Pollution Prevention Frontiers (PPF) and Other Approaches to Pollution Prevention Assessment

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POLLUTION PREVENTION FRONTIERS (PPF) AND OTHER APPROACHES TO POLLUTION PREVENTION ASSESSMENT

COMPARISON BASED ON NEW JERSEY MATERIALS ACCOUNTING DATA

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1.0 INTRODUCTION

This report documents the results of Phase 2 of the Pollution Prevention Frontiers (PPF) project. The results of Phase 1 are reported in a prior report titled, "Pollution Prevention Frontiers: An Approach to Measuring Pollution Progress."[1] The conceptual framework for PPF analysis is presented in that report, and discussed in the present report only to the extent necessary to clarify the nature of the application being studied. Interested readers are encouraged to access the prior report for more detailed information.

1.1 Objectives

The four objectives of Phase 2 of the PPF project were:

- To assess the nature and quality of materials accounting data collected in New Jersey for the years 1989 through 1991, and identify any potential benefits that might be gained by extending the Toxics Release Inventory (TRI) survey to include additional data elements contained in the New Jersey data.

- To compare the results obtained via PPF analysis of pollution prevention performance at New Jersey chemical firms over the 1989 through 1991 period vis-a-vis results obtained by alternative measurement approaches.

[1]"Pollution Prevention Frontiers (PPF): An Approach to Measuring Pollution Prevention Progress," Cummings-Saxton, J., S. J. Ratick, and A. Desai, prepared for the EPA Office of Policy Analysis, October 1993.

- To compare the facility performance ratings obtained via PPF analysis with ratings suggested by other types of data that offer insights into environmental performance at the New Jersey facilities.

- To identify potential policy applications of PPF analysis in the public and private sectors.

1.2 Approach

An important aspect of the PPF analysis and alternative methodologies considered in this study is that they use **publicly available data**, such as that provided by New Jersey materials accounting data or TRI survey data. Limiting data inputs to publicly available data restricts the level of analysis that can be conducted, since to fully understand the nature of pollution prevention efforts at each facility it is necessary to examine in detail the nature of the technology employed, and the market being served in terms of desired operating and product characteristics. Thus, analyses of the type discussed here are intended as initial **screening analyses** to provide a basis for priority setting and for dialogue with, and additional data collection regarding, pollution prevention activities at the facilities of interest.

In addition to PPF, a number of other analytic approaches have been proposed for this type of application. Three of these are: (1) waste-to-throughput ratios, as suggested by the Natural Resources Defense Council (NRDC);[2] (2) total TRI releases or waste generation; and (3) percent reduction in TRI releases or waste generation relative to a base year.[3] The latter two approaches are variations on the use of TRI data, while the waste-to-throughput ratio uses the same primary variable as the PPF analysis. The advantages and disadvantages of each approach are examined in terms of the perspective they provide regarding pollution prevention performance at eighty-one New Jersey chemical firms that submitted materials accounting data for each of the three years 1989, 1990, and 1991.

In order to provide perspective on the results obtained using the four analytic approaches, a variety of sources were reviewed to assemble data independently characterizing environmental performance at the eighty-one chemical facilities of interest. The apparent quality of the data submitted by each firm is considered to be one indication the reliability of performance rankings based on that data. Supplemental data sources accessed included: (1) EPA's Facility Index System (FINDS) data to determine facility Dun and Bradstreet numbers, total number of employees, and total sales; (2) RTK NET to obtain docket information and 1991 TRI data; CEP

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[2] "The Use of Mass Balance Data in the Natural Resources Defense Council's Proposed Model Waste Reduction Program," Ned C. Smith, March 1988.

[3] The Research Triangle Institute (RTI) appraised alternative pollution prevention measurement approaches in an April 1990 report for the EPA Pollution Prevention Office titled, "Evaluation of Measures Used to Assess Progress in Pollution Prevention."

1991 to obtain firm ratings regarding environmental performance;[4] and Fortune magazine identification of top performers, laggers, and improving firms in environmental performance.[5] The perspective on each firm provided by these supplemental data sources are compared with the ratings generated by each of the three measurement approaches -- PPF, waste-to-throughput ratios, and total TRI releases or TRI ratios.

1.3 PPF Methodology

As mentioned above, a full discussion of the PPF methodology is provided in the Phase 1 report. The following paragraphs provide a synoptic review of the PPF methodology. Additional background on PPF and other approaches to measuring pollution prevention efficiency is presented in Appendices A and B. The interested reader is referred to the prior report for a more detailed discussion of the PPF methodology.

The computational basis for constructing pollution prevention frontiers is Data Envelopment Analysis (DEA), in the form framed by Charnes, Cooper, and Rhodes.[6] Given data on a number of plants or facilities that share a common technology and produce a common set of outputs from a common set of inputs, DEA can be used to: (1) identify the best observed practice, i.e., designate those plants that are most "efficient" in converting inputs into outputs;[7] (2) construct a frontier defined by these efficient plants, i.e., a performance frontier beyond which none of the plants in the data set have been observed to perform; and (3) provide a measure, based on distance from this frontier, that indicates the level of performance of non-frontier plants relative to the efficient plants. The PPF score of each plant, found using the DEA computational method, is determined relative to the pollution prevention achievements of other competing plants. The relative performance of each plant is expressed in terms of an "index of pollution performance effectiveness."

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[4] CEP 1991, Shopping for a Better World, Alice Tepper Marlin, Jonathan Schorsch, Emily Swaab, and Rosalyn Will, the Council on Economic Priorities, Ballantine Books, USA, 1991.

[5] "Who Scores Best on the Environment," Fortune Magazine, pp. 114-122, July 26, 1993.

[6] "Measuring the Efficiency of Decision Making Units," Charnes, A., W.W. Cooper, and E. Rhodes, European Journal of Operational Research, Vol. 2, No. 4, 1979. For a brief technical overview, see Appendices A and B.

[7] In the PPF formulation, "efficiency" of pollution prevention performance is defined on the basis of generating least quantities of chemical waste per unit product output. The waste-to-throughput ratio provides only an indication of pollution prevention "efficiency" in terms of avoiding waste generation, i.e., the goal of pollution prevention, but not of overall efficiency in plant operation. To determine the latter requires a great deal of information regarding the plant's financial expenditures and full slate of inputs and outputs. This type of data is seldom publicly available, and it cannot be approximated using monetary data alone. The products produced and raw materials employed need to be identified in physical terms in order for detailed comparisons to be made between plants producing different slates of products that potentially embody different performance characteristics.

The PPF index of pollution prevention effectiveness represents a multi-dimensional extension of the waste-to-throughput ratio proposed by NRDC. The PPF formulation enables different characteristics of chemicals to be taken into account when assessing the risks inherent in generation of these chemical wastes. For example, chemical risks that might be relevant in a given evaluation include: carcinogenicity, mutagenicity, toxicity, urban ozone formation, stratospheric ozone depletion, global warming, environmental persistence, and others. The PPF approach enables these risks to be taken into account without reducing them to a common metric on the basis of arbitrary decision factors. Also, the implications of relative weights placed on the risks of concern can be easily evaluated. Since the PPF formulation is based on waste-to-throughput values for each chemical or risk, the results are not base-year dependent, i.e., chemical producers or users are not penalized by ignoring efforts undertaken prior to an arbitrarily designated base year.

1.4 Report Organization

The remainder of the report is organized into five chapters. Chapter 2 discusses the nature of materials accounting data collected by the state of New Jersey. These data, which are collected in conjunction with annual Toxic Release Inventory (TRI) surveys, provide the basic inputs used in PPF analysis of pollution prevention efforts at New Jersey chemical firms. The results of data quality analysis of the New Jersey data for the years 1989 through 1991 are presented. The manner in which records and facilities were screened for inclusion in the analysis of alternative measurement approaches is discussed.

Chapter 3 presents a comparison of the results achieved by PPF analysis of pollution prevention performance at New Jersey chemical companies over the 1989 to 1991 period vis-vis the results achieved by throughput ratio analysis and by TRI ratio analysis. The advantages and disadvantages of each approach are discussed. Chapter 4 compares the rankings of chemical facilities obtained through the analyses in Chapter 3 against other data assembled to characterize environmental management performance at these facilities.

Chapter 5 discusses potential applications of the PPF approach to policy applications in the public and private sectors. Chapter 6 concludes the report by: (1) presenting the principal findings of the analysis with regard to the materials accounting data, PPF vis-a-vis TRI ratio and throughput ratio analysis, and the comparison with other facility performance data; and (2) stating the conclusions and recommendations framed on the basis of these findings.

2.0 NEW JERSEY MATERIALS ACCOUNTING DATA

2.1 Nature of Data

The project utilized two principal sources of data: (1) Toxic Release Inventory (TRI) survey data, and (2) New Jersey Worker and Community Right-to-Know (CRTK) data. The TRI survey is a nationwide survey administered by the US EPA. In the TRI survey, for each listed chemical employed above threshold quantities, reporting facilities must provide the following release quantities:

(a) fugitive air emissions
(b) point source air emissions
(c) water borne discharges to surface water
(d) water borne discharges to POTWs
(e) on-site land disposal
(f) underground injection
(g) off-site transfers of solid waste

In addition, the TRI survey requests, on an optional basis, information on the method and effectiveness of waste minimization efforts. In accord with the Pollution Prevention Act of 1990, the TRI survey has been extended to add pollution prevention oriented data, effective for the year 1991 submissions. The new data include quantities of chemicals recycled and chemical byproducts generated. The extended TRI data do not include, however, a number of significant data elements for each chemical, such as annual change in inventory, quantities brought-on-site, quantities produced, quantities consumed, and quantities shipped off-site. These missing data are needed if a chemical-specific materials accounting framework is to be established.

The New Jersey state survey supplements the TRI data by collecting the following data for 161 environmental hazardous substances:

(a) quantity of each chemical brought on site
(b) start and end of year inventories of each chemical
(c) quantity of the chemical produced at the facility
(d) quantity recycled
(e) quantity shipped off-site as or in product

Starting in 1990, the New Jersey CRTK survey also collected the following release quantity data in partial duplication of the information collected in the TRI survey:

(a) fugitive air emissions
(b) stack air emissions
(c) surface water releases
(d) releases to POTWs
(e) ground water releases
(f) on-site releases

In 1991, the number of chemicals for which CRTK data are collected was expanded to the full set of TRI chemicals. Combined TRI and CRTK data are equivalent to information the National Academy of Sciences refers to as **materials accounting data**[1], i.e., the information is sufficient to identify where the chemical comes from and where it goes.

The present study uses TRI and CRTK data as the basis for comparatively assessing pollution prevention performance at Chemical and Allied Products (SIC 28) firms in New Jersey. One objective of this study was to assess progress in pollution prevention over time. Due to concern for data quality and temporal consistency as explained below, not all of the available records were utilized for this study. Table 2.1 presents the summary statistics for the complete set of data as collected by the CRTK survey for a four year span, 1988-1991.

The information on chemical releases was not collected via the CRTK survey prior to 1990. For that reason, in 1988 and 1989 the CRTK records had to be matched with the TRI survey records in order to establish the materials accounting data for those years. Inconsistencies and irregularities in the data made matching the two databases an arduous task. As a result, both 1988 and 1989, some portion of the total records could not be incorporated into this study.

Table 2.1
Summary Statistics for 1988-1991 CRTK/TRI Data

	1988	1988/TRI	1989	1989/TRI	1990	1991
# of Facilities	233	152	254	225	260	289
# of Reports	746	424	780	661	873	1518
# of Chemicals	127	95	114	105	136	176

[1] "Tracking Toxic Substances at Industrial Facilities: Engineering Mass Balance Versus Materials Accounting," Commission to Evaluate Mass Balance Information for Facilities Handling Toxic Substances, Board on Environmental Studies and Toxicology, Commission on Geosciences, Environment, and Resources, National Academy Press, Washington, DC (1990) p. 5.

2.2 Assessment of Data Quality

Materials Balance Analysis

Conservation of mass requires that the quantity of a chemical made available for use in a given year equals the quantity of the chemical that is utilized at the facility. The **material (or mass) balance** requirement can be expressed in the form inputs minus outputs equals zero, as follows:

$$(Q_{bos} + Q_{prd} + \Delta I) - (Q_{cns} + Q_{shp} + Q_{wst}) = 0 \qquad (2.1)$$

where

$$Q_{wst} = Q_{dst} + Q_{rel} + Q_{tr} \qquad (2.1a)$$

or

$$Q_{wst} = Q_{dst} + Q_{rtr} \qquad (2.1b)$$

Inputs include the quantity of chemical brought on-site (Q_{bos}) plus the quantity produced on-site (Q_{prd}) plus the net discharge of that chemical form inventory over the course of the year (ΔI); and outputs equal quantity of the chemical consumed during the year (Q_{cns}) plus quantity shipped off-site as or in product (Q_{shp}) plus quantity destroyed during the year (Q_{dst}) plus quantity releases to the environment (Q_{rel}) or transferred off-site for recycling, treatment, or disposal (Q_{tr}).

Instructions provided with the New Jersey CRTK data collection package characterize each of the variables and show how to check on data consistency by establishing the balance shown in Equations (2.1) and (2.1a and 2.1b). For example,Q_{bos} includes all quantities of the chemical brought on-site as raw materials, chemical processing aids, manufacturing aids, ancillary materials, acquired as or in a waste, or materials repackaged for shipment. Q_{prd} includes all quantities of the chemical produced through intentional or unintentional syntheses, isolated as an intermediate, or generated as a waste, byproduct, or impurity. Q_{cns} includes all quantities of the chemical whose molecular structure is altered during use at the site, e.g., raw material is consumed but contaminated solvent is not. Q_{shp} includes all quantities of the chemical that are shipped off-site as or in a final product, or in a form suitable for further processing to produce a final product. Q_{dst} includes quantities destroyed through treatment on-site that changes the physical, chemical, or biological character or composition of the waste, e.g., incineration or anaerobic digestion. Shipments from or to other facilities or divisions of the same company are categorized as off-site shipments. When the chemical is contained within a mixture, only the weight of the chemical itself should be recorded, not the contribution of other constituents.

Table 2.2 characterizes the percent of the original data collected from 1988 to 1991, by the CRTK survey that satisfy the materials balance requirement. The extent by which the chemical records at a facility employing N reported chemicals diverge from materials balancing is reflected in its materials balance error percent (MBE%), defined as:

$$MBE\% = \sum_{1}^{N} \frac{100\ |MBE(i)|}{Q_{bus}(i) + Q_{prd}(i) + \Delta I(i)} \tag{2.2}$$

where

$$MBE(i) = (Q_{bus} + Q_{prd} + \Delta I) - (Q_{cns} + Q_{dsp} + Q_{dis} + Q_{rcy}) \tag{2.3}$$

For the purpose of this study a cut-off point for the MBE% of 2% was used as a screening device on data quality. However, if a record do not meet the mass balance requirement then there is sufficient reason to suspect that the record may contain errors. Table 2.2 shows the number and percent of the records which passed the 2% mass balance error screening.

Table 2.2
Summary Statistics for 1988-1991
CRTK/TRI Data Meeting the <=2% MBE Requirement

	1988/TRI	1989/TRI	1990	1991
# of Facilities	108 (71%)	125 (56%)	134 (52%)	230 (80%)
# of Reports	240 (57%)	243 (37%)	271 (31%)	814 (54%)
# of Chemicals	72 (45%)	67 (42%)	84 (52%)	134 (41%)

It is notable that the data deficiencies occur not only for small firms with limited technical resources, but also for larger firms renowned for their technical expertise. These results seem to indicate that insufficient attention is paid to ensuring that the submitted data are of high quality. Since the TRI data are among the most difficult to estimate of the elements of the CRTK/TRI data set, deficiencies in the CRTK/TRI data call into question the accuracy of the TRI data currently being used to characterize industry behavior.

Types of Reporting Errors

Examination of the CRTK data revealed a number of records in which double counting seemed to be a large part of the materials balance error. For example, in a number of cases in which an acid had been neutralized, the materials balance error was identical to the quantity of acid destroyed (neutralized) and an identical amount was specified as released. In this case, the correct response would appear to be to report the quantity of acid neutralized as destroyed and to report any residual acid as released. Making this adjustment would eliminate the materials balance error for that record.

The data review suggested that the following are the most frequently occurring errors:

- Environmental releases or off-site transfers of waste were also reported as consumption
- Environmental releases or off-site transfers of waste were also reported as off-site shipments of product
- Chemicals destroyed through on-site treatment were also reported as released to the environment or transferred off-site
- Estimated consumption was set equal to all inputs, even when some material was shipped off-site or released to the environment
- When matching CRTK records with TRI records for years prior to 1990, the quantity reported as consumed in the CRTK survey was equal to the quantity reported as total releases in the TRI survey

In addition to the errors observed in the 1990 and 1991 data, a number of other frequent errors had been identified by the New Jersey Department of Environmental Protection and Energy (DEPE) through examination of the CRTK submissions for previous years, in particular 1987. New Jersey DEPE identified potential errors by examining the 1987 data, and confirmed the nature of these errors through telephone queries and selected site visits. A similar procedure is currently being undertaken involving the 1990 data. Many of these errors may appear to be present in a data record but without direct contact and follow-up with the particular firm and in some cases with the individual who was responsible for completing the survey, corrections cannot be made to the data. The most frequently occurring errors identified in the DEPE analysis, in addition to those identified above, were:

- Contaminated material shipped off-site for recovery and recycle was not reported as an off-site transfer of waste
- Total quantity of a mixture was reported rather than the quantity of the chemical constituent of interest
- In the case of metals, the weight associated with the entire molecule was reported rather than just the metal content

2.3 Data Used for Analysis

One objective of the present study was to investigate progress in pollution prevention over time. It was necessary to identify a subset of the CRTK/TRI data in which the same facilities reporting on the same chemicals over the selected time period could be tracked. Table 2.3 gives the summary statistics for the time sequence data populations over the 1988 to 1991 time period. Only those records that were matched with or contained the TRI releases information and that balanced within the 2% MBE criteria were used in the analysis (see Table 2.4).

Table 2.3
Summary Statistics for Time Sequence Analysis

	1988-91	1988-90	1988-89	1989-91	1989-90	1990-91
# of Facilities	93	115	149	139	175	210
# of Reports	206	264	375	379	470	649
# of Chemicals	49	63	77	80	83	115

Table 2.4
Summary Statistics for Time Series Analysis
Data Including TRI Release Information and Meeting 2% MBE Criteria

	1988-91	1989-91	1990-91
# of Facilities	25	89	136
# of Reports	45	170	302
# of Chemicals	22	61	84

Pollution prevention can be measured in a number of different ways. A major goal of pollution prevention activities is to prevent the hazardous elements from ever being produced or used either through chemical-use efficiency measures or through waste reduction measures. In the Pollution Prevention Frontier analysis, the focus is on the quantity of the chemical waste generated per unit chemical activity (refer to the previous report for further discussion). The

TRI survey prior to 1991 has focused on releases, which reflect pollution control, as opposed to pollution prevention, which focuses on waste generation. In order to be able to compare the different methodologies, for some segments of the analysis PPF has been applied both to the quantities of waste generated and to the quantities released.

Chemical throughput (Q_t) was used in the PPF analysis as the measure of chemical activity at a facility. The metric used for waste intensity was Q_{wst}/Q_t. Chemical throughput (Qt) can be thought of either as the quantity of a chemical made available for use at the facility over the course of a year (identifying where it comes from) or the quantity of a chemical disposed of at the facility during the year (identifying where it goes). In this study we define Q_t to be the former:

$$Q_t = Q_{base} + Q_{prd} + \Delta I \tag{2.5}$$

As mentioned previously, the PPF index represents a multidimensional extension of a ratio approach proposed by the Natural Resources Defense Council (NRDC) The NRDC formulation was proposed as a basis for developing a performance standard for pollution control, i.e., performance is assessed on the basis of pollutant releases. By considering the quantity of waste generated as opposed to the quantity released, the ratio can be used to focus on pollution prevention instead of pollution control.

The TRI or TRI ratio and waste-to-throughput ratio methods, as defined in the next chapter, will be employed in this study as a basis of comparison for the PPF analysis. It is important to note that pollution prevention is a complex concept and no one measure can encompass all relevant aspects within a single variable. This report discusses the strengths and limitations of each approach in the belief that ultimately they can be used to augment and complement each other.

Because the four year span from 1988 to 1991 only included twenty-five individual facilities, the three year span from 1989 to 1991 was selected as the focus for this study. Of the 89 facilities (see Table 2.4), only those that reported waste and/or release quantities greater than zero throughout the three years were used to assess pollution prevention progress. High-ratio chemicals, chemicals used for dispersive applications (e.g., solvents), were omitted from the project data. High ratio chemicals always have a waste-to-throughput ratio of one or very close to one regardless of the progress made in pollution prevention. The final data set used for the analysis was composed of 81 facilities each reporting on the same chemical for the three consecutive years (1989-1991).

3.0 COMPARISON OF COMPUTATIONAL APPROACHES

This chapter illustrates how publicly available data can be used to compare pollution prevention progress among a subset of New Jersey chemical manufacturing facilities. Three approaches are compared: (1) TRI Releases, (2) Release-to-Throughput Ratio, and (3) PPF. It is shown that each approach possesses certain strengths and weaknesses, and that taken together the three perspectives complement and enhance each other.

The following sections present highlights of each approach and compare their performance in analyzing pollution prevention performance at 81 New Jersey chemical plants. The basic aspects of each approach are:

- TRI-based analysis evaluates pollution prevention on the basis of total quantity of chemicals released to the environment.[1] Using this data, plants are ranked with regard to: (a) total releases in a given year; or (b) the ratio of total releases in a given year to total releases in the previous year, or in a prior "base year."

- Release-to-Throughput Ratio adds a second dimension to pollution prevention measurement. The level of chemical usage at each facility is taken into account when assessing the implications of the quantities of waste generated or released.

- PPF analysis expands upon the Release-to-Throughput Ratio approach by enabling the concurrent evaluation of multiple risks in the pollution prevention assessment. PPF ranks plants by comparing their release-(or waste-)to-throughput ratios for multiple risk groups.

Since TRI data have until 1991 provided information only on chemical releases (not on waste generation), the comparison between measurement approaches is made on the basis of release data. As discussed in Chapter 2, reduction in quantity of waste generated is the appropriate metric for pollution prevention, and this measure is employed in parts of the

[1]With the information added to the TRI survey by the Pollution Prevention Act of 1990, TRI analysis for each chemical in 1991 and subsequent years can also determine the total amount of waste generated. In addition, for 1991 and subsequent years, the quantities of wastes generated and released can be adjusted to take into account changes in chemical-related production at each facility from one year to the next.

discussion of PPF results. In Chapter 4, we examine additional sources of information to provide comparative perspective regarding environmental performance at the plants of interest.

Because results of the three approaches are expressed in different units, making direct comparisons difficult, we express the results in terms of **comparative rankings** of the 81 selected plants. In this manner, each approach ranks plants from 1 to 81, with 1 being the best plant under that measure for that year, and 81 being the worst.[2] Plants that tie under a given measure are awarded an identical rank. The resulting ranks provide a relative measure that depends not only on how the plant in question is performing, but also on how the other plants are doing. If a "good" plant maintains its current performance level while other plants improve, the plant may lose its status as "good" because it has not kept up with the other plants.

Complete tabular results for each of the three analytic approaches are presented in Appendix C. To illustrate the nature of these results, we selected a representative ten-plant subset from among the 81 plants. We translated the numerical designations of these ten plants into alphabetic equivalents, ranging from A to J. We discuss these plants in greater depth to illustrate the three measurement approaches and interesting aspects of the results. Data on the releases and chemical throughputs of the ten plants are presented in Table 3.1.

In assembling the data in Appendix C and Table 3.1, TRI chemicals were screened as to their membership in two risk groups: acute toxins and volatile organic compounds (VOC). The process employed for making risk group assignments was described in the PPF phase 1 report, referenced in Chapter 1. For simplicity, only two risk groups were used in the present analysis in order to be able to discuss results within a two-dimensional framework. Chemicals not falling within one or both of the selected risk groups were excluded from the analysis. This simplification affects only one facility in a notable way. All facilities were found to involve either acute toxins alone or both acute toxins and VOC; in no plant were only VOC involved. All three analytic approaches were evaluated using the risk group sorted data, but only PPF takes risk group membership into account.

The alphabetic equivalents of the numerical designations of each of the ten plants are shown in the first two columns of Table 3.1. The quantities of acutely toxic releases and of VOC releases at each facility in 1989 are listed in the third and fourth columns of the table, and the sum of acute and VOC releases are listed in the fifth column. Total throughput in 1989 of chemicals classed as acute toxins and VOC is given for each facility in column six of Table 3.1. The remaining columns of the table present the corresponding data for 1990 and 1991. To illustrate, plant 4 in the Appendix C listing is designated plant C in Table 3.1. Plant C in 1989 released 1,500 total pounds of chemicals. From columns 3 and 4 of Table 3.1, we see that all chemicals released from plant C were acute toxins, but only two-thirds (1,000 pounds) were VOC. This illustrates the fact that the same chemical can both be acutely toxic and be a VOC. The columns for 1990 and 1991 in Table 3.1 indicate that plant C substantially reduces both acutely toxic releases and VOC releases in these two years.

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[2]In each of the three years, data from some plants fail the data acceptability screening tests. Thus, while data from each of the eighty-one plants are included in some portions of the evaluation, the total number of plants evaluated varies between years, as follows: 70 plants in 1989, 64 in 1990, and 65 in 1991.

Table 3.1
Releases and Throughputs at Ten Representative Facilitites
1989-1991

PLANT ID #	ALPHA ID	1989				1990				1991			
		Releases			Throughput	Releases			Throughput	Releases			Throughput
		ACUTE	VOC	Total	(ACUTE and VOC)	ACUTE	VOC	Total	(ACUTE and VOC)	ACUTE	VOC	Total	(ACUTE and VOC)
2	A	0	5750	5750	2102095	0	5361	5361	1908588	0	3950	3950	1410774
3	B	0	500	500	2967638	0	3535	3535	910400	0	3535	3535	950574
4	C	1000	1500	1500	10900790	10	20	20	7280471	5	9	9	7329767
12	D	41603	41603	41603	96734705	23736	23736	23736	93096647	53166	53166	53166	100212476
16	E	84715	92832	92832	197311254	727460	18158992	18158992	198099237	195592	198218	198218	181614576
29	F	847	847	847	20421365	670	670	670	14099000	3110	3110	3110	3149191
37	G	0	2000	2000	1093550	0	20	20	1068020	0	20	20	890000
40	H	0	1000	1000	3705915	0	97	97	5306835	0	225	225	11248598
66	I	31105	31409	31409	13638848	27093	102128	102128	13056466	62678	62724	62724	14833497
74	J	0	500	500	41624920	0	786	786	41445706	0	381	381	19095240

3.1 TRI Based Analysis

Total Releases

TRI-based analysis measures pollution prevention progress on the basis of each facility's **total releases** to the environment. From this perspective, plants with large releases are potentially causing more extensive environmental damage, and for that reason are ranked lower than plants releasing less. Table 3.2 shows the total quantities released each year in the ten representative plants, and how these plants rank relative to other plants in each of the three years.

To illustrate, in 1989 plant C ranks 35th among the 70 plants evaluated in that year, i.e., plant C's release of 41,603 pounds of acute and VOC pollutants was the 35th largest release of those pollutants among the 70 plant population. At the bottom of the 1989 column in Table 3.2, we see that plant 50 is top ranked as a result of releasing only 3 pounds of acute and VOC pollutants, and plant 67 is lowest ranked on the basis of 109,930 pounds of releases. Looking across the bottom of each column, we see that the largest quantity of releases in any facility increased substantially between 1989 and 1990, from 110 thousand pounds in the former year to 18 million pounds in the latter, and then decreased to 252 thousand pounds in 1991.

TRI analysis based on total releases clearly identifies where large quantities of chemical pollutants are being released, and reveals that some plants are releasing close to zero amounts of chemicals. Looking at Table 3.2 the following findings can be made:

- Some plants, such as plant C, decrease their releases over time and thus improve in TRI rank between 1989 and 1991.

- Similarly, other plants, such as plants B and F, increase their releases and worsen in TRI rank.

- In some plants, total releases decrease from the previous year, however, their rank worsens because greater progress is made by other plants in the data set. Examples of this behavior include: plants A, I, and J from 1990 to 1991.

- A small number of plants report significant increases between 1989 and 1990 in the quantity of chemicals released, e.g., plant E.

Table 3.2 Total TRI Releases						
PLANT ID	1989 (n = 70 plants)		1990 (n = 64 plants)		1991 (n = 65 plants)	
	Total Releases	TRI Rank	Total Releases	TRI Rank	Total Releases	TRI Rank
A	5750	49	5361	42	3950	44
B	500	12	3535	37	3535	43
C	1500	35	20	6	9	5
D	41603	64	25846	54	55784	61
E	92832	67	18158992	64	198218	63
F	847	24	670	25	3110	42
G	2000	41	20	6	20	11
H	1000	25	97	15	225	25
I	31409	62	102128	58	62724	62
J	500	12	786	26	381	27
HIGHEST RANK PLANT/ RELEASES	Plant 50/ 3	1	Plant 18/ 1	1	Plant 50/ 1	1
LOWEST RANK PLANT/ RELEASES	Plant 67/ 109,930	70	Plant 16/ 18,158,992	64	Plant 67/ 252,095	65

An effective use of total TRI releases is as a measure of progress for an aggregate group of facilities, such as those located in the same geographic area or operating in the same economic sector. For example, year-to-year progress by all New Jersey chemical facilities in reducing TRI chemical releases can be easily obtained from the TRI survey results.

Total releases alone do not take into account the overall size of the plants, however. As a result, large plants tend to be singled out because of their size, rather than judged on how well they handle their larger amounts of chemical throughput. Post 1990, the TRI survey includes an index of year-to-year adjustments in production. The year-to-year index makes it possible to normalize the changes in releases, but does not place the magnitude of releases within the context of total chemical usage at the facility. Without the latter, it is not possible to eliminate base year dependence in use of TRI data. Base year dependence is not a deterrent when examining net progress of aggregate groups of facilities over time, but is a problem when attempting to compare performance at different facilities on an equivalent basis.

TRI Ratios

TRI ratios are oriented more directly toward inter-facility comparisons. This use of TRI data examines the change in release levels from the previous year, or from some prior base year. The TRI ratio is computed by dividing releases in the current year by releases in the prior year:

$$TRI\ RATIO = \frac{Total\ Releases\ (current\ year)}{Total\ Releases\ (prior\ year)} \tag{3.1}$$

The TRI-ratio-based ranks for the ten plants are shown in Table 3.3. Because it is more natural to think in terms of percent change (either up or down) than in percent of the total, the TRI ratio is expressed in Table 3.3 as the percent change relative to the previous year:

$$\%\ Change\ TRI\ Releases = \frac{Total\ Releases\ (current) - Total\ Releases\ (prior)}{Total\ Releases\ (prior)} \tag{3.2}$$

Each plant is ranked in Table 3.3 on the basis of how much it reduces its releases from one year to the next as compared to how well other plants perform in this regard. The following observations can be made:

- Simply staying at their current release level between 1990 and 1991, i.e., with no change in releases, leads to plants B and G being ranked at the midpoint of facilities. That is, as many plants increase as decrease releases between those two years.

- Some plants achieve 100%, or nearly 100%, reductions in the quantity of chemicals released (plants C, E, G, and 32).

- For some plants, TRI ratios vary a great deal on a year-to-year basis, even though their trend in releases may not be unusually variable. For example, plant D's releases decrease by 38 percent between 1989 and 1990, then increase by 116 percent between 1990 and 1991. In using the TRI ratios it may be helpful to track both year-to-year variations and the trend relative to a fixed base year.

As noted, the TRI ratio is limited to comparison against a base year. Therefore, it cannot take into consideration pollution prevention efforts that have been implemented prior to the base year. Thus, a plant could rank poorly in % Change over the years under consideration, yet be one of the most pollution-prevention-effective plants, with little room for improvement. Similarly, a plant that ranks high in % Change may still fall a great distance from being a leader in pollution prevention, with much room for improvement.

Table 3.3 TRI Ratio (% Change From Previous Year)				
PLANT ID#	1990 from 1989 (n = 70 plants)		1991 from 1990 (n = 64 plants)	
	% Change	Rank	% Change	Rank
A	-6.8	41	-26.3	26
B	607.0	63	0.0	37
C	-98.7	12	-55.0	17
D	-37.9	33	115.8	57
E	19461.1	69	-98.9	9
F	-20.9	36	364.2	62
G	-99.0	11	0.0	37
H	-90.3	18	132.0	58
I	225.2	58	-38.56	24
J	57.2	55	-51.5	18
HIGHEST RANK/ % Change	Plant 18/ -99.67	1	Plant 32/ -100.0	1
LOWEST RANK/ % Change	Plant 32/ +31,974,066	70	Plant 38/ +24,233	64

3.2 Throughput Ratio Analysis

The Release-to-Throughput Ratio extends TRI analysis of total releases by taking into consideration the amount of the chemical used at each plant (i.e., throughput).[3] By adding this dimension to the measurement process, the situation can be avoided in which inefficient plants that use small amounts of chemicals are ranked higher than efficient plants using larger amounts of chemicals. Table 3.4 presents the Release-to-Throughput (R/T) information for the ten plants in our example.

- Plant F illustrates the case in which a plant's R/T-based rank may worsen, even though its total releases decrease. From Table 3.1 we see that total releases form plant F decreased somewhat between 1989 and 1990 (from 847 lbs to 670 lbs), but its chemical throughput decreased by a much larger amount (from 20,421,365 lbs in 1989 to 14,099,000 lbs in 1990). Thus, in 1990 plant F is handling a lesser amount of chemicals less efficiently.

- The ranks of some plants (including plants B and I) grow progressively worse over the three years. Referring to the original data in Table 3.1, we see that overall throughput is decreasing at these plants, and yet their total releases are increasing. The net result of this combined change is that these plants drop rapidly in the R/T-based ranks.

In Figure 3.1 the 1991 R/T ranks of the 65 plants evaluated are graphically compared with the ranks for those plants based on their TRI releases. To illustrate, plant D is ranked 31 on the basis of R/T, but 61 on the basis of total TRI releases. Conversely, plant 79 is ranked 57 on the basis of R/T, and 29 on basis of total TRI releases. The corresponding results for 1989 and 1990 are given in Appendix D.

- For all three years plant J has a high R/T rank (ranging from 1 in 1989 to 3 in 1991); however, its rank based on total releases is much lower (13 in 1989, 26 in 1990, and 27 in 1991). The TRI release rank does not take into consideration the large quantities of chemicals (throughput) that plant J handles.

- In contrast, plant 79's R/T rank is almost twice as bad as its TRI releases rank. While its releases are fairly low, so is its level of throughput.

- The pattern of data in Figure 3.1 and the equivalent results for 1989 and 1990 (Appendix D) shows substantial discrepancies between plant rankings based on R/T vis-a-vis rankings based on total TRI releases. The R/T measure takes extent of usage into account, and for that reason is better suited to inter-facility comparisons.

---

[3]The components of throughput are: quantity of the chemical brought on-site, quantity produced, and net outflow from inventory of that chemical over the course of the year. Definitions of throughput and other materials accounting variables are presented in Chapter 2.

Table 3.4 Release-to-Throughput Ratio x 1000						
PLANT ID	1989 (n = 70 plants)		1990 (n = 64 plants)		1991 (n = 65 plants)	
	Ratio	Rank	Ratio	Rank	Ratio	Rank
A	2.74	38	2.81	39	2.80	46
B	0.17	11	3.8	43	3.72	48
C	0.14	10	0.00	1	0.00	1
D	0.22	13	0.29	22	0.16	18
E	0.47	18	91.67	59	1.09	35
F	0.04	4	0.05	8	0.99	34
G	1.83	32	0.02	2	0.02	3
H	0.27	15	0.02	2	0.02	3
I	2.30	34	7.82	47	4.23	50
J	0.01	1	0.02	2	0.02	3
HIGHEST RANK/ RATIO	Plant J/ 0.01	1	Plant C/ 0.00	1	Plant C/ 0.00	1
LOWEST RANK/ RATIO	Plant 43/ 255.86	68	Plant 77/ 507.24	64	Plant 49/ 44.80	65

Figure 3.2 graphically compares the 1991 plant rankings based on R/T with those based on TRI ratios between the years 1991 and 1990. The corresponding results for 1989 to 1990 are presented in Appendix D. An equivalent, perhaps greater, amount of scatter is seen between TRI ratio ranks and R/T ranks than was seen between ranks based on total TRI releases and R/T ranks. As discussed above, the TRI ratio ranks are base year dependent. R/T ranks, in contrast, are independent of base year, i.e., plant rank depends only upon the relative efficiency of chemical usage in the year of interest, not on how that plant performed in previous years.

Table 3.5 illustrates the importance of considering both the amount of throughput and the amount of releases in measuring pollution prevention progress. Five plants have been identified in the 1991 data whose total releases approximately sum to the total releases of plant F. However, plant F by itself is handling nearly four times the combined throughput of the five

smaller plants. Viewed from the perspective of efficiency in usage, if the five smaller plants were as effective at pollution prevention as plant F, they would generate only one-third the releases they do at present.

Table 3.5
Illustration of the Importance of Both Total Releases and the Release-to-Throughput Ratio (1991)

PLANT ID#	Total Throughput (lb/yr)	Total Releases (lb)
28	1,033,214	10,032
39	2,129,392	8,000
46	9,634,419	25,280
52	15,773,480	7,973
79	42,500	578
Five Plants Together	28,613,005	51,863
Plant F	100,041,776	55,784

Figure 3.1
TRI Release Ranks vs
Release-to-Throughput Ranks

1991

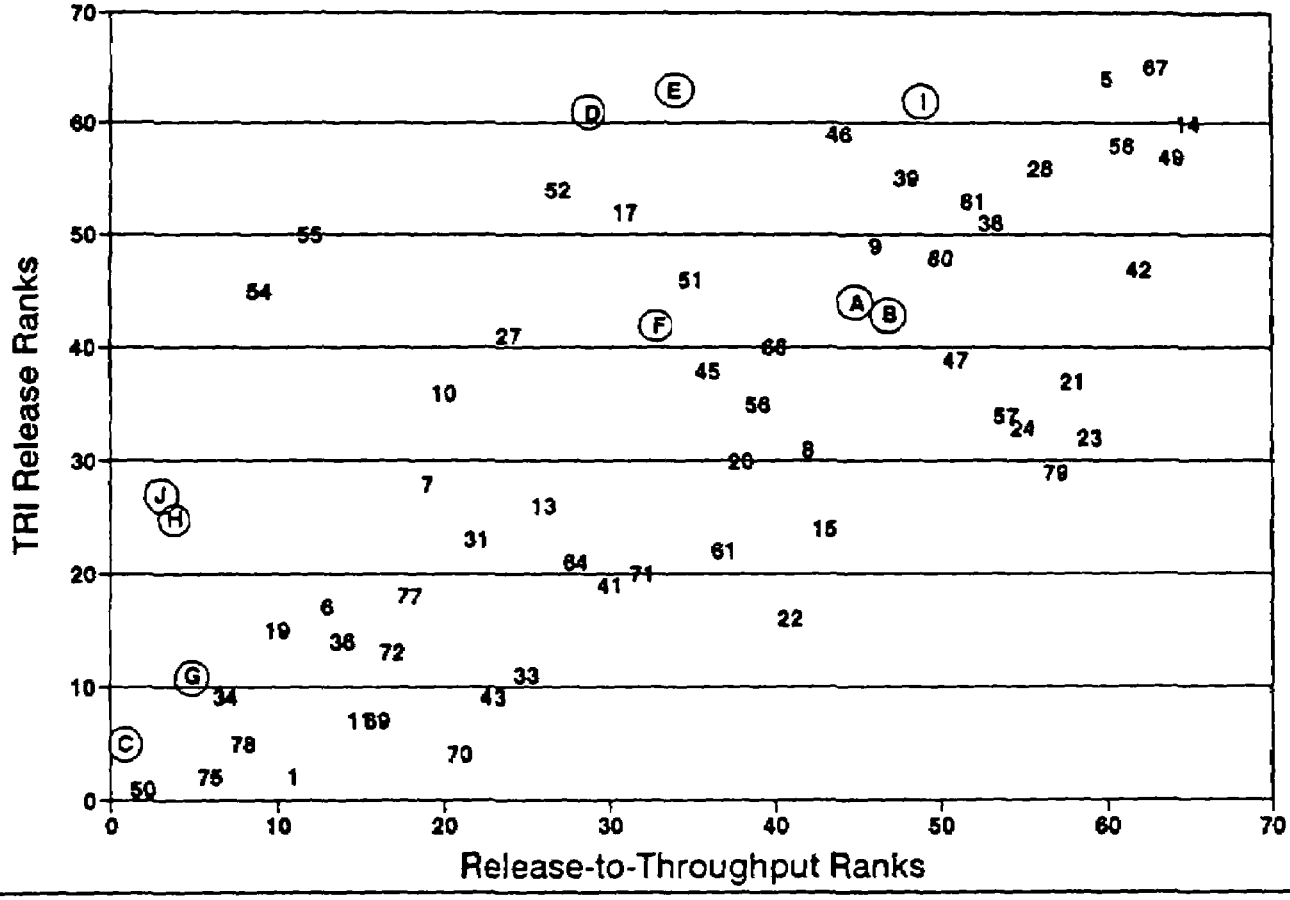
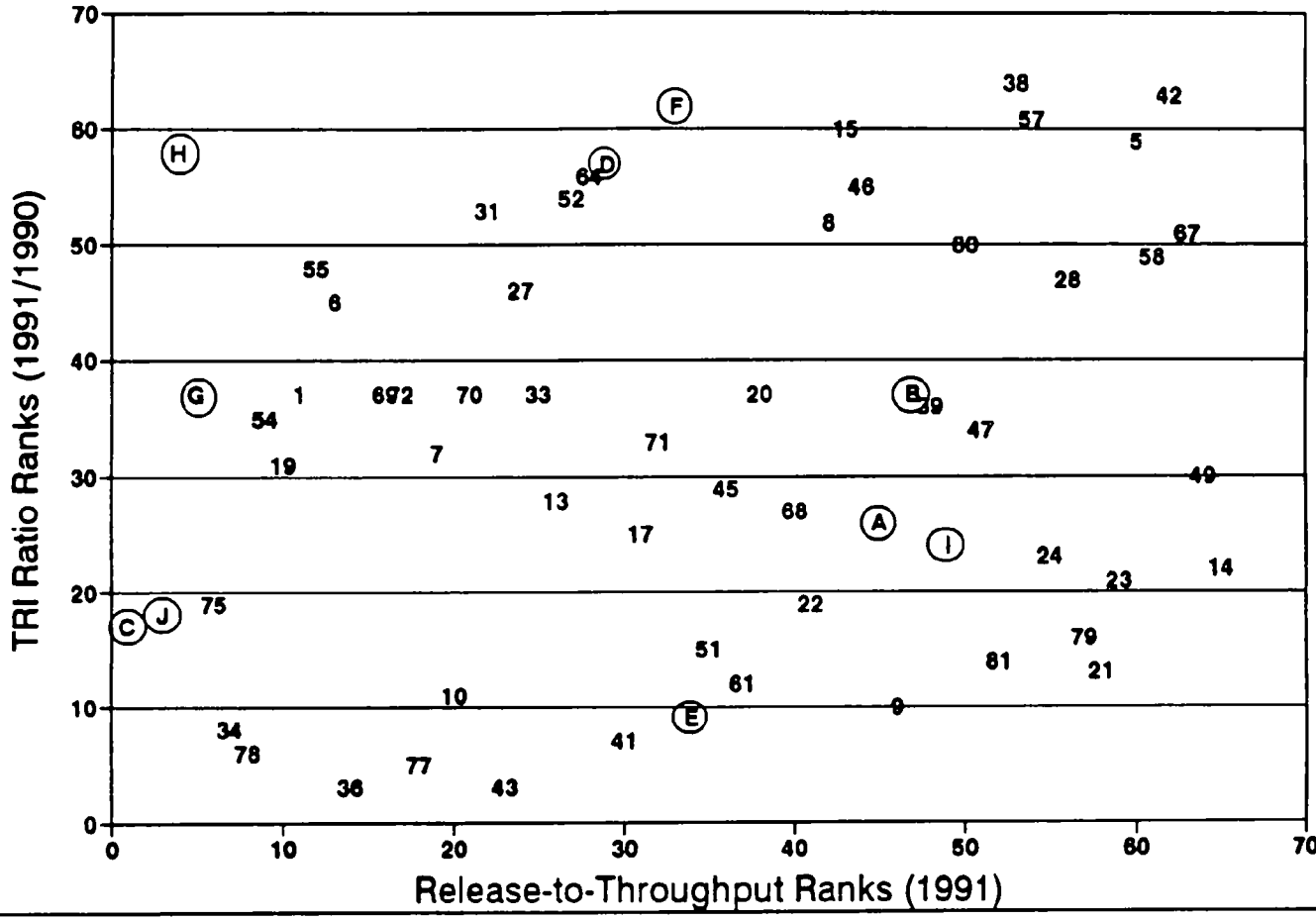


Figure 3.2
TRI Ratio Ranks vs
Release-to-Throughput Ranks
1991/1990



3.3 PPF Analysis

As explained in the Phase 1 report and summarized in Chapter 2 of this report, PPF utilizes a **multi-dimensional release-to-throughput ratio** as the basis for analysis. Synergistic aspects of pollution prevention can be directly assessed using the multidimensional character of PPF. The specific dimensions employed depend on the underlying goal at hand, as discussed in Chapter 4 of the Phase 1 report. As noted at the beginning of the present chapter, in this study we analyzed the chemicals with regard to their membership in two risk groups, acute toxins and VOC. By limiting the analysis to two dimensions, we could demonstrate the multidimensional nature of the analysis while being able to present graphical results within a two-dimensional framework. Most policy analyses involve a larger number of dimensions.

Table 3.6 shows the PPF scores and ranks for the ten example plants in 1989, 1990, and 1991. To illustrate, plant F receives a PPF score of 15.9 percent in 1989, resulting in a PPF rank of 5. By 1991, the PPF score for plant F has fallen to 0.1 percent, resulting in a rank of 36. Using PPF to assess pollution prevention progress over time shows the relative movement among plants, as well as movement of the frontier itself, as new plants improve their effectiveness and the frontier is redefined.

- Some plants showed improvement over the three years by moving up in rank (e.g., plants C, G, and H), and in some cases defining the new frontier (e.g., plant C)

- Some plants that were initially among the leaders did not keep pace and eventually became relative laggers, when compared to the evolving performance frontier (e.g., plants B and F).

