FEATURES AND OPERATING EXPERIENCES OF HEAT RECOVERY INCINERATORS

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ABSTRACT

The military services are concerned with solid waste disposal problems as acceptable landfill sites become more difficult to find. For this reason, the U.S. Army Construction Engineering Research Laboratory (USA-CERL) has been conducting an evaluation of heat recovery incinerator (HRI) technologies to determine their reliability and performance characteristics.

Part of the evaluation has involved a study of the equipment of approximately 30 manufacturers. This equipment falls into the four categories of Excess Air Grate, Modular Starved Air, Rotary Kiln, and Fluidized Bed Combustion. The data gathered for each type of equipment was summarized and their characteristics compared.

The other part of the evaluation was the study of 52 commercial incineration plants to determine their frequency of operating problems. Methods of avoiding these problems are suggested.

INTRODUCTION

In many parts of the country, existing sites for solid waste disposal are nearing the end of their useful lives. Location of new sites is becoming extremely difficult and very expensive. The Army is facing the same difficulties as the rest of the nation in complying with Federal, State, and local environmental regulations governing new landfill sites. On-site incineration provides a mechanism to increase the expected life of a landfill. Furthermore, coupling the incinerator to a heat recovery boiler will result in the added benefit of energy production. Currently, the Army has constructed five heat recovery incinerator (HRI) plants. A sixth plant is under construction at Fort Dix, and a seventh is in design for Fort Lewis. Several other posts, both inside and outside the continental U.S., also have an imminent need for such a facility. Unfortunately, several of the plants already constructed have failed to perform as well as expected.

The U.S. Army Construction Engineering Research Laboratory has been investigating the incineration of waste since the mid-1970's, and since 1983 this research has been oriented toward standardized approaches to the design and construction of HRI projects. This paper reports on USA-CERL investigations concerning the characteristics of the manufacturer's equipment and the operation of commercial HRI plants. The collection of this information is not considered to be complete and is still being expanded upon as the incineration technologies continue to evolve.

EQUIPMENT CHARACTERISTICS

Information concerning approximately 30 manufacturers of incineration equipment was obtained by careful survey of the technical literature, some direct survey work, and exchange of information with the Naval Civil Engineering Laboratory, the Air Force, and Argonne National Laboratory. The manufacturers and their equipment were then grouped into four categories: Starved Air Modular, Rotary Kiln, Excess Air Grate, and Fluidized Bed Combustion (FBC). The characteristic process for each category was defined. Any especially interesting or unique aspect of each manufacturer was noted. The technical characteristics of each manufacturer's equipment was then compared to the other manufacturers within that category. Finally, the general characteristics of each category of equipment were then compared. It should be noted that most of the technical information is ultimately from the manufacturers themselves, and may not always accurately represent field experience.

Table 1 illustrates the comparison of the various technologies. All technologies report that most of their units have been sold for industrial use. This is probably due to the ease of burning well defined and homogeneous waste streams and the problems associated with landfilling many industrial wastes. Starved Air and Rotary Kiln seem to be the technologies with the largest number of units being sold each year. Starved Air appears to have the shortest life expectancy (10 to 15 years). All technologies were reported as being available in very small units; less than 10 TPD (9.07 tpd).

There does not seem to be a good consensus between the technologies as to the recommended waste loading system. Smaller plants will usually use a front-end loader and the larger ones will be able to justify a pit-and-clamshell crane. The size at which one method is preferred over the other is not clearly defined. Ram feeders seem to be the most common charging system, but other types are also used. Within the Starved Air category, the need for supplemental fuel is highly variable, with some designs needing virtually none. The other technologies generally do not need any supplemental fuel once the waste is ignited. Rotary Kiln systems indicated a need for some supplemental fuel when burning an extremely difficult waste (high moisture or low volatility). Each technology uses a different method to agitate the waste in order to promote complete combustion. There is considerable variability in the primary combustion zone temperatures with the Starved Air and FBC units having the lowest values. This minimizes NO_x production. Refractories show some variation, but castable and brick seem to be the most widely used.

