHR#1	144	Packer Truck	Container	6/wk	Packer Truck	Land Fill	
	MFHR#2	206	Packer Truck	Compactor & Container	2/wk	Packer Truck	Land Fill	
St. Louis, MO	SFA	731	Manual	Pen & Container	6/wk	Packer Truck	Power Plant	Municipal service 2/wk
	MFLR	68	Manual	Compactor, Container, & Pen	6/wk 6/wk	Packer Truck	Power Plant	Municipal service 2/wk
	MFMR	147	Manual	Compactor & Container	6/wk 6/wk	Packer Truck	Power Plant	Municipal and private service 2/wk
	MFHR	174	Packer Truck	Compactor & Container	6/wk 2/wk	Packer Truck	Power Plant	Private service 2/wk
King County, WA	SFA	80	Curbisde/Manual	Cans	1/wk	Packer Truck	Land Fill	Private service
	SFD	74	Curbside/Manual	Cans	1/wk	Packer Truck	Land Fill	Private service
	MFLR	24	Packer Truck	Container	1/wk	Packer Truck	Land Fill	Private service
Sacramento, CA	SFA	179	Backyard/Manual	Cans	1/wk	Packer Truck	Land Fill	Municipal service
	SFD	20	Backyard/Manual	Cans/Pens	6/wk	Packer Truck	Land Fill	Municipal service
	MFLR	96	Manual	Cans/Pens	6/wk	Packer Truck	Land Fill	Municipal service
	MFHR	306	Chute/Container	Container	6/wk	Packer Truck	Land Fill	Municipal service
Seattle, WA	SFA	38	Manual/Pen	Container	2/wk	Packer Truck	Land Fill	Private service provided
	MFLR	20	Manual/Chute	Container	2/wk	Packer Truck	Land Fill	under municipal contract.
Jersey City, NJ	MFLR	12	Pneumatic	Compactor Container	Not Applicable	Pull-on Container Truck	Land Fill	Private service
	MFMR	64						
	MFHR	410						

This report is a summary of the results developed in three reports prepared in the contract:

- "Evaluation of the Refuse Management System at the Jersey City Operation Breakthrough Site."
- "Evaluation of the Refuse Management Systems of Operation Breakthrough Sites."
- "Survey of User Acceptance of the Solid Waste Removal Systems at Operation Breakthrough Sites."

All reports were prepared for the U.S. Environmental Protection Agency and sponsored by the U.S. Department of Housing and Urban Development under contract number 68-03-0094.

EVALUATIONS

All of the sites were evaluated to ascertain the economics, the technical aspects, the environmental factors, and the resident and management acceptance elements of each system. Data were gathered during short site visits to each site. However, because the pneumatic trash collection system at the Jersey City site was so unique, it required extensive, detailed investigations. An instrumentation package was designed and installed at the site to monitor the system for 18 months of operation. Specific tests and experiments were performed to determine overall system performance with respect to design specifications and effects on air quality and sanitation.

Technical Evaluation Objectives

The technical aspects of each of the waste management systems were analyzed to determine the effectiveness and efficiency. This was accomplished by examining the following aspects of the systems.

- Quantity of solid waste collected in terms of type and number of containers at each service and the number and type of dwelling units.
- Distances traveled between services and total distance to collect on site.
- Time spent on various collection activities including productive collection time, handling and walking time, waiting time, and time spent on other activities.
- Mechanical equipment performance effectiveness, safety, convenience, user acceptance, noise, odor, sanitation, aesthetics, and other aspects pertinent to each system.

- Compactor (where installed) load capacity and the weight, size, and handling requirements of compacted packages.

- Storage containers effectiveness, sanitation, user acceptance, and other aspects pertinent to each system.

More detailed technical analyses were required for the PTC system. Overall system performance was evaluated by investigating the system reliability and maintainability; performance; and expected service life.

Reliability and Maintainability--

The PTC system reliability and maintainability was evaluated by analyzing operational data to determine:

- The availability of the system and the probability that the system will be in an operable mode at any time;

- The probability that the system can continue to collect refuse automatically after the completion of a specified number of cycles;

- The probable repair time required to correct malfunctions;

- The effects of system malfunctions on the collection service;

- The effects and probability of a major system breakdown; and

- The reliability and maintainability characteristics of the system.

Performance--

The system performance was evaluated to determine the effectiveness of the PTC system in terms of:

- The ability to meet design criteria for the refuse loads and economics for the site;

- The ability to transport various shapes and densities of refuse;

- The capacity of the system for the design loads, actual loads, and operating schedule, including determination of the optimium operating schedule;

- The ability to safely handle dangerous materials;

- The adaptability of the system to recycle specific solid waste classes;

- The ability to recover valuable items mistakenly placed in the system; and

- The adequacy of safety equipment.

Expected Service Life--

The service life of the PTC system was determined by evaluating the operational degradation and wear with respect to service time.

In addition, a special study was conducted at the King County, Washington site. A comparative study was made of plastic bag versus standard containers for curbside collection. For this study, half of the King County residences were furnished plastic bags for lining trash cans. On pickup day, the plastic bags were tied and set at curbside. The other half of the residences utilized standard cans in the usual manner by setting them at curbside on pickup day. The data were collected over a one month period.