- Other plants did not show much movement in either direction: consistently good -- plant J, or consistently middling -- plant A.

Figures 3.3 and 3.4 graphically compare the PPF ranks for 1991 with the TRI release ranks and the TRI ratio ranks for that year. In both cases, very little correlation is found between the results. For example, plant D is ranked 32 by PPF, but 61 by TRI releases and 57 by TRI ratio. The comparison is similar to the results obtained when TRI release ranks and TRI ratio ranks are compared against R/T ranks. As discussed previously, the TRI release approach assigns low ranks to facilities with large releases regardless of the amount of throughput they are handling. Also, some small plants with poor pollution prevention efforts are ranked high because they use small amounts of the chemical. Like the R/T approach, PPF normalizes releases (or wastes) with respect to throughput.

Table 3.6 PPF Analysis Scores						
PLANT ID	1989		1990		1991	
	PPF Score (in %)	PPF Rank	PPF Score (in %)	PPF Rank	PPF Score (in %)	PPF Rank
A	0.4	36	0.7	28	0.3	29
B	7.1	11	0.5	30	0.2	32
C	4.8	10	100.0	1	100.0	1
D	2.8	16	14.9	23	8.9	32
E	1.4	18	0.014	56	0.1	37
F	15.9	5	5.8	14	0.1	36
G	0.7	30	97.6	3	36.40	5
H	4.5	14	100.0	1	40.9	4
I	0.3	33	0.058	47	0.029	51
J	100.0	1	96.4	4	41.0	3

In Figure 3.5, PPF ranks for 1991 are graphically compared with R/T results for that year. The corresponding results for 1989 and 1990 are presented in Appendix D. For comparison, the TRI release based ranks are plotted as crosses in each graph. Perfect agreement between the rankings would result in all scores lying along the 45° axis. The PPF and R/T ranks are indeed seen to be in very close agreement, while the TRI release rankings are distributed relatively randomly about the graph. An important difference between PPF and R/T rankings is that:

- In both 1990 and 1991, the PPF rankings split into two groups: one lying above the 45° line and one lying below. Overwhelmingly, the top set of plants, which receive poorer PPF ranks than R/T ranks, is comprised of plants handling chemicals that represent both VOC and acute hazards. The bottom set of plants, which receive better PPF ranks than R/T ranks, is composed mostly of plants handling chemicals that represent only acute hazards. The general agreement seen in Figure 3.5 shows that PPF shares the R/T ratio's ability to factor throughput into account, while the bifurcation of plants demonstrates that PPF is able to take into account the potentially greater degree of risk that some releases pose to surrounding communities.

Figure 3.3
TRI Release Ranks vs PPF Ranks
1991

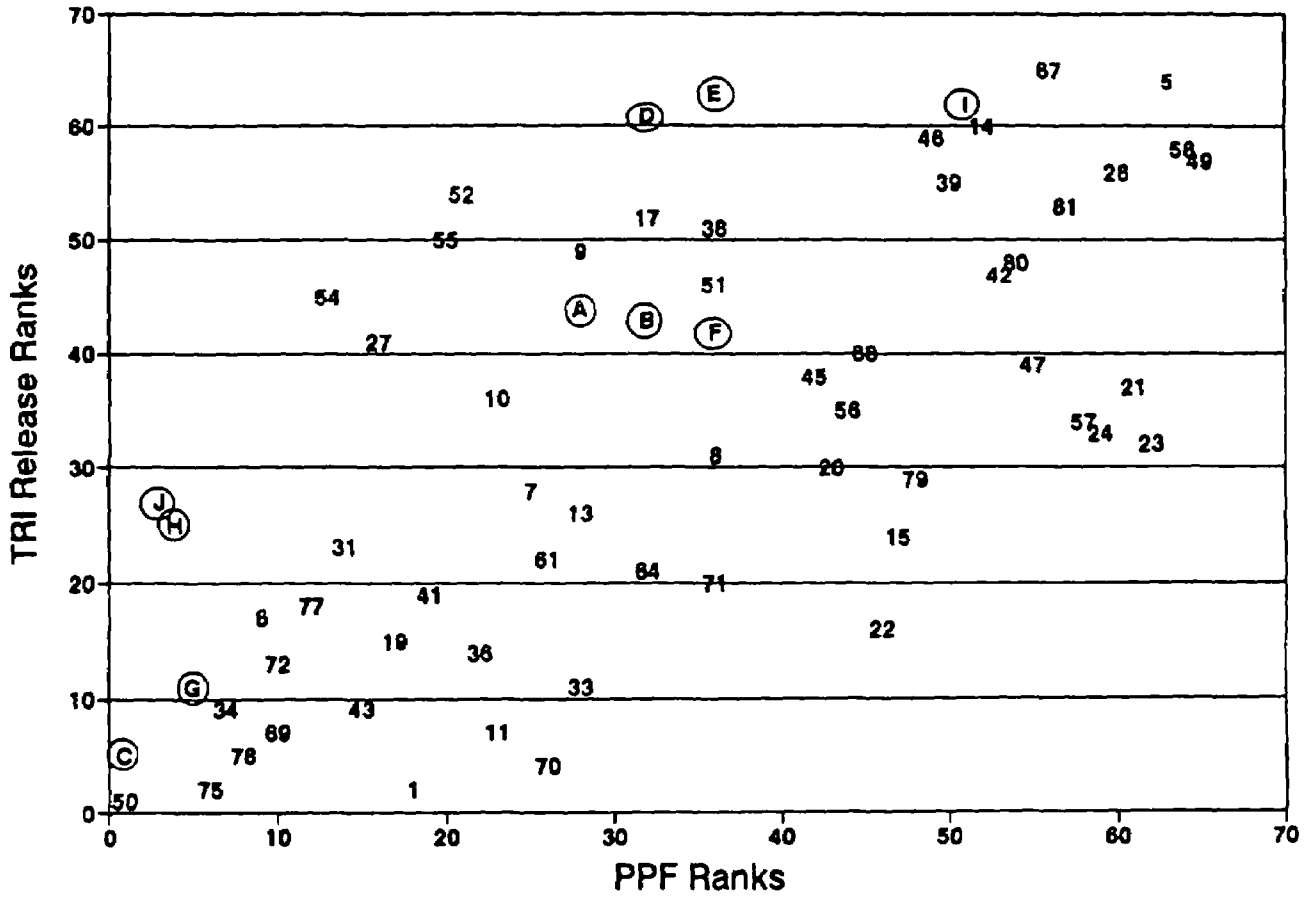


Figure 3.4
TRI Ratio Ranks vs PPF Ranks
1991/1990

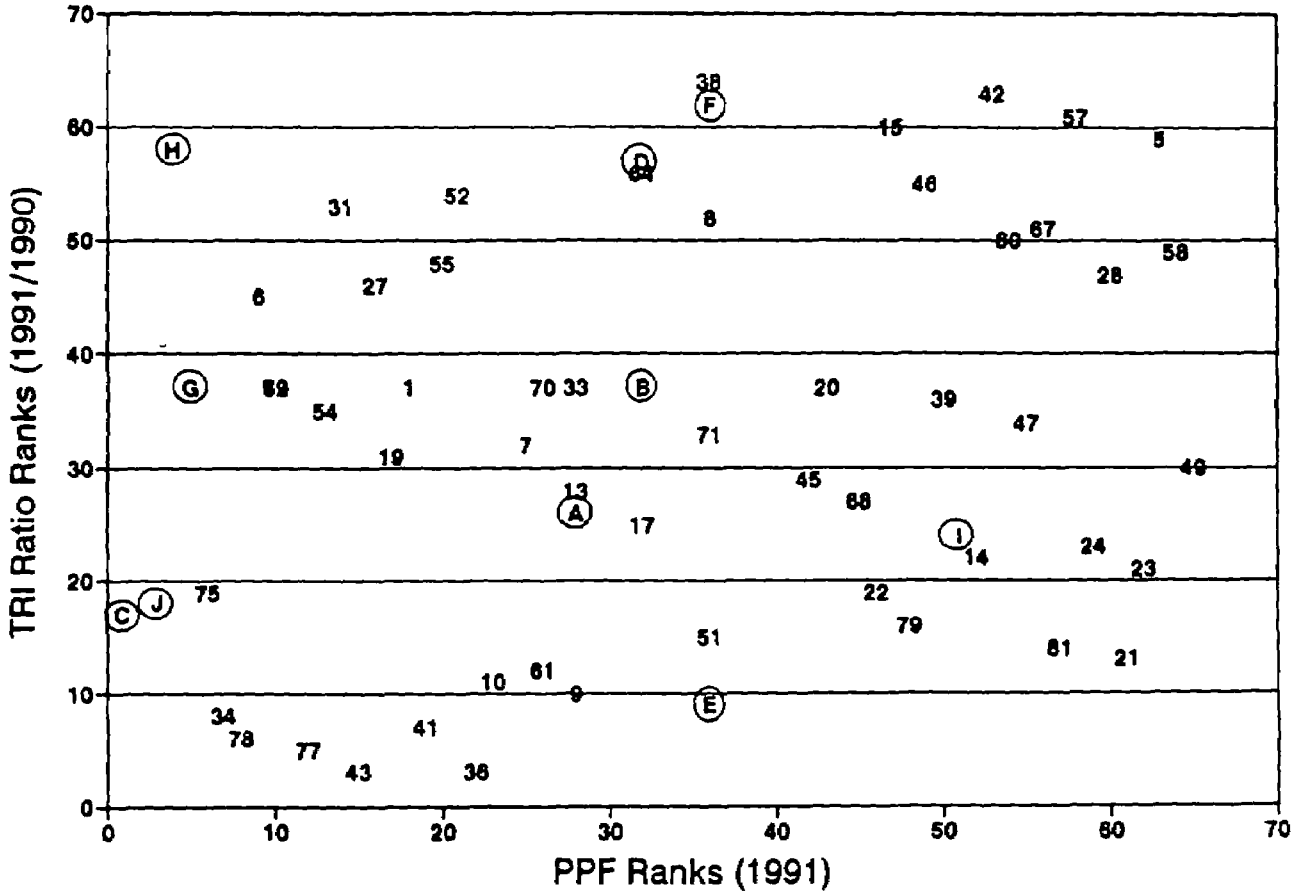
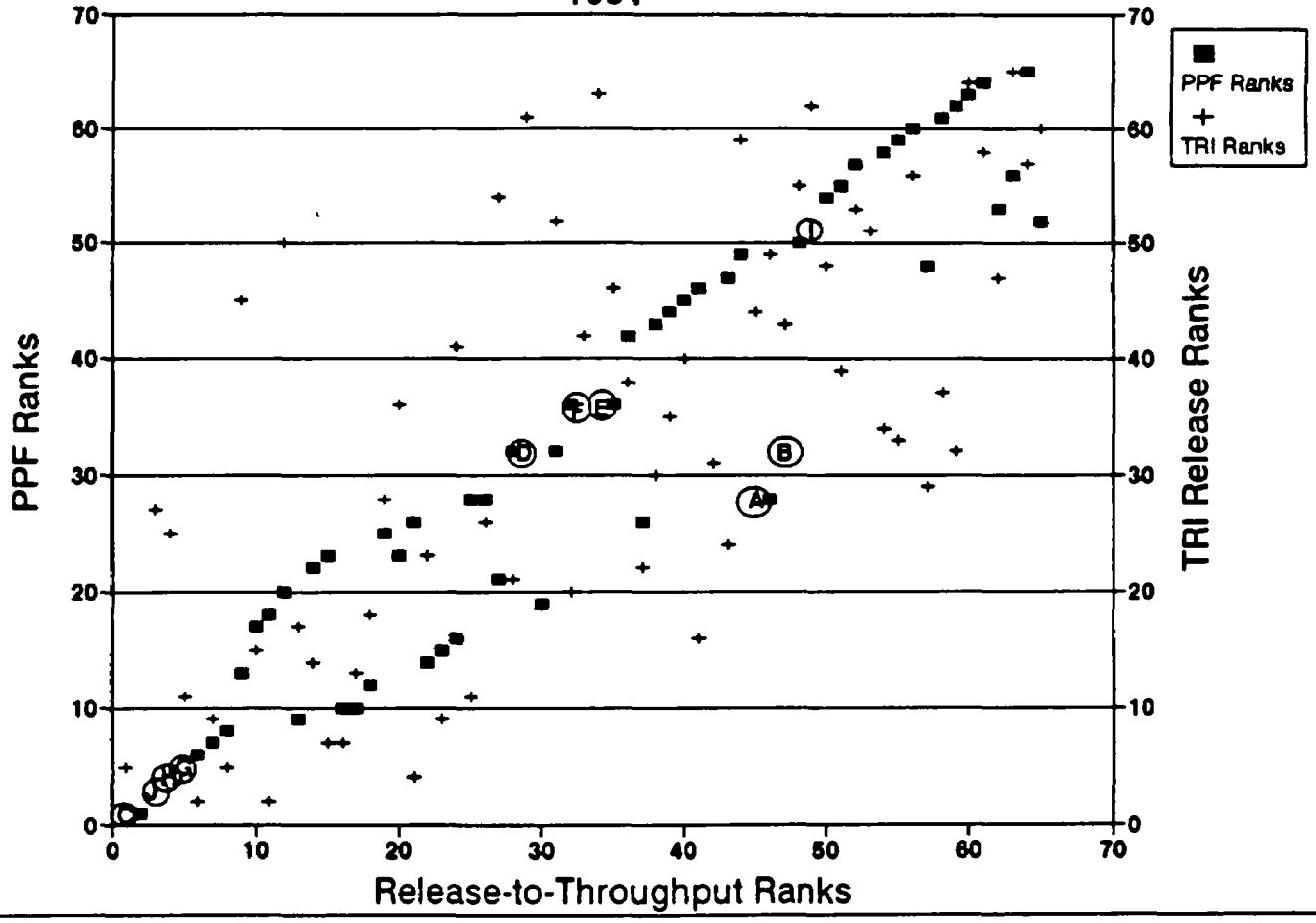


Figure 3.5
PPF Ranks and TRI Release Ranks vs Release-to-Throughput Ranks
1991



Effect of Technology

As discussed in Chapter 1, PPF is envisioned as a screening analysis. Using PPF to assess pollution prevention performance across a broad range of facilities involves a number of simplifications. Each facility is to a certain extent unique in terms of its technology, raw materials, capital and human resources, and specific attributes of its products. In order to examine the effect of technology differences, PPF results for SIC 28 were segregated into the following three-digit SIC categories:

- SIC 281 - Industrial Inorganic Chemicals
- SIC 282 - Plastics Materials and Synthetics
- SIC 283 - Drugs
- SIC 284 - Soaps, Cleaners, and Toilet Goods
- SIC 285 - Paints and Allied Products
- SIC 286 - Industrial Organic Compounds
- SIC 289 - Miscellaneous Chemical Products

A number of differences exist between the materials and technologies typically employed in these seven sectors. To illustrate the former difference, consider SIC 281, which as its name indicates is predominantly oriented toward inorganic chemicals, and uses relatively few VOC. Technology differences are illustrated by comparing Drugs (SIC 283) and Paints and Allied Products (SIC 285), which tend to be batch processing oriented, with organic chemicals production (SIC 286), which generally employs continuous processing. Some of these differences are overridden because a number of medium and larger firms are integrated across three-digit sectors. For example, many organic chemical producers manufacture the inorganic chemical precursors used in production of their organic chemical products.

Figure 3.6 graphically compares the PPF ranks in 1991 for plants in SIC 282 (Plastics Materials and Synthetics) with R/T and TRI release based ranks for those facilities. The results for SIC 282 are illustrative of the form of results obtained for each three-digit sector in each of the three years. (All SIC sector results are presented in Appendix D.) The PPF ranks for SIC 282 facilities span the range from high to low ranked facilities; generally agree with R/T ranks, but are somewhat higher, indicating the presence of chemicals that are both acute toxins and VOC; and do not generally agree with TRI based ranks.

PPF ranks for 1991 are graphed by decile in Figure 3.7 for four SIC: 281, 282, 286, and 289. The results for all sectors in each year are presented in Appendix D. The following observations can be made:

- All SIC 281 facilities are ranked by PPF among the top 40 percent of facilities, the only sector to receive consistently high ranks. One factor probably contributing to these high ranks is that SIC 281 facilities handle few VOC, and thereby benefit in a relative sense when PPF assigns lower ranks to facilities handling multiple-risk chemicals, e.g., acute toxins and VOC.

Figure 3.6
1991 PPF Ranks and TRI Release Ranks vs Release-to-Throughput Ranks
SIC 282

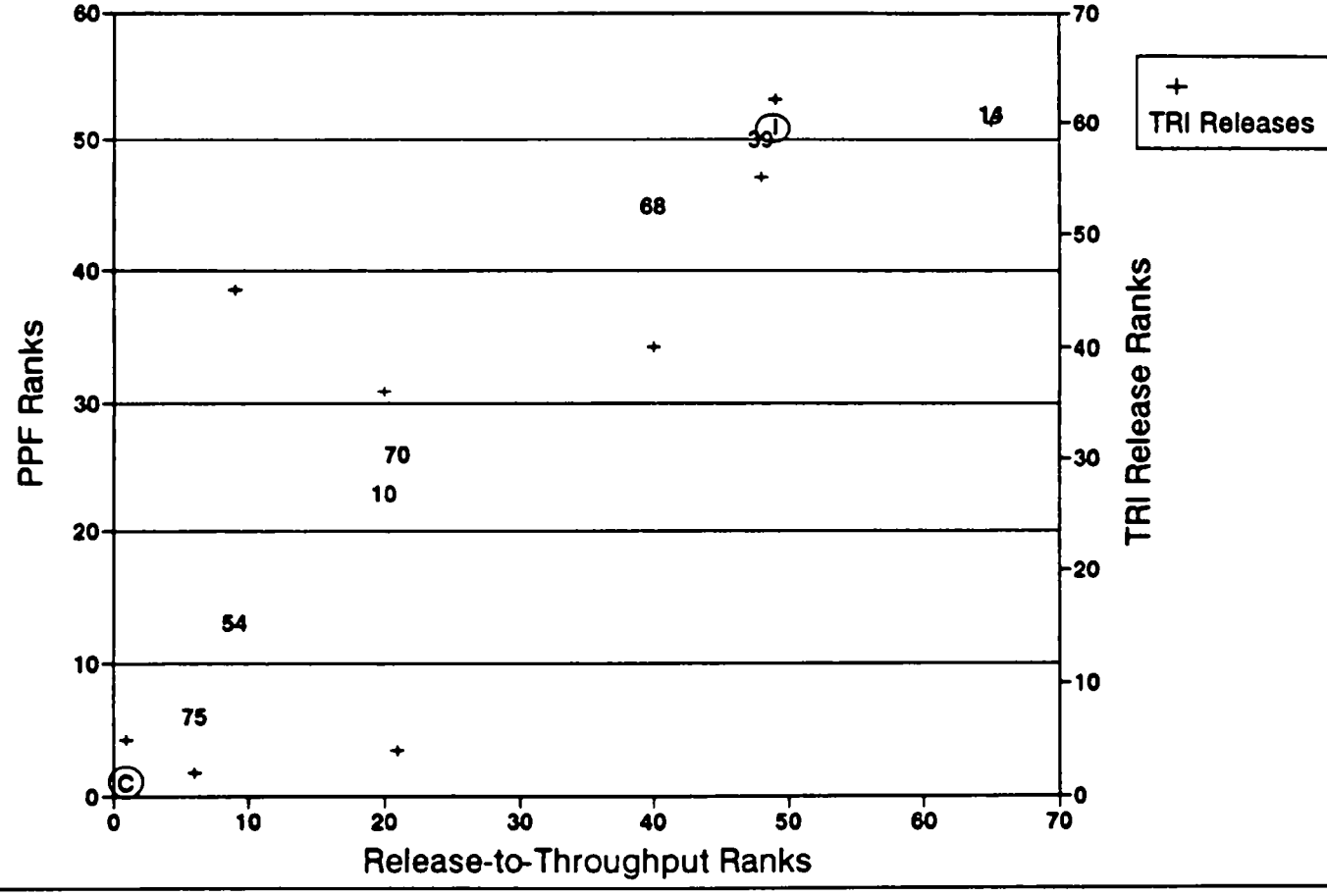
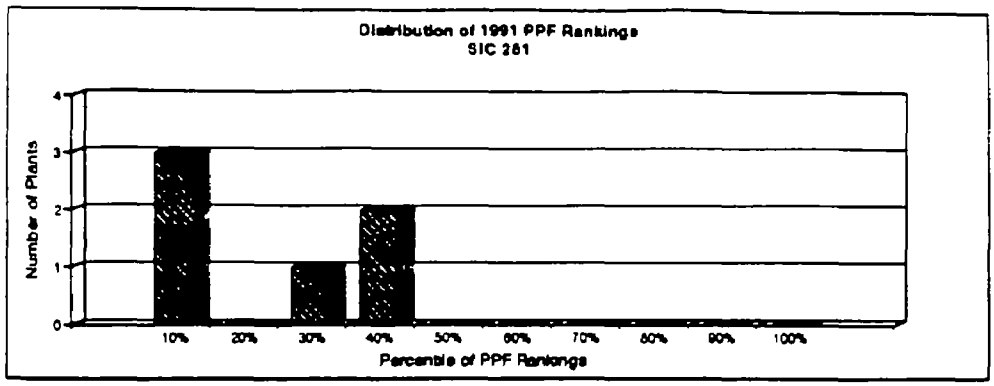
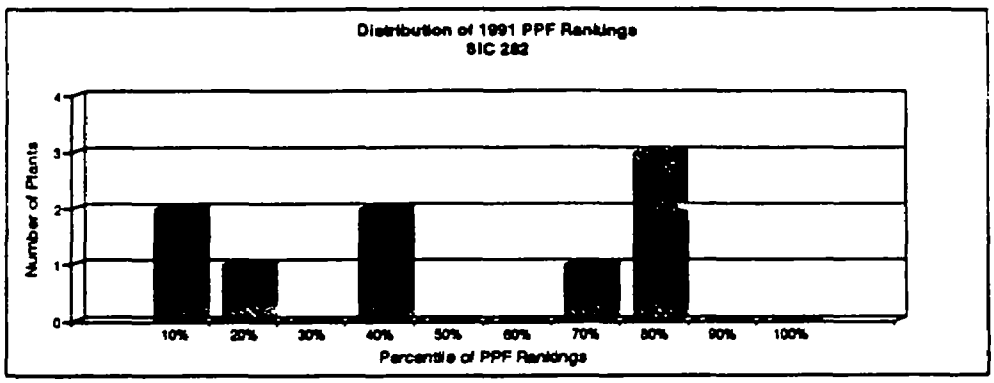
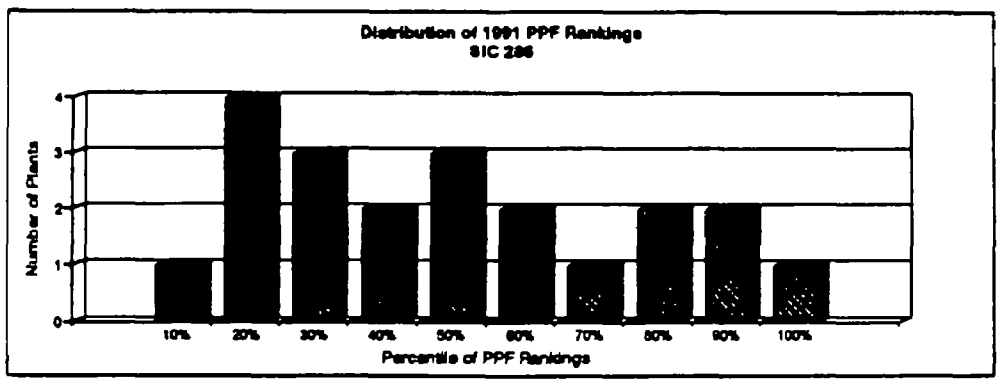
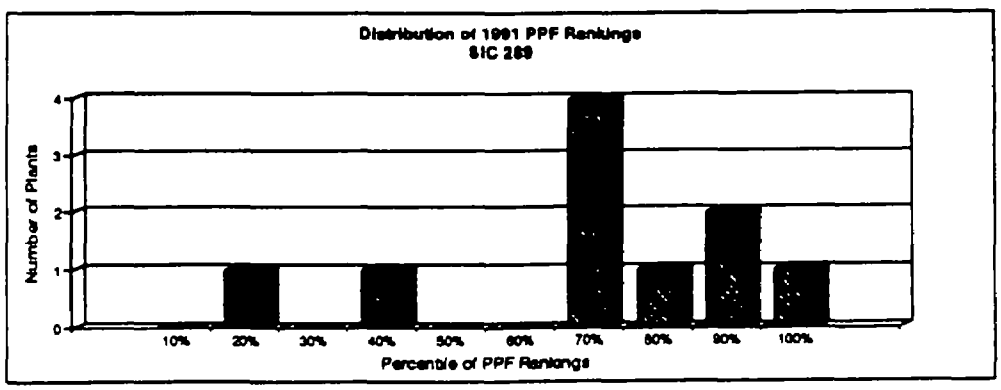


Figure 3.7


Distribution of 1991 PPF Rankings
SIC 281
Number of Plants
0
1
2
3
4
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentile of PPF Rankings


Distribution of 1991 PPF Rankings
SIC 282
Number of Plants
0
1
2
3
4
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentile of PPF Rankings


Distribution of 1991 PPF Rankings
SIC 286
Number of Plants
0
1
2
3
4
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentile of PPF Rankings


Distribution of 1991 PPF Rankings
SIC 289
Number of Plants
0
1
2
3
4
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentile of PPF Rankings

- Eighty percent of SIC 289 facilities lie in the bottom 40 percent of the rankings, the only sector to exhibit a significant bias toward low rankings. SIC 289 facilities tend to be relatively small facilities engaged, as the sector title indicates, in a multitude of miscellaneous activities, generally employing batch processing. The products involved include: adhesives and sealants, explosives, printing inks, carbon black, and a large number of others. PPF rankings indicate that in relative terms these facilities are not operating at the same level of pollution prevention as facilities in the other three-digit chemical manufacturing sectors.

- Facilities in both SIC 282 and 286 span the range of PPF rankings, with a slightly larger share (62 percent) of SIC 286 firms lying in the top half of the rankings.

Effect of Plant Size

A second factor that may have affect pollution prevention performance at facilities is the availability of resources -- capital, labor, management, and expertise -- for conducting proactive environmental management. PPF ranks were reviewed using company size as a proxy for resource availability. Companies were allocated into four size categories using total employment at the firm as the metric for size. Use of this metric presumes that smaller facilities belonging to larger firms can access the resources, and are governed by the environmental ethic, of the larger firm. The four size categories were: small (less than 150 total employees); medium (between 150 and 1,000 employees); large (between 1,000 and 10,000 employees); and very large (over 10,000 employees).

Figures 3.8 and 3.9 graphically compare the PPF ranks of the small and very large facilities in 1991 with the R/T and TRI release based ranks of those same facilities. The results for all facility sizes in each of the three years are given in Appendix D.

- Generally good agreement is found between PPF and R/T ranks, with the former bifurcated according to whether the chemicals at each plant are only acute toxins or both acute toxins and VOC.

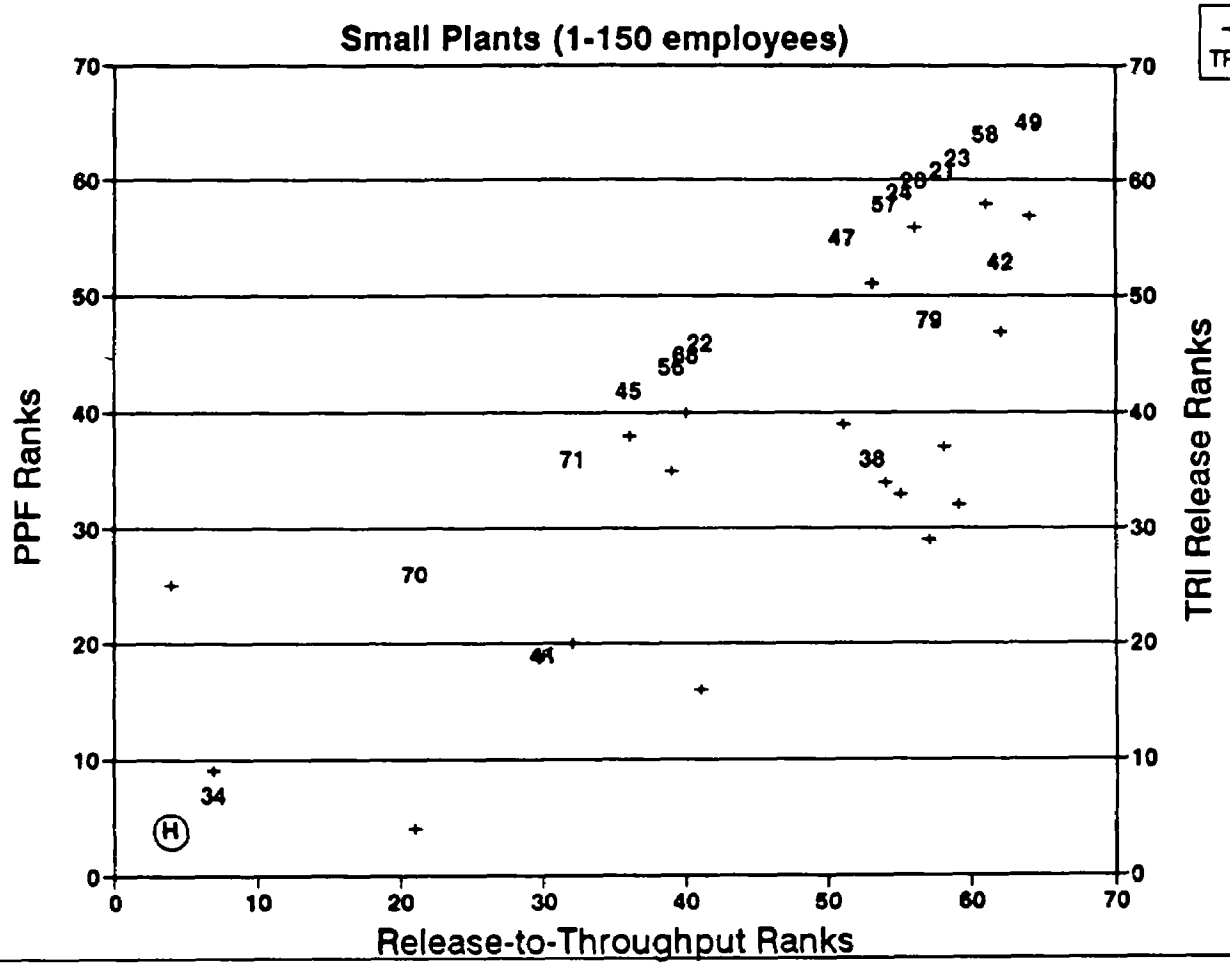
- TRI release based results show better agreement with R/T and PPF results than found in prior comparisons. A likely explanation for this improved correlation is that segregating facilities according to employment concurrently separates the facilities into groups having similar throughputs. The effect of throughput normalization is thereby muted.

The distribution of PPF ranks for 1991 are shown by decile in bar graph form for small and very large plants in Figure 3.10. Bar graphs giving the PPF rank distribution by decile for all plant sizes for each of the three years are presented in Appendix D. A line graph of the 1991 PPF rank distributions for all facility sizes is presented in Figure 3.11. The following observations can be made:

Figure 3.8

1991 PPF Ranks and TRI Release Ranks vs Release-to-Throughput Ranks

Small Plants (1-150 employees)



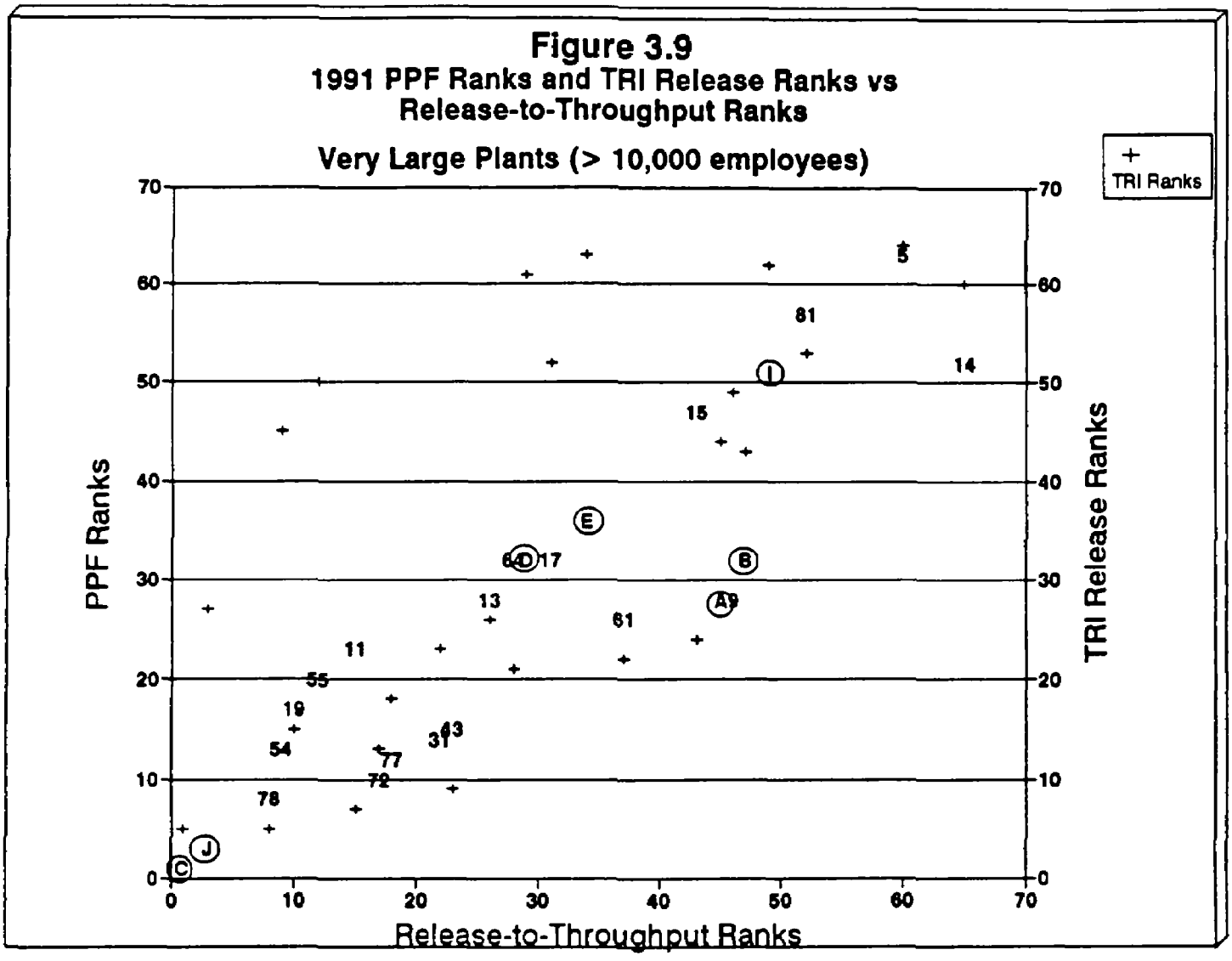
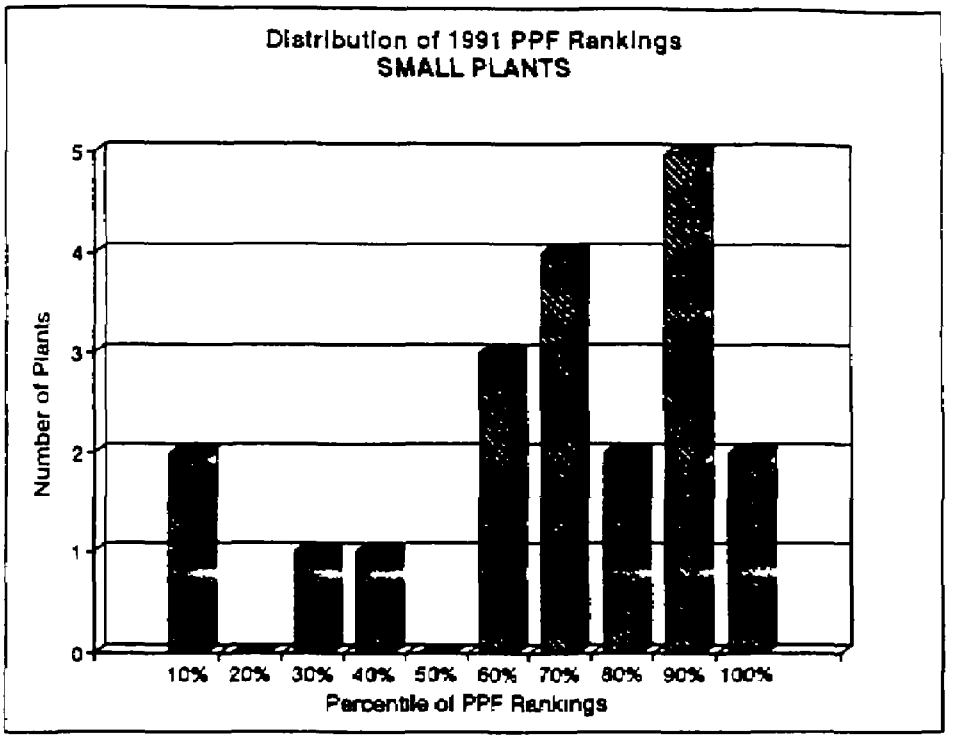
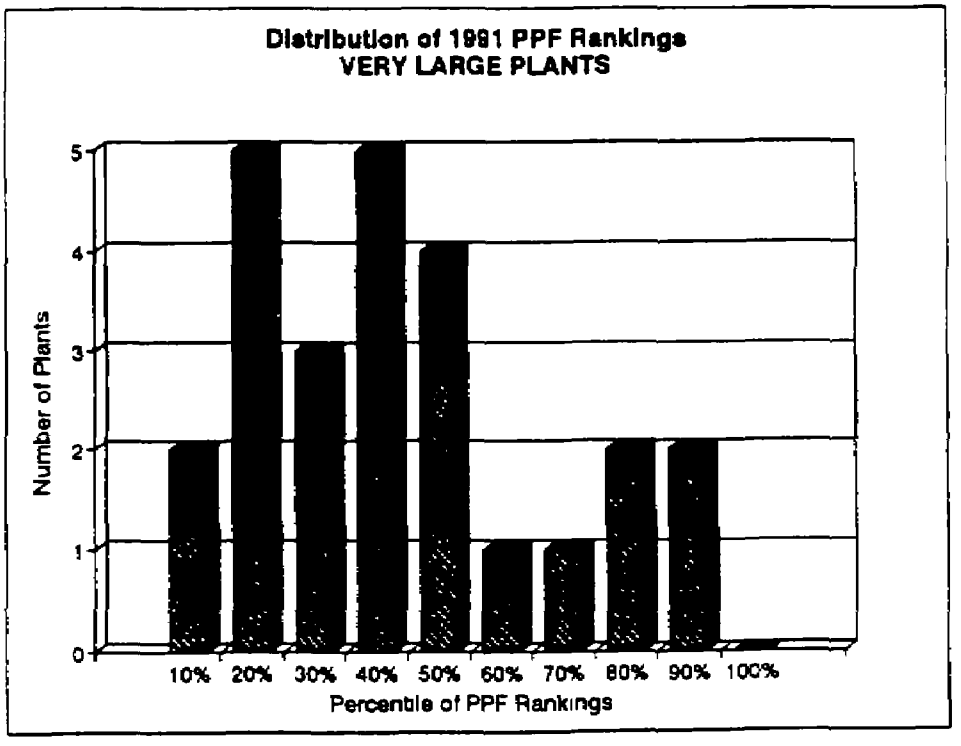


Figure 3.9
1991 PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
Very Large Plants (> 10,000 employees)
TRI Ranks
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
0
10
20
30
40
50
60
70
5
81
14
15
E
64
D
17
B
13
A
9
61
11
55
19
54
31
63
77
72
78
J
C
I

Figure 3.10


Distribution of 1991 PPF Rankings
SMALL PLANTS
Number of Plants
0
1
2
3
4
5
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentile of PPF Rankings


Distribution of 1991 PPF Rankings
VERY LARGE PLANTS
Number of Plants
0
1
2
3
4
5
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentile of PPF Rankings

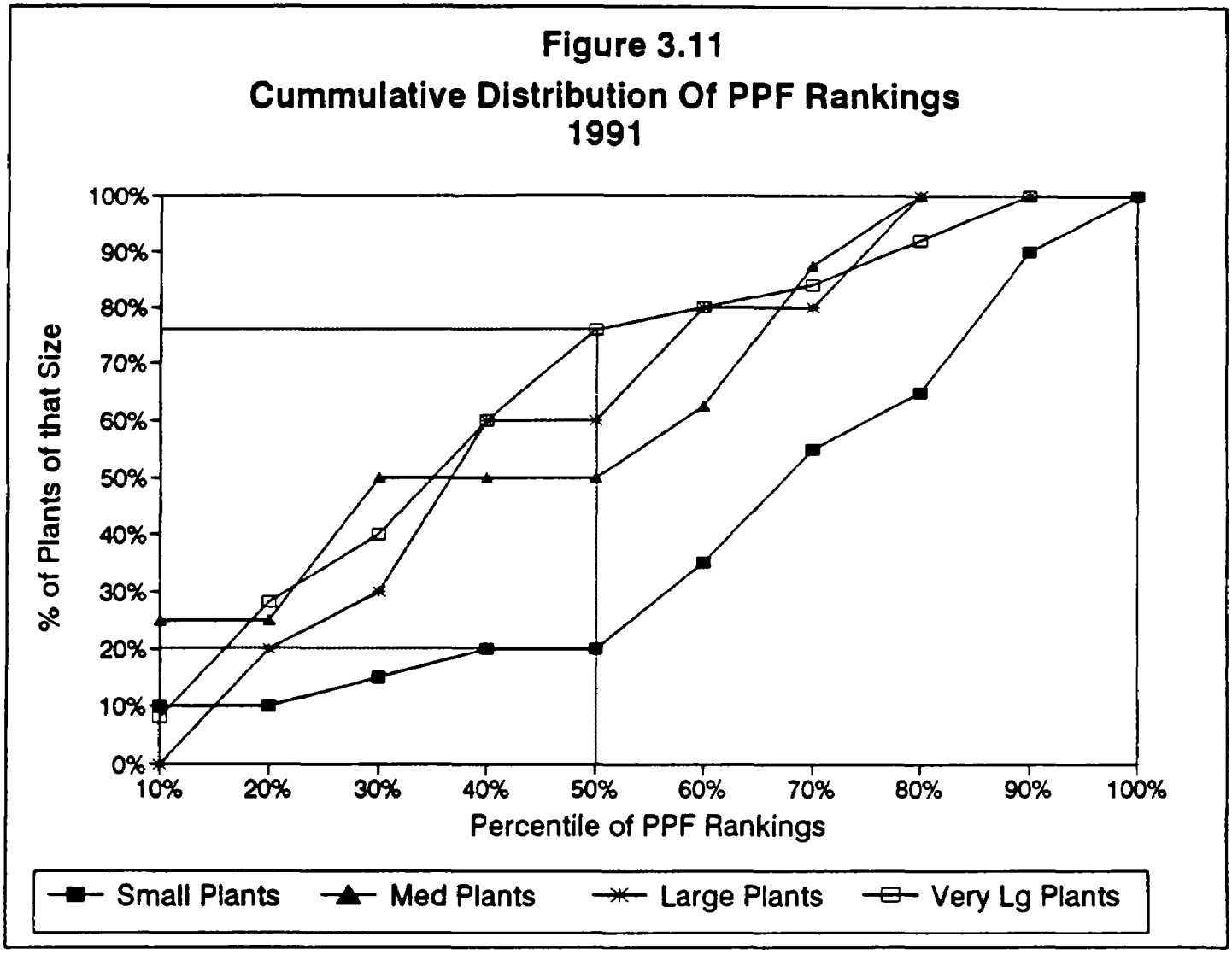


Figure 3.11
Cummulative Distribution Of PPF Rankings
1991
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% of Plants of that Size
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentile of PPF Rankings
Small Plants
Med Plants
Large Plants
Very Lg Plants

- Very large facilities receive the highest ranks, with over three quarters of these facilities being ranked among the top half of facilities. Medium and large facilities fare almost as well.

- Small facilities substantially lag all other facilities in PPF rankings. Only 20 percent of small firms are ranked by PPF among the top half of facilities.