Except for Excess Air Grate units, both water-tube and fire-tube boilers are used, and soot blowers are available for both types of boilers. Steam pressures can be developed up to 900 psig (6204 kPa) and temperatures are generally less than 750°F (339°C), although FBC can go as high as 950°F (510°C). Based upon information from the manufacturers, the ratio of bottom ash to fly ash has not been well defined for any of the technologies. This can be important for proper sizing of the ash and particulate control systems. Automatic controls are generally available, and temperature is used by all technologies to control the firing rate. Only Starved Air units below 50 TPD (45 tpd) do not usually need air pollution control equipment at this time, but limits on HCl emissions are being considered by several states. Typical NO_x and HCl emissions are not well defined.

INCINERATOR PLANT CHARACTERISTICS

Figures 1, 2, and 3 illustrate the range of characteristics found in the 52 commercial plants that were studied by USA-CERL for operational problems. The plants were selected from a list published twice each year by the U.S. Conference of Mayors in their newsletter "City Currents". The study was oriented toward smaller plants that would be typical of the size that the Army might build, and they ranged from 5 to 200 TPD (4.5–181 tpd) with most of them below 50 TPD (45 tpd). A majority (62%) of these plants have only one incineration unit, and 58% of them operate 16–24 hr/day, with an average of five personnel. The most typical waste burned in these facilities can be classified as IIA (Incinerator Institute of America) Type 2, although Type 1 and Type 0 waste streams are also commonly reported. Most of the plants in this study have fire-tube heat recovery boilers. Most of the plants produce less than 20,000 lb/hr (9072 kg/h) of steam with the average being 10,000 lb/hr (4536 kg/h). These plants were also found to be fairly new, with 75% of them in operation for less than 4 years. Most were also built for less than $3,000,000 and few of them know what their operating costs are.

Since the original study of 52 commercial installations, USA-CERL has begun to develop a computer data base of all HRI plants that we can identify in the continental U.S. In addition to searching the literature, we have also obtained listings from other data bases. At present, we have at least "some indication" of 178 installations. We have been able to identify 100 of these installations as Starved Air, and only 44 of them as Excess Air. However, the Starved Air units account

TABLE 1 TECHNOLOGY COMPARISON

I GENERAL CHARACTERISTICS				
1. Type of units.	Starved	Rotary	Grate	FBC
2. Number of units sold each year.	5-15	3-10	8	3
3. Percent industrial versus municipal.	94	100	85	97
4. Company contracts to operate units?	Yes	Yes	Yes	Yes
5. Number of units currently in service.	1-2000	1-20	18-1455	34
6. Expected life of unit (years).	10-15	10-30	20-40	20
7. Average equipment availability (%).	90	88	90-95	90
8. Size range of units (TPD).	2-100	2-320	1-1250	10-400
9. Steam generation range (lb/hr).	1K-50K	720-72K	6K-250K	3K-250K
10. Expected thermal efficiency (%).	40-70	50-75	30-70	60-85
11. Fans routinely provided?	Yes	Yes	Yes	Yes
12. Pre-heating combustion air?	Avail.	Yes	Yes	Avail.
13. Type of waste fuel (MSW, Indust.).	MSW & I	MSW & I	MSW & I	I & RDF
II FEED SYSTEMS				
14. Recommended waste retrieval.	F. Load	Varies	Varies	F. Load
15. Types of pre-processing req.	Bulky	None	Varies	Shred
16. Type of feeding (batch or cont.).	Both	Cont.	Cont.	Cont.
17. Type of feed system.	Ram	Varies	Ram	Varies
18. Expected feed system outage (%).	1-5	**	1-5	2-5
19. Maximum allowable moisture (%).	25-70	50	30-60	30-60
20. Maximum allowable ash (%).	15	No Lim.	25-40	10-50
21. Maximum allowable glass (%).	10	No Lim.	15-30	2-20
22. Maximum allowable metal (%).	?	No Lim.	8-30	5-10
23. System special maintenance.	Lub.	None	None	None
24. Amount of supplemental fuel.	Varies	Varies	Start-up	None
III COMBUSTION ZONE AND BOILER				
25. Type of grate.	Ram	Rotary	Grate	F.B.
26. Introduction of under-fire air.	Ports	None	Grate	Nozzles
27. Grate heat release rate (BTU/hr-ft²)	**	**	Varies	Varies
28. Carbon burn-up (%).	95	93-98	95-98	98
29. Primary comb. zone temp. (°F).	1000-2000	1400-2900	1600-2200	1200-1800
30. Method of maintaining temp.	Air/Feed	Air/Feed	Air	Air/Feed
31. Secondary comb. zone temp. (°F).	1500-2200	1600-2800	1700-2000	1400-2000
32. Expected comb. system outage (%).	1-5	0-5	None	1-5
33. Type of refractory.	Cast,Brk	Varies	Varies	Cast,Brk
34. Expected life of refractory.	5-15	1-5	10-20	5-30
35. Type of boiler (fire- or water-tube)	Both	Both	**	Both
36. Heat transfer rate (BTU/hr-ft²).	**	**	**	**
37. Soot cleaning method.	Man/Blow	Blowers	**	Blowers
38. Steam temp. range (°F).	Sat.-600	Sat.-750	**	400-950
39. Steam pressure range (PSIG).	11-600	0-800	**	5-900
40. Feedwater consumed (gal/ton).	**	**	**	**
41. Type and freq. of blowdown.	Either	**	**	**
42. Expected boiler outage (%).	1-2	0-5	**	1-5

