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Data Summaries of Licensee Event Reports of Valves at U.S. Commercial Nuclear Power Plants

Main Report

January 1, 1976 to December 31, 1978

epared by Warren H. Hubble, Charles F. Miller

G&G Idaho, Inc.

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Main Report
January 1, 1976 - December 31, 1978

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ABSTRACT

This report consists of three volumes; Volume 1 contains the main report, and Volumes 2 and 3 contain the complete Appendix.

The report describes the creation of a computer-based data file from Licensee Event Reports (LERs) of valves at commercial nuclear power plants for the period January 1, 1976, to December 31, 1978. In addition to creation of the file, summaries of the data contained in the file were made to obtain data for risk and statistical purposes. Gross constant failure rates were estimated for major valve types in selected safety systems. Explanations and summary tables of the results are provided.

NRC FIN No. A6276 - LER Failure Rate Analysis Program

FOREWORD

This report is one in a series summarizing the statistics of Licensee Event Reports (LERs) as recorded by the U.S. Nuclear Regulatory Commission. The goal of the report is twofold: (a) to summarize the data for risk and statistical analyses, and (b) to obtain gross constant failure rate estimates and gross categorizations of the failures.

Because subjective judgments had to be made regarding population sizes and pertinence of recorded events, and because some component failures may not be recorded in the LERs, the component failure rates estimated in this report should be interpreted as being only tentative gross indicators of the true failure rates. The analyst himself must validate the applicability of the LER-derived failure rates for his own particular use. Furthermore, because LER reporting requirements can differ from plant to plant, comparisons of plant-to-plant failure rates should be interpreted with care; a higher failure rate may simply be because of stricter reporting requirements. As more data are collected and more analyses are performed in the future, improved failure rate estimates will be produced.

The failure rates given in the report are only one of many kinds of information presented. The tables and discussions give important information on failure classifications, according to failure modes, failure causes, and systems affected. Gross time trends are examined. Human errors are identified as are common cause failures and recurring failures. Each LER analyzed is presented in a useful, summarized form, and all evaluations are presented such that you can modify the authors' calculations or perform your own evaluations if you so desire.

William E. Vesely
Project Manager
November 16, 1979

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NOMENCLATURE

Terms and acronyms used in this report are defined herein.

Terms

1. Component - A component is the largest entity of hardware for which data are most generally collected and expected to be available (for example, pump with motor, valve with operator, amplifier, pressure transmitter). It is generally an off-the-shelf item procured by the system designer as a basic building block for his system. It would be distinguished from seals, bearings, nuts, bolts, and other piece parts from which the component is manufactured.

2. System - A system is a collection of components arranged so as to provide a desired function (for example, Containment Spray System, Residual Heat Removal System, High Pressure Coolant Injection System).

3. Fault - A fault is any undesired state of a component or system. A fault does not necessarily require failure (for example, a valve might be closed when it should be open because of some other component input or human error--a "command fault").

4. Failure - A failure is a subset of a fault and represents an irreversible state of a component such that it must be repaired in order for it to perform its design function. Failures are sometimes classified as primary or secondary failures. However, in classifying failures for this report, no distinction has been made between these two classifications:

    a. A primary failure is the so called "random failure" found in the literature. It results from no external cause.

b. A secondary failure results when the component is subject to conditions that exceed its design envelope (for example, excessive voltage, pressure, shock, vibration, temperature).

5. Common Cause Failure - Common cause failures are two or more redundant components failing together because of a single cause. The common cause events that cause multiple failures are usually secondary failures. Human errors are a special type of command fault that are considered common cause for multiple failures.

6. Failure Mode - The description of the manner in which a component ceases to perform its intended function.

7. Failure Mechanism - The identified cause that prevented the component from performing its intended function.

8. Demand Failure Rate - The probability (per demand) that a component will fail to operate when required to start, change state, or function.

9. Standby Failure Rate - The probability (per hour) of failure for those components that are normally dormant or in a stand-by state until tested or required to operate or function for a period of time.

10. Operating Failure Rate - The probability (per hour) of failure for those operating components required to operate or function for a period of time.

Acronyms

ADS - Automatic Depressurization System
AOV - Air-Operated Valve
BWR - Boiling Water Reactor
ESF - Engineered Safety Features
FSAR - Final Safety Analysis Report
HPCI - High Pressure Coolant Injection

LER - Licensee Event Report

LPCI - Low Pressure Coolant Injection

MOV - Motor-Operated Valve

NPRDS - Nuclear Plant Reliability Data System

NRC - Nuclear Regulatory Commission

NSSS - Nuclear Steam Supply System

P&ID - Piping and Instrumentation Diagram

PORV - Power-Operated Relief Valve

PPS - Plant Protection System

PSAR - Preliminary Safety Analysis Report

PWR - Pressurized Water Reactor

RHR - Residual Heat Removal

SOV - Solenoid-Operated Valve

DATA SUMMARIES OF LICENSEE EVENT REPORTS OF VALVES AT
U.S. COMMERCIAL NUCLEAR POWER PLANTS
FROM JANUARY 1, 1976, TO DECEMBER 31, 1978

INTRODUCTION

This report evaluates all Licensee Event Reports (LERs) submitted between January 1, 1976, and December 31, 1978, pertaining to valves and supports the U.S. Nuclear Regulatory Commission's (NRC's) data gathering and analysis effort. Initially, we obtained all reports in the NRC file with the component code VALVEX or VALVOP submitted during this period. Subsequently, however, to ensure that all LERs pertaining to valve events were retrieved from the NRC file, a text search for the word "valve" was conducted by the NRC on those LERs without a VALVEX or VALVOP component code. We believe that these sorts yielded all of the LERs pertaining to valve events for the period of January 1, 1976, through December 31, 1978.

We qualitatively evaluated the data reported in these LERs, and coded the pertinent information contained in each LER that described a valve event (for example, failure mode, failure mechanism, event date) into a one-line description of the event. Each one-line description was then stored in a computer-based data file for future use. The computer has the capability to search, collate, retrieve, update, and display the coded one-line LERs of the file by almost any item of data contained in the original LER, for example, plant, Nuclear Steam Supply System (NSSS) vendor, event date, failure mode, and failure mechanism. This capability makes the LER data file a useful tool for obtaining various LER summary statistics for use in further analyses of valve events.

One method used to summarize data for this report was to estimate failure rates (called "LER rates") based on data in the LER data file. Specifically, we estimated various standby and demand LER rates for selected valves in all operating U.S. commercial nuclear power plants, with the exceptions of Fort St. Vrain, Humboldt Bay, LaCrosse, Indian Point 1, and Dresden 1. We then averaged these estimates to obtain various LER rates for the four NSSS vendors considered (that is, Babcock & Wilcox, Combustion

Engineering, General Electric, and Westinghouse). Finally, we averaged specific plant failure data to obtain various LER rates for Pressurized Water Reactors (PWRs), Boiling Water Reactors (BWRs), and the aggregate population.

LER rates, as well as the one-line LERs, are useful for probabilistic assessment, such as gross risk and reliability evaluations. However, when using the LER rates, the analyst must apply them with caution. Our LER rates are estimates based on information contained in the LERs, and may not represent actual failure rates of nuclear plant valves. A difference between the actual failure rate and the LER rate may be because of the averaging performed. Individual plant interpretations of the criteria used for LER reporting could also result in variations between actual failure rates and LER rates. See Appendix A for a brief explanation of some of the causes of these variations.

The body of our report has two major parts: (a) a description of the LER analysis and evaluation methodology and (b) a summary of results. The LER analysis is described first, and includes the definitions, ground rules, rationale, and assumptions used to summarize the data. In the summary of results section, we discuss the tables, sorts, and LER rate estimates. In Appendix A, we explain some of the causes for variations in LER reporting practices. In Appendix B, we describe the LER coding scheme used to encode the LERs into the data file. In Appendix C, we discuss the methods used to estimate the LER failure rates. In Appendix D, we list those plants licensed to operate using Standard Technical Specifications. In Appendix E, we provide general plant information for all plants considered in this report. In Appendix F, we present all of the codes used in coding the LERs. We provide selected sorts on data contained in the computer-based data file in Appendices G through R, and in Appendices S through Y, we provide the results of each LER rate estimated for this report.

It was our objective to provide the reader with all the information that we used, whether that information was in the form of the rationale used in the classification process or the numbers used in the estimates performed. We recognize that all analysts will not agree with our approaches to the problems encountered here, but by providing our reasoning, assumptions, and approaches to the problems, we hope to give these analysts the information they need to reanalyze the problem using their own definitions or their own more precise data.

DESCRIPTION OF THE LER ANALYSIS AND EVALUATION METHODOLOGY

In order to analyze and evaluate the data contained in the LERs, we found it was first necessary to define the valve component in a way that was applicable for our use in this evaluation. Once we accomplished this task, we made various assumptions and defined terms that were necessary for encoding the applicable LER data. When the data were encoded, we collected pertinent component information and applied the statistical methods needed to estimate the valve LER rates.

Component Definition

For the purposes of this report, a valve is defined as the valve body and all its internal parts, the valve operator (motor, solenoid, hand wheel, etc.), and any limit and torque switches mounted on the valve body or operator that are needed to make the valve function. Supply systems to the valve (such as, electrical, air, or hydraulic) are considered outside the bounds of the component.

LER Classification

After defining the bounds for the component, the LERs were examined to determine what data could be extracted from a typical LER. From this examination, 18 pertinent items of data were identified as follows:

1. NSSS Vendor
2. Plant
3. Control Number
4. Event Date
5. System
6. Component Type
7. Failure Mode
8. Failure Mechanism
9. Type of Event
10. Number of Components Failed
11. Numerical Key Words

12. Failure Mode Description
13. Failure Mechanism Description
14. Event Classification
15. Activity Resulting in Discovery
16. Operator Type
17. Valve Type
18. Manufacturer.

These 18 items contained in the LER were subsequently stored in the computer-based data file as a data record and used as the basis for the summaries presented in this report. The following is a discussion of items that are not self-explanatory and includes definitions and rationale as to why some items were classified as they were. For a discussion of the actual codes used for each item and how the coded events are presented in this report, see Appendix B.

Component Type

Using the information contained in the LERs, the valve components were classified as follows:

1. Motor-Operated Valve (Electric)
2. Pneumatic-Operated Valve
3. Solenoid-Operated Valve
4. Hydraulic-Operated Valve
5. Remote-Operated Valve
6. Manual-Operated Valve
7. Check Valve
8. Relief Valve/Safety Valve
9. Damper Valve
10. Operator Type or Valve Function Not Stated.

It is apparent from this list that the LERs concentrated primarily upon the type of operator a valve has or the function that the valve serves, and sometimes neither is provided. Some LERs contained just enough information for us to determine that a valve had an operator (other than a manual operator) that was capable of being operated remotely, but contained no mention as to the type of operator. Valves in LERs such as this, were coded Remote-Operated Valves. Although this is not specific information, it is better than coding the valve as Operator Type or Valve Function Not Stated.

Failure Mode

From the LERs, 11 failure modes were identified for valves. These failure modes are defined as follows:

1. Failed to Open - Valve failed to open fully when called upon to open.

2. Failed to Close - Valve failed to close fully when called upon tc close.

3. Internal Leakage - Valve leaks through (measurable leakage past seat) even though the valve indicates closed. A typical example would be measured leakage during a containment isolation leak rate test, repairable by cleaning and lapping the valve seat and disk. Some analysts would consider this a failure to close. To others it would be considered a wear-out failure. The large number of LERs reporting internal leakage prompted us to separate the Internal Leakage reports from the Failed to Close reports.

4. External Leakage/Rupture - A leak or rupture of the valve that would allow the contained medium to escape from the component boundary. The most common example of this mode is a packing failure around the valve stem.

5. Reverse Leakage - Reverse Leakage is a mode used to describe internal leakage through a check valve. It is a separate and distinct mode, applying only to check

valves and is not considered part of the Internal Leakage mode.

6. Failed to Operate as Required - Some control valves such as pressure, level, or flow are not "open" or "close" oriented, but are designed to constantly change positions during operation. Other valves are required to open or close within rigid time constraints in order to have systems operate properly. Many LERs do not specifically state how a valve fails but only state, "valve failed to operate during testing." The Failed to Operate as Required mode was used whenever (a) a valve failed to meet specific requirements such as closing or opening times, (b) a valve lost the ability to control system parameters, or (c) the LER failed to provide sufficient information concerning the event, information that would have enabled us to place the event into a specific mode, such as, Failed to Open or Failed to Close.

7. Plugged (Fails To Remain Open) - This failure mode refers to any event that would stop or limit flow through a normally-open valve. If a valve fails to open or a person closes a valve that is required open, these events are not considered plugged valves. Two examples of a plugging event would be (a) a valve disc separates from the stem and falls into the closed position and (b) the air supply to an air-operated valve fails, allowing the valve to drift closed.

8. Premature Open - This failure mode is characteristic of relief or safety valves. A relief or safety valve opening prior to the setpoint pressure being reached would be a typical example of this mode.

9. Maintenance/Replacement - LERs occasionally reported events that were potential problems. Examples of some potential problems are, "staked locknuts found missing from motor operators," "motors found with the wrong class windings," and "valve noisy in operation (two teeth missing from gear)." Although the valves in these examples were still able to perform their designed functions and were, therefore, not failed (using definitions in the other failure modes), they were worked on to repair or replace parts, because it was felt that these parts might fail in the immediate future. Since these valves had to be taken out of service to repair the potential problem, these events are considered failures for the purposes of this report.

10. Technical Specification Violation - This mode is not concerned with valve failures but is concerned with failures of plant personnel to perform their duties concerning valve-related directives and procedures. Examples of some events coded under T are as follows:

Mode Description	Mechanism Description
Valve not tested prior to return to service	Maintenance error
Surveillance not performed when required	Operating personnel error

Technical Specification Violations are considered nonfailures in that the consequence of these acts of ommission do not affect the valve's ability to perform its function.

11. Improper Valve Configuration - This mode consists entirely of events caused by personnel errors that resulted in valves not being in the correct position required by plant conditions. These events are usually

a simple matter of operations personnel failing to close a valve or closing the wrong valve during a valve line-up procedure. Other events that can cause a valve to be positioned wrong can be traced back to a logic error made while wiring a control circuit or a valve of improper design being installed in a system. Personnel error during operation, maintenance, testing, fabrication, construction, quality control, or procedural activities could result in an improper valve line-up. All events in this mode are considered command faults.

Failure Mechanism

The failure mechanisms (causes of failure) used in our report are the mechanisms reported in the respective LERs, and should be self-explanatory. However, the mechanism reported may or may not be the true, root cause of the failure. The quality of the LERs varies, and an intermediate mechanism may be reported as the cause.

The failure mechanisms are grouped into logical categories in Table 1. This table provides an insight into the rationale used in analyzing the LERs.

Many of the LERs failed to report a cause for the valve failure or command fault. In this type of report, the failure mechanism was coded as Unknown.

Normal Wear was used for end of normal service life, while Excessive Wear implies a shorter than normal component life (for example, galling was considered Excessive Wear). Ideally, normal wear failures should be deterred by preventive maintenance and replacement. Many LERs, however, reported the cause of failure to be Normal Wear; because of these LERs, we included Normal Wear as a failure mechanism in our analysis.

Electrical Input Failure/Problem and Failure of Component Supply System are two failure mechanisms used in conjunction with command faults caused

TABLE 1. FAILURE MECHANISMS LISTED BY CATEGORIES

Categories	Mechanisms
Mechanisms not stated or unknown	00 Unknown
Personnel originated mechanisms	01 Personnel (Operation) 02 Personnel (Maintenance) 03 Personnel (Testing) 04 Design Error 05 Fabrication/Construction/Quality Control 06 Procedural Discrepancy
General mechanisms existing independent of component[a] type	07 Normal Wear 08 Excessive Wear 09 Corrosion 10 Foreign Material Contamination 11 Excessive Vibration
General mechanisms related to a specific component[a] type	12 Mechanical Controls/Parts; Failed or Out of Adjustment 18 Weld Failure 19 Lack of Lubrication
Mechanisms related to specific parts within a valve	13 Seal/Gasket Failure/Problem 14 Packing Failure/Problem 15 Bellows/Boot Failure/Problem 17 Bearing/Bushing Failure/Problem 20 Electric Motor Operator Failure/Problem 21 Solenoid Failure/Problem 22 Leaking/Ruptured Diaphragm 23 Torque Switch Failure/Problem 25 Seat/Disc Failure/Problem 26 Limit Switch Failure/Problem 27 Pilot Valve Failure/Problem
General hardware oriented command fault mechanisms	16 Electrical Input Failure/Problem 24 Failure of Component Supply System

a. "Component" as used here is not limited to valves but includes all types of components (for example, pumps, diesels, control rods).

by component failures outside the bounds of the valve as defined in this report. These mechanisms are used to show that the valve could not function because it had no source of power, electrical or mechanical, to command the valve to function. If the valve failed to operate because of one of these reasons, the event was not considered to be a valve failure, but a command fault.

Type of Event

In analyzing the LERs, we were able to identify failure events as either random, recurring, common cause, or recurring common cause; command fault events could be identified as random or recurring.

"Recurring" in this report means two or more LERs from a plant or plants at one site (for example, Quad-Cities 1 and 2) reporting problems of a similar enough nature that some note should be taken. Recurring makes no attempt to compare events at Quad-Cities 1 with events at Zion 1 (that is, intersite failures).

An example illustrates recurring failures: At one plant, two separate LERs state, "motor-operated valve, MV21A, failed to operate because of a sheared key in the motor-to-operator shaft." Both of these events would be classified as recurring.

One other criterion for classifying an event as recurring is to have an LER state, "this is a recurring failure", or "similar failures have been reported on this component."

A common cause failure is defined as two or more valves failing together from a single identifiable causal event such as fire, flood, poor maintenance, or manufacturing defects. As a possible aid to future common cause studies, we also classified some single component failures as common cause when the failure mechanism might have caused more than one component to fail. These single component events were labelled common cause to provide data for those interested in investigating common cause failures. The common cause definition was made purposely broad with the thought that it would be easier for analysts to exclude data from the list rather than to try to add data.

A typical common cause example would be four motor-operated valves failing to operate because they were all in a flooded pit. The common cause, flooding, is easily identified here. Other common cause factors may not be as easily identified. For example, a report stating, "two valves leaked externally because of failed packing," is hard to classify, as far as common cause is concerned, without additional information. The packing might have had a manufacturing defect, it might have been installed improperly during maintenance, or there may be no common cause factors at all, that is, the packing of both valves may have just worn out at the same time. When we could determine that the packing failures were not simply wear-out failures, we coded the event as common cause.

Recurring common cause failures are failures that are classified as both recurring and common cause (for example, during maintenance, two valves are packed wrong, resulting in external leakage, and a month later, at the same plant, another report states, "Two valves leaked externally because of improper packing"). The similarity of these common cause reports would prompt us to classify both reports as recurring common cause.

Command faults are events in which the valve did not function as required, not because of a failure in the valve, but because of inputs or lack of inputs to the valve that were supplied by personnel or components external to the valve. Two examples of command fault events are an electrical breaker failure results in no power to operate the valve and a personnel error that results in an improper valve line-up. An example of a recurring command fault would be a valve being lined-up improperly on two or more separate occasions.

It should be noted that the same rationale discussed for recurring failures applies to recurring common cause and recurring command faults.

Because we grouped LERs by plant or plants at one site, and then classified the LERs as to Type of Event, a sort of the different types of events provides plant-specific data. Trends may become evident within plants, such as, a particular valve with a high failure rate, poor maintenance practices, or a frequent inability by personnel to follow valve line-up procedures.

Number of Components

The Number of Components data are important because there is not a one-to-one relationship between the number of reports and the number of valves in the data file. For example, 1166 reports contained failures of 1775 valves, while 483 reports contained command faults involving 543 valves. These multiple valve reports used the Number of Components data to indicate the number of valves contained in each report. Reports involving only one valve have no number in the Number of Components data, implying only one valve event was contained in these reports.

Not all LERs contained explicit numbers. Some LERs contained phrases such as, "many containment valves," "several isolation valves," or often, just the plural "valves." The number assigned to Number of Components classified from these LERs was not explicit, but was subjectively assigned, based upon key words within the LERs. The next section contains the rationale used to select these numbers.

Numerical Key Words

For reports that did not precisely state the number of components involved, a number had to be assigned. These assigned numbers were based upon key words or phases within the LER. The following is a list of the key words found and the numerical values assigned to the Number of Components, based upon these key words:

Key Word	Number Assigned
Valves	2
Some	3
Various	3
Several	3
Other	≥2[a]

The "Other" refers to phrases, rather than a specific word within the LER, such as, "all containment motor-operated valves" or "a series of valves and check valves." These phrases helped us determine a number to assign to the Number of Components classification. It can be seen from the list that a minimum number was assigned, based upon the key word or phrase.

A letter in the key column, contained in the various sorts of this report, alerts the reader that the value in the Number of Components column was assigned and, therefore, is not explicit. This allows the analyst to modify the number if he feels the assigned number does not fit his needs. Only 65 of the 1675 reports had to have values assigned to the Number of Components classification.

Event Classification

In an attempt to extract additional information from the LERs, each report was examined to determine whether the cause of the event was related to the number of changes of state (starts, stops, openings, closings, etc.) to which the component was subjected or, simply, the age of the component.

An example of the Change of State classification is a motor-operated valve failing to open during a test because of teeth shearing from a gear in the operator mechanism; while age would be used to classify an event describing a valve body failing from corrosion, allowing external leakage

a. Number assigned varies based upon the phrase contained in the LER narrative.

of fluid. Many LERs did not provide adequate information (that is, information that would enable us to determine the event classification). "Unknown" was used to classify these events.

All reports involving personnel error were classified as Change of State, because we felt that the probability of these events increased as the number of personnel interactions with the component increased. All command faults were also classified as Change of State, because the fault occurred when the component was commanded to change state. We did not attempt to classify the component or problem that caused the improper command.

Subjective judgments had to be made in classifying events; therefore, care should be exercised when using this information.

Operator and Valve Type

LERs reported after January 1, 1978, contained additional information that identified either the operator or valve type. Problems with motor-operated valves could now be separated into motor problems such as an ac motor, or problems in a specific valve type, such as a gate valve.

Although these data are present in the data file, they were not used in any quantitative summaries prepared for this report. However, the data are presented in Appendix H if an analyst desires to use them. We chose not to summarize these data because they were not available for the major portion of time covered by this report. We have included it in the data file for future use, when more LERs containing this type of information are available.

Data Collection for LER Rate Estimates

The computational formulas used to estimate the LER rates are discussed in Appendix C. LER rates were estimated for (a) each licensed operating plant, (b) each NSSS vendor, (c) PWRs and BWRs, and (d) the aggregate of all licensed operating plants. This section describes the rationale used in selecting data for LER rate estimates.

For our analysis, the data necessary to estimate valve LER rates were collected from various sources. The number of failures and command faults were extracted from our computer-based data file, while the standby time, number of demands, and valve populations came from other sources. The following discussion gives a summary of each of these data gathering efforts and the assumptions and sources used to arrive at values for each of these data needs.

Failures

The data file contains events; that is, failures, command faults, and technical specification violations. LER rates on both failures and failures plus command faults were estimated, if data were available for both. Sorts of the data file provided us with the number of failures and/or command faults to use in the various estimates.

In estimating the LER rates in this report, each failure or command fault was assumed to be an individual random event, when, in fact, some of the events involving multiple valves were suspected to be common cause events. It is beyond the scope of this report, however, to treat the common cause events separately when doing LER rate estimates.

Time

The hours used to estimate failure-per-hour rates are the calendar hours from the date of a plant's initial criticality to December 31, 1978, or the number of calendar hours covering the entire period of this report (that is, 26,280 hours) whichever is the smallest. Calendar hours are based on a 24-hour day and a 365-day year. Initial-criticality dates for all plants were obtained from the NRC "Gray Book".[1] These calendar hours were used as standby hours in the LER rate estimates. We chose to think of the valves as being in a standby status while awaiting a command to open or close, even though the valve can be considered operational in terms of acting as a pressure boundary.

Demands

To obtain an estimate of the number of demands experienced by different types of valves, information was gathered on both testing and operational demands.

Testing Demands. Quarterly testing is specified in Section XI of the ASME Boiler and Pressure Vessel Code[2] for all valve types except safety and relief valves. The number of testing demands assigned to these valves was adjusted according to the initial criticality date for each plant. A quarter was considered to be 2190 hours. This figure was divided into the calendar hours for each plant to arrive at the number of testing demands. Any quotient that was not an integer was rounded to the next highest integer.

We assumed, for the purposes of our estimates, that testing demands were the only demands experienced by all types of valves, with the exception of the safety and relief valves. We further assumed that testing was done at the minimal frequency required by Technical Specifications. These assumptions resulted in demand LER rates that were conservative (that is, higher than actual) compared to when testing was performed more frequently and no more failures resulted from this additional testing.

Safety and relief valves are required to be tested once every 5 years.[2] No test demands were used in the rate estimates for safety and relief valves because of the short time period covered by this report in comparison to the 5-year-test interval.

Operational Demands. Since test demands were not considered for safety or relief valves, operational demands were used to estimate LER rates for these valves. By operational demands, we mean plant pressure transients that raise system pressures above the setpoint of the safety or relief valves. It was beyond the scope of this report to obtain a 3-year pressure history for each plant, however, so some assumptions were made. Before presenting these assumptions, it is appropriate to first discuss what safety and relief valves were used in the LER rate estimates and why.

PWRs have both Power-Operated Relief Valves (PORVs) and safety valves. According to individual plant Final Safety Analysis Reports (FSARs), these PORVs contribute to plant pressure control and help limit the number of times the safety valves are required to lift; however, no credit was taken for them in the plants' accident analysis, and they are not considered part of the plants' safety systems. LERs for PWR PORVs are not required to be submitted by the plants and, therefore, were not summarized in this report. PWR safety valves are included in this report and LER rate estimates were obtained for them.

BWRs have both relief and safety valves, except Edwin I. Hatch 2 which has 11 relief valves and no safety valves. Older BWRs tend to have a small relief valve population and a large safety valve population, while newer designs have reversed that trend. The BWR relief valves actuate from either an external signal or system pressure. All BWRs have either all or part of their relief valves capable of actuating from a signal from the Automatic Depressurization System (ADS). All BWR relief valves, whether ADS or ordinary relief valves, were treated as one group when doing LER rate estimates. BWR safety valves were not included in the estimates contained in this report, as the LERs reported no BWR safety valve failures.

After deciding to do LER rate estimates for only PWR safety valves and BWR relief valves, some assumptions were needed to allow us to obtain the operational demands needed for these estimates. We obtained the number of forced automatic scrams, for each PWR plant, from the "Nuclear Power Plant Operating Experiences,"[3,4,5] and assumed that one-half of these scrams resulted in a pressure transient of sufficient magnitude to lift the entire population of a plant's safety valves. The same sources were used to find the number of forced automatic scrams plus manual scrams for BWR plants. We assumed that the total number of these scrams caused pressure transients in BWRs that would lift the entire population of a plant's relief valves. Different assumptions were used for PWRs and BWRs because (a) different valve types are being analyzed and (b) there are differences in the operational characteristics of the two reactor types.

Valve Populations

We lacked a comprehensive source of data from which to obtain valve populations for all systems within each plant. We chose to obtain valve populations for selected systems that were designed to mitigate a loss-of-coolant accident, that is, Engineered Safety Features (ESF) systems. The ESF systems selected for both PWRs and BWRs are listed in Table 2.

TABLE 2. SELECTED ESF SYSTEMS

ESF System (PWR)	ESF System (BWR)
Containment Spray Injection	Low Pressure Core Spray
High Pressure Coolant Injection (HPCI)	Containment Spray Injection
Low Pressure Coolant Injection (LPCI) and Residual Heat Removal (RHR)	HPCI
Auxiliary Feed	LPCI and RHR
Chemical Volume Control[a]	Condensate and Feed[b]

a. This system is shared with the HPCI in certain PWRs.

b. This system takes the place of HPCI in certain BWRs.

In addition to valve populations obtained from the ESF systems listed in Table 2, we obtained primary relief and safety valve populations. All valve populations were obtained from the Preliminary Safety Analysis Report (PSAR) or FSAR for each plant. We excluded valves from the population data that were in piping systems of 1 inch or less for PWRs and 1-1/4 inch or less for BWRs. These dimensions are nominal pipe sizes and were chosen to correspond to minimum valve sizes included in reports to the "Nuclear Plant Reliability Data System" (NPRDS).[6] Relief and safety valve populations were stated in the text of the PSARs or FSARs. The other valve-type populations had to be obtained from Piping and Instrumentation Diagrams (P&IDs) and process flow diagrams. These numbers may not be exact because of differences in quality of the diagrams and changes in the as-built design.

Although only failures and command faults of selected ESF system valves and primary relief and safety valves were used to obtain LER rates for this report, other analysts may wish to expand on this. We have provided sorts of failures and command faults for four additional systems that can also provide safety functions in accident situations (see Appendix R). The systems are the Containment Isolation System in both PWRs and BWRs, the Chemical Volume Control System in PWRs, the Standby Liquid Control System in BWRs, and the Reactor Core Isolation Cooling System in BWRs.

SUMMARY OF RESULTS

The LERs used for this analysis were selected from two computer sorts of LERs pertaining to valves. Both sorts were obtained from the NRC and contained LERs submitted between January 1, 1976, and December 31, 1978. The first sort contained reports that were coded as either VALVEX or VALVOP in the LER. This sort contained 1489 LERs. The second sort of the NRC LER file was a text search of the LER narrative for the word "valve" and excluded those reports obtained in the first sort. The second sort (the word search) contained 921 LERs and was conducted to ensure that all LERs pertaining to valves were available to us for evaluation. These two sorts contained 2410 LERs and are believed to contain all LERs concerning valves. Not all of these LERs were used for this analysis, however.

Of the 2410 LERs reviewed, we exluded 820 for the following reasons:

1. LERs were excluded if they contained only informational items. An example would be a report that states, "Checked all MOV locknuts for proper staking as per NRC request, no discrepancies found."

2. LERs were excluded if they were not reporting a valve failure, but the word "valve" appeared in the description of the failure (for example, the pipe between valve MV121A and recirculating pump 2A was found leaking).

3. LERs were excluded if they were submitted prior to the date of initial criticality for their respective plants.

4. LERs were excluded if they were submitted for plants that we considered atypical. A list of these plants and the reason for their exclusion is presented in Table 3.

TABLE 3. ATYPICAL PLANTS EXCLUDED FROM ANALYSIS

NSSS Vendor	Plants Excluded	MW(e)	Remarks
General Atomic Co.	Fort St. Vrain[a]	330	Gas-cooled reactor
Babcock & Wilcox	Indian Point 1	265	Not operational for the period covered by this report
Allis-Chalmers	LaCrosse	48	Small megawatt rating[b] and only plant supplied by this vendor
General Electric	Big Rock Point	72	Small megawatt rating,[b] BWR/Class 1
General Electric	Dresden 1	200	Small megawatt rating,[b] BWR/Class 1
General Electric	Humboldt Bay	63	Small megawatt rating,[b] BWR/Class 1

a. Fort St. Vrain does not meet the reactor type criterion.

b. The average electrical rating of the BWRs considered in this analysis is 795 MW(e).

The NSSS vendors of plants considered in this report are Babcock & Wilcox, Combustion Engineering, Westinghouse, and General Electric. All of the plants considered in this report use either PWRs or BWRs supplied by one of these four NSSS vendors. Appendix E contains the complete list of the 64 plants used as well as pertinent information about each plant.

After reviewing the 2410 LERs and excluding 820, the 1590 LERs remaining were the major source of information from which data in this report were derived. Figures 1 and 2 illustrate the information gathering process.

Before we could encode the 1590 LERs into a computer-based data file, we had to know what type of events they contained. These LERs contained three types of events: failures, command faults, and technical specification violations (see Figure 2).

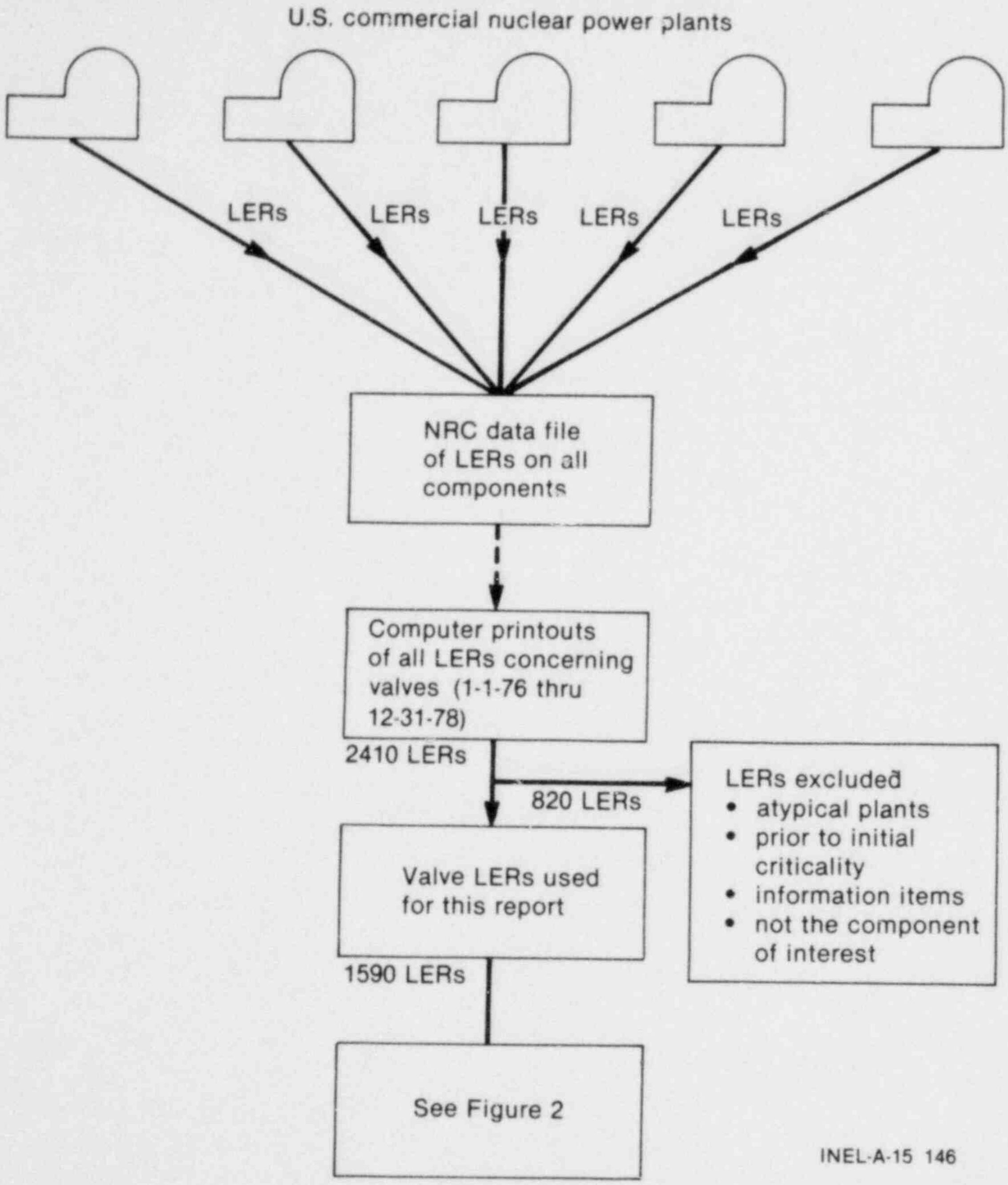


Figure 1. Diagram of how LERs were obtained for use in this report.