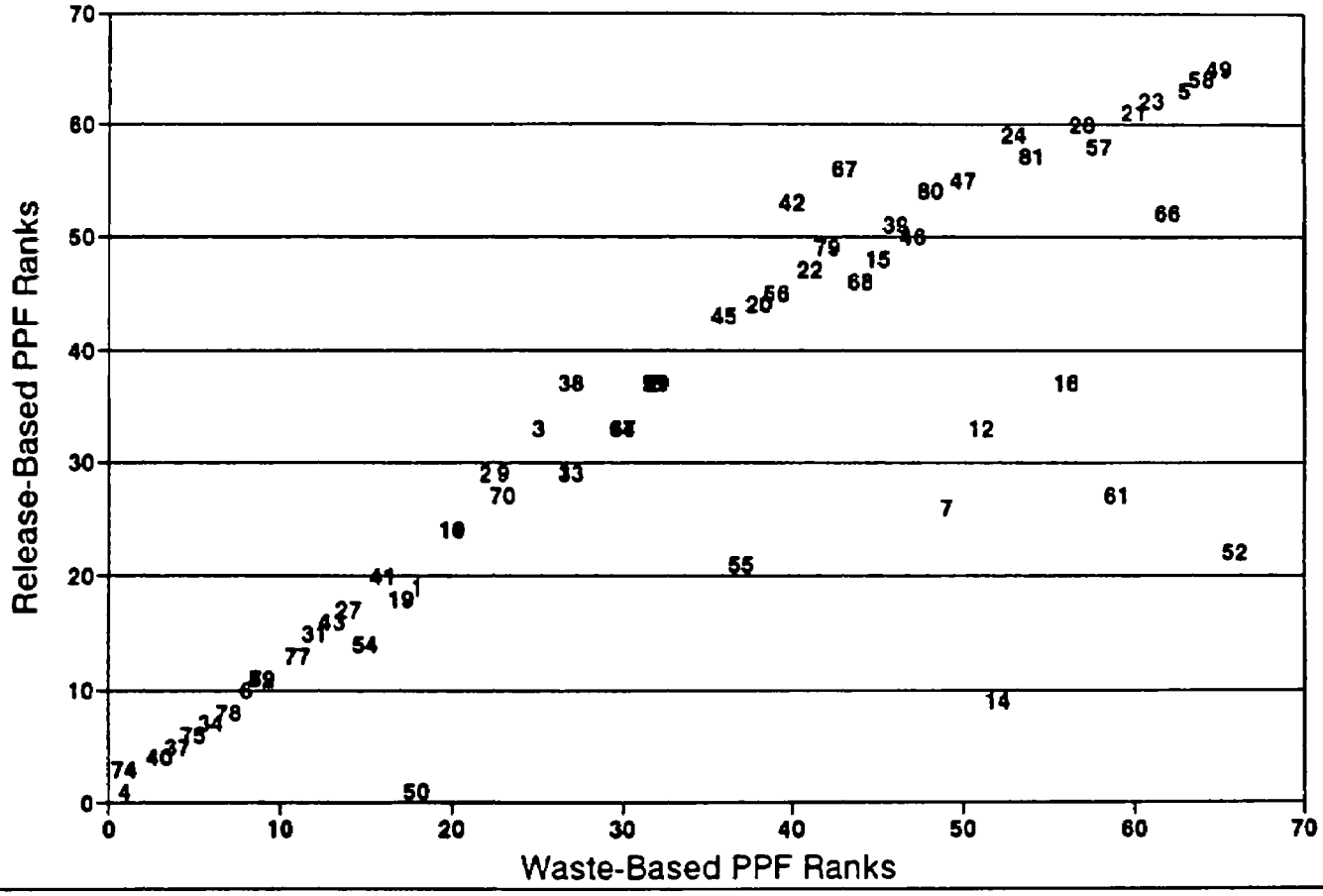
Ranks based on Waste Generation Rather than Releases

Pollution prevention focuses on reducing waste generation at the source, rather than the historical goal of preventing environmental releases of undesired contaminants. For this reason, the desired pollution prevention metric is reduction of waste generation, and the PPF approach has been developed using this metric. The present study focused on releases so that comparisons could be made between PPF and TRI based rankings over the 1989 to 1991 period. As noted previously, TRI data for 1991 and subsequent years include information on waste generation and, therefore, in the future TRI data can be used to examine progress in reducing waste generation.

In order to examine how a focus on waste generation would affect the results obtained in the present study, a waste-based analysis was conducted for the three approaches using data from the New Jersey Worker and Community Right-to-Know surveys for 1989, 1990, and 1991. The tabulated results of this analysis are presented in Appendix C, and graphical results are presented in Appendix E. Figure 3.12 graphically compares release-based PPF ranks for 1991 with waste-based ranks for the same facilities.

- Waste-based PPF ranks are in good accord with release-based ranks except when firms treated their wastes in such a way that releases were substantially lower than wastes initially generated. For example, in Figure 3.12 plant 50 is ranked number 1 on the basis of releases, but number 18 on the basis of waste generation. For the same reason, eight other firms lying below the 45° line receive better release-based than waste-based rankings.

Figure 3.12
Release-Based PPF Ranks vs Waste-Based PPF Ranks
1991



3.4 Summary of Results

The ranks assigned to each of the ten representative plants using the pollution prevention metrics examined in the present study are shown in Table 3.7. The important points regarding each approach and how each compares with other alternatives have been stated in previous sections. A few points are evident in Table 3.7:

- PPF and R/T ranks correspond closely. Both take throughput into account in assessing the efficiency of the chemical usage leading to the reported releases. In two cases, plants A and B, PPF assigns better scores than R/T does. The comparatively favorable PPF rank occurs because those two plants handle only acute toxins, while many competing plants handle chemicals that are both acutely toxic and VOC. This difference reflects PPF's capability of dealing with the multi-dimensional risks associated with many chemicals.

- TRI release based ranks and TRI ratio based ranks are neither correlated with each other nor with PPF or R/T ranks. The two TRI metrics are valuable for assessing progress over time by aggregate sets of facilities, e.g., the trend in TRI releases over time at New Jersey chemical facilities. However, not taking into account the level of chemical usage at each facility limits the effectiveness of TRI release based inter-facility comparisons. Likewise, not taking level of chemical usage into account means that TRI ratio comparisons are subject to base-year limitations. This limitation results in firms that have achieved substantial pollution prevention advances prior to the base year not only receiving no credit for those achievements, but also being penalized in the sense that their efforts to achieve further improvements are likely to be more costly than efforts at firms that did little prior to the base year.

Table 3.7

COMPARATIVE POLLUTION PREVENTION RANKS OF SELECTED PLANTS 1991

Plant ID	PPF Rank	TRI Rel Rank	TRI Ratio Rank	Rel-to-Thpt Rank
A	28	44	26	45
B	32	43	37	47
C	1	5	17	1
D	32	61	57	29
E	36	63	9	34
F	36	42	62	33
G	5	11	37	5
H	4	25	58	4
I	51	62	24	49
J	3	27	18	3

4.0 PERSPECTIVE PROVIDED BY OTHER DATA

A limited number of publicly available sources of information provide perspective on the pollution prevention and other environmental activities of the New Jersey chemical firms examined in this study. Public data sources accessed with reasonable effort include: records of litigation proceedings (dockets); published rankings, such as those of The Council on Economic Priorities (CEP) and Fortune magazine; and local newspaper articles or feature stories. The difficulty in using these types of sources is that the information tends to be sparse, sporadic, and focused on the larger firms.

Two additional indicators of each firm's environmental performance can be obtained from the CRTK survey data. The first indicator is determined by assessing the "apparent quality" of the materials accounting data submitted. As described in Chapter 2, the chemical records retained for analysis in the present study are those that passed a two-percent materials-accounting-balance screening. By reviewing all the records submitted by each facility, an approximate gage of the quality of the firm's reports can be inferred by determining what fraction of their total reports passed the 2-percent screening test, and the extent of materials accounting balance error in the non-acceptable records. The second indicator of a firm's environmental performance that can be obtained from the CRTK survey submissions is the extent to which waste generation has been reduced through source reduction.[1] Because of its year-to-year nature, this information is subject to base-year dependence, but it does indicate whether the firm has given any priority to pollution prevention.

State records documenting the performance of facilities under their discharge and/or RCRA permits represent another potential indication of firms' environmental performance. These records are not kept in a centralized location, however, and are not computerized. Accessing the records requires going to each of the New Jersey regional offices and searching through file cabinets of written reports. In addition, the files for the air, water, and solid waste programs are maintained in separate files within the regional offices, and each of these files must be accessed in order to arrive at a holistic picture of the firm's performance. This level of effort is justified when a detailed evaluation of a firm is undertaken, but involves too great an effort for the screening analysis

[1]Source reduction data collected via the CRTK survey include the share of reduction attributable to each source reduction mode, e.g., materials substitution, including the quantity and identity of chemical replacement; reformulation or redesign of product; process or procedure modifications; equipment or technology modifications; improved operations; discontinuance of operations; export of use; or miscellaneous. In addition, the facility is asked whether there are plans to reduce the use of the substance or its generation as waste in the next two to five years and, if so, the quantity of reduction projected to be achieved.

undertaken in the present study.

The supplemental information assembled for the 81 New Jersey facilities is summarized in Table 4.1, listed in order of total firm employment. Facility identification number is listed in the first column; total firm employment is given in the second column; docket information in the third column identifies how many environmental litigation proceedings have been brought against that specific facility; environmental performance ratings established by CEP and Fortune magazine are shown in the fourth and fifth columns; and the last four columns show how many of the chemical records submitted by each facility designated that source reduction efforts had been accomplished in 1990 and/or 1991.

Sections 4.1 through 4.4 discuss the extent of correspondence between the environmental performance at the firms, suggested by the supplemental data, vis-a-vis the rankings determined via PPF analysis.

4.1 Litigation (or Docket) Information

The Right-to-Know Computer Network (RTK Net) based in Washington, D.C. is a joint effort of OMB Watch and Unison Institute. RTK Net contains information on U.S. facilities relating to their operations, size, environmental performance, and litigation proceedings. We accessed RTK Net to gather as much information as possible on the 81 New Jersey chemical facilities of interest. We focused on the docket file, which reports litigation brought against a facility for environmental reasons.

In Table 4.2, the PPF rankings for the years 1989 through 1991 are shown for those New Jersey chemical plants for which docket information is reported.[2] As in Table 4.1, the plants are listed by firm size. The following findings emerge from the data in Tables 4.1 and 4.2:

- Most of the dockets pertain to very large facilities, employing more that 10,000 workers. Litigation was reported for 17 of the 33 (52 percent) very large facilities among the 79 New Jersey facilities for which total employment could be identified.

- Litigation proceedings are reported in RTK Net for only 9 of the 46 (20 percent) small, medium, and large facilities (employing less than 10,000 workers).

[2]Facilities 30, 35, 53, 59, 60, and 62, for which docket proceedings are identified in Table 4.1, are not included in Table 4.2. These six facilities reported zero waste generation for two or more of the three years from 1989 to 1991, and were excluded from PPF analysis.

Table 4.1
Supplemental Data Regarding Facility Environmental Performance

ID#	Total Employ.	Docket	CEP	Fortune	Source Reduction 1990 Y	1990 N	1991 Y	1991 N
33	UNK					2		2
47	UNK					3		7
50	UNK	1				1		3
26	8				1	1	1	
21	17				2		2	4
60	18					1		1
79	18					2		10
44	20					1		3
56	25					5	2	
59	25					3		3
58	26					2		3
45	28					4		3
28	30					3		7
23	35					6	1	9
49	35					2		1
22	45				1	1	1	1
71	59	1				3		4
34	60					1		5
42	60				3	1	1	6
40	62					3		9
62	65					7		8
48	75					5		4
68	80					5	1	11
41	92					8		9
70	100					6		9
24	120					1		7
38	125					1	2	
57	150	2				2	2	5
1	160	1				5		9
52	180	2			1	7		8
51	200				2	1	2	3
75	200				1			6
67	260					5		13
35	300					3		4
37	300					4		3
46	325	1				6	1	16
20	470					6		6
65	700					2		2
32	725					1		1
25	1,000				1	4	2	4
29	1,311					2		8

Table 4.1
(Continued)
Supplemental Data Regarding Facility Environmental Performance

ID#	Total Employ.	Docket*	CEP	Fortune	Source Reduction 1990 Y	1990 N	1991 Y	1991 N
8	1,850					4		14
36	2,000				1	6	3	13
63	3,000				1			3
73	3,500					3		8
69	4,000					1		1
6	4,180					1		1
7	4,180	3			1	8	1	19
39	5,400	1				1	2	
80	6,000				3	3		10
27	6,919				1	3		5
10	9,500					10		7
81	10,200	1				4		6
76	10,500				5		6	9
77	10,500	1			4	2	1	7
78	10,500	1				1	1	1
64	12,000	2	M			7	3	6
74	13,931					1	1	
14	14,415	1				10	1	15
2	16,000				6	8	3	10
3	16,000				2	8	2	7
43	16,200			I		17		10
54	17,000	1				2		3
4	17,324				4	6		9
5	17,324	1				4		6
18	19,000				3	2	2	2
53	19,366	1				5		2
55	19,366					2	2	4
15	27,000					1		2
72	27,000					2		2
61	30,000		M*			3	7	
11	37,700	4			1	8	5	14
19	37,756	2				5		8
16	39,281			P	1	11	1	13
17	39,281	1		P	1	1		3
30	55,000	4			2	7		8
66	86,000	1				11	6	16
9	94,000		M			6		19
31	94,000		M			1	1	
12	143,961	6		P	6	25	19	36
13	143,961			P	1	1		3

Notes

Total Employ Total number of employees in company (CRTK, 1991 and FINDS, 1994)

Source Reduction: Number of chemicals for which the company employs source reduction techniques (Y = Yes), and the number for which it doesn't (N = No) The years 1990 and 1991 are represented (CRTK, 1991)

Docket Number of civil judicial cases over environmental pollution according to the DOCKET database

CEP Environmental Ratings T = Top Performer, M = Mixed Performer; M* = Nothing Outstanding Positively or Negatively, P = Poor Performer (CEP, 1991)

Fortune Magazine Environmental Ratings T = Top Performer; I = Intermediate Performer; P = Poor Performer (Fortune, 1994).

Table 4.2 Plants for which RTK NET has Docket Information				
PLANT ID#	Plant Size (based on total # of employees)	PPF RANKING BASED ON WASTES		
		1989 (n=70 plants)	1990 (n=64 plants)	1991 (n=65 plants)
50	unknown	42	NA	18
71	small	31	28	32
57	small	28	26	58
1	medium	NA	13	18
52	medium	61	61	66
46	medium	22	42	47
7	large	42	18	49
39	large	38	40	46
81	very large	31	55	54
77	very large	54	NA	11
78	very large	34	32	7
64	very large	42	17	30
14	very large	31	32	52
54	very large	3	10	15
5	very large	49	45	63
11	very large	6	NA	20
19	very large	8	52	17
17	very large	22	28	30
66	very large	60	47	62

- PPF did not rank any of the 19 plants listed in Table 4.2 among the top 20-percent of facilities for more than one of the three years from 1989 to 1991.

- Twelve of the 19 plants in Table 4.2 moved downward in PPF rank over the three-year period, three plants maintained a relatively steady rank, and only three plants improved in rank.

- All seven plants involved in more than one docket proceeding have lower PPF ranks in 1989 than in 1991.

These findings indicate a concentration of litigation proceedings among the very large firms, and an absence of litigation-involved firms among the highest PPF ranks. Regarding the former result, a skewed distribution is not surprising given the greater attention given to very large firms in the design and administration of environmental regulations.

The lack of litigation-involved firms among PPF-ranked leaders and the downward trend in performance over time by these firms, particularly those involved in multiple dockets, is somewhat surprising, however. Most of the dockets pertain to facility performance in the early and mid 1980s, while the PPF ranks are based on performance in the late 1980s and early 1990s. It would have seemed likely, especially among the very large firms, that litigation would spur the firm to greater emphasis on pollution prevention and control. The results shown in Table 4.1 suggest that this is not the case. Involvement in litigation seems to be an indication that a firm is reactive, rather than proactive, in environmental outlook, and can be expected to lag in environmental performance until a major shift in corporate perspective occurs.

When considering the preceding results, it is important to bear in mind that: (a) PPF is intended as a screening analysis, (b) the results presented here are subject to the inadequacies of reporting under the TRI and CRTK surveys, and (c) the specific characteristics of the firms involved must be reviewed before conclusions can be drawn. Nevertheless, the results do suggest that PPF-type screening represents a useful addition to the available array of analytic methods for use in comparatively assessing facility environmental performance.

4.2 Published Rankings of Firm Environmental Performance.

Two published sources of firm rankings according to environmental performance were reviewed: (1) The Council on Economic Priorities (CEP) ranked firms within four categories -- top performers, mixed performers, nothing outstanding either positively or negatively, and poor performers; and (2) Fortune magazine evaluated the environmental performance of 130 of the largest U.S. manufacturers and identified the ten leading firms, ten firms that have significantly improved their performance over the last five years, and ten laggards.

The CEP rankings for 1991 and the 1993 Fortune magazine rankings are shown in Table 4.1 for those New Jersey chemical firms receiving ranks. Only six of the very largest firms were ranked -- three firms operating four facilities were ranked by CEP, and three firms operating five facilities were ranked by Fortune magazine. Two of the CEP-ranked firms received "mixed performer" ranks,

and the third received a "nothing outstanding" rank. One of the Fortune magazine ranked firms was judged one of the ten "most improved" performers, and the other two were judged environmental "laggards."

Table 4.3
Comparison of CEP, Fortune Magazine, and PPF Rankings

PLANT ID#	Total Employ-ment	CEP Rank	Fortune Magazine Rank	PPF Score Based on Wastes		
				1989	1990	1991
64	12,000	M		55	23	33
43	16,200		I	69	64	16
61	30,000	M*		35	33	27
16	39,281		P	19	56	37
17	39,281		P	53	33	33
9	94,000	M		31	48	29
31	94,000	M		23	17	15
12	143,961		P	18	23	33
13	143,961		P	19	25	29

Table 4.3 compares the PPF ranks for these firms with the ranks assigned by CEP and Fortune magazine. The comparison indicates the following:

- None of the firms are rated "top performers" by CEP or Fortune magazine. This is consistent with the PPF rankings, which rate none of these firms within the top 20 percent of New Jersey chemical facilities.

- Two of the three facilities owned by firms rated "mixed performers" by CEP exhibit erratic PPF rankings, moving from a 55 to 23 to 33 ranking over the 1989 to 1991 period in one case, and from 31 to 48 to 29 in the other case. The third facility improved gradually in PPF rank, from 23 to 17 to 15, over the three year period.

- The firm judged as one of the ten "most improved" in environmental performance by Fortune magazine significantly improved in PPF rank, moving from a 69 to 64 to 16 ranking from 1989 to 1991.

- Three of the four facilities owned by the two firms judged poor performers by Fortune magazine declined steadily in PPF rankings from 1989 to 1991. The fourth facility improved from a PPF rank of 55 in 1989 (poor) to a rank of 33 (intermediate) in 1990 and retained that rank in 1991.

In summary, the PPF rankings have been found to correspond reasonably well with the limited amount of published data that is available to rank firms on the basis of environmental performance.

4.3 Quality of Materials Accounting Data

As discussed in Chapter 2, the quality of data collected via the CRTK and TRI surveys is of uncertain quality. Since the accuracy of PPF and other analyses depend directly on the quality of the data, it is important to select the more reliable records for analysis, and over the longer term to move toward increasingly better data quality. In the present study, a materials accounting balance threshold of two-percent was used to screen out records judged to be of unacceptable quality. In addition, records in which zero waste generation was reported for throughput quantities exceeding the survey reporting threshold were also judged unacceptable. Such a report indicates that 100 percent of entering chemical was successfully transformed to useful product, i.e., a no-loss condition has been maintained over the full year.

Having excluded records because of unacceptable materials accounting balance and/or zero waste generation, the 81 chemical facilities were assessed by PPF on the basis of those records judged acceptable. An insight into the probable reliability of the data submitted by each of these facilities can be obtained by examining the overall quality of all records submitted by each facility. For example, data from a facility that submitted five records, each of which passed the two-percent threshold and finite waste generation tests, is judged more reliable than data from a facility that submitted 7 records, only three of which passed the screening test. Likewise, if the 4 non-acceptable records from the latter facility had an average materials accounting error of four-percent, the records from this facility would be judged of higher reliability than the records from another facility having 3 acceptable records and 4 non-acceptable records averaging a ten-percent materials balance error.

Table 4.4 presents the data quality assessment results compared to the PPF rankings for the 81 New Jersey facilities. Each facility is designated as having submitted data that are of excellent, good, poor, or mixed quality on the following basis: (1) facilities in which all records satisfy the materials balance and finite waste thresholds are judged to have submitted data of excellent quality; (2) facilities for which 70 percent or more of the records satisfy the two screening criteria and the non-acceptable records have a materials accounting error of less than 5 percent are judged to have submitted data of good quality; facilities for which less that 30 percent of the records are acceptable or the average materials accounting balance error of the non-acceptable records is 10-percent or more are judged to have submitted records of poor data quality; and (4) all other facilities are judged to *have submitted data of mixed data quality.*

TABLE 4.4 COMPARISON OF PPF RATING AND DATA QUALITY RATING 1990				
PPF RATING BASED ON PPF SCORE*	DATA QUALITY RATING**			
	Excellent	Good	Mixed	Poor
Excellent	7	0	2	3
Good	6	0	2	4
Mixed	14	3	3	3
Poor	6	0	1	5
TOTAL	33	3	8	15

* PPF Ratings are based on the percentile PPF rank, as follows:
Excellent (Top 20%), Good (21%-40%), Mixed (41%-80%), and Poor (Bottom 20%)
** Data Quality Ratings are based on # of acceptable reports (meeting the <= 2.0% MBE and total waste > 0 requirements), as follows:
Excellent (100% of reports acceptable); Good (70% or more of reports acceptable and MBE% of unacceptable reports < 5.0%); Poor (less than 30% of reports acceptable OR the MBE% of unacceptable reports greater than 10%);
Mixed (all other facilities)

The following observations can be made based on the data quality results shown in Table 4.4:

- Over half of the 59 facilities evaluated submitted data of excellent quality, as defined by the criteria above, in their 1990 CRTK survey responses.

- Data quality was either excellent or poor among the facilities evaluated. Fifty-six percent submitted excellent quality data, and 25 percent submitted poor quality data. Only 19 percent submitted reports judged to be of either good or mixed quality.

- Little correlation was found between the PPF ratings of facilities and the quality of data submitted by those facilities.

- One potential use of the result is to recompute the PPF analysis placing greater uncertainty on data from those facilities submitting poorer quality data. The largest modification of PPF results would occur if one of the poor-data-quality facilities functions as a PPF frontier facility.

4.4 Implementation of Source Reduction Initiatives

The source reduction information for each plant given in Table 4.1 is compared in Table 4.5 with PPF rankings for those plants in each of the three years. To illustrate, plant 8 reported that no source reduction was undertaken with regard to the four chemicals they reported in 1990, nor with regard to the 14 chemicals reported in 1991. Plant 8 was ranked 20 by PPF in 1989 and 1990, then fell off somewhat to 32 in 1991. Plant 13, listed at the bottom of the first page of Table 4.5, implemented source reduction for the one chemical it reported in 1990, but exercised no source reduction for the three chemicals it reported in 1991. Plant 13 had a PPF rank of 17 in 1989, 18 in 1990, then fell off to 27 in 1991. The following observations can be made with regard to the data in Table 4.5:

- There seems to be little correlation between a facility's reporting source reduction activity in the CRTK survey and that facility being highly ranked by PPF.

- It seems likely that a consistent pattern of source reduction over a period of years will result in higher PPF rankings. The lack of such correlation in the two years examined may stem from the base year effect already discussed with regard to TRI ratios.

Table 4.8
(Continued)
Correspondence Between Source Reduction and PPF Rankings

		Source Reduction				PPF Ranking Based on Waste		
ID#	Total Employ	1990 Y	1990 N	1991 Y	1991 N	1989	1990	1991
8	1,850		4		14	20	20	32
36	2,000	1	6	3	13			
63	3,000	1			3			25
73	3,500		3		8	58		
69	4,000		1		1		9	9
6	4,180		1		1	26	7	8
7	4,180	1	8	1	19	42	18	49
39	5,400		1	2		38	40	46
80	6,000	3	3		10	42	32	48
27	6,919	1	3		5	11	11	14
10	9,500		10		7	22	30	20
81	10,200		4		6	31	55	54
76	10,500	5		6	9			
77	10,500	4	2	1	7	54		11
78	10,500		1	1	1	34	32	7
64	12,000		7	3	6	42	17	30
74	13,931		1	1		1	4	1
14	14,415		10	1	15	31	32	52
2	16,000	6	8	3	10	38	21	22
3	16,000	2	8	2	7	10	24	25
43	16,200		17		10			13
54	17,000		2		3	3	10	15
4	17,324	4	6		9	7	1	1
5	17,324		4		6	49	45	63
18	19,000	3	2	2	2	2	5	
53	19,366		5		2			
55	19,366		2	2	4	13	30	37
15	27,000		1		2	13	26	45
72	27,000		2		2	34	8	9
61	30,000		3	7		34	50	59
11	37,700	1	8	5	14	6		20
19	37,756		5		8	8	52	17
16	39,281	1	11	1	13	9	58	56
17	39,281	1	1		3	22	28	30
30	55,000	2	7		8			
66	86,000		11	6	16	60	47	62
9	94,000		6		19	57	49	23
31	94,000		1	1			15	12
12	143,981	6	25	19	36	51	21	51
13	143,961	1	1		3	17	18	27

Notes

Total Employ Total number of employees in company (CRTK, 1991 and FINDS, 1994)

Source Reduction: Number of chemicals for which the company employs source reduction techniques (Y = Yes), and the number for which it doesn't (N = No) The years 1990 and 1991 are represented (CRTK, 1991)

Table 4.5
Correspondence Between Source Reduction and PPF Rankings

		Source Reduction				PPF Ranking Based on Waste		
ID#	Total Employ.	1990 Y	1990 N	1991 Y	1991 N	1989	1990	1991
33	UNK		2		2	51	23	27
47	UNK		3		7	42	43	50
50	UNK		1		3	42		18
26	8	1	1	1				
21	17	2		2	4	38	60	60
60	18		1		1			
79	18		2		10	49	44	42
44	20		1		3	55		
56	25		5	2		25		39
59	25		3		3			
58	26		2		3	34	54	64
45	28		4		3	30	38	36
28	30		3		7	51	48	57
23	35		6	1	9	56	56	61
49	35		2		1	59	59	65
22	45	1	1	1	1	38	32	41
71	59		3		4	31	28	32
34	60		1		5	15	13	6
42	60	3	1	1	6	28	51	40
40	62		3		9	16	1	3
62	65		7		8			
48	75		5		4			
68	80		5	1	11	26	32	44
41	92		8		9	62	57	16
70	100		6		9	19	16	23
24	120		1		7		53	53
38	125		1	2		42	24	27
57	150		2	2	5	28	26	58
1	160		5		9		13	18
52	180	1	7		8	61	61	66
51	200	2	1	2	3	42	39	32
75	200	1			6	5	6	5
67	260		5		13	12	41	43
35	300		3		4			
37	300		4		3	17	3	4
46	325		6	1	16	22	42	47
20	470		6		6	21	32	38
65	700		2		2	63	46	55
32	725		1		1			
25	1,000	1	4	2	4			
29	1,311		2		8	4	12	32

5.0 POTENTIAL POLICY AND PRIVATE SECTOR APPLICATIONS

The analyses conducted in the two phases of the PPF project help bridge the gap between the policy analysis functions of EPA and its regulatory responsibilities. As EPA attempts to develop more collaborative arrangements with the regulated population, its' data and information management needs will alter and grow. In the following sections, we discuss potential policy actions that might help EPA address some of these data issues, and comment on how the work reported here and in the earlier report, titled "Pollution Prevention Frontiers (PPF): An Approach to Measuring Pollution Prevention Progress," may assist in this effort. Specific issues addressed are:

- how PPF supports comprehensive approaches to data collection and evaluation;
- how EPA can use PPF for monitoring and evaluation purposes; and
- how PPF can be used for diagnosis and managerial control within industry.

5.1 Policy Options for Data Collection and Evaluation

The demand for reducing the burden on industry of government regulations poses a dilemma for EPA. The dilemma arises from the fact that a collaborative approach increases the flexibility in the interactions between EPA and the organizations it oversees. This greater flexibility creates the opportunity for increased diversity in the approaches undertaken to achieve pollution prevention and control. In order to fairly monitor the resulting broader set of options, different types of information are required to insure that the various regulatory and enforcement goals are met. As a result, coincident with greater latitude in their interactions with EPA, the regulated organizations may be required to report additional information in order to enable EPA to fairly evaluate the spectrum of proposed environmental compliance options. Hence, with the increase in flexibility in ways of achieving pollution prevention and control, there may also be a requisite increase in the amount and variety of data collected.

Among the initial steps in moving toward such a more flexible system, EPA may need to re-evaluate what additional types of data must be collected. As part of this evaluation, EPA may also need to develop a more comprehensive information evaluation and management system in order to support the evaluation of the more diverse approaches undertaken to satisfy environmental mandates. The emerging call for increased reliance on risk-based mandates illustrates the nature of more

complex regulatory analyses that appear inevitable as the relative benefits and costs of diverse types of options must be comparatively evaluated.

Some of the criteria we implemented in determining the adequacy of the data and the analytical tools for evaluation of pollution prevention and control efforts include: (1) public availability; (2) independence from a base year; (3) utility for screening non-regulatory interactions, (4) the ability to synergistically incorporate multidimensional risks.

- **Public availability of data:** For the analytic approach to be useful in policy applications, it is essential that the data employed be publicly available. Discussion of policy issues is hampered when the data on which analyses are based cannot be subjected to broad public scrutiny. PPF has been designed to extract as much information as reasonable from the most extensive public assembly of data characterizing pollution prevention performance at industrial facilities. As discussed in footnote 7 of Chapter 1, more detailed evaluation of firm performance is possible, but the information requirements rise sharply when the needed data are not publicly available.

- **Independence from a base year:** The ability of a firm or plant to reduce its pollution levels depends upon the level of success it has already had with pollution prevention efforts. Clearly, firms that have not made any effort will seem to make big strides, particularly in percentage terms, when they first begin to implement pollution prevention and control strategies. Thus, in order to be fair, performance evaluations should take previous efforts into consideration or, alternatively, conduct evaluations that are not based an arbitrary starting date.

- **Utility for screening non-regulatory interactions:** As the scope of EPA's activities continues to expand beyond regulatory actions to include increased efforts in information dissemination, technical assistance and other forms of support, EPA will need to determine how to effectively couple these activities with economic and other types of incentives. The information required for such activity is qualitatively different from that used for regulation and control. Furthermore, the analyses must become more sophisticated in order to determine who should receive what form of assistance, i.e., incentives or disincentives. Oftentimes, the data required for such evaluations are episodic, i.e., are not available on a continuous basis, hence the data systems required are different from those traditionally used for monitoring purposes.

- **Multidimensional Risks:** It has been know for some time that pollutants are frequently not confined to a single hazard category, nor do they necessarily pose the same risks when in the presence of other pollutants or products. The data systems required to monitor these multidimensional risks and the analytical tools required to evaluate such data must be capable of analyzing the synergistic nature of combinations of pollutants and their corresponding risks.

Over the two phases of the PPF project, we have concluded that it is possible, albeit for a limited number of chemicals used in certain segments of the chemical industry, to collect data and analyze them so as to provide information that meets the above criteria, and thereby to evaluate the comparative effectiveness of pollution prevention efforts at industrial firms. This determination is based on an audit of the data publicly available on these chemicals, and the process of embedding these data within a materials accounting framework in order to evaluate the quality of these data.

Information Audit: Policy implementation, particularly for an agency such as the EPA, relies heavily upon the Agency's ability to acquire and analyze reliable data. Therefore, in the first part of this study we invested heavily in conducting a thorough **information audit**. We identified by source and nature the publicly available data that might be used to monitor pollution prevention efforts. The major sources of the data identified were the TRI survey and the New Jersey Worker and Community Right to Know (CRTK) Act survey.

The purpose of this audit was to organize in one location all publicly available, internally consistent data that pertain to the evaluation of the pollution prevention efforts of a significant industrial sector -- New Jersey chemical manufacturers categorized in Standard Industrial Code 28. This effort identified for consideration by policy makers the type of pollution-prevention-relevant data that could be assembled with a reasonable degree of effort. Having identified all publicly available data, the project undertook: (1) to evaluate the reliability of these data, and, more importantly, (2) to determine the value of these data in supporting decision making processes within EPA and within industry.

Evaluation of Data Reliability: The framework we used to evaluate these data is the **materials accounting (balance) approach**. This approach assesses the reasonableness of reported data in terms of the balance between the quantity of chemical input versus the quantity of chemical consumed or output. The National Academy of Science in reviewing the utility of materials accounting data notes that the materials accounting approach "could be useful in comparing operations in a given industry or in different industries that use the same listed chemical. It could also be useful for assessing the reasonableness of reported release estimates."[1] As our study demonstrates, reconciling such data given the current state in which they exist is, while useful, a laborious and painstaking process.

Given that the collection and transmission of much of the data used in this study is required by various state or federal agencies, the policy issue facing EPA is whether it should invest in a comprehensive information system to maintain these data in a readily accessible fashion. Crucial information for this decision would be a comprehensive audit of the data that are currently collected. Although limited to one aspect of the chemical industry, we have demonstrated the feasibility of such an exercise. As the demand for reducing the burden of complying with various government rules and regulation increases, EPA, having conducted such an audit will be well positioned to comment on the type of data being currently collected, and eventually determine where data redundancies exist, where reporting requirements might be changed in light of up-to-date information on potential hazards and risks associated with the chemicals under consideration and how these data serve the needs of EPA in the execution of its various policy formulation, implementation and evaluation functions.

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[1]National Academy of Sciences. "Tracking Toxic Substances at Industrial Facilities: Engineering Mass Balance versus Materials Accounting" National Academy Press, Washington DC, 1990, p. 3-4.

We have also demonstrated that it is possible to build simple checks into the system that are based upon materials accounting principles. These consistency checks would ensure a minimal level of data reliability. In addition to helping evaluate data quality by determining whether the materials accounting balance is achieved, the materials accounting approach offers the capability to conduct alternative analyses. Throughput data, which represents a central component of materials accounting data, not only allows analyses that are independent of base year, but also provides valuable indicators of data quality. For example, the reasonableness of reported waste-to-throughput ratios can be assessed in terms of the activities being undertaken in the use of each chemical.

Materials accounting data also provide an initial basis for life cycle analyses of the reported chemicals. To illustrate, between 1988 and 1991 New Jersey firms reported shipping off-site as-or-in products approximately 7 million pounds of 1,1,1-trichloroethane. Over the same period, 2.3 million pounds of 1,1,1-trichloroethane were reported as released to the environment during manufacturing activities at these facilities. The TRI data record only the quantity released during manufacturing. However, during use of 1,1,1-trichloroethane in coatings and other applications, nearly all of the chemical is released to the environment. As a result, within a period of three to twelve months most of the chemical shipped off-site within products will have been released to the environment. Thus, a more accurate estimate of 1,1,1-trichloroethane releases to the environment associated with the New Jersey facilities between 1988 and 1991 is 9.3 million pounds. From this life cycle perspective, TRI reporting identifies only 25 percent (2.3/9.3) of the actual environmental load.

As the 1,1,1-trichloroethane example illustrates, a materials accounting framework provides the perspective for evaluating environmental releases in other phases of the chemical's life cycle. Collection of such data on a national basis would enable the characterization of chemical flows from origin to final consumption. Presently available data are insufficient to accomplish this task. A general body of knowledge exists that identifies for major chemicals the general types of uses, and in some cases approximate estimates of usage quantities, and TRI data codifies the reported quantities of specified chemicals that are released during at manufacturing facilities. The materials accounting framework would establish a comprehensive database identifying how TRI chemicals flow into, between and out of manufacturing facilities, as well as the environmental releases that occur during manufacturing operations. This type of approach is one of three models EPA is considering for updating and expanding the Chemical Usage Inventory (CUI) program.

Evaluation of Data Value: To assess the value of materials accounting data, it is important: (1) to clearly identify and define the criteria by which the pollution prevention efforts are to be judged, and (2) to determine the types of data summaries and analyses that will be used to make these judgments. It is clear from the analyses presented here that the types of measures that can be constructed are severely limited by the availability of data. Hence, in order to fully exploit the potential of PPF as an analytical tool, EPA, in conjunction with industry and other stakeholders, would have to determine the criteria by which the pollution prevention efforts to are to be judged. This study demonstrates the flexibility of the PPF approach in developing different measures of performance that emphasize different aspects of pollution prevention performance. Once the evaluation criteria have been established, PPF, in conjunction with other data analysis tools, can be used to develop the measures necessary to determine whether the established performance criteria are being met. Thus, PPF analysis offers another check of the value of the data being collected in terms of its utility for analysis.

In this context, determining the nature and type of data that are necessary for EPA to fulfill

its expanded policy analysis and performance role represents a central data management challenge facing EPA. The Agency will have to rethink its data needs, preferably with inputs from industry and other stakeholders, and design a database management system sufficient to utilize these data in conduct of increasingly complex policy analyses.

5.2 Potential Applications of Pollution Prevention Frontiers

PPF indices can be developed and used by EPA and industry to serve a variety of diagnosis, monitoring and control functions. Illustrative applications are discussed for the public and private sectors in the following sections.

Potential Applications within EPA

PPF indices can be used by EPA for both policy formulation and evaluation.

Diagnosis: For policy formulation, PPF can be used as a diagnostic tool to explore the implications of using different criteria and their associated measures. Given the flexibility of the PPF indices, EPA could use this approach as a data exploration and reduction tool that yields simple qualitative rankings. Analysis of the different measures obtained by using various criteria could help determine the implications of implementing different policy options. These PPF indices, could then also serve as points of departure for discussions, with the industry and other stakeholders, on evaluation criteria and their implications in terms of data requirements and implicit incentives. PPF is particularly suited for such discussions since the concepts underlying the technique are intuitively straightforward in that the index is based on comparisons with the best observed practice. Furthermore, the criteria used in these computations are explicitly stated, and the decision rule for is that each plant be shown in its best possible light. These measures can be, therefore, be perceived as being fair in that they take into consideration the context within which the different plants operate.

Attention Focusing and Screening: Given the current quality of the data and the exploratory nature of the indices, the PPF approach has not yet been validated for use for valuative and control purposes. However, even at this formative stage it can be used to distinguish between leaders and laggers, in terms of pollution prevention efforts, within the industry. This qualitative partitioning into two groups can serve as a screening device for focusing attention on plants whose performance seems to be exceptionally good or poor. Validation of the index as a viable measurement tool can then be done through case studies of the plants that have been thus identified.

Evaluation and Monitoring: Once the PPF indices have been validated they can be used for evaluating pollution prevention efforts. The evaluation can be done with respect to the performance of other plants in the industry or against a pre-defined benchmark. Incentive structures could be designed to effect improvements relative to other plants as well as for rewarding innovations that improve the overall performance of the industry. Improvements over time, of the whole industry or of individual plants can be studied by analyzing movements in the PPF frontier. Thus, the PPF approach yields information not only on average improvements in the industry but also plant specific information relative to the performance of the industry. Thus a variety of incentive structures can be designed which reward or punish plants for their performance, relative to themselves, relative to the best observed practice, relative to some industry average, or some combination of these relative measures.

Information Dissemination: PPF, unlike many other data reduction techniques yields plant specific information which can be useful for developing databases where the best practices in the industry can be documented and information can be shared, subject to confidentiality restrictions, on how performance might be enhanced by emulating the best practice.

Additionally, the public release of plant specific rankings of pollution prevention activity can serve as a powerful motivator for improving performance without having to resort to specific incentives.[2]

Potential Applications within Industry

Much of the value of the PPF analysis for EPA can be translated fairly readily to individual companies or plants. In particular, companies can maintain their own PPF indices for comparisons among multiple plants or vis-a-vis plants of other companies, e.g., benchmark facilities. In this way, PPF results can be used as a motivator for effective self regulation and compliance

For a variety of reasons, mainly pertaining to the confidentiality of the production activities, detailed data of the type needed for monitoring and assessing managerial performance are seldom publicly available. However, companies, can implement PPF indices for their own internal monitoring and use PPF for managerial control.

Diagnosis: As industry attempts to design new technologies in response to emerging environmental imperatives, PPF analysis can be used constructively at the process level. PPF can be first used to establish performance benchmarks, and then to monitor process performance with respect to these benchmarks. Using data not available in the public domain, companies could construct indices that go well beyond the ones discussed in this report. These indices would provide insights regarding the relative performance of various processes and/or manufacturing activities, as well as other managerial and economic initiatives.

Managerial Control: Measures of organizational effectiveness, as well as those of managerial output and outcomes, can be developed using the computational techniques underlying PPF. The precise nature of these measures would be designed to support specific organizational goals and objectives. However, the basic logic of the PPF approach could implemented using data not pertaining to pollution prevention activity.

Process Control: The PPF indices constructed to measure pollution prevent effort can be used, as is or in some modified form, to monitor process quality. Using concepts similar to those from Statistical Quality Control, PPF indices can be implemented to provide a multidimensional view of process performance. Process monitoring using pollution prevention as a criterion for superior performance can be readily done using the PPF indices without any modification. However, other aspects of process performance, including for instance output measures, downtime, and other engineering criteria would have to be incorporated to obtain a complete indicator of process performance.

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[2]Evidence of the effectiveness of such public release of information can be seen, for instance, by the influence of the J.D. Power and Associates' survey of consumer satisfaction in the car industry, or the FAA's release of "on-time" data for the airlines, and even by the effect of occasional rankings of companies' environmental performance by magazines such as Fortune and Business Week.

6.0 SUMMARY AND CONCLUSIONS

As stated in Section 1.1, the objectives of Phase 2 of the PPF project were:

- To assess the nature and quality of materials accounting data collected in New Jersey for the years 1989 through 1991, and identify any potential benefits that might be gained by extending the Toxics Release Inventory (TRI) survey to include additional data elements contained in the New Jersey data.

- To compare the results obtained via PPF analysis of pollution prevention performance at New Jersey chemical firms over the 1989 through 1991 period vis-a-vis results obtained by alternative measurement approaches.

- To compare the facility performance ratings obtained via PPF analysis with ratings suggested by other types of data that offer insights into environmental performance at the New Jersey facilities.

- To identify potential policy applications of PPF analysis in the public and private sectors.

The following sections summarize the findings achieved with regard to each objective during the present study.

6.1 Usefulness of Materials Accounting Data

Materials accounting data have been shown to provide an extremely valuable, arguably needed, perspective on the release and waste generation estimates reported in response to the annual TRI surveys. Useful applications of this data include:

- Materials accounting data provide a useful check on whether the TRI-reported data are internally consistent with overall usage data for the chemical at the reporting facility. While exact closure may not be established, depending upon the method of estimating some of the chemical usage variables, the quantity of chemical available for use

during the year should approximately equal the quantity used, i.e., an approximate materials accounting balance should be achieved. When the data fail to satisfy this consistence check, further examination of the data submission is in order.

- Materials accounting data also provide a basis for life cycle analysis of the chemicals of interest. As the 1,1,1 trichloroethane example in Chapter 5 illustrates, the bulk of a chemical's releases may occur in pre- or post-manufacturing phases of its life cycle. Materials accounting data provide useful input into analyses to more precisely pin down the sources of greatest environmental releases for the chemicals of interest.

- Collection of materials accounting data on a national basis would facilitate establishment of a reasonably complete picture of the flows of chemicals within our economy and the points at which most significant environmental releases occur.[1] Total annual production quantities of most organic chemicals are already reported to the Census. National materials accounting data would extend this information by identifying where the bulk of this production occurred and where the chemical was consumed in what types of applications. This data could be used for life cycle analyses, as described above, and gaps in the pattern of chemical flows could be readily identified and studied.

- The New Jersey survey also collects information on the nature and intensity of the manufacturing activity using the reported chemical. For example, in 1990 5,000 pounds of the chemical may have been consumed in the production of 200 refrigerators, and in 1991 the chemicals usage may have grown to 6,000 pounds in the production of 220 refrigerators and 50 desks. This type of information can be used in production normalized assessments of the effectiveness of pollution prevention at facilities producing similar types of products.

6.2 PPF vis-a-vis Other Pollution Prevention Metrics

Comparison of PPF with pollution prevention assessments based on total TRI releases, year-to-year ratios of TRI releases, and waste-to-throughput ratios have shown that each have certain advantages. Use of throughput as a normalizing factor was found to provide an invaluable perspective on the efficiency of chemical usage.

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[1]Collection of facility-specific materials accounting data is one of three approaches EPA is currently considering for collection of chemical use inventory (CUI) data.

- Comparisons of facility ranks based on total TRI releases or year-to-year TRI ratios were found to bear little relationship to ranks based on release-to-throughput ratios:

  - **Total TRI releases** are primarily an indication of the **size of the facility**. An illustration in Chapter 3 shows how a single facility reporting the same release quantity of a chemical as five smaller facility has nearly four times the throughput as those five facilities, i.e., is nearly four times as efficient in chemical usage even though reporting larger total releases.

  - **Year-to-year TRI ratios**, on the other hand, suffer from **base-year dependence**. Facilities that have done little pollution prevention prior to the base year may achieve significant year-to-year improvements at lesser efforts than facilities that had proactively conducted substantial pollution prevention prior to the base year.

- **Waste-to-throughput ratios** are not effective as a basis for assessing improvements in **dispersive chemical usages**. These include applications, such as volatile solvent use, where the quantity of materials entering the application identically equals that leaving the system, because the entering materials directly replace losses to the environment. In such cases, the waste-to-throughput ratio remains equal to unity irrespective of changes in the efficiency of usage. Relatively few dispersive chemical applications were reported at the New Jersey chemical facilities analyzed, however. Thus, the benefits of the throughput ratio in **surmounting the base year barrier** at the New Jersey facilities substantially out weighed the difficulties in its use in the few reported dispersive chemical applications.

  If a situation were encountered in which a significant fraction of the chemical uses did involve dispersive applications, the **units of production** data being collected by the New Jersey survey might be used (instead of throughput) to normalize waste generation.

- **PPF analysis** represents an important extension of waste-to-throughput ratios when the chemical population poses multiple risks, such as carcinogens, mutagens, acute toxins, urban ozone precursors, global warming contributors, and others. PPF was designed to easily accommodate such multiple risk factors and, as discussed in Chapter 5, future policy evaluations will increasingly have to deal with such complexities.

6.3 PPF Ranks Compared to Other Facility Ratings

Publicly available data providing comparative rankings of the environmental performance of industrial facilities and firms are limited. Information that was identified included: litigation proceedings (or dockets); published rankings by the Council on Economic Priorities (CEP) and by Fortune magazine; assessments of the data quality of reports submitted in CRTK survey; and indications in the CRTK survey that source reduction had been undertaken. Although the supplemental data was limited in quantity, the associated facility ratings corresponded reasonably well with facility rankings generated by PPF. The following results were obtained:

- Over half of the very large New Jersey chemical facilities (employing more than 10,000 workers) have been involved in litigation, as compared to litigation involvement by only one-fifth of all smaller facilities. This skewed distribution is not surprising given the greater attention given larger, technically sophisticated firms in regulatory design and enforcement.

- None of the New Jersey facilities involved in litigation were ranked by PPF among the top 20-percent performing facilities. Sixty percent of the litigation-involved facilities moved down in PPF rank between 1989 and 1991, 20 percent remained steady in rank, and only 20 percent improved in PPF rank. None of the plants involved in more than one litigation proceeding improved in PPF rank over the three year period. As discussed in Chapter 4, these results suggest that:

  (a) PPF ranks are consistent with the litigation results, assuming that participation in litigation represents a failure in environmental performance; and

  (b) involvement in litigation seems to indicate that a firm is reactive, rather than proactive, in environmental outlook, and will continue to lag in performance until a fundamental shift in perspective occurs.

- None of New Jersey firms are rated top performers by CEP or Fortune magazine. PPF rankings are consistent with this result in that none of the firms are ranked in the top 20 percent by PPF. The movement of the firms in PPF rank over the 1989 to 1991 period was consistent with the ratings of those firms by CEP and Fortune magazine. For example, three of the four facilities owned by two firms ranked poor performers by Fortune magazine declined steadily in PPF rank over the three year period, and the fourth facility improved from an initially poor rank, but then remained in the middle rank of facilities.