** - no information provided

TABLE 1 (Cont'd) TECHNOLOGY COMPARISON

	Starved	Rotary	Grate	FBC
IV ASH SYSTEM				
43. Ratio of bottom ash to fly ash.	**	**	**	1:3
44. Type of bottom ash removal.	Ram & Cnv	**	Varies	Varies
45. Method of sealing ash hopper.	Varies	Varies	Varies	Mech.
46. Expected ash system outage (%).	1-5	1-5	**	1-5
47. Type of bottom ash cooling.	Q or S	Q or S	Q or S	Dry
48. Ash water produced (gal/ton).	0	Varies	**	0
V CONTROLS				
49. Control system (auto., semi-, man.)	Auto.	Auto.	Au/Semi-	Auto.
50. Response to steam demand (yes/no).	Yes	No	Yes	Yes
51. Method of controlling steam output.	By-pass	Varies	Varies	Feed
52. Origin of control signal.	Temp.	Temp.	Temp.	Temp.& O_2
53. Type and location of gas monitors.	None	None	Varies	Varies
54. Method of controlling fans.	Damper	Damper	Damper	Damper
55. Turn-down ratio of units.	2-10:1	2-4:1	3.5:1	2-3:1
56. Number of operators required.	1-2	1-2	1	1
57. Expected control system outage (%).	1	0-2	<5	1-5
VI ENVIRONMENTAL				
58. Pollution control devices supplied.	None	Baghouse ESP & Scrubber	Baghouse ESP & Scrubber	Baghouse Multiclone
59. Expected uncontrolled emissions.				
a. Particulate (gr/dscf).	0.13-0.08	0.5-0.03	1.1-0.41	1-3
b. Nitrogen Oxides (PPM).	**	**	<35	100-130
c. Other measured pollutants (Cl)	**	**	Varies	?
d. Opacity (%).	**	**	20	10-20
60. Expected controlled emissions.				
a. Particulate (gr/dscf).	0.13-0.08	.03-.005	0.05-0.01	0.03
b. Nitrogen Oxides (PPM).	**	**	<35	100-130
c. Other measured pollutants (Cl).	**	**	Varies	**
d. Opacity (%).	**	**	0-3	10
61. Ash water solids content.	**	**	<50%	**
62. Other pollutants in the ash water.	0	**	**	0
63. Add'l pollution control devices.	Scrubber	Varies	Scrubber	None
VII OPERATION				
64. Number of personnel required per shift.				
a. Operators	1-2	1-2	1	1
b. Mechanics	0-1	1	1	0
c. Laborers	0-2	1	0	1
65. Designed operating schedule (s/d/w).	3/6-7	3/7	3/7	3/7