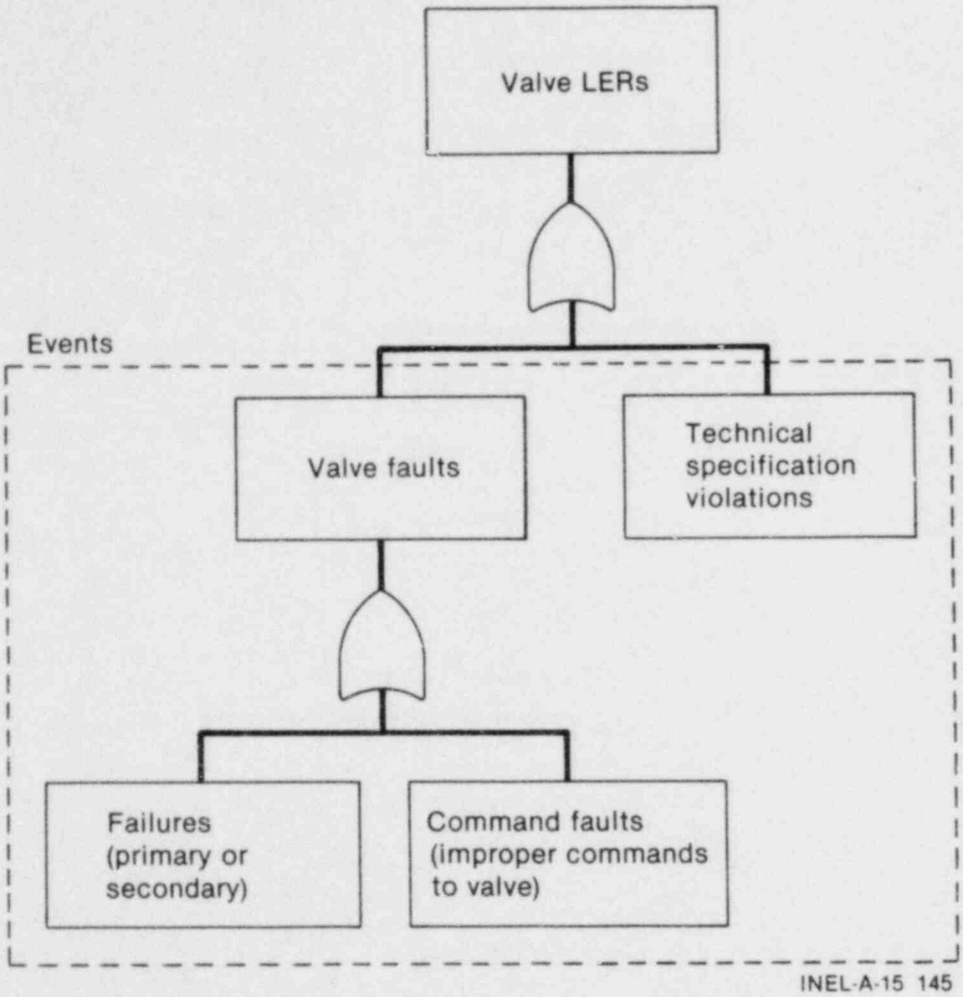
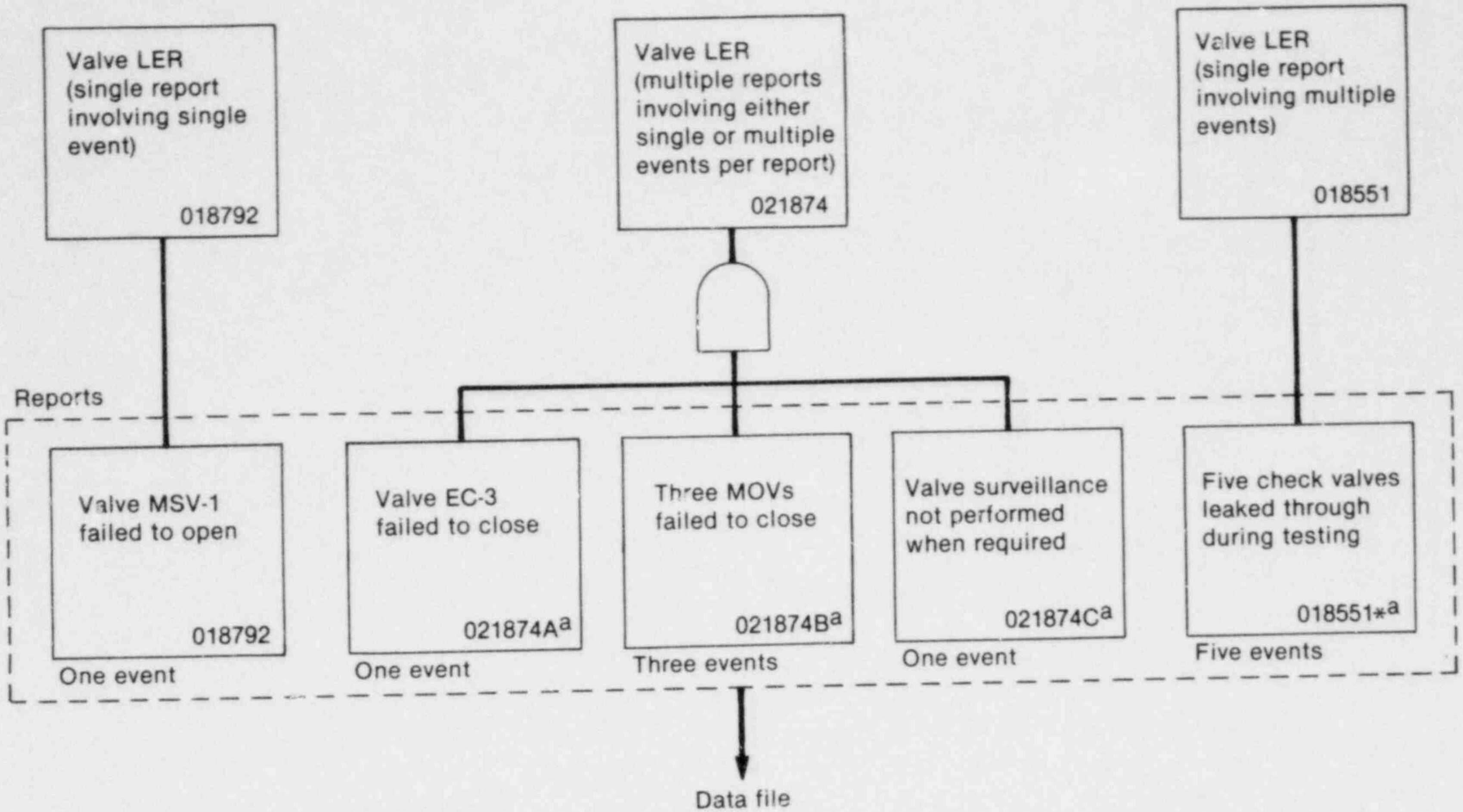


Figure 2. Simplified diagram of the type of events that are contained in the LERs used for this report.

Although most LERs contained only a single report involving one event (either a failure, a command fault, or a technical specification violation), some LERs contained multiple reports involving either single or multiple events. An example of a multiple-report LER is one that states, "Three valves, MV-1, -2, and -3, failed to open because of an open supply breaker and valve HCV14 failed to close because of a broken stem." This LER contained two reports involving four events, a command fault involving three valves (that is, three events), and a failure involving one valve (that is, one event), respectively. Figure 3 shows the relationship between the LERs and the information placed in the data file and how the control number is used to ensure both uniqueness and traceability of each report back to the original LER.

From Figure 3 it is apparent that 1590 LERs represent more than 1590 events in the data file because some of the LERs contained multiple reports. Also, some reports contained multiple events. Of the 1590 LERs, 70 LERs contained multiple reports, which increased the total number of reports in the data file to 1675. Some of the 1675 reports described multiple events (that is, failures or command faults of more than one component). In fact, the 1675 reports represent 2344 component failures, command faults, or technical specification violations. An accounting of the LERs analyzed for this report is presented in Table 4.

Appendices G and H contain all data extracted from the 1590 LERs. We summarized these data into tables, sorts, and LER rates.



a A control number, as used in our computer-based data file, which ends in an alphabetic character may indicate either single or multiple events per report, while a control number ending with an asterisk (*) indicates multiple events per report.

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Figure 3. Examples showing the logic used in creating the data file from different types of valve LERs and the use of control numbers.

TABLE 4. ACCOUNTING OF LERs ANALYZED

LERs Analyzed	Number
NRC VALVEX and VALVOP LERs	1489
NRC LERs not coded as VALVEX or VALVOP but containing the word "valve"	921
Total LERs available for screening	2410
Minus LERs not applicable	-820
Total LERs available for analysis	1590
Number of reports contained in the 1590 LERs (70 LERs contained multiple reports)	1675
Number of events (that is, failures, command faults, and technical specification violations) contained in the 1675 reports (280 reports contained multiple events)	2344

Tables

The tables presented here show numerical tabulations of the valve events by failure mode, failure mechanism, component, system, activity resulting in discovery, manufacturer, event classification, year, type of event, plant, and combinations of these items.

Failure Mode

Table 5 summarizes the number of events for each failure mode. The three failure modes, Failed to Open, Failed to Close, and Failed to Operate as Required accounted for 48% (1122) of the total (2318) failures and command faults. The next largest number of failures and command faults (461, or 20%) is attributed to the failure mode, Internal Leakage.

The failure mode, Improper Valve Configuration, accounted for 39% (212) of the total 543 command faults. This mode consists entirely of personnel-originated command faults. Regardless of the number of valves lined up improperly, each report was coded as a single event. We recognize that this practice may cause difficulties for the analyst studying common cause events because the number of events per report would be necessary. Therefore, we have provided Table 6 that shows a yearly breakdown of the number and type of valves lined up improperly in each Improper Valve Configuration report. Appendix I provides a sort of the Improper Valve Configuration reports from which Table 6 was derived.

TABLE 5. SUMMARY OF VALVE EVENTS BY FAILURE MODE

	Failures		Command Faults		Total		Nonfailures
Failure Mode	No.	%	No.	%	No.	%	No.
Failed to Open	293	17	80	15	373	16	
Failed to Close	251	14	119	22	370	16	
Internal Leakage	460	26	1	0	461	20	
External Leakage/ Rupture	154	9	1	0	155	7	
Reverse Leakage (Check Valves)	115	6	0	--	115	5	
Failed to Operate as Required	273	15	106	20	379	16	
Plugged (Fails to Remain Open)	11	1	21	4	32	1	
Premature Open (Relief Valves)	74	4	2	0	76	3	
Maintenance/ Replacement	144	8	1	0	145	6	
Improper Valve Configuration	0	--	212	39	212	9	
Technical Specification Violation							26
Total	1775		543		2318		26

TABLE 6. SUMMARY OF IMPROPER VALVE CONFIGURATION EVENTS[a] BY YEAR AND COMPONENT[b]

Component	1976[c]	1977[d]	1978[e]	1976 Through 1978	Percent of Total
Motor-Operated Valve (Electric)	3	4	1	8	3
Pneumatic-Operated Valve	2	3	2	7	2
Solenoid-Operated Valve	2	0	0	2	1
Hydraulic-Operated Valve	0	0	0	0	--
Remote-Operated Valve	7	15	19	41	13
Manual-Operated Valve	29	27	49	105	33
Check Valve	3	0	1	4	1
Relief Valve	0	0	3	3	1
Damper Valve	2	1	6	9	3
Operator Type or Function Not Stated	42	45	50	137	43
Total number of valves affected	90	95	131	316	
Total number of reports	61	63	88	212	
Average number of events per report	1.5	1.5	1.5	1.5	

a. All improper valve configuration events are command faults.

b. These are probably the minimum number of events resulting from improper valve line-up. It was necessary to estimate the total number of valves involved in 63 of the 212 LERs reporting these events (see Appendix I).

c. This report considered 56 commercial nuclear power plants operational at the end of 1976.

d. This report considered 59 commercial nuclear power plants operational at the end of 1977.

e. This report considered 64 commercial nuclear power plants operational at the end of 1978.

The Technical Specification Violations are shown separately, as they are considered nonfailure events. Appendix J is a sort of all Technical Specification Violation mode reports.

Failure Mechanism

Table 7 summarizes the number of failures and command faults for each failure mechanism. Approximately a quarter (430, or 24%) of all 1775 failures were reported as cause "unknown." Although many causes may be unknown, it was apparent that some causes were known but not reported; reports in the latter case stated, "valve repaired," but gave no information as to what part of the valve failed. See Appendix A for causes of variations in reporting. The general cause Mechanical Controls/Parts; Failed or Out of Adjustment accounts for the next largest percentage, 11% (194).

Hardware-originated command faults (that is, command faults caused by electrical input problems or component supply system problems) accounted for 61% (331) of all 543 command faults. Operations personnel accounted for 24% (129), while maintenance and testing personnel accounted for 5% (27) and 4% (21), respectively, of all 543 command faults. See Appendices K through N for sorts of all personnel-related failure mechanisms (Mechanisms 01 through 06). These appendices contain failures, command faults, and technical specification violations.

Failure Mode and Mechanism

Table 8 summarizes the number of events in each failure mode by failure mechanism. Review of this table shows the major causes of failures and command faults for each failure mode. For example, packing failures accounted for 55% (84) of the 154 External Leakage failures. The Fabrication/Construction/Quality Control mechanism accounted for 33% (47) of the 144 Maintenance/Replacement mode failures. Foreign Material Contamination accounted for 28% (32) of the 115 Reverse Leakage (Check Valve) failures. Appendix O provides a list of each failure mode sorted by failure mechanism.

TABLE 7. SUMMARY OF VALVE FAILURES AND COMMAND FAULTS BY FAILURE MECHANISM

Failure Mechanism	Failures		Command Faults		Total	
	No.	%	No.	%	No.	%
Unknown	430	24	3	1	433	19
Personnel (Operation)	21	1	129	24	150	6
Personnel (Maintenance)	58	3	27	5	85	4
Personnel (Testing)	13	1	21	4	34	1
Design Error	64	4	3	1	67	3
Fabrication/Construction/Quality Control	61	3	1	0	62	3
Procedural Discrepancy	63	4	28	5	91	4
Normal Wear	59	3	--	--	59	3
Excessive Wear	21	1	--	--	21	1
Corrosion	14	1	--	--	14	1
Foreign Material Contamination	104	6	--	--	104	4
Excessive Vibration	5	0	--	--	5	0
Mechanical Controls/Parts; Failed/Out of Adjustment	194	11	--	--	194	8
Seal/Gasket Failure/Problem	54	3	--	--	54	2
Packing Failure/Problem	116	7	--	--	116	5
Bellows/Boot Failure/Problem	0	--	--	--	0	--
lectrical Input Failure/Problem	--	--	186	34	186	8
Bearing/Bushing Failure/Problem	8	0	--	--	8	0
Weld Failure	6	0	--	--	6	0
ack of Lubrication	25	1	--	--	25	1
lectric Motor Operator Failure/Problem	66	4	--	--	66	3
olenoid Failure/Problem	19	1	--	--	19	1
eaking/Ruptured Diaphragm	60	3	--	--	60	3
orque Switch Failure/Problem	75	4	--	--	75	3
ailure of Component Supply System	--	--	145	27	145	6
eat/Disc Failure/Problem	139	8	--	--	139	6
imit Switch Failure/Problem	31	2	--	--	31	1
ilot Valve Failure/Problem	69	4	--	--	69	3
Total	1775		543		2318	

TABLE 8. SUMMARY OF VALVE EVENTS BY FAILURE MECHANISM AND FAILURE MODE

	Failed to Open				Failed to Close				Internal Leakage				External Leakage				Reverse Leakage (Check Valves)				Fa
	Failures		Command Faults		Failures		Command Faults		Failures		Command Faults		Failures		Command Faults		Failures		Command Faults		Fa
Failure Mechanism	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No
Unknown	78	27	0	--	46	18	0	--	171	37	0	--	17	11	0	--	39	34	0	--	3
Personnel (Operation)	2	1	0	--	2	1	0	--	1	0	0	--	0	--	0	--	0	--	0	--	
Personnel (Maintenance)	5	2	0	--	8	3	0	--	6	1	0	--	3	2	0	--	1	1	0	--	2
Personnel (Testing)	1	0	0	--	0	--	0	--	0	--	0	--	0	--	0	--	0	--	0	--	
Design Error	5	2	0	--	14	6	0	--	9	2	0	--	4	3	0	--	2	2	0	--	
Fabrication/ Construction/ Quality Control	2	1	0	--	0	--	0	--	2	0	0	--	3	2	0	--	2	2	0	--	
Procedural Discrepancy	38	13	0	--	2	1	0	--	0	--	0	--	0	--	0	--	0	--	0	--	1
Normal Wear	0	--	--	--	0	--	--	--	52	11	--	--	3	2	--	--	1	1	--	--	
Excessive Wear	3	1	--	--	4	2	--	--	0	--	--	--	3	2	--	--	7	6	--	--	
Corrosion	4	1	--	--	2	1	--	--	1	0	--	--	2	1	--	--	1	1	--	--	
Foreign Material Contamination	12	4	--	--	24	10	--	--	21	5	--	--	0	--	--	--	32	28	--	--	
Excessive Vibration	0	--	--	--	0	--	--	--	0	--	--	--	4	3	--	--	0	--	--	--	
Mechanical Controls/ Parts; Failed/Out of Adjustment	31	11	--	--	32	13	--	--	39	8	--	--	5	3	--	--	14	12	--	--	6
Seal/Gasket Failure/ Problem	2	1	--	--	0	--	--	--	6	1	--	--	12	8	--	--	3	3	--	--	
Packing Failure/ Problem	4	1	--	--	17	7	--	--	6	1	--	--	84	55	--	--	0	--	--	--	
Bellows/Boot Failure/ Problem	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	
Electrical Input Failure/Problem	0	--	55	69	0	--	58	49	0	--	0	--	0	--	0	--	0	--	0	--	
Bearing/Bushing Failure/Problem	0	--	--	--	6	2	--	--	0	--	--	--	0	--	--	--	0	--	--	--	
Weld Failure	1	0	--	--	0	--	--	--	0	--	--	--	5	3	--	--	0	--	--	--	
Lack of Lubrication	6	2	--	--	14	6	--	--	1	0	--	--	2	1	--	--	0	--	--	--	
Electric Motor Operator Failure/Problem	25	9	--	--	14	6	--	--	1	0	--	--	0	--	--	--	0	--	--	--	2
Solenoid Failure/ Problem	8	3	--	--	6	2	--	--	0	--	--	--	0	--	--	--	0	-	--	--	
Leaking/Ruptured Diaphragm	6	2	--	--	1	0	--	--	11	2	--	--	3	2	--	--	0	--	--	--	2
Torque Switch Failure/ Problem	32	11	--	--	29	12	--	--	4	1	--	--	0	--	--	--	0	--	--	--	1
Failure of Component Supply System	0	--	25	31	0	--	61	51	0	--	1	100	0	--	1	100	0	--	0	--	
Seat/Disc Failure/ Problem	1	0	--	--	0	--	--	--	117	25	--	--	4	3	--	--	13	11	--	--	
Limit Switch Failure/ Problem	16	5	--	--	9	4	--	-	0	--	--	--	0	--	--	--	0	--	--	--	
Pilot Valve Failure/ Problem	11	4	--	--	21	8	--	--	12	3	--	--	0	--	--	--	0	--	--	--	1
Failure Mode Total	293		80		251		119		460		1		154		1		115		0		27

Failure Mode

...led to Operate as Required				Plugged (Fails to Remain Open)				Premature Open (Relief Valves)				Maintenance/ Replacement				Improper Valve Configuration				Failure Mechanism Total				Technical Specification Violations
...lures		Command Faults		Failures		Command Faults		Failures		Command Faults		Failures		Command Faults		Failures		Command Faults		Failures		Command Faults		
No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	Events
[illegible]	13	0	--	0	--	0	--	39	53	0	--	5	3	0	--	0	--	3	1	430	24	3	1	0
[illegible]	3	0	--	0	--	0	--	0	--	0	--	7	5	0	--	0	--	129	61	21	1	129	24	10
[illegible]	8	0	--	0	--	0	--	0	--	0	--	12	8	0	--	0	--	27	13	58	3	27	5	6
[illegible]	2	0	--	0	--	0	--	7	9	0	--	0	--	0	--	0	--	21	10	13	1	21	4	5
[illegible]	2	0	--	0	--	0	--	1	1	0	--	23	16	0	--	0	--	3	1	64	4	3	1	0
[illegible]	1	0	--	1	9	0	--	0	--	0	--	47	33	0	--	0	--	1	0	61	3	1	0	0
[illegible]	6	0	--	0	--	0	--	2	3	0	--	5	3	0	--	0	--	28	13	63	4	28	5	5
[illegible]	1	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	59	3	--	--	0
[illegible]	0	--	--	0	--	--	--	3	4	--	--	0	--	--	--	0	--	--	--	21	1	--	--	0
[illegible]	--	--	--	3	27	--	--	0	--	--	--	1	1	--	--	0	--	--	--	14	1	--	--	0
[illegible]	3	--	--	4	36	--	--	1	1	--	--	3	2	--	--	0	--	--	--	104	6	--	--	0
[illegible]	--	--	--	0	--	--	--	0	--	--	--	1	1	--	--	0	--	--	--	5	0	--	--	0
[illegible]	23	--	--	0	--	--	--	9	12	--	--	1	1	--	--	0	--	--	--	194	11	--	--	0
[illegible]	1	--	--	0	--	--	--	0	--	--	--	27	19	--	--	0	--	--	--	54	3	--	--	0
[illegible]	2	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	116	7	--	--	0
[illegible]	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0
[illegible]	--	61	58	0	--	10	48	0	--	1	50	0	--	1	100	0	--	0	--	0	--	186	34	0
[illegible]	1	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	8	0	--	--	0
[illegible]	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	6	0	--	--	0
[illegible]	1	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	25	1	--	--	0
[illegible]	10	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	66	4	--	--	0
[illegible]	2	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	19	1	--	--	0
[illegible]	10	--	--	2	18	--	--	0	--	--	--	9	6	--	--	0	--	--	--	60	3	--	--	0
[illegible]	4	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	75	4	--	--	0
[illegible]	--	45	42	0	--	11	52	0	--	1	50	0	--	0	--	0	--	0	--	0	--	145	27	0
[illegible]	--	--	--	0	--	--	--	4	5	--	--	0	--	--	--	0	--	--	--	139	8	--	--	0
[illegible]	2	--	--	0	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	31	2	--	--	0
[illegible]	5	--	--	1	9	--	--	8	11	--	--	3	2	--	--	0	--	--	--	69	4	--	--	0
[illegible]		106		11		21		74		2		144		1		0		212		1775		543		26

Component

Table 9 summarizes the number of valve failures and command faults by valve type. The largest number (520, or 22%) of the 2318 failures and command faults were for Remote-Operated Valves. Motor-Operated Valves accounted for the next largest number (449, or 19%) of failures and command faults. We could not identify the operator type or valve function for 15% (346) of the failure and command fault events because the information was not provided in the LERs. Appendix P provides a listing of each component type sorted by failure mode and failure mechanism.

TABLE 9. SUMMARY OF VALVE FAILURES AND COMMAND FAULTS BY COMPONENT

	Failures		Command Faults		Total	
Component	No.	%	No.	%	No.	%
Motor-Operated Valve (Electric)	351	20	98	18	449	19
Pneumatic-Operated Valve	153	9	98	18	251	11
Solenoid-Operated Valve	59	3	4	1	63	3
Hydraulic-Operated Valve	18	1	16	3	34	1
Remote-Operated Valve	397	22	123	23	520	22
Manual-Operated Valve	78	4	78	14	156	7
Check Valve	165	9	3	1	168	7
Relief Valve	273	15	14	3	287	12
Damper Valve	22	1	22	4	44	2
Operator Type or Function Not Stated	259	15	87	16	346	15
Total	1775		543		2318	

System

Table 10 summarizes the number of failures and command faults by reactor type (PWR and BWR) and by system. The largest number of failures and command faults for each reactor type (257, or 21%, for PWR; 222, or 20%, for BWRs) occurred in the Containment Isolation System.

It is interesting to note that the BWR plants, which accounted for 34% (22) of the 64 plants considered in this report, accounted for 48% (1104) of the 2318 failures and command faults.

Activity Resulting in Discovery

Table 11 summarizes the number of failures and command faults by the activity resulting in discovery. The majority of these 2318 events were discovered during (or, in some cases, caused by) testing (1169, or 50%) or normal plant operation (802, or 35%).

Table 12 summarizes the number of failures and command faults by the activity resulting in discovery, component, and failure mode.

Manufacturer

Table 13 summarizes the number of reports by manufacturer. We chose to use the number of reports rather than the number of events contained in the reports to avoid biasing the data. Some LERs reported multiple events, but listed only one manufacturer. From the information provided in these LERs, it was not obvious that all of the valves involved were manufactured by the same company. It should be noted that the number of reports submitted for a manufacturer may not be indicative of the quality, but rather the quantity, of a manufacturer's product in the subject plants.

TABLE 10. SUMMARY OF VALVE FAILURES AND COMMAND FAULTS BY SYSTEMS OF BOTH REACTOR TYPES

System	Reactor Type											
	PWR[a]						BWR[b]					
	Failures		Command Faults		Total		Failures		Command Faults		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Automatic Depressurization	--	--	--	--	--	--	34	4	6	3	40	4
Auxiliary Feed	33	4	21	6	54	4	--	--	--	--	--	--
Containment Isolation (including penetrations)	199	22	58	18	257	21	188	21	34	16	222	20
Low Pressure Core Spray	--	--	--	--	--	--	27	3	10	5	37	3
Electric Power[c]	7	1	3	1	10	1	4	0	2	1	6	1
Containment Spray Injection	17	2	10	3	27	2	11	1	4	2	15	1
Chemical Volume Control (make-up)	92	10	11	3	103	8	--	--	--	--	--	--
Standby Liquid Control (boron)	--	--	--	--	--	--	21	2	3	1	24	2
High Pressure Coolant Injection	48	5	26	8	74	6	50	6	13	6	63	6
Component Cooling Water	7	1	5	2	12	1	2	0	2	1	4	0
Reactor Coolant	50	6	13	4	63	5	27	3	13	6	40	4
Low Pressure Coolant Injection (RHR)	48	5	26	8	74	6	65	7	23	11	88	8
Reactor Protection (control rods)	3	0	6	2	9	1	--	--	--	--	--	--
Control Rod Drive Hydraulic (scram)	--	--	--	--	--	--	70	8	7	3	77	7
Nonsafety related	114	13	67	21	181	15	62	7	39	18	101	9
System Unknown/Not Applicable	37	4	5	2	42	3	42	5	0	--	42	4

TABLE 10 (continued)

	Reactor Type											
	PWR[a]						BWR[b]					
	Failures		Command Faults		Total		Failures		Command Faults		Total	
System	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Reactor Core Isolation Cooling	--	--	--	--	--	--	40	5	16	7	56	5
Containment Fan Cooling System	15	2	4	1	19	2	--	--	--	--	--	--
Service Water	34	4	14	4	48	4	5	1	4	2	9	1
Standby Gas Treatment	--	--	--	--	--	--	9	1	3	1	12	1
Condensate and Feed	24	3	16	5	40	3	18	2	5	2	23	2
Main Steam	124	14	20	6	144	12	177	20	20	9	197	18
Reactor Protection (PPS)	18	2	6	2	24	2	6	1	6	3	12	1
Containment Air/Effluent; Purification/ Sampling	17	2	15	5	32	3	29	3	7	3	36	3
Failed Fuel Element Detection	1	0	0	--	1	0	0	--	0	--	0	--
Total	888		326		1214		887		217		1104	

a. As of the end of 1978, there were 42 operating commercial PWR plants.

b. As of the end of 1978 there were 22 operating commercial BWR plants.

c. Electric Power System as used in this report is the diesel support systems.

TABLE 11. SUMMARY OF VALVE FAILURES AND COMMAND FAULTS BY ACTIVITY RESULTING IN DISCOVERY

Activity Resulting in Discovery	Failures		Command Faults		Total	
	No.	%	No.	%	No.	%
Demand on Component[a]	35	2	9	2	44	2
Maintenance	101	6	30	6	131	6
Normal Operation	559	31	243	45	802	35
Records Review	70	4	3	1	73	3
Testing	943	53	226	42	1169	50
Unknown	67	4	32	6	99	4
Total	1775		543		2318	

ı. Only demands resulting from an emergency or accident situation are ncluded in this classification.

:vent Classification

Table 14 summarizes the failures and command faults by failure mode nd event classification, while Table 15 summarizes them by component and vent classification. The Change of State, Age, and Unknown classifications ccount for 36% (631), 33% (594), and 31% (550) of the 1775 failures, espectively, in each table. All of the 543 command faults are classified hange of State.

ear

Table 16 summarizes failures and command faults by year. Table 17 ımmarizes failures and command faults by year and failure mode, Table 18 y year and component, Table 19 by year and type of event, and Table 20 by ear and plant.

TABLE 12. SUMMARY OF VALVE FAILURES AND COMMAND FAULTS BY ACTIVITY RESULTING IN DISCOVERY

Activity Resulting in Discovery

D - Demand on Component[a]
M - Maintenance
N - Normal Operation
R - Records Review
T - Testing
U - Unknown

Failure Mode	Motor-Operated Valve (Electrical)		Pneumatic-Operated Valve		Solenoid-Operated Valve		Hydraulic-Operated Valve		Remote-Operated Valve	
	Failures	Command Faults	Failures	Command Faults	Failures	Command Faults	Failures	Command Faults	Failures	Comman Faults
Failed to Open	7D,1M 29N,69T 1U	1D,8N 25T,3U	1D,5N 3T	5N, 1U	3D,6N 9T,1U	--	--	1N	2D,7N 19T,2U	1M,3N 12T,1U
Failed to Close	3D,25N 42T,1U	9N,18T 1U	2M,16N 18T,1U	3D,1M 18N,27T	2D,5N 7T	1T	1D,1M 1N,2T	1M,5N 1T	3D,2M 21N,37T 1U	3D,1M 8N,16T
Internal Leakage	7N,17T 1U	--	17N,46T 1U	1N	1N,2T	--	1T	--	2M,19N 5R,12T 18U	--
External Leakage/ Rupture	1M,10N	--	1M,2N 8T,1U	--	--	--	--	--	5N,9T	1N
Reverse Leakage (Check Valves)	--	--	--	--	--	--	--	--	--	--
Failed to Operate as Required	2D,5M 29N,39T 2U	12N,6T 3U	8N,13T 1U	1D,3M 7N,11T 2U	3M,10N 7R,6T 1U	1N,1T	4N,7T	2M,3N 3T	48N,1R 34T,9U	2M,10N 32T,1U
Plugged (Fails to Remain Open)	--	1N,3T	3N	9N	--	--	--	--	--	6N,2T
Premature Open (Relief Valves)	--	--	--	--	--	--	--	--	--	--
Maintenance/ Replacement	7M,1N 36R,11T 5U	1U	1M,2R 3U	--	--	--	1N	--	9M,28N 2T,2U	--
Improper Valve Configuration	--	4N,3T	--	4N,1T	--	1T	--	--	--	2M,14 1R,7T
Component Total	12D,14M 101N,36R 178T,10U	1D,34N 55T,8U	1D,4M 51N,2R 88T,7U	4D,4M 44N,43T 3U	5D,3M 22N,7R 20T,2U	1N,3T	1D,1M 6N,10T	3M,9N 4T	5D,13M 128N,6R 213T,32U	3D,6M 42N,1 69T,2

a. Only demands resulting from an emergency or accident situation are included in this classification.