Economic Evaluation Objectives

The objectives of the economic evaluations were to determine the costs of each system. The particular costs considered were:

- Capital costs of equipment (including installation costs, where applicable;

- Operating costs such as electrical power, labor, maintenance, parts and supplies, fuel, repair costs, container rental, disposable liners, transport and disposal fees; and

- Recurring costs such as taxes and insurance.

Here again, because of its nature, the PTC system at the Jersey City site required additional economic evaluations. Not only were the capital and operational costs examined, but the maintenance and annualized costs were considered as well. All of these costs were compared to design estimates. Furthermore, the economics of the PTC system were compared to the estimated costs of conventional refuse collection systems which might have been installed at the site.

All cost results were compared to the "1968 National Survey of Community Solid Wastes Practices"* and the results derived from

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*"1968 National Survey of Community Solid Wastes Practices," an Interim Report, EPA, USPHS, Cincinnati, Ohio, 1968.

that survey by Hagerty, Pavoni, and Heer.* To obtain comparative costs, all site cost data and the results of Hagerty, et. al., were modified to a common base in October 1975 using the building and common labor cost indexes found in the Engineering News Record.

Environmental Evaluation Objectives

The objectives of the evaluation were to define the environmental effects, if any, each refuse collection system presented. Specifically, the following areas were explored.

- Sanitation effects such as litter, cleanliness, odor, and presence of rodents and vermin.
- Noise levels produced by the refuse collection activities compared to background noise levels and acceptability to residential use of the system.
- Aesthetic qualities attributed to the system.
- Advantages of a reduced number of service vehicle visits to the site to pick up and dispose refuse.

Aside from evaluating the effects that the PTC might have on the aforementioned environmental areas, the air quality of the system, including both internal and exhaust air, was assessed. This included running tests on both airborne particulates and viable particles.

User Acceptance Survey

Resident and management acceptance of the solid waste management systems was determined by surveying a sample of the residents and the management at each site and by conducting interviews using an approved survey questionnaire. Residents and site management personnel were surveyed at the Jersey City site and seven other Operation Breakthrough sites to learn their perceptions of and reactions to the various trash storage, handling, and collection methods in use at those sites. St. Louis was not surveyed because of the site management's unwillingness to participate in the survey. The results of the analyses were used to determine:

- Type of resident at each site;

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*Solid Waste Management, Hagerty, D. Joseph, Joseph L. Pavoni, and John E. Heer, Jr., Van Nostrand Reinhold Company, New York, 1973, p. 16.

- User solid waste disposal requirements;
- Suitability of the system to the user; and
- Suitability of the system to the environment.

SECTION 2

CONCLUSIONS

The major results of the evaluations of the solid waste management system data gathered at the nine Operation Breakthrough sites are summarized in Table 2. In addition, the results are presented for a four week study of the curbside pickup of plastic bags versus standard garbage cans at the King County, Washington site. The findings are based on the overall objective of the study, namely to evaluate the economics, effectiveness, and feasibility of using improved solid waste collection systems in new communities.

The evaluations indicate that the methods employed at Macon, Georgia; Memphis, Tennessee; Sacramento, California; and King County, Washington were the most economical and effective. The St. Louis, Missouri site desperately needs modifying because it was extremely costly and very ineffective. The pneumatic trash system as the Jersey City site was found to be unreliable, over designed, and costly. Specific conclusions for each follow.

INDIANAPOLIS, INDIANA

The system is satisfactory in that refuse is collected and disposed. The city charges for collection for the entire site even though the MFMR and the maintenance buildings are serviced by a private contractor. The costs are $2.22 per cu yd which is reasonable and equates to $44.38 per dwelling unit per year. The costs could be reduced if the city services the entire site. The total costs are $12.62 per capita per year (average) which is higher than the adjusted national average of $12.08 per capita per year. Site labor requirements could be reduced if residents were required to store refuse in their homes until pickup day. The manual pickup by the city incurs a high nonproductive rate with 35 percent of the active collection time spent waiting.

Site environmental aspects are generally good. Site aesthetics could be greatly improved if shrubbery were planted around the pens. Restriction of residents to placing refuse in pens only on collection days could minimize odors, insects, and animal problems. Chronic overloading of the central storage bins caused littering, odors, pet and weather scattering of garbage, and problems with insects and vermin.

TABLE 2. SUMMARY OF ECONOMIC AND TECHNICAL ANALYSIS RESULTS

Site	Annual Costs	Cost/DU/ Year	Cost/ Cap./yr	Cost/ cu yd	Miles per stop	DUs per stop	Man-minutes per stop	Man-minutes per cu yd
Indianapolis	$13,091	$44.38	$12.62	$2.22	0.2	8.4	8.2	2.5
Kalamazoo	15,072	51.09	14.52	2.55	0.1	13.6	9.7	15.2
Macon	21,105	73.53	28.52	3.52	0.1	4.9	8.0	4.1
Memphis	22,614	43.65	25.35	2.25	0.1	26.1	9.4	3.0
St.Louis	124,541	111.20	46.00	8.24	33.1 miles per week	32.6 DUs per mile	11.3 man-minutes per DU	42.9 man-minutes per cu yd
Seattle	4,727	81.50	22.19	5.56	0.03	18.7	26.5	5.0
Sacramento	14,486	24.10	11.34	2.68	0.1	20.1	9.6	7.8
King County	9,540	53.90	13.65	4.54	0.1	8.4	6.5	3.4
Jersey City	120,021	246.96	96.02	N/A	N/A	N/A	N/A	N/A