- Neither facility ratings based on the data quality of their survey submissions nor the reported undertaking of source reduction by facilities appeared to be correlated with the PPF ranks for these facilities. The former finding suggests that sensitivity analyses of PPF rankings be conducted with each facility's performance weighted according to the estimated quality of its data. The latter finding is probably attributable to the base year effect, i.e., some of the facilities undertaking source reduction in the two years for which this information has been collected may not have initiated much pollution prevention in prior years.

6.4 Potential PPF Policy and Private Sector Applications

Economic considerations and the growing importance of pollution prevention are bringing increasing pressure to bear on EPA to develop a more collaborative relationship with the regulated population. As greater flexibility is introduced in the way environmental goals may be achieved, EPA's need for more comprehensive data characterizing a wider range of environmental actions will continue to expand. For example, increased consideration of the risk implications of alternative regulatory approaches will require more refined delineation of the context within which releases will occur. As discussed in Chapter 5, PPF has the capability to accommodate and analyze such a wide variety of data. Potential applications in the public policy and private sector arenas include:

- PPF applications in policy analysis fall into four general categories:

  - **Diagnosis**: As EPA explores different, more flexible monitoring and reporting arrangements, PPF provides a multidimensional approach to assessing the value of available data for valuative and decision making purposes.

  - **Attention Focusing and Screening**: PPF provides a qualitative partitioning of plants into leaders and laggers. This partitioning can serve as a valuable first step in identifying exceptional plants and focusing attention on their exceptionally poor or good performance.

  - **Evaluation and Monitoring**: Once the validity of the PPF measures has been established, they can be implemented in a management system for evaluating and monitoring pollution prevention activity.

  - **Information Dissemination**: EPA can serve as a data clearing house and use PPF to provide plant-specific information, in contrast to the industry averages generally available for valuative purposes.

- Many of the benefits of PPF analysis that apply to the public sector can be transferred directly to private sector applications. Three potential applications are:

  - **Diagnosis:** Industry can use PPF measures to diagnose the implications, with respect to EPA's criteria, of different pollution prevention options. Compared to the analyses that can be done with publicly available data, industry will be able to conduct mush richer analyses and obtain valuable insights into the relative merits of different options.

  - **Managerial and Process Control:** As a generic approach for constructing multidimensional indices, the computational models underlying PPF can be readily modified to develop indices of managerial and process performance and to link these measures to other measures of pollution prevention.

APPENDIX A

OPERATIONALIZING MEASUREMENT WITHIN THE MATERIALS ACCOUNTING FRAMEWORK

APPENDIX A

Operationalizing Measurement Within the Materials Accounting Framework

The purpose of this appendix is to describe the mathematical basis for the construction of Pollution Prevention Frontiers and the ensuing indices for comparing the pollution prevention performance of industrial facilities. Other uses of DEA for environmental applications are briefly considered.

A fundamental goal of pollution prevention is to minimize the amount of pollutant or waste (Q_{wst}) generated per unit of product output (P). The objective for developing an analytical framework for comparing the performance of a plant in terms of its success at reducing pollutants per unit of production is threefold: (a) for *focusing attention*, (b) for *diagnosis*, and (c) for *feedback*. Finally, if and when the validity and reliability of the performance indicators have been established, the information could be used for *control*. Implicit in the analytical framework is a metric to measure the level of performance of each plant. This appendix discusses the nature of the PPF metric employed to determine the level of performance at each plant.

The value of the proposed metric depends crucially on the criteria established for evaluation and the ability to reliably operationalize the performance criteria into valid measures (Desai, 1992). The Materials Accounting approach discussed in Section 1 of Chapter 2 of the report offers a framework within which the measurement of pollution prevention efforts can be operationalized. Chemical processes, in general, use and produce chemicals according to well defined formulae. Therefore, it is theoretically possible to identify for each process the minimal amount of pollutants that will be generated by that process. However, for a variety of reasons, these theoretical minima are rarely attained. Oftentimes, the problem is further compounded by the fact that a particular chemical can be produced a number of ways and different plants use different technologies for reducing pollution. Hence, the motivation for PPF is the development of a common index on which various plants, producing a variety of chemicals using different chemical processes, can be evaluated in terms of the amount of pollutant generated per unit of production activity.

The problem of evaluating or ranking plants when they produce a single product and a single pollutant is trivial. The plant that generates the minimum amount of pollutant per unit product is obviously the best. The performance of other plants can be evaluated relative to the performance of this plant. The required index is simply an ordering of this ratio of pollutant to product, the smallest implying the best performance and the largest indicating the worst. The problem of constructing an index, however, becomes non-trivial when multiple products are produced resulting in multiple pollutants. The extension of the simple ratio analysis to multiple dimensions can be effected in a number of ways as documented, for instance, in the literature on economic indices [Caves, Christensen and Diewert, 1982; Malmquist, 1953; Tornquist, 1936]. The PPF index is the result of implementing a mathematical-programming-based index-construction technique in the context of pollution prevention. This index-construction technique, called Data Envelopment Analysis (DEA), has its basis in operations research and the economic theory of production.

While this index has its origins in the economic theory of production, its mathematical formulation is independent of that theory. In the context of comparing the pollution prevention efforts of plants, the index to be developed corresponds to the following verbal statement:

Find a multivariate ratio which (1) characterizes each plant in terms of its activity levels and pollutants and (2) provides an ordering, from best to worst, of plants with similar activity and pollutants.

Considering, for the purposes of illustration, the level of activity at a plant to be measured by the amount of product generated, then, a multivariate ratio that meets the above description can be expressed, for each of n plants, as:

$$\frac{\sum_q w_q I_q}{\sum_h u_{hj} P_{hj}}, \qquad 1 \le j \le n \tag{1}$$

Where: P_{hj} = Amount of product h being produced at plant j
I_q = Amount of pollutant q being produced at plant j and
u_{hj} and w_q are weights assigned to the products and the pollutants.

Thus, we have in (A.1) the ratio of a *virtual* pollutant to a *virtual* product, where the virtual pollutant is the weighted linear combination of pollutants and the virtual product is the weighted linear combination of products. Given this characterization of the plants' activity, the computational issue to be addressed is (a) how should the weights u and w be obtained and, subsequently, (b) how should the ordering of these plants be achieved.

In creating DEA, Charnes, Cooper and Rhodes (1978) proposed a mathematical programming formulation of this problem that simultaneously solves for the weights, and provides a relative ordering of these plants. The weights are to be selected such that each plant obtains a score that places it in the best possible light. Ideally, each plant would want to minimize (1) or, conversely, maximize the inverse of (1). Charnes, Cooper and Rhodes (CCR) formulated the problem in terms of maximizing the inverse of (1). Since the weights are to be "objectively" assigned so as to maximize this ratio, the size of the ratio has no upper limit. In order to bound the maximum value that any plant could obtain, CCR proposed an upper bound of 1. CCR operationalized the above verbal statement of the problem as follows:

Find weights u_{hj} and w_q such that the ratio of virtual products to virtual pollutants (i.e., inverse of (1)) is maximized subject to the constraint that no ratio exceeds unity.

The mathematical expression for this statement is:

$$\textit{Maximize} \qquad e_j = \frac{\sum_h u_{hj} P_{hj}}{\sum_q w_{qj} I_{qj}} \tag{2}$$

such that

$$\frac{\sum_h u_{hj} P_{hj}}{\sum_q w_{qj} I_{qj}} \le 1 \qquad \forall i = 1, 2, \cdots, n \tag{3}$$

$$w_{qj} \textit{ and } u_{hj} \ge 0 \qquad \forall j. \tag{4}$$

where e_j is value of the ratio associated with plant j. Note that this value is bounded above at 1 and is always positive. This fractional program was, as mentioned above, developed in the context of production theory. In that context, the numerator denotes a *virtual* output, being the combination of actual outputs, and the denominator denotes a *virtual* input, being the combination of actual inputs.

Charnes and Cooper (1962) developed a transformation that yields a linear equivalent for the fractional program (2)-(4), thereby considerably simplifying the computation of e_j The fractional program yields an infinite number of solutions. For example, if (u, w) is an optimal solution, then $(\alpha u, \alpha w)$ is also optimal for $\alpha > 0$. Transforming the variables (u, w) into (μ, v), CCR offered the following equivalent linear programming formulation, which is representative of one of the potential solutions of (2)-(4):

$$\max_{\mu, v} \; z = \mu^{\tau} P_j \tag{5}$$

$$s.t. \quad v^{\tau} I_j = 1 \tag{6}$$

$$\mu^{\tau}P - \nu^{\tau}I \leq 0 \tag{7}$$

$$\mu^{\tau},\nu^{\tau} \geq 0. \tag{8}$$

The corresponding dual of (5)-(8) is as follows, where λ is a vector of weights and θ is the measure of performance.

$$\min_{\theta,\lambda} \theta, \tag{9}$$

$$s.t.\ P\lambda \geq P_j \tag{10}$$

$$\theta I_j - I\lambda \geq 0, \tag{11}$$

$$\theta\ free,\ \lambda \geq 0. \tag{12}$$

Over the decade-and-a-half since Charnes, Cooper, and Rhodes' original work, a number of variations of these linear programs have been developed and implemented in a variety of contexts. For instance, the ratio (2) can be maximized either by maximizing the numerator for a given value of the denominator or the denominator can be minimized for a given value of the numerator. Each of these options yields a different linear program. Similarly, different assumptions about the weights yield different sets of constraints and restrictions on the values of the weights, thereby modifying (5)-(8) and (9)-(12). These different assumptions affect not only the membership of the set of plants that define the frontier, but also how differences in the size of the plants and their activity levels affect their performance scores. For a more detailed discussion of these models and the underlying assumptions, see Seiford and Thrall (1990); additionally, see Seiford (1990) for a list of approximately four hundred papers pertaining to the theory and applications of DEA.

One group of investigators has used DEA to examine the economic implications of "undesirable outputs," or wastes. Fare, Grosskopf and Pasurka (1986) modeled "the effects of environmental controls when these are viewed as restricting disposal of outputs." They considered the cases of strong (free) disposability of outputs, in which no economic penalty is incurred, and weak (restricted) disposability, in which undesired outputs are subject to environmental regulations. Their study of U.S. steam electric plants "captured the opportunity or indirect cost of those regulations as the difference in output when disposablity is free (i.e., unregulated) and when disposability is restricted." They estimated the lack of disposability 'cost' to average 16 million kilowatt-hours in lost potential output for each of the 100 electric utilities they examined. A subsequent study by Fare, Grosskopf, Lovell, and Pasurka (1989) considered two modifications to the standard Farrell approach to efficiency measurement: relaxing the restriction on production technology "to allow for the fact

that undesirable outputs may be freely disposable." and modifying the efficiency measures to allow for "asymmetric treatment of desirable and undesirable outputs." The resulting hyperbolic efficiency measure was found in a study of 30 U.S. pulp and paper mills to be "very sensitive to whether or not undesirable outputs were included," and it was determined that "departures of measured productivity assuming strong disposability from those assuming weak disposability can be converted into measures of output and revenue loss due to any lack of strong disposability of undesirable outputs."

In summary, the analysis of pollution prevention can be modeled within in a number of theoretical contexts. We have formulated it within the materials accounting framework suggested in the National Academy of Science (1990) study. Even within this framework, a number of interpretations can be developed by varying the criteria used to define pollution prevention activity. For instance, as we have demonstrated, pollution prevention efforts in a plant can be evaluated with respect to throughput of a particular chemical, or with respect to the amount of desirable products produced, or more generally, in terms of the effects of the pollution on public health and general well being. PPF analysis is intended as a screening device to help focus attention on plants, which under a given model, appear to be leaders or laggers in terms of pollution prevention efforts. Development of precise recommendations on how the leaders may be emulated or the laggers helped to improve their performance requires further scrutiny and study.

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APPENDIX B

Features of the PPF Approach*

Cognitive complexity - PPF reduces multiple variables to a single performance measure thereby making inter-facility comparisons relatively simple.

Best observed practice - Estimates of performance are based on comparisons with the best pattern of pollution prevention found in practice rather than comparisons with a theoretical construct.

Comparison - Performance is a relative concept based on the comparison of similar plants. In particular, for each plant, its score on the performance index is a measure of the amount of pollution for the plant relative to the pollution output that other plants produce while maintaining at least the same level activity.

Fairness of the comparisons - The choice of weights assigned to the various activities and pollutants considered in the construction of the performance index is such that it shows each plant in its best light. Hence, there is a perceived fairness in the weighting of the variables. However, as discussed below, the choice of variables is critical to the definition of good performance

Multiple activities, multiple pollutants - The method uses information on the plant's activities and the levels of pollution generated. It allows for the simultaneous incorporation of a multiplicity of measures of plant activity and pollution generation in the creation of the performance index.

Model choice and variable choice - While PPF does not pose any restrictions on the choice of variables, it should be noted that the choice of any subset of variables implies a specific model and choice of criteria. The performance score that a plant receives depends critically on the criteria used for determining performance. Therefore, it is advisable that a number of representations of pollution prevention performance be explored in order to capture the multiple facets of superior performance. Different specifications are particularly important since the frontier, which is defined by actual plants, it is not always robust with respect to extreme variations in the data.

Values - The choice of a model determines which performance criteria are valued. Hence data reduction and variable selection is very important when direct comparisons are involved and there is a potential for setting up dysfunctional incentives.

Controls - By making a distinction between plant or other characteristics which are outside the control of the plant managers and those that are within their control, it is possible to

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*This section is based on the authors' personal experiences, Epstein and Henderson (1989) and Schinnar (1980).

identify what portion of the plant's performance is directly attributable to the manager's performance versus being due to other factors outside the control of the managers.

Comparison sets - The PPF approach partitions the data into comparison sets wherein plants with similar mixes of activity and pollutants are evaluated relative to each other and with respect to a common frontier. Plants which belong to a common comparison set are all compared to a common reference set of plants that define the best practice frontier. These plants on the frontier that exhibit the best observed practice can therefore be selected as candidates for greater scrutiny and more detailed case studies which might shed light on the factors that contribute to their superior performance. Similarly, attention can be focused on plants that appear to lag in their performance and more detailed comparisons of leaders and laggers could potentially yield insights into how to improve pollution prevention efforts.

Unit and level of analysis - In PPF analyses, the observation which is the unit of analysis is also the level at which results are obtained. Unlike statistical techniques where the analysis is based on the means and variance of the data and the results reflect the aggregate features of the data, PPF yields information pertinent to each observation as well as results on aggregate information.

Longitudinal analyses - PPF is well suited for monitoring performance over time. Comparisons can be conducted relative to a plant's own previous performance or with respect to other plants included in the dataset.

Computational complexity - PPF scores are obtained by solving linear programs, one for each plant being evaluated. Optimizers for solving linear programs are readily available, however, specialized software developed to take advantage of some special features of the problem can result in computational efficiencies.

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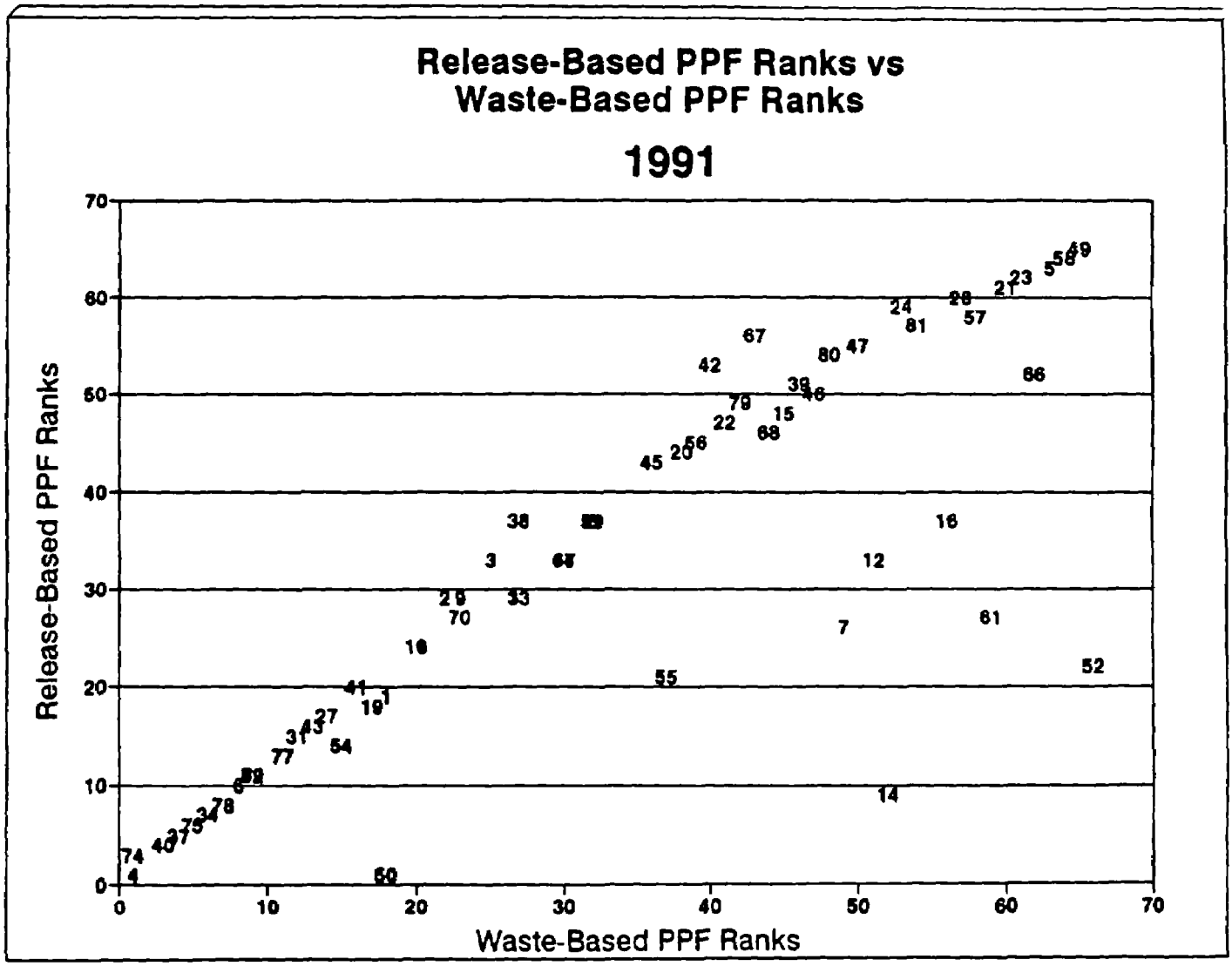
APPENDIX C

TABULATED RESULTS FOR ALL ANALYSES

APPENDIX C

TABULATED RESULTS FOR ALL ANALYSES


Release-Based PPF Ranks vs
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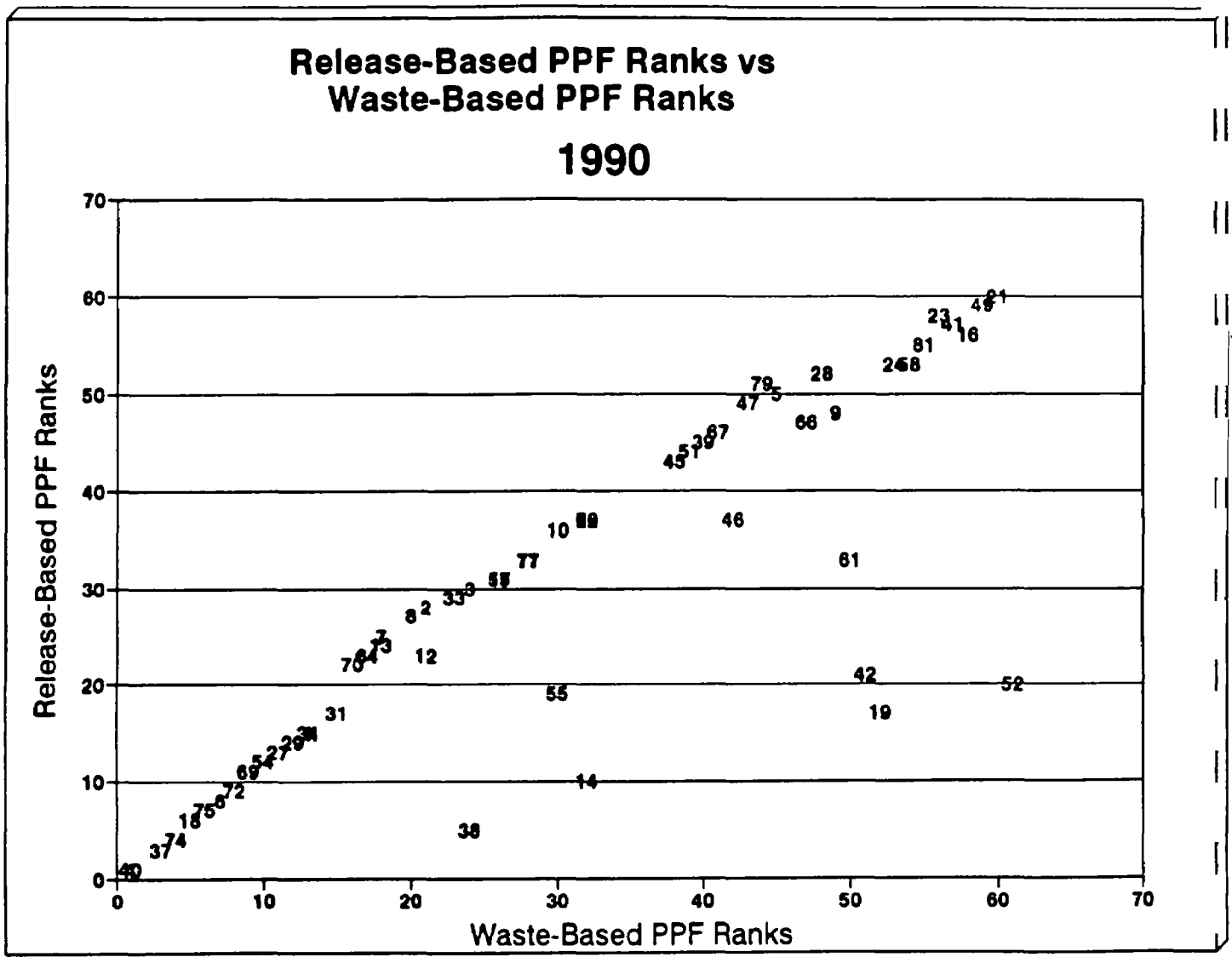
Release-Based PPF Ranks vs
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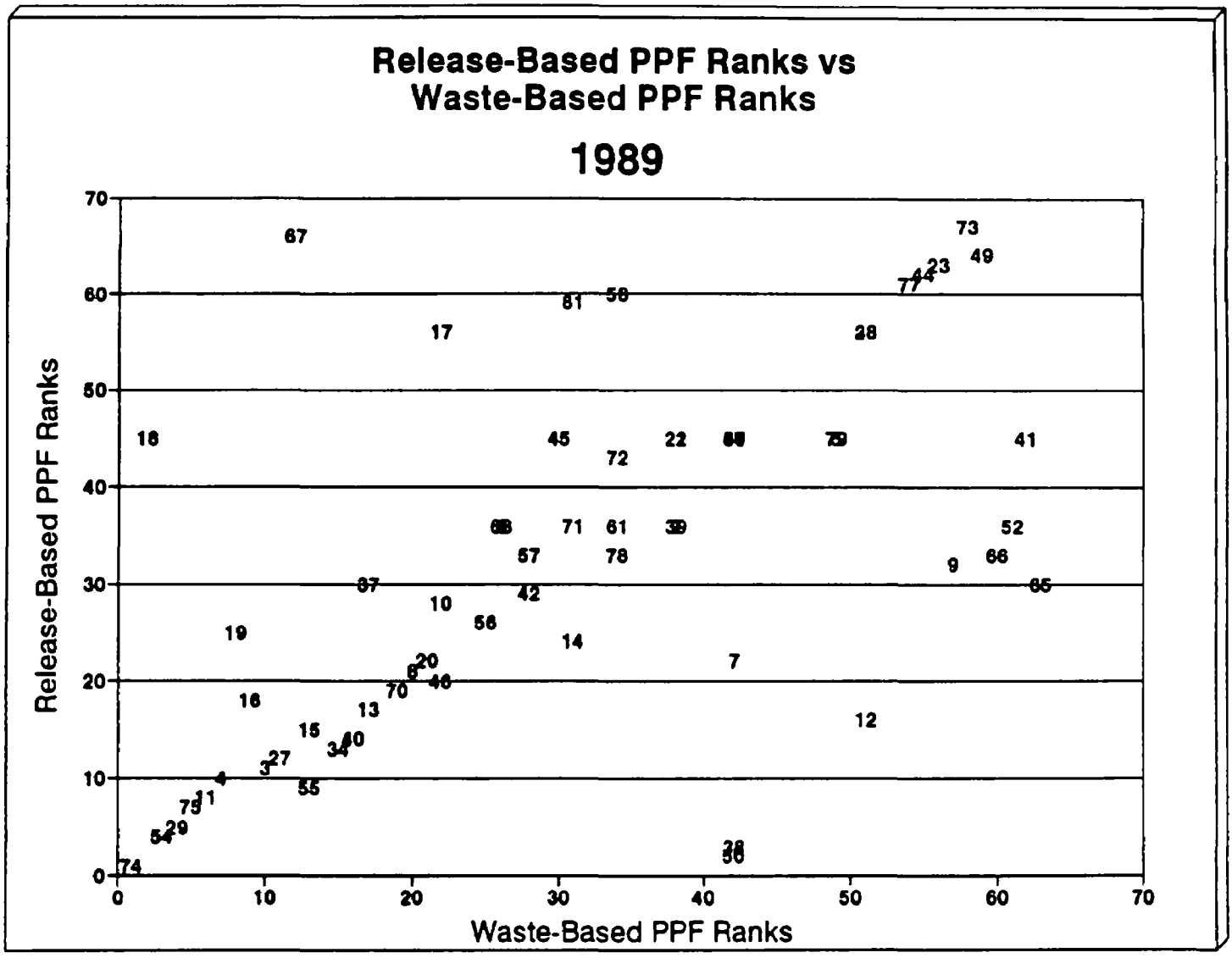
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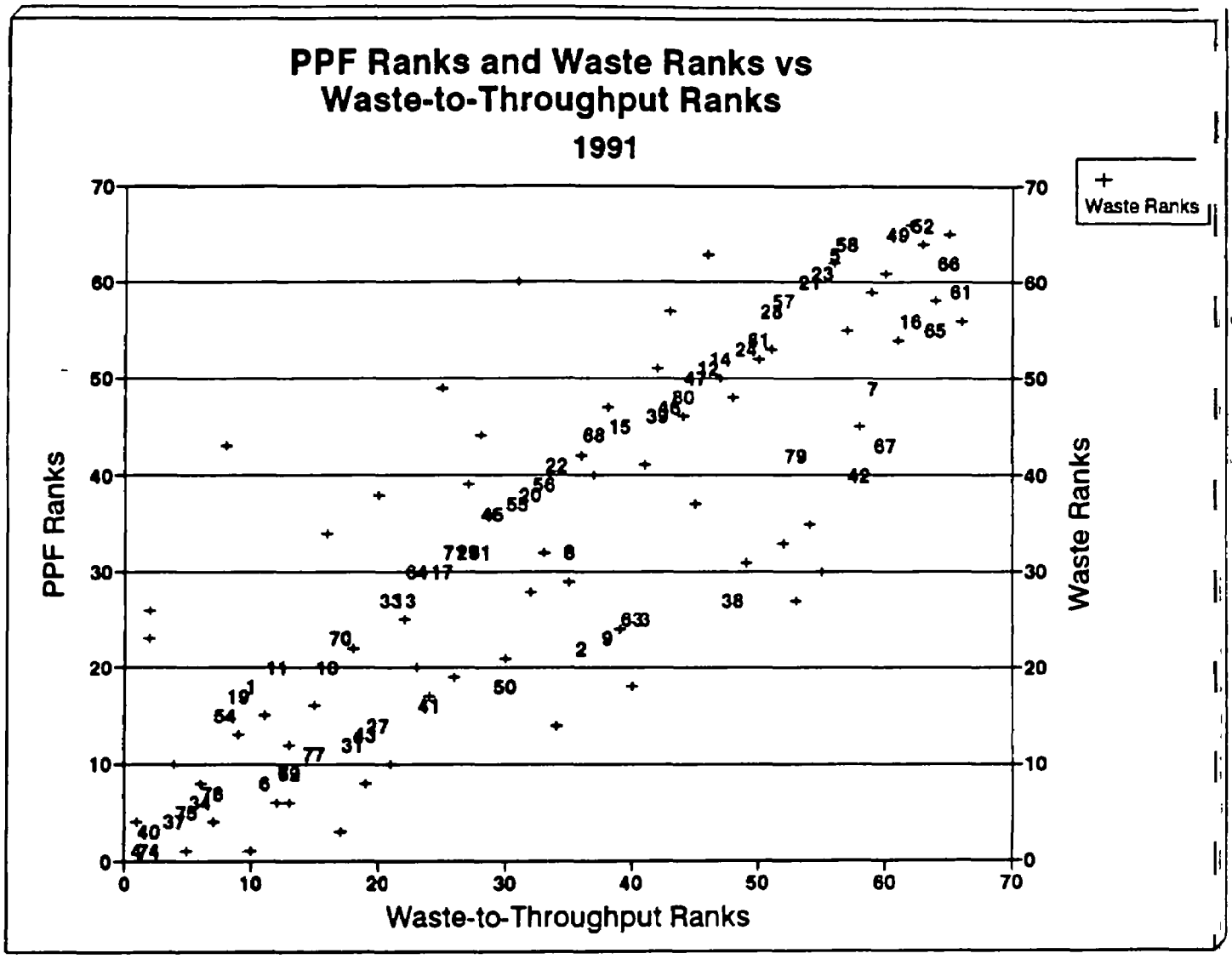
PPF Ranks and Waste Ranks vs
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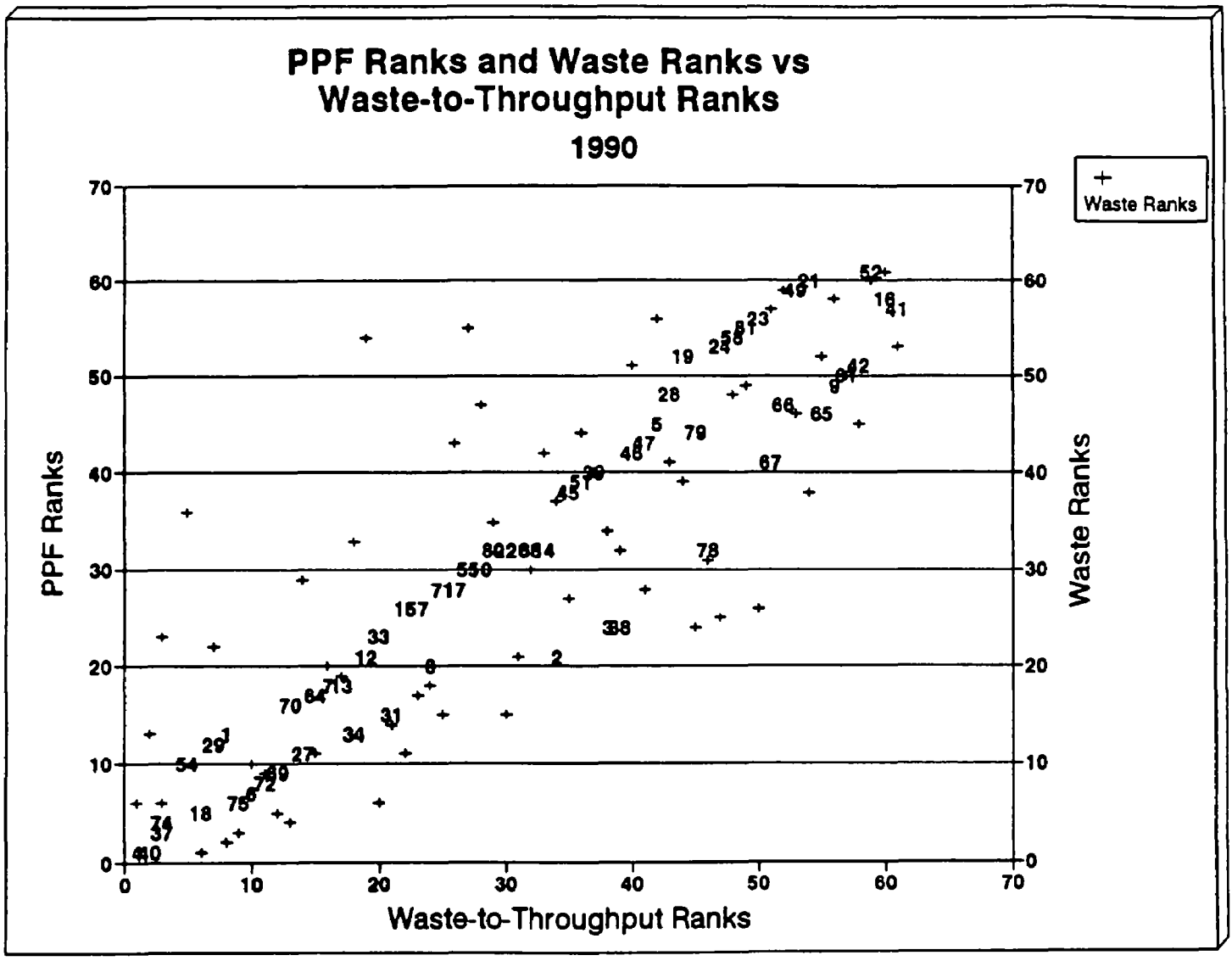
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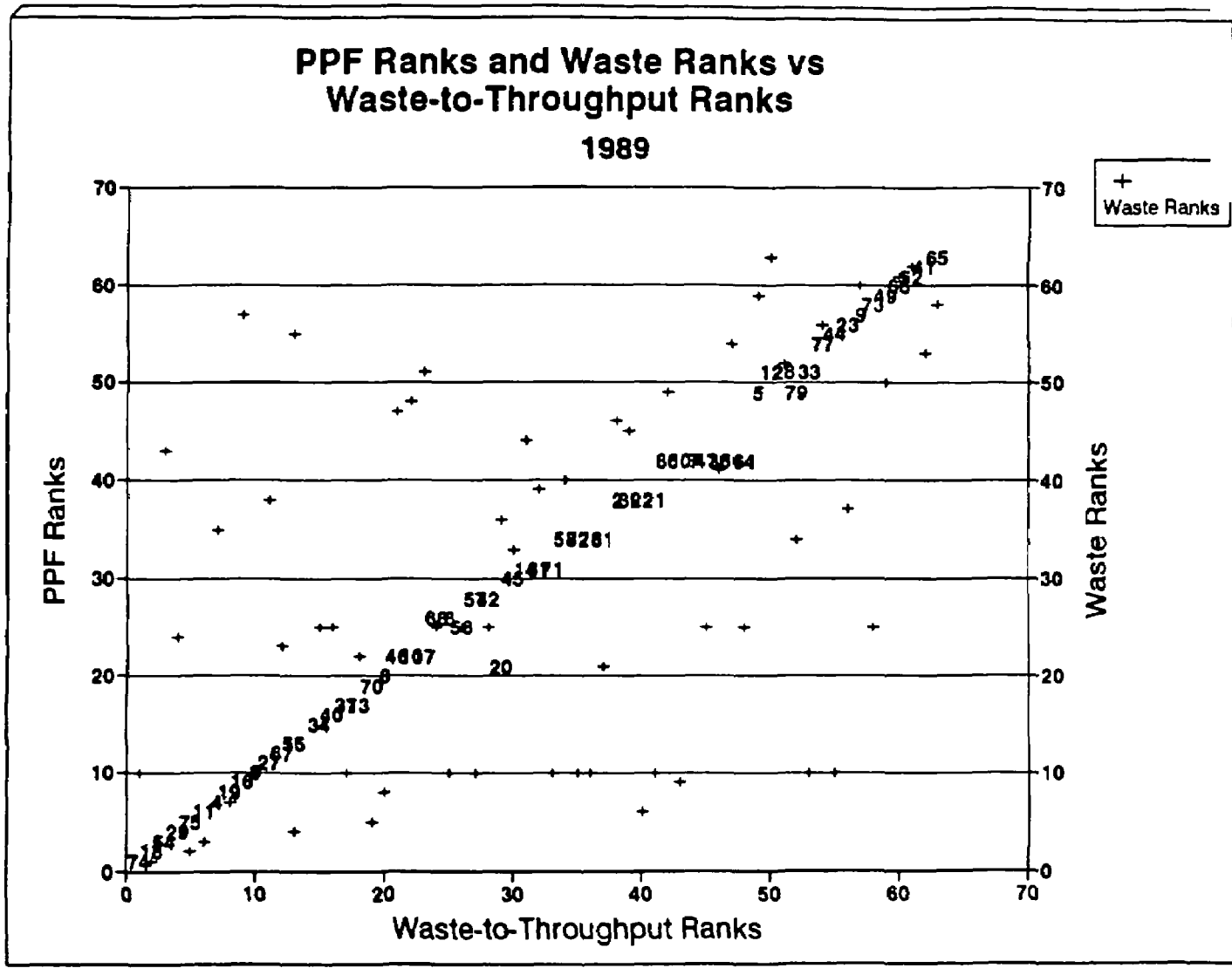
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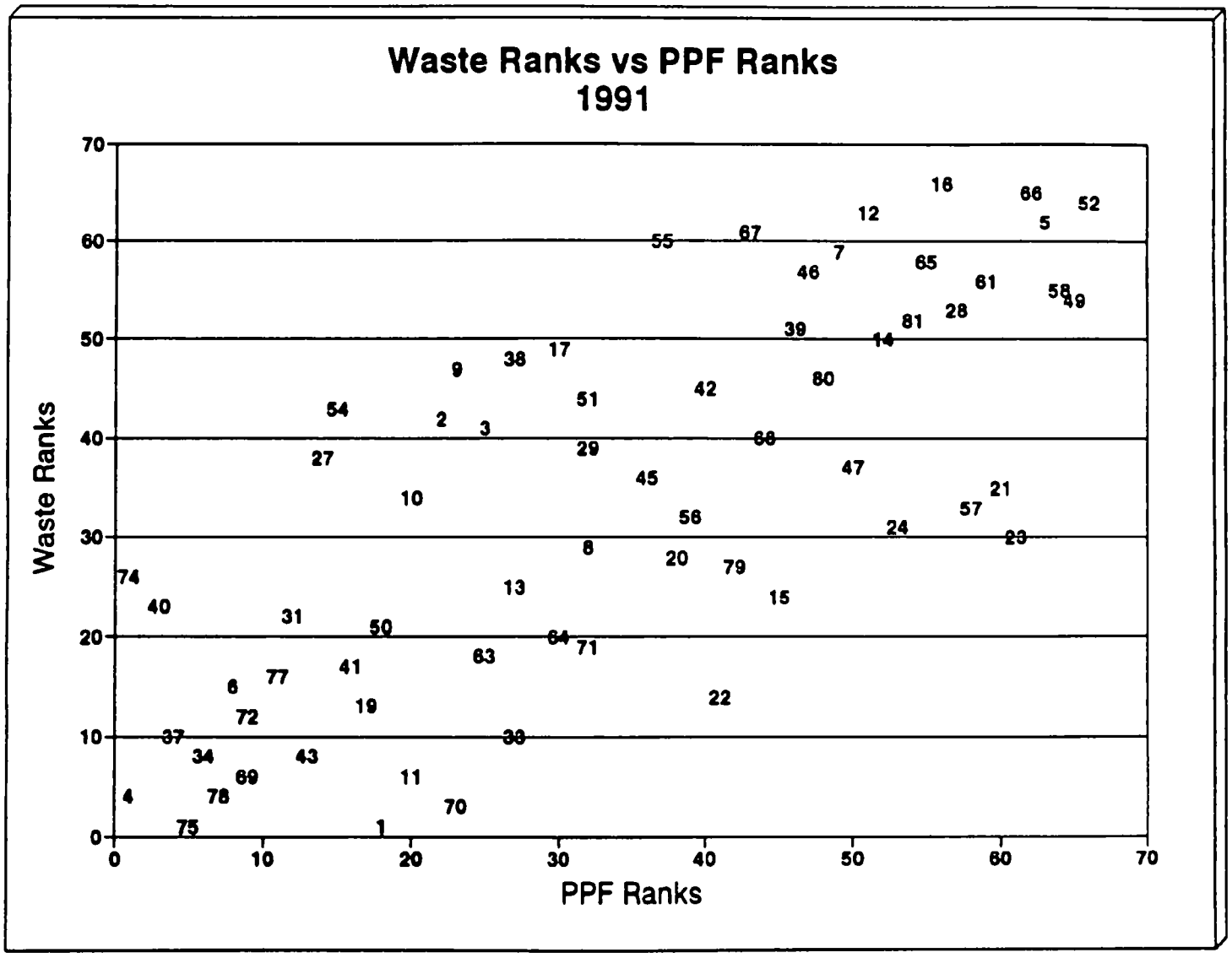
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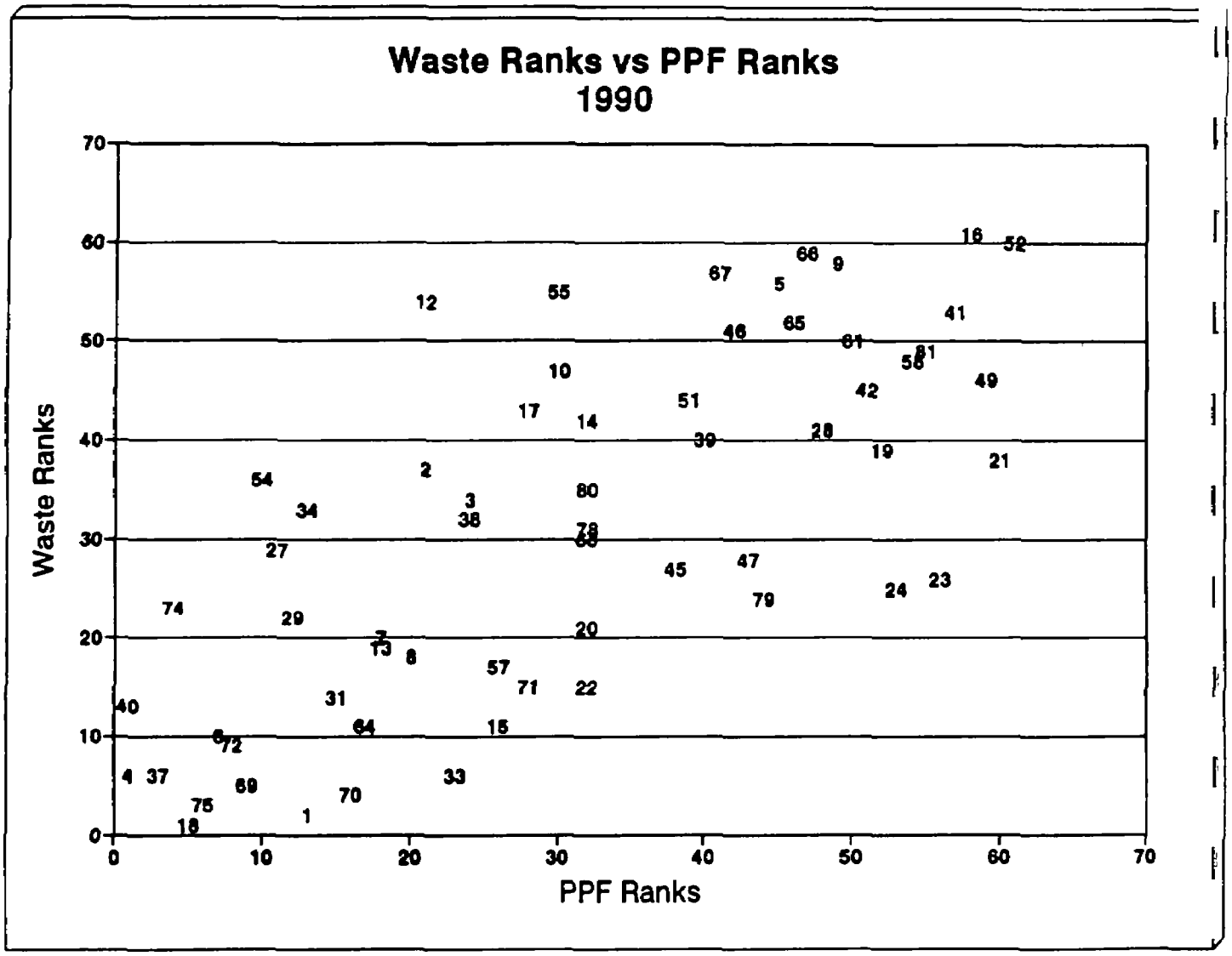
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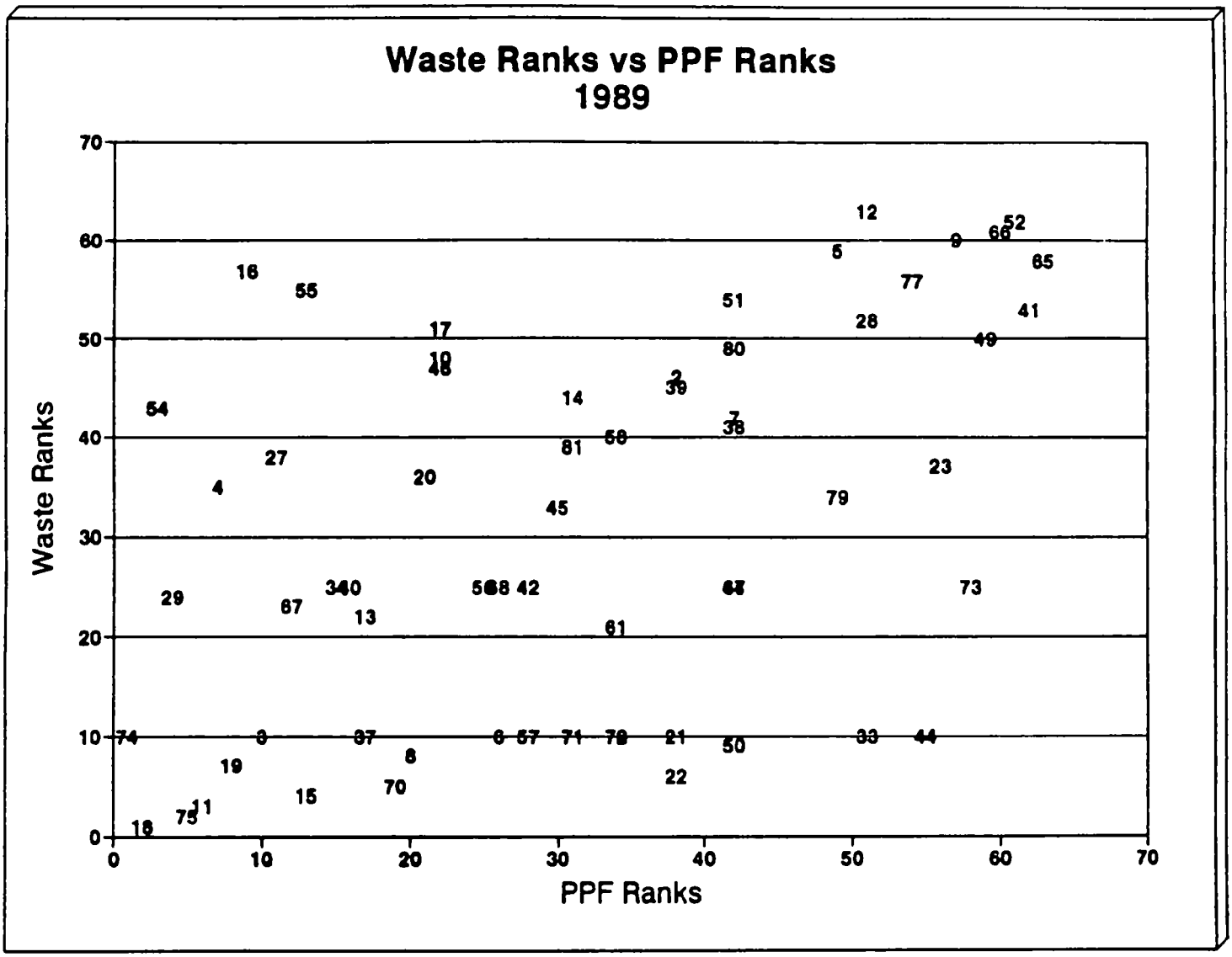
Waste Ranks vs PPF Ranks
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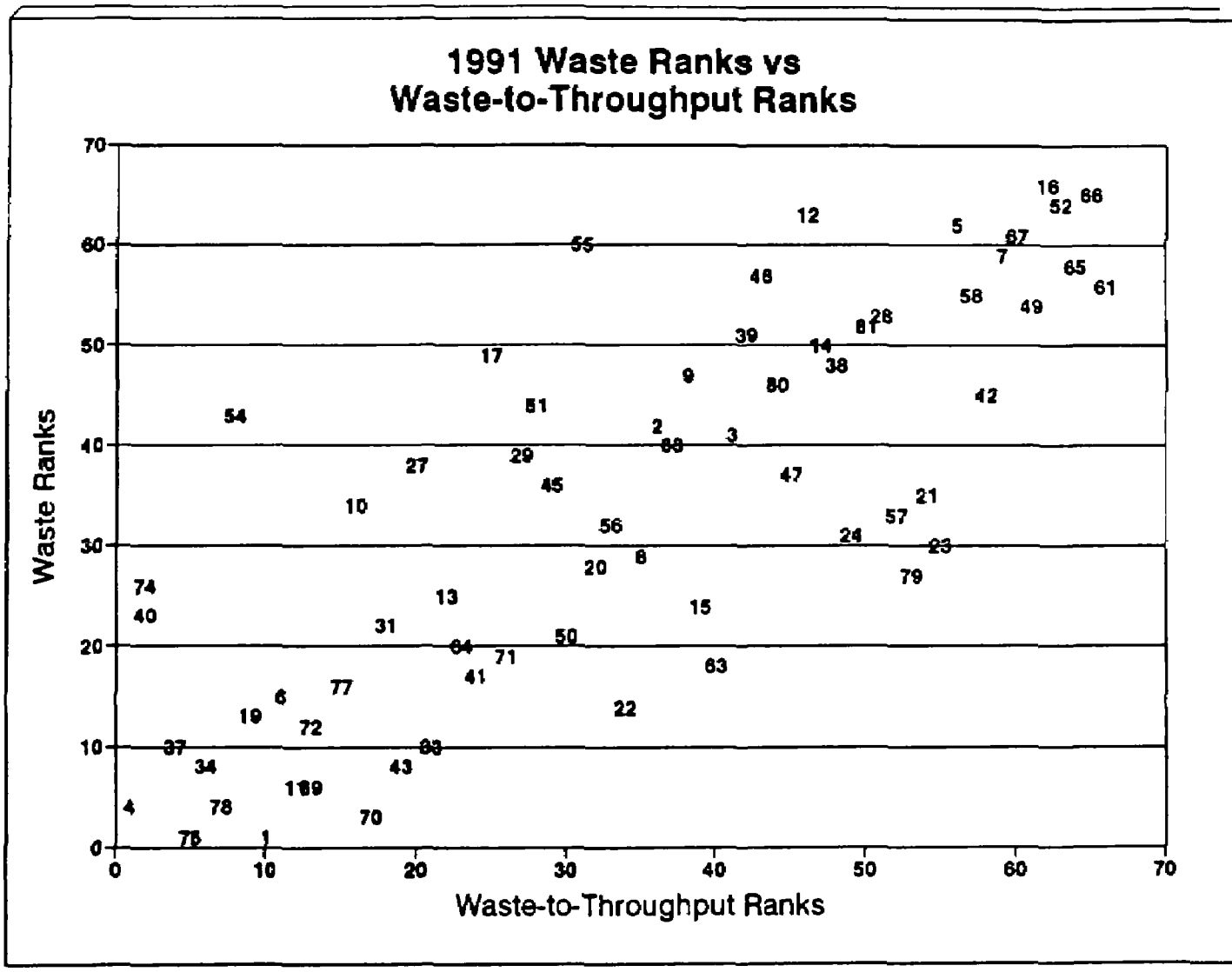
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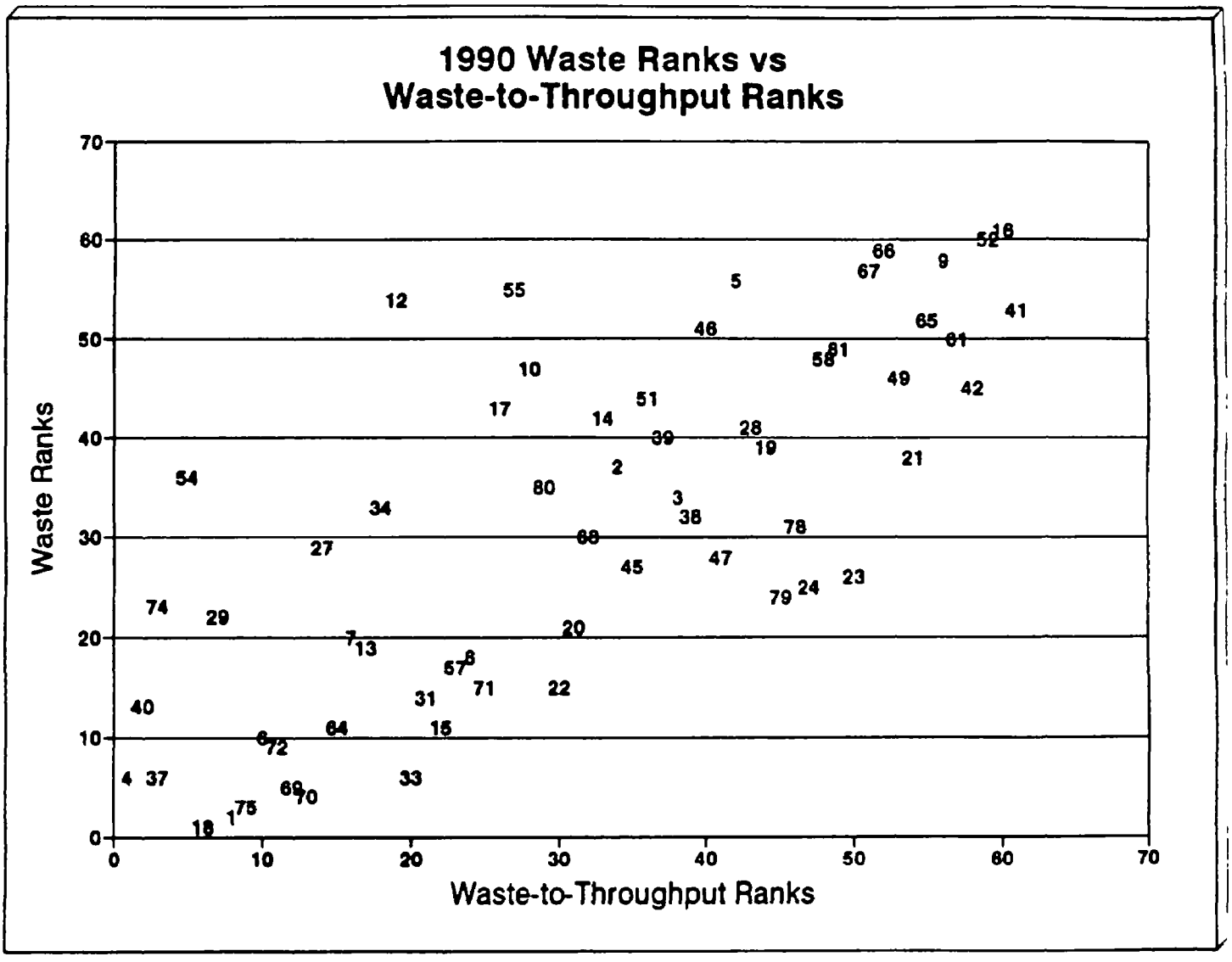
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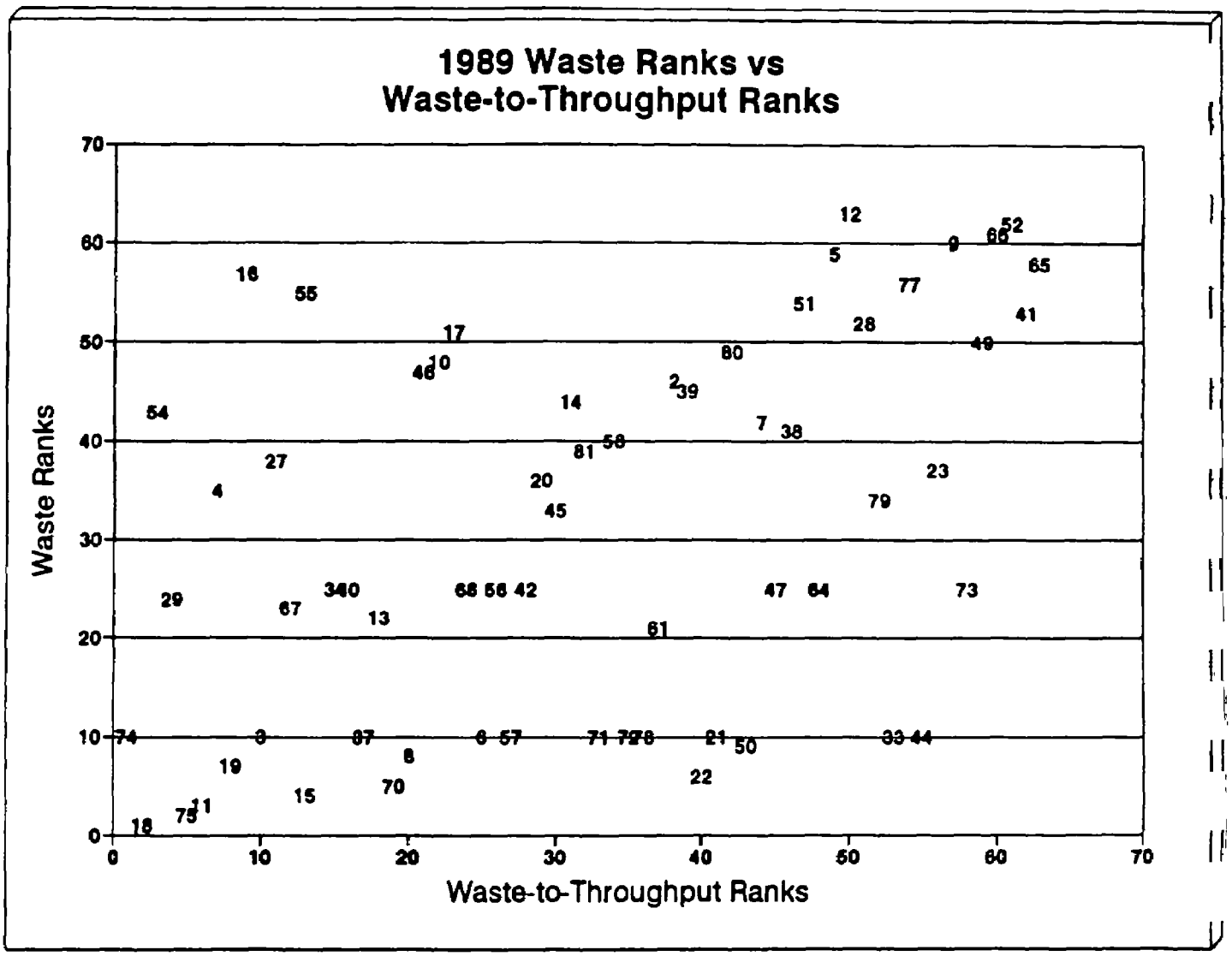
1989 Waste Ranks vs
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APPENDIX D