, FAILURE MODE, AND COMPONENT

Component											
Manual-Operated Valve		Check Valve		Relief Valve		Damper Valve		Operator Type or Function Not Stated		Failure Mode Total	
Failures	Command Faults	Failures	Command Faults	Failures	Command Faults	Failures	Command Faults	Failures	Command Faults	Failures	Command Faults
3N	--	3D,6N 5T	--	5D,20M 1N,2R 82T	1D,4N 4T	1N,2T	6T	2T	--	21D,21M 58N,2R 187T,4U	2D,1M 21N,51T 5U
3N	--	1M,4N 13T,1U	--	3D,20N 2T,1U	1N	1N,6T	5T	4N,1U	--	12D,6M 100N,127T 6U	6D,3M 41N,68T 1U
2M,10N 10T	--	--	--	1M,14N 14T,1U	--	2T	--	8M,29N 120T	--	13M,97N 5R,324T 21U	1N
4M,32N 7T,2U	--	6N,2T 1U	--	[illegible]	--	--	--	2M,35N 15T,5U	--	8M,96N 41T,9U	1N
--	--	2M,22N 1R,89T 1U	--	--	--	--	--	--	--	2M,22N 1R,89T 1U	--
2N,1T	--	4N,3T	--	--	--	4N,6T	6T	1M,5N 10R,8T	--	2D,9M 114N,18R 117T,13U	1D,7M 33N,59T 6U
1M,1N	--	--	--	--	--	--	--	2M,4N	--	3M,8N	16N,5T
--	--	--	--	10M,31N 33T	1M,1U	--	--	--	--	10M,31N 33T	1M,1U
--	--	1U	--	12M,1N 12T,2U	--	--	--	2N,6R	--	29M,33N 44R,25T 13U	1U
--	8M,42N 2R,16T 10U	--	1M,2N	--	1M,1T	--	2N,2T 1U	--	6M,62N 12T,7U	--	18M,130N 3R,43T 18U
7M,51N 18T,2U	8M,42N 2R,16T 10U	3D,3M 42N,1R 112T,4U	1M,2N	8D,43M 73N,2R 143T,4U	1D,2M 5N,5T 1U	6N,16T	2N,19T 1U	13M,79N 1[illegible]R,145T 6U	6M,62N 12T,7U	35D,101M 559N,70R 943T,67U	9D,30M 243N,3R 226T,32U

TABLE 13. SUMMARY OF REPORTS BY MANUFACTURER

Manufacturer Code	Manufacturer	Number of Reports[a]
A180	Allis Chalmers	10
A200	Aloyco, Inc.	9
A220	American Air Filter Co., Inc.	2
A285	American Machine & Foundry Company	1
A310	American Standard Industries	2
A325	American Tel & Radio	1
A340	American Warming & Ventilating Inc.	3
A391	Anchor/Darling Valve Co. (see Vendor D020)	2
A394	Anchor Packing Co.	1
A395	Anchor Valve Co.	19
A415	Anderson, Greenwood & Co.	1
A485	Armstrong Mach.	1
A499	ASCO	24
A507	Associated Control Equipment	2
A515	Astro Industries, Inc.	1
A535	Atkomatic Valve Co., Inc.	8
A552	Atlas Valve	2
A585	Atwood & Morrill Co., Inc.	48
A610	Automatic Switch Co. (ASCO)	57
A613	Automatic Valve Company	5
A660	AVCO Corp. - Tulsa Operation	3
B015	Babcock & Wilcox Company	1
B040	Bailey Instrument Co., Inc.	1
B130	Bechtel Corp.	2
B135	Beckman Instruments, Inc.	2
B237	Bettis Corporation	3
B290	Black-Sivals-Bryson	6
B485	Bruce GM Diesel, Inc.	1

TABLE 13 (continued)

Manufacturer Code	Manufacturer	Number of Reports[a]
C182	Center-Line Inc.	1
C255	Chapman Valve & Mfg.	5
C256	Chapman Div. of Crane Co.	2
C295	Chemiquip Products Co., Inc.	1
C311	Chicago Fluid Power	1
C339	Circle Seal	1
C470	Colt Industries, Inc.	1
C490	Combustion Engineering, Inc.	2
C502	Commonwealth Edison Company	1
C515	Conax Corp.	1
C530	Conoflow Corp.	1
C567	Consolidated Safety Relief Valves	2
C587	Continental Equip. Co.	5
C600	Control Components	1
C630	Contromatics Corp.	3
C631	Conval Inc.	2
C635	Copes-Vulcan, Inc.	20
C665	Crane Company	51
C672	Crane, John Co.	1
C710	Crosby Valve & Gage Co.	34
C715	Crosby-Ashton Gage Co.	4
C780	CVI Corp.	1
D020	Darling Valve & Mfg. Co. (see Vendor A391)	19
D025	Darling/Anchor (see Vendor A393)	3
D147	Dezurik	4
D232	Dragon Valve, Inc.	3
D243	Dresser Industrial Valve & Inst. Div.	27
D245	Dresser Industries, Inc.	11

TABLE 13 (continued)

Manufacturer Code	Manufacturer	Number of Reports[a]
E090	Edwards Co.	4
E095	Edwards Valves Div.	3
F011	Fairis Engineering	1
F035	Farris Engineering	3
F103	Fike Metal Co.	1
F125	Fisher Continental	3
F127	Fisher Flow Control Div. (Rockwell Inter.)	2
F130	Fisher Controls Co.	21
F135	Fisher Governor	2
F167	Fluid Controls Corp.	1
F195	Franklin Institute Research Laboratories	1
F212	Frumsen Heat Transfer Ltd (Canada)	2
G080	General Electric Co.	14
G153	Gimbel Machine Works	1
G167	Goddard Manufacturing Corp.	1
G202	GPE Controls	2
G250	Greer Hydraulics, Inc.	5
G255	Grinnell Corp.	13
G265	Grove Valve & Regulator Co.	1
H015	Hagan Controls	1
H035	Hammel Dahl	9
H037	Hancock Co.	6
H195	Hills-McCanna Co.	2
H230	Hoke, Inc.	4
H343	Hydro Line Mfg. Company	1
I005	I-T-E Circuit Breaker	2
I075	Ingersoll-Rand Co.	1

TABLE 13 (continued)

Manufacturer Code	Manufacturer	Number of Reports[a]
I200	Isotope Products Laboratories	1
I206	ITT General Controls	2
I208	ITT Hammel Dahl Conoflow	5
J010	James Bury Corp.	1
J073	Johnson Controls Inc.	1
J085	Johnson Manufacturing	1
J090	Johnson Service Co.	3
K030	Kavlico Electronics Inc.	1
K075	Kennedy Valve Mfg. Co.	1
K085	Kerotest Manufacturing Corp.	4
K125	Kieley & Mueller Co.	3
K235	Kunkle Valve Co.	1
L200	Limitorque Corp.	169
L263	Lonegan, J. E., Company	1
L265	Lonergan	2
L300	Lunkenheimer Co., The	4
M065	Manning-Maxwell-Moore	3
M090	Marotta Scientific Controls, Inc.	4
M095	Marotta Valve Corp.	1
M115	Mason & Hanger-Silas Mason Co., Inc.	1
M120	Masoneilan International, Inc.	20
M322	Miller Fluid Power Co.	2
M358	Mission Manufacturing Co.	1
M360	Mission Valve and Pump Co.	2
M430	Moore Products Company	2

TABLE 13 (continued)

Manufacturer Code	Manufacturer	Number of Reports[a]
N015	National ACME Co.	3
N030	National Electric Sign	1
N305	Nuclear Measurements Corp.	3
O020	Offshore Power Systems	2
O034	Oilrite Corporation	1
P014	Pacific Air Products	4
P032	Pacific Valves Inc.	5
P070	Parker Hannifin Corp.	1
P195	Philadelphia Gear Corp.	5
P295	Porter, H. K., Co., Inc.	1
P296	Porter Peerless Motors	1
P305	Powell Co., Wm., The	8
P312	Powell, M. W., Co.	3
P335	Pratt Whitney Aircraft	1
P340	Pratt, Henry, Co.	31
R082	Ramcon Corp.	1
R165	Reliance Electric Company	7
R197	Republic Mfg. Co	1
R290	Robertshaw Controls Co.	2
R322	Robotarm	1
R340	Rockwell Manufacturing Co.	31
R344	Rockwell-International	3
S075	Shutte and Koerting Co.	10
S149	Shan-Rod Corp.	2
S205	Singer Co., The	2
S212	Skinner Uniflow Valves	1
S413	Stockham Valve Co.	1

TABLE 13 (continued)

Manufacturer Code	Manufacturer	Number of Reports[a]
T020	Target Rock Corporation	50
T083	Teledyne Corporation	4
T095	Teledyne-Farris Engineering	1
T340	Tufline	1
V080	Velan Engineering Companies	3
V085	Velan Valve Corp.	30
V095	Versa Products	12
V105	Vickers, Inc.	1
V135	Vogt, Henry, Machine Co.	6
W030	Walworth Co.	32
W120	Westinghouse Electric Corporation	10
W121	Westinghouse Electric Company (Elev. Div.)	1
W127	Weston Hydraulics Div.	1
W165	Whitey Co.	2
W185	Whittaker Corp.	6
W220	Williams Products, Inc.	4
W255	WKM Valve Div.	3
W315	Worthington Corp.	1
ZZZZ	Unknown/Not Stated	368
Total		1437

a. Reports attributed to Technical Specification Violations (nonfailures) and Improper Valve Configuration (command faults due to personnel errors) are not contained in this table.

TABLE 14. SUMMARY OF VALVE FAILURES AND COMMAND FAULTS BY FAILURE MODE AND EVENT CLASSIFICATION

	Event Classification															
	Change of State				Age				Unknown				Total			
	Failures		Command Faults		Failures		Command Faults		Failures		Command Faults		Failures		Command Faults	
Failure Mode	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Failed to Open	128	20	80	15	57	10	0	--	108	20	0	--	293	17	80	15
Failed to Close	97	15	119	22	93	16	0	--	61	11	0	--	251	14	119	22
Internal Leakage	81	13	1	0	189	32	0	--	190	35	0	--	460	26	1	0
External Leakage/ Rupture	19	3	1	0	109	18	0	--	26	5	0	--	154	9	1	0
Reverse Leakage (Check Valves)	14	2	0	--	62	10	0	--	39	7	0	--	115	6	0	--
Failed to Operate as Required	174	28	106	20	46	8	0	--	53	10	0	--	273	15	106	20
Plugged (Fails to Remain Open)	2	0	21	4	6	1	0	--	3	1	0	--	11	1	21	4
Premature Open (Relief Valves)	20	3	2	0	17	3	0	--	37	7	0	--	74	4	2	0
Maintenance/ Replacement	96	15	1	0	15	3	0	--	33	6	0	--	144	8	1	0
Improper Valve Configuration	0	--	212	39	0	--	0	--	0	--	0	--	0	--	212	39
Total	631		543		594		0		550		0		1775		543	

TABLE 15. SUMMARY OF VALVE FAILURES AND COMMAND FAULTS BY COMPONENT AND EVENT CLASSIFICATION

	Event Classification															
	Change of State				Age				Unknown				Total			
	Failures		Command Faults		Failures		Command Faults		Failures		Command Faults		Failures		Command Faults	
Component	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Motor-Operated Valve (Electric)	200	32	98	18	75	13	0	--	76	14	0	--	351	20	98	18
Pneumatic-Operated Valve	48	8	98	18	68	11	0	--	37	7	0	--	153	9	98	18
Solenoid-Operated Valve	23	4	4	1	21	4	0	--	15	3	0	--	59	3	4	1
Hydraulic-Operated Valve	4	1	16	3	6	1	0	--	8	1	0	--	18	1	16	3
Remote-Operated Valve	150	24	123	23	119	20	0	--	128	23	0	--	397	22	123	23
Manual-Operated Valve	14	2	78	14	40	7	0	--	24	4	0	--	78	4	78	14
Check Valve	32	5	3	1	84	14	0	--	49	9	0	--	165	9	3	1
Relief Valve	90	14	14	3	64	11	0	--	119	22	0	--	273	15	14	3
Damper Valve	13	2	22	4	6	1	0	--	3	1	0	--	22	1	22	4
Operator Type or Function Not Stated	57	9	87	16	111	19	0	--	91	17	0	--	259	15	87	16
Total	631		543		594		0		550		0		1775		543	

TABLE 16. SUMMARY OF VALVE FAILURES AND COMMAND FAULTS BY YEAR

Year	Failures No.	Failures %	Command Faults No.	Command Faults %	Total No.	Total %	Calendar Hours[a]
1976	460	26	168	31	628	27	454,008
1977	664	37	158	29	822	35	505,080
1978	651	37	217	40	868	37	541,920
Total	1,775		543		2,318		1,501,008

a. Calendar hours are the total number of hours for all plants during each year starting from January 1 of each year or the date of initial criticality.

Table 20 shows a wide spread in the number of failures reported by plants of the same NSSS vendor. A list of the average number of failures per plant, by vendor, and those plants that deviate the most from these averages is provided in Table 21. It is interesting to note that the average number of failures reported by General Electric plants is approximately double the average number of failures reported by the plants of the other vendors.

TABLE 17. SUMMARY OF VALVE FAILURES AND COMMAND FAULTS BY FAILURE MODE AND YEAR

	1976[a]				1977[b]				1978[c]				Total			
	Failures		Command Faults		Failures		Command Faults		Failures		Command Faults		Failures		Command Faults	
Failure Mode	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Failed to Open	78	17	30	18	99	15	24	15	116	18	26	12	293	17	80	15
Failed to Close	76	17	38	23	84	13	29	18	91	14	52	24	251	14	119	22
Internal Leakage	112	24	1	1	199	30	0	--	149	23	0	--	460	26	1	0
External Leakage/ Rupture	24	5	0	--	60	9	0	--	70	11	1	0	154	9	1	0
Reverse Leakage (Check Valve)	41	9	0	--	33	5	0	--	41	6	0	--	115	6	0	--
Failed to Operate as Required	71	15	33	20	110	17	35	22	92	14	38	18	273	15	106	20
Plugged (Fails to Remain Open)	2	0	4	2	2	0	5	3	7	1	12	6	11	1	21	4
Premature Open (Relief Valves)	32	7	1	1	30	5	1	1	12	2	0	--	74	4	2	0

TABLE 17 (continued)

Failure Mode	1976[a] Failures No.	1976[a] Failures %	1976[a] Command Faults No.	1976[a] Command Faults %	1977[b] Failures No.	1977[b] Failures %	1977[b] Command Faults No.	1977[b] Command Faults %	1978[c] Failures No.	1978[c] Failures %	1978[c] Command Faults No.	1978[c] Command Faults %	Total Failures No.	Total Failures %	Total Command Faults No.	Total Command Faults %
Maintenance/ Replacement	24	5	0	--	47	7	1	1	73	11	0	--	144	8	1	0
Improper Valve Configuration	0	--	61	36	0	--	63	40	0	--	88	41	0	--	212	39
Total	460		168		664		158		651		217		1775		543	

a. This report considered 56 commercial nuclear power plants operational at the end of 1976.

b. This report considered 59 commercial nuclear power plants operational at the end of 1977.

c. This report considered 64 commercial nuclear power plants operational at the end of 1978.

TABLE 18. SUMMARY OF VALVE FAILURES AND COMMAND FAULTS BY COMPONENT AND YEAR

Component	1976[a]				1977[b]				1978[c]				Total			
	Failures		Command Faults		Failures		Command Faults		Failures		Command Faults		Failures		Command Faults	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Motor-Operated Valve (Electric)	102	22	38	23	113	17	30	19	136	21	30	14	351	20	98	18
Pneumatic-Operated Valve	45	10	24	14	50	8	25	16	58	9	49	23	153	9	98	18
Solenoid-Operated Valve	18	4	3	2	10	2	1	1	31	5	0	--	59	3	4	1
Hydraulic-Operated Valve	4	1	6	4	4	1	5	3	10	2	5	2	18	1	16	3
Remote-Operated Valve	118	26	38	23	187	28	36	23	92	14	49	23	397	22	123	23
Manual-Operated Valve	6	1	22	13	32	5	19	12	40	6	37	17	78	4	78	14
Check Valve	51	11	2	1	47	7	0	--	67	10	1	0	165	9	3	1
Relief Valve	71	15	3	2	100	15	8	5	102	16	3	1	273	15	14	3

TABLE 18 (continued)

Component	1976[a]				1977[b]				1978[c]				Total			
	Failures		Command Faults		Failures		Command Faults		Failures		Command Faults		Failures		Command Faults	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Damper Valve	5	1	6	4	5	1	5	3	12	2	11	5	22	1	22	4
Operator Type or Function Not Stated	40	9	26	15	116	17	29	18	103	16	32	15	259	15	87	16
Total	460		168		664		158		651		217		1775		543	

a. This report considered 56 commercial nuclear power plants operational at the end of 1976.

b. This report considered 59 commercial nuclear power plants operational at the end of 1977.

c. This report considered 64 commercial nuclear power plants operational at the end of 1978.

TABLE 19. SUMMARY OF VALVE FAILURES AND COMMAND FAULTS BY TYPE OF EVENT AND YEAR

	1976[a]				1977[b]				1978[c]				Total			
	Failures		Command Faults		Failures		Command Faults		Failures		Command Faults		Failures		Command Faults	
Type of Event	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Recurring Common Cause	15	3	--	--	19	3	--	--	18	3	--	--	52	3	--	--
Common Cause	19	4	--	--	57	9	--	--	46	7	--	--	122	7	--	--
Recurring	95	21	--	--	171	26	--	--	118	18	--	--	384	22	--	--
Command Fault	--	--	142	85	--	--	129	82	--	--	189	87	--	--	460	85
Recurring Command Fault	--	--	26	15	--	--	29	18	--	--	28	13	--	--	83	15
Other (i.e., random)	331	72	--	--	417	63	--	--	469	72	--	--	1217	69	--	--
Total	460		168		664		158		651		217		1775		543	

a. This report considered 56 commercial nuclear power plants operational at the end of 1976.

b. This report considered 59 commercial nuclear power plants operational at the end of 1977.

c. This report considered 64 commercial nuclear power plants operational at the end of 1978.

TABLE 20. SUMMARY OF VALVE FAILURES AND COMMAND FAULTS BY PLANT AND YEAR

BABCOCK & WILCOX

Plant Code	Plant Name	1976 Failures	1976 Command Faults	1976 Hours[a]	1977 Failures	1977 Command Faults	1977 Hours[a]	1978 Failures	1978 Command Faults	1978 Hours[a]	Total Failures	Total Command Faults	Total Hours[a]
AR1	Arkansas Nuclear One 1	5	5	8,760	2	3	8,760	2	8	8,760	9	16	26,280
CR3	Crystal River 3	--	--	--	21	13	8,424	8	10	8,760	29	23	17,184
DB1	Davis-Besse 1	--	--	--	7	5	2,664	44	8	8,760	51	13	11,424
OE1	Oconee 1	2	1	8,760	8	3	8,760	2	0	8,760	12	4	26,280
OE2	Oconee 2	2	4	8,760	6	1	8,760	3	2	8,760	11	7	26,280
OE3	Oconee 3	2	3	8,760	2	1	8,760	8	3	8,760	12	7	26,280
RS1	Rancho Seco	4	0	8,760	5	1	8,760	5	2	8,760	14	3	26,280
TI1	Three Mile Island 1	14	7	8,760	6	0	8,760	1	1	8,760	21	8	26,280
TI2	Three Mile Island 2	--	--	--	--	--	--	14	5	6,648	14	5	6,648
		29	20	52,560	57	27	63,648	87	39	76,728	173	86	192,936

COMBUSTION ENGINEERING

Plant Code	Plant Name	1976 Failures	1976 Command Faults	1976 Hours[a]	1977 Failures	1977 Command Faults	1977 Hours[a]	1978 Failures	1978 Command Faults	1978 Hours[a]	Total Failures	Total Command Faults	Total Hours[a]
AR2	Arkansas Nuclear One 2	--	--	--	--	--	--	1	1	600	1	1	600
CC1	Calvert Cliffs 1	11	4	8,760	4	4	8,760	19	2	8,760	34	10	26,280
CC2	Calvert Cliffs 2	0	0	774	16	3	8,760	16	3	8,760	32	6	18,264
FC1	Fort Calhoun	21	3	8,760	11	1	8,760	42	3	8,760	74	7	26,280
MI2	Millstone 2	3	2	8,760	8	2	8,760	1	3	8,760	12	7	26,280
MY1	Maine Yankee	0	1	8,760	1	2	8,760	10	1	8,760	11	4	26,280
PA1	Palisades	5	1	8,760	7	2	8,760	8	5	8,760	20	8	26,280
SL1	St. Lucie	5	4	6,072	5	1	8,760	16	2	8,760	26	7	23,592
		45	15	50,616	52	15	61,320	113	20	61,920	210	50	173,856

TABLE 20 (continued)

WESTINGHOUSE

Plant Code	Plant Name	1976 Failures	1976 Command Faults	1976 Hours[a]	1977 Failures	1977 Command Faults	1977 Hours[a]	1978 Failures	1978 Command Faults	1978 Hours[a]	Total Failures	Total Command Faults	Total Hours[a]
BV1	Beaver Valley 1	4	6	5,616	11	5	8,760	22	5	8,760	37	16	23,136
DC1	Donald C. Cook 1	6	8	8,760	8	4	8,760	9	7	8,760	23	19	26,280
DC2	Donald C. Cook 2	--	--	--	--	--	--	9	7	7,080	9	7	7,080
HN1	Haddam Neck	3	1	8,760	6	0	8,760	5	5	8,760	14	6	26,280
IP2	Indian Point 2	10	2	8,760	8	0	8,760	9	0	8,760	27	2	26,280
IP3	Indian Point 3	4	3	6,432	1	0	8,760	15	0	8,760	20	3	23,952
JF1	Joseph M. Farley 1	--	--	--	2	1	3,432	4	8	8,760	6	9	12,192
KE1	Kewaunee	3	6	8,760	13	4	8,760	4	2	8,760	20	12	26,280
NA1	North Anna 1	--	--	--	--	--	--	9	6	6,456	9	6	6,456
PR1	Prairie Island 1	4	2	8,760	12	1	8,760	1	2	8,760	17	5	26,280
PR2	Prairie Island 2	8	1	8,760	3	2	8,760	4	0	8,760	15	3	26,280
PT1	Point Beach 1	11	0	8,760	3	3	8,760	1	1	8,760	15	4	26,280
PT2	Point Beach 2	5	0	8,760	4	4	8,760	3	2	8,760	12	6	26,280
RG1	Robert E. Ginna	8	1	8,760	3	0	8,760	0	1	8,760	11	2	26,280
RO2	H. B. Robinson 2	2	0	8,760	9	3	8,760	9	2	8,760	20	5	26,280
SA1	Salem 1	0	1	456	31	7	8,760	5	3	8,760	36	11	17,976
SO1	San Onofre 1	0	0	8,760	1	0	8,760	2	2	8,760	3	2	26,280
SU1	Surry 1	9	4	8,760	10	0	8,760	10	3	8,760	29	7	26,280
SU2	Surry 2	10	1	8,760	23	1	8,760	8	0	8,760	41	2	26,280
TR1	Trojan	4	6	8,760	6	4	8,760	5	6	8,760	15	16	26,280
TU3	Turkey Point 3	1	0	8,760	0	0	8,760	0	1	8,760	1	1	26,280
TU4	Turkey Point 4	2	0	8,760	0	1	8,760	0	3	8,760	2	4	26,280
YR1	Yankee Rowe	0	0	8,760	25	1	8,760	6	1	8,760	31	2	26,280
ZI1	Zion 1	22	6	8,760	17	9	8,760	12	14	8,760	51	29	26,280
ZI2	Zion 2	9	4	8,760	21	5	8,760	11	2	8,760	41	11	26,280
		125	52	178,944	217	55	196,152	163	83	215,016	505	190	590,112

TABLE 20 (continued)

GENERAL ELECTRIC

Plant Code	Plant Name	1976 Failures	1976 Command Faults	1976 Hours[a]	1977 Failures	1977 Command Faults	1977 Hours[a]	1978 Failures	1978 Command Faults	1978 Hours[a]	Total Failures	Total Command Faults	Total Hours[a]
BF1	Browns Ferry 1	0	2	8,760	12	0	8,760	11	0	8,760	23	2	26,280
BF2	Browns Ferry 2	2	2	8,760	0	1	8,760	11	1	8,760	13	4	26,280
BF3	Browns Ferry 3	1	0	3,456	6	1	8,760	48	3	8,760	55	4	20,976
BR1	Brunswick 1	1	3	1,992	22	5	8,760	18	5	8,760	41	13	19,512
BR2	Brunswick 2	24	20	8,760	10	2	8,760	11	2	8,760	45	24	26,280
CO1	Cooper Station	8	6	8,760	10	3	8,760	6	5	8,760	24	14	26,280
DA1	Duane Arnold	40	9	8,760	15	1	8,760	7	5	8,760	62	15	26,280
DR2	Dresden 2	15	6	8,760	19	0	8,760	13	9	8,760	47	15	26,280
DR3	Dresden 3	11	4	8,760	12	1	8,760	12	2	8,760	35	7	26,280
EN1	Edwin I. Hatch 1	28	5	8,760	31	5	8,760	7	4	8,760	66	14	26,280
EN2	Edwin I. Hatch 2	--	--	--	--	--	--	11	7	4,296	11	7	4,296
FP1	James A. Fitzpatrick	20	2	8,760	20	2	8,760	25	5	8,760	65	9	26,280
MI1	Millstone 1	7	1	8,760	9	5	8,760	16	1	8,760	32	7	26,280
MO1	Monticello	5	2	8,760	19	4	8,760	19	2	8,760	43	8	26,280
NM1	Nine Mile Point 1	2	0	8,760	58	5	8,760	3	1	8,760	63	6	26,280
OC1	Oyster Creek	6	3	8,760	6	7	8,760	16	3	8,760	28	13	26,280
PB2	Peach Bottom 2	29	5	8,760	24	2	8,760	14	3	8,760	67	10	26,280
PB3	Peach Bottom 3	26	8	8,760	6	3	8,760	5	4	8,760	37	15	26,280
PI1	Pilgrim 1	2	0	8,760	24	4	3,760	5	3	8,760	31	7	26,280
QC1	Quad-Cities 1	14	1	8,760	15	6	8,760	8	2	8,760	37	9	26,280
QC2	Quad-Cities 2	3	1	8,760	6	3	8,760	9	7	8,760	18	11	26,280
VY1	Vermont Yankee	17	1	8,760	14	1	8,760	13	1	8,760	44	3	26,280
		261	81	171,888	338	61	183,960	288	75	188,256	887	217	544,104

a. Hours are calendar hours from date of initial criticality or from January 1 of the specific year.

TABLE 21. PLANTS REPORTING LARGEST AND SMALLEST NUMBER OF FAILURES

NSSS Vendor	Average Number of Failures (1976-1978)	Plant Reporting Largest Number of Failures	No.	Plant Reporting Smallest Number of Failures[a]	No.
Babcock & Wilcox	19	Davis-Besse 1	51	Arkansas Nuclear One	9
Combustion Engineering	26	Fort Calhoun	74	Maine Yankee	11
Westinghouse	20	Zion 1	51	Turkey Point 3	1
General Electric	40	Peach Bottom 2	67	Browns Ferry 2	13

a. Only those plants that were operational for the full 3-year period, were considered when selecting the plant with the smallest number of failures.

Sorts

Appendices G through R permit examination, both qualitative and quantitative, of specific reports or groups of reports. These appendices contain reports sorted into classes we considered important (for example, all reports concerning personnel error or all reports concerning recurring failures). Plant specific information can be obtained by examining these sorts. Appendices K and Q are discussed in more detail in this section.

Personnel Errors

Appendix K contains sorts for the Personnel (Operation), Personnel (Maintenance), and Personnel (Testing) failure mechanisms. The total number of reports contained in these sorts is 255 with 151 for Operations, 72 for Maintenance, and 32 for Testing.

Command faults, resulting in 177 improper valve line-ups, accounted for 69% of the 255 reports. Operations personnel accounted for 73% (129) of the 177 command fault reports.

Of the 78 reports coded as failures, maintenance personnel accounted for 59% (46).

One plant, Edwin I. Hatch 1 (EN1), accounted for the largest number (15, or 6%) of the 255 reports. Nine of Hatch's 15 reports involved improper valve line-up. Of the 64 plants considered in this report, four plants reported no personnel errors: Arkansas Nuclear One 2 (AR2), Edwin I. Hatch 2 (EN2), Millstone 1 (MI1), and Turkey Point 3 (TU3). It should be noted that Arkansas Nuclear One 2 (AR2) was operational for only 600 calendar hours and Edwin I. Hatch 2 (EN2) for only 4,196 calendar hours of the 26,280 calendar hours covered by the time period of this report. The remaining two plants were operational for the full 26,280 calendar hours.

Type of Event

Appendix Q provides five sorts of valve events by event type, that is, common cause, recurring common cause, recurring, command fault, and recurring command fault. All other valve events were considered to be random.

Common Cause and Recurring Common Cause. Common cause and recurring common cause events are presented as the first two sorts in Appendix Q. These two types of events accounted for 5% of the total number (1166) of failure reports, 3% (39) and 2% (28), respectively.

Twenty-six plants submitted 39 reports that we considered to contain common cause events. With the exception of Salem 1 (SA1), which submitted 3 reports, the remaining 25 plants submitted either 1 or 2 reports. Packing failures accounted for two of Salem's reports, while the third report involved a maintenance error.

Only 13 plants submitted reports that we considered to contain recurring common cause events. Of the 28 reports submitted by these 13 plants, 6 reports were attributed to Zion 1 and 5 to Zion 2. The remaining 11 plants each submitted 4 or less. Three of the reports from Zion 1 involved internal leakage caused by the valve seat shrinking away from the valve body because of extreme low temperature conditions.

Recurring. Forty-nine plants submitted 271 reports that we considered to contain recurring failure events. These 271 reports are 23% of the 1166 failure reports. The largest number (18) of the recurring failure events were reported by Zion 2 (ZI2). Five of the Zion 2 reports were submitted between May 5, 1977, and July 3, 1978, and involved solenoid valve failures resulting from recurring problems with the Zion 2 air supply system (that is, oil or other impurities in the system).

Command Faults and Recurring Command Faults. The final two sorts in Appendix Q are command faults and recurring command faults. They accounted for 407 (24%) and 76 (5%) of all 1675 reports contained in the data file, respectively.

All 64 plants, considered in this report, submitted reports that we considered to contain command fault events. Brunswick 2 (BR2) submitted the largest number (18, or 4%) of these reports, while Arkansas Nuclear One 2 (AR2) and Turkey Point 3 (TU3) each submitted one report. Ten of the Brunswick 2 reports involved improper valve line-ups.

Twenty six plants submitted 76 reports that we consider recurring command fault events. Zion 1 (ZI1) submitted the largest number (17), that accounted for 22% of these reports. Fourteen of the reports involved air-operated valves failing to operate because of failures of solenoid valves in their air supply lines. The remaining three reports all involved motor-operated valves failing to open because of auxiliary contacts in their control circuits sticking.

LER Rates

Appendices S through Y contain the reports used to provide valve failure and command fault data for the LER rate estimates and the results of these LER rate estimates. Each appendix contains failure data and results of the LER rate estimates for a different valve type. The following is a list of the valve types associated with each appendix:

1. Appendix S - Motor-Operated Valves

2. Appendix T - Remote-Operated Valves plus Motor-Operated Valves

3. Appendix U - Air-Operated Valves

4. Appendix V - Manual-Operated Valves

5. Appendix W - Check Valves

6. Appendix X - Safety Valves (PWR)

7. Appendix Y - Relief Valves (BWR).

LER rates were estimated for the various failure modes of the valve types. For example, LER rates for the Motor-Operated Valves (MOVs) were estimated for the failure modes (a) Failed to Open, Failed to Close, and Failed to Operate as Required (which were combined to form the category "Failed to Operate"), (b) External Leakage, and (c) Plugged (see Appendix S).

In addition to selecting the failure modes and valve types used in the LER rate estimates, another consideration was whether a failure-per-demand or a failure-per-hour rate estimate was appropriate. The failure mode definition was the determining factor in this decision. Failed to Operate as Required, Failed to Open, and Failed to Close are the failure modes associated with the failure-per-demand estimates, while External Leakage, Reverse Leakage, Plugged, and Premature Open are the failure modes associated with the failure-per-hour estimates. It is evident from the failure modes that some are component dependent. Table 22 is presented here to show the basic relationship existing between the failure mode, valve type,

TABLE 22. LER RATES ESTIMATED FOR THIS REPORT

Estimates[a]	Failure Mode[b]	Type of Valve	Type of Estimate
Failed to Operate	A,B,F	MOV	Demand
	A,B,F	Remote-Operated plus MOV	Demand
	A,B,F	AOV[c]	Demand
	A,B,F	Manual	Demand
Failed to Open	A	Check	Demand
	A	Relief (BWRs)	Demand
	A	Safety (PWRs)	Demand
Failed to Reseat	B	Relief (BWRs)	Demand
External Leakage	D	MOV	Hourly
	D	Remote-Operated plus MOV	Hourly
	D	AOV	Hourly
	D	Check	Hourly
	D	Manual	Hourly
Plugged	G	MOV	Hourly
	G	Remote-Operated plus MOV	Hourly
	G	AOV	Hourly
Reverse Leakage	E,B	Check	Hourly
Premature Open	H	Relief (BWRs)	Hourly
	H	Safety (PWRs)	Hourly

a. LER rates were estimated for both failures and failures plus command faults, if data were available for both.

b. See Appendix F for a list of the failure mode codes.

c. AOV - Air-Operated Valve.

and type of estimate (that is, failure-per-demand or failure-per-hour) for the LER rate estimates obtained in this report.

The Remote-Operated plus MOV under Type of Valves in Table 22, is a special category of failures. As stated earlier, many LERs did not specify the valve type, but did provide information that allowed us to classify valves in these LERs as remote-operated. Since the majority of the valves in the systems selected for LER rate estimates are MOVs, we believe that most of the failures involving remote-operated valves are actually failures of MOVs. Therefore, we estimated rates on the combined failures for both remote-operated and motor-operated valves. We believe these estimates represent an upper bound for the LER rate estimates obtained for MOVs.

A sort of failures and command faults is provided for each estimate within each appendix. To extract the applicable reports used in each LER rate estimate, the reader needs to note whether the LER rate estimate was done on failures only, or on the combination of failures and command faults. If the estimate was done on failures only, those events that are coded as command faults (that is, those reports that contain an S or T in the column labeled TYPE) must be excluded. The results of each estimate are in the form of five pages of computer output; one page for the plants of each NSSS vendor, and a page containing Final Statistics. The Final Statistics section for each estimate contains the averaged NSSS vendor LER rates, averaged PWR LER rates, and an overall LER rate. Along with the LER rates contained in this Final Statistics section, the upper 95% confidence limit and lower 5% confidence limit are given and expressed as a multiple of the LER rate estimate. To obtain the upper 95% confidence limit, multiply the given LER rate estimate by the upper multiple associated with this estimate. To get the corresponding lower 5% confidence limit, divide the LER rate estimate by the lower multiple associated with this estimate. For example:

Multiply X.X times Y.YE-YY to obtain upper 95% confidence limit

and

Divide Z.Z into Y.YE-YY for lower 5% confidence limit

where

X.X is the upper 95% confidence multiple

Y.YE-YY is the LER rate estimate

Z.Z is the lower 5% confidence multiple.

Table 23 provides a summary of valve LER rates for all estimates performed in this report. Table 24 provides a summary of WASH-1400[7] failure rates for valves and those LER rates that have similar failure mode definitions. The plant specific data used for the LER rate estimates are provided in Table 25. This table is provided to allow the reader to modify the data if known differences exist.

The specific plant LER rates are plotted on scatter plots in Figures 4a through 28. These plots illustrate the plant-to-plant variability associated with the LER rate estimates.

Four scatter plots, one for each NSSS vendor, were generated for each LER rate estimate performed in this report, with the following exception: If all plants of a vendor type reported no failures for a particular estimate, a plot for that vendor was not generated. A pound symbol (#) immediately following the coded plant name indicates that there were no failures or command faults reported for that plant. The LER rate plotted for a plant that reported no failures or command faults is the averaged LER rate for the plant NSSS vendor.