TABLE 2. (Continued)

	Advantages	Disadvantages
Indianapolis	Low cost	35 percent nonproductive use of labor. Odors, insects, weather effects occur.
Kalamazoo	Proper compactor use could result in low costs and reduction in required service frequency. Good aesthetics. Free from odors, insects, vermin.	Poor effectiveness. Residents do not use compactors. High capital costs. High maintenance costs. 17 percent nonproductive use of labor. Excessive refuse handling which is labor intensive.
Macon	High effectiveness. Low capital costs. Clean and free from odors, insects, vermin.	Improper compactor installation causes increased costs. High maintenance costs. 13 percent nonproductive use of labor. Serviced too frequently. Noisy collection. Litter in MFM/HR trash room.
Memphis	Low capital costs. Very effective. Good aesthetics. Free from odors, insects, vermin. No sanitary problems.	Municipal inspection fee of $0.50 per DU per month. High operating costs. Overhead clearance not sufficient for front loader truck. Containers do not fit pens. 23 percent nonproductive labor utilization. Safety problem moving containers on casters.
St. Louis	The compactors in the Operation Breakthrough portions would be an advantage if properly utilized.	Excessive costs. Compactors are not effectively utilized. Excessive handling of refuse which is labor intensive. Poor effectiveness, Sanitary problems with odors, insects, vermin. Storage pen is overloaded.
Seattle	Low capital costs. Very effective. Excellent appearance. Clean and free from odors, insects, vermin.	High collection service costs. 22 percent nonproductive labor utilization. One portion serviced too frequently.
Sacramento	Low costs particularly low capital costs. Good effectiveness. Excellent appearance. Clean and free from odors, insects, vermin.	High collection costs. Labor intensive. Overloaded pens.
King County	Low costs for subscribers to refuse service contractor. No problems with odors, insects, vermin.	High costs for residents disposing their own refuse. Cans left curbside detract from site aesthetics.
Jersey City	Convenient to residents, Clean and free from odors, insects, vermin.	High capital costs. The system is over sized for the site load; consequently, it is not used to capacity. The reliability is poor.

KALAMAZOO, MICHIGAN

The system is not being properly utilized and thus the full effectiveness of the design of the system is not being achieved. Excessive costs are incurred for pickup labor, plastic bags, on-site hauling, and disposal costs. The total costs observed are $2.55 per cu yd of loose refuse. Costs could be reduced to $2.29 per cu yd if proper compactor operation were performed by site residents. The $2.29 per cu yd is based upon proper utilization of the compactors which would then allow reduction of pickups from seven to three per week by site maintenance personnel and reduction to one pickup per week by the private service contractor.

Residents do not start the compactors. Trash is placed inside the compactors if the chamber is not full, but the residents do not push the start button after placing refuse inside. Subsequent visits by residents result in refuse being left on the ground around the compactor rather than compacted in the chamber. Household pets worsen the problem of scattered trash at this site.

The use of plastic bags in the chamber of the compactor created a safety hazard due to broken glass. This has resulted in the need to segregate glass from the trash. It is recommended that a metal, hinged carrying "caddy" or similar device be devised for handling compacted packages which are removed for disposal.

MACON, GEORGIA

The refuse system is effective, efficient, and fairly economical. A lack of design consideration is evident in the refuse chute to compactor interface. Future projects should specifically give more consideration to refuse room location, refuse chute location, and compactor installation so that the necessary space is allowed for a proper installation of the equipment. The containers as well as the pens in most cases blend well into the site. Consideration should be given to specifying the color of containers such that they do not detract from the site. Also, container locations should receive more consideration for access by the service truck.

Walking time and some nonproductive labor can be reduced. It will not reduce overall costs much, but consideration for future sites should include planning to improve labor utilization. The containers inside of pens must be rolled out and positioned in front of the packer truck. After emptying the container must be rolled back. Future sites should contain provisions for allowing direct access to the container by the truck. Packer trucks should have some provision to prevent liquids from being squeezed out of the truck onto the parking lot or grounds of a residential area.

This type of refuse system should not be affected by weather conditions except ice or snow which may prevent the packer truck from being operational.

Noncompliance with the site regulation that trash be disposed in the containers aggravated environmental concerns.

MEMPHIS, TENNESSEE

The refuse collection system is economical. However, future compactor installations should consider the basis of hauling and disposal charges during the planning stages. If reduced volume does not save money, the only reason to install the equipment is reduce the number of pickups. The system as installed at Memphis requires a private contractor to remove and dispose refuse which is the single most expensive part of the system. The contracts account for 55 percent of the annualized system costs.

The concrete pens serve to blend the containers into the site. However, future sites should more closely match pen size to container size so that the container will fit into the pen. Pen orientation should be considered for ease of emptying by the truck. Presently a hazardous situation exists because the containers must be manually pushed down inclined ramps to the truck. This requires dexterity and a fair amount of strength to prevent the heavily ladened containers from running wildly down the inclines possibly crashing into automobiles in the parking lots or injuring personnel. Also, container size and method of emptying should be considered where there may be limited overhead space.

The manual movement of the containers is consumptive of time and labor. The 144-unit MFHR building should have been a serious candidate for compactor installations because of the number of tenants. At present, the containers are emptied once each day, six days a week. Installation of compactors should reduce the number of pickups to a maximum of three pickups per week. This would not reduce dumping charges, but it should reduce pickup fees and reduce the labor expended in removing backed-up refuse in the chute.