GRAPHICAL RESULTS FOR RELEASE-BASED ANALYSES

1991 COMPARISON OF PPF RATING AND DATA QUALITY RATING				
PPF RATING BASED ON PPF SCORE*	DATA QUALITY RATING**			
	Excellent	Good	Mixed	Poor
Excellent	5	0	4	4
Good	2	0	2	8
Mixed	3	5	7	7
Poor	2	3	4	9
TOTAL	12	8	17	28

(1989-1991) COMPARISON OF PPF RATING AND DATA QUALITY RATING				
PPF RATING BASED ON PPF SCORE*	DATA QUALITY RATING**			
	Excellent	Good	Mixed	Poor
Excellent	18	0	10	11
Good	15	0	5	17
Mixed	31	10	11	14
Poor	16	4	6	19
TOTAL	80	14	32	61

* PPF Ratings are based on the percentile PPF rank, as follows:
Excellent (Top 20%), Good (21%-40%), Mixed (41%-80%), and Poor (Bottom 20%)

** Data Quality Ratings are based on # of acceptable reports (meeting the <= 2.0% MBE and total waste > 0 requirements), as follows:
Excellent (100% of reports acceptable); Good (70% or more of reports acceptable and MBE% of unacceptable reports < 5.0%); Poor (less than 30% of reports acceptable OR the MBE% of unacceptable reports greater than 10%);
Mixed (all other facilities)

1989 COMPARISON OF PPF RATING AND DATA QUALITY RATING				
PPF RATING BASED ON PPF SCORE*	DATA QUALITY RATING**			
	Excellent	Good	Mixed	Poor
Excellent	6	0	4	4
Good	7	0	1	5
Mixed	14	2	1	4
Poor	8	1	1	5
TOTAL	35	3	7	18

1990 COMPARISON OF PPF RATING AND DATA QUALITY RATING				
PPF RATING BASED ON PPF SCORE*	DATA QUALITY RATING**			
	Excellent	Good	Mixed	Poor
Excellent	7	0	2	3
Good	6	0	2	4
Mixed	14	3	3	3
Poor	6	0	1	5
TOTAL	33	3	8	15

* PPF Ratings are based on the percentile PPF rank, as follows:
Excellent (Top 20%), Good (21%-40%), Mixed (41%-80%), and Poor (Bottom 20%)

** Data Quality Ratings are based on # of acceptable reports (meeting the <= 2.0% MBE and total waste > 0 requirements), as follows:
Excellent (100% of reports acceptable); Good (70% or more of reports acceptable and MBE% of unacceptable reports < 5.0%); Poor (less than 30% of reports acceptable OR the MBE% of unacceptable reports greater than 10%);
Mixed (all other facilities)

COMPARISON BETWEEN DATA QUALITY RATINGS AND PPF RANKINGS
1991 (continued)

PLANT ID#	TOTAL EMPLOY.	TOTAL NO. REPORTS	NO. OF ACCEPT. REPORTS	NO. OF UNACCEPT. REPORTS	AVG MISS% UNACCEPT. REPORTS	PERCENT ACCEPT. REPORTS	DATA QUALITY RATING	PPF RANKING 1991
36	2,000	16	7	9	67.8	44%	P	
63	3,000	3	3	0		100%	E	25
73	3,500	5	3	2		60%	M	
69	4,000	1	1	0		100%	E	9
6	4,180	1	1	0		100%	E	8
7	4,180	20	13	7	35.3	65%	P	49
39	5,400	2	1	1	2.3	50%	M	46
60	6,000	10	7	3	22.0	70%	P	48
27	6,919	5	4	1	99.9	80%	P	14
10	9,500	7	7	0		100%	E	20
61	10,200	6	4	2	49.9	67%	P	54
76	10,500	15	8	7	9.1	53%	M	
78	10,500	2	1	1	4.4	50%	M	7
77	10,500	8	4	4	33.1	50%	P	11
64	12,000	9	6	3	35.2	67%	P	30
74	13,931	1	1	0		100%	E	1
14	14,415	16	15	1	6.8	94%	M	52
2	16,000	13	12	1	58.6	92%	P	22
3	16,000	9	3	6	29.8	33%	P	25
43	16,200	9	4	5	58.0	44%	P	13
54	17,000	3	2	1		67%	M	15
4	17,324	9	9	0		100%	E	1
5	17,324	6	2	4	11.2	33%	P	63
18	19,000	4	4	0		100%	E	
53	19,366	2	1	1	3.0	50%	M	
55	19,366	6	5	1	37.9	83%	P	37
72	27,000	2	1	1	2.1	50%	M	9
15	27,000	5	4	1	96.7	80%	P	45
61	30,000	7	1	6	15.8	14%	P	59
11	37,700	19	9	10	17.5	47%	P	20
19	37,756	8	6	2	88.8	75%	P	17
17	39,281	3	2	1		67%	M	30
16	39,281	14	10	4	42.4	71%	P	56
30	55,000	8	6	2	8.7	75%	M	
66	86,000	21	11	10	27.7	52%	P	82
31	94,000	1	1	0		100%	E	12
9	94,000	19	15	4	49.7	79%	P	23
13	143,961	3	3	0		100%	E	27
12	143,961	54	29	25	20.5	54%	P	51

COMPARISON BETWEEN DATA QUALITY RATINGS AND PPE RANKINGS
1991

PLANT ID#	TOTAL EMPLOY.	TOTAL No. REPORTS	No. OF ACCEPT. REPORTS	No. OF UNACCEPT. REPORTS	AVG MRS% UNACCEPT. REPORTS	PERCENT ACCEPT. REPORTS	DATA QUALITY RATING	PPE RANKING 1991
47	UNK	7	6	1	2.0	86%	G	50
33	UNK	2	1	1	3.2	50%	M	27
50	UNK	3	2	1		67%	M	16
26	8	1		1		0%	P	
21	17	6	5	1	3.3	83%	G	60
79	18	8	6	2		75%	G	42
80	18	1		1		0%	P	
44	20	1		1		0%	P	
56	25	2	2	0		100%	E	39
59	25	2		2		0%	P	
58	25	3	2	1	2.5	67%	M	64
45	26	4	3	1		75%	G	36
28	30	7	7	0		100%	E	57
49	35	1	1	0		100%	E	65
23	36	7	6	1		86%	G	61
22	45	2	1	1	116.0	50%	P	41
71	58	4	2	2	7.9	50%	M	32
42	60	7	5	2	3.8	71%	G	40
34	60	5	2	3		40%	M	6
40	62	9	3	6	36.1	33%	P	3
62	65	2		2		0%	P	
48	75	4	4	0		100%	E	
68	80	12	10	2	3.7	83%	G	44
41	92	9	5	4	34.2	56%	P	16
70	100	8	6	2	30.9	75%	P	23
24	120	6	4	2	2.2	67%	M	53
38	125	2	1	1	3.8	50%	M	27
57	150	7	4	3	95.0	57%	P	58
1	160	8	8	0		100%	E	18
52	180	8	5	3	4.8	63%	M	66
51	200	5	3	2	4.1	60%	M	32
75	200	6	4	2		67%	M	5
67	280	13	5	8	15.8	38%	P	43
37	300	3	2	1	17.5	67%	P	4
36	300	4	1	3	28.2	25%	P	
46	325	17	15	2	99.9	88%	P	47
20	470	6	4	2	4.0	67%	M	38
66	700	2	1	1	10.7	50%	P	55
32	725	1		1	100.0	0%	P	
25	1,000	6	5	1	3.7	83%	G	
29	1,311	8	8	0		100%	E	32
8	1,850	14	12	2	4.2	86%	G	32

GRAND ARCH BETWEEN DATA QUALITY RATINGS AND PPP RANKINGS 1990 (continued)								
PLANT ID#	TOTAL EMPLOY.	TOTAL NO. REPORTS	No. OF ACCEPT. REPORTS	No. OF UNACCEPT. REPORTS	AVG WEEK UNACCEPT. REPORTS	PERCENT ACCEPT. REPORTS	DATA QUALITY RATING	PPP RANKING 1990
38	2,000	6	5	1		83%	G	
63	3,000	1	1	0		100%	E	
73	3,500	2	1	1	78.8	50%	P	
69	4,000	1		1		0%	P	9
6	4,180	1	1	0		100%	E	7
7	4,180	12	4	8	47.9	33%	P	16
39	5,400	1	1	0		100%	E	40
80	6,000	4	3	1		75%	G	32
27	6,919	3	1	2	15.4	33%	P	11
10	9,500	6	5	1	11.8	83%	P	30
81	10,200	4	3	1	7.3	75%	M	55
76	10,500	1	1	0		100%	E	32
78	10,500	6	4	2	37.5	67%	P	
77	10,500	8	3	5	20057.9	38%	P	
64	12,000	4	4	0		100%	E	17
74	13,931	1	1	0		100%	E	4
14	14,415	9	8	1	2.1	89%	G	32
2	16,000	4	4	0		100%	E	21
3	16,000	5	2	3	38.1	40%	P	24
43	16,200	18	15	3	55.1	83%	P	
54	17,000	2	2	0		100%	E	10
5	17,324	4	4	0		100%	E	45
4	17,324	5	5	0		100%	E	1
18	19,000	5	3	2	6.7	60%	M	5
55	19,366	2	2	0		100%	E	30
53	19,366	7	7	0		100%	E	
72	27,000	1	1	0		100%	E	8
15	27,000	5	2	3	8.4	40%	M	28
61	30,000	3	1	2	98.1	33%	P	50
11	37,700	11	3	8	58.1	27%	P	
19	37,758	7	7	0		100%	E	52
17	38,281	2	2	0		100%	E	28
16	38,281	11	7	4	10.7	64%	P	58
30	55,000	5	4	1		80%	G	
66	86,000	9	8	1		89%	G	47
31	94,000	1	1	0		100%	E	15
9	94,000	6	4	2	4.9	67%	M	49
13	143,961	4	2	2	2.3	50%	M	18
12	143,961	25	14	11	30.2	56%	P	21

COMPARISON BETWEEN DATA QUALITY RATINGS AND PPF RANKINGS 1990								
PLANT ID#	TOTAL EMPLOY.	TOTAL NO. REPORTS	No. OF ACCEPT. REPORTS	No. OF UNACCEPT. REPORTS	AVG MBE% UNACCEPT. REPORTS	PERCENT ACCEPT. REPORTS	DATA QUALITY RATING	PPF RANKING 1990
50	UNK	3	3	0		100%	E	
47	UNK	3	3	0		100%	E	43
33	UNK	1	1	0		100%	E	23
28	8	1		1		0%	P	
21	17	2	1	1	14.7	50%	P	60
79	18	2	2	0		100%	E	44
60	18	1		1		0%	P	
44	20	1	1	0		100%	E	
56	25	1	1	0		100%	E	
59	25	1		1		0%	P	
58	28	1	1	0		100%	E	54
46	28	3	3	0		100%	E	38
26	30	2	2	0		100%	E	48
49	35	1	1	0		100%	E	59
23	35	4	4	0		100%	E	56
22	45	1	1	0		100%	E	32
71	50	3	3	0		100%	E	28
34	60	1	1	0		100%	E	13
42	60	4	4	0		100%	E	51
40	62	3	1	2	48.3	33%	P	1
62	65	1		1		0%	P	
48	75	2	2	0		100%	E	
68	80	5	3	2	4.0	60%	M	32
41	92	5	2	3	92.8	40%	P	57
70	100	6	3	3	41.3	50%	P	16
24	120	1	1	0		100%	E	53
38	125	1	1	0		100%	E	24
57	150	3	3	0		100%	E	28
1	160	3	1	2	163.8	33%	P	13
52	180	6	5	1	95.8	83%	P	61
75	200	1	1	0		100%	E	6
51	200	3	2	1	287.4	67%	P	39
67	280	6	4	2	6.2	67%	M	41
37	300	3	3	0		100%	E	3
36	300	2	1	1		50%	M	
46	325	6	6	0		100%	E	42
20	470	3	2	1	41.4	67%	P	32
65	700	2	2	0		100%	E	46
32	725	1	1	0		100%	E	
25	1,000	4	3	1	29.8	75%	P	
29	1,311	2	1	1	2.8	50%	M	12
8	1,850	4	4	0		100%	E	20

COMPARISON BETWEEN DATA QUALITY RATINGS AND PPP RANKINGS 1989 (continued)								
PLANT ID#	TOTAL EMPLOY.	TOTAL NO. REPORTS	NO. OF ACCEPT. REPORTS	NO. OF UNACCEPT. REPORTS	AVG MBR'S UNACCEPT. REPORTS	PERCENT ACCEPT. REPORTS	DATA QUALITY RATING	PPP RANKING 1988
36	2,000	6	5	1		83%	G	
63	3,000	1	1	0		100%	E	
73	3,500	2	1	1	76.8	50%	P	58
69	4,000	1		1		0%	P	
8	4,150	1	1	0		100%	E	26
7	4,160	12	4	8	47.9	33%	P	42
39	5,400	1	1	0		100%	E	38
60	6,000	4	3	1		75%	G	42
27	8,919	3	1	2	15.4	33%	P	11
10	9,500	6	5	1	11.5	83%	P	22
81	10,200	4	3	1	7.3	75%	M	31
78	10,500	1	1	0		100%	E	34
77	10,500	8	3	5	20057.9	38%	P	54
76	10,500	6	4	2	37.5	67%	P	
64	12,000	4	4	0		100%	E	42
74	13,931	1	1	0		100%	E	1
14	14,415	9	8	1	2.1	89%	G	31
2	16,000	4	4	0		100%	E	36
3	16,000	5	2	3	38.1	40%	P	10
43	16,200	18	15	3	55.1	83%	P	
54	17,000	2	2	0		100%	E	3
4	17,324	5	5	0		100%	E	7
5	17,324	4	4	0		100%	E	49
18	19,000	5	3	2	6.7	60%	M	2
53	19,366	7	7	0		100%	E	
55	19,366	2	2	0		100%	E	13
72	27,000	1	1	0		100%	E	34
15	27,000	5	2	3	8.4	40%	M	13
61	30,000	3	1	2	98.1	33%	P	34
11	37,700	11	3	8	58.1	27%	P	6
19	37,756	7	7	0		100%	E	8
17	39,281	2	2	0		100%	E	22
16	39,281	11	7	4	10.7	64%	P	9
30	55,000	5	4	1		80%	G	
66	56,000	9	8	1		89%	G	60
31	64,000	1	1	0		100%	E	
9	64,000	6	4	2	4.9	67%	M	57
13	143,961	4	2	2	2.3	50%	M	17
12	143,961	25	13	12	30.2	52%	P	51

COMPARISON BETWEEN DATA QUALITY RATINGS AND PIF RANKINGS 1994								
PLANT ID#	TOTAL EMPLOY.	TOTAL No. REPORTS	No. OF ACCEPT. REPORTS	No. OF UNACCEPT. REPORTS	EVG WEEK UNACCEPT. REPORTS	PERCENT ACCEPT. REPORTS	DEPT. QUALITY RATING	PIF RANKING 1994
33	UNK	1	1	0		100%	E	61
47	UNK	3	3	0		100%	E	42
50	UNK	3	3	0		100%	E	42
26	6	1		1		0%	P	
21	17	2	1	1	14.7	50%	P	36
79	18	2	2	0		100%	E	49
60	18	1		1		0%	P	
44	20	1	1	0		100%	E	55
58	25	1	1	0		100%	E	25
59	25	1		1		0%	P	
54	26	1	1	0		100%	E	34
45	28	3	3	0		100%	E	30
28	30	2	2	0		100%	E	51
49	34	1	1	0		100%	E	59
23	36	4	4	0		100%	E	56
22	46	1	1	0		100%	E	38
71	59	3	3	0		100%	E	31
42	60	4	4	0		100%	E	28
34	80	1	1	0		100%	E	15
40	62	3	1	2	48.3	33%	P	18
62	65	1		1		0%	P	
48	75	2	2	0		100%	E	
68	80	5	3	2	4.0	60%	M	28
41	92	5	2	3	92.8	40%	P	82
70	100	6	3	3	41.3	50%	P	19
24	120	1	1	0		100%	E	
38	125	1	1	0		100%	E	42
57	150	3	3	0		100%	E	28
1	160	3	1	2	183.8	33%	P	
52	180	6	6	1	96.8	83%	P	61
75	200	1	1	0		100%	E	5
51	200	3	2	1	267.4	67%	P	42
67	260	6	4	2	6.2	67%	M	12
37	300	3	3	0		100%	E	17
36	300	2	1	1		50%	M	
46	325	6	6	0		100%	E	22
20	470	3	2	1	41.4	67%	P	21
65	700	2	2	0		100%	E	63
32	725	1	1	0		100%	E	
25	1,000	4	3	1	29.8	75%	P	
29	1,311	2	1	1	2.8	50%	M	4
8	1,850	4	4	0		100%	E	20

RESULTS OF THE DATA QUALITY RATINGS

[illegible]	[illegible]	DATA QUALITY RATING			[illegible]	[illegible]	DATA QUALITY RATING		
[illegible]	[illegible]	1988	1990	1991	[illegible]	[illegible]	1988	1990	1991
[illegible]	180	P	P	E	[illegible]	60	E	E	G
[illegible]	16,000	E	E	P	[illegible]	16,200	P	P	P
[illegible]	16,000	P	P	P	[illegible]	20	E	E	P
[illegible]	17,324	E	E	E	[illegible]	28	E	E	G
[illegible]	17,324	E	E	P	[illegible]	325	E	E	P
[illegible]	4,180	E	E	E	[illegible]	UNK	E	E	G
[illegible]	4,180	P	P	P	[illegible]	75	E	E	E
[illegible]	1,850	E	E	G	[illegible]	35	E	E	E
[illegible]	94,000	M	M	P	[illegible]	UNK	E	E	M
[illegible]	9,500	P	P	E	[illegible]	200	P	P	M
[illegible]	37,700	P	P	P	[illegible]	180	P	P	M
[illegible]	143,961	P	P	P	[illegible]	19,366	E	E	M
[illegible]	143,961	M	M	E	[illegible]	17,000	E	E	M
[illegible]	14,415	G	G	M	[illegible]	19,360	E	E	P
[illegible]	27,000	M	M	P	[illegible]	25	E	E	E
[illegible]	39,281	P	P	P	[illegible]	150	E	E	P
[illegible]	39,281	E	E	M	[illegible]	26	E	E	M
[illegible]	19,000	M	M	E	[illegible]	25	P	P	P
[illegible]	37,756	E	E	P	[illegible]	16	P	P	P
[illegible]	470	P	P	M	[illegible]	30,000	P	P	P
[illegible]	17	P	P	G	[illegible]	65	P	P	P
[illegible]	45	E	E	P	[illegible]	3,000	E	E	E
[illegible]	35	E	E	G	[illegible]	12,000	E	E	P
[illegible]	120	E	E	M	[illegible]	700	E	E	P
[illegible]	1,000	P	P	G	[illegible]	86,000	G	G	P
[illegible]	8	P	P	P	[illegible]	260	M	M	P
[illegible]	6,919	P	P	P	[illegible]	80	M	M	G
[illegible]	30	E	E	E	[illegible]	4,000	P	P	E
[illegible]	1,311	M	M	E	[illegible]	100	P	P	P
[illegible]	56,000	G	G	M	[illegible]	59	E	E	M
[illegible]	94,000	E	E	E	[illegible]	27,000	E	E	M
[illegible]	725	E	E	P	[illegible]	3,500	P	P	M
[illegible]	UNK	E	E	M	[illegible]	13,931	E	E	E
[illegible]	60	E	E	M	[illegible]	200	E	E	M
[illegible]	300	M	M	P	[illegible]	10,500	P	P	M
[illegible]	2,000	G	G	P	[illegible]	10,500	P	P	P
[illegible]	300	E	E	P	[illegible]	10,500	E	E	M
[illegible]	125	E	E	M	[illegible]	18	E	E	G
[illegible]	5,400	E	E	M	[illegible]	6,000	G	G	P
[illegible]	62	P	P	P	[illegible]	10,200	M	M	P
[illegible]	92	P	P	P	[illegible]				

RESULTS AND RANKS OF THE THREE APPROACHES BASED ON WASTES

1991

PLANT ID	CRTK WASTES WASTES	CRTK WASTES RANK	WST/THPT RATIO RATIO	WST/THPT RATIO RANK	PPF ANALYSIS SCORE	PPF ANALYSIS RANK
1	3	1	0.00006	10	1.5000%	16
2	3,950	42	0.00280	36	0.7000%	22
3	3,535	41	0.00372	41	0.5000%	25
4	9	4	0.00000	1	100.0000	1
5	270,000	62	0.02156	56	0.0067%	63
6	61	15	0.00011	11	16.4000%	8
7	70,700	58	0.03115	59	0.0231%	49
8	680	29	0.00169	35	0.1000%	32
9	5,630	47	0.00312	38	0.6000%	23
10	1,359	34	0.00021	16	0.8000%	20
11	10	6	0.00015	12	0.6000%	20
12	673,412	63	0.00673	46	0.0182%	51
13	367	25	0.00042	22	0.3000%	27
14	7,913	50	0.00776	47	0.0156%	52
15	337	24	0.00348	39	0.0353%	45
16	18,633,333	66	0.10280	62	0.0129%	56
17	8,605	49	0.00063	25	0.2000%	30
18						
19	42	13	0.00006	9	2.1000%	17
20	661	28	0.00164	32	0.0764%	38
21	1,412	36	0.01569	54	0.0078%	60
22	60	14	0.00161	34	0.0679%	41
23	800	30	0.01823	55	0.0067%	61
24	830	31	0.00804	49	0.0138%	53
25						
26						
27	2,113	38	0.00034	20	5.9000%	14
28	10,032	53	0.00871	51	0.0127%	57
29	3,110	39	0.00068	27	0.1000%	32
30						
31	160	22	0.00027	18	7.5000%	12
32						
33	20	10	0.00041	21	0.3000%	27
34	15	8	0.00003	6	71.0000%	6
35						
36						
37	20	10	0.00002	4	88.8000%	4
38	6,570	48	0.00763	46	0.3000%	27
39	8,000	51	0.00376	42	0.0327%	46
40	228	23	0.00002	2	99.8000%	3
41	71	17	0.00069	24	3.4000%	16
42	5,325	46	0.03913	58	0.0886%	40
43	15	8	0.00039	19	6.0000%	13
44						
45	1,479	38	0.00127	29	0.0963%	38
46	46,825	57	0.00477	43	0.0258%	47
47	1,778	37	0.00539	45	0.0192%	50
48						
49	11,191	54	0.04490	61	0.0027%	66
50	158	21	0.00129	30	1.5000%	18
51	4,289	44	0.00111	28	0.1000%	32
52	2,302,627	64	0.14698	63	0.0011%	66
53						
54	4,102	43	0.00003	8	3.8000%	15
55	108,200	60	0.00160	31	0.0769%	37
56	1,000	32	0.00164	33	0.0747%	39
57	1,244	33	0.01078	52	0.0114%	58
58	24,867	58	0.02335	57	0.0053%	64
59						
60						
61	25,918	59	0.25081	65	0.0080%	59
62						
63	98	18	0.00372	40	0.5000%	25
64	125	20	0.00063	23	0.2000%	30
65	61,575	56	0.15288	64	0.0130%	55
66	3,077,332	65	0.20746	65	0.0062%	62
67	252,095	61	0.04440	60	0.0449%	43
68	3,465	40	0.00298	37	0.0413%	44
69	10	6	0.00015	13	13.0000%	9
70	7	3	0.00022	17	0.6000%	23
71	110	19	0.00084	28	0.1000%	32
72	25	12	0.00015	13	13.0000%	9
73						
74	381	26	0.00002	2	100.0000	1
75	3	1	0.00003	5	77.0000%	5
76						
77	67	16	0.00017	15	11.6000%	11
78	9	4	0.00003	7	62.3000%	7
79	578	27	0.01380	53	0.0812%	42
80	5,537	46	0.00513	44	0.0239%	48
81	9,428	52	0.00936	50	0.0131%	54

RESULTS AND RANKS OF THE THREE APPROACHES
BASED ON WASTES
1990

PLANT ID	CRTK WASTES WASTES	RANK	WST/THPT RATIO RATIO	RANK	PPF ANALYSIS SCORE	RANK
1	3	2	0.00006	8	4.9000%	13
2	5,361	37	0.00281	34	0.7000%	21
3	3,535	34	0.00366	36	0.5000%	24
4	20	6	0.00000	1	100.0000	1
5	136,174	56	0.00948	42	0.0325%	45
6	59	10	0.00010	10	17.9000%	7
7	510	20	0.00029	16	1.0000%	18
8	407	18	0.00078	24	0.8000%	20
9	246,861	58	0.06734	56	0.0271%	49
10	14,597	47	0.00167	28	0.2000%	30
11						
12	36,194	54	0.00039	19	0.7000%	21
13	455	19	0.00029	17	1.0000%	18
14	9,314	42	0.00282	33	0.1000%	32
15	60	11	0.00062	22	0.4000%	26
16	36,279,799	61	0.18314	60	0.0088%	58
17	9,700	43	0.00091	28	0.3000%	26
18	1	1	0.00004	6	43.4000%	5
19	8,049	39	0.01206	44	0.0227%	52
20	861	21	0.00246	31	0.1000%	32
21	8,862	38	0.06817	54	0.0046%	60
22	120	15	0.00200	30	0.1000%	32
23	1,500	29	0.02143	50	0.0128%	56
24	1,487	25	0.01563	47	0.0178%	53
25						
26						
27	1,987	29	0.00023	14	8.0000%	11
28	9,043	41	0.00867	43	0.0278%	48
29	670	22	0.00006	7	5.8000%	12
30						
31	100	14	0.00060	21	3.7000%	15
32						
33	20	6	0.00044	20	0.8000%	23
34	3,513	33	0.00037	18	4.9000%	13
35						
36						
37	20	6	0.00002	3	87.8000%	3
38	3,400	32	0.00363	39	0.5000%	24
39	8,300	40	0.00378	37	0.0727%	40
40	67	13	0.00002	2	100.0000	1
41	30,780	53	0.22094	61	0.0083%	57
42	12,210	46	0.07867	56	0.0230%	51
43						
44						
45	1,746	27	0.00287	35	0.0864%	38
46	21,818	51	0.00435	40	0.0832%	42
47	1,804	28	0.00885	41	0.0401%	43
48						
49	13,100	48	0.04748	53	0.0058%	59
50						
51	10,827	44	0.00352	38	0.0781%	39
52	1,810,752	60	0.10403	59	0.0028%	61
53						
54	4,273	36	0.00003	5	8.2000%	10
55	80,180	55	0.00146	27	0.2000%	30
56						
57	270	17	0.00071	23	0.4000%	26
58	19,477	46	0.01609	46	0.0171%	54
59						
60						
61	20,378	50	0.07309	57	0.0250%	50
62						
63						
64	60	11	0.00025	15	1.1000%	17
65	24,000	52	0.08154	55	0.0287%	48
66	449,782	59	0.03446	52	0.0282%	47
67	161,307	57	0.02592	51	0.0706%	41
68	2,625	30	0.00248	32	0.1000%	32
69	10	5	0.00012	12	14.6000%	9
70	7	4	0.00013	13	2.0000%	16
71	120	15	0.00079	25	0.3000%	28
72	25	9	0.00011	11	18.5000%	8
73						
74	756	23	0.00002	3	98.4000%	4
75	6	3	0.00007	9	25.3000%	6
76						
77						
78	2,876	31	0.01383	46	0.1000%	32
79	1,285	24	0.01232	45	0.0343%	44
80	3,643	35	0.00183	29	0.1000%	32
81	20,030	49	0.01862	49	0.0145%	55

RESULTS AND RANKS OF THE THREE APPROACHES BASED ON WASTES

1989

PLANT ID	CRTK WASTES WASTES	CRTK WASTES RANK	WST/THPT RATIO RATIO	WST/THPT RATIO RANK	PPF ANALYSIS (in %) SCORE	PPF ANALYSIS (in %) RANK
1						
2	5 750	46	0 00274	36	0 4000%	36
3	500	10	0 00017	10	7 1000%	10
4	1 250	35	0 00011	7	10 5000%	7
5	83,974	59	0 00637	49	0 2000%	49
6	500	10	0 00106	25	1 1000%	26
7	4 500	42	0 00398	44	0 3000%	42
8	371	8	0 00097	20	1 5000%	20
9	128 180	60	0 02920	57	0 0411%	57
10	8 627	46	0 00099	22	1 2000%	22
11	9	3	0 00010	6	11 6000%	6
12	892,863	63	0 00924	50	0 1000%	51
13	560	22	0 00047	16	2.6000%	17
14	4 820	44	0 00186	31	0 6000%	31
15	20	4	0 00023	13	5 1000%	13
16	32,432	57	0.00016	9	7 3000%	9
17	10,800	51	0 00102	23	1 2000%	22
18	1	1	0 00003	2	41 7000%	2
19	251	7	0 00016	8	7 5000%	8
20	1 293	38	0.00143	29	1 4000%	21
21	500	10	0 00025	41	0 4000%	36
22	250	6	0 00324	40	0 4000%	38
23	1 500	37	0 02242	56	0 0536%	56
24						
25						
26						
27	1 682	38	0.00018	11	6.6000%	11
28	10,806	52	0 00966	51	0 1000%	51
29	847	24	0 00004	4	29.0000%	4
30						
31						
32						
33	500	10	0.01119	53	0 1000%	51
34	1,000	25	0 00024	15	5 0000%	15
35						
36						
37	500	10	0 00046	17	2.6000%	17
38	3,596	41	0.00415	46	0.3000%	42
39	5 421	45	0.00301	39	0 4000%	38
40	1 000	25	0.00027	18	4.6000%	18
41	11 441	53	0.06607	62	0 0200%	62
42	1,000	25	0.00136	28	0 9000%	28
43						
44	500	10	0.02069	56	0.0581%	56
45	1 148	33	0 00147	30	0.8000%	30
46	6 460	47	0 00086	21	1 2000%	22
47	1,000	25	0 00402	45	0.3000%	42
48						
49	9,500	50	0.03241	59	0 0371%	59
50	400	9	0.00386	43	0.3000%	42
51	13,584	54	0.00436	47	0.3000%	42
52	788,477	62	0 06681	61	0 0211%	61
53						
54	4,505	43	0 00003	3	37 6000%	3
55	14 600	55	0 00024	13	5 1000%	13
56	1 000	25	0 00112	26	1 1000%	25
57	500	10	0 00129	27	0.9000%	26
58	2,977	40	0.00220	34	0.5000%	34
59						
60						
61	561	21	0.00246	37	0.5000%	34
62						
63						
64	1 000	25	0 00476	46	0 3000%	42
65	42,500	58	0 15179	63	0 0076%	63
66	449,986	61	0 03298	60	0 0364%	60
67	588	23	0 00021	12	5 7000%	12
68	1 000	25	0 00106	24	1 1000%	26
69						
70	34	5	0 00056	19	2.2000%	19
71	500	10	0 00206	33	0 6000%	31
72	500	10	0 00233	35	0.5000%	34
73	1 000	25	0 02941	58	0 0408%	58
74	500	10	0 00001	1	100.0000	1
75	5	2	0 00006	5	22.1000%	5
76						
77	17 200	56	0 01623	54	0 0740%	54
78	500	10	0 00242	36	0 5000%	34
79	1 150	34	0 01103	52	0 2000%	49
80	6,947	49	0 00381	42	0 3000%	42
81	2 000	39	0 00200	32	0 6000%	31

RESULTS AND RANKS OF THE THREE APPROACHES BASED ON RELEASES

1991

PLANT ID	TRI RELEASES RELEASE	RANK	REL/THPT RATIO RATIO	RANK	PPF ANALYSIS (in %) SCORE	RANK
1	3	2	0.000061	11	1.5000%	18
2	3,960	44	0.002800	45	0.3000%	28
3	3,535	43	0.003719	47	0.2000%	32
4	9	5	0.000001	1	100.0000	1
5	250,629	64	0.020030	60	0.0061%	63
6	61	17	0.000109	13	7.5000%	9
7	468	28	0.000206	19	0.7000%	25
8	880	31	0.001866	42	0.1000%	36
9	5,630	49	0.003121	46	0.3000%	28
10	1,356	36	0.000212	20	0.6000%	23
11	10	7	0.000145	15	0.6000%	23
12	56,784	61	0.000656	29	0.2000%	32
13	367	26	0.000422	26	0.3000%	28
14	50,696	60	0.049666	65	0.0287%	52
15	194	24	0.002004	43	0.0613%	47
16	196,218	63	0.001081	34	0.1000%	36
17	6,605	52	0.000628	31	0.2000%	32
18						
19	42	15	0.000054	10	2.1000%	17
20	691	30	0.001636	38	0.0784%	43
21	1,412	37	0.015669	58	0.0078%	61
22	60	18	0.001807	41	0.0679%	46
23	800	32	0.018229	59	0.0067%	62
24	630	33	0.008036	55	0.0136%	59
25						
26						
27	2,113	41	0.000338	24	2.4000%	18
28	10,032	56	0.009710	56	0.0127%	60
29	3,110	42	0.000868	33	0.1000%	36
30						
31	150	23	0.000287	22	3.1000%	14
32						
33	20	11	0.000406	25	0.3000%	28
34	15	9	0.000026	7	29.1000%	7
35						
36	31	14	0.000130	14	0.8000%	22
37	20	11	0.000022	6	38.4000%	5
38	8,570	51	0.007928	53	0.1000%	36
39	8,000	50	0.003757	48	0.0327%	50
40	225	25	0.000020	4	40.8000%	4
41	71	19	0.000593	30	1.4000%	19
42	5,325	47	0.029127	62	0.0281%	53
43	15	9	0.000333	23	2.5000%	15
44						
45	1,479	38	0.001275	36	0.0983%	42
46	25,280	59	0.002824	44	0.0466%	49
47	1,667	39	0.008087	51	0.0201%	55
48						
49	11,191	57	0.044806	64	0.0027%	65
50	1	1	0.000006	2	100.0000	1
51	4,293	46	0.001109	35	0.1000%	36
52	7,873	54	0.000606	27	1.2000%	21
53						
54	4,102	45	0.000034	9	3.8000%	13
55	6,200	50	0.000093	12	1.3000%	20
56	1,000	35	0.001644	39	0.0747%	44
57	957	34	0.008281	54	0.0146%	56
58	24,867	58	0.023250	61	0.0063%	64
59						
60						
61	150	22	0.001451	37	0.6000%	28
62						
63						
64	125	21	0.000629	28	0.2000%	32
65						
66	62,724	62	0.004229	49	0.0280%	51
67	252,006	65	0.044404	63	0.0184%	56
68	1,965	40	0.001666	40	0.0727%	45
69	10	7	0.000154	16	5.3000%	10
70	7	4	0.000219	21	0.6000%	28
71	110	20	0.000638	32	0.1000%	36
72	25	13	0.000154	17	5.3000%	10
73						
74	381	27	0.000020	3	41.0000%	3
75	3	2	0.000028	8	31.6000%	6
76						
77	67	16	0.000173	18	4.7000%	12
78	9	5	0.000032	6	25.5000%	8
79	578	29	0.013800	57	0.0512%	48
80	5,537	48	0.006130	50	0.0230%	54
81	7,127	53	0.007067	52	0.0174%	57