TABLE 23. SUMMARY OF VALVE LER RATES[a] BY NSSS VENDOR, VALVE TYPE, AND FAILURE MODE

	Motor-Operated Valves (MOVs)[b]			Remote-Operated Valves Plus MOVs[b]			Air-Operated Valves (AOV		
	Failed to Operate	Plugged	External Leakage	Failed to Operate	Plugged	External Leakage	Failed to Operate	Plugged	Ext Lea
NSSS Vendor	Q_d	λ_s	λ_s	Q_d	λ_s	λ_s	Q_d	λ_s	
Babcock & Wilcox	5E-3/d (5E-3/d)[d]	(4E-7/hr)[c]	1E-7/hr	6E-3/d (7E-3/d)	(1E-7/hr)	1E-7/hr	6E-3/d (6E-3/d)	(4E-6/hr)[c]	4E-
Combustion Engineering	2E-3/d (5E-3/d)	(2E-7/hr)	7E-7/hr[c]	3E-3/d (8E-3/d)	(2E-7/hr)	7E-7hr[c]	3E-3/d[c] (9E-4d)	(1E-6/hr)[c]	1E-
Westinghouse	2E-3/d (4E-3/d)	(1E-7/hr)	1E-7/hr	3E-3/d (5E-3/d)	(2E-7/hr)	2E-7/hr	5E-3/d (1E-3/d)	(2E-7/hr)	2E-
General Electric (BWRs)	6E-3/d (8E-3/d)	(1E-7/hr)[c]	7E-8/hr	7E-3/d (1E-2/d)	(7E-8/hr)	2E-7/hr	3E-3/d[c] (4E-3/d)	(1E-6/hr)[c]	4E-
PWRs	3E-3/d (4E-3/d)	(1E-7/hr)	1E-7/hr	4E-3/d (5E-3/d)	(2E-7/hr)	1E-7/hr	9E-4/d (2E-3/d)	(1E-7/hr)	1E-
Overall[e]	4E-3/d ([illegible])	(6E-8/hr)	1E-7/hr	5E-3/d (7E-3/d)	(1E-7/hr)	2E-7/hr	7E-4/d (2E-3/d)	(1E-7/hr)	2E-

a. All LER rates have been rounded to the next highest integer. Confidence bounds for the LER rates ar

b. Q_d = demand LER rate, λ_s = standby hourly LER rate based on calendar hours.

c. Upper 95% confidence bound when no failures were recorded.

d. LER rates in parentheses include both failures and command faults; Plugged rates are command faults

e. The "overall" LER rate is the average LER rate obtained by combining data from all plants.

Valve Type										
s)[b]	Check Valves[b]			Manual-Operated Valves[b]		PWR Safety Valves[b]		BWR Relief Valves[b]		
ernal Leakage	Failed to Open	Internal Leakage	External Leakage	Failed to Operate	External Leakage	Failed to Open	Premature Open	Failed to Open	Premature Open	Failed to Reseat
λ_s	Q_d	λ_s	λ_s	Q_d	λ_s	Q_d	λ_s	Q_d	λ_s	Q_d
6/hr[c]	9E-4/d[c]	3E-7/hr	3E-7/hr	2E-4/d	3E-7/hr[c]	3E-2/d[c]	8E-6/hr[c]	--	--	--
6/hr[c]	8E-4/d[c]	7E-7/hr	4E-7/hr[c]	2E-4/d	1E-7/hr	1E-2/d	5E-6/hr	--	--	--
7/hr	2E-4/d	4E-7/hr	1E-7/hr[c]	2E-4/d[c]	8E-8/hr[c]	6E-3/d	3E-6/hr	--	--	--
7/hr	1E-4/d	1E-6/hr	7E-8/hr	1E-4/d	1E-7/hr[c]	--	--	8E-3/d (1E-2/d)	6E-6/hr (6E-6/hr)	5E-3/d (5E-3/d)
7/hr	1E-4/d	5E-7/hr	5E-8/hr	8E-5/d	2E-8/hr	6E-3/d	3E-6/hr	--	--	--
7/hr	1E-4/d	7E-7/hr	5E-8/hr	8E-5/d	1E-8/hr	--	--	--	--	--

e provided in Appendices S through Y in the form of upper and lower confidence multiples.

only, no failures were reported.

TABLE 24. TABLE OF WASH-1400 FAILURE RATES AND LER RATES

Valve	Failure Mode	WASH-1400	LER Rates[a]	
MOV	Failed to Operate	1×10^{-3}/d	4×10^{-3}/d (6×10^{-3}/d)	
	Plugged[b]	1×10^{-4}/d	(6×10^{-8}/hr)	
	External Leakage	1×10^{-8}/hr	1×10^{-7}/hr	
AOV	Failed to Operate	3×10^{-4}/d	7×10^{-4}/d (2×10^{-3}/d)	
	Plugged[b]	1×10^{-4}/d	(1×10^{-7}/hr)	
	External Leakage	1×10^{-8}/hr	2×10^{-7}/hr	
Check	Failed to Open	1×10^{-4}/d	1×10^{-4}/d	
	Reverse Leakage	3×10^{-7}/hr	7×10^{-7}/hr	
	External Leakage	1×10^{-8}/hr	5×10^{-8}/hr	
Manual	Plugged[b]	1×10^{-4}/d	No manual plugging failures reported	
			PWR Safety Valves	BWR Relief Valv
Relief	Failed to Open	1×10^{-5}/d	6×10^{-3}/d	8×10^{-3}/c (1×10^{-2}/c
	Premature Open	1×10^{-5}/hr	3×10^{-6}/hr	6×10^{-6}/h (6×10^{-6}/h

a. LER rates are for (a) failures and (b) the combination of failures anc command faults (which appear in parentheses), and are the average of all plants.

b. LER rates for Plugged are standby hourly estimates (λ_s), while WASH-14 performed demand (Q_d) estimates.

TABLE 25. PLANT DATA USED FOR LER RATES

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

BABCOCK & WILCOX

Plant Code	Plant Name	System	Valve Population M	A	C	X	S	R	Demands/Component M,A,C,X	S	R	Demand Hours/Component
AR1	Arkansas Nuclear One 1	Auxiliary Feed	10	--	5	--	--	--	12	--	--	26,280
		Containment Spray	2	--	4	16	--	--	12	--	--	26,280
		High Pressure Coolant Injection[a]	6	--	12	17	--	--	12	--	--	26,280
		Low Pressure Coolant Injection	10	--	8	6	--	--	12	--	--	26,280
		Safety/Relief Valves	--	--	--	--	2	--	--	5	--	26,280
CR3	Crystal River 3	Auxiliary Feed[b]	6	1	13	15	--	--	8	--	--	17,184
		Containment Spray	6	--	4	7	--	--	8	--	--	17,184
		ECCS[c]	16	--	23	12	--	--	8	--	--	17,184
		High Pressure Coolant Injection[a]	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	6	--	17,184
DB1	Davis-Besse 1	Auxiliary Feed	1	--	11	18	--	--	6	--	--	11,424
		Containment Spray	4	--	2	6	--	--	6	--	--	11,424
		ECCS[c]	17	14	26	--	--	--	6	--	--	11,424
		High Pressure Coolant Injection[a]	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	5	--	11,424

a. High Pressure Coolant Injection and Chemical Volume Control Systems are shared; those valves shared by both systems wer

b. No drawings were available for the Auxiliary Feed System ; populations used were the averaged Auxiliary Feed System pop

c. Due to composite drawing, Low Pressure Coolant Injection and High Pressure Coolant Injection Systems population data ar

Data Used for Demand LER Rates						Data Used for Standby LER Rates					
Failed to Operate M,A,U,X		Failed to Open C,R,S		Failed to Reseat R		Standby Hours/ Component	External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
Failures	Command Faults	Failures	Command Faults	Failures	Command Faults		Failures	Command Faults	Failures	Failures	Command Faults
1M,1U	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
1U	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	17,184	--	--	--	--	--
--	--	--	--	--	--	17,184	--	--	--	--	--
--	--	--	--	--	--	17,184	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
5M,7U	1U	--	--	--	--	--	--	1U	--	--	--
--	--	--	--	--	--	17,184	--	--	--	--	--
1M,1U	--	--	--	--	--	11,424	1C	--	2C	--	--
--	--	--	--	--	--	11,424	--	--	--	--	--
--	--	--	--	--	--	11,424	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
1M,1U	--	--	--	--	--	--	1C	--	--	--	--
--	--	--	--	--	--	11,424	--	--	--	--	--

e included in the High Pressure Coolant Injection System population data.

ulations for all Babcock & Wilcox plants.

e not presented separately.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

BABCOCK & WILCOX (continued)

												Data Use	
			Valve Population						Demands/ Component				Failed t M,A
Plant Code	Plant Name	System	M	A	C	X	S	R	M,A,C,X	S	R	Demand Hours/ Component	Failures
OE1	Oconee 1	Auxiliary Feed	9	3	9	14	--	--	12	--	--	26,280	--
		Containment Spray	2	--	--	5	--	--	12	--	--	26,280	--
		High Pressure Coolant Injection[a]	12	1	13	39	--	--	12	--	--	26,280	1X
		Low Pressure Coolant Injection	29	--	7	17	--	--	12	--	--	26,280	--
		Safety/Relief Valves	--	--	--	--	2	--	--	12	--	26,280	--
OE2	Oconee 2	Auxiliary Feed	9	3	9	14	--	--	12	--	--	26,280	--
		Containment Spray	2	--	--	5	--	--	12	--	--	26,280	--
		High Pressure Coolant Injection[a]	12	1	14	40	--	--	12	--	--	26,280	1M,1U
		Low Pressure Coolant Injection	28	--	7	18	--	--	12	--	--	26,280	--
		Safety/Relief Valves	--	--	--	--	2	--	--	5	--	26,280	--
OE3	Oconee 3	Auxiliary Feed	9	3	9	14	--	--	12	--	--	26,280	--
		Containment Spray	2	--	--	5	--	--	12	--	--	26,280	2M,2U
		High Pressure Coolant Injection[a]	12	1	14	41	--	--	12	--	--	26,280	--
		Low Pressure Coolant Injection	23	4	7	15	--	--	12	--	--	26,280	1A,1U
		Safety/Relief Valves	--	--	--	--	2	--	--	6	--	26,280	--

a. High Pressure Coolant Injection and Chemical Volume Control Systems are shared; those valves shared by both systems were included

or Demand LER Rates					Data Used for Standby LER Rates					
perate X	Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
ommand 'aults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--

the High Pressure Coolant Injection system population data.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

BABCOCK & WILCOX (continued)

Plant Code	Plant Name	System	Valve Population M	A	C	X	S	R	Demands/ Component M,A,C,X	S	R	Demand Hours/ Component	Da… Fa… Fa…
RS1	Rancho Seco	Auxiliary Feed	2	--	12	12	--	--	12	--	--	26,280	
		Containment Spray	8	--	14	29	--	--	12	--	--	26,280	
		ECCS[a]	20	--	30	33	--	--	12	--	--	26,280	
		High Pressure Coolant Injection[b]	--	--	--	--	--	--	--	--	--	--	1…
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	4…
		Safety/Relief Valves	--	--	--	--	2	--	--	5	--	26,280	
TI1	Three Mile Island 1	Auxiliary Feed	4	3	11	10	--	--	12	--	--	26,280	
		Containment Spray	10	--	8	7	--	--	12	--	--	26,280	
		ECCS[a]	17	--	19	8	--	--	12	--	--	26,280	
		High Pressure Coolant Injection[b]	--	--	--	--	--	--	--	--	--	--	
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	
		Safety/Relief Valves	--	--	--	--	2	--	--	1	--	26,280	
TI2	Three Mile Island 2	Auxiliary Feed	7	2	10	9	--	--	4	--	--	6,648	
		Containment Spray	27	--	12	18	--	--	4	--	--	6,648	
		ECCS[a]	8	2	19	32	--	--	4	--	--	6,648	
		High Pressure Coolant Injection[b]	--	--	--	--	--	--	--	--	--	--	
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	1…
		Safety/Relief Valves	--	--	--	--	2	--	--	1	--	6,648	

a. Due to composite drawing, Low Pressure Coolant Injection and High Pressure Coolant Injection Systems population data are no…

b. High Pressure Coolant Injection and Chemical Volume Control Systems are shared; those valves shared by both systems were in…

a Used f Demand LER Rates						Data Used for Standby LER Rates					
led to Operate M,A,U,X		Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
lures	Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
,1U	--	--	--	--	--	--	--	--	--	--	--
,4U	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	1M,1U	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	6,648	--	--	--	--	--
--	--	--	--	--	--	6,648	--	--	--	--	--
--	--	--	--	--	--	6,648	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	6,648	--	--	--	--	--

t presented separately.

cluded in the High Pressure Coolant Injection system population data.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

COMBUSTION ENGINEERING

Plant Code	Plant Name	System	Valve Population M	A	C	X	S	R	Demands/Component M,A,C,X	S	R	Demand Hours/Component	Data Us Failed M, Failure
AR2	Arkansas Nuclear One 2	Auxiliary Feed	14	4	16	7	--	--	1	--	--	600	--
		Containment Spray	13	--	13	21	--	--	1	--	--	600	--
		Safety Injection[a]	36	2	30	14	--	--	1	--	--	600	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	1	--	60C	--
CC1	Calvert Cliffs 1	Auxiliary Feed	--	2	8	10	--	--	12	--	--	26,280	--
		ECCS[b]	31	4	45	39	--	--	12	--	--	26,280	--
		Containment Spray	--	--	--	--	--	--	--	--	--	--	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	1M,1U
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	10	--	26,280	--
CC2	Calvert Cliffs 2	Auxiliary Feed	--	2	8	10	--	--	9	--	--	18,264	1X
		ECCS[b]	31	4	45	39	--	--	9	--	--	18,264	--
		Containment Spray	--	--	--	--	--	--	--	--	--	--	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	1M,1U
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	5	--	18,264	--

a. Due to composite drawing, High Pressure Coolant Injection and Low Pressure Coolant Injection Systems population data are not pre

b. Due to composite drawing, Containment Spray, High Pressure Coolant Injection, and Low Pressure Coolant Injection Systems populat

for Demand LER Rates					Data Used for Standby LER Rates					
Operate),X	Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	600	--	--	--	--	--
--	--	--	--	--	600	--	--	--	--	--
--	--	--	--	--	600	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	600	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
1M,1U	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	18,264	--	--	--	--	--
--	--	--	--	--	18,264	--	--	--	--	--
1U	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	2C	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	18,264	--	--	--	--	--

ited separately.

data are not presented separately.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

COMBUSTION ENGINEERING (continued)

Plant Code	Plant Name	System	Valve Population						Demands/ Component			Demand Hours/ Component
			M	A	C	X	S	R	M,A,C,X	S	R	
FC1	Fort Calhoun	Auxiliary Feed	1	5	[illegible]	10	--	--	12	--	--	26,280
		ECCS[a]	5	32	45	45	--	--	12	--	--	26,280
		Containment Spray	--	--	--	--	--	--	--	--	--	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	5	--	26,280
MI2	Millstone 2	Auxiliary Feed	3	2	4	25	--	--	12	--	--	26,280
		Safety Injection[c]	3C	4	47	36	--	--	12	--	--	26,280
		Containment Spray	--	--	--	--	--	--	--	--	--	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	16	--	26,280
MY1	Maine Yankee	Auxiliary Feed	--	3	8	15	--	--	12	--	--	26,280
		ECCS[a]	35	22	49	72	--	--	12	--	--	26,280
		Containment Spray	--	--	--	--	--	--	--	--	--	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	6	--	26,280

a. Due to composite drawing, Containment Spray, High Pressure Coolant Injection, and Low Pressure Coolant Injection Systems

ata Used for Demand LER Rates						Data Used for Standby LER Ra .es					
ailed to Operate M,A,U,X		Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
ailures	Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	1U	--	--	--	--	26,280	--	--	1C	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	1U	--	--	--	--	--	--	--	--	--	--
--	1U	--	--	--	--	--	--	--	--	--	--
--	--	1S	--	--	--	26,280	--	--	--	2S	--
1M,1U	1U	--	--	--	--	26,280	1X	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	3C	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	1U	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	1S	--	--	--	26,280	--	--	--	--	--

opulation data are not presented separately.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

COMBUSTION ENGINEERING (continued)

Plant Code	Plant Name	System	Valve Population						Demands/ Component			Data Us Demand Hours/ Component	Failed t M,/ Failures
			M	A	C	X	S	R	M,A,C,X	S	R		
PA1	Palisades	Auxiliary Feed	--	4	6	8	--	--	12	--	--	26,280	--
		Safety Injection[a]	15	--	21	31	--	--	12	--	--	26,280	--
		Containment Spray	--	--	--	--	--	--	--	--	--	--	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	15	--	26,280	--
SL1	St. Lucie 1	Auxiliary Feed	--	4	9	16	--	--	11	--	--	23,592	1M,1U
		Containment Spray	4	2	10	16	--	--	11	--	--	23,592	2U
		Safety Injection[b]	30	1	30	27	--	--	11	--	--	23,592	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	1M,1U
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	8	--	23,592	--
WESTINGHOUSE													
BV1	Beaver Valley 1	Auxiliary Feed	9	--	6	17	--	--	11	--	--	23,136	1U
		Containment Spray	10	--	4	--	--	--	11	--	--	23,136	--
		High Pressure Coolant Injection	15	3	22	19	--	--	11	--	--	23,136	--
		Low Pressure Coolant Injection	15	--	14	2	--	--	11	--	--	23,136	1U
		Safety/Relief Valves	--	--	--	--	3	--	--	41	--	23,136	--

a. Due to composite drawing, Containment Spray, High Pressure Coolant Injection, and Low Pressure Coolant Injection Systems populati

b. Due to composite drawing, High Pressure Coolant Injection and Low Pressure Coolant Injection Systems population data are not pres

for Demand LER Rates					Data Used for Standby LER Rates					
Operate ,X	Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	.	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
1M,1U	--	--	--	--	--	--	1M,1U	--	--	--
1A	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
3M,3U	--	--	--	--	23,592	--	--	--	--	--
--	--	--	--	--	23,592	--	--	--	--	--
--	--	--	--	--	23,592	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	23,592	--	--	--	--	--
--	--	--	--	--	23,136	--	--	--	--	--
--	--	--	--	--	23,136	--	1A	--	--	--
2M,2U,1A	--	--	--	--	23,136	--	--	--	--	--
--	--	--	--	--	23,136	--	--	--	--	--
--	--	--	--	--	23,136	--	--	--	--	--

data are not presented separately.

ted separately.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

WESTINGHOUSE (continued)

Plant Code	Plant Name	System	Valve Population						Demands/ Component			Demand Hours/ Component
			M	A	C	X	S	R	M,A,C,X	S	R	
DC1	D. C. Cook 1	Auxiliary Feed[a]	10	5	12	32	--	--	12	--	--	26,280
		Containment Spray	10	--	10	13	--	--	12	--	--	26,280
		ECCS[b]	43	25	34	46	--	--	12	--	--	26,280
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	11	--	26,280
DC2	D. C. Cook 2	Auxiliary Feed[a]	10	5	12	32	--	--	3	--	--	7,080
		Containment Spray	10	--	10	13	--	--	3	--	--	7,080
		ECCS[b]	43	25	34	46	--	--	3	--	--	7,080
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	3	--	7,080
HN1	Haddam Neck	Auxiliary Feed	--	4	8	19	--	--	12	--	--	26,280
		ECCS[c]	28	--	27	46	--	--	12	--	--	26,280
		Containment Spray[d]	--	--	--	--	--	--	--	--	--	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	6	--	26,280

a. Components in this system are shared by Units 1 and 2.

b. Due to composite drawing, High Pressure Coolant Injection and Low Pressure Coolant Injection Systems population data re n

c. Due to composite drawing, Containment Spray, High Pressure Coolant Injection, and Low Pressure Coolant Injection Systems p

d. Containment Spray System uses Low Pressure Coolant Injection/Residual Heat Removal pumps.

ata Used for Demand LER Rates						Data Used for Standby LER Rates					
ailed to Operate M,A,U,X		Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
ailures	Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	2M,2U	--	--	--	--	26,280	1M,1U	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	3M,3U	--	--	--	--	--	--	--	--	--	--
1M,1U	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	7,080	--	--	1C	--	--
--	--	2C	--	--	--	7,080	--	--	--	--	--
--	--	--	--	--	--	7,080	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
1M,1U	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	7,080	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	2C	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--

ot presented separately.

opulation data are not presented separately.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

WESTINGHOUSE (continued)

Plant Code	Plant Name	System	Valve Population M	A	C	X	S	R	Demands/Component M,A,C,X	S	R	Demand Hours/Component	Data Use Failed t M,A Failures
IP2	Indian Point 2	Auxiliary Feed	8	4	18	20	--	--	12	--	--	26,280	--
		ECCS[a]	52	--	36	53	--	--	12	--	--	26,280	--
		Containment Spray	--	--	--	--	--	--	--	--	--	--	1U
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	17	--	26,280	--
IP3	Indian Point 3	Auxiliary Feed	8	4	23	24	--	--	11	--	--	23,952	--
		ECCS[a]	58	4	45	52	--	--	11	--	--	23,952	--
		Containment Spray	--	--	--	--	--	--	--	--	--	--	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	10	--	23,952	--
JF1	Joseph M. Farley 1	Auxiliary Feed	11	8	21	42	--	--	6	--	--	12,192	--
		Containment Spray	10	--	5	16	--	--	6	--	--	12,192	--
		High Pressure Coolant Injection[b]	27	--	28	20	--	--	6	--	--	12,192	--
		Low Pressure Coolant Injection	20	--	5	16	--	--	6	--	--	12,192	--
		Safety/Relief Valves	--	--	--	--	3	--	--	14	--	12,192	--

a. Due to composite drawing, Containment Spray, High Pressure Coolant Injection, and Low Pressure Coolant Injection Systems populatic

b. High Pressure Coolant Injection and Chemical Volume Control Systems are shared; those valves shared by both systems were included

for Demand LER Rates					Data Used for Standby LER Rates					
Operate I,X	Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	1C	--	--
--	--	--		--	--	2M,2U	--	--	--	--
--	1S	--	--	--	26,280	--	--	--	1S	--
--	--	--	--	--	23,952	--	--	--	--	--
--	--	--	--	--	23,952	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	23,952	--	--	--	--	--
3U	--	--	--	--	12,192	--	--	--	--	--
--	--	--	--	--	12,1[illegible]2	--	--	--	--	--
--	--	--	--	--	12,1[illegible]2	--	--	--	--	--
--	--	--	--	--	[illegible]1,192	--	--	--	--	--
--	--	--	--	--	12,192	--	--	--	--	--

data are not presented separately.

n the High Pressure Coolant Injection System population data.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

WESTINGHOUSE (continued)

Plant Code	Plant Name	System	Valve Population M	A	C	X	S	R	Demands/ Component M,A,C,X	S	R	Demand Hours/ Component
KE1	Kewaunee	Auxiliary Feed	4	--	11	9	--	--	12	--	--	26,280
		Containment Spray	8	--	13	14	--	--	12	--	--	26,280
		ECCS[a]	29	--	19	27	--	--	12	--	--	26,280
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	11	--	26,280
NA1	North Anna 1	Auxiliary Feed	3	3	6	24	--	--	3	--	--	6,456
		Containment Spray	8	--	5	6	--	--	3	--	--	6,456
		High Pressure Coolant Injection[b]	25	--	22	6	--	--	3	--	--	6,456
		Low Pressure Coolant Injection	12	--	14	6	--	--	3	--	--	6,456
		Safety/Relief Valves	--	--	--	--	3	--	--	2	--	6,456
PR1	Prairie Island 1	Auxiliary Feed[c]	3	4	11	9	--	--	12	--	--	26,280
		Containment Spray	23	2	5	11	--	--	12	--	--	26,280
		ECCS[a]	28	--	23	22	--	--	12	--	--	26,280
		High Pressure Coolant Injection[c]	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	8	--	26,280

a. Due to composite drawing, High Pressure Coolant Injection and Low Pressure Coolant Injection Systems population data are no

b. High Pressure Coolant Injection and Chemical Volume Control Systems are shared; those valves shared by both systems were i

c. Components in this system are shared by Units 1 and 2.

ta Used for Demand LER Rates						Data Used for Standby LER Rates					
iled to Operate M,A,U,X		Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
ilures	Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	--	26,280	--	--	--	--	--
M,2U	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
M,3U	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	6,456	--	--	--	--	--
--	--	--	--	--	--	6,456	--	--	--	--	--
U	--	--	--	--	--	6,456	--	--	--	--	--
M,1U	--	--	--	--	--	6,456	--	--	--	--	--
--	--	--	--	--	--	6,456	--	--	--	--	--
M,1U	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	-
--	--	--	--	--	--	--	--	--	--	--	--
M,1U	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--

t presented separately.

cluded in the High Pressure Coolant Injection System population data.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

WESTINGHOUSE (continued)

Plant Code	Plant Name	System	Valve Population						Data L Demands/ Component			Demand Hours/ Component	Failed M
			M	A	C	X	S	R	M,A,C,X	S	R		Failur
PR2	Prairie Island 2	Auxiliary Feed[a]	3	4	11	9	--	--	12	--	--	26,280	--
		Containment Spray	23	2	5	11	--	--	12	--	--	26,280	--
		ECCS[b]	28	--	23	22	--	--	12	--	--	26,280	--
		High Pressure Coolant Injection[a]	--	--	--	--	--	--	--	--	--	--	2M,3U
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	7	--	26,280	--
PT1	Point Beach 1	Auxiliary Feed[a]	11	3	16	21	--	--	12	--	--	26,280	1M,1U
		Containment Spray	4	2	10	15	--	--	12	--	--	26,280	--
		ECCS[b]	27	2	21	38	--	--	12	--	--	26,280	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	3	--	26,280	--
PT2	Point Beach 2	Auxiliary Feed[a]	11	3	16	21	--	--	12	--	--	26,280	1M,1U
		Containment Spray	4	2	10	15	--	--	12	--	--	26,280	1M,1U
		ECCS[b]	27	2	21	38	--	--	12	--	--	26,280	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	3	--	26,280	--

a. Components in this system are shared by Units 1 and 2.

b. Due to composite drawing, High Pressure Coolant Injection and Low Pressure Coolant Injection Systems population data are not pr

...for Demand LER Rates					Data Used for Standby LER Rates					
...Operate ...U,X	Failed to Open C,R,S		Failed to Reseat R			External Leakage 4,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
1M,1U	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	1U	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	-	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--

...nted separately.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

WESTINGHOUSE (continued)

Plant Code	Plant Name	System	Valve Population						Demands/ Component			Demand Hours/ Component
			M	A	C	X	S	R	M,A,C,X	S	R	
RG1	R. E. Ginna 1	Auxiliary Feed	3	7	12	22	--	--	12	--	--	26,280
		ECCS[a]	44	--	21	42	--	--	12	--	--	26,280
		Containment Spray	--	--	--	--	--	--	--	--	--	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	2	--	26,280
RO2	H. B. Robinson 2	Auxiliary Feed	8	3	10	20	--	--	12	--	--	26,280
		Safety Injection[a]	29	8	25	57	--	--	12	--	--	26,280
		Containment Spray	--	--	--	--	--	--	--	--	--	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	11	--	26,280
SA1	Salem 1	Auxiliary Feed	--	14	17	28	--	--	8	--	--	17,976
		Containment Spray	7	--	6	16	--	--	8	--	--	17,976
		ECCS[b]	32	4	32	41	--	--	8	--	--	17,976
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	10	--	17,976

a. Due to composite drawing, Containment Spray, High Pressure Coolant Injection, and Low Pressure Coolant Injection Systems

b. Due to composite drawing, High Pressure Coolant Injection and Low Pressure Coolant Injection Systems population data are

Data Used for Demand LER Rates						Data Used for Standby LER Rates					
Failed to Operate M,A,U,X		Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
Failures	Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	1C	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
3M,5U	--	--	--	--	--	26,280	--	--	1C	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	1C	--	--
2M,2U	1M,1U	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
1A,1U	--	--	--	--	--	17,976	--	--	--	--	--
--	--	--	--	--	--	17,976	--	2U	--	--	--
--	--	--	--	--	--	17,976	--	--	--	--	--
3M,3U	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	17,976	--	--	--	--	--

population data are not presented separately.

not presented separately.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

WESTINGHOUSE (continued)

			Valve Population						Demands/ Component				Data Used f	
													Fa:led to O M,A,U,	
Plant Code	Plant Name	System	M	A	C	X	S	R	M,A,C,X	S	R	Demand Hours/ Component	Failures	C F
SO1	San Onofre 1	Auxiliary Feed	3	7	12	27	--	--	12	--	--	26,280	--	
		Containment Spray[a]	--	--	--	--	--	--	--	--	--	--	1U	
		ECCS[b]	23	--	18	12	--	--	12	--	--	26,280	--	
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	1M,1U	
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--	
		Safety/Relief Valves	--	--	--	--	2	--	--	7	--	26,290	--	
SU1	Surry 1	Auxiliary Feed	6	--	16	20	--	--	12	--	--	26,280	--	
		Containment Spray[c]	10	--	7	9	--	--	12	--	--	26,280	--	
		ECCS[b]	39	--	25	27	--	--	12	--	--	26,280	--	
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--	
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	1M,1U	
		Safety/Relief Valves	--	--	--	--	3	--	--	10	--	26,280	--	
SU2	Surry 2	Auxiliary Feed	6	--	16	20	--	--	12	--	--	26,280	--	
		Containment Spray[c]	10	--	7	9	--	--	12	--	--	26,280	--	
		ECCS[b]	39	--	25	27	--	--	12	--	--	26,280	--	
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--	
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	1M,1U	
		Safety/Relief Valves	--	--	--	--	3	--	--	8	--	26,280	--	

a. No valve population data were available for this system.

b. Due to composite drawing, High Pressure Coolant Injection and Low Pressure Coolant Injection Systems population data are not presen

c. Components in this system are shared by Units 1 and 2.

r Demand LER Rates					Data Used for Standby LER Rates					
erate	Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Pr ture Open R,S	
mmand ults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
M,1U	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	2C	--	--
--	--	--	--	--	--	--	--	--	--	--
--	1S	--	--	--	26,280	--	--	--	1S	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	1C	--	--
--	--	--	--	--	--	1M,1U	--	--	--	--
--	--	--	--	--	26,280	--	--	--	3S	--

d separately.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

WESTINGHOUSE (continued)

Plant Code	Plant Name	System	Valve Population M	A	C	X	S	R	Demands/ Component M,A,C,X	S	R	Demand Hours/ Component
TR1	Trojan	Auxiliary Feed	11	--	15	26	--	--	12	--	--	26,280
		Containment Spray	10	--	6	13	--	--	12	--	--	26,280
		ECCS[a]	20	--	22	19	--	--	12	--	--	26,280
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	13	--	26,280
TU3	Turkey Point 3	Auxiliary Feed[b]	--	6	7	17	--	--	12	--	--	26,280
		Safety Injection[c]	50	2	34	40	--	--	12	--	--	26,280
		Containment Spray	--	--	--	--	--	--	--	--	--	--
		High Pressure Coolant Injection	--	--	--	-	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	12	--	26,280
TU4	Turkey Point 4	Auxiliary Feed[b]	--	6	7	17	--	--	12	--	--	26,280
		Safety Injection[c]	50	2	34	40	--	--	12	--	--	26,280
		Containment Spray	--	--	--	--	--	--	--	--	--	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	17	--	26,280

a. Due to composite drawing, High Pressure Coolant Injection and Low Pressure Coolant Injection Systems population data are

b. Components in this system are shared by Units 3 and 4.

c. Due to composite drawing, Containment Spray, High Pressure Coolant Injection, and Low Pressure Coolant Injection Systems

Data Used for Demand LER Rates						Data Used for Standby LER Rates					
Failed to Operate M,A,U,X		Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
Failures	Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
1M,1U	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
2M,2U	1M,1U	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	3M,3U	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--

not presented separately.

population data are not presented separately.

TABLE 25 (continued)

M - Mrtor-Operated Valve
U - Remote-Operated Valv plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

WESTINGHOUSE (continued)			Valve Population						Demands/ Component			Data Use	Failed t M,A
Plant Code	Plant Name	System	M	A	C	X	S	R	M,A,C,X	S	R	Demand Hours/ Component	Failures
YR1	Yankee Rowe	Auxiliary Feed	8	--	4	10	--	--	12	--	--	26,280	--
		Containment Spray[a]	--	--	--	--	--	--	--	--	--	--	--
		Safety Injection[b]	20	--	17	26	--	--	12	--	--	26,280	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	1U
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	2	--	--	5	--	26,280	--
ZI1	Zion 1	Auxiliary Feed	17	8	7	8	--	--	12	--	--	26,280	--
		Containment Spray	9	--	12	22	--	--	12	--	--	26,280	1M,1U
		ECCS[b]	56	4	50	42	--	--	12	--	--	26,280	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	1M,1U
		Safety/Relief Valves	--	--	--	--	3	--	--	12	--	26,280	--
ZI2	Zion 2	Auxiliary Feed	17	8	7	8	--	--	12	--	--	26,280	--
		Containment Spray	9	--	12	22	--	--	12	--	--	26,280	--
		ECCS[b]	56	4	50	42	--	--	12	--	--	26,280	--
		High Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	2M,2U
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	3	--	--	12	--	26,280	--

a. No valve population data were available for this system.

b. Due to composite drawing, High Pressure Coolant Injection and Low Pressure Coolant Injection Systems population data are not pres

'or Demand LER Rates					Data Used for Standby LER Rates					
'perate X	Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
'ommand 'aults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	2S	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
3M,3U	--	--	--	--	--	1A	--	2C	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	--	--	--	--	--	--
1M,1U	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--

'ed separately.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

GENERAL ELECTRIC

Plant Code	Plant Name	System	Valve Population M	A	C	X	S	R	Demands/Component M,A,C,X	S	R	Demand Hours/Component
BF1	Browns Ferry 1	Core Spray	12	--	12	17	--	--	12	--	--	26,280
		High Pressure Coolant Injection	11	--	12	6	--	--	12	--	--	26,280
		Low Pressure Coolant Injection (RHR)[a]	40	--	11	15	--	--	12	--	--	26,280
		Safety/Relief Valves	--	--	--	--	--	11	--	--	33	26,280
BF2	Browns Ferry 2	Core Spray	12	--	12	17	--	--	12	--	--	26,280
		High Pressure Coolant Injection	11	--	12	6	--	--	12	--	--	26,280
		Low Pressure Coolant Injection (RHR)[a]	40	--	11	15	--	--	12	--	--	26,280
		Safety/Relief Valves	--	--	--	--	--	11	--	--	34	26,280
BF3	Browns Ferry 3	Core Spray	12	--	12	17	--	--	10	--	--	20,976
		High Pressure Coolant Injection	11	--	12	6	--	--	10	--	--	20,976
		Low Pressure Coolant Injection (RHR)[a]	40	--	11	15	--	--	10	--	--	20,976
		Safety/Relief Valves	--	--	--	--	--	11	--	--	36	20,976

a. Containment Spray System is an integral part of the Residual Heat Removal (RHR) System.