The system has no apparent odor, sanitation, or noise problems.

ST LOUIS, MISSOURI

The system is not economical for the entire site. The effectiveness and efficiency of the refuse collection system is degraded by the labor intensive efforts and excessive handling of refuse. Curbside pickup would benefit the La Clede Town portion of the site by eliminating the need to place refuse in containers and then move refuse from containers to street areas for pickup. Similarly, the refuse is then placed in pens to await pickup and disposal by the municipal service and by private contractor. A recommended improvement is to eliminate excessive handling of the refuse.

The existing system is not aesthetically obtrusive. All containers and pens are well disguised by shrubbery. The storage pens are outside and the sanitation is questionable because refuse builds up in the pens, decays, attracts flies, causes extreme odor problems, and probably attracts vermin. Also, excessive handling of the bagged refuse caused bag tears and refuse spillage which increases the probability that storage problems occur.

A complete study should be performed so that the refuse management system could be improved. A study of once-only-handling of refuse should be included in the study. By decreasing handling, it would probably decrease costs and sanitary problems and increase efficiency and effectiveness. Curbside pickup and disposal by the site, the city, or a private contractor may offer cost benefits to the site.

SEATTLE, WASHINGTON

The Seattle site refuse system is effective, efficient, and environmentally satisfactory. The annual costs appear high due to the costs of the city provided collection and disposal service. The costs could be lowered by servicing the chute-fed containers once a week.

The efficiency of the collection crew could be improved at the site if a one or two man crew was used in place of the three-man crew. With a three man crew, one man stands idle while collection is performed at the site. This reduction may not be possible due to requirements for personnel when servicing urban areas other than the Operation Breakthrough site.

Over half of the respondents surveyed said they saw potential personal hazards (primarily from falls and criminal assault) in their use of the external storage facilities.

SACRAMENTO, CALIFORNIA

The capital costs for the Sacramento site refuse system are low and the operation and maintenance costs are high. Collection and disposal fees account for 71 percent of the costs of the refuse system. Overall, the costs per dwelling unit, per capita, and per cu yd of refuse are fairly low and are less than national averages.

Excellent efficiency is achieved in refuse collection activities at the site. The effectiveness and efficiency of collection in terms of cost are high, but the volume of refuse collected per unit of time appears low which is due to the backyard collection activities required to service 295 dwelling units.

Odors occur in the trash can pens in hot weather but the system exhibits no environmental problems associated with aesthetics, noise or sanitation. Resident requirements for handling refuse are minimal.

KING COUNTY, WASHINGTON

Refuse collection and disposal at the King County site is very effective with the exception of the residents who dispose of their own refuse. Curbside collection once a week using a two-man crew is efficient and environmental problems are minimized. The refuse system would be much more economical if all SFA and SFD residents subscribed to the private collection service. It is an option of the homeowner to subscribe or dispose of his own refuse.

KING COUNTY PLASTIC BAG STUDY

The use of plastic bags in place of standard trash cans results in $17.41 higher annual costs to the homeowner. Refuse collection activities are more efficient and require less labor when plastic bags are utilized. Refuse is collected faster but the contractor will not reduce pickup fees even if bags are used. The collection crew prefers plastic bags because of increased pickup speed.

The site appearance is improved because cans are not left curbside in the SFD areas after pickup of refuse. Site environmental conditions are as good or better when plastic bags are used and there is less collection noise. Odors are minimized, and there appears to be less possibility of sanitation problems when plastic bags are used.

Overall, a site would appear to be improved if plastic bags are used in place of trash cans for curbside pickup; however, heavy duty bags (3-mil thickness) were used in the study and bags of less strength might have different results.

JERSEY CITY, NEW JERSEY

The Jersey City site, which utilized pneumatic trash collection, was monitored for 18 months of operation while the other sites were monitored for only several days. Thus, considerably more conclusions could be drawn.

Technical Conclusions

Reliability and Maintainability--

The availability of the PTC system was calculated to be 54 percent. However, design specifications stated that the system should be in an operable mode around 97 percent of the time.

The probability that the system would successfully operate (without failure) for a given number of cycles decreases drastically as the number of cycles increases. There is a 50 percent probability of failure for 16 hours (15 cycles) of operation and a 90 percent probability of failure for 40 hours (37 cycles) of operation. The system exhibited 16 hours (15 cycles) mean time between failures. This represents a very, very low reliability.

Total calendar downtime increased with the extent of the system malfunction. Fifty percent of the malfunctions were repaired within three hours of total downtime while 10 percent of the malfunctions required 36 hours. However, 60 percent of the malfunctions were repaired within one-half hour after repair work was actively begun. Considerable amounts of downtime were attributable to the slow response of site personnel in reacting to system problems.

The design specifications called for all system malfunctions to be repaired within 24 hours. The operational data indicated that 16 percent of the malfunctions required more than 24 hours for repairs, which did not comply with the design criteria.