RESULTS AND RANKS OF THE THREE APPROACHES BASED ON RELEASES

1990

PLANT ID	TRI RELEASES RELEASES	RANK	REL/THPT RATIO RATIO	RANK	PPF ANALYSIS (in %) SCORE	RANK
1	3	2	0.000056	9	4.9000%	15
2	5,361	42	0.002809	39	0.7000%	26
3	3,535	37	0.003583	43	0.5000%	30
4	20	6	0.000003	1	100.0000	1
5	96,919	57	0.006653	46	0.0413%	50
6	59	12	0.000102	13	17.9000%	8
7	510	23	0.000262	19	1.0000%	25
8	407	21	0.000784	30	0.6000%	27
9	128,861	60	0.034603	56	0.0525%	48
10	14,597	50	0.001674	33	0.2000%	36
11						
12	25,846	54	0.000278	21	1.1000%	23
13	456	22	0.000267	23	1.0000%	24
14	94,249	56	0.000258	22	14.8000%	10
15	60	13	0.000817	27	0.4000%	31
16	15,158,992	64	0.091698	59	0.0137%	56
17	9,700	46	0.000908	32	0.3000%	33
18	1	1	0.000042	7	43.4000%	6
19	49	11	0.000074	11	3.7000%	17
20	661	24	0.002451	38	0.1000%	37
21	6,652	43	0.059169	58	0.0046%	60
22	120	18	0.001998	36	0.1000%	37
23	1,500	29	0.021433	54	0.0125%	56
24	1,467	28	0.015627	51	0.0178%	53
25						
26						
27	1,987	33	0.000230	17	8.0000%	13
28	9,043	45	0.008674	48	0.0278%	52
29	670	25	0.000046	8	5.8000%	14
30						
31	100	16	0.000485	28	3.7000%	17
32						
33	20	6	0.000444	25	0.6000%	29
34	3,513	36	0.000369	24	4.8000%	15
35						
36	109,888	59	0.420518	61	0.0043%	61
37	20	6	0.000019	3	97.6000%	3
38	27	10	0.000031	5	58.6000%	5
39	8,300	44	0.003779	42	0.0727%	46
40	87	15	0.000018	2	100.0000	1
41	18,821	51	0.135815	60	0.0136%	57
42	110	17	0.000717	29	2.8000%	21
43						
44						
45	1,746	31	0.002888	40	0.0958%	43
46	12,518	48	0.002518	38	0.1000%	37
47	1,827	32	0.008570	46	0.0416%	49
48						
49	13,100	49	0.047458	57	0.0058%	59
50						
51	10,827	47	0.003520	41	0.0781%	44
52	4,113	39	0.000288	20	2.9000%	20
53						
54	4,273	40	0.000034	6	8.2000%	12
55	5,180	41	0.000084	12	3.3000%	19
56						
57	270	20	0.000714	28	0.4000%	31
58	19,477	52	0.016088	52	0.0171%	53
59						
60						
61	1,525	30	0.005470	44	0.3000%	33
62						
63						
64	60	13	0.000253	18	1.1000%	23
65						
66	102,128	58	0.007822	47	0.0584%	47
67	181,207	62	0.025825	55	0.0705%	46
68	2,625	34	0.002475	37	0.1000%	37
69	10	5	0.000125	15	14.6000%	11
70	7	4	0.000135	16	2.0000%	22
71	120	18	0.000787	31	0.3000%	33
72	25	9	0.000111	14	16.5000%	9
73						
74	788	28	0.000019	4	98.4000%	4
75	6	3	0.000072	10	25.3000%	7
76						
77	160,699	61	0.507244	62	0.0036%	62
78	2,878	35	0.013928	50	0.1000%	37
79	1,286	27	0.012322	49	0.0343%	51
80	3,643	38	0.001834	34	0.1000%	37
81	20,030	53	0.018923	53	0.0145%	55

RESULTS AND RANKS OF THE THREE APPROACHES
BASED ON RELEASES
1989

PLANT ID	TRI RELEASES RELEASE	RANK	REL/THPT RATIO RATIO	RANK	PPF ANALYSIS (in %) SCORE	RANK
1						
2	5 750	49	0 002736	37	0 4000%	38
3	500	12	0 000168	11	7 1000%	11
4	1 500	35	0 000138	10	8 7000%	10
5	68 500	66	0 005196	47	0 2000%	45
6	1 500	35	0 003164	40	0 4000%	36
7	1,000	25	0 000679	21	1 4000%	22
8	360	11	0 000991	23	1 5000%	21
9	8 180	52	0 001663	32	0 6000%	32
10	10,428	54	0 001197	27	1 0000%	28
11	9	3	0 000104	8	11 6000%	8
12	41,803	64	0 000431	18	2 8000%	18
13	560	19	0 000467	17	2.6000%	17
14	2,223	43	0 000682	22	1 3000%	24
15	30	6	0 000352	15	3 4000%	15
16	92,832	67	0 000470	16	2.5000%	16
17	87,000	66	0 008161	56	0 1000%	56
18	212	9	0.008106	46	0 2000%	45
19	1,998	39	0 001025	24	1 2000%	25
20	1,290	34	0 001436	28	1 4000%	22
21	750	20	0 004878	46	0 2000%	45
22	500	12	0.008486	51	0 2000%	45
23	1 500	36	0 022422	63	0 0539%	63
24	2,666	44	0 033487	65	0 0368%	66
25	279	10	0 004371	44	0.3000%	43
26						
27	1,662	40	0 000176	12	6.8000%	12
28	10,806	56	0.008666	58	0 1000%	58
29	647	24	0.000041	5	28.0000%	5
30	12	4	0.000046	6	25.8000%	6
31	206	8	0.001121	25	1 1000%	28
32						
33	500	12	0.011180	58	0 1000%	58
34	1 000	25	0.000242	13	5.0000%	13
35						
36						
37	2,000	41	0.001829	31	0 7000%	30
38	29	5	0.000033	3	36.6000%	3
39	5,671	48	0.003144	39	0 4000%	38
40	1,000	25	0 000270	14	4.8000%	14
41	1,250	32	0.008464	50	0 2000%	46
42	1,000	25	0.001383	28	0.8000%	29
43	10,656	55	0.256884	66	0.0047%	68
44	500	12	0 020881	62	0 0581%	62
45	5,818	50	0.007440	54	0 2000%	45
46	3,760	46	0.000568	20	2.1000%	20
47	1,250	32	0 008024	49	0 2000%	45
48						
49	9,500	53	0 032412	64	0.0371%	64
50	3	1	0.000028	2	41.5000%	2
51	18,941	61	0.008080	48	0.2000%	45
52	37,237	63	0.002883	36	0 4000%	36
53						
54	5,309	47	0.000036	4	31.8000%	4
55	6,100	51	0.000131	9	9 2000%	9
56	1,000	25	0.001123	26	1 1000%	28
57	1,000	25	0.002576	35	0.8000%	33
58	16,811	60	0.013881	60	0.0865%	60
59						
60						
61	760	22	0.003341	41	0 4000%	38
62						
63						
64	1,500	36	0 007132	53	0 2000%	45
65	500	12	0.001786	30	0 7000%	30
66	31,409	62	0 002303	33	0.5000%	33
67	109,930	68	0 038456	68	0.0304%	68
68	3,250	45	0.003428	42	0 4000%	38
69						
70	34	7	0.000568	19	2.2000%	19
71	790	20	0 003074	38	0 4000%	38
72	751	23	0 003487	43	0.3000%	43
73	2,000	41	0 058624	67	0.0204%	67
74	500	12	0 000012	1	100.0000	1
75	5	2	0.000064	7	22.1000%	7
76						
77	17 200	59	0 016227	61	0 0740%	61
78	500	12	0 002418	34	0.5000%	33
79	1 180	31	0 011027	57	0 2000%	45
80	18 413	58	0 008666	52	0 2000%	45
81	13 000	57	0 012968	59	0 0928%	59

TRI RATIO AND % CHANGE IN TOTAL RELEASES

PLANT ID	RELEASES Rel 89	Rel 90	Rel 91	PLANT ID#	TRI RATIO 90/89	% CHANGE 89 TO 90	Rank	PLANT ID#	TRI RATIO 91/90	% CHANGE 90 TO 91	Rank
1	0	3	3	1	NA	NA	NA	1	100.00%	0.0000%	37
2	5,750	5,361	3,950	2	93.23%	-6.7652%	41	2	73.66%	26.3197%	26
3	500	3,536	3,536	3	707.00%	607.0000%	63	3	100.00%	0.0000%	37
4	1,500	20	9	4	1.33%	-98.6667%	12	4	45.00%	55.0000%	17
5	68,500	96,918	250,629	5	141.49%	41.4876%	50	5	258.60%	158.5984%	58
6	1,500	58	61	6	3.93%	-96.0667%	15	6	103.39%	3.3898%	45
7	1,000	510	466	7	51.00%	-49.0000%	29	7	91.37%	-8.6275%	32
8	380	407	680	8	107.11%	7.1053%	44	8	167.08%	67.0782%	52
9	8,180	128,861	5,830	9	1550.75%	1450.7457%	67	9	4.44%	95.5617%	10
10	10,425	14,597	1,350	10	139.96%	39.6780%	49	10	9.31%	90.6569%	11
11	9	0	10	11	0.00%	-100.0000%	1	11	NA	NA	NA
12	43,468	25,849	56,764	12	62.13%	-37.8747%	33	12	219.63%	119.5322%	57
13	580	466	387	13	78.46%	21.5517%	36	13	80.86%	19.3407%	28
14	74,288	94,249	50,696	14	4238.72%	4139.7211%	68	14	53.79%	-46.2061%	22
15	30	60	194	15	200.00%	100.0000%	56	15	323.33%	223.3333%	60
16	92,832	16,156,862	198,216	16	19661.13%	19461.1341%	69	16	1.00%	-98.9064%	9
17	57,000	9,700	6,606	17	11.15%	-88.0646%	21	17	68.09%	-31.9072%	25
18	212	1	0	18	0.47%	-99.5283%	10	18	0.00%	100.0000%	1
19	1,588	49	42	19	3.07%	-96.9266%	13	19	85.71%	-14.2857%	31
20	1,283	661	661	20	51.12%	-48.5788%	30	20	100.00%	0.0000%	37
21	750	6,862	1,412	21	913.60%	813.6000%	64	21	20.61%	79.3928%	13
22	500	120	60	22	24.00%	-76.0000%	28	22	50.00%	-50.0000%	19
23	1,500	1,500	500	23	100.00%	0.0000%	42	23	33.33%	-66.6667%	21
24	2,688	1,487	830	24	55.36%	-44.6182%	37	24	55.82%	-44.1828%	23
25	279	0	0	25	0.00%	-100.0000%	1	25	NA	NA	NA
26	0	0	0	26	NA	NA	NA	26	NA	NA	NA
27	1,682	1,967	2,113	27	116.93%	16.9332%	46	27	108.34%	8.3412%	46
28	10,906	9,043	10,032	28	82.90%	17.0975%	36	28	110.94%	10.9366%	47
29	847	670	3,110	29	79.10%	-20.8673%	38	29	464.18%	364.1791%	62
30	12	0	0	30	0.00%	-100.0000%	1	30	NA	NA	NA
31	208	100	180	31	48.78%	-51.2195%	28	31	180.00%	80.0000%	53
32	30	9,892,250	0	32	31974166.67%	31974066.6667%	70	32	0.00%	100.0000%	1
33	500	20	20	33	4.00%	-96.0000%	18	33	100.00%	0.0000%	37
34	1,000	3,513	15	34	351.30%	251.3000%	60	34	0.43%	-99.5730%	8
35	0	0	0	35	NA	NA	NA	35	NA	NA	NA
36	11	108,888	31	36	NA	NA	NA	36	0.03%	-99.9718%	3
37	2,000	20	20	37	1.00%	-99.0000%	11	37	100.00%	0.0000%	37
38	29	27	6,570	38	93.10%	-6.8966%	40	38	24333.33%	24233.3333%	64
39	5,671	5,300	5,000	39	146.38%	46.3587%	52	39	94.39%	-3.8146%	39
40	1,000	97	225	40	9.70%	-90.3000%	16	40	231.96%	131.9588%	58
41	1,280	19,021	71	41	1513.88%	1413.8800%	68	41	0.38%	-99.6248%	7
42	1,000	110	5,328	42	11.00%	-89.0000%	19	42	4840.91%	4740.9091%	63
43	10,656	46,654	15	43	430.23%	330.2306%	61	43	0.03%	-99.9673%	4
44	500	0	0	44	0.00%	-100.0000%	1	44	NA	NA	NA
45	5,816	1,746	1,479	45	30.01%	-69.9667%	27	45	84.71%	15.2921%	29
46	3,750	12,516	25,280	46	333.76%	233.7600%	59	46	201.96%	101.9616%	56
47	1,230	1,827	1,697	47	148.18%	48.1800%	51	47	92.88%	-7.1196%	34
48	500	0	4,038	48	NA	NA	NA	48	NA	NA	NA
49	9,500	13,100	11,191	49	137.89%	37.8947%	48	49	85.43%	14.5725%	30
50	3	0	1	50	0.00%	-100.0000%	1	50	NA	NA	NA
51	18,841	10,827	4,280	51	57.69%	-42.3103%	32	51	39.29%	-60.7120%	15
52	37,257	4,119	7,973	52	11.05%	-88.9546%	20	52	193.65%	93.6488%	54
53	178,189	28,110	9,127	53	NA	NA	NA	53	NA	NA	NA
54	5,309	4,279	4,192	54	80.49%	-19.5140%	37	54	98.00%	-4.0019%	35
55	8,100	5,190	6,200	55	64.07%	-35.9259%	34	55	119.46%	19.4605%	48
56	1,000	0	1,000	56	0.00%	-100.0000%	1	56	NA	NA	NA
57	1,000	270	957	57	27.00%	-73.0000%	28	57	354.44%	254.4444%	61
58	18,511	19,477	24,867	58	103.54%	3.5400%	43	58	127.67%	27.6737%	49
59	0	0	0	59	NA	NA	NA	59	NA	NA	NA
60	0	0	0	60	NA	NA	NA	60	NA	NA	NA
61	750	1,525	150	61	203.33%	103.3333%	57	61	9.84%	-90.1639%	12
62	0	0	0	62	NA	NA	NA	62	NA	NA	NA
63	47,000	0	0	63	0.00%	-100.0000%	1	63	NA	NA	NA
64	1,500	60	125	64	4.00%	-96.0000%	16	64	208.33%	108.3333%	58
65	500	0	0	65	0.00%	-100.0000%	1	65	NA	NA	NA
66	31,409	102,128	62,724	66	325.19%	225.1562%	56	66	61.42%	38.5830%	24
67	108,939	161,307	252,085	67	148.74%	48.7381%	53	67	156.28%	56.2827%	51
68	3,250	2,825	1,965	68	86.77%	-13.2308%	35	68	74.69%	25.1429%	27
69	0	10	10	69	NA	NA	NA	69	100.00%	0.0000%	37
70	34	7	7	70	20.59%	-79.4118%	23	70	100.00%	0.0000%	37
71	750	120	110	71	16.00%	-84.0000%	22	71	91.67%	-8.3333%	33
72	751	25	25	72	3.33%	-96.6711%	14	72	100.00%	0.0000%	37
73	2,000	0	0	73	0.00%	-100.0000%	1	73	NA	NA	NA
74	500	786	381	74	157.20%	57.2000%	55	74	48.47%	-51.5267%	18
75	5	6	3	75	120.00%	20.0000%	47	75	50.00%	-50.0000%	19
76	889	7	1,478	76	NA	NA	NA	76	NA	NA	NA
77	17,200	160,888	67	77	934.30%	834.2988%	66	77	0.04%	-99.9583%	5
78	500	2,878	9	78	575.20%	475.2000%	62	78	0.31%	-98.6871%	6
79	1,150	1,286	578	79	111.74%	11.7391%	46	79	44.96%	-55.0156%	16
80	16,413	3,843	5,537	80	22.20%	77.8042%	24	80	151.99%	51.9901%	50
81	13,000	20,030	7,127	81	154.08%	54.0769%	54	81	35.58%	-64.4154%	14

Reported Throughput for the 81 Plants

1989-1991

PLANT ID	1989 VOC	1989 ACUTE	1989 TOTAL	1990 VOC	1990 ACUTE	1990 TOTAL	1991 VOC	1991 ACUTE	1991 TOTAL
1	95 423	95 423	95 423	53 695	53 695	53 695	36 830	36 830	36 830
2	0	2,102,095	2,102,095	0	1 908,568	1 908 568	0	1 410 774	1 410 774
3	0	2 967 638	2,967 638	0	910 400	910 400	0	950 574	950,574
4	8 860 050	10 900 790	10 900 790	7 186 471	7 280 471	7 280 471	7 193 767	7 329 767	7 329 767
5	13 182,345	6 887 453	13 182,345	14 568,377	9 607 146	14 568 377	12 512,651	7 790 241	12 512 651
6	0	474 146	474 146	0	577 345	577 345	0	561 290	561 290
7	461 734	1 137,734	1 137 734	539 207	1 944 463	1 944 463	549 117	2 289 888	2 289,888
8	78,800	308,843	383 843	104,800	414 400	519 000	72,049	288 168	360 217
9	0	4 390,000	4,390 000	0	3 685,861	3 685 861	0	1 804 000	1 804 000
10	3 129,303	6 713,546	6 713,546	2 577,901	6 717,307	6 717 307	1 228 653	6 424 166	6 424 166
11	68,870	68 870	68,870	41 215	41 215	41 215	68 746	68 746	68 746
12	98,589,409	98,589 409	98 734 706	93 003,398	93,003,398	93 098 647	100,041 778	100 041 778	100 212,478
13	1 242,000	1 242,000	1,242,000	1,588 456	1,588,456	1 588 456	870,460	870 460	870 460
14	2,393,360	2,492,362	336,387,879	3 497 788	3,580,020	329,819,940	948 430	1 020 788	315 683 027
15	86,281	86,281	86 281	97 277	97,277	97 277	96,527	96,527	96,527
16	124 121,828	197,311 254	197,311 254	119 488 333	196 089 237	196 089 237	112,391 566	181 614 578	181,614 578
17	10 821,507	10 821,507	10,821,507	10 898,391	10 898,391	10 898,391	10,508,700	10 508 700	10,508,700
18	0	34,709	34,709	0	23 721	23,721	0	5,560	5,560
19	1,567,229	1,567 229	1,567 229	898,361	898,361	898 361	729 003	729 003	729 003
20	901 258	873,989	901,258	289 711	239,207	289 711	403,396	373,339	403,396
21	153,749	153 749	153 749	115,804	115,804	115,804	90,000	90 000	90,000
22	77,091	77,091	77 091	60 133	60 133	60 133	33,200	33 200	33 200
23	68,800	68,800	68,800	69,867	69,867	69,867	43 687	43 687	43,687
24	60 160	60 160	60 160	95 157	95 157	95 157	91,654	91,654	91,654
25	0	63,825	63,825	0	47,907	47,907	0	22,084	22,084
26	0	5 693	5 693	0	5,721	5 721	0	6 292	6 292
27	0	9 564 068	9,564,068	0	8,848,467	8,848,467	0	6 297 160	6,297 160
28	1 087,546	1 108,428	1,108,428	887 486	915,807	915,807	986 014	1 033 214	1,033 214
29	20,421,366	20,421,366	20,421,366	14,089,000	14,089,000	14,089,000	3 148 191	3 148 191	3,148 191
30	0	258,332	258,332	0	291,832	291,832	0	122,760	122,760
31	0	182,803	182,803	0	201,885	201,885	0	675 000	675,000
32	0	108,214	108,214	0	8,592,250	8,592,250	0	102,714	102,714
33	44,884	44 884	44 884	45,020	45,020	45,020	49 000	49 000	49,000
34	0	4,131,818	4,131,818	0	9,512,773	9,512,773	0	534,000	534,000
35	0	58,325	58,325	0	67,313	67,313	0	81,000	81,000
36	0	0	0	114,886	281,508	281,508	132,083	238,842	238,842
37	0	1,083,550	1,083,550	0	1,088,020	1,088,020	0	890,000	890,000
38	0	668,570	668,570	0	884,409	884,409	0	828 730	828,730
39	1,803,732	1,803 732	1,803,732	2,186,592	2,186,592	2,186,592	2,129,392	2,129,392	2,129,392
40	0	3,706,915	3,706,915	0	5,306,835	5,306,835	0	11,248,598	11,248,598
41	0	183,674	183,674	0	139,315	139,315	0	119,701	119,701
42	0	722,802	722,802	0	153,450	153,450	0	182,823	182,823
43	0	41,856	41,856	0	41,539	41,539	0	45,090	45,090
44	0	24,200	24,200	0	83,367	83,367	0	47,980	47,980
45	374 182	781,880	781,880	334,441	608,888	608,888	285,862	1 160,212	1 160,212
46	6,587,080	6,587 080	6,587 080	4,970,333	4,970,333	4,970,333	9 834 419	9 834 419	9,834 419
47	248,781	248,781	248 781	278,086	278,086	278 086	278,314	278,314	278,314
48	0	0	0	0	0	0	0	0	0
49	293,104	293,104	293,104	278,031	278,031	278,031	249,774	249 774	249,774
50	0	103,600	103,600	0	128,600	128,600	0	122,275	122,275
51	3,115,494	3,115,494	3,115,494	3,104,584	3,104,584	3,104,584	3,870,788	3 870 788	3,870,788
52	8,008,843	13,579,215	13,579,215	8,638,800	15,463,860	15,463,860	6,374,880	15,773,460	15 773,460
53	0	0	69,202,033	0	0	57,141,700	0	0	380,000
54	141,089,200	141,107,330	141 107,330	128,938,000	127,101,840	127 101,840	121,756,000	121,908,000	121,908,000
55	62,010,000	62,010,000	62,010,000	62,000,000	62,000,000	62,000 000	66,510,000	66,510,000	66,510,000
56	880,488	880,488	880,488	728,357	728,357	728,357	608,386	608,386	608,386
57	58,508	388,128	388,128	27,016	377,808	377,808	30,404	115,566	115,566
58	1,388,128	1,388,128	1,388,128	1,210,891	1 210,891	1 210,891	1 069,556	1 069 556	1 069,556
59	0	46,200	46,200	0	84,000	84,000	0	131,632	131,632
60	73,840	73,840	73,840	73,480	73,480	73,480	64,880	64,880	64,880
61	0	224,484	224,484	0	278,804	278,804	0	103,410	103,410
62	159,287	1 177,288	1,284,344	160,754	1,073,728	1 107,512	154,174	914 896	983,538
63	0	48,800	48,800	0	72,000	72,000	0	25,818	25,818
64	210,333	210,333	210,333	238,880	238,880	238,880	238,100	238,100	238,100
65	0	280,000	280,000	0	380,000	380,000	0	402,500	402,500
66	12,051,539	13,838,848	13 838,848	12,481 045	13 058 488	13,058,488	11,883,018	14 833,487	14,833 487
67	0	2,786 134	2,786,134	0	6 222,117	6 222,117	0	5 677 247	5 677 247
68	948,500	948,500	948,500	1 080 486	1,080 486	1,080,486	1,183,954	1 183,954	1 183,954
69	0	87,221	87 221	0	80,084	80,084	0	65,118	65,118
70	61 221	61,221	61,221	51,943	51,943	51,943	31,870	31,870	31,870
71	244,000	244,000	244 000	152,400	152,400	152,400	131,250	131,250	131,250
72	0	214 732	214,732	0	225,158	225,158	0	182,831	182,831
73	0	34,000	34,000	0	71,030	71,030	0	37 420	37,420
74	0	41 824,920	41 824,920	0	41 446 708	41 446 708	0	19,086 240	19,086,240
75	0	92,000	92,000	0	83,000	83 000	0	115,800	115,800
76	0	0	650,580	0	0	334,839	0	0	108,872
77	0	1,059,864	1 059,864	0	318,808	318,808	0	387,884	387,884
78	0	208,885	208 885	0	208 487	208 487	0	281,033	281 033
79	104 288	72,832	104 288	104 288	72,832	104 288	42,500	10,872	42,500
80	1 440,000	2,349 490	2,349 490	1 451 274	1,988 184	1 988 184	824,000	1 079 290	1 079 290
81	199 464	1 002,420	1 002 420	207 931	1 058 489	1 058 489	202,709	1 006 442	1 006 442

Reported Wastes for the 81 Plants

1989-1991

	1989			1990			1991		
PLANT ID	VOC	ACUTE	TOTAL VOC/ACUTE	VOC	ACUTE	TOTAL VOC/ACUTE	VOC	ACUTE	TOTAL VOC/ACUTE
1				3	3	3	3	3	3
2	0	5 750	5 750	0	5 361	5 361	0	3 950	3 950
3	0	500	500	0	3 535	3 535	0	3 535	3 535
4	750	1 250	1 250	10	20	20	5	9	9
5	83 974	89 829	83,974	138 174	123 068	138 174	270 000	270 000	270 000
6	0	500	500	0	59	59	0	61	61
7	3,500	4 500	4 500	256	510	510	4 575	70 700	70 700
8	64	307	371	71	336	407	177	503	680
9	0	128 180	128 180	0	246 651	246 651	0	5 830	5 830
10	500	8,627	8 627	5 830	14,587	14 587	502	1,359	1 359
11	9	9	9				10	10	10
12	892,663	892,663	892,663	36 194	36 194	36,194	673 412	673 412	677 466
13	560	560	560	456	456	456	367	367	367
14	3 444	4 620	4 620	7 289	9,314	9 314	4 792	7 913	57 018
15	20	20	20	60	60	60	337	337	337
16	27,515	32,432	32,432	1 425,938	36,279,799	36 279 799	348 687	18 833,333	18 833,333
17	10,800	10,800	10 800	9 700	9 700	9 700	6 606	6 606	6 606
18	0	1	1	0	1	1			
19	251	251	251	8 049	8,049	8 049	42	42	42
20	1 293	793	1 293	661	648	661	661	648	661
21	500	500	500	6 862	6,862	6 862	1 412	1 412	1 412
22	250	250	250	120	120	120	60	60	60
23	1 500	1,500	1 500	1 500	1 500	1 500	600	600	600
24				1 487	1 487	1 487	630	630	630
25									
26									
27	0	1 682	1 682	0	1,987	1,987	0	2,113	2,113
28	10 675	10,906	10,906	8,874	9,043	9,043	9 746	10 032	10 032
29	847	847	847	670	670	670	3,110	3,110	3 110
30						100			
31				0	100		0	180	180
32							0	205,368	205,368
33	500	500	500	20	20	20	20	20	20
34	0	1 000	1 000	0	3 513	3,513	0	15	15
35									
36							29	191,880	191,880
37	0	500	500	0	20	20	0	20	20
38	0	3,598	3,598	0	3,400	3 400	0	6 570	6,570
39	5,421	5,421	5,421	8,300	8,300	8,300	8,000	8 000	8,000
40	0	1 000	1,000	0	97	97	0	225	225
41	0	11 441	11,441	0	30,760	30 760	0	71	71
42	0	1,000	1 000	0	12,210	12,210	0	5,325	5,325
43							0	15	15
44	0	500	500						
45	1 063	1,148	1 148	1,614	1,748	1 748	1,348	1 479	1,479
46	6 460	6,460	6 460	21,816	21,816	21,816	45,925	45,925	45,925
47	1 000	1 000	1 000	1 904	1,904	1 904	1 778	1 778	1 778
48									
49	9,500	9 500	9,500	13 100	13,100	13 100	11,191	11 191	11 191
50	0	400	400				0	156	156
51	13,584	13,584	13,584	10,927	10,927	10,927	4,293	4,293	4,293
52	788,050	788,477	788,477	920,494	1 610,752	1,610,752	973,846	2,302,827	2,302,827
53									
54	4 497	4 505	4,505	4 200	4,273	4,273	4 032	4 102	4 102
55	14 600	14,600	14,600	90,190	90 190	90 190	108 200	108,200	108 200
56	1,000	1,000	1,000				1 000	1 000	1 000
57	500	500	500	270	270	270	1 244	1 244	1 244
58	2,877	2,877	2,877	19,477	19 477	19 477	24,867	24,867	24,867
59									
60									
61	0	551	551	0	20,378	20,378	0	25,918	25,918
62									
63							0	96	96
64	1 000	1 000	1 000	60	60	60	125	125	125
65	0	42,500	42,500	0	24 000	24,000	0	61,575	61,575
66	52,856	449,986	449,986	35 211	449 762	449,762	62,298	3 077,332	3 077,332
67	0	568	568	0	181,307	181,307	0	252,096	252,096
68	1 000	1 000	1 000	2,625	2,625	2,625	3 466	3 466	3,466
69				0	10	10	0	10	10
70	34	34	34	7	7	7	7	7	7
71	500	500	500	120	120	120	110	110	110
72	0	500	500	0	25	25	0	25	25
73	0	1 000	1 000			786			
74	0	500	500	0	786		0	381	381
75	0	5	5	0	6	6	0	3	3
76									
77	0	17 200	17 200				0	67	67
78	0	500	500	0	2,878	2,878	0	9	9
79	1 150	700	1 150	1 286	836	1 286	578	102	578
80	6 447	6,947	6 947	3 177	3 643	3 643	5 537	5 537	5 537
81	500	2 000	2 000	15 593	20 000	20 000	8 584	9 428	9 428

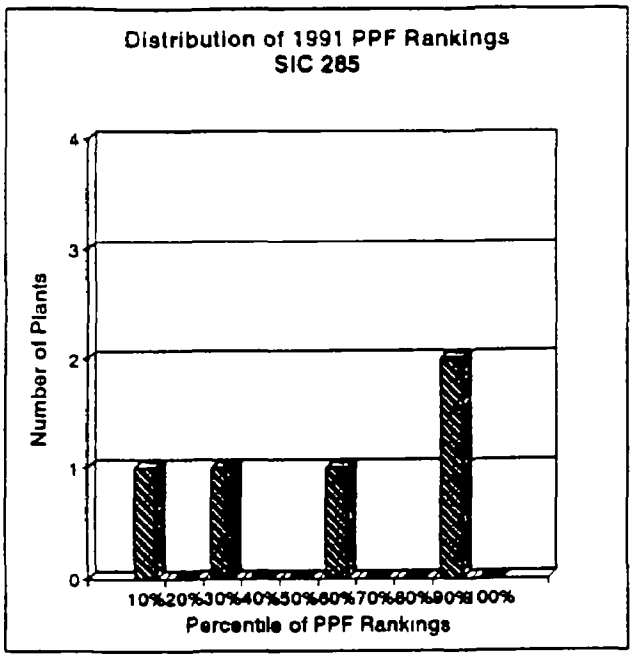
Reported Releases for the 61 Plants

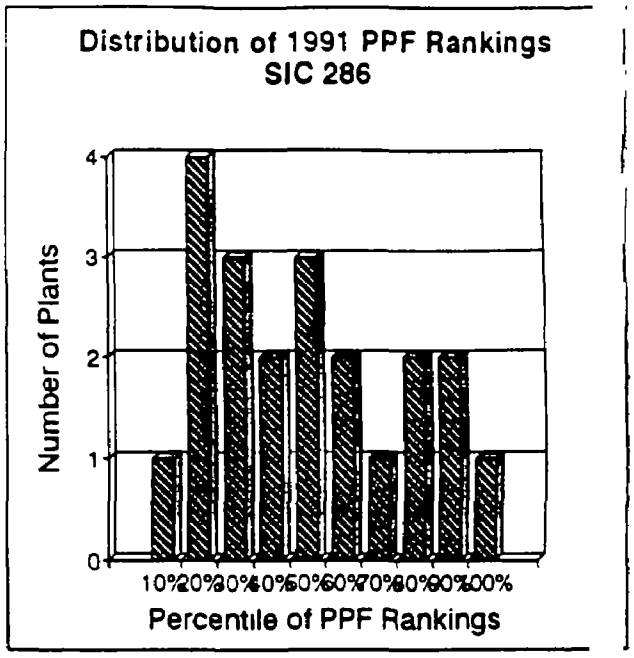
1989-1991

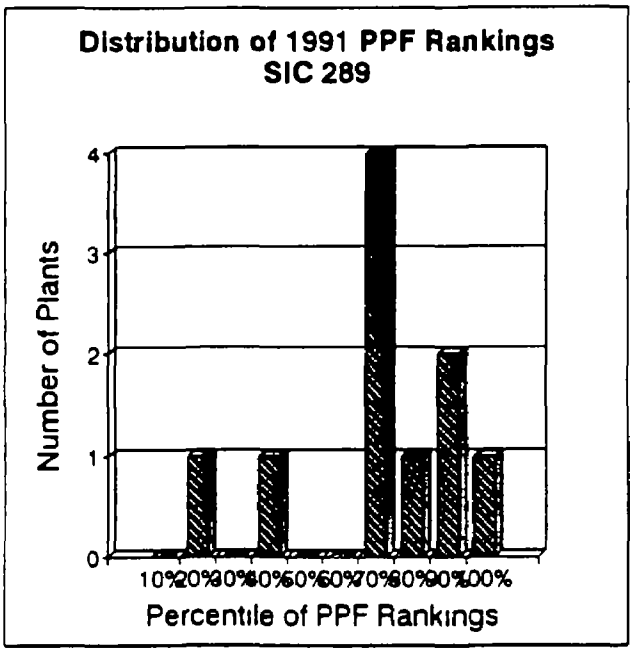
PLANT ID		1989 VOC	1989 ACUTE	1989 TOTAL VOC/ACUTE	1990 VOC	1990 ACUTE	1990 TOTAL VOC/ACUTE	1991 VOC	1991 ACUTE	1991 TOTAL VOC/ACUTE
1					3	3	3	3	3	3
2	✓	0	5 750	5 750	0	5,361	5 361	0	3 950	3 950
3	✓	0	500	500	0	3 535	3 535	0	3 535	3 535
4	✓	1 000	1 500	1 500	10	20	20	5	9	9
5		68,500	87 250	68 500	96,919	96,919	96,919	250 629	250 629	250 629
6		0	1 500	1 500	0	59	59	0	61	61
7		500	1 000	1 000	256	510	510	221	466	466
8		66	314	380	71	336	407	177	503	680
9		0	8 180	8 180	0	126 851	126 851	0	5 630	5 630
10		500	10 428	10 428	5 630	14 567	14 597	302	1 359	1 359
11		9	9	9				10	10	10
12	✓	41 603	41 603	41 603	23 736	23 736	25 846	53,166	53 166	55 764
13		560	560	560	456	456	456	367	367	367
14		821	2,223	2 223	4 067	6 060	94 249	2 402	4 593	50 698
15		30	30	30	60	60	60	194	194	194
16	✓	84 715	92,832	92,832	727 460	18 158,992	18 158,992	195,592	198 218	198 218
17		87 000	87 000	87 000	9 700	9 700	9 700	6 606	6 606	6 606
18		0	212	212	0	1	1			
19		1,598	1 598	1,598	49	49	49	42	42	42
20		1 293	793	1 293	661	648	661	661	644	661
21		750	750	750	6,852	6 852	6 852	1 412	1 412	1 412
22		500	500	500	120	120	120	60	60	60
23		1 500	1 500	1,500	1 500	1 500	1,500	600	600	600
24		2,666	2 666	2,666	1,487	1,487	1 487	630	630	630
25		0	279	279						
26										
27		0	1 662	1 662	0	1,987	1 987	0	2,113	2,113
28		10,676	10,808	10,808	8,874	9,043	9,043	9 746	10,032	10 032
29	✓	847	847	847	670	670	670	3,110	3 110	3,110
30		0	12	12						
31		0	206	206	0	100	100	0	160	160
32		0	30	30	0	9,592,250	9,592,250			
33		500	500	500	20	20	20	20	20	20
34		0	1 000	1 000	0	3,513	3,513	0	15	15
35										
36					0	109,968	109,968	22	31	31
37	✓	0	2,000	2,000	0	20	20	0	20	20
38		0	29	29	0	27	27	0	6,570	6 570
39		5,671	5,671	5,671	8,300	8,300	8,300	6 000	6,000	6 000
40	✓	0	1 000	1,000	0	97	97	0	228	228
41		0	1 250	1 250	0	18,921	18,921	0	71	71
42		0	1,000	1 000	0	110	110	0	5,325	5,325
43		0	10 868	10 868	0	45,864	45,864	0	15	15
44		0	500	500						
45		5 628	5,818	5,818	1 614	1 746	1,746	1 346	1,479	1 479
46		3,750	3 750	3,750	12,516	12,516	12,516	25,280	25,280	25,280
47		1 250	1 250	1 250	1,827	1,827	1,827	1 697	1,697	1 697
48										
49		9,500	9,500	9,500	13,100	13,100	13,100	11 191	11 191	11,191
50		0	3	3				0	1	1
51		18,941	18,941	18,941	10,927	10,927	10,927	4 293	4,293	4 293
52		50	37,237	37,237	494	4,113	4,113	245	7,973	7,973
53										
54		5 061	5,308	5,308	4,200	4 273	4,273	4 032	4,102	4,102
55		8 100	8 100	8 100	5 180	5,180	5 180	6 200	6 200	6 200
56		1 000	1 000	1,000				1 000	1,000	1 000
57		750	1,000	1,000	270	270	270	957	957	957
58		18,811	18,811	18,811	19,477	19,477	19,477	24,867	24,867	24,867
59										
60										
61		0	750	750	0	1,525	1,525	0	150	150
62										
63		0	47,000	47 000						
64		1,500	1,500	1,500	60	60	60	125	125	125
65		0	500	500						
66	✓	31 106	31,409	31,409	27 083	102,128	102,128	82,678	82,724	82,724
67		0	109,830	109,830	0	161,307	161,307	0	252,095	252,095
68		3,250	3 250	3,250	2,625	2,625	2,625	1 965	1,965	1 965
69					0	10	10	0	10	10
70		34	34	34	7	7	7	7	7	7
71		750	750	750	120	120	120	110	110	110
72		0	751	751	0	25	25	0	25	25
73		0	2,000	2,000						
74	✓	0	500	500	0	786	786	0	381	381
75		0	5	5	0	6	6	0	3	3
76										
77		0	17 200	17 200	0	160 699	160 699	0	67	67
78		0	500	500	0	2,878	2,878	0	9	9
79		1 150	700	1 150	1 286	636	1 286	578	102	578
80		4 447	16 413	16 413	3 177	3 643	3 643	5 537	5 537	5 537
81		11 500	13 000	13 000	16 593	20 030	20 030	6 253	7 127	7 127

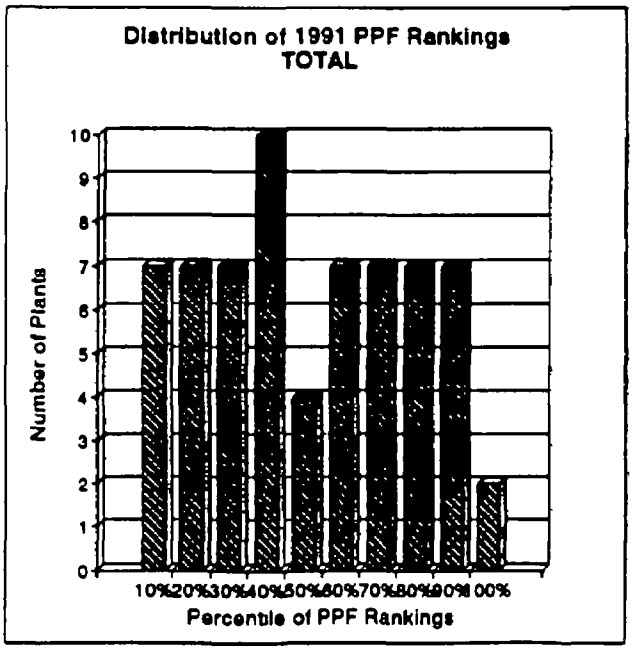
APPENDIX E

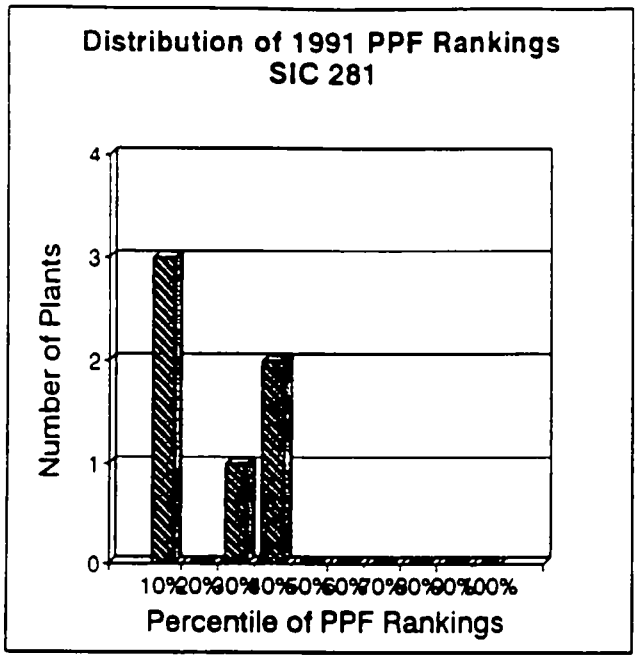
GRAPHICAL RESULTS FOR WASTE-BASED ANALYSES

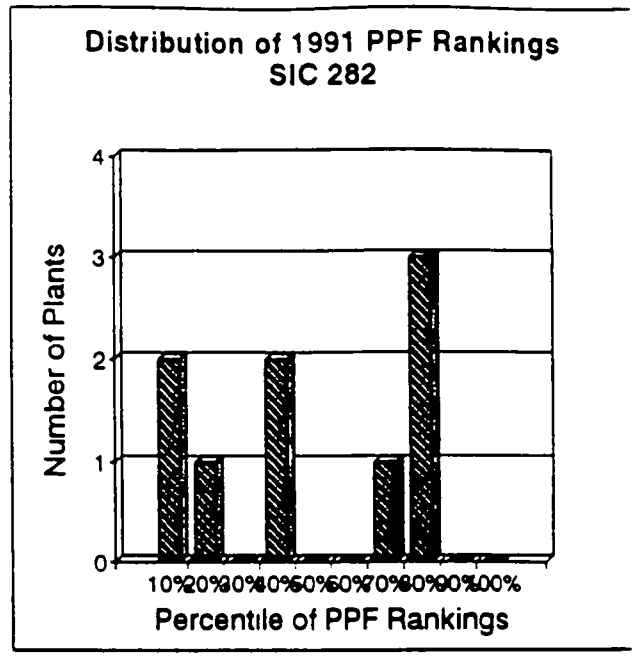

Distribution of 1991 PPF Rankings
SIC 285
Number of Plants
0
1
2
3
4
10%20%30%40%50%60%70%80%90%100%
Percentile of PPF Rankings

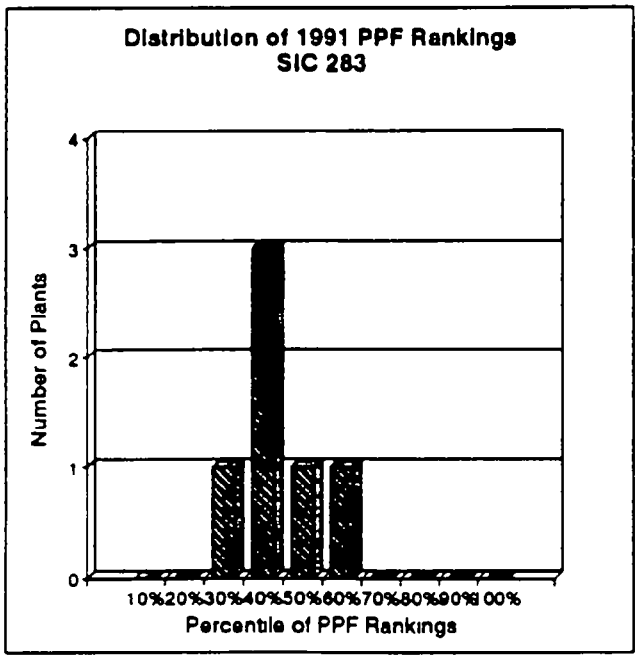

Distribution of 1991 PPF Rankings
SIC 286
Number of Plants
0
1
2
3
4
10%20%30%40%50%60%70%80%90%100%
Percentile of PPF Rankings

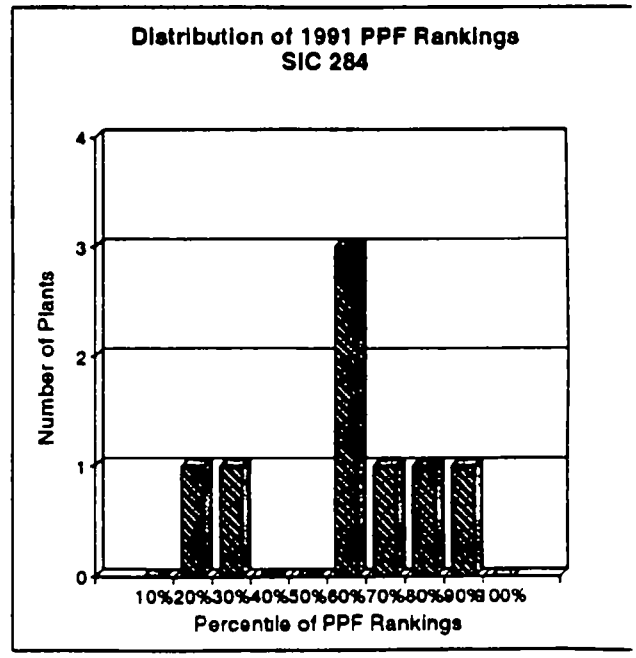

Distribution of 1991 PPF Rankings
SIC 289
Number of Plants
0
1
2
3
4
10%20%30%40%50%60%70%80%90%100%
Percentile of PPF Rankings