** - no information provided

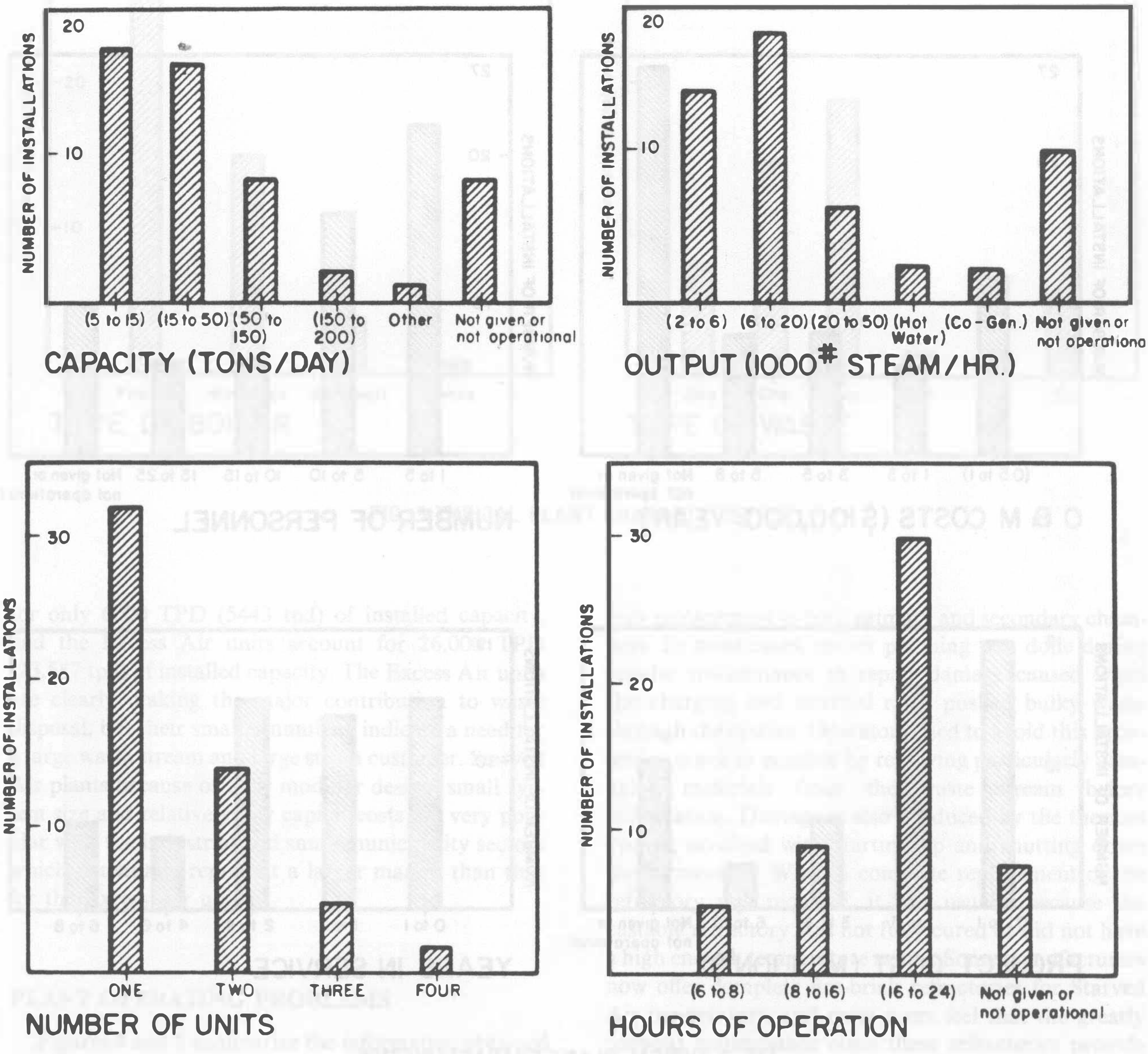


FIG. 1 TYPICAL PLANT CHARACTERISTICS