The probability of a major system breakdown was found to be directly related to the probability of a failure with six critical components. These components were the main transport line, the programmer, the discharge valves, the control panel, the vertical trash chutes, and the compactor. They contributed to 88 percent of all system malfunctions, 94 percent of all downtime, 89 percent of the total repair time, and 91 percent of the total man-hours needed to effect repairs. It was found that design improvements for these components could reduce the total number of system malfunctions by 51 percent, total downtime by 62 percent, total repair time by 46 percent, and total man-hours for repair by 51 percent. Furthermore, the system availability would be increased by 32 percent, or be about 86 percent.

The effects of system malfunctions were found to be more pronounced as the amount of time that the system did not operate increased. Minor problems with sanitation, litter, and odor were experienced with short downtime periods. Whenever the downtime exceeded 24 hours, major problems ensued. As a result of the PTC system being inoperable for periods longer than 24 hours, an alternative refuse collection service was required. During these periods, the site personnel manually collected refuse which was a highly labor-intensive activity.

The prolonged downtime and the alternative collection service combined to cause a variety of problems with litter, odor, and vermin. At times, these sanitation conditions were so repulsive that the residents complained to the site management.

Performance--

The PTC did meet the design capacity criteria for the refuse loads, however, the loads at the site were only about one-sixth of design load criteria. The observed load was about 248 tons per year, while the design load criteria was from 1300 to 1600 tons per year.

The design specifications stated that the system must be able to collect refuse with densities ranging to 50 pounds per cubic foot. Under normal operating conditions, the system complied with these qualifications. Additionally, it was noticed that many overweight, oversize, and other bulky items were collected without any problems.

The operating schedule of 18 cycles per day more than adequately handled the actual loads of the PTC system because the actual loads were only one-sixth of the design loads. It was determined that for the actual loads, the optimum operating schedule would be between seven and nine cycles per day. The times for the cycling of the system would vary due to daily, seasonal, and other load factors.

The PTC system did have the ability to safely handle some types of dangerous materials.

The investigations into the adaptability of the system to recycle specific solid waste classes showed that the system could be modified to do so without major design changes and with reasonable success. The modifications would most likely be centered around the collection hopper. The quantities of recycled solid waste annually could be about 196 tons, or 79 percent of the annual refuse loading.

Valuable items mistakenly placed into the system could be recovered; however, the probability of retrieving the item undamaged is small. The chances of recovery and the effort required for recovery depend upon the extent of system operations.

The design specifications for the system called for equipment to prevent component and plant failures, service interruptions, fires, and personnel injuries. Many of the PTC system safety features did not satisfy these requirements. However, for the most part, the safety equipment for the PTC system did prevent injury and property damage.

The performance of the system was found to deteriorate with low room temperatures. Because components were located in rooms that were not properly heated and components were built to operate properly at normal room temperatures, component failures occurred. Most of these failures were related to ice formation in the pneumatic air actuation lines for the air inlet and discharge valves and the sluggish behavior of the hydraulic oil used in the compactor.

The design specifications stated that the service life of the PTC system should be 40 years. It was determined through wear measurements that two system components did not meet this design criteria. The main transport line would fail after 36 years of operation while the compactor would fail after 38 years.

Economic Conclusions

The PTC system was not, as stated in the design specifications, cost effective. The total annualized cost of the system (i.e., capital, operating, and maintenance) to collect 248.3 tons of refuse per year is $120,021. The annual costs for three alternative conventional systems, which might have been installed, to collect 248 tons of refuse ranged from $26,231 to $74,699. Hence, the PTC system was from 161 to 458 percent more costly than conventional approaches.

The costs for all four refuse collection systems were projected to the year 1995. The annual cost in 1995 for the PTC system to collect 248.3 tons of refuse is about $178,389. The corresponding costs for the three conventional systems ranged from $66,782 to $213,228. Thus, the annual cost for the PTC system was about 0.84 to 2.67 times the costs for the conventional systems.

As previously di ussed, the PTC system was not utilized to its design capacity. If the actual refuse loads were six times the loads observed which would then equal the design load criteria, the cost per ton of refuse disposed by the PTC system would be from $99 to $116. The corresponding values for the three alternative conventional systems would range from $104 to $341. Thus, the PTC system could be cost-effective if the refuse loadings at the site approached the design criteria of 1300 to 1600 tons of refuse per year.

The capital costs of the PTC system, which totaled to $89,782 per year, accounted for about 75 percent of the annual cost. The major capital expenditures were: (1) the main transport line ($36,751 per year or 31 percent of the annual cost), (2) the equipment space in the Central Equipment Building (CEB) ($15,451 per year or 13 percent of the annual cost), and (3) engineering ($12,906 per year or 11 percent of the annual cost). If measures were implemented to reduce the capital costs of the PTC system, especially with the main transport line, equipment space, and engineering, the conomics of the system would become more attractive.

User Acceptance Conclusions

In general, it can be deduced that both residents and management accepted the PTC system. The acceptance was attributable to: the ease in using the system, relatively few sanitation problems, the infrequent visits by service vehicles, the removal of most of the visible and audible signs associated with refuse collection system, the disappearance of vermin and rodents, and to other advantages which were intrinsic to the PTC system.

Although site management accepted the PTC system, they felt that many problems associated with the system could have been avoided if the tenants had used the system properly. Specific problems cited by the site management included:

- Residents breaking PTC system components by forcing large, bulky wastes into the chute door;
- Residents causing chute blockages by not pushing refuse all the way down the chute;
- Residents leaving food wastes and moist garbage on charging station floors or in hallways and stairways; and
- Residents improperly wrapping refuse which created unsanitary and unhealthy conditions in discharge valve rooms, especially during periods of operating problems.