Data Used for Demand LER Rates						Data Used for Standby LER Rates					
Failed to Operate M,A,U,X		Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
Failures	Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	--	26,280	--	--	--	--	--
2M,2U	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	1R	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	--	26,280	--	--	1C	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	2R	--	26,280	--	--	--	--	--
--	--	--	--	--	--	20,976	--	--	--	--	--
1M,1U	--	1C	--	--	--	20,976	--	--	--	--	--
2M,2U	--	--	--	--	--	20,976	--	--	--	--	--
--	--	--	--	2R	--	20,976	--	--	--	4R	--

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

GENERAL ELECTRIC (continued)

Plant Code	Plant Name	System	Valve Population M	A	C	X	S	R	Demands/ Component M,A,C,X	S	R	Demand Hours/ Component	Data Faile Faiiu
BR1	Brunswick 1	Core Spray	10	--	10	12	--	--	9	--	--	19,512	--
		High Pressure Coolant Injection	13	--	10	4	--	--	9	--	--	19,512	1M,1
		Low Pressure Coolant Injection (RHR)[a]	49	4	18	25	--	--	9	--	--	19,512	3M,3
		Safety/Relief Valves	--	--	--	--	--	9	--	--	26	19,512	--
BR2	Brunswick 2	Core Spray	10	--	10	12	--	--	12	--	--	26,280	--
		High Pressure Coolant Injection	13	--	10	4	--	--	12	--	--	26,280	1M,2
		Low Pressure Coolant Injection (RHR)[a]	49	4	18	25	--	--	12	--	--	26,280	2M,2
		Safety/Relief Valves	--	--	--	--	--	9	--	--	52	26,280	--
CO1	Cooper Station	Core Spray	10	--	6	4	--	--	12	--	--	26,280	3M,3
		High Pressure Coolant Injection	10	--	--	1	--	--	12	--	--	26,280	--
		Low Pressure Coolant Injection (RHR)[a]	37	7	6	--	--	--	12	--	--	26,280	3M,3
		Safety/Relief Valves	--	--	--	--	--	8	--	--	9	26,280	--

a. Containment Spray System is an integral part of the Residual Heat Removal (RHR) System.

for Demand LER Rates					Data Used for Standby LER Rates					
Operate J,X	Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
1M,1U	--	--	--	--	19,512	--	--	--	--	--
--	--	--	--	--	19,512	--	--	--	--	--
3M,3U	--	--	--	--	19,512	--	--	--	--	--
--	--	--	1R	--	19,512	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
1U	--	--	--	--	26,280	--	--	1C	--	--
--	--	--	--	1R	26,280	--	--	--	2R	--
--	--	--	--	--	26,280	--	--	--	--	--
1U	--	--	--	--	26,280	--	--	1C	--	--
1M,2U	--	--	--	--	26,280	--	--	--	--	--
--	1R	--	--	--	26,280	--	--	--	--	--

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

GENERAL ELECTRIC (continued)

Plant Code	Plant Name	System	Valve Population						Demands/ Component			Demand Hours/ Component
			M	A	C	X	S	R	M,A,C,X	S	R	
DR2	Dresden 2	Core Spray	10	--	2	14	--	--	12	--	--	26,280
		High Pressure Coolant Injection	13	--	12	12	--	--	12	--	--	26,280
		Low Pressure Coolant Injection (RHR)[a]	28	--	10	18	--	--	12	--	--	26,280
		Safety/Relief Valves	--	--	--	--	--	5	--	--	20	26,280
DR3	Dresden 3	Core Spray	10	--	2	14	--	--	12	--	--	26,280
		High Pressure Coolant Injection	13	--	12	12	--	--	12	--	--	26,280
		Low Pressure Coolant Injection (RHR)[a]	28	--	10	18	--	--	12	--	--	26,280
		Safety/Relief Valves	--	--	--	--	--	5	--	--	13	26,280
DA1	Duane Arnold	Core Spray	10	2	2	4	--	--	12	--	--	26,280
		High Pressure Coolant Injection	7	--	3	2	--	--	12	--	--	25,280
		Low Pressure Coolant Injection (RHR)[a]	50	8	16	28	--	--	12	--	--	26,280
		Safety/Relief Valves	--	--	--	--	--	6	--	--	17	26,280

a. Containment Spray System is an integral part of the Residual Heat Removal (RHR) System.

Data Used for Demand LER Rates						Data Used for Standby LER Rates					
Failed to Operate M,A,U,X		Failed to Open C,R,S		Failed to Reseat R		Standby Hours/ Component	External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
Failures	Command Faults	Failures	Command Faults	Failures	Command Faults		Failures	Command Faults	Failures	Failures	Command Faults
1M,3U	--	--	--	--	--	26,280	--	--	--	--	--
3M,3U	1U	--	--	--	--	26,280	1U	--	1C	--	--
2M,3U	--	--	--	--	--	26,280	--	--	--	--	--
--	--	1R	--	1R	--	26,280	--	--	--	--	--
--	1M,1U	--	--	--	--	26,280	--	--	--	--	--
--	1M,1U	--	--	--	--	26,280	--	--	--	--	--
5M,5U	2M,2U	--	--	--	--	26,280	--	--	2C	--	--
--	--	1R	--	--	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	--	26,280	--	--	--	--	--
1M,2U	--	--	--	--	--	26,280	--	--	--	--	--
1M,2U	--	--	--	--	--	26,280	--	--	--	--	--
--	--	6R	--	--	--	26,280	--	--	--	--	--

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

GENERAL ELECTRIC (continued)

Plant Code	Plant Name	System	Valve Population						Demands/ Component			Demand Hours/ Component	Data Use[illegible] Failed t[illegible] M,A.[illegible]
			M	A	C	X	S	R	M,A,C,X	S	R		Failures
EN1	Edwin I. Hatch 1	Core Spray	10	2	12	12	--	--	12	--	--	26,280	--
		High Pressure Coolant Injection	13	1	11	4	--	--	12	--	--	26,280	2M,2U
		Low Pressure Coolant Injection (RHR)[a]	45	10	21	24	--	--	12	--	--	26,280	1M,1U
		Safety/Relief Valves	--	--	--	--	--	9	--	--	49	26,280	--
EN2	Edwin I. Hatch 2	Core Spray	10	4	6	9	--	--	2	--	--	4,296	--
		High Pressure Coolant Injection	14	1	12	4	--	--	2	--	--	4,296	1M,1U
		Low Pressure Coolant Injection (RHR)[a]	43	10	12	30	--	--	2	--	--	4,296	4U
		Safety/Relief Valves	--	--	--	--	--	11	--	--	1	4,296	--
FP1	Fitzpatrick	Core Spray	10	2	2	4	--	--	12	--	--	26,280	3M,3U
		High Pressure Coolant Injection	8	--	1	--	--	--	12	--	--	26,280	6M,6U
		Low Pressure Coolant Injection (RHR)[a]	--	7	5	29	--	--	12	--	--	26,280	3M,3U
		Safety/Relief Valves	--	--	--	--	--	9	--	--	29	26,280	--

a. Containment Spray System is an integral part of the Residual Heat Removal (RHR) System.

or Demand LER Rates					Data Used for Standby LER Rates					
'perate X	Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
ommand aults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	26,280	--	1U	--	--	--
--	7R	--	3R	--	26,280	--	--	--	8R	--
--	--	--	--	--	4,296	--	--	--	--	--
2U	--	--	--	--	4,296	--	--	--	--	--
2M,2U	--	--	--	--	4,296	--	--	--	--	--
--	--	--	--	--	4,296	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	26,280	1M,1U	--	3C	--	--
--	--	--	--	--	26,280	--	--	--	3R	--

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

GENERAL ELECTRIC (continued)

Plant Code	Plant Name	System	Valve Population M	A	C	X	S	R	Demands/Component M,A,C,X	S	R	Demand Hours/Component
MI1	Millstone 1	Core Spray	10	2	--	8	--	--	12	--	--	26,280
		High Pressure Coolant Injection[a]	--	--	9	35	--	--	12	--	--	26,280
		Low Pressure Coolant Injection (RHR)[b]	24	2	--	28	--	--	12	--	--	26,280
		Safety/Relief Valves	--	--	--	--	--	3	--	--	18	26,280
MO1	Monticello	Core Spray	8	--	8	14	--	--	12	--	--	26,280
		High Pressure Coolant Injection	12	--	8	4	--	--	12	--	--	26,280
		Low Pressure Coolant Injection (RHR)[b]	27	7	17	34	--	--	12	--	--	26,280
		Safety/Relief Valves	--	--	--	--	--	4	--	--	16	26,280
NM1	Nine Mile Point 1	Core Spray	12	1	13	8	--	--	12	--	--	26,280
		Containment Spray	4	4	10	1[illegible]	--	-	12	--	--	26,280
		ECCS[c]	5	8	2	8	--	--	12	--	--	26,280
		High Pressure Coolant Injection[a]	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--
		Safety/Relief Valves	--	--	--	--	--	6	--	--	12	26,280

a. Main Feed System serves as the High Pressure Coolant Injection System.

b. Containment Spray System is an integral part of the Residual Heat Removal (RHR) System.

c. Due to composite drawing, High Pressure Coolant Injection and Low Pressure Coolant Injection Systems population data are n

ta Used for Demand LER Rates						Data Used for Standby LER Rates					
iled to Operate M,A,U,X		Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
ilures	Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	--	26,280	--	--	--	--	--
--	4A	--	--	--	--	26,280	--	--	4C	--	--
M,3U	--	--	--	--	--	26,280	1C	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	3R	1R
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
M,1U	3M,3U	--	--	--	--	26,280	1U	--	--	--	--
--	--	--	1R	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--		--	--	--	--	26,280	--	--	--	--	--
--	1U	--	--	--	--	--	--	--	--	--	--
M,1	.	--	--	--	--	--	--	--	--	--	--
--	-	--	3R	--	--	26,280	--	--	--	--	--

ot presented separately.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

GENERAL ELECTRIC (continued)

Plant Code	Plant Name	System	Valve Population						Demands/ Component			Demand Hours/ Component	Data Fail
			M	A	C	X	S	R	M,A,C,X	S	R		Fail
OC1	Oyster Creek	Core Spray	14	--	12	7	--	--	12	--	--	26,280	--
		Containment Spray	10	--	6	--	--	--	12	--	--	26,280	1U
		ECCS[a]	18	7	5	8	--	--	12	--	--	26,280	--
		High Pressure Coolant Injection[b]	--	--	--	--	--	--	--	--	--	--	--
		Low Pressure Coolant Injection	--	--	--	--	--	--	--	--	--	--	1M,1
		Safety/Relief Valves	--	--	--	--	--	4	--	--	6	26,280	--
PB2	Peach Bottom 2	Core Spray	14	--	18	18	--	--	12	--	--	26,280	1M,4
		High Pressure Coolant Injection	12	--	11	10	--	--	12	--	--	26,280	--
		Low Pressure Coolant Injection (RHR)[c]	32	2	21	30	--	--	12	--	--	26,280	3M,4
		Safety/Relief Valves	--	--	--	--		11	--	--	18	26,280	--
PB3	Peach Bottom 3	Core Spray	14	--	18	18	--	--	12	--	--	26,280	1M,4
		High Pressure Coolant Injection	12	--	11	10	--	--	12	--	--	26,280	1M,1
		Low Pressure Coolant Injection (RHR)[c]	32	2	21	30	--	--	12	--	--	26,280	1M,2
		Safety/Relief Valves	--	--	--	--	--	11	--	--	16	26,280	--

a. Due to composite drawing, High Pressure Coolant Injection and Low Pressure Coolant Injection Systems population data are not p

b. Main Feed System serves as the High Pressure Coolant Injection System.

c. Containment Spray System is an integral part of the Residual Heat Removal (RHR) System.

d for Demand LFR Rates					Data Used for Standby LER Rates					
o Operate ,U,X	Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
5M,5U	--	--	--	--	26,280	--	--	--	--	--
3M,3U	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--
--	1R	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	26,280	1A,1M,2U	--	1C	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	3R	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	1U	--	1C	--	--
1M,1U	--	--	--	--	26,280	--	--	--	--	--
--	--	--	2R	--	26,280	--	--	--	--	--

ented separately.

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

GENERAL ELECTRIC (continued)

Plant Code	Plant Name	System	Valve Population M	A	C	X	S	R	Demands/ Component M,A,C,X	S	R	Demand Hours/ Component
PI1	Pilgrim 1	Core Spray	8	--	--	2	--	--	12	--	--	26,280
		High Pressure Coolant Injection	7	--	1	1	--	--	12	--	--	26,280
		Low Pressure Coolant Injection (RHR)[a]	32	5	8	27	--	--	12	--	--	26,280
		Safety/Relief Valves	--	--	--	--	--	3	--	--	23	26,280
QC1	Quad-Cities 1	Core Spray	10	--	2	8	--	--	12	--	--	26,280
		High Pressure Coolant Injection	15	5	14	11	--	--	12	--	--	26,280
		Low Pressure Coolant Injection (RHR)[a]	32	1	10	20	--	--	12	--	--	26,280
		Safety/Relief Valves	--	--	--	--	--	5	--	--	23	26,280
QC2	Quad-Cities 2	Core Spray	10	--	2	8	--	--	12	--	--	26,280
		High Pressure Coolant Injection	15	5	14	11	--	--	12	--	--	26,280
		Low Pressure Coolant Injection (RHR)[a]	32	1	10	20	--	--	12	--	--	26,280
		Safety/Relief Valves	--	--	--	--	--	5	--	--	20	26,280

a. Containment Spray System is an integral part of the Residual Heat Removal (RHR) System.

ata Used for Demand LER Rates							Data Used for Standby LER Rates				
ailed to Operate M,A,U,X		Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
ailures	Command Faults	Failures	Command Faults	Failures	Command Fau'ts	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
2M,2U	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	2R	1R	--	26,280	--	--	--	1R	--
1M,1U	--	--	--	--	--	26,280	--	--	--	--	--
2M,2U	--	--	--	--	--	26,280	--	1U	1C	--	--
2M,2U	1A	--	--	--	--	26,280	--	--	--	--	--
--	--	5R	1R	--	--	26,280	--	--	--	--	--
1M,1U	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	--	26,280	--	--	1C	--	--
--	--	4R	1R	1R	--	26,280	--	--	--	--	--

TABLE 25 (continued)

M - Motor-Operated Valve
U - Remote-Operated Valve plus MOV
A - Air-Operated Valve
C - Check Valve
R - BWR Relief Valve
S - PWR Safety Valve
X - Manual-Operated Valve

GENERAL ELECTRIC (continued)

Plant Code	Plant Name	System	Valve Population M	A	C	X	S	R	Demands/Component M,A,C,X	S	R	Demand Hours/Component	Data Us Failed M, Failure
VY1	Vermont Yankee	Core Spray	10	--	8	11	--	--	12	--	--	26,280	1X
		High Pressure Coolant Injection	11	--	11	6	--	--	12	--	--	26,280	--
		Low Pressure Coolant Injection (RHR)[a]	35	--	16	34	--	--	12	--	--	26,280	5M,5U
		Safety/Relief Valves	--	--	--	--	--	4	--	--	11	26,280	--

a. Containment Spray System is an integral part of the Residual Heat Removal (RHR) System.

for Demand LER Rates					Data Used for Standby LER Rates					
Operate J,X	Failed to Open C,R,S		Failed to Reseat R			External Leakage M,A,U,C,X	Plugged M,A,U	Internal Leakage C	Premature Open R,S	
Command Faults	Failures	Command Faults	Failures	Command Faults	Standby Hours/ Component	Failures	Command Faults	Failures	Failures	Command Faults
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	--	--	--
--	--	--	--	--	26,280	--	--	1C	--	--
--	4R	--	--	--	26,280	--	--	--	--	--

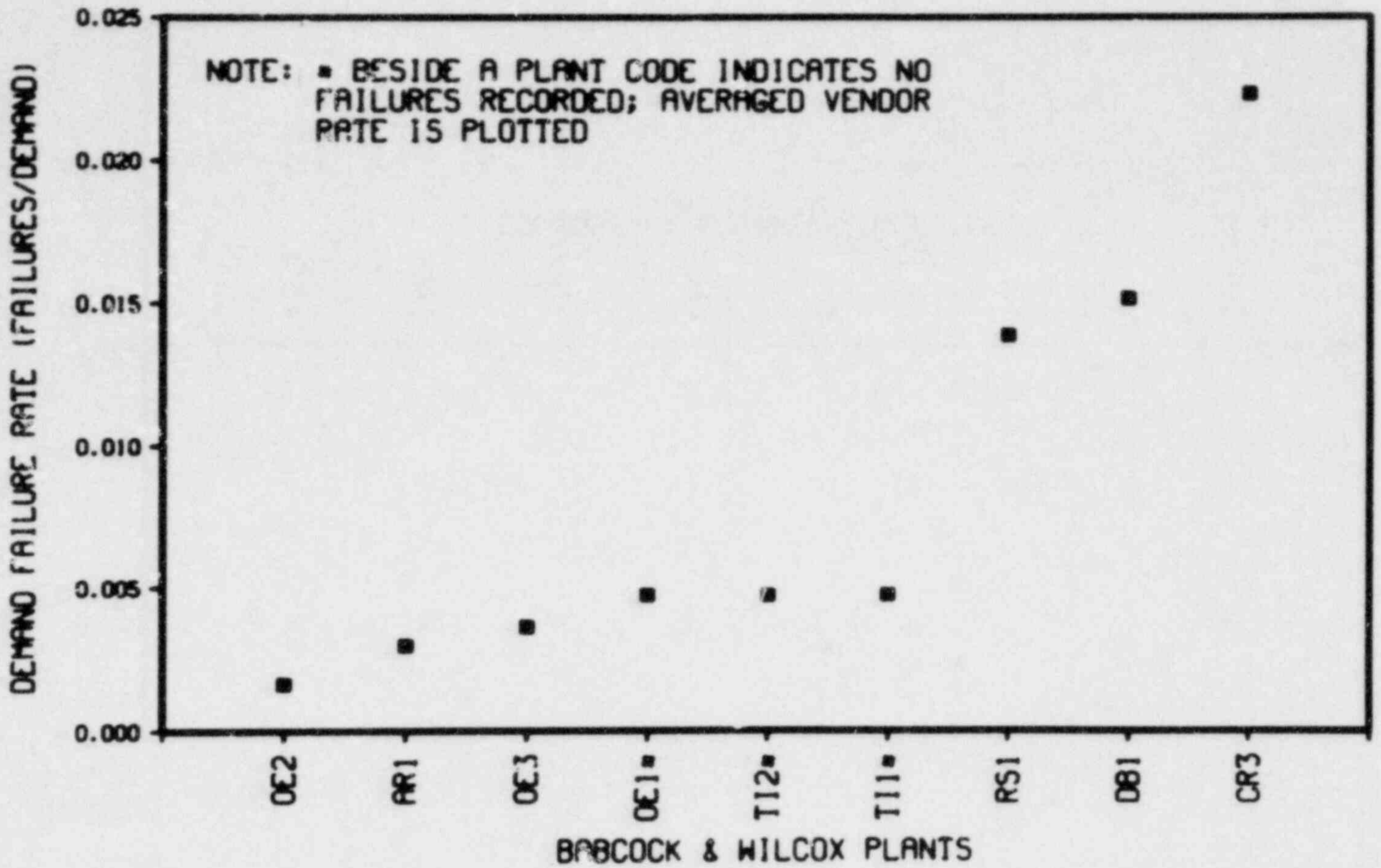

Figure 4a. Scatter plot of demand LER rates for "Valve--Operator (Motor)--Fail to Operate" in Babcock & Wilcox plants.

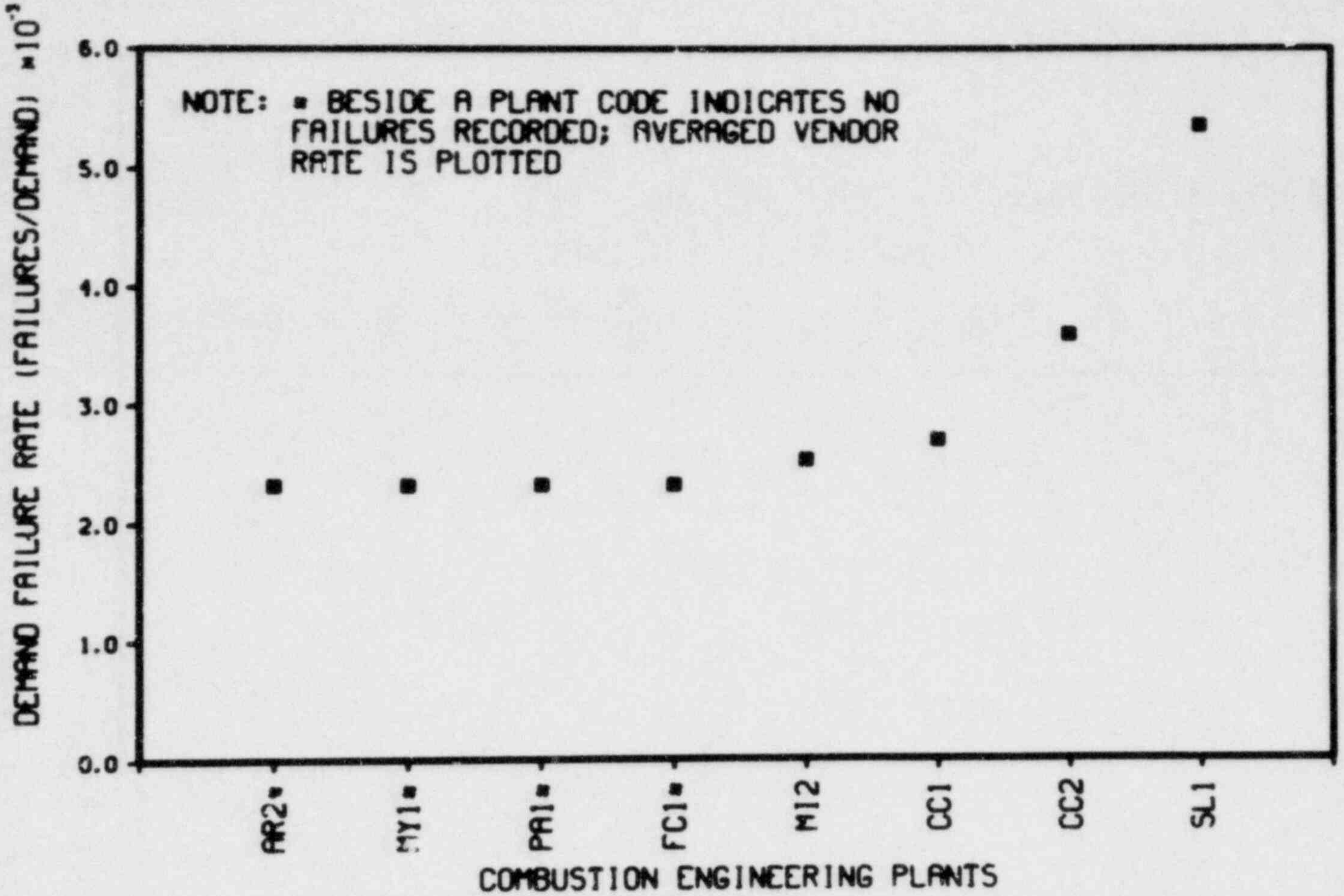

Figure 4b. Scatter plot of demand LER rates for "Valve--Operator (Motor)--Fail to Operate" in Combustion Engineering plants.

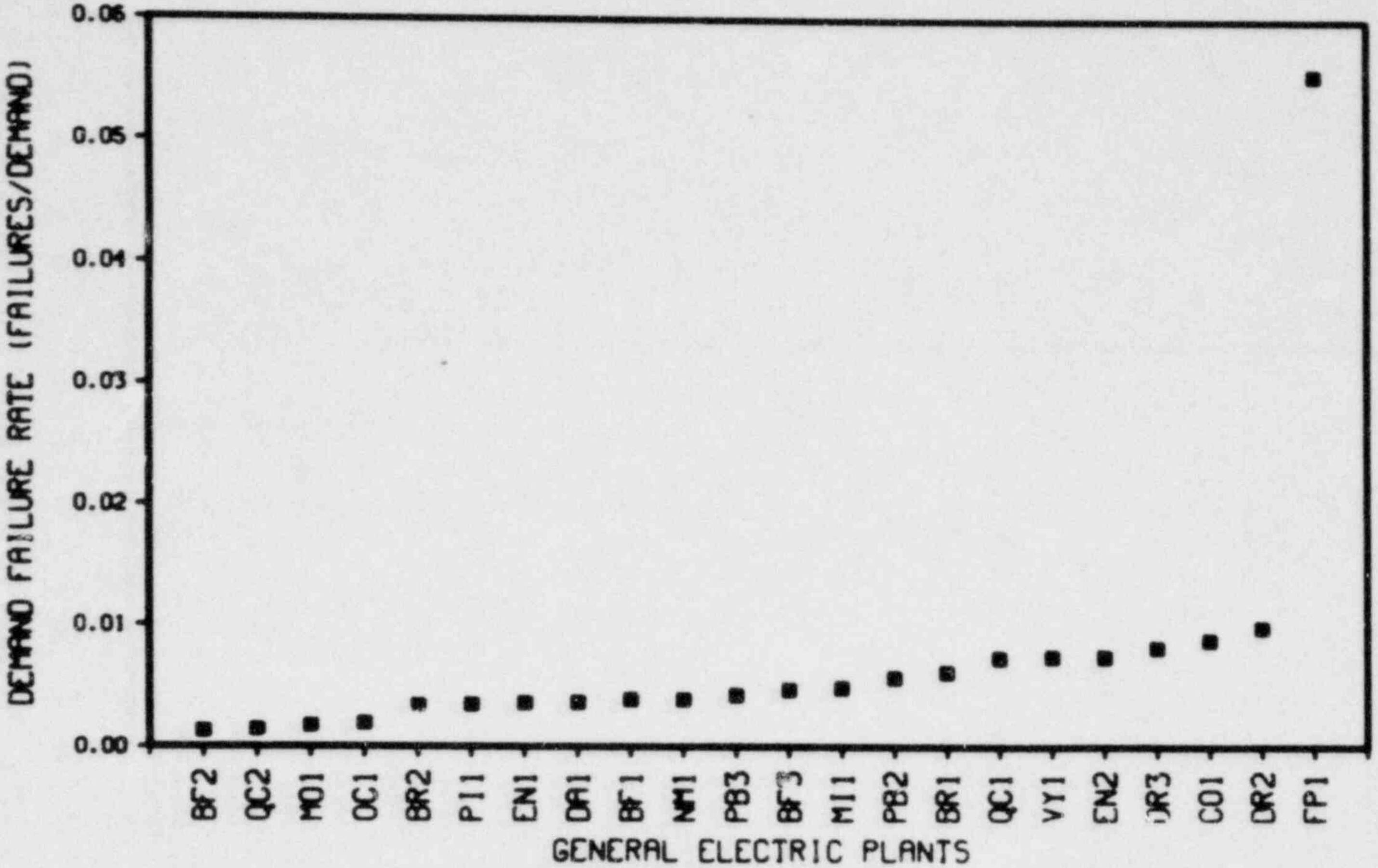

Figure 4c. Scatter plot of demand LER rates for "Valve--Operator (Motor)--Fail to Operate" in General Electric plants.

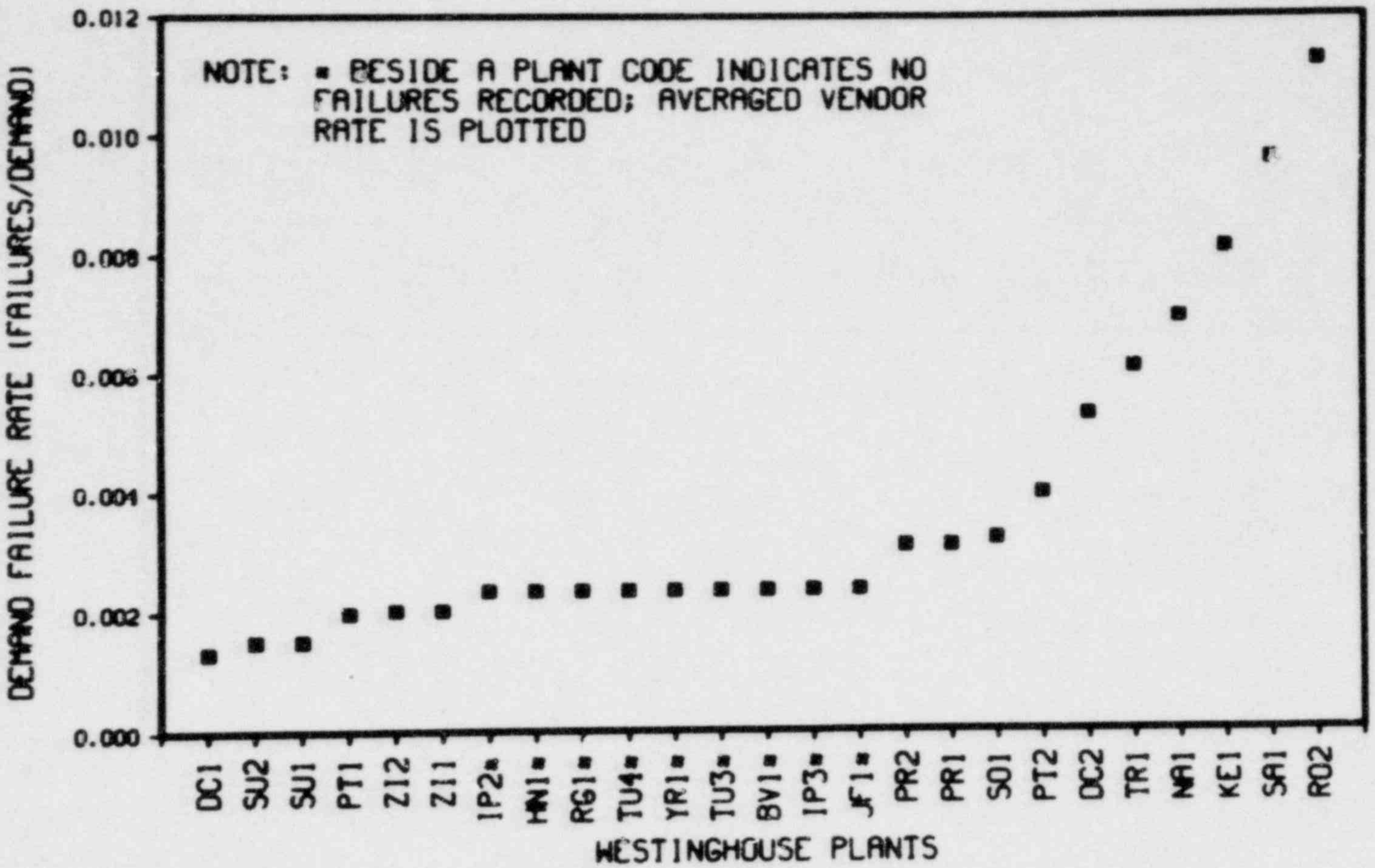

Figure 4d. Scatter plot of demand LER rates for "Valve--Operator (Motor)--Fail to Operate" in Westinghouse plants.

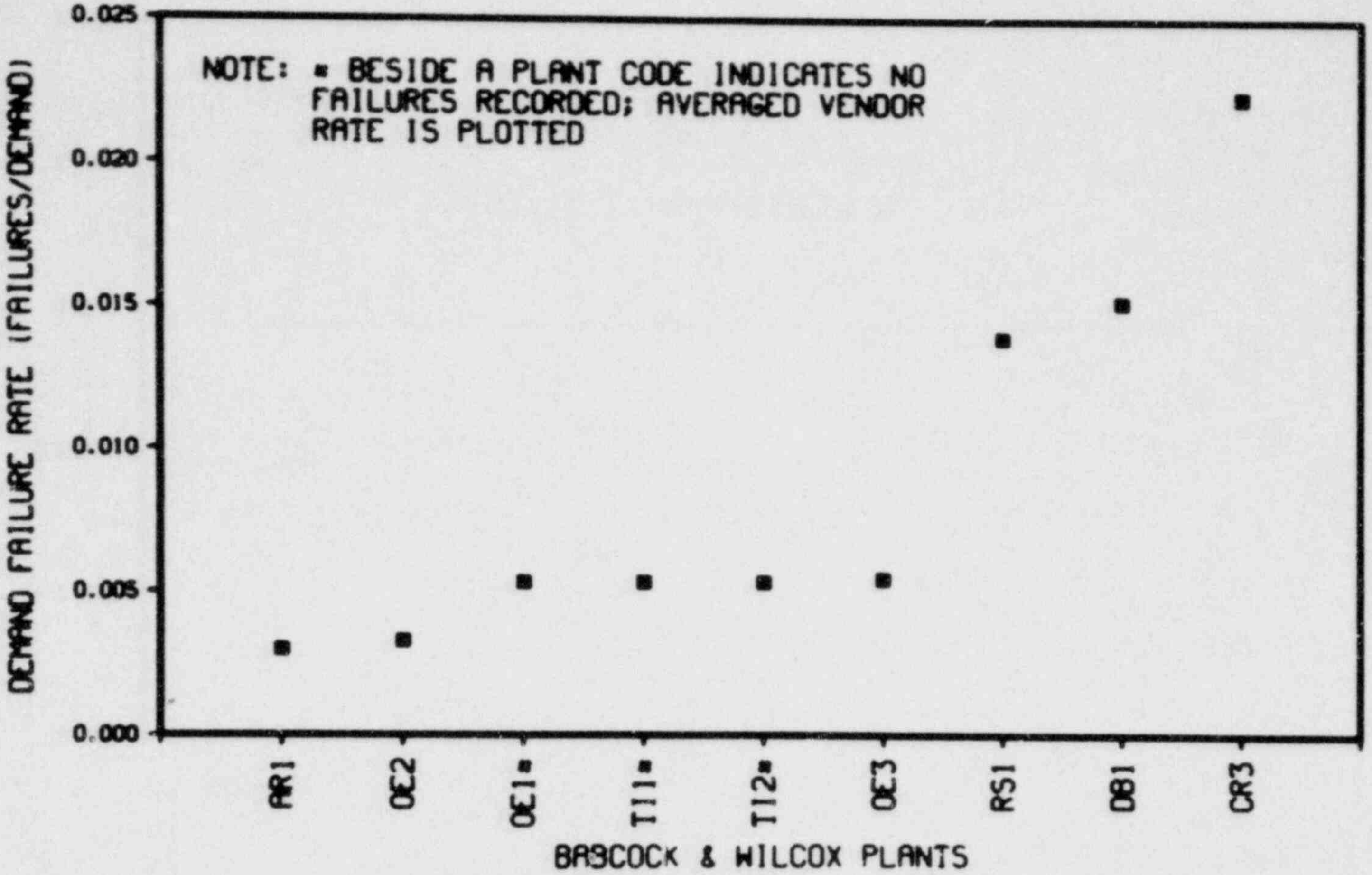

Figure 5a. Scatter plot of demand LER rates for "Valve--Operator (Motor)--Fail to Operate (Command Faults Included)" in Babcock & Wilcox plants.