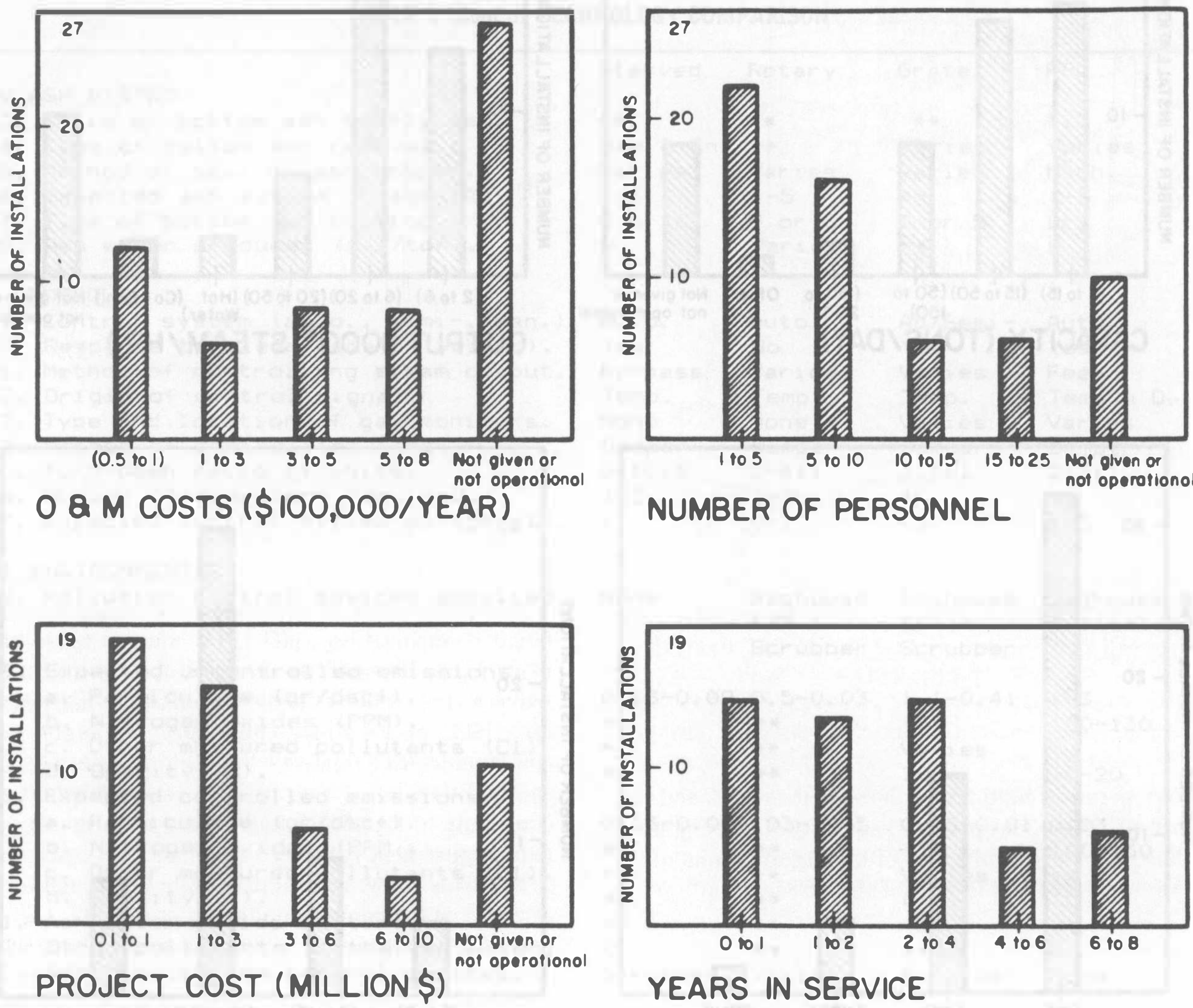
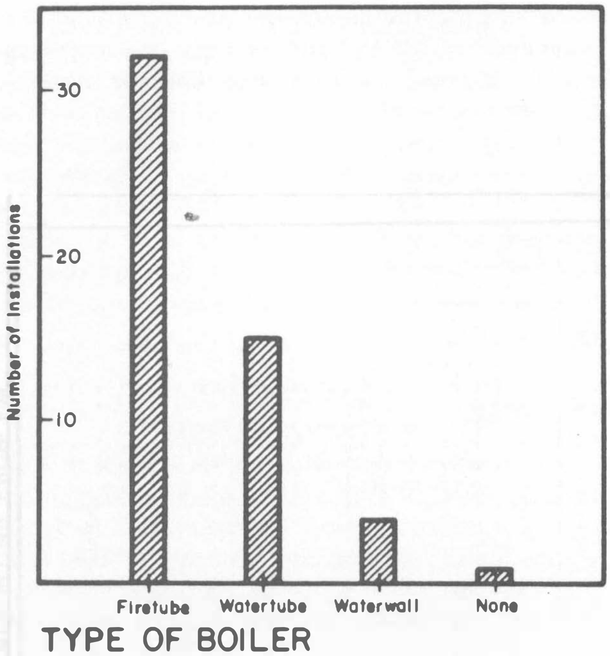