Environmental Conclusions

Sanitation effects such as litter, cleanliness, odor, and presence of rodents and vermin were minimal. The effort of site personnel, combined with attributes of the PTC system, controlled litter and odor, and this clenliness kept the vermin population down. Furthermore, it should be noted, that during the entire monitoring program no rodents were observed. The problems with litter, odor, and vermin occurred only during prolonged system downtimes, particularly during hot, humid weather.

Although the internal air of the system had excessive levels of airborne particulates and viable particles, the dust collector effectively removed the matter such that the concentration levels in the system exhaust air were consistently lower than the levels in ambient air. Additionally, the concentration of airborne particles in the system exhaust air never exceeded the Primary Standard for the National Ambient Air Quality Standards for particulate matter which was 3.28 x 10^{-5} grains per cubic foot. The average values of total airborne particulate matter were 13.74 x 10^{-5}, 2.11 x 10^{-5} and 3.97 x 10^{-5} grains per cubic foot for system internal air, system exhaust air and ambient air, respectively. Thus, the system exhaust air had lower levels of airborne particulates than the ambient air which also complied with the design criteria.

The viable particle concentrations for the system internal air, system exhaust air, and ambient air were 7.3, 3.8, and 5.8 colonies per cubic foot, respectively. The concentration of viable particles in the system exhaust air was lower than in the ambient air. This met the design criteria. In addition, the odor, which was negligible, from the exhaust air was undetected by the residents.

The noise produced by the PTC collection activities was generally lower than background noise levels. Much of the noise was isolated from the residential areas by locating many of the noise-producing components in the CEB. Furthermore, the noise attributed to the PTC system never exceeded OSHA requirements. As such, the effects of the noise from the PTC system were limited and not a factor to residents.

The design of the system considered retaining the site aesthetics; hence, most of the PTC system components were located underground, behind walls, or in the CEB. Those components that were visible were made to blend into the site. These measures were most effective in removing the visible signs of the PTC system.

There were definite advantages to a reduced number of service vehicle visits to the site to pick up and dispose refuse. These advantages included:

- Less noise,
- Less expense,
- Less tenant awareness,
- Less chance of accidents, and
- Freed service vehicles for other operations.

SECTION 3

RECOMMENDATIONS

Planning for future developments should include detailed consideration of refuse management requirements. The requirements should be incorporated into designs during development of site plans and buildings to assure adequate considerations for installation, location, and operation. Particularly important is the planning required for innovative systems which may have unusual requirements or may not be acceptable to residents. The results and conclusions of the study demonstrate that conventional collection methods such as curbside, chute, and dumpster containers are easily used by residents whereas innovative methods are not properly utilized by residents. Recommendations for each site follow:

INDIANAPOLIS, INDIANA

The site is serviced by a stationary bin/plastic bag system. The site itself contains 295 units of single and multifamily housing.

Methods should be studied to allow municipal servicing of the MFMR building as well as the rest of the site because the site pays the city for the service even though it is not used. The $1824 per year paid to the private contractor could be saved if the city serviced the MFMR building and the site hauled bulky wastes away.

A regulation not allowing residents to place bags of refuse in the pens except on pickup days should be considered. This would influence residents to properly close and tie bags and prevent exposure to weather and animals (pets, mostly cats and dogs). Drainage or windscreen facilities should be studied to prevent weather scattering of garbage.

Collection crew performance efficiency could be greatly increased if the truck driver participated in refuse handling.

Methods should be considered to install a slope from the vertical chute to the container in the MFMR building. The current design results in chute clogging and backups with scattered refuse in the container room.

KALAMAZOO, MICHIGAN

There are 245 single and multifamily dwelling units at this site. The SFD, SFA, and MFLR units use communal compactors located outside of buildings. The MFMR units use a chute-fed compactor.

Considerable effort on the part of the site management has not resulted in residents using the communal compactors so that maximum benefits of refuse volume reduction are realized. It is doubtful that the residents will ever properly utilize the equipment; therefore, it is recommended that curbside pickup once a week be initiated at the site with a one or two-man crew. Another alternative is to use centrally located containers serviced by a private contractor.

If communal compactors are considered for future developments, automatic cycling would be a desirable feature. The charging chamber should also be located at least 36 to 42 inches above the ground to prevent entry by adventuresome youngsters. The higher location would allow easier servicing by the collection crew. The greatest benefit that automatic cycling attains is the reduction of refuse volume which requires fewer servicing trips by the collection crew. A special carrying device should be used with compacted refuse to prevent injuries to service personnel. A two handled device could be easily developed as a caddy for bags of compacted refuse.

MACON, GEORGIA

Dumpsters are the major form of storage and collection facilities available to the residents of the 287 single and multifamily units at this site. Singlefamily unit residents are required to dispose of their trash in the containers.

The use of central containers works very well. Future site planning should incorporate better locations for containers to allow easy access by the pickup truck. Container enclosures should be oriented to prevent the containers from being very noticeable. The planting of shrubbery instead of (or in addition to) using frame enclosures might also be considered to improve aesthetics.

The compactor installation under the chute of future multilevel buildings should consider the interface problems before installation so that adequate space is allowed to provide a proper fall for refuse to enter the compactor chamber. Refuse container rooms should be locked to prevent entry by people and pets. Compactor containers should have metal or canvas compactor-port covers to prevent spillage when moving or emptying the containers.