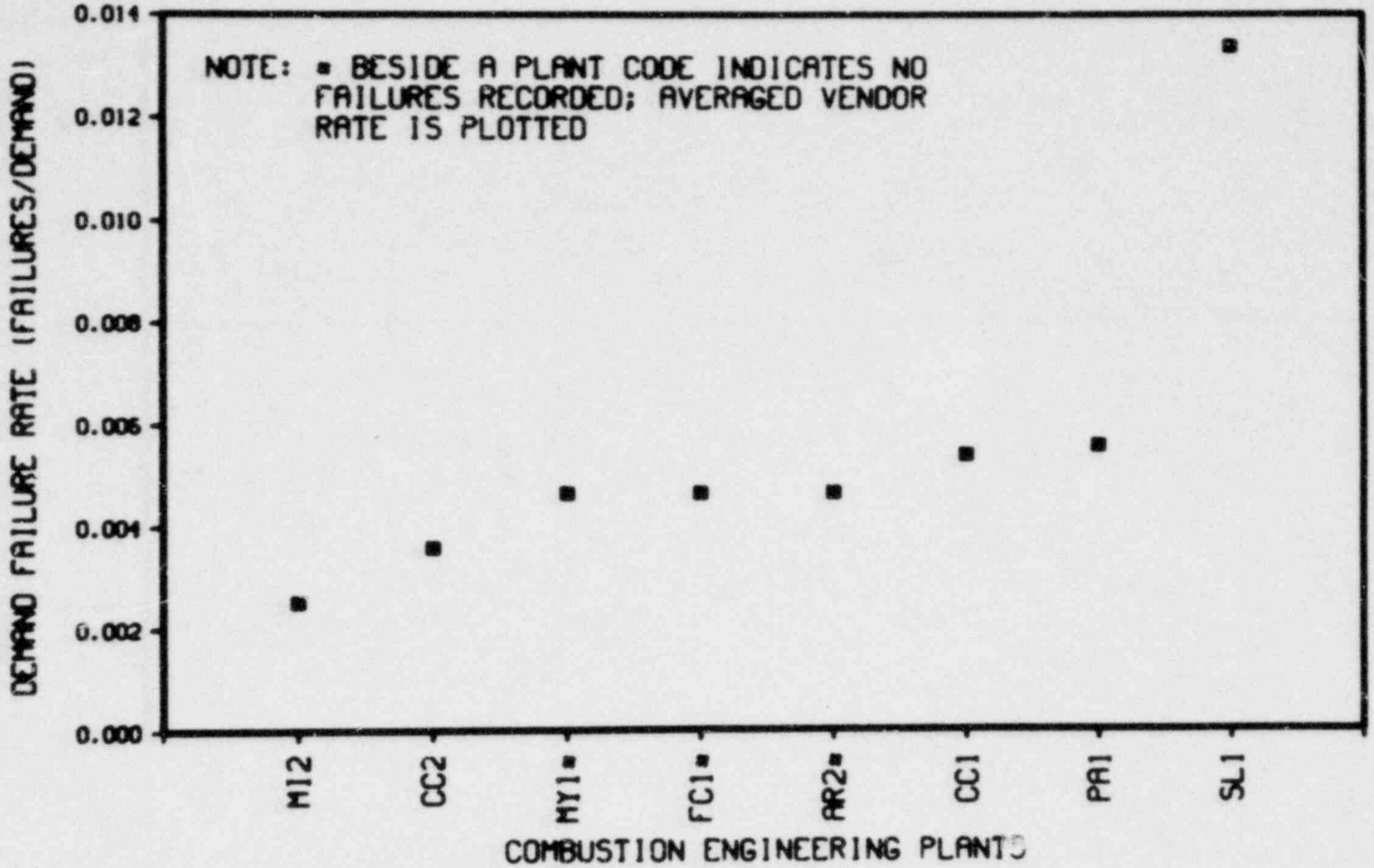

Figure 5b. Scatter plot of demand LER rates for "Valve--Operator (Motor)--Fail to Operate (Command Faults Included)" in Combustion Engineering plants.

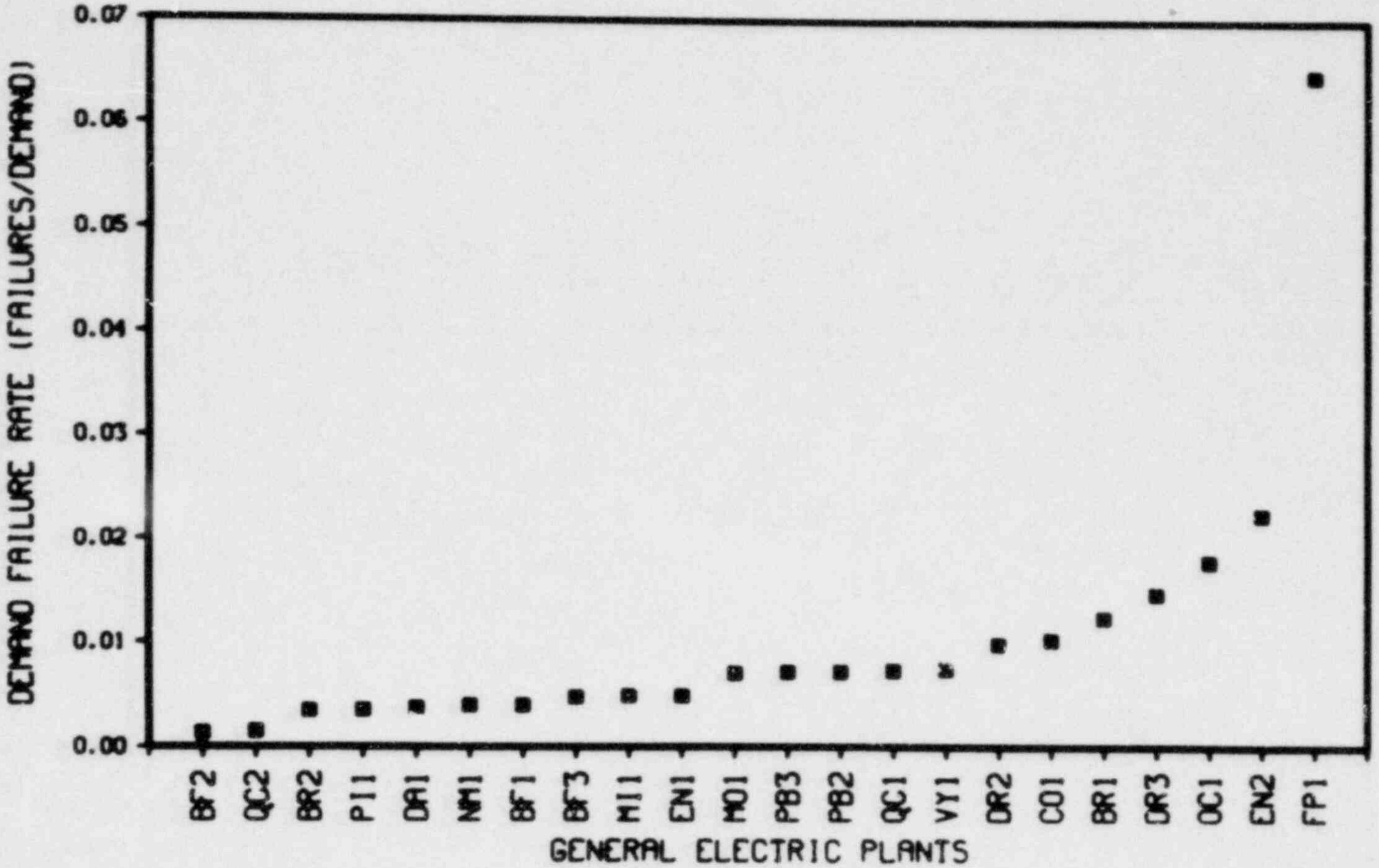

Figure 5c. Scatter plot of demand LER rates for "Valve--Operator (Motor)--Fail to Operate (Command Faults Included)" in General Electric plants.

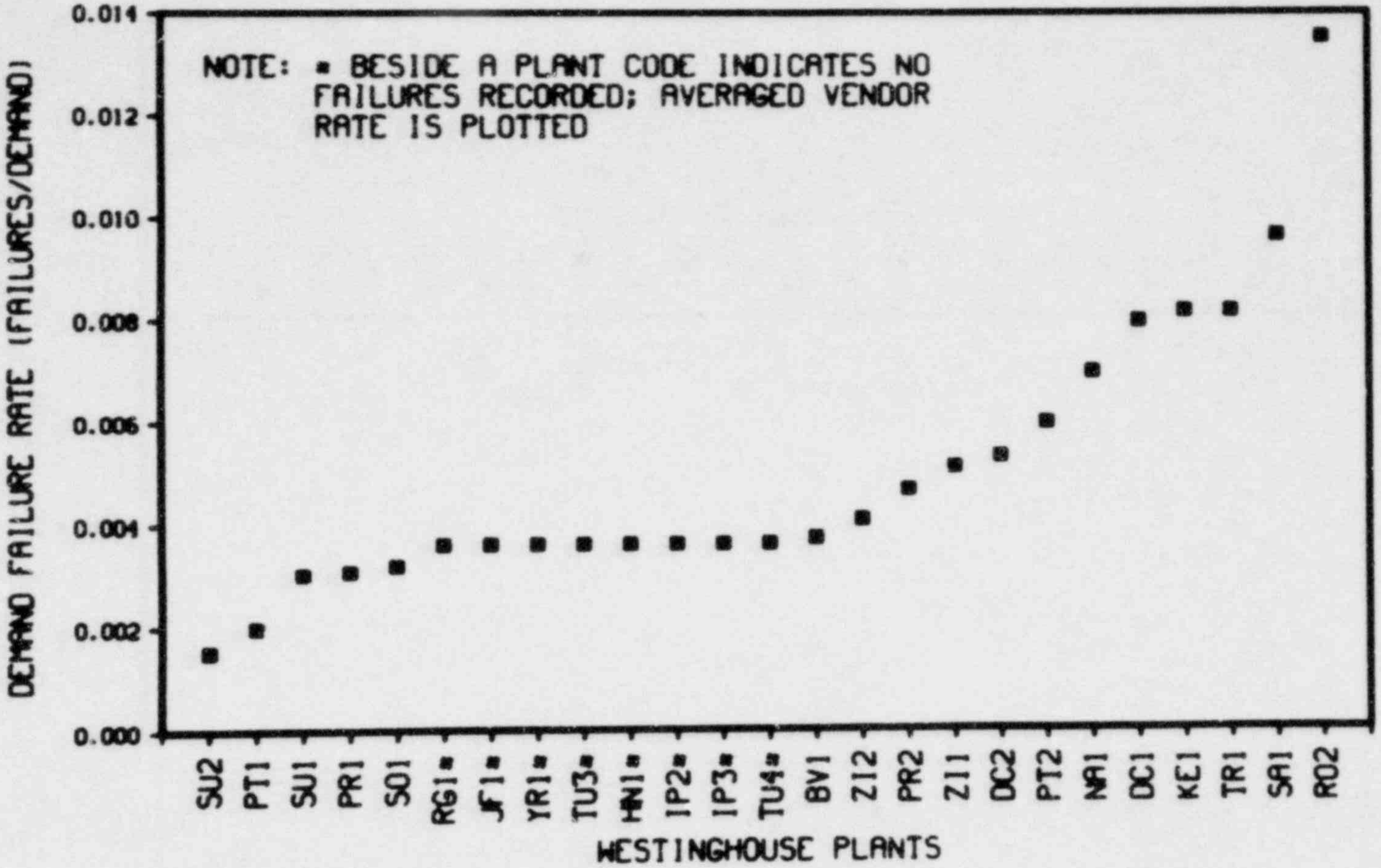

Figure 5d. Scatter plot of demand LER rates for "Valve--Operator (Motor)--Fail to Operate (Command Faults Included)" in Westinghouse plants.

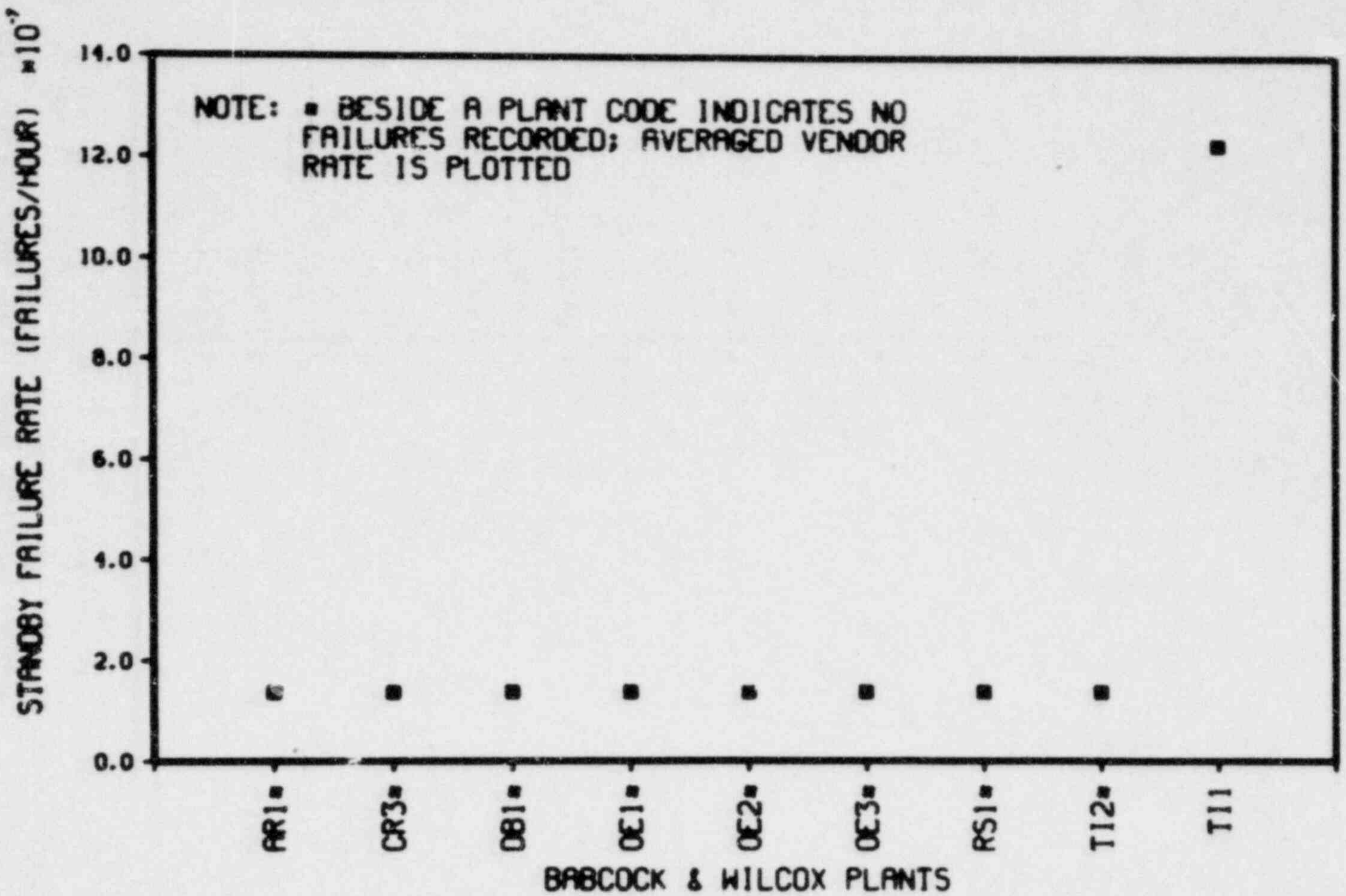

Figure 6a. Scatter plot of standby LER rates for "Valve--Operator (Motor)--Leak Externally" in Babcock & Wilcox plants.

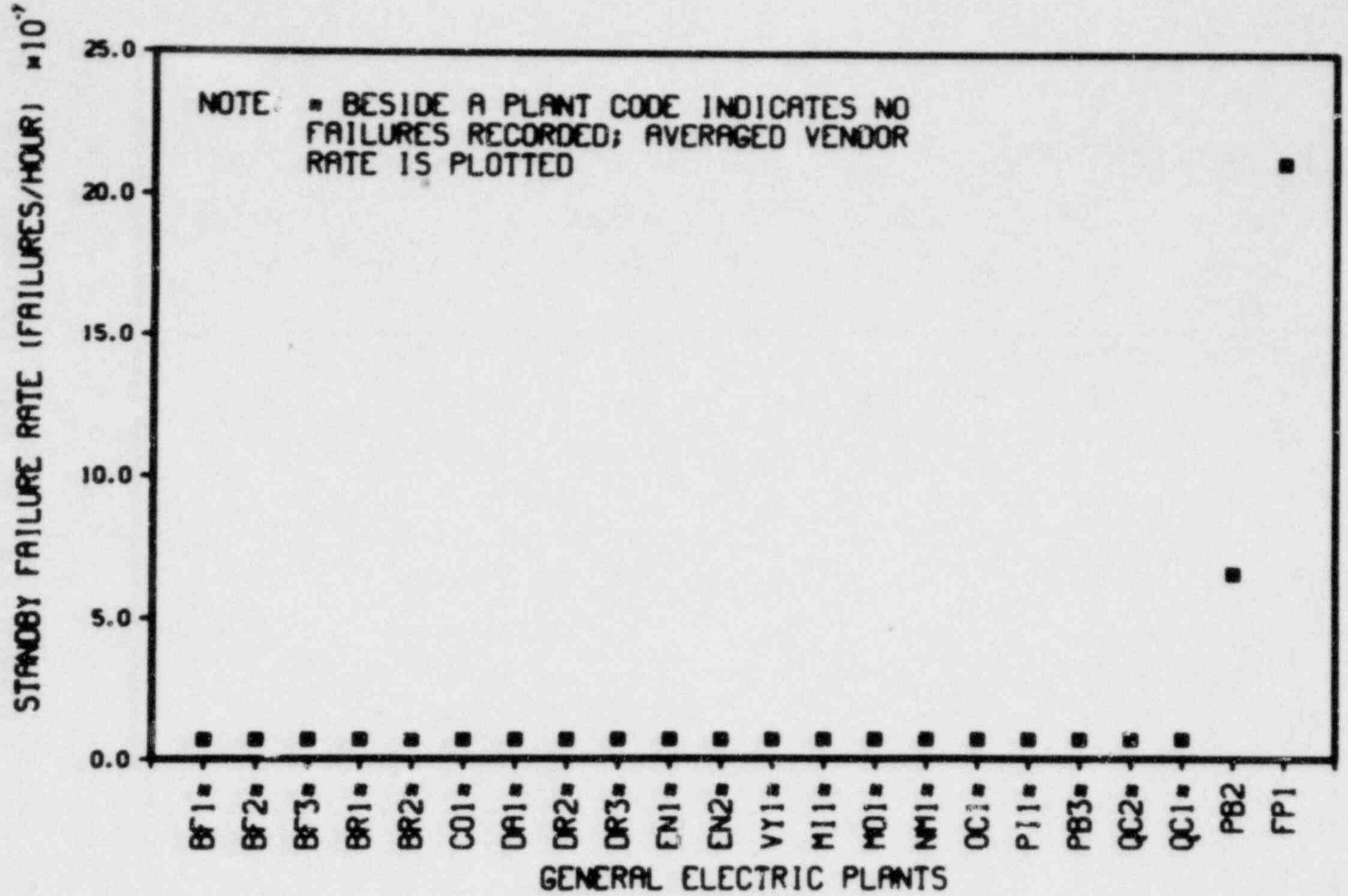

Figure 6b. Scatter plot of standby LER rates for "Valve--Operator (Motor)--Leak Externally" in General Electric plants.

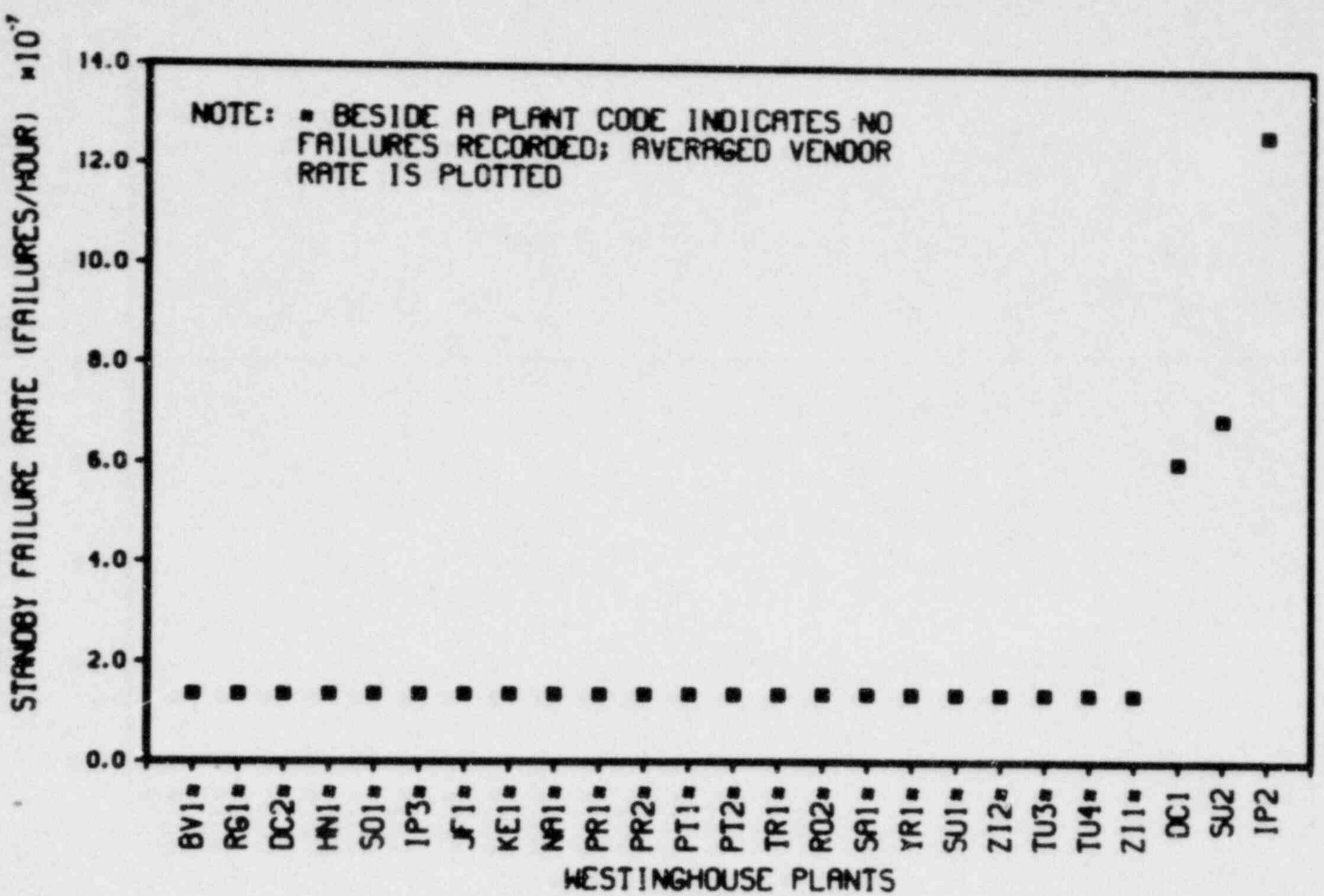

Figure 6c. Scatter plot of standby LER rates for "Valve--Operator (Motor)--Leak Externally" in Westinghouse plants.

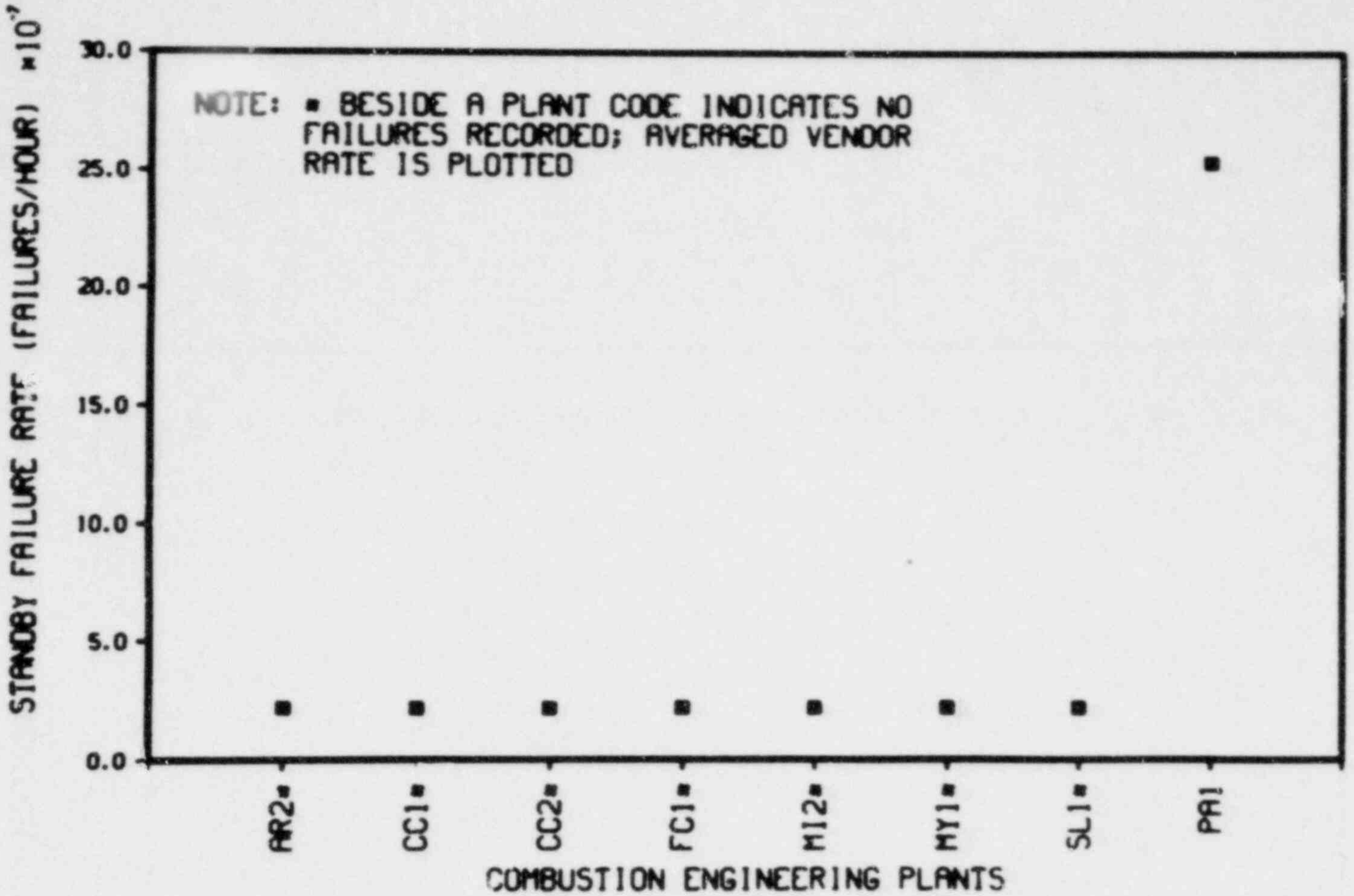

Figure 7a. Scatter plot of standby LER rates for "Valve--Operator (Motor)--Plugged (Command Faults Included)" in Combustion Engineering plants.

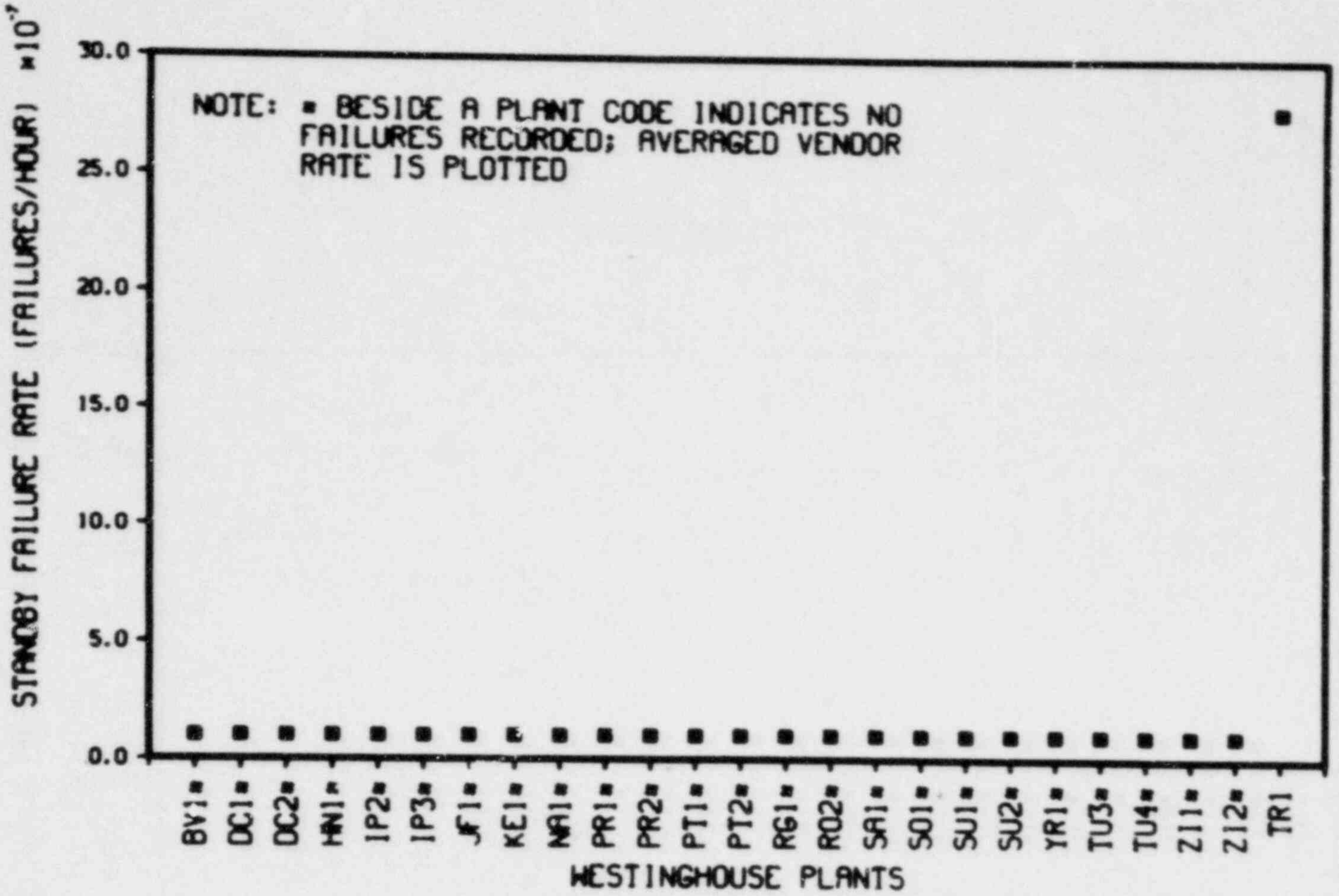

Figure 7b. Scatter plot of standby LER rates for "Valve--Operator (Motor)--Plugged (Command Faults Included)" in Westinghouse plants.

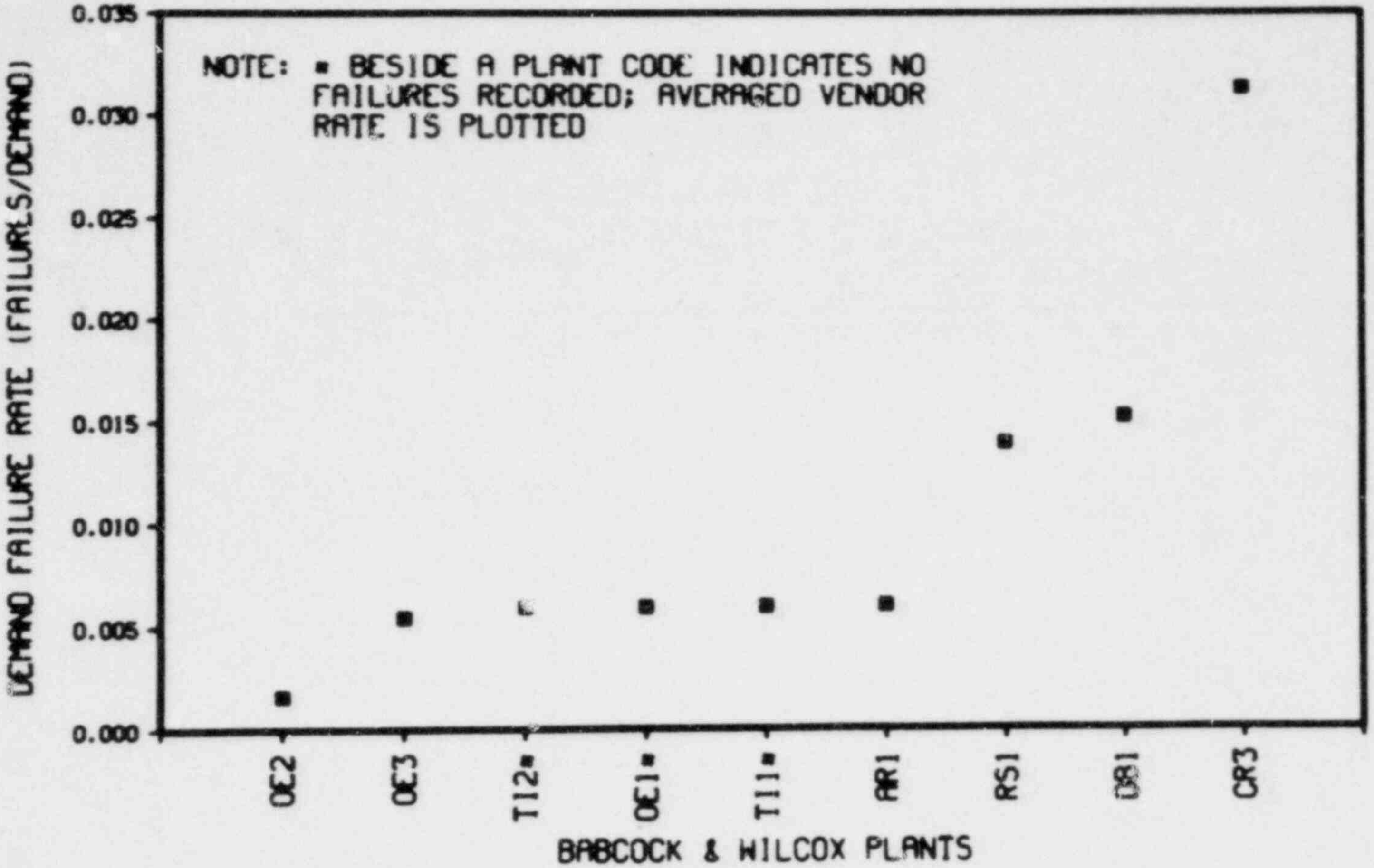

Figure 8a. Scatter plot of demand LER rates for "Valve--Operator (Unknown Remote & Motor)--Fail to Operate" in Babcock & Wilcox plants.