FIG. 2 TYPICAL PLANT CHARACTERISTICS



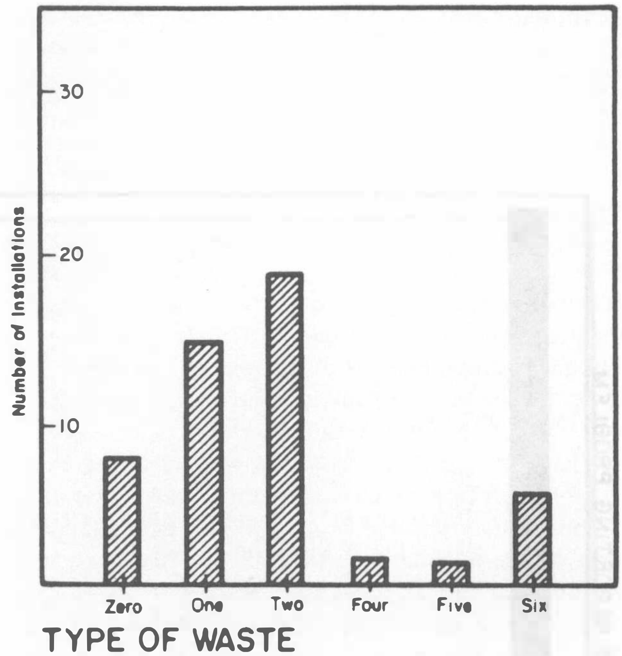


FIG. 3 TYPICAL PLANT CHARACTERISTICS

for only 6000 TPD (5443 tpd) of installed capacity, and the Excess Air units account for 26,000 TPD (23,587 tpd) of installed capacity. The Excess Air units are clearly making the major contribution to waste disposal, but their smaller numbers indicate a need for a large waste stream and large steam customer. Starved Air plants because of their modular design, small system size and relatively low capital costs are very popular with the industrial and small municipality sectors which potentially represent a larger market than that for the Excess Air units.

PLANT OPERATING PROBLEMS

Figures 4 and 5 summarize the information obtained from the 52 commercial installations on equipment performance. The 20 most common problem areas are itemized on the horizontal axis, and the percentage (frequency) of installations reporting each problem is represented by the height of the bar on the vertical axis. The percentages are based upon the total number of plants contacted. The following describes the most frequently reported problems.

Refractory (71%) was by far the most frequently reported problem. The severity of the problem ranged from the need for minor patching to complete refractory replacement in both primary and secondary chambers. In most cases, minor patching was done during regular maintenance to repair damage caused when the charging and internal rams pushed bulky waste through the system. Operators tried to avoid this problem as much as possible by removing particularly damaging materials from the waste stream before incineration. Damage is also produced by the thermal cycling involved with starting up and shutting down the incinerator. When a complete replacement of the refractory was required, it was usually because the castable refractory was not fully cured or did not have a high enough temperature rating. Some manufacturers now offer complete fire-brick refractories for Starved Air incinerators, and most users feel that the greatly reduced maintenance costs these refractories provide justify the higher initial investment.

Under-fire air ports (35%) plug easily and require frequent cleaning. To solve this problem, operators have tried enlarging the orifices and periodically purging them with steam. This problem was usually treated through regular maintenance and cleaning of the ports.

The universal complaint about tipping floors (29%) is that the storage area was too small. Operations with a 24 hr/day schedule were particularly affected because waste was delivered during an 8–12 hr period and the tipping floor had to be sized to store this waste for