MEMPHIS, TENNESSEE

The site contains 518 single and multifamily units. Centrally located bins serve the single-family units, chute-fed containers serve residents of one multifamily structure, and a chute-fed compactor serves residents of the other multifamily structure.

The site is charged landfill fees on a loose refuse basis. A four to one compaction ratio means the site is charged four times the loose refuse price. Therefore, compacting the refuse has not saved money. Future developments should consider the basis of landfill fees before installing compaction equipment. The equipment does allow fewer service trips by the contracted pickup service.

Future sites which use container enclosures should design and install enclosures of sufficient size to allow the container to be fully inserted into the enclosure. Site management should provide either additional storage containers or more frequent trash collection.

ST. LOUIS, MISSOURI

This site is composed of 1120 single and multifamily dwelling units. The single-family unit residents use external refuse storage containers. The multifamily units utilized a household trash compactors and chute-fed compactors.

The St. Louis site refuse system has many problems and a complete in-depth study of the refuse management system is desparately needed. Such a study is recommended and it should incorporate the following minimum features: (1) the possibility of once or twice a week curbside pickup in La Clede Town to reduce refuse handling and storage, (2) picking up the refuse from the Operation Breakthrough portions (La Clede Town East and West) only once a week since all households have compactors, and (3) storing refuse in containers which can be dumped by trucks rather than requiring manual loading.

SEATTLE, WASHINGTON

A bulk container system provides trash storage and collection service for the 58 multifamily units.

The chute-fed containers do not need emptying twice a week. Either by adding one or two containers, once a week service could reduce the costs of servicing the site.

The management should survey and correct physical features of the disposal system which might cause falls. Site management should also secure the trash bin areas to lessen resident fears of criminal assault.

SACRAMENTO, CALIFORNIA

The 601 single and multifamily units at this site are served by a municipal agency. SFD AND SFA units are serviced with curbside and backyard pickup. The MFLR units have central storage pens. The MFHR structures use chute-fed containers.

The Sacramento site refuse management system is very effective. Some overloading in some of the multifamily low-rise (MFLR) pens occurs while other pens are virtually unused. It is suggested that the pens be better located for use by residents. The pens near automobile parking areas are frequently overloaded; therefore, additional pens in those areas might solve the problem. Another approach is to move the three pens in the MFLR alleys to the curbs of the parking lots. Ten pens appear adequate for the load.

The high-rise buildings should have compactors installed to reduce pickup frequency. The buildings have plenty of space under the refuse chutes where compactors would easily fit. The installation could easily reduce servicing from six days a week to three times (or less) a week.

KING COUNTY, WASHINGTON

A private contractor provides curbside or garage trash pickup service for the residents of the 178 units of single and multifamily housing at this site.

All residents of the King County site should subscribe to the refuse collection service. Thirty-five residents that haul their own refuse away could save money by subscribing to the service. Also, the Homeowners Association should take an active role in monitoring the collection system.

JERSEY CITY, NEW JERSEY

Here again because of the extensive data collected and analyzed on the PTC system at this site, detailed recommendations can be made.

Technical Recommendations

First and foremost, the design loads of refuse should be carefully estimated to insure that the actual loadings of a proposed site would justify the capital costs of a pneumatic trash collection system. This can be achieved by observing the refuse loads of similar nearby residential complexes.

Future designs should consider features to provide an efficient and effective service to handle: (1) the collection of bulky refuse that cannot be collected by the system, and (2) an alternative refuse collection service during prolonged system downtimes. The present system had no such provisions.

Design of future PTC system applications should also consider methods of resolving:

- Water infiltration and refuse blockages in the main transport line.
- Design changes for the following system components which were identified as critical for proper system operations.
    - main transport line,
    - programmer,
    - discharge valves,
    - control panel,
    - vertical trash chutes, and
    - compactor.
- Blockages in discharge valves and chutes.
- Proper operation of the container handling system.
- Proper heating of the rooms housing system components.

The problem of water infiltration could be solved by placing a water trap and pump at the lowest points in the transport line. The pump should be able to handle solids, such as refuse, as well as liquids.

The observed PTC system had six critical components (the main transport line, the programmer, the discharge valves, the control panel, the vertical trash chutes, and the compactor) which created most of the problems with the system operations. Improvements in the design of these components could benefit in lower downtime costs as well as providing for an improved collection service.

As for refuse blockages in the line, the PTC system was designed and built with access plates at strategic points along the line. These plates allowed equipment to be placed in the line to remove the blockages. However, many of these plates were inaccessible. Future design of PTC systems should consider placing more access plates at locations more convenient for the equipment needed to remove blockages and no further apart than thirty feet.

To alleviate problems with chute blockages, future chutes should be designed without bends and restrictions, and with larger cross-sectional areas. The addition of energy absorbing baffles would also prevent refuse compaction when objects free fall on to loose refuse at the bottom of chutes.

To resolve problems with blockages in the discharges valves, future designs should consider either improvements in the discharge valves themselves or alternative means for passing refuse from the chutes to the main transport line. Positive suction through the trash chute rather than gravity feed through a discharge valve would improve this situation.