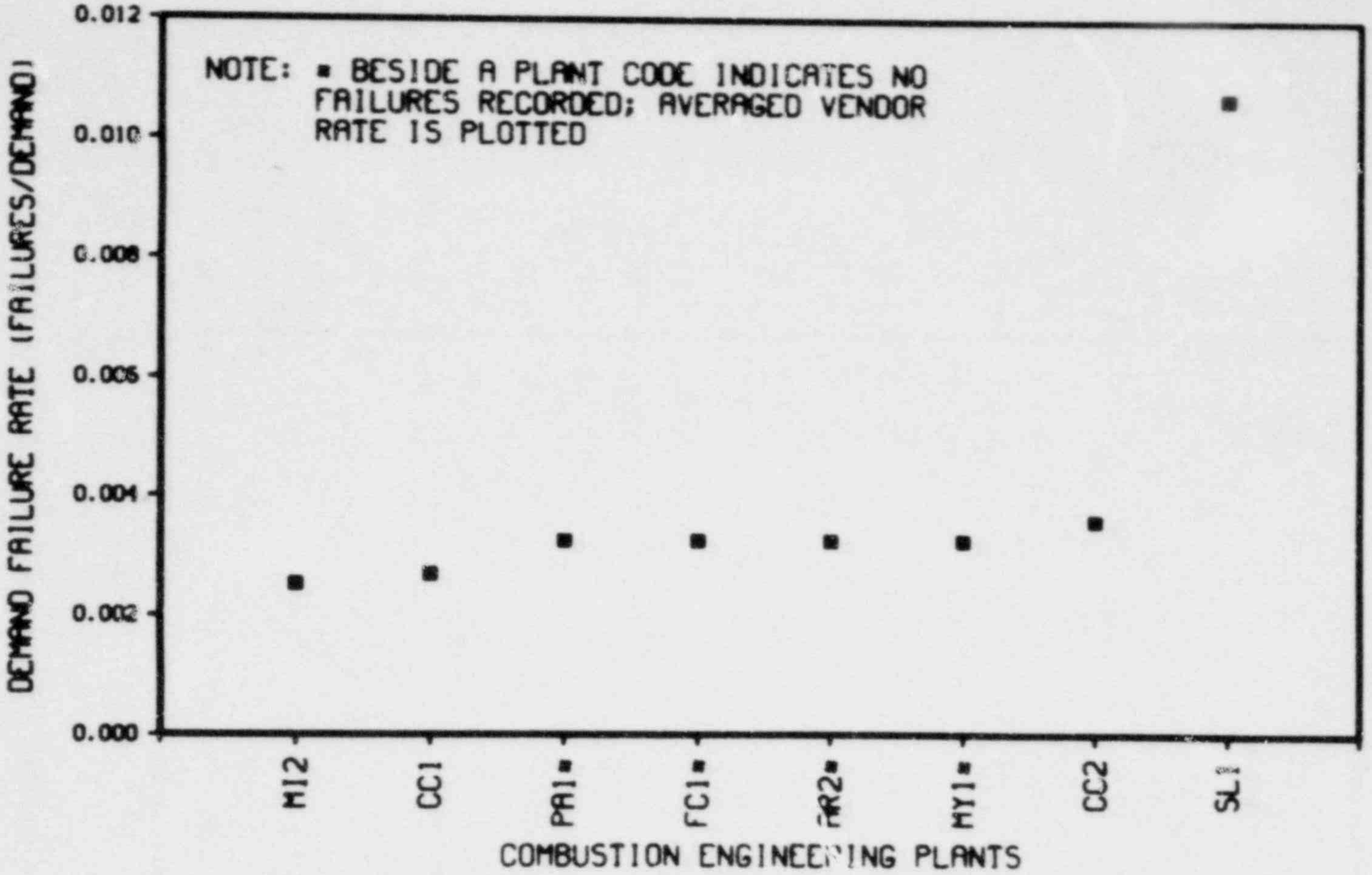

Figure 8b. Scatter plot of demand LER rates for "Valve--Operator (Unknown Remote & Motor)--Fail to Operate" in Combustion Engineering plants.

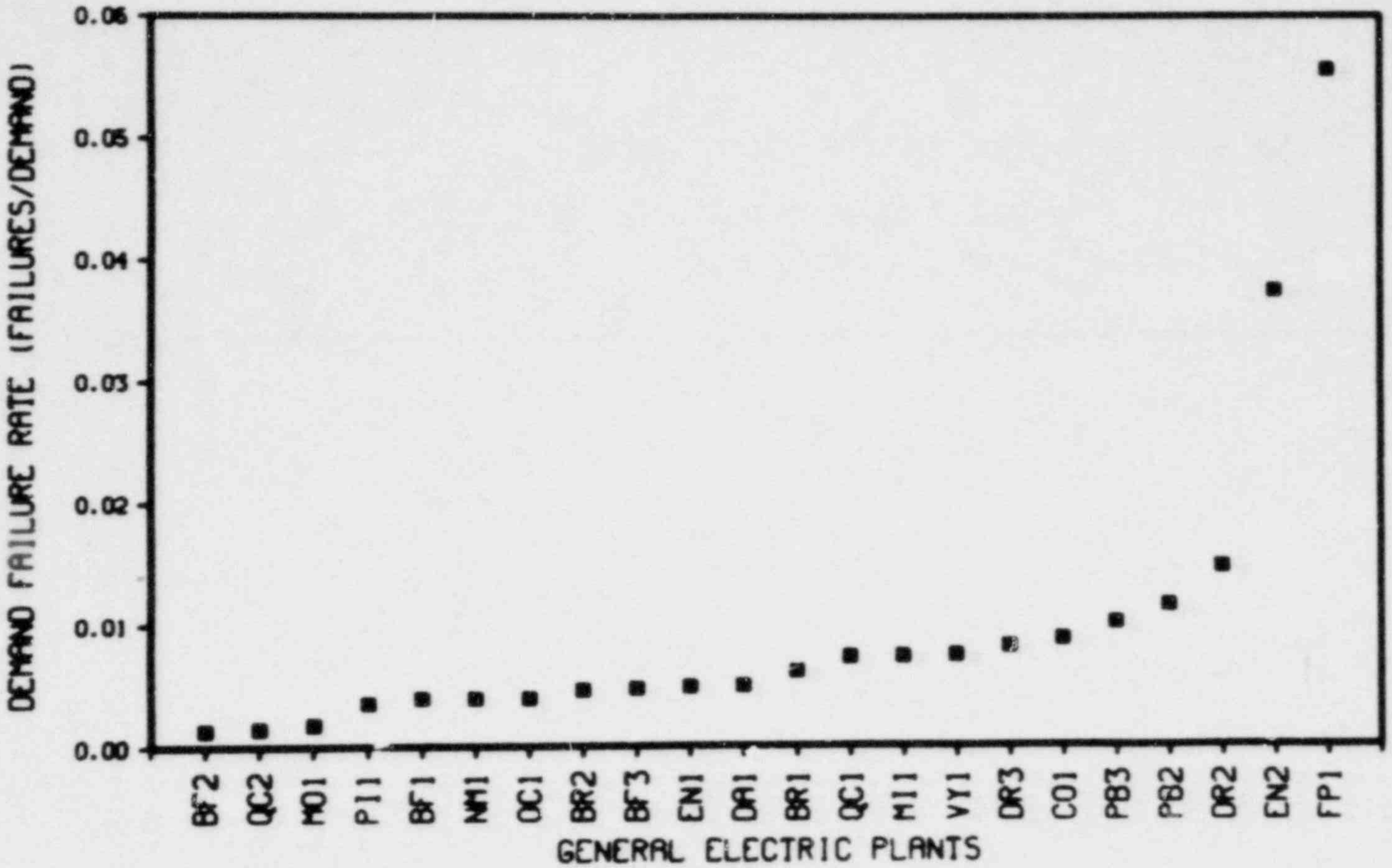

Figure 8c. Scatter plot of demand LER rates for "Valve--Operator (Unknown Remote & Motor)--Fail to Operate" in General Electric plants.

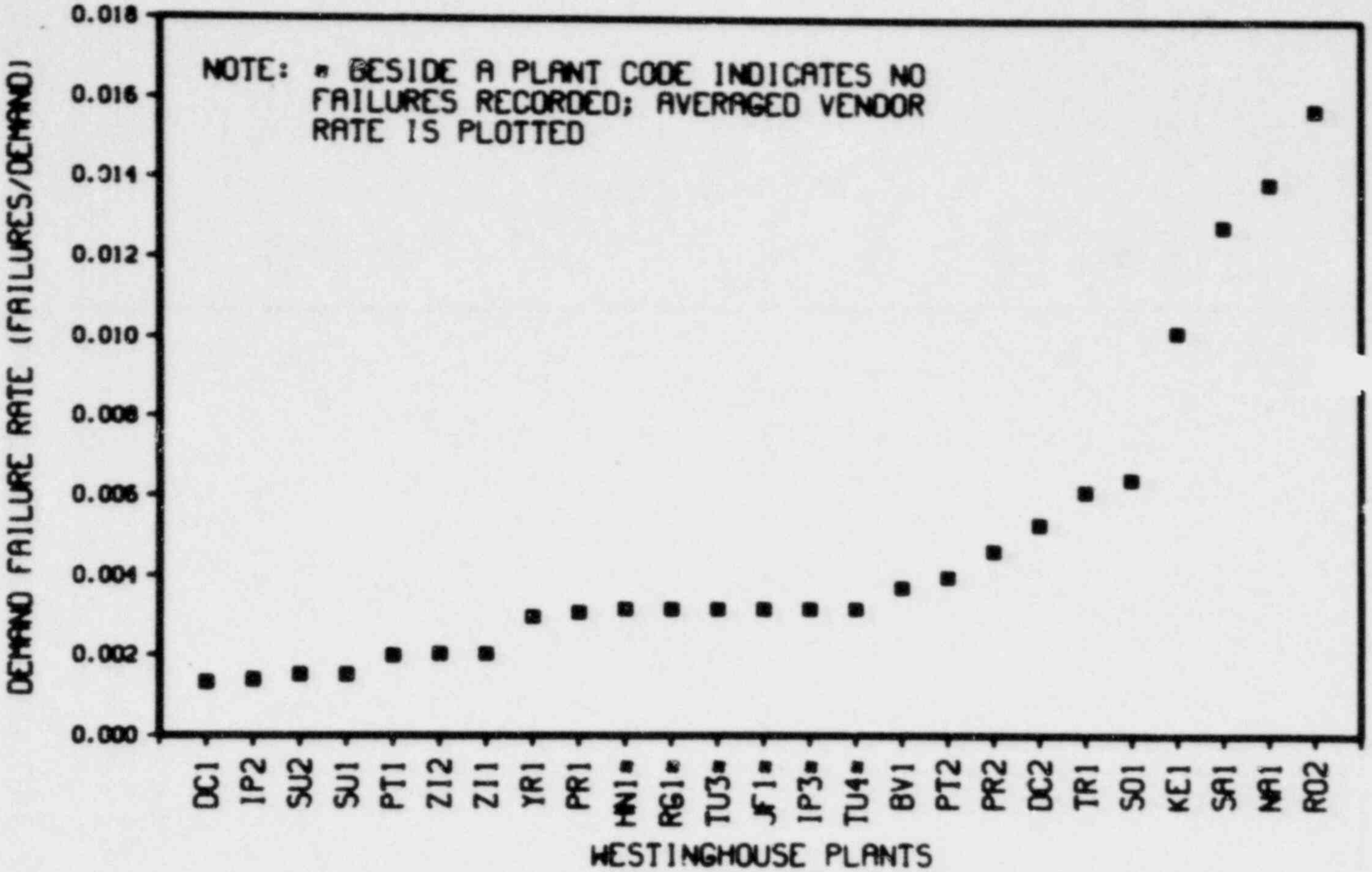

Figure 8d. Scatter plot of demand LER rates for "Valve--Operator (Unknown Remote & Motor)--Fail to Operate" in Westinghouse plants.

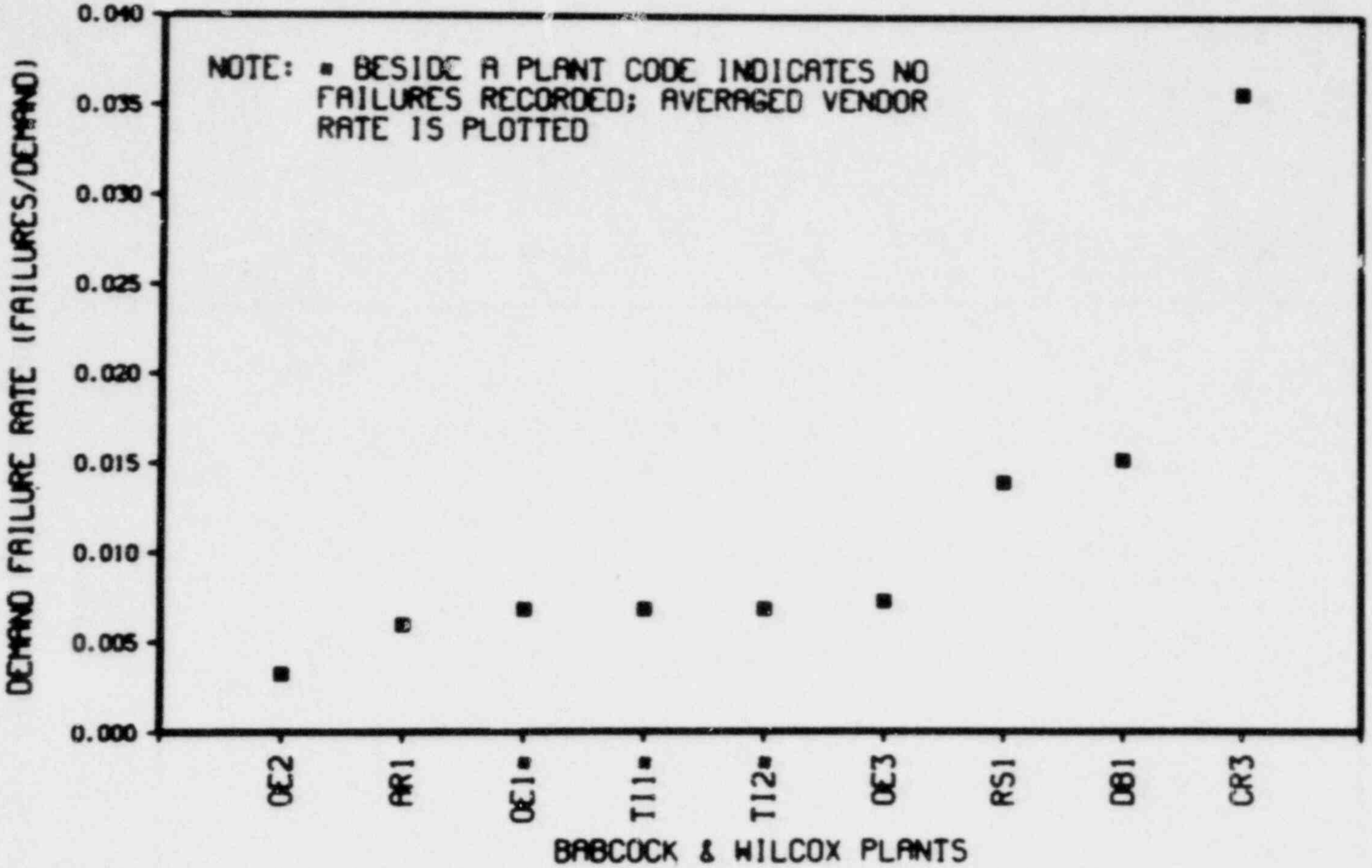

Figure 9a. Scatter plot of demand LER rates for "Valve--Operator (Unknown Remote & Motor)--Fail to Operate (Command Faults)" in Babcock & Wilcox plants.

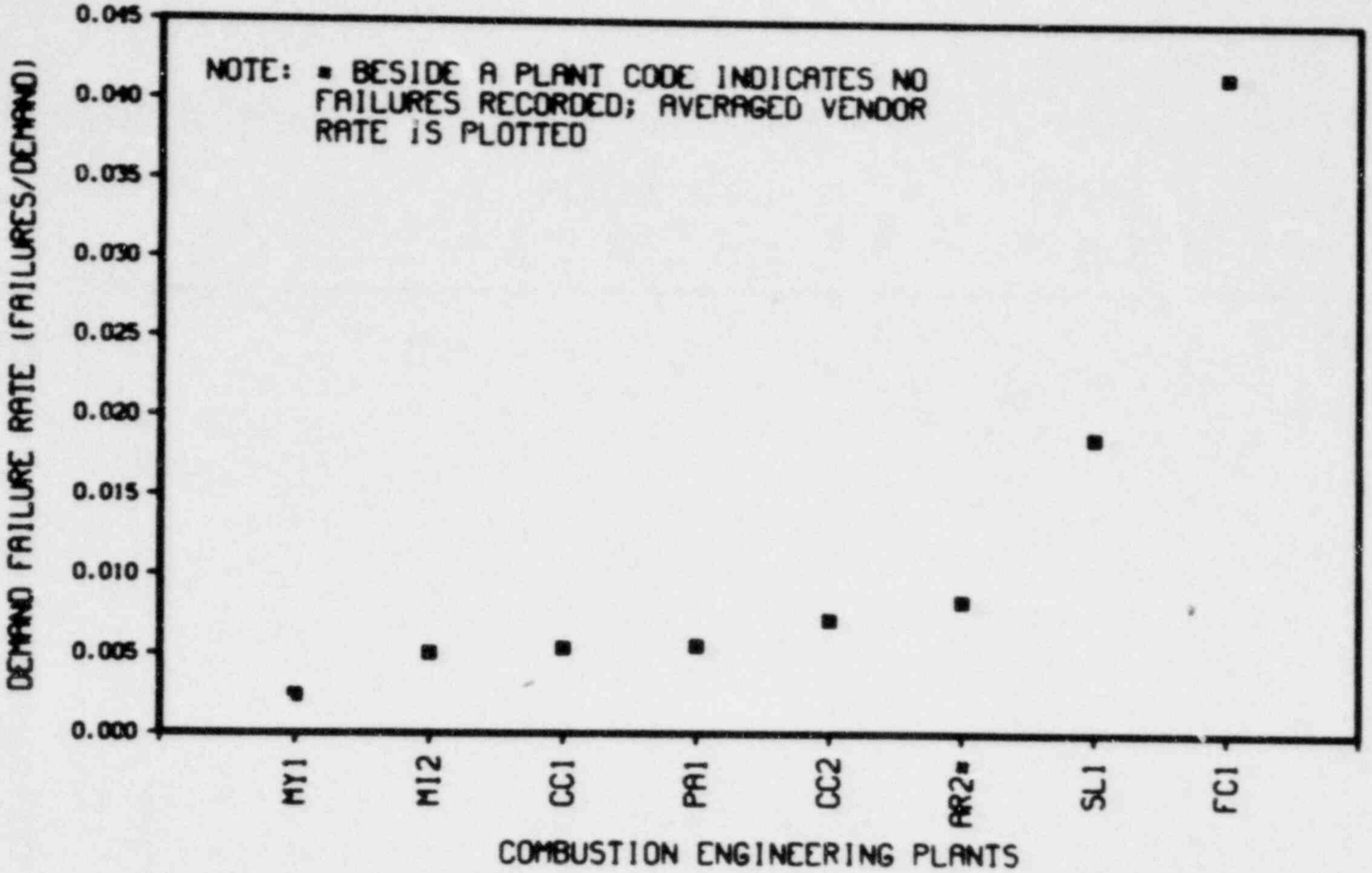

Figure 9b. Scatter plot of demand LER rates for "Valve--Operator (Unknown Remote & Motor)--Fail to Operate (Command Faults)" in Combustion Engineering plants.

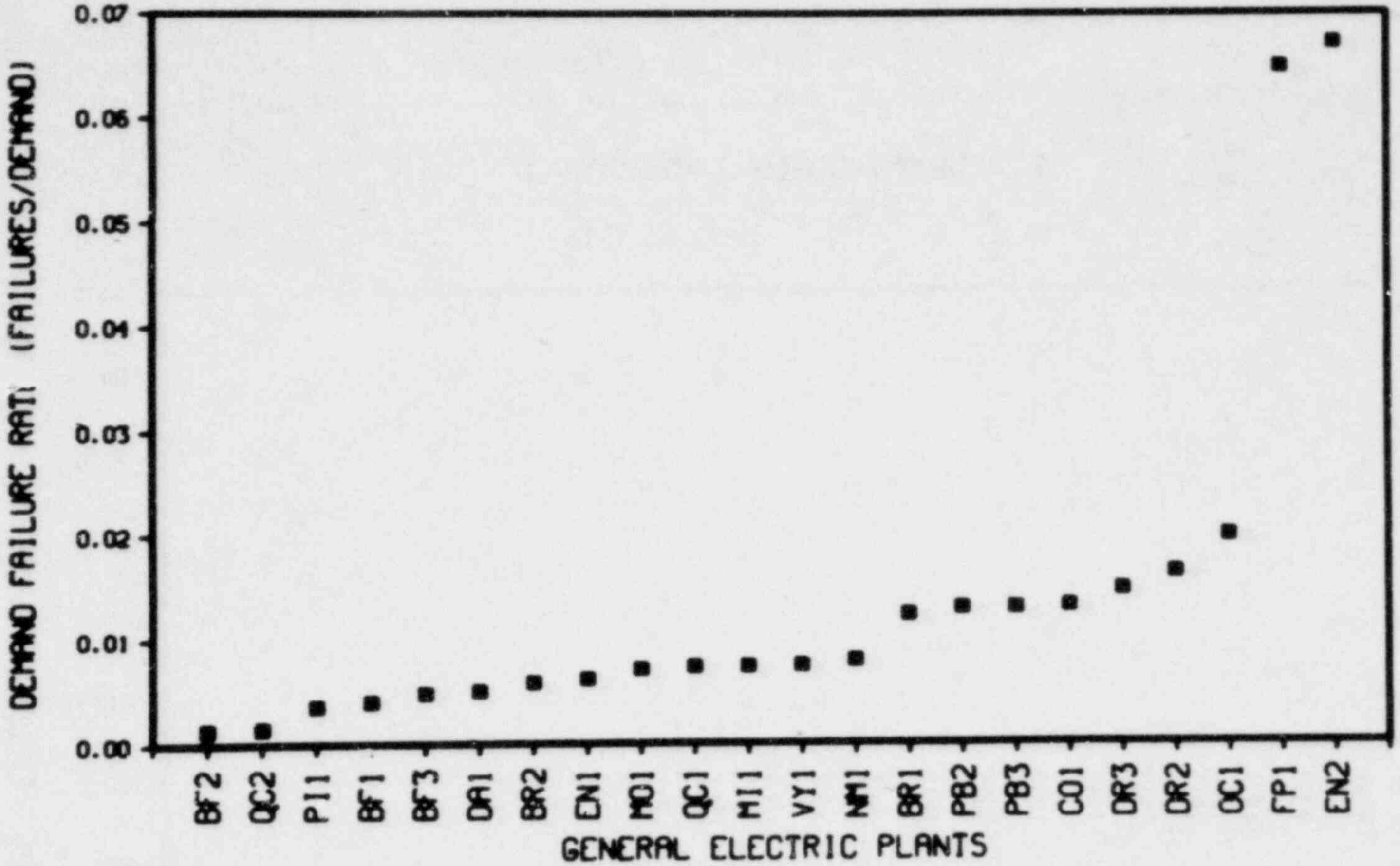

Figure 9c. Scatter plot of demand LER rates for "Valve--Operator (Unknown Remote & Motor)--Fail to Operate (Command Faults)" in General Electric plants.

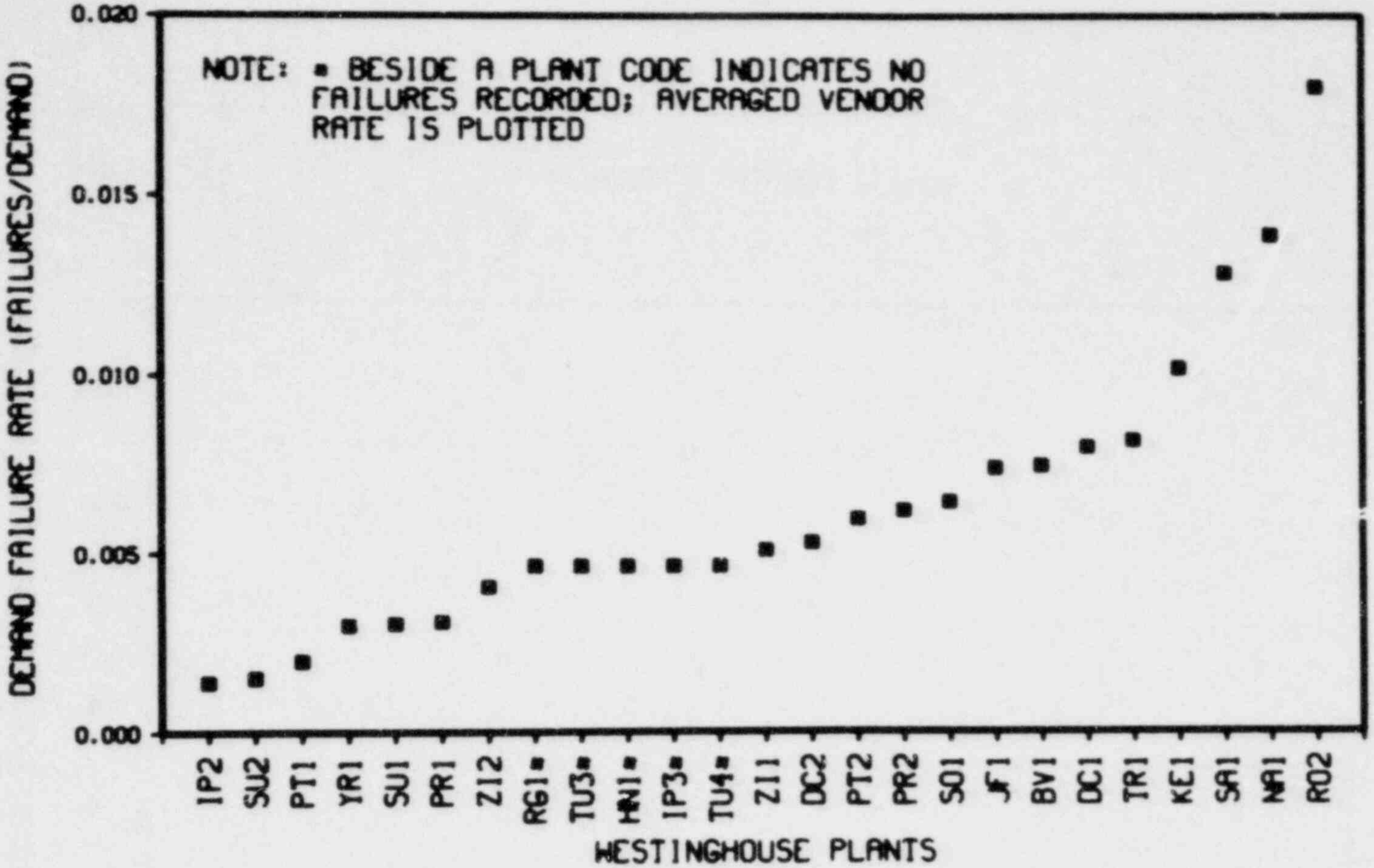

Figure 9d. Scatter plot of demand LER rates for "Valve--Operator (Unknown Remote & Motor)--Fail to Operate (Command Faults)" in Westinghouse plants.

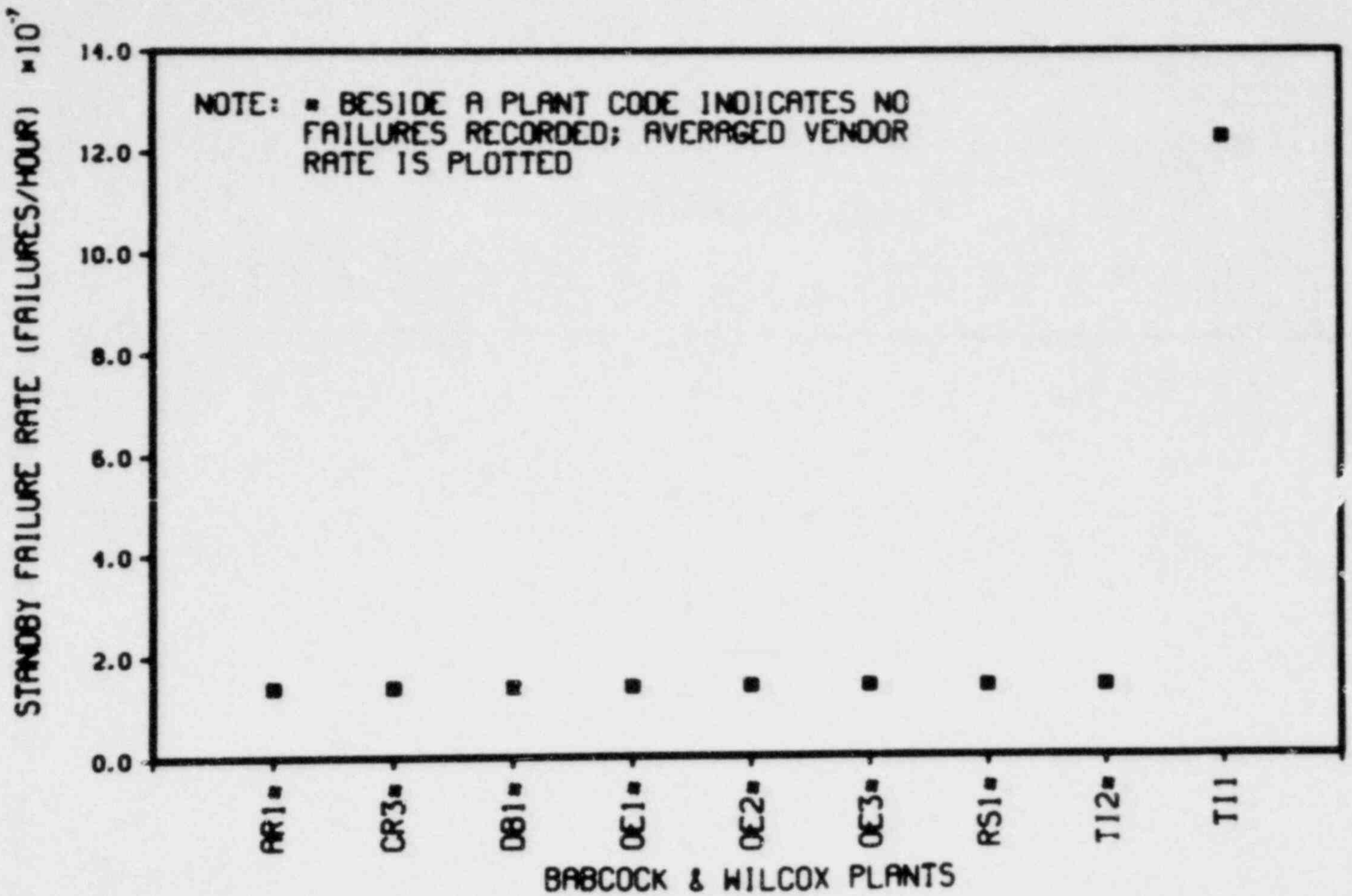

Figure 10a. Scatter plot of standby LER rates for "Valve--Operator (Unknown Remote & Motor)--Leak Externally" in Babcock & Wilcox plants.

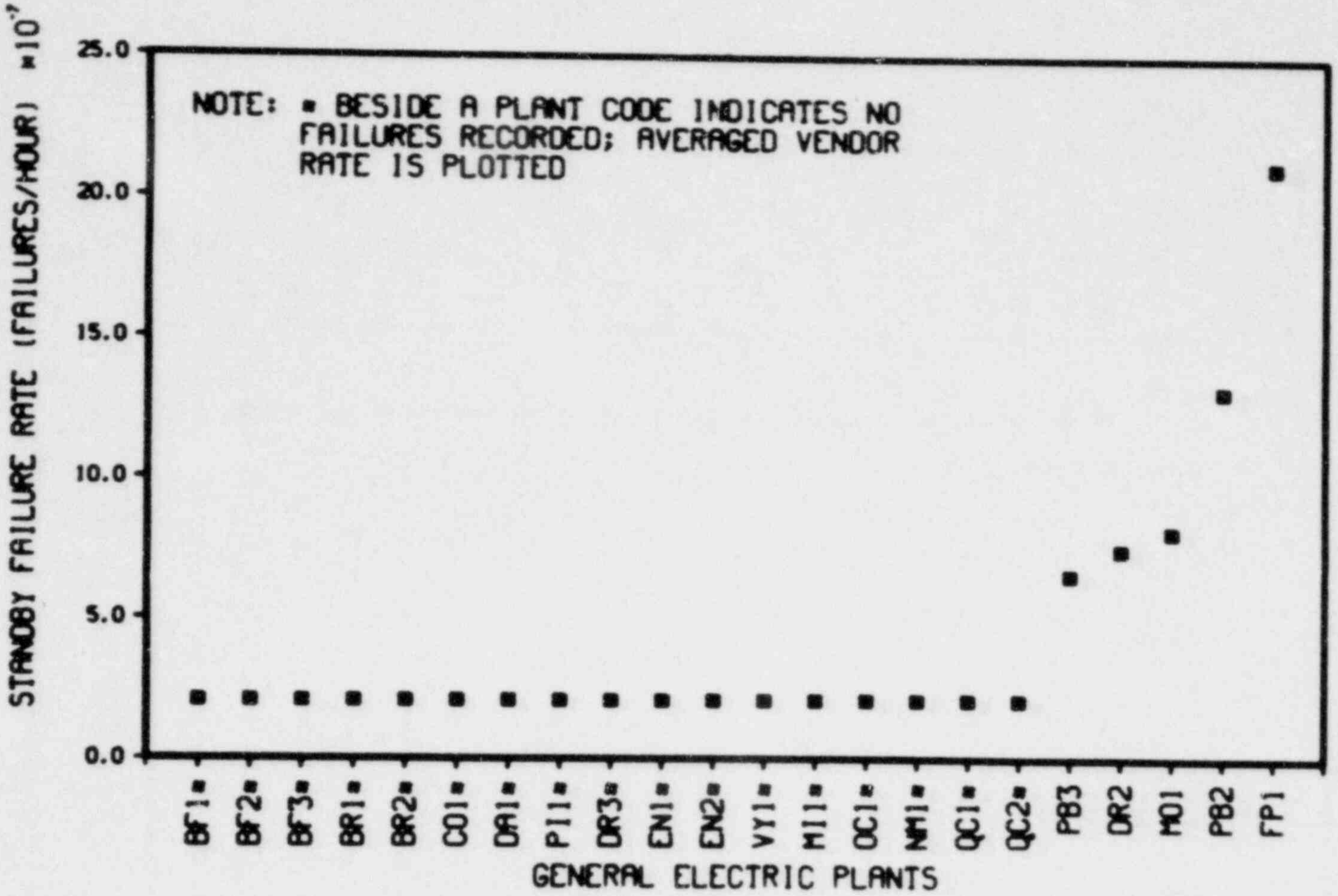

Figure 10b. Scatter plot of standby LER rates for "Valve--Operator (Unknown Remote & Motor)--Leak Externally" in General Electric plants.