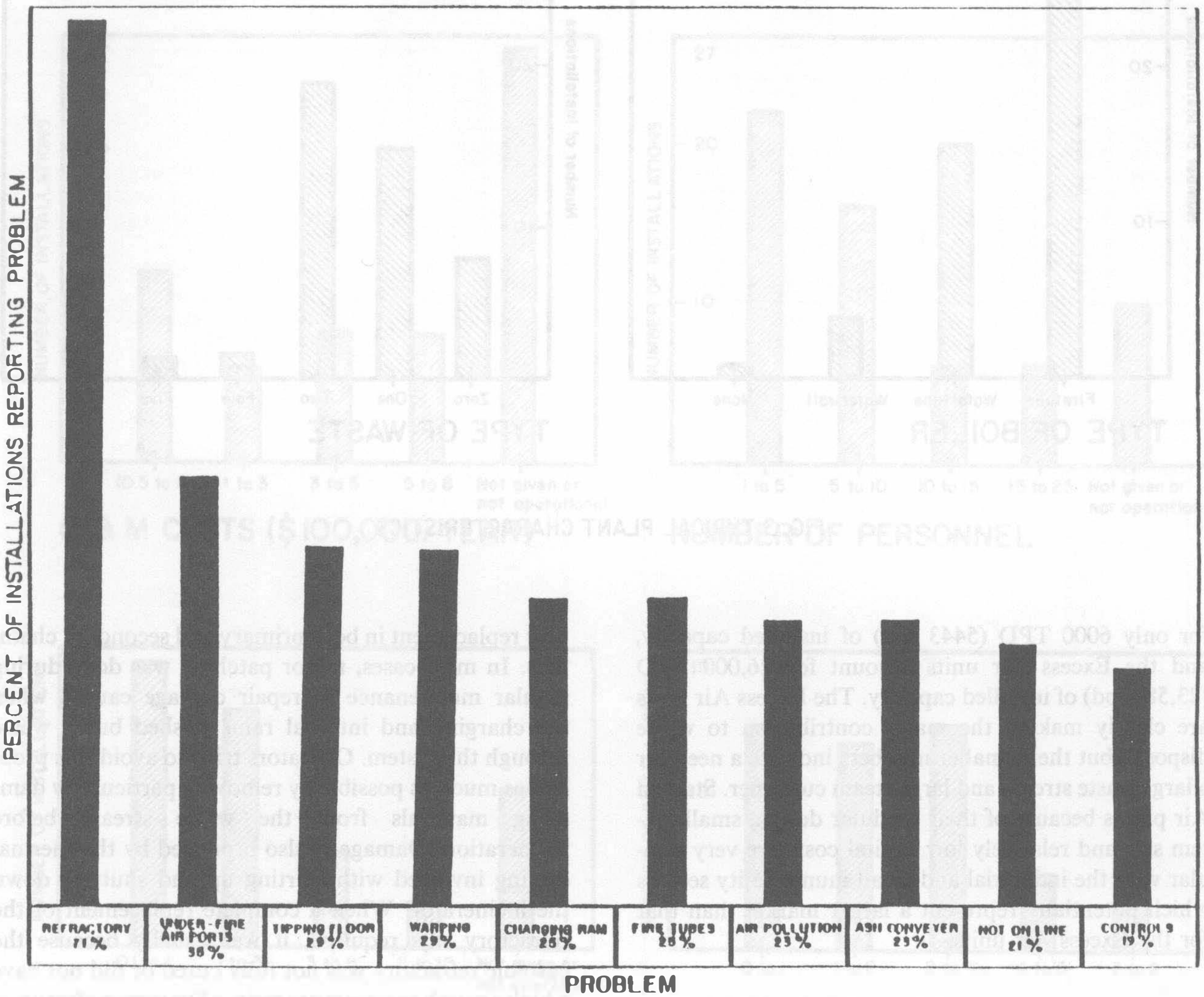


FIG. 4 PROBLEM AREAS

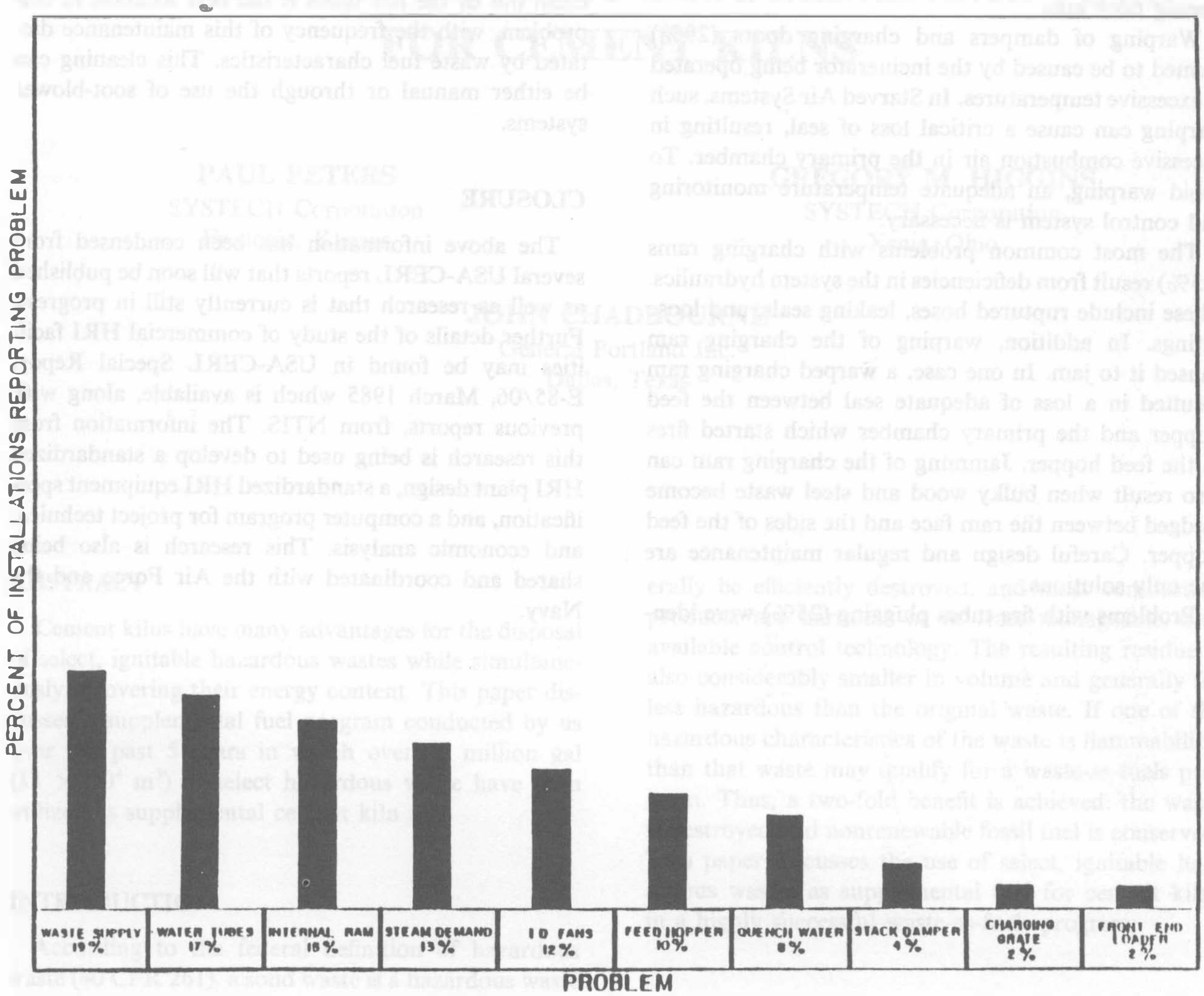


FIG. 5 PROBLEM AREAS

nondelivery periods. In most cases, the preferred size is 125–150 sq ft/TPD (12.8–15.4 m^2/tpd) of capacity. However, some plants were identified that had more area than this and still did not consider it enough. This problem indicates a need to consider traffic patterns of both delivery and charging vehicles when evaluating tipping floor area.

Warping of dampers and charging doors (29%) seemed to be caused by the incinerator being operated at excessive temperatures. In Starved Air Systems, such warping can cause a critical loss of seal, resulting in excessive combustion air in the primary chamber. To avoid warping, an adequate temperature monitoring and control system is necessary.

The most common problems with charging rams (25%) result from deficiencies in the system hydraulics. These include ruptured hoses, leaking seals, and loose fittings. In addition, warping of the charging ram caused it to jam. In one case, a warped charging ram resulted in a loss of adequate seal between the feed hopper and the primary chamber which started fires in the feed hopper. Jamming of the charging ram can also result when bulky wood and steel waste become wedged between the ram face and the sides of the feed hopper. Careful design and regular maintenance are the only solutions.

Problems with fire tubes plugging (25%) were identified as a significant problem overall, but the true magnitude of the problem becomes more apparent when it is noted that only about half the sites used fire-tube boilers. Plugging is caused by poor combustion of high moisture content waste or poor operation and maintenance procedures. Regularly scheduled clean out of the fire tubes is the best solution to this problem, with the frequency of this maintenance dictated by waste fuel characteristics. This cleaning can be either manual or through the use of soot-blower systems.

CLOSURE

The above information has been condensed from several USA-CERL reports that will soon be published as well as research that is currently still in progress. Further details of the study of commercial HRI facilities may be found in USA-CERL Special Report E-85/06, March 1985 which is available, along with previous reports, from NTIS. The information from this research is being used to develop a standardized HRI plant design, a standardized HRI equipment specification, and a computer program for project technical and economic analysis. This research is also being shared and coordinated with the Air Force and the Navy.