The container handling system used at the site was insufficient, basically due to two problems: (1) the hydraulic lefts could not raise a fully loaded refuse container, and (2) the power assisted rollers frequently failed. Future PTC system designs should make certain that the components for the container handling system are properly sized to handle the weight and stress of a fully loaded refuse container.

Future systems should take into account the temperatures at which system components best operate. Measures should be incorporated so that the temperatures of rooms housing system components can be maintained at the proper levels.

Discharge valve rooms should be designed to be more accessible to site personnel. Better locations would facilitate manual collection services when needed and aid in proper maintenance activities.

Future PTC systems should consider placing the central control panel in a more conveninet location for all authorized site personnel. New systems should be designed with new and improved alarm systems. Additionally, future designs should incorporate methods to control litter and spillage from trash chutes.

When considering the service life for future PTC systems, requirements for components should be investigated more thoroughly.

It is not enough just to design a better system. Measures should be taken to insure that new systems meet the design requirements. This would entail detailed inspections of all system components, safety equipment, and other related pieces. Furthermore, inspections and test methods should be implemented to assure proper installation.

Pneumatic trash collection systems could operate more effectively and with less wear and problems if users are fully aware of the system capabilities and their responsibilities. Precautions should be taken to insure that users not only are aware of how to properly use the system, but do in fact consistently do so.

Some measures that might be taken to achieve this goal would be:

- A special clause in leases about PTC system operation and use;
- The posting of signs at strategic places promulgating system capabilities and use;
- An indoctrination as to proper system use; and
- A different concept of operation, similar to those used successfully at other PTC installations such as allowing only site personnel to charge refuse into the system.

With better educated system users and operators, the PTC system could more fully attain its expectations.

Economic Recommendations

The design loads of refuse should be carefully estimated to insure that the capital expenditures justify the use of a PTC system. This can be achieved by observing refuse loads of similar nearby residential complexes. The PTC system at Jersey City could be less costly if it were used to its design capacity.

The PTC system could appear to be easily modified for recycling resource materials such as paper, plastics, glass, and metals. Future system applications could consider reclamation of these materials and determine the suitability of this innovation.

Future PTC systems should also consider educating personnel responsible for the system in its use, operation, and maintenance. Considerable money, time, and effort can be saved when operating personnel fully understand the system. This can be achieved by conducting indoctrination and training classes, preparing manuals, and by additional measures.

Preventive maintenance programs for future PTC systems should be a major concern. There was no preventive maintenance program at the site studied. However, with a properly planned and executed preventive maintenance program, the service of the system would be improved. Furthermore, benefits of a good program would be savings in time, labor, and money.

Environmental Recommendations

The design of the PTC system effectively controls odors and the discharge of particulate and viable particles. The bag filter arrangement should be used in future PTC installations. Proper maintenance of the system would insure that litter in valve rooms and the compactor room is minimized. The use of PTC systems offers improvements in site aesthetics, noise reduction, and generally excellent sanitation benefits.

SUMMARY FOR FUTURE DEVELOPMENTS

Single-family attached (SFA) and detached (SFD) housing developments appear to be most effectively serviced by curbside, once a week pickup of refuse. Multifamily low-rise (MFLR) buildings can effectively utilize curbside pickup but should probably be serviced with centrally located containers. Household compactors can only be recommended if once a week pickup will be used and residents are taught to use their compactors. Communal compactors are not recommended; but, if used, they should automatically cycle without relying on residents to actuate the units.

Communal compactors must also be carefully designed and installed to preclude entry by children and injury to personnel when handling the compacted package.

Multifamily medium (MFMR) and high-rise (MFHR) buildings should always be candidates for chute-fed compactors. Specific attention should be focused on allowance of space for proper equipment installation. Also, designs should provide easy access for servicing by a packer truck to minimize manual handling of containers.

The special plastic bag study at the King County site showed definite advantages to use of plastic bags in place of containers. A warmer time of day for pickup or a warmer climate might change the results if bags weaken. Only heavy duty bags are recommended if a plastic bag requirement is instituted.

The installation of a pneumatic trash collection system requires careful study of site dwelling unit and resident density and refuse load. The system is high in capital costs and these costs must be projected and compared with other refuse collection methods. Extreme care should be taken in future PTC system installations to insure accomplishment of maintenance and the provision for full-time attention to the system operations. Proper installation is required to prevent problems with water infiltration. If properly installed to match the load, if properly operated, and if properly maintained, the PTC system can have many advantages such as costs comparable to other systems, beneficial environmental effects, few labor requirements, reduced volume of refuse for disposal, and excellent environmental and aesthetic benefits for a site.

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16. ABSTRACT

The Department of Housing and Urban Development Operation Breakthrough programs demonstrate quieter, more sanitary, more convenient, and more economical waste collection systems within buildings, complexes, and municipalities. In the study summarized here, nine Operation Breakthrough sites were analyzed and compared as to economics, effectiveness, environmental factors, efficiency of operation, and acceptance by residents. Eight of the sites used various trash collection methods ranging from conventional curbside pickup to centralized compaction and pickup. The ninth site, Jersey City, New Jersey, used a pneumatic trash collection (PTC) system, the first installation of its kind in a residential complex in the U.S. This report summarizes the evaluation of the refuse management system at Operation Breakthrough sites, particularily the PTC system evaluation and the refuse system user acceptance surveys at eight of the nine sites.

17. KEY WORDS AND DOCUMENT ANALYSIS

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