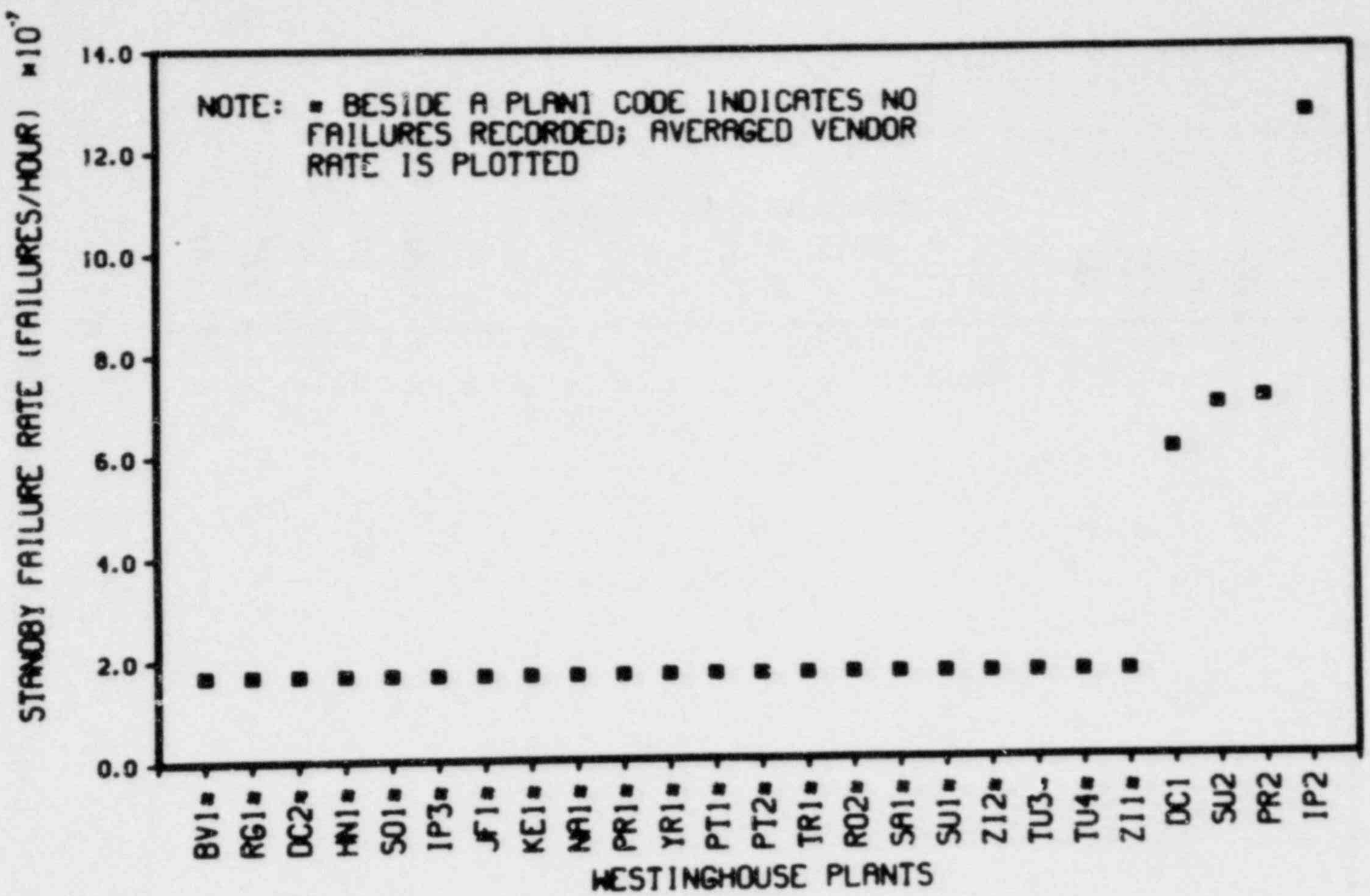

Figure 10c. Scatter plot of standby LER rates for "Valve--Operator (Unknown Remote & Motor)--Leak Externally" in Westinghouse plants.

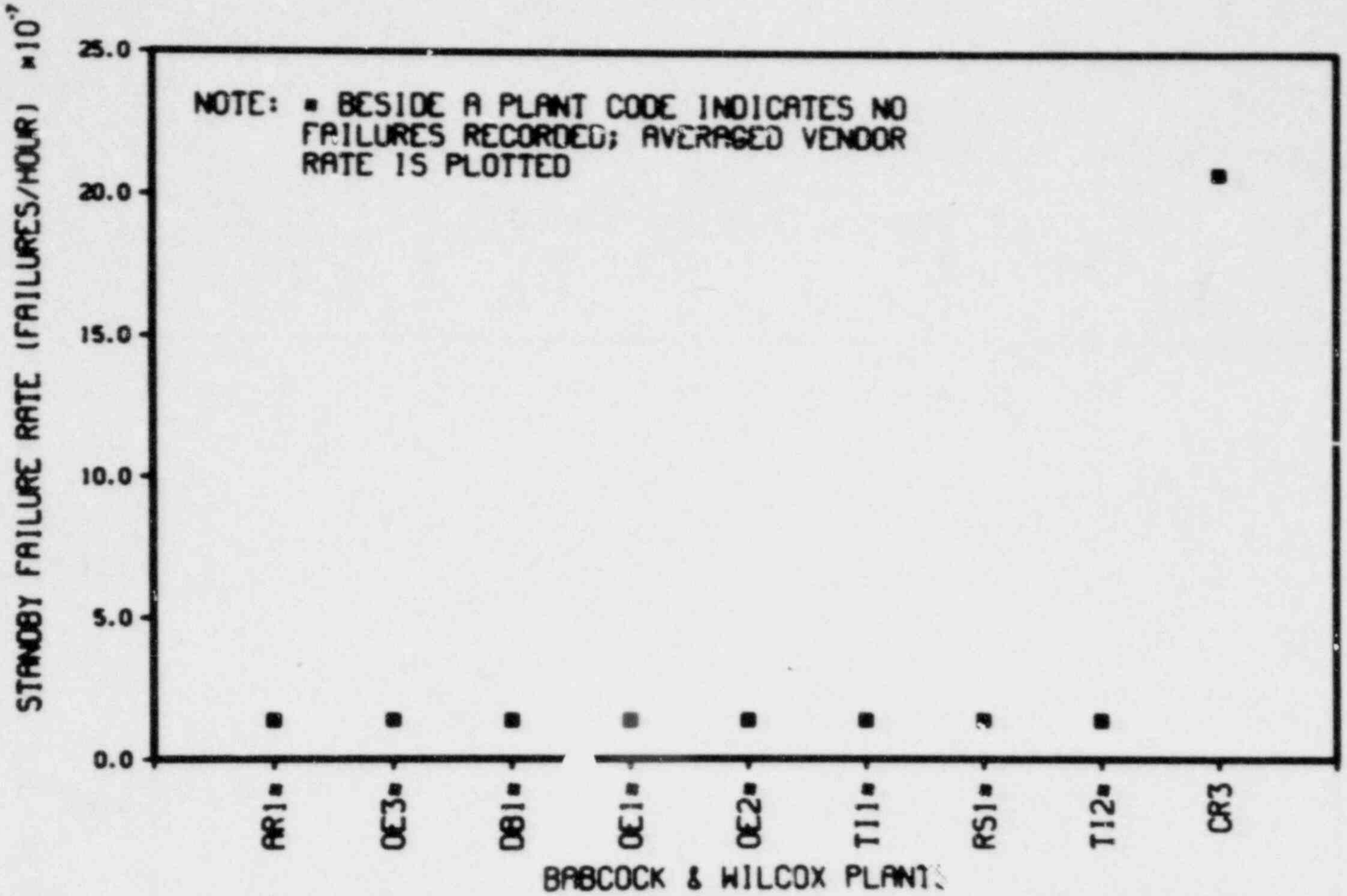

Figure 11a. Scatter plot of standby LER rates for "Valve--Operator (Unknown Remote & Motor)--Plugged (Command Faults)" in Babcock & Wilcox plants.

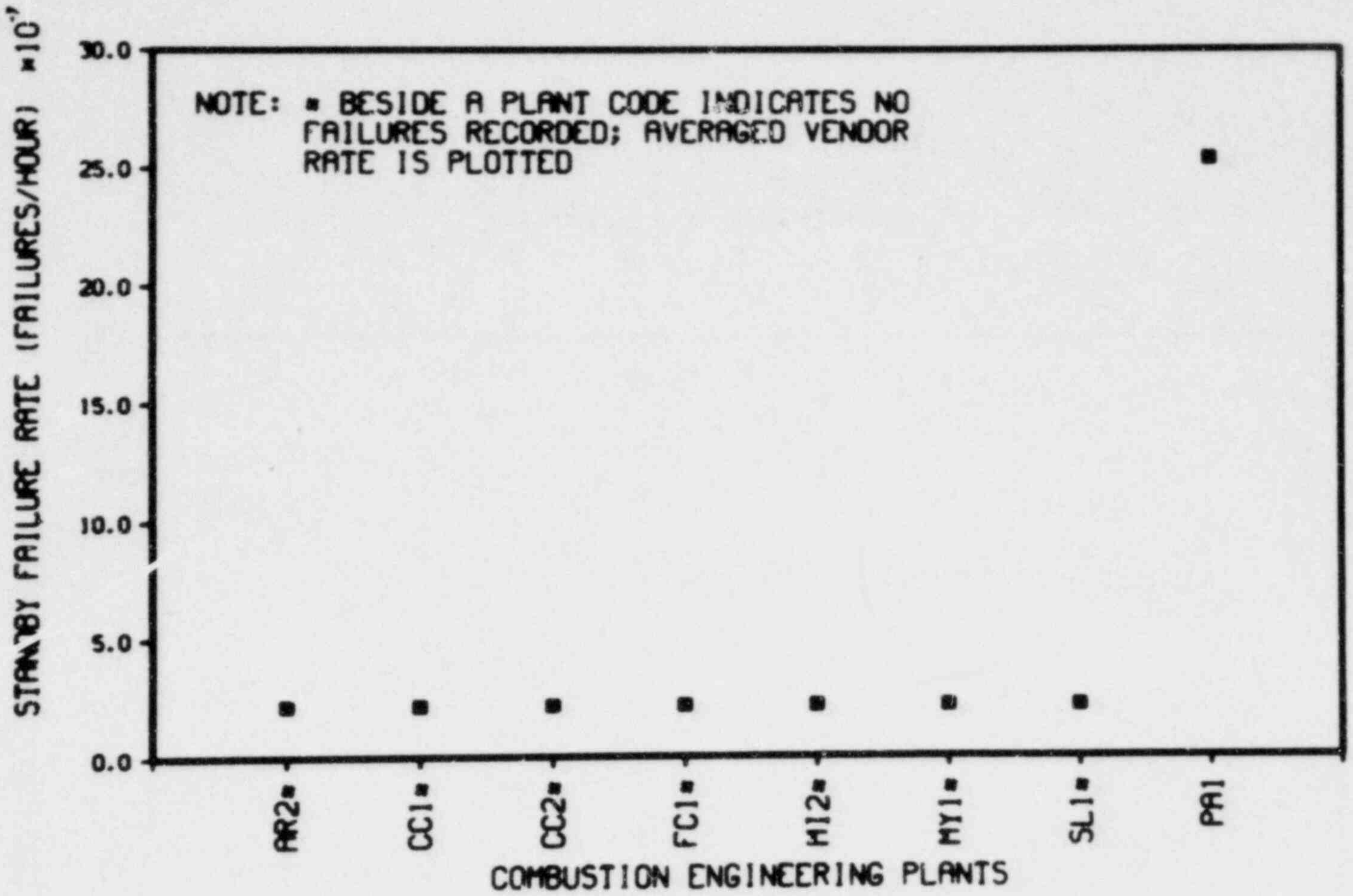

Figure 11b. Scatter plot of standby LER rates for "Valve--Operator (Unknown Remote & Motor)--Plugged (Command Faults)" in Combustion Engineering plants.

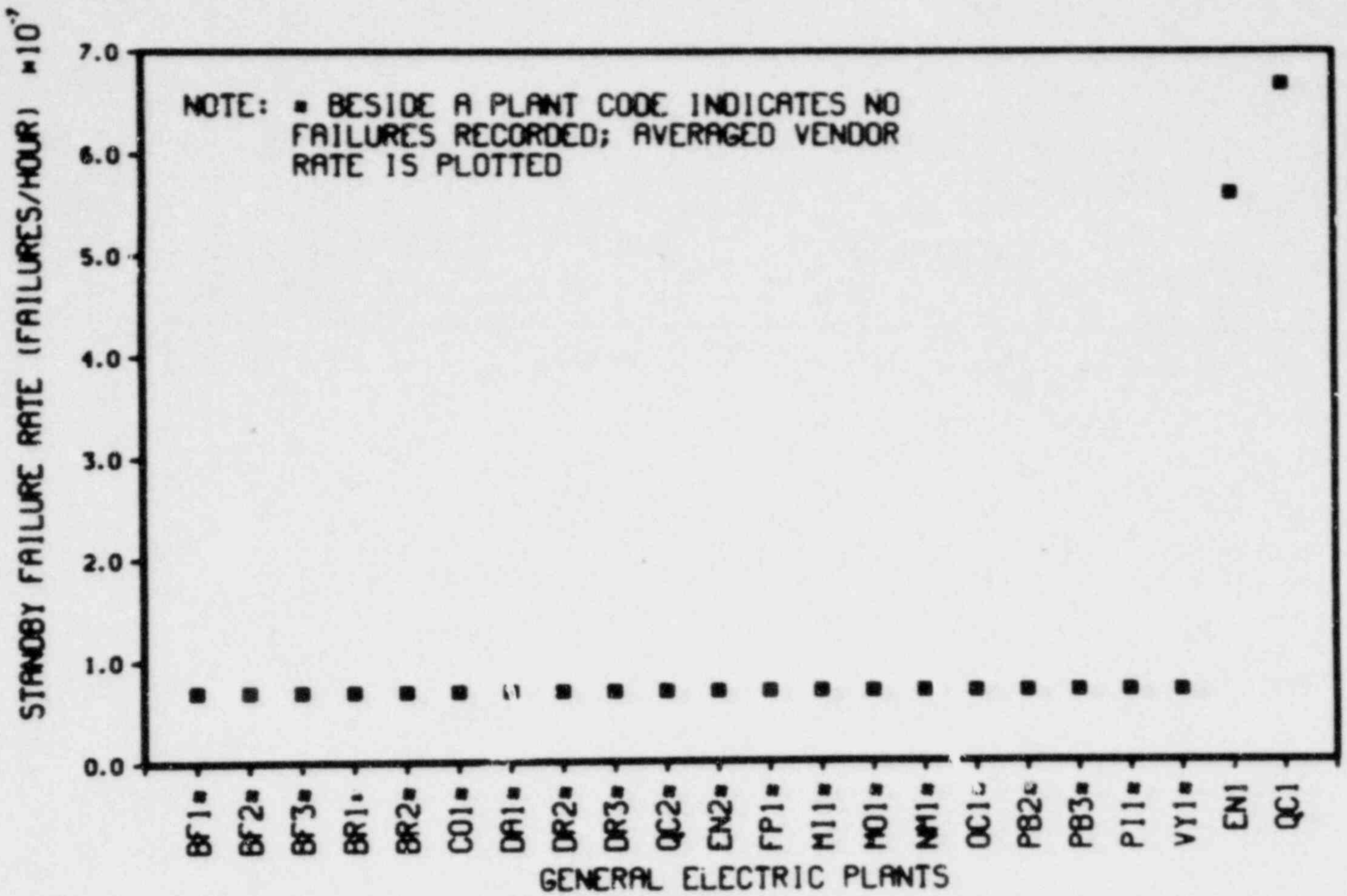

Figure 11c. Scatter plot of standby LER rates for "Valve--Operator (Unknown Remote & Motor)--Plugged (Command Faults)" in General Electric plants.

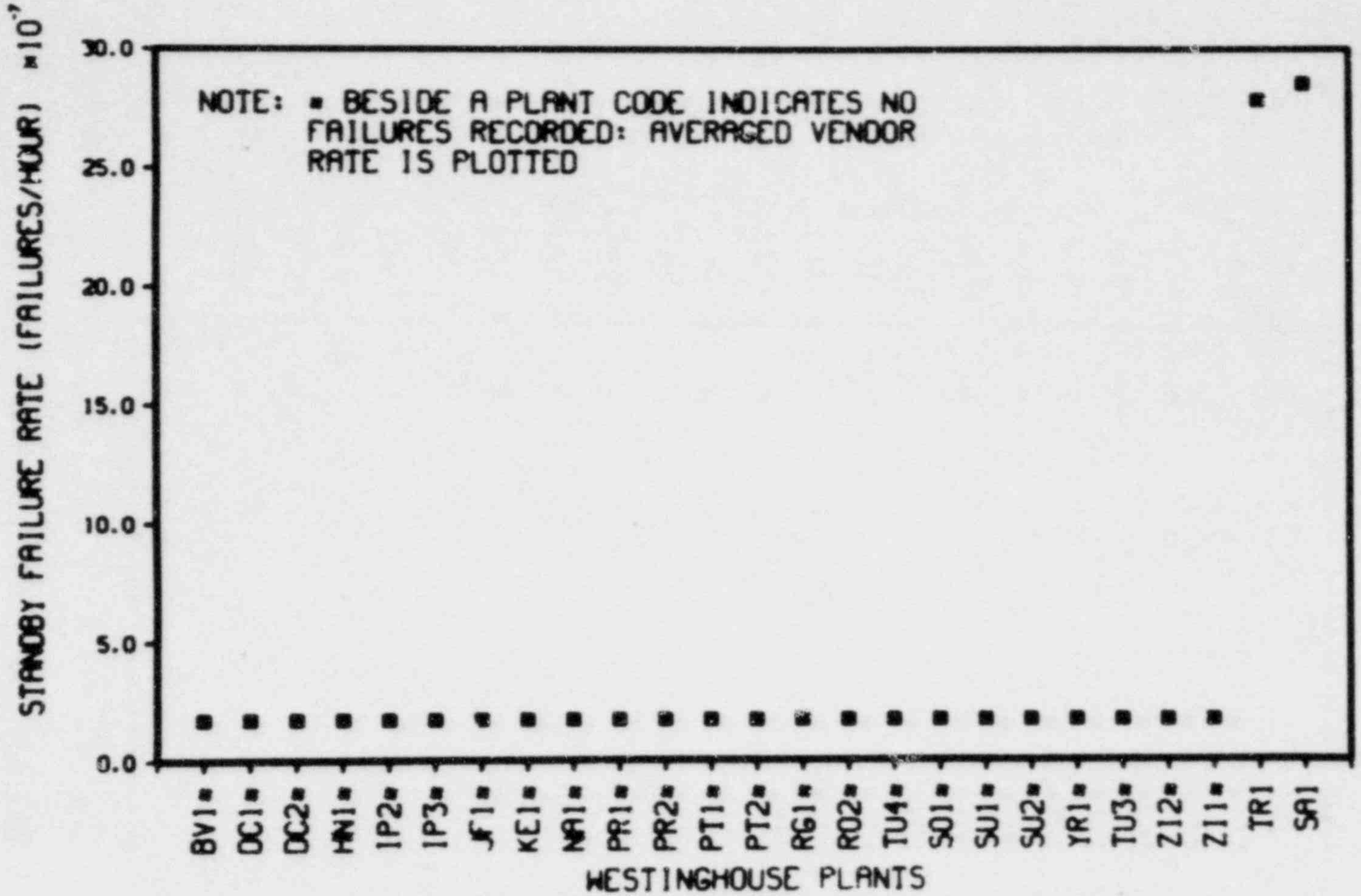

Figure 11d. Scatter plot of standby LER rates for "Valve--Operator (Unknown Remote & Motor)--Plugged (Command Faults)" in Westinghouse plants.

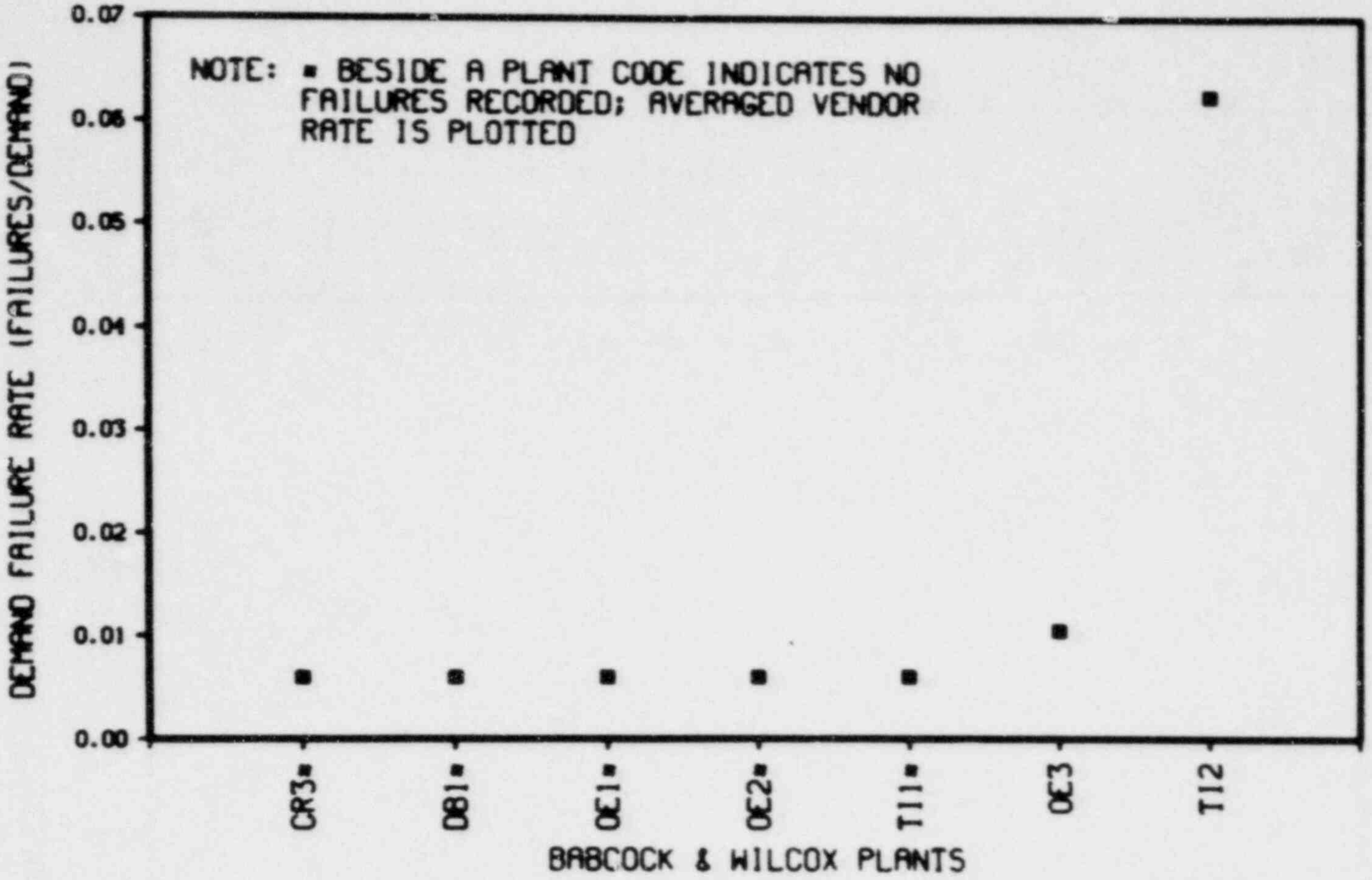

Figure 12a. Scatter plot of demand LER rates for "Valve--Operator (Air)--Fail to Operate" in Babcock & Wilcox plants.

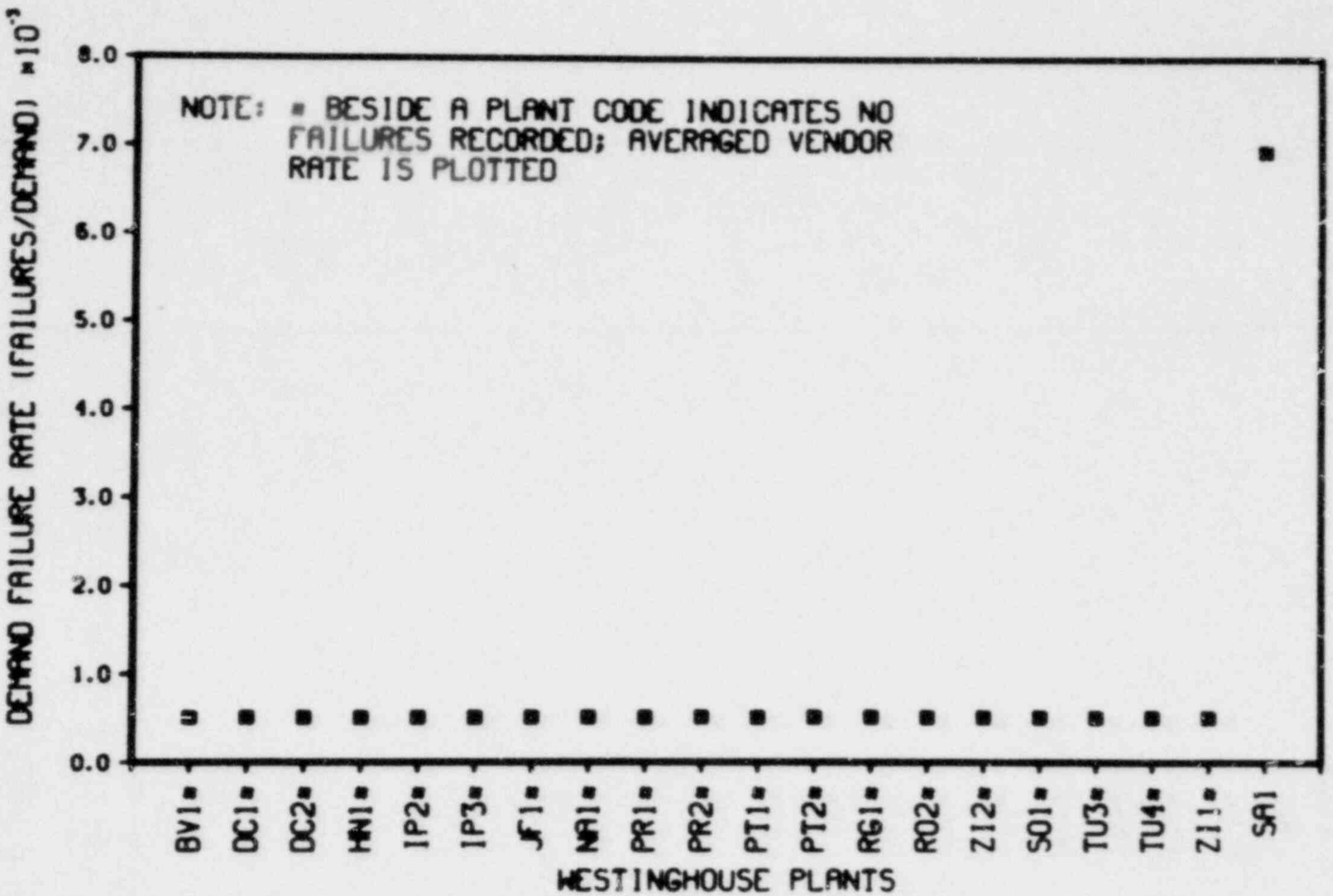

Figure 12b. Scatter plot of demand LER rates for "Valve--Operator (Air)--Fail to Operate" in Westinghouse plants.

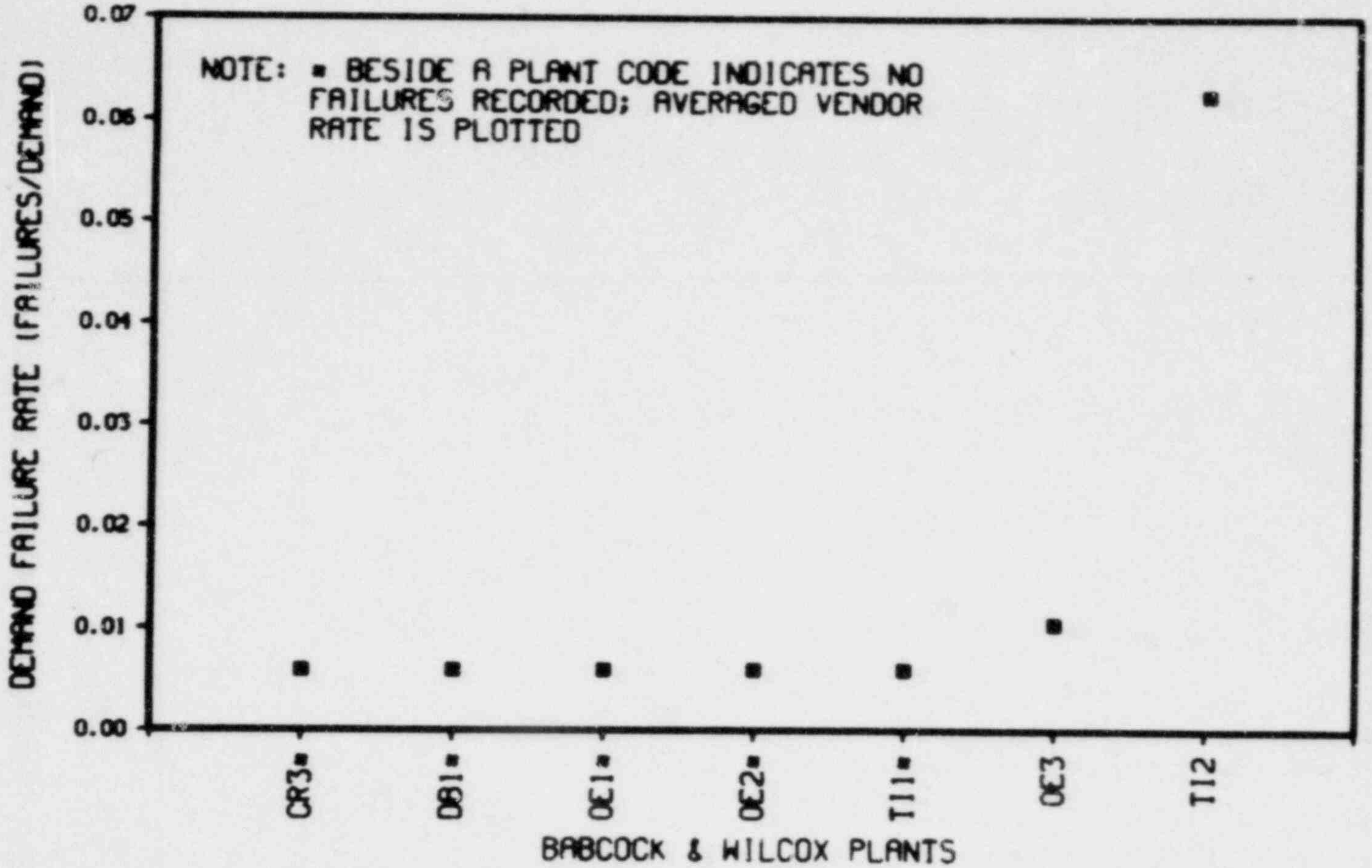

Figure 13a. Scatter plot of demand LER rates for "Valve--Operator (Air)--Fail to Operate (Command Faults Included)" in Babcock & Wilcox plants.

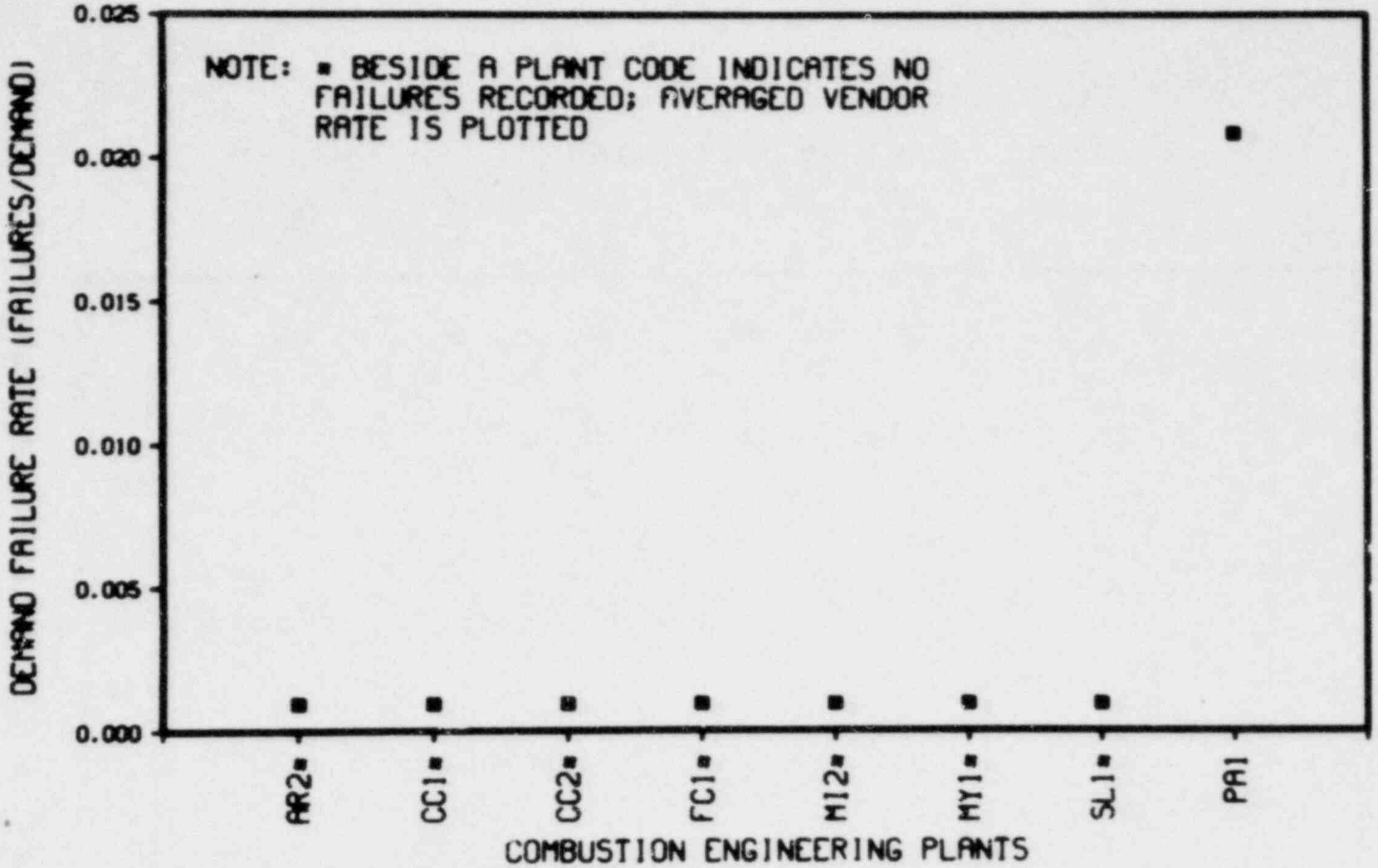

Figure 13b. Scatter plot of demand LER rates for "Valve--Operator (Air)--Fail to Operate (Command Faults Included)" in Combustion Engineering plants.