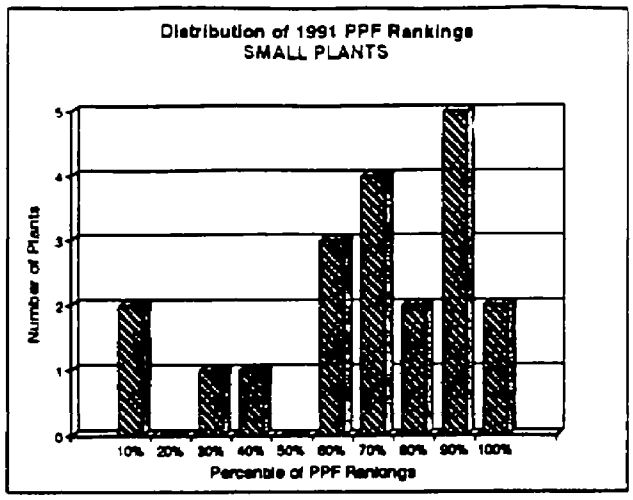

Distribution of 1991 PPF Rankings
TOTAL
Number of Plants
0
1
2
3
4
5
6
7
8
9
10
10%20%30%40%50%60%70%80%90%100%
Percentile of PPF Rankings

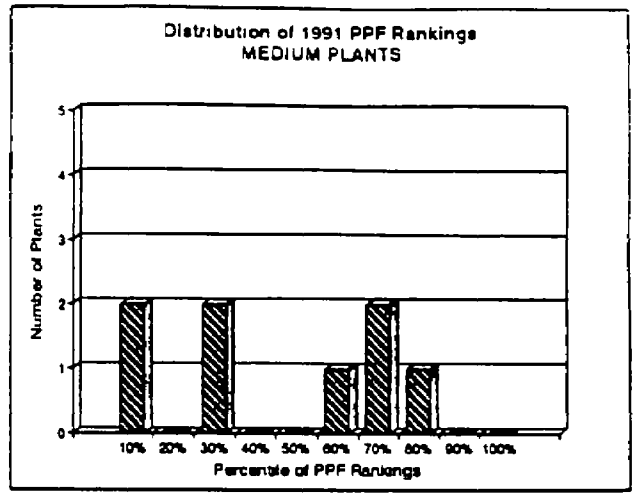

Distribution of 1991 PPF Rankings
SIC 281
Number of Plants
0
1
2
3
4
10%20%30%40%50%60%70%80%90%100%
Percentile of PPF Rankings

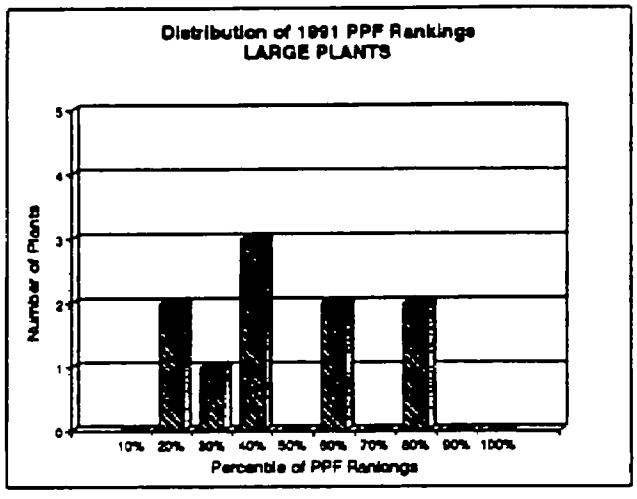

Distribution of 1991 PPF Rankings
SIC 282
Number of Plants
0
1
2
3
4
10%20%30%40%50%60%70%80%90%100%
Percentile of PPF Rankings

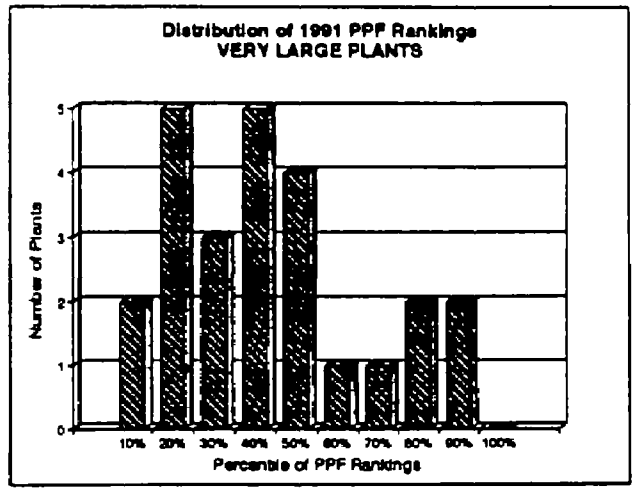

Distribution of 1991 PPF Rankings
SIC 283
Number of Plants
0
1
2
3
4
10%20%30%40%50%60%70%80%90%100%
Percentile of PPF Rankings

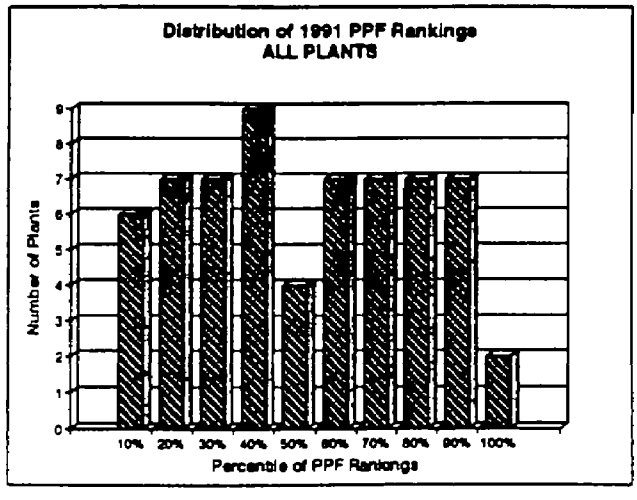

Distribution of 1991 PPF Rankings
SIC 284
Number of Plants
0
1
2
3
4
10%20%30%40%50%60%70%80%90%100%
Percentile of PPF Rankings

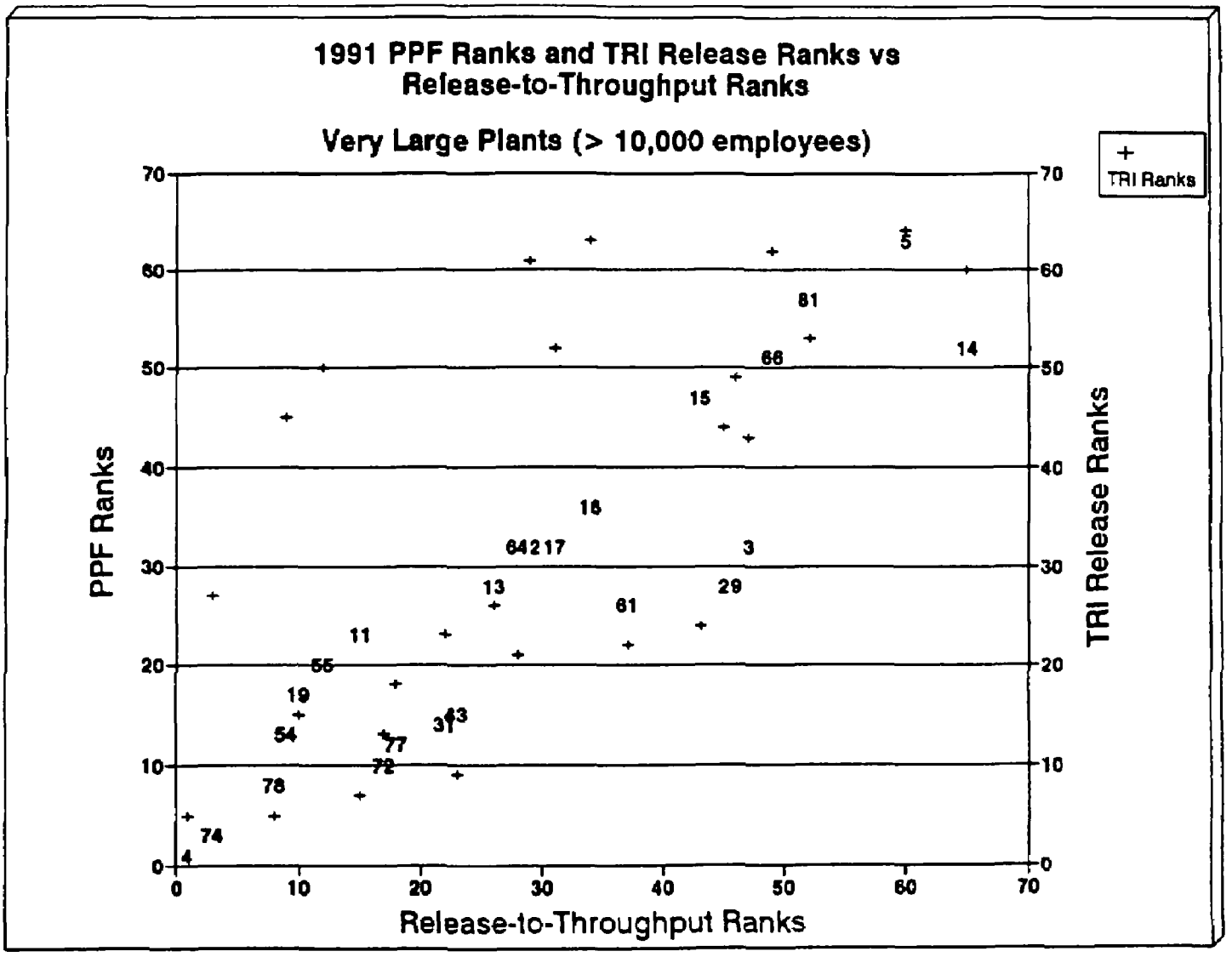

Distribution of 1991 PPF Rankings
SMALL PLANTS
Number of Plants
0
1
2
3
4
5
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Percentile of PPF Rankings

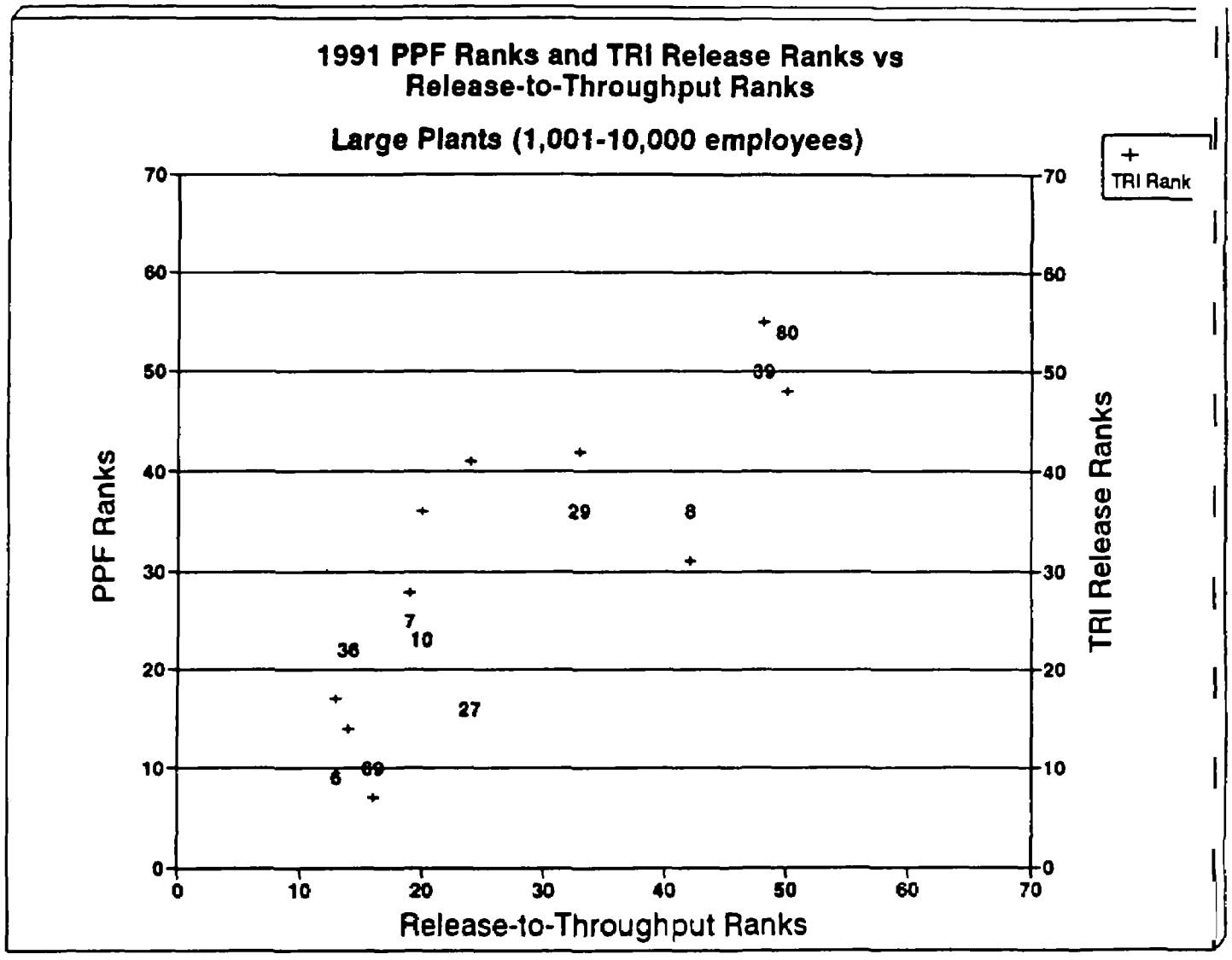

Distribution of 1991 PPF Rankings
MEDIUM PLANTS
Number of Plants
0
1
2
3
4
5
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Percentile of PPF Rankings

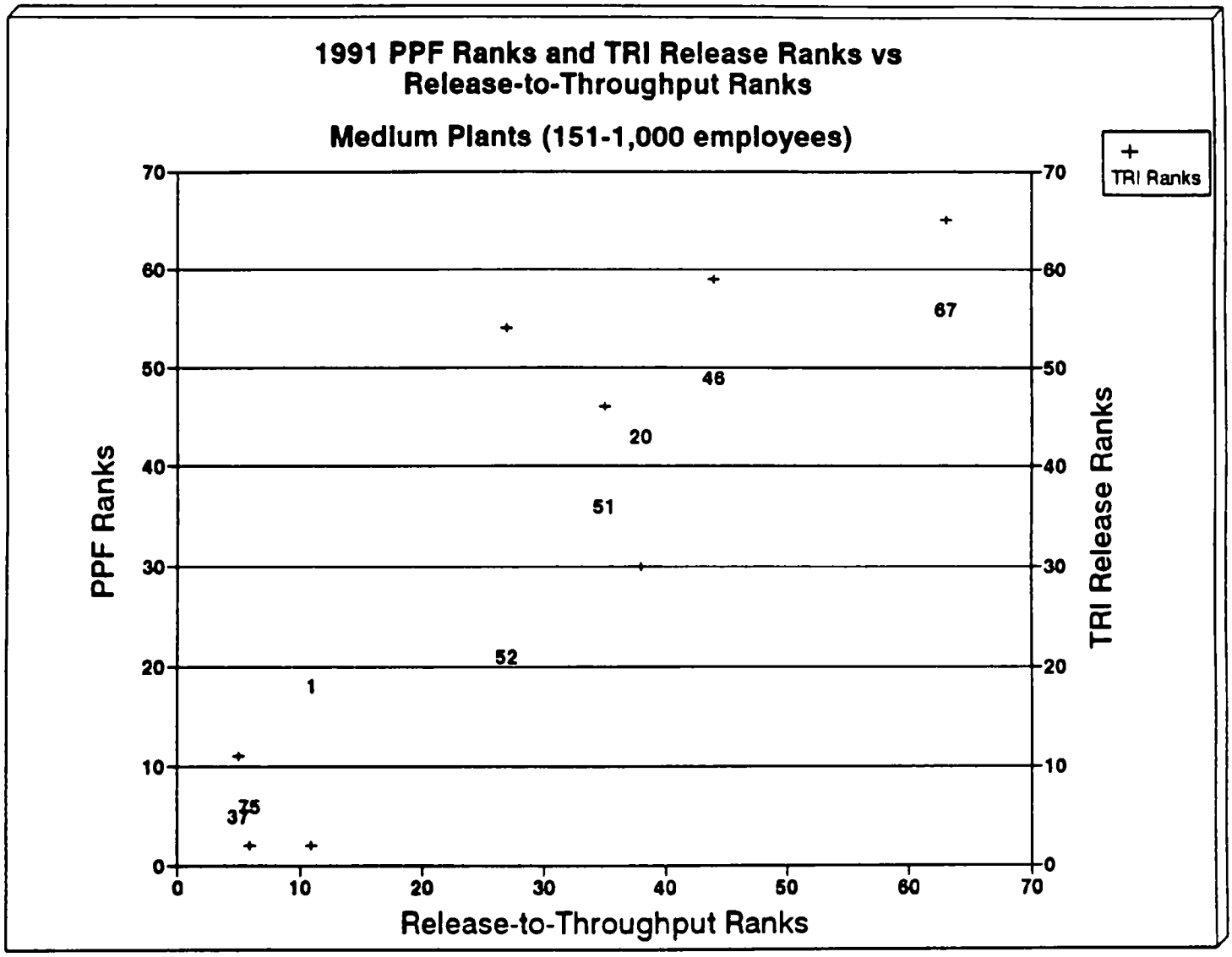

Distribution of 1991 PPF Rankings
LARGE PLANTS
Number of Plants
0
1
2
3
4
5
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Percentile of PPF Rankings

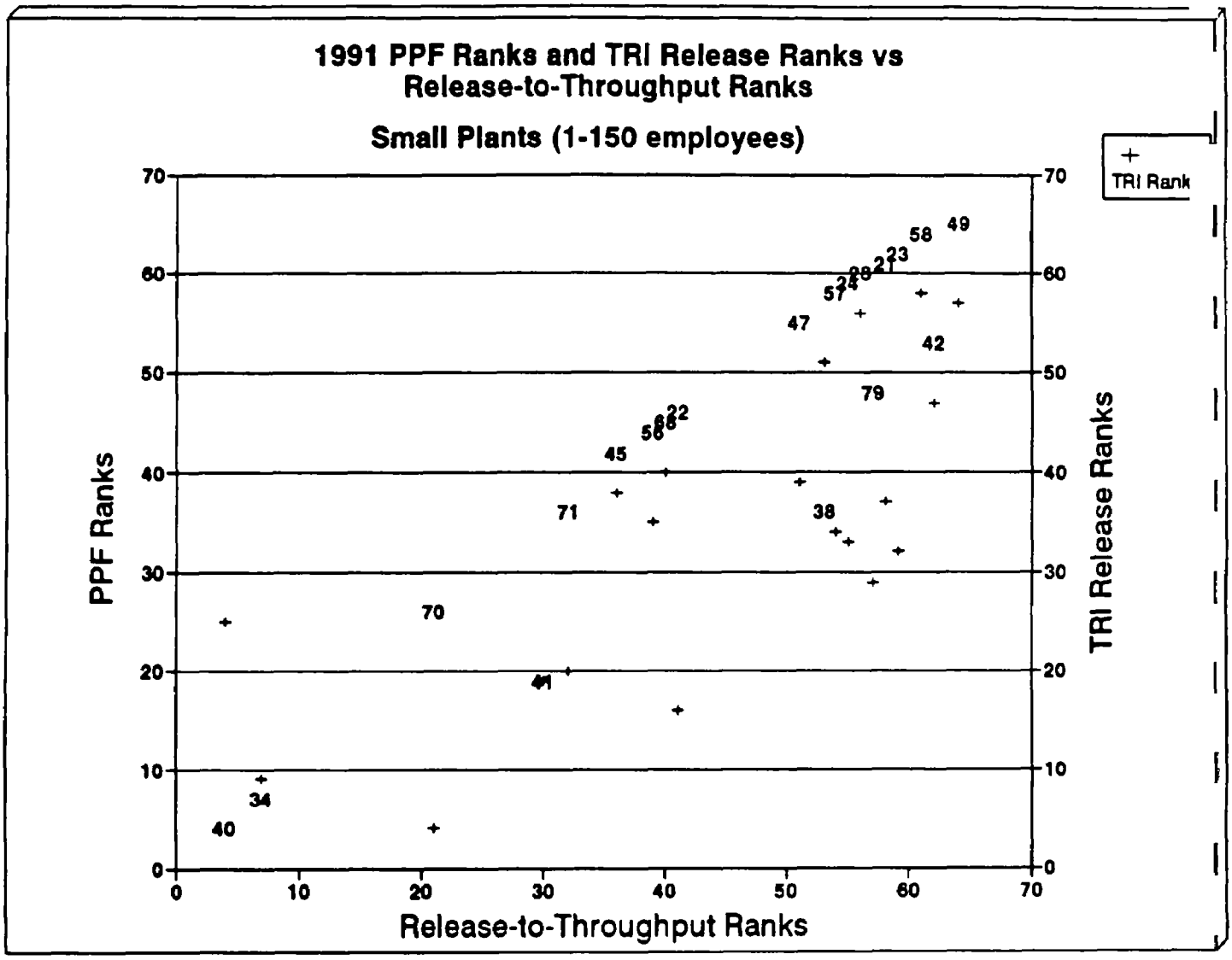

Distribution of 1991 PPF Rankings
VERY LARGE PLANTS
Number of Plants
0
1
2
3
4
5
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Percentile of PPF Rankings

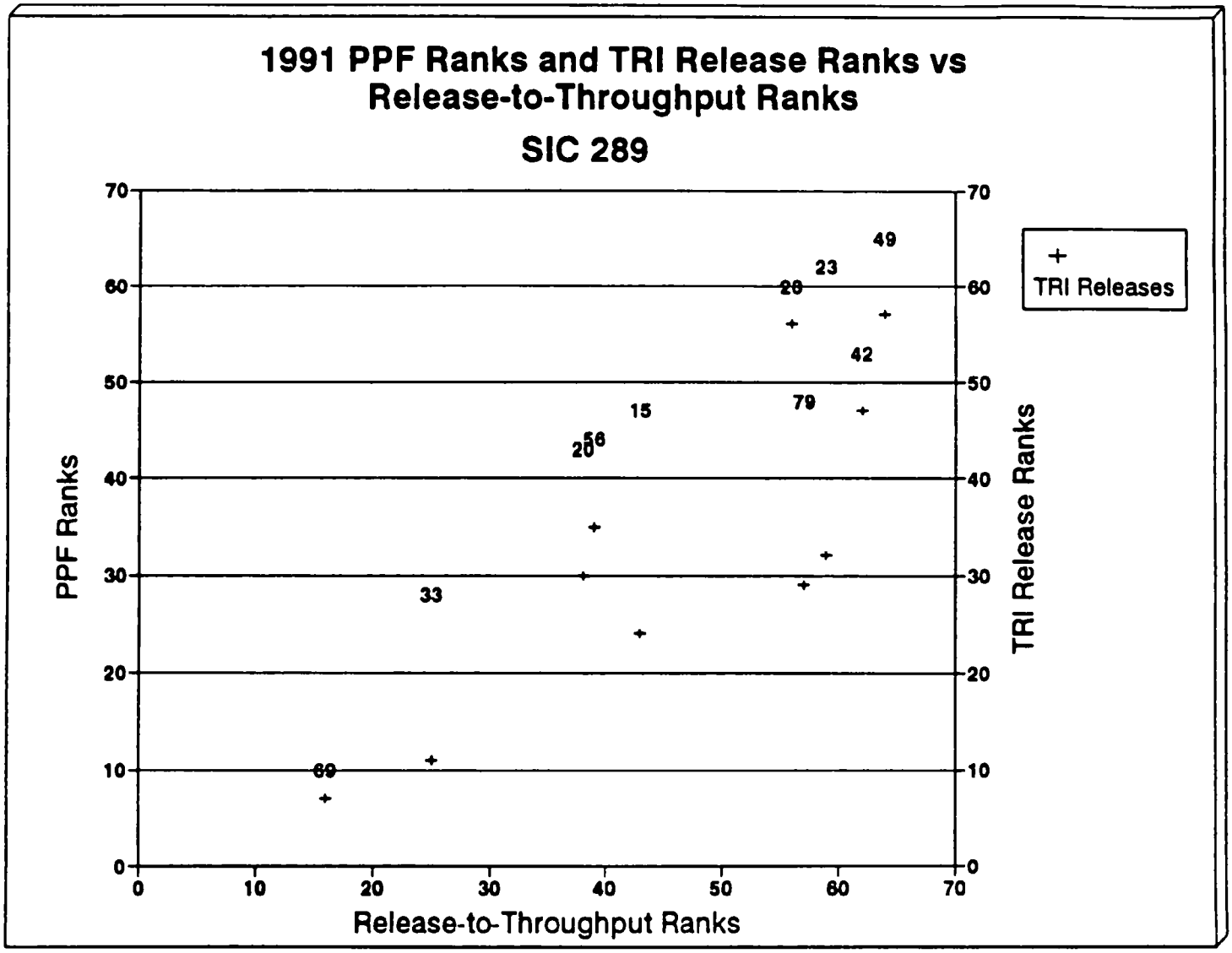

Distribution of 1991 PPF Rankings
ALL PLANTS
Number of Plants
0
1
2
3
4
5
6
7
8
9
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Percentile of PPF Rankings

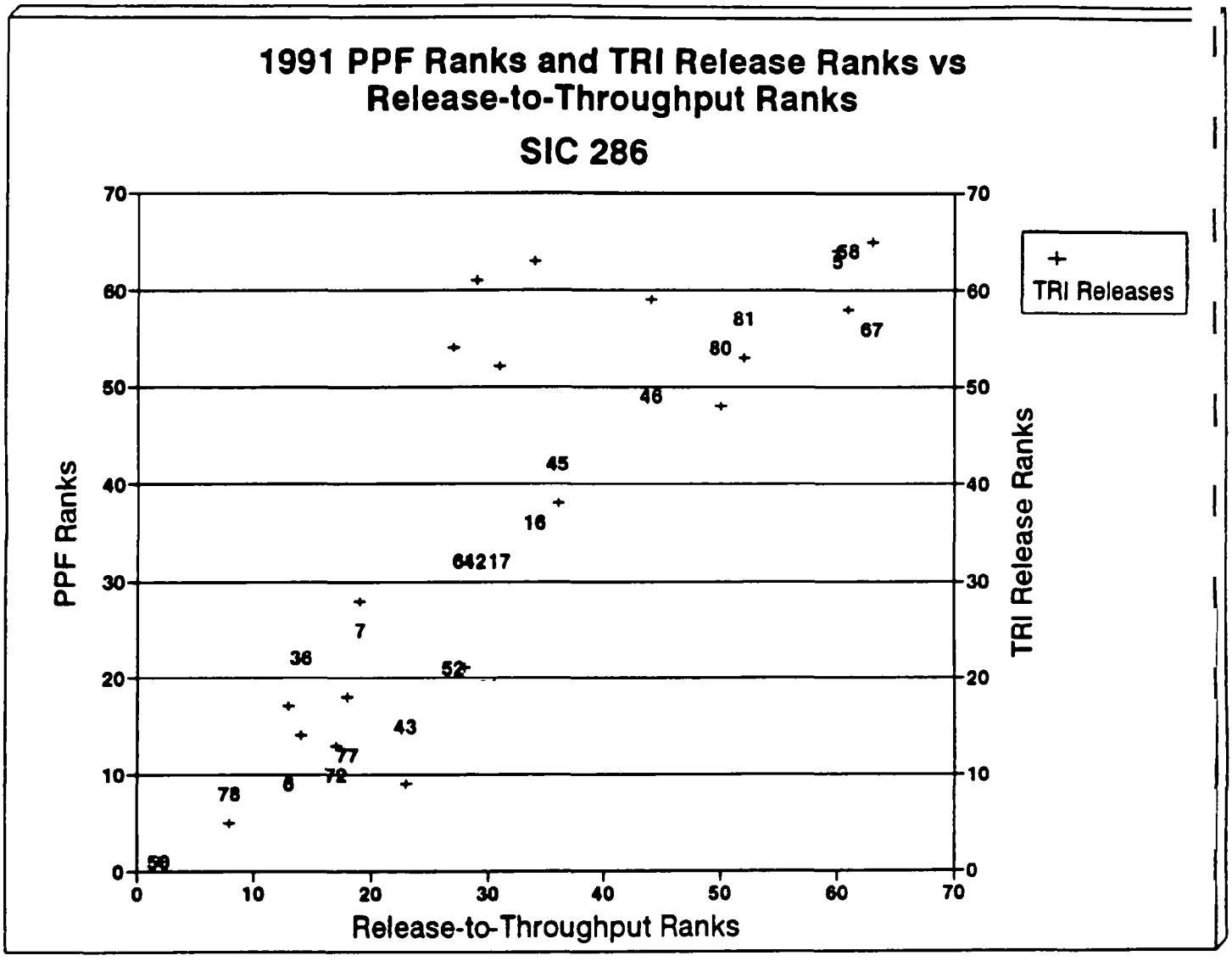

1991 PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
Very Large Plants (> 10,000 employees)
TRI Ranks
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
0
10
20
30
40
50
60
70

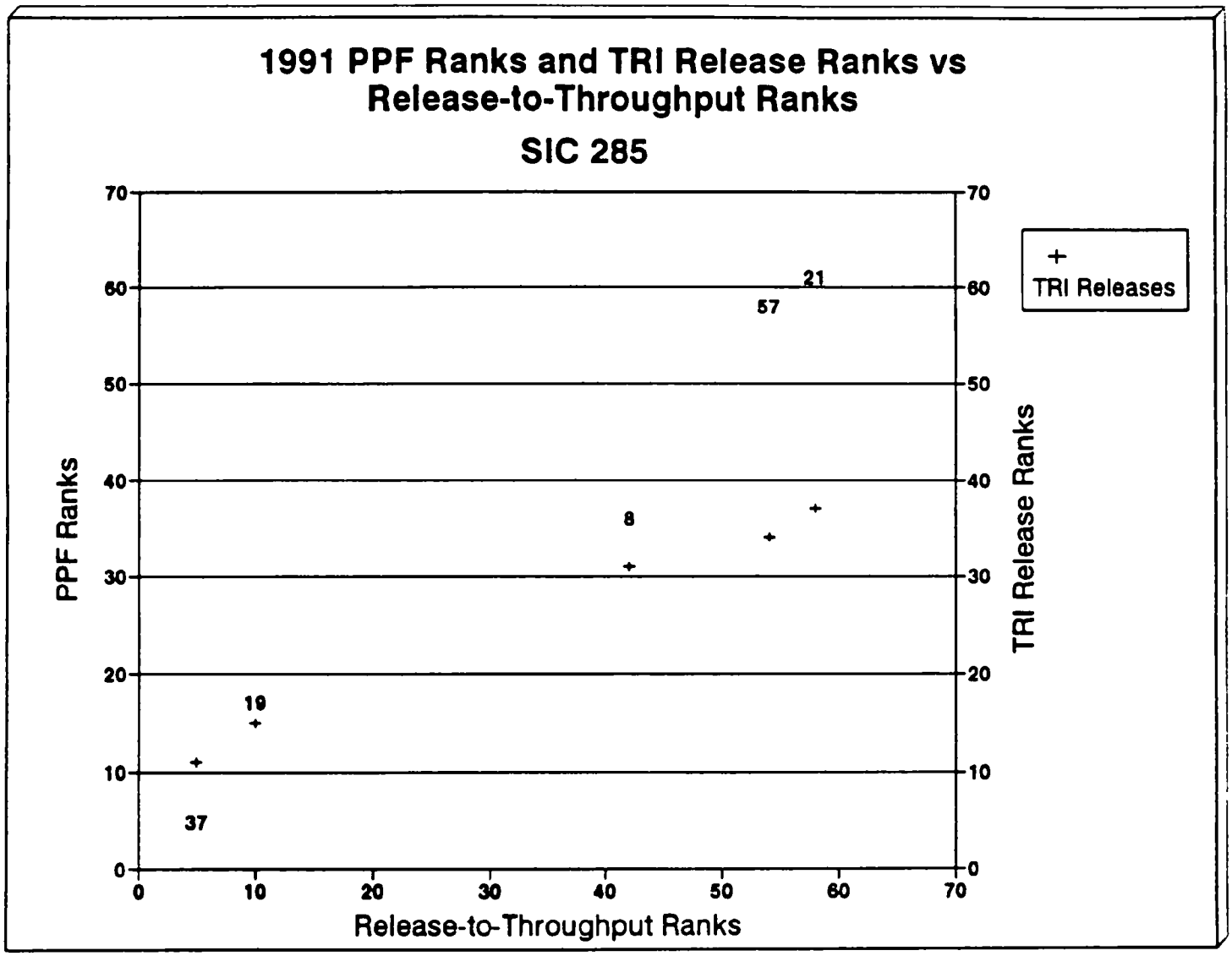

1991 PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
Large Plants (1,001-10,000 employees)
TRI Rank
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
0
10
20
30
40
50
60
70
80
39
29
8
7
10
36
27
6
69

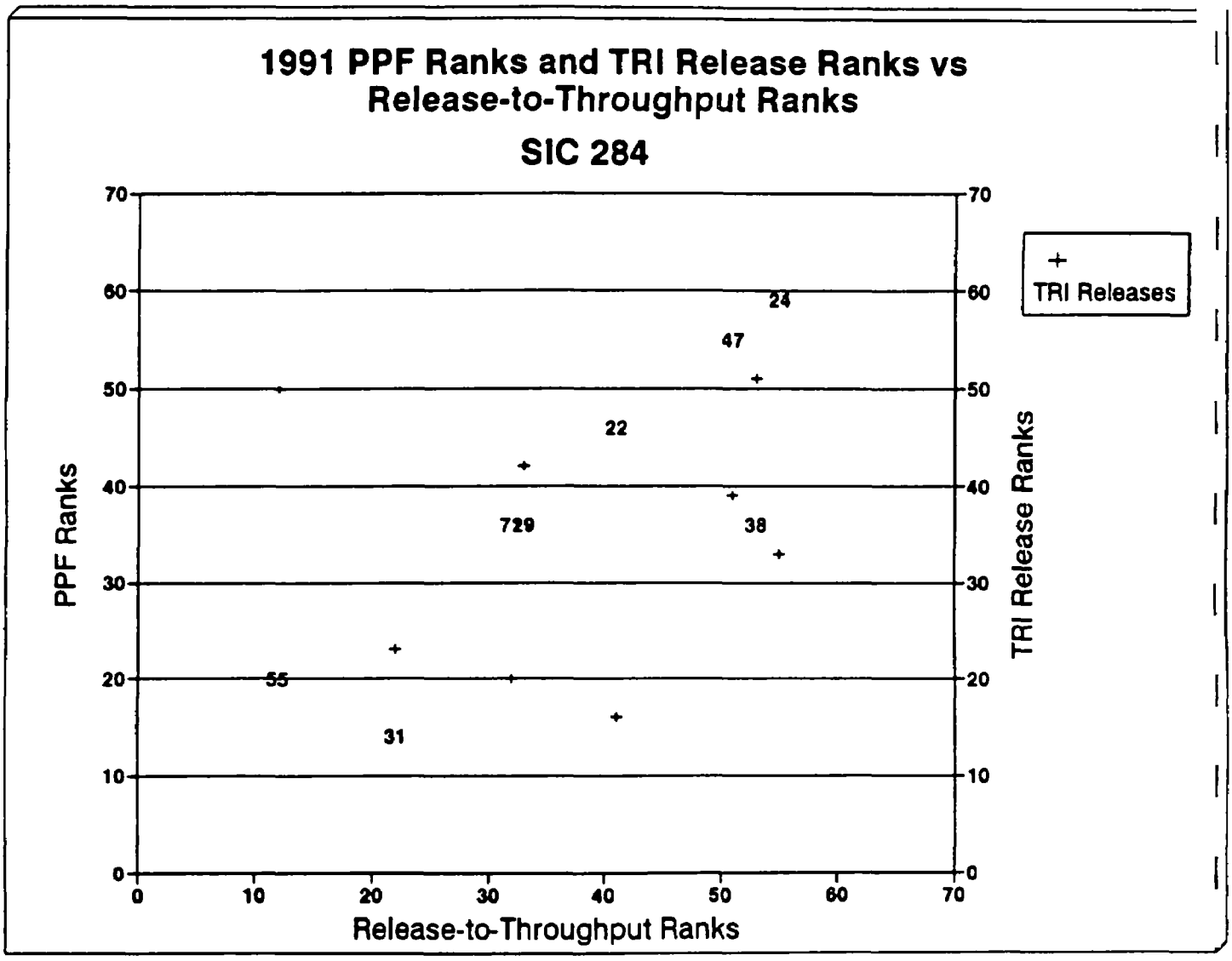

1991 PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
Medium Plants (151-1,000 employees)
TRI Ranks
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
0
10
20
30
40
50
60
70
67
46
20
51
52
1
75
37

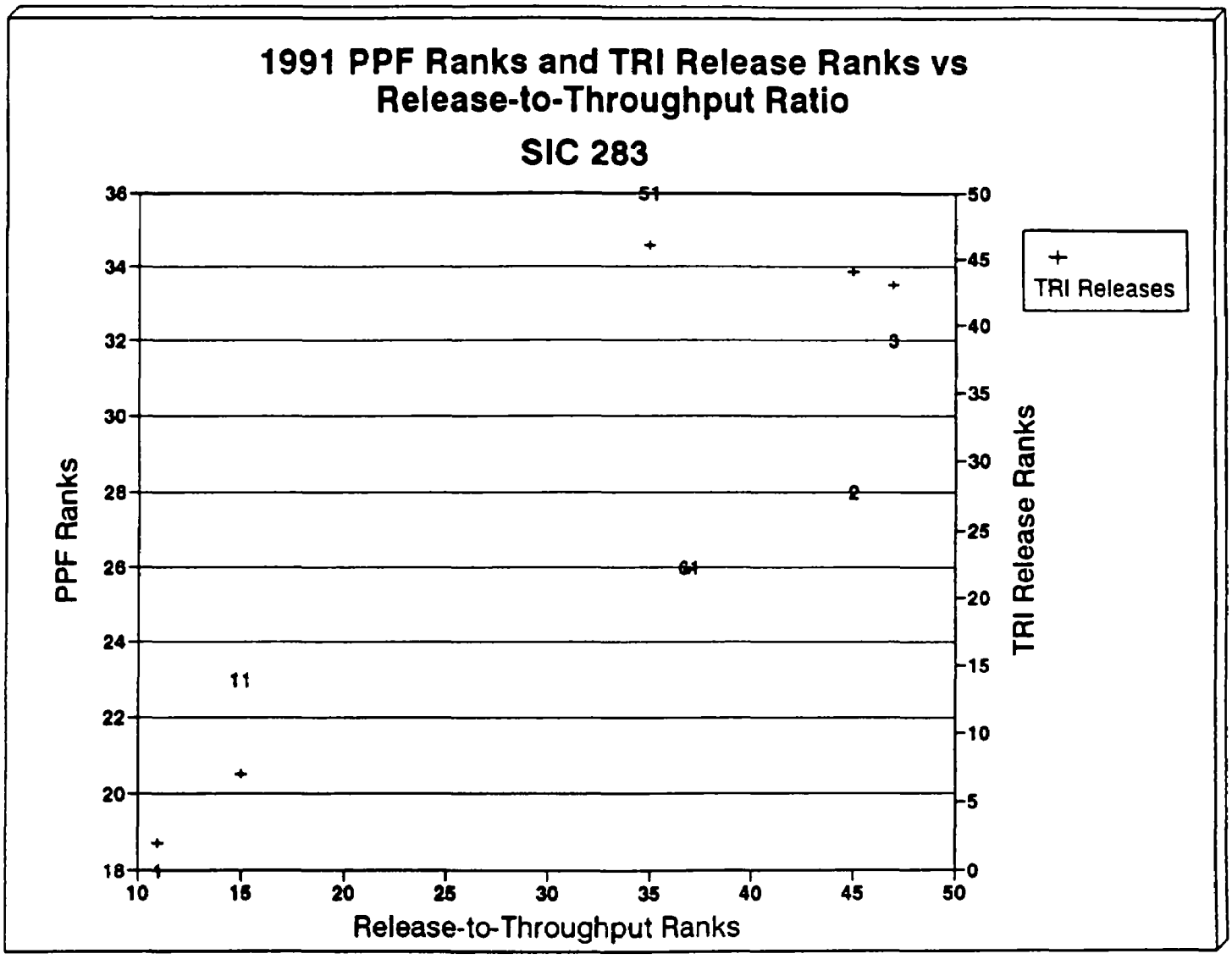

1991 PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
Small Plants (1-150 employees)
TRI Rank
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
0
10
20
30
40
50
60
70
49
58
23
21
28
24
57
47
42
79
22
58
56
45
71
38
70
41
34
40

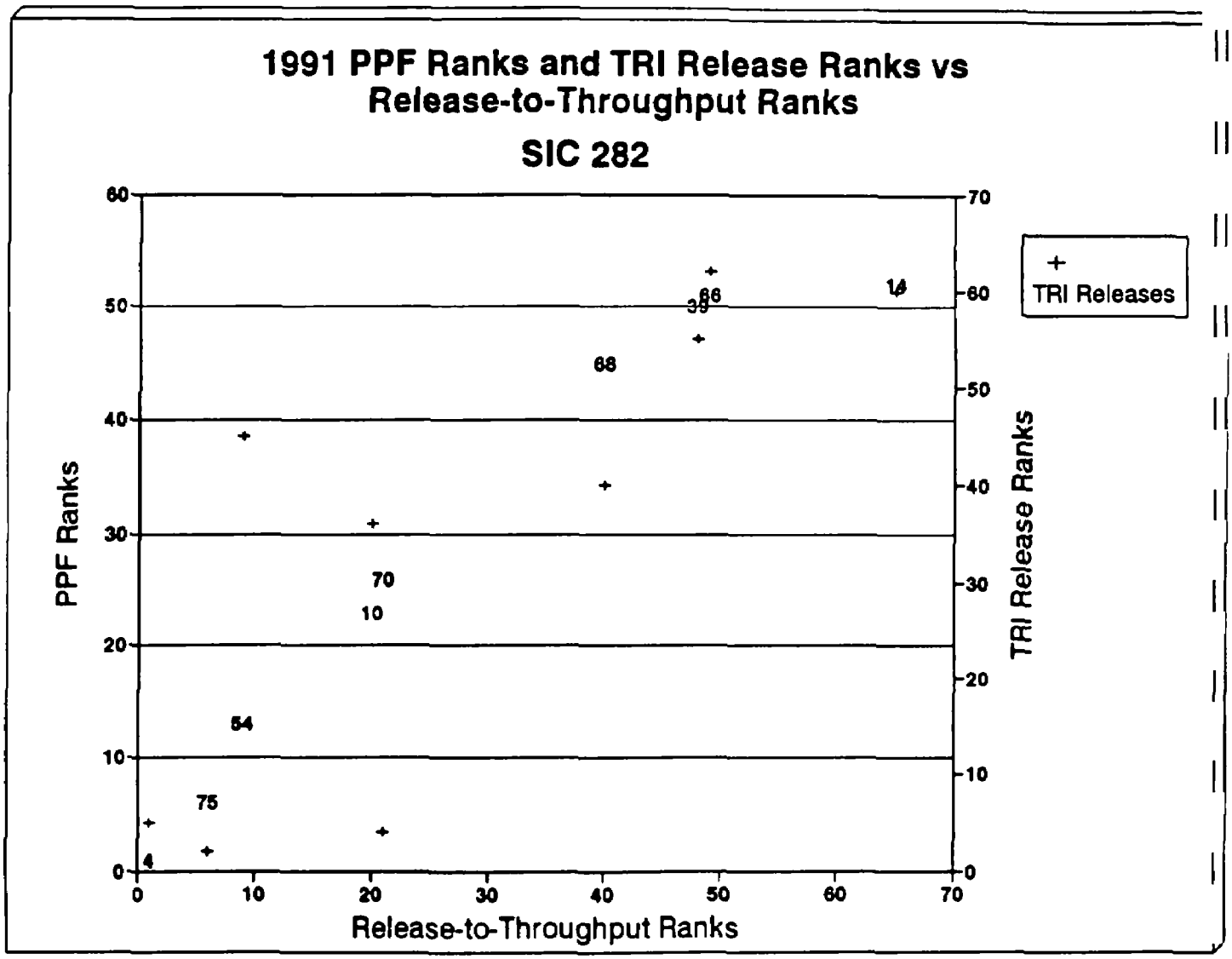

1991 PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
SIC 289
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
TRI Releases
0
10
20
30
40
50
60
70
49
23
26
42
79
15
20
56
33
69

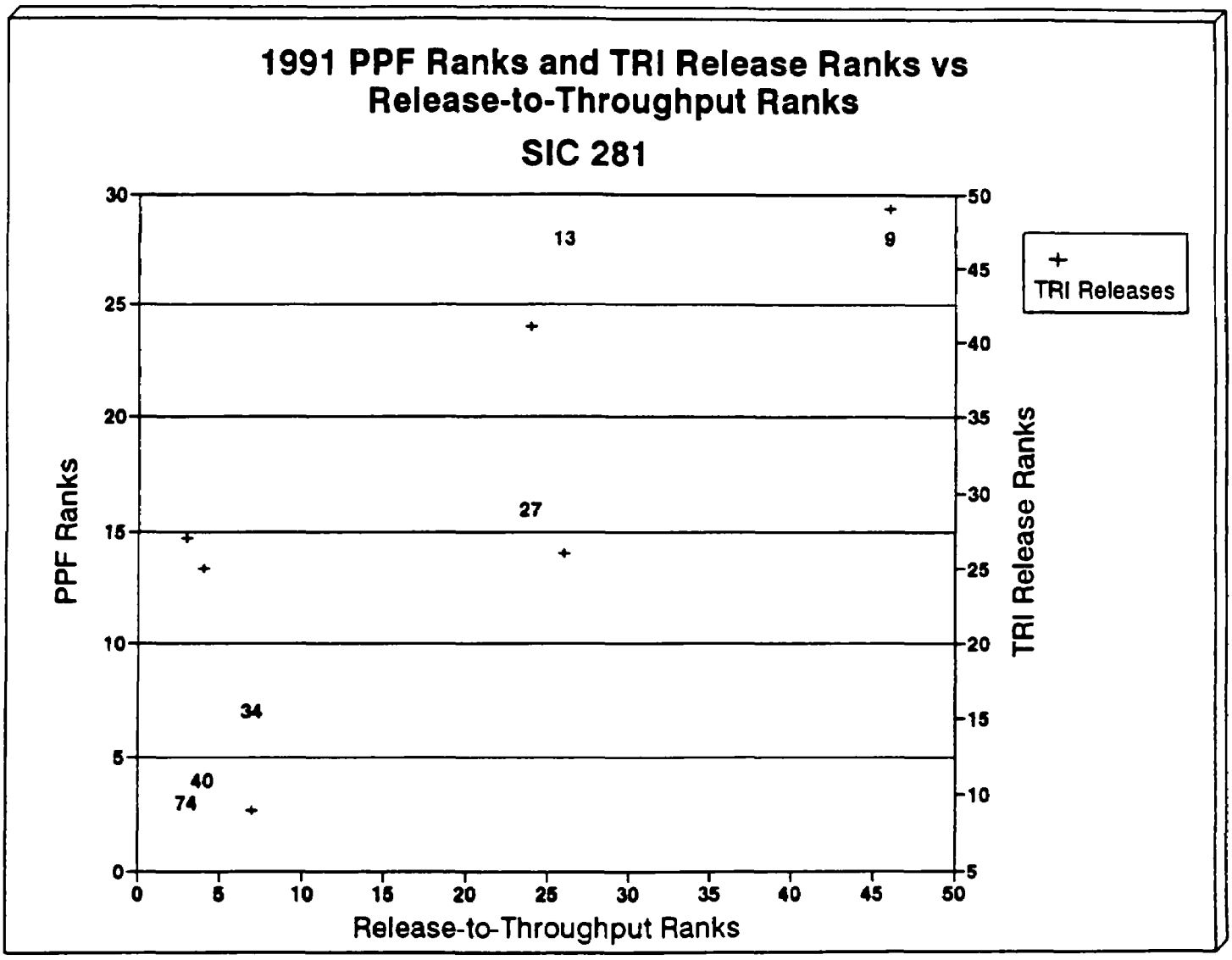

1991 PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
SIC 286
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
TRI Releases
0
10
20
30
40
50
60
70
58
5
81
67
80
46
45
16
64217
7
36
52
43
77
72
6
78
59

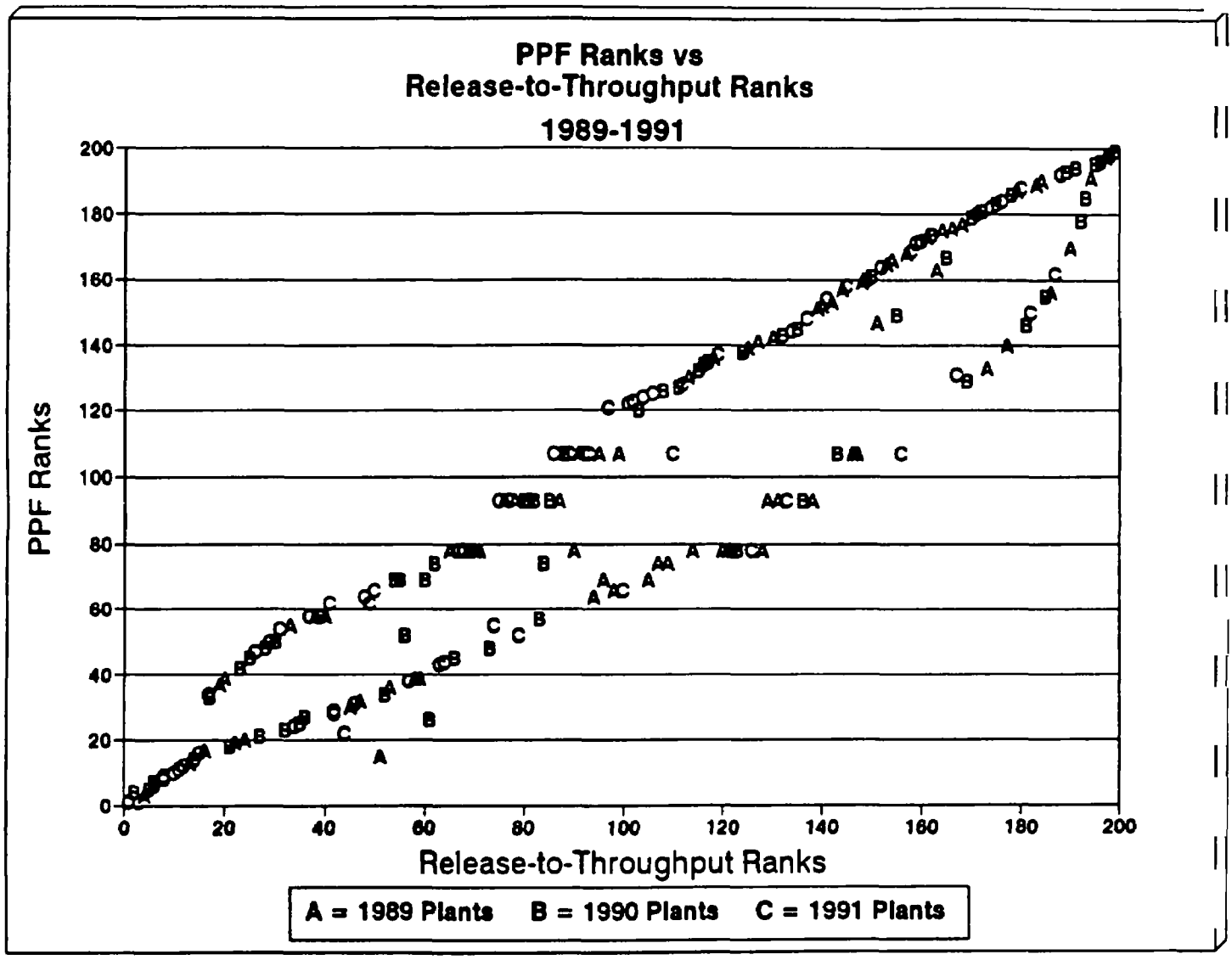

1991 PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
SIC 285
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
TRI Releases
0
10
20
30
40
50
60
70
37
19
8
57
21

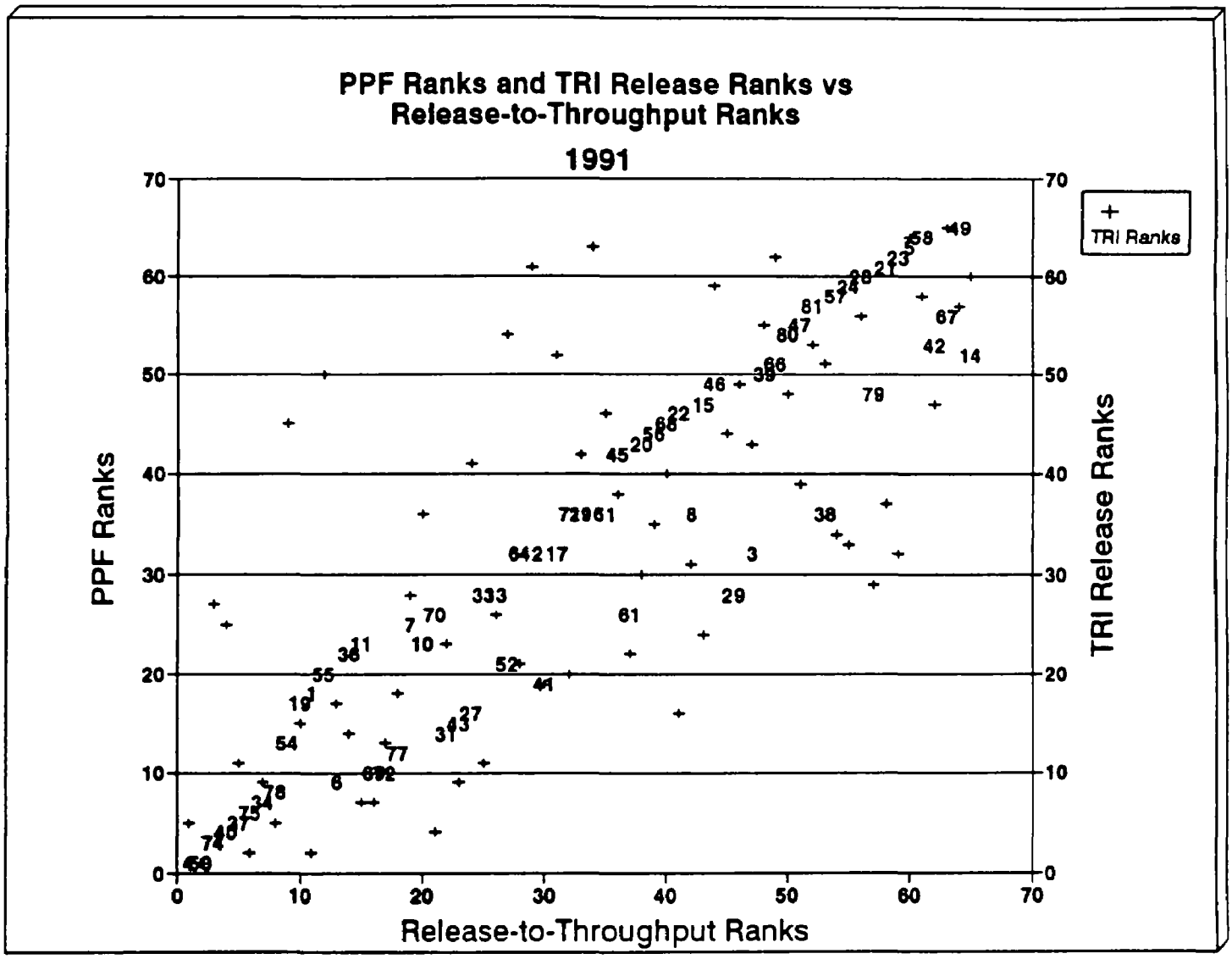

1991 PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
SIC 284
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
TRI Releases
0
10
20
30
40
50
60
70
24
47
22
729
38
55
31

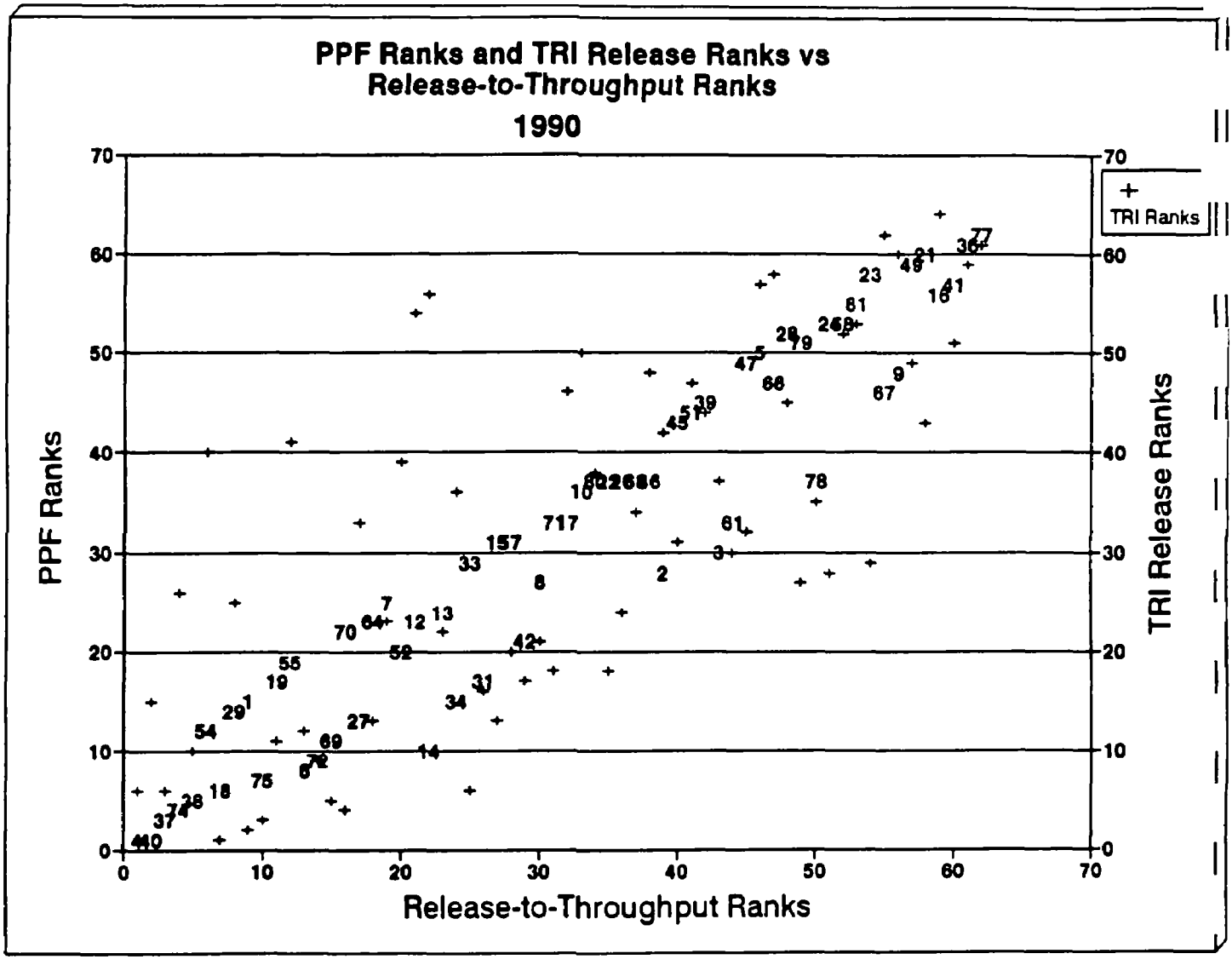

1991 PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ratio
SIC 283
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
TRI Releases
36
34
32
30
28
26
24
22
20
18
50
45
40
35
30
25
20
15
10
5
0
10
15
20
25
30
35
40
45
50
51
3
2
61
11
1

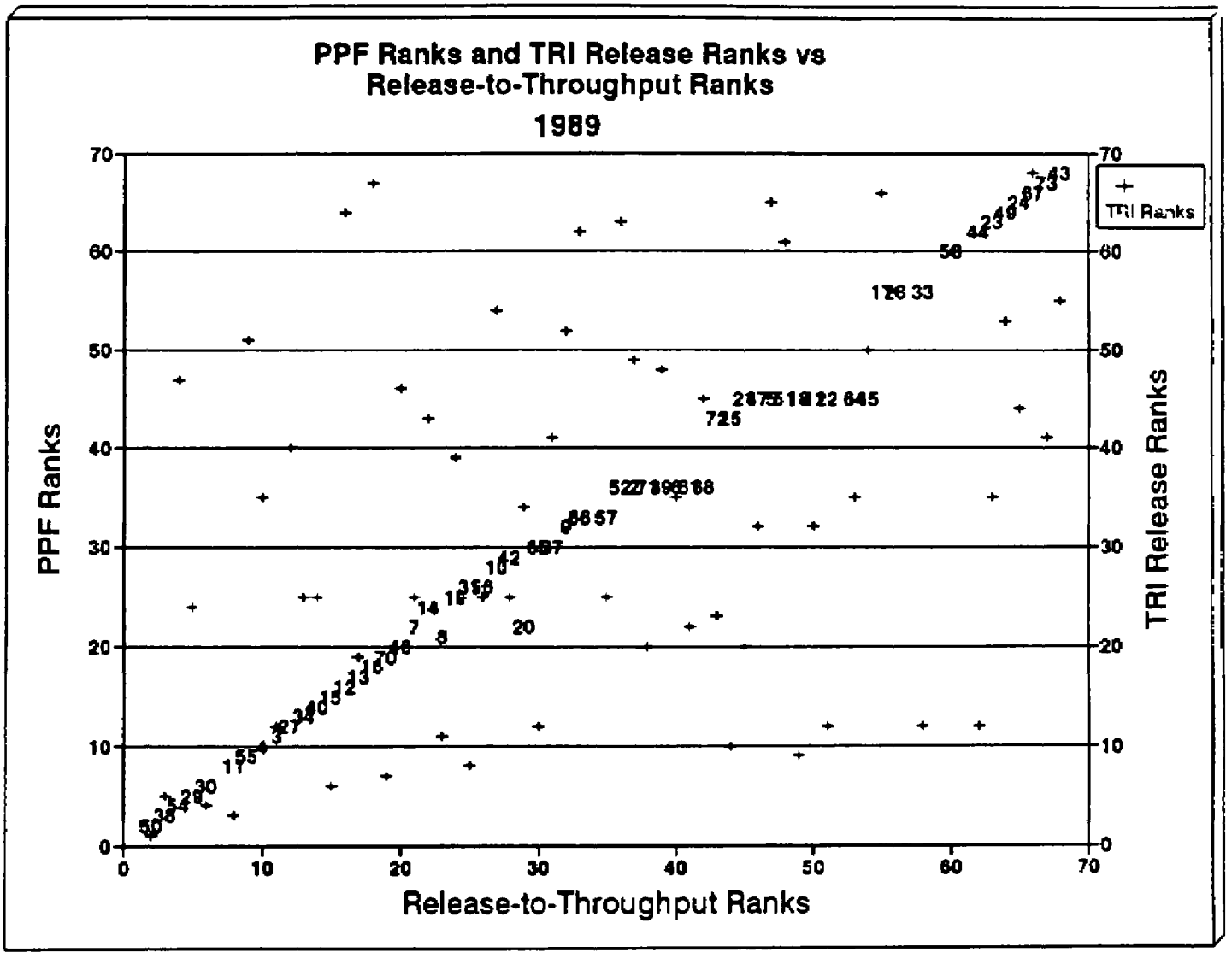

1991 PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
SIC 282
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
TRI Releases
0
10
20
30
40
50
60
70
4
75
54
10
70
68
39
66
14

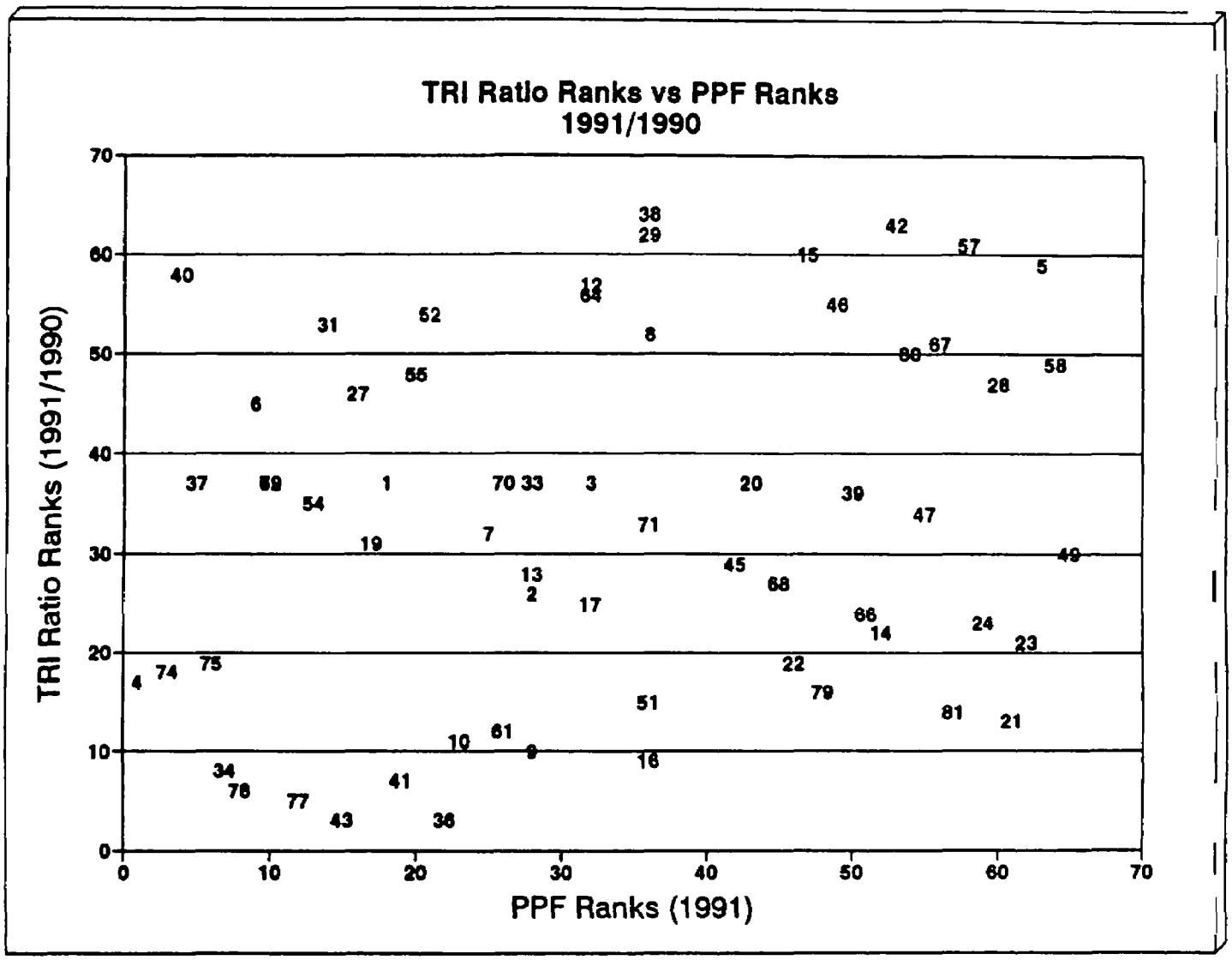

1991 PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
SIC 281
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
TRI Releases
13
9
27
34
40
74
0
5
10
15
20
25
30
35
40
45
50

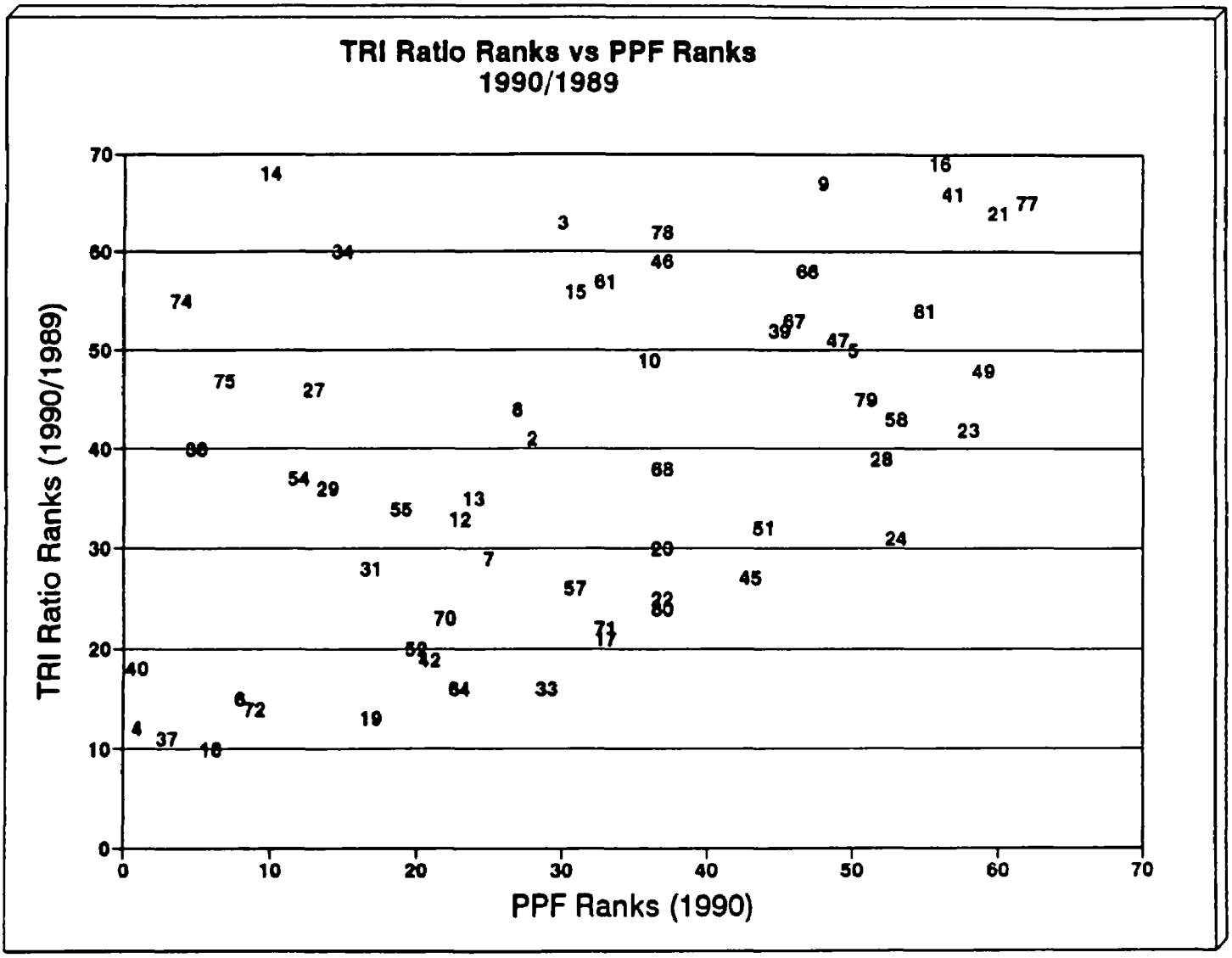

PPF Ranks vs
Release-to-Throughput Ranks
1989-1991
PPF Ranks
Release-to-Throughput Ranks
0
20
40
60
80
100
120
140
160
180
200
A = 1989 Plants
B = 1990 Plants
C = 1991 Plants

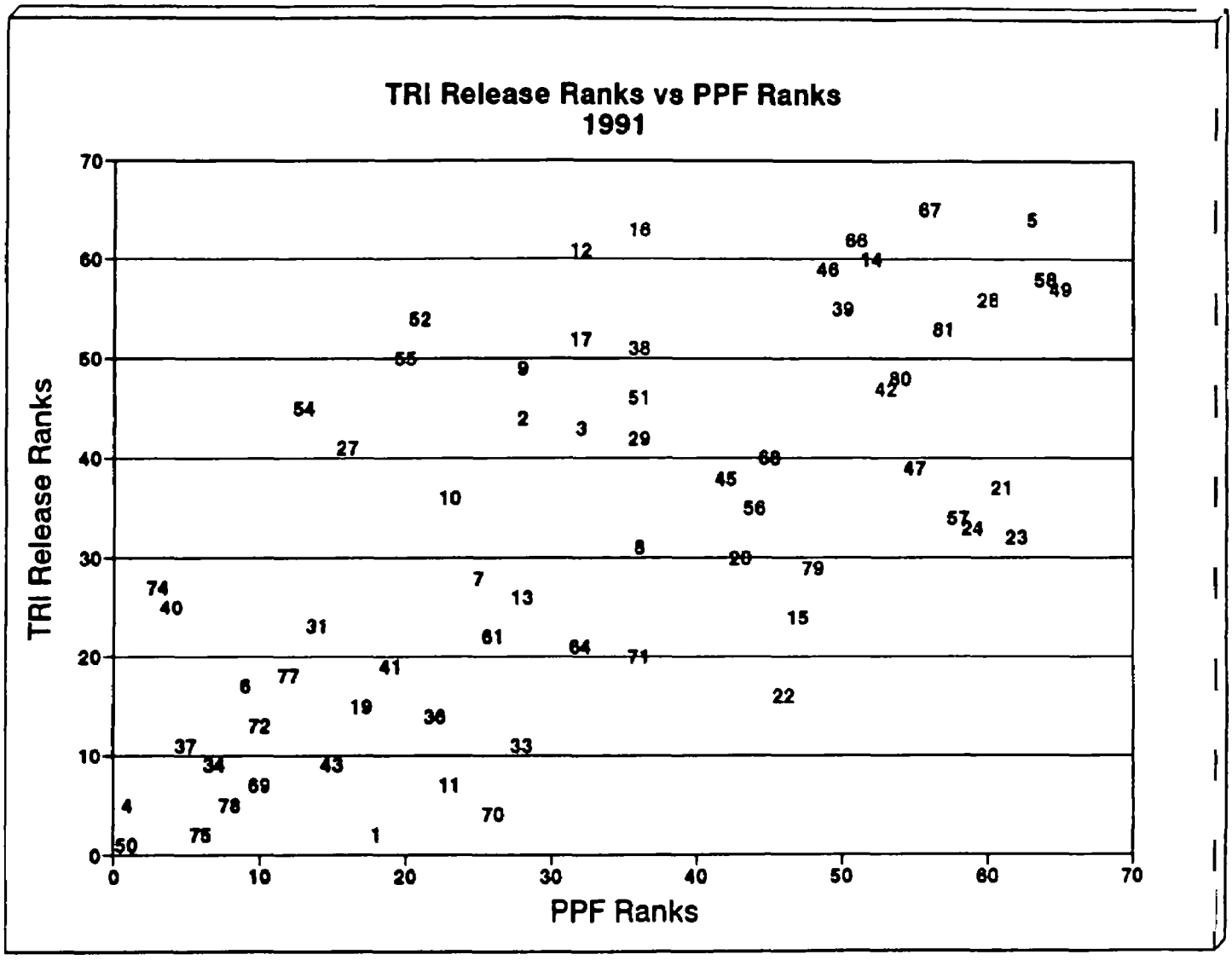

PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
1991
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
TRI Ranks
0
10
20
30
40
50
60
70

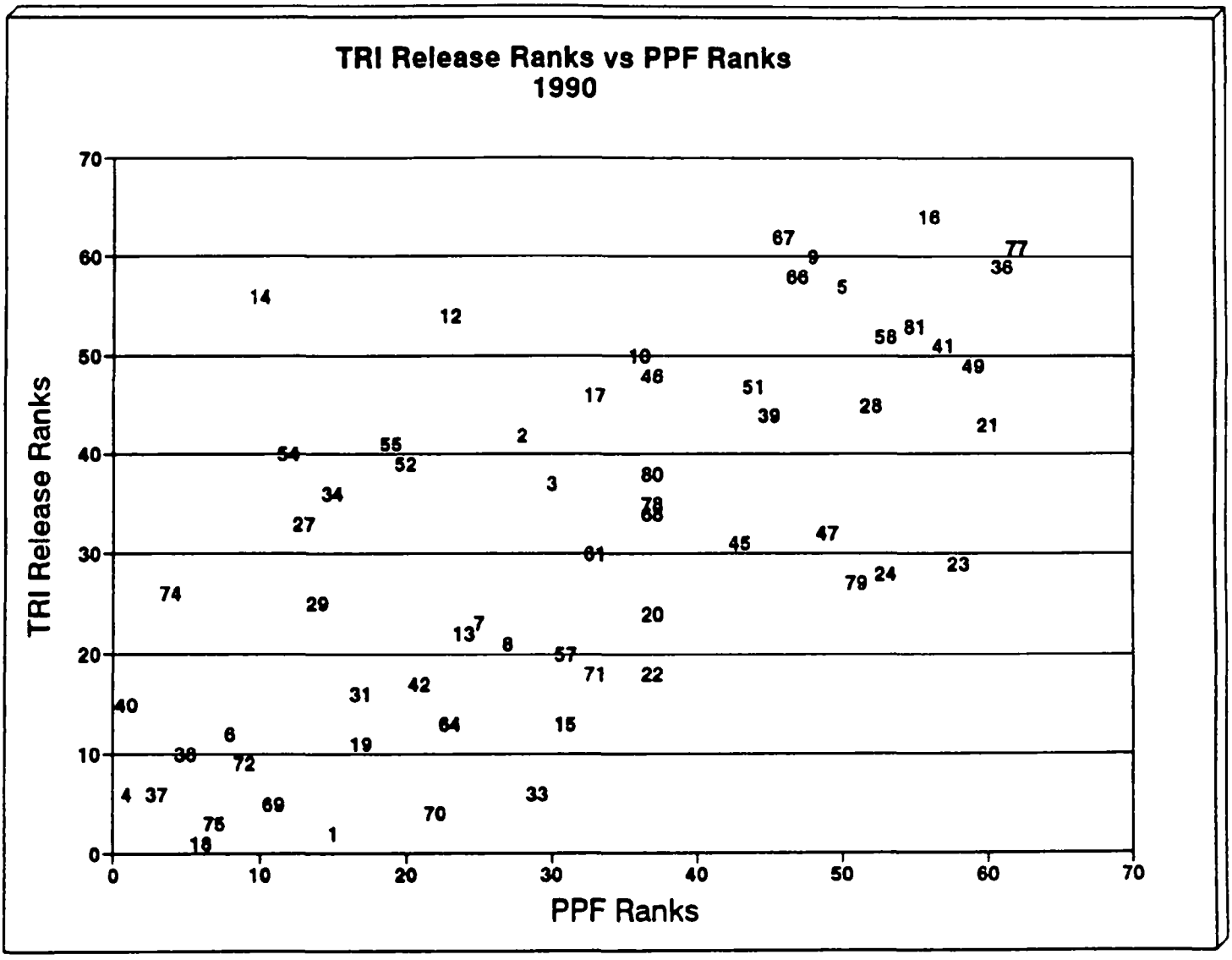

PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
1990
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
TRI Ranks
0
10
20
30
40
50
60
70

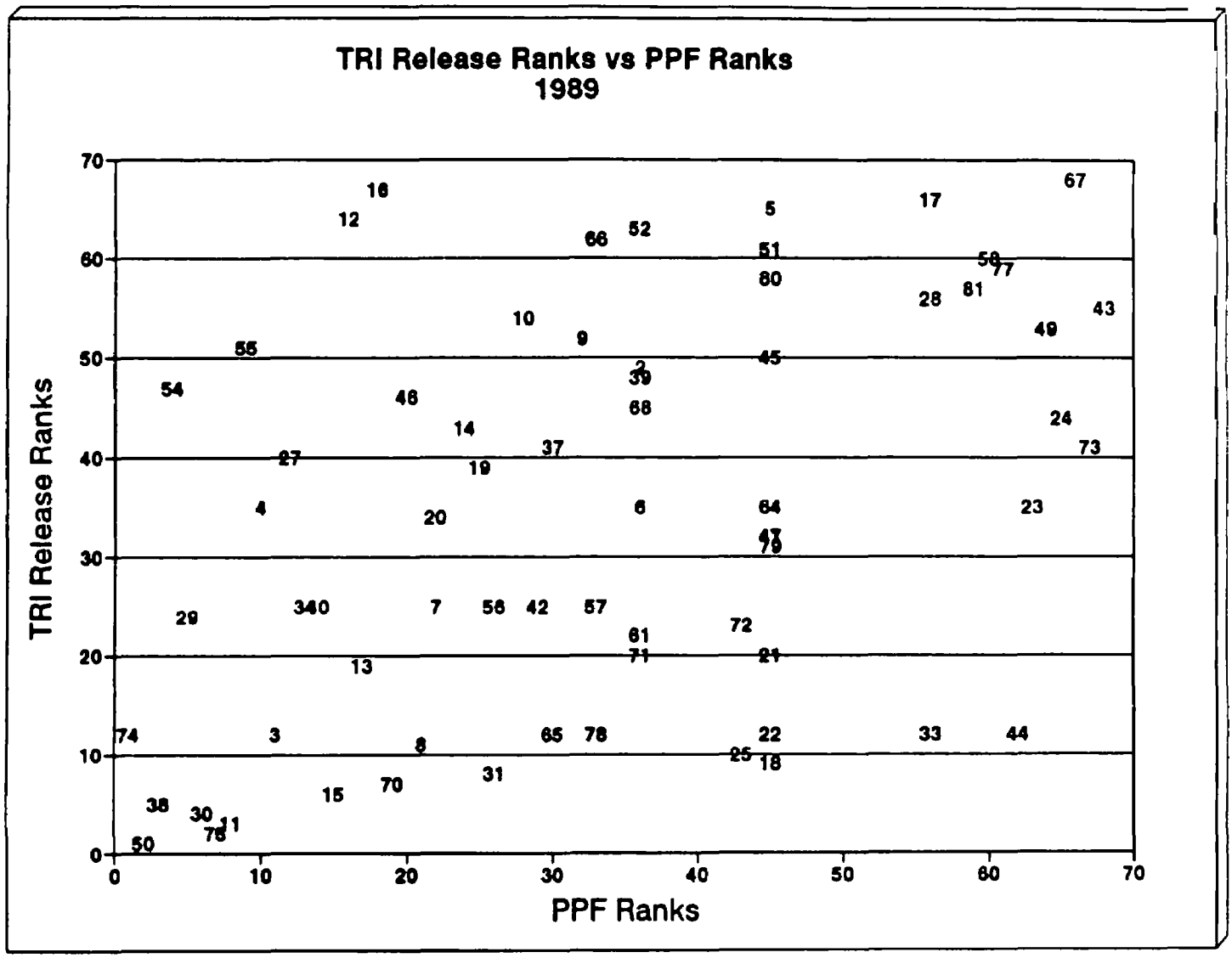

PPF Ranks and TRI Release Ranks vs
Release-to-Throughput Ranks
1989
PPF Ranks
TRI Release Ranks
Release-to-Throughput Ranks
TRI Ranks
0
10
20
30
40
50
60
70

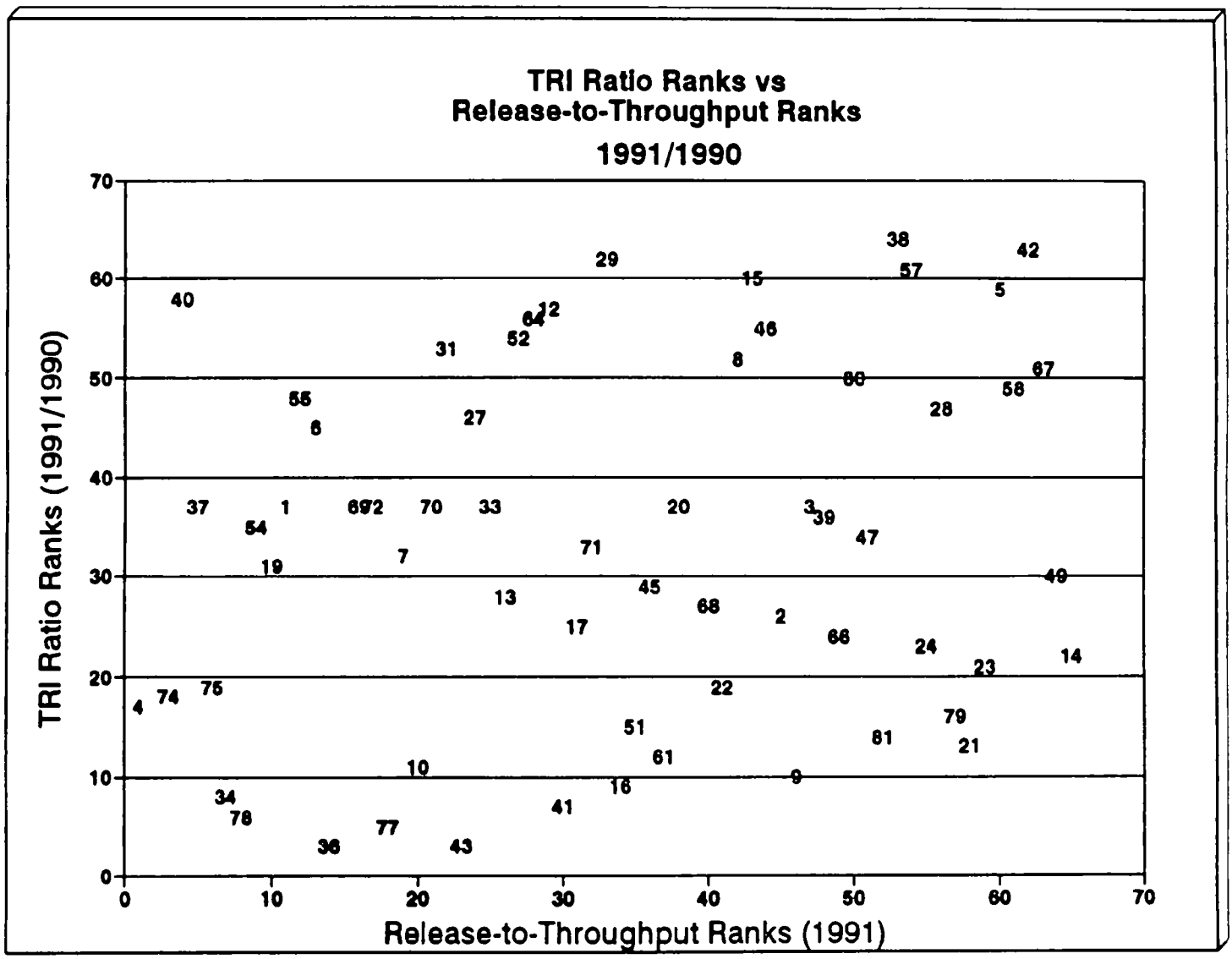

TRI Ratio Ranks vs PPF Ranks
1991/1990
TRI Ratio Ranks (1991/1990)
PPF Ranks (1991)
0
10
20
30
40
50
60
70

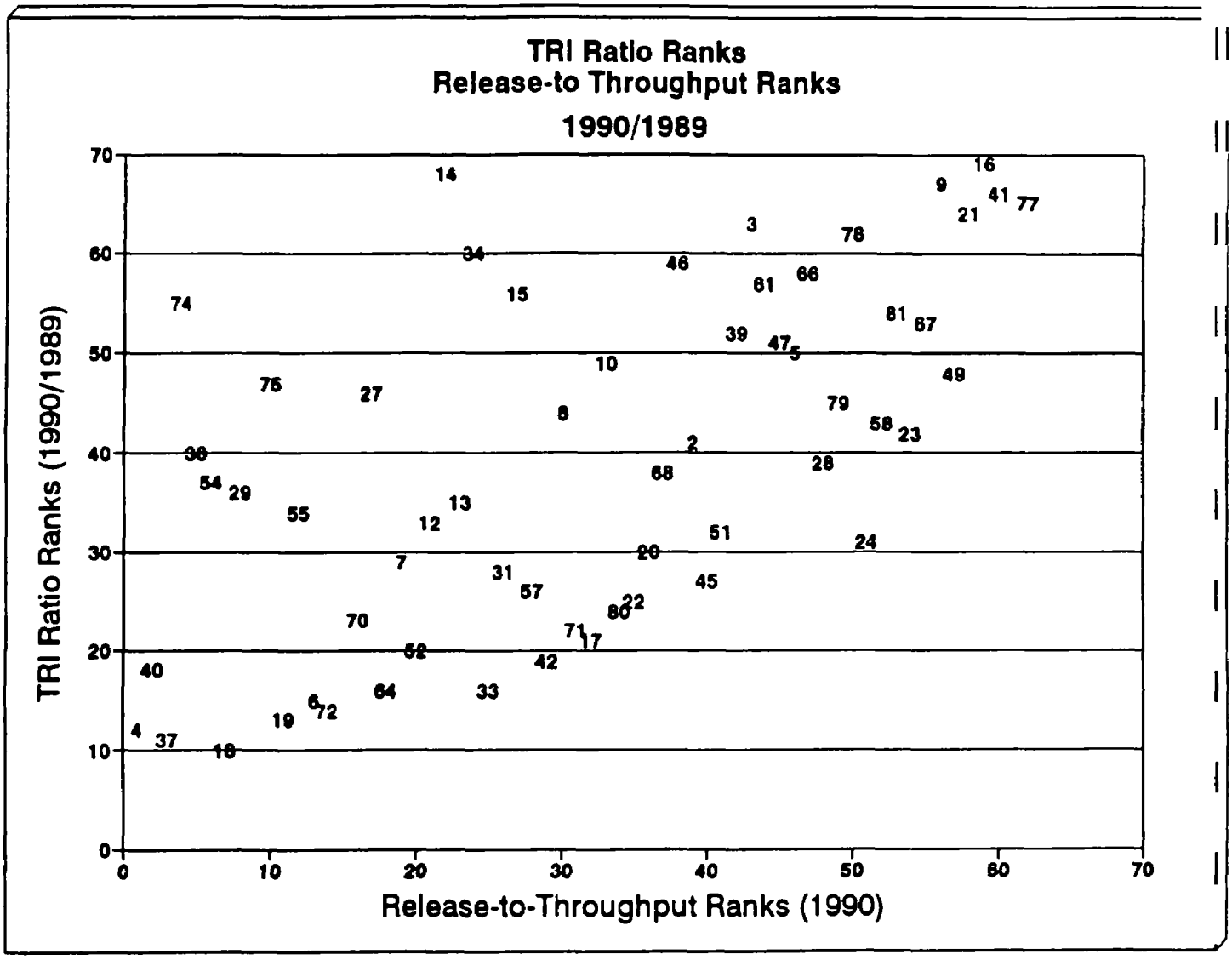

TRI Ratio Ranks vs PPF Ranks
1990/1989
TRI Ratio Ranks (1990/1989)
PPF Ranks (1990)
0
10
20
30
40
50
60
70


TRI Release Ranks vs PPF Ranks
1991
TRI Release Ranks
PPF Ranks
0
10
20
30
40
50
60
70


TRI Release Ranks vs PPF Ranks
1990
TRI Release Ranks
PPF Ranks
0
10
20
30
40
50
60
70
16
67
9
77
66
36
5
14
12
58
81
41
10
49
46
51
17
39
28
21
2
55
54
52
80
3
34
78
68
27
45
47
61
23
79
24
74
29
20
13
7
8
57
71
22
42
31
40
64
15
6
19
38
72
4
37
33
69
70
75
1
18


TRI Release Ranks vs PPF Ranks
1989
TRI Release Ranks
PPF Ranks
0
10
20
30
40
50
60
70


TRI Ratio Ranks vs
Release-to-Throughput Ranks
1991/1990
TRI Ratio Ranks (1991/1990)
Release-to-Throughput Ranks (1991)
0
10
20
30
40
50
60
70


TRI Ratio Ranks
Release-to Throughput Ranks
1990/1989
TRI Ratio Ranks (1990/1989)
Release-to-Throughput Ranks (1990)
0
10
20
30
40
50
60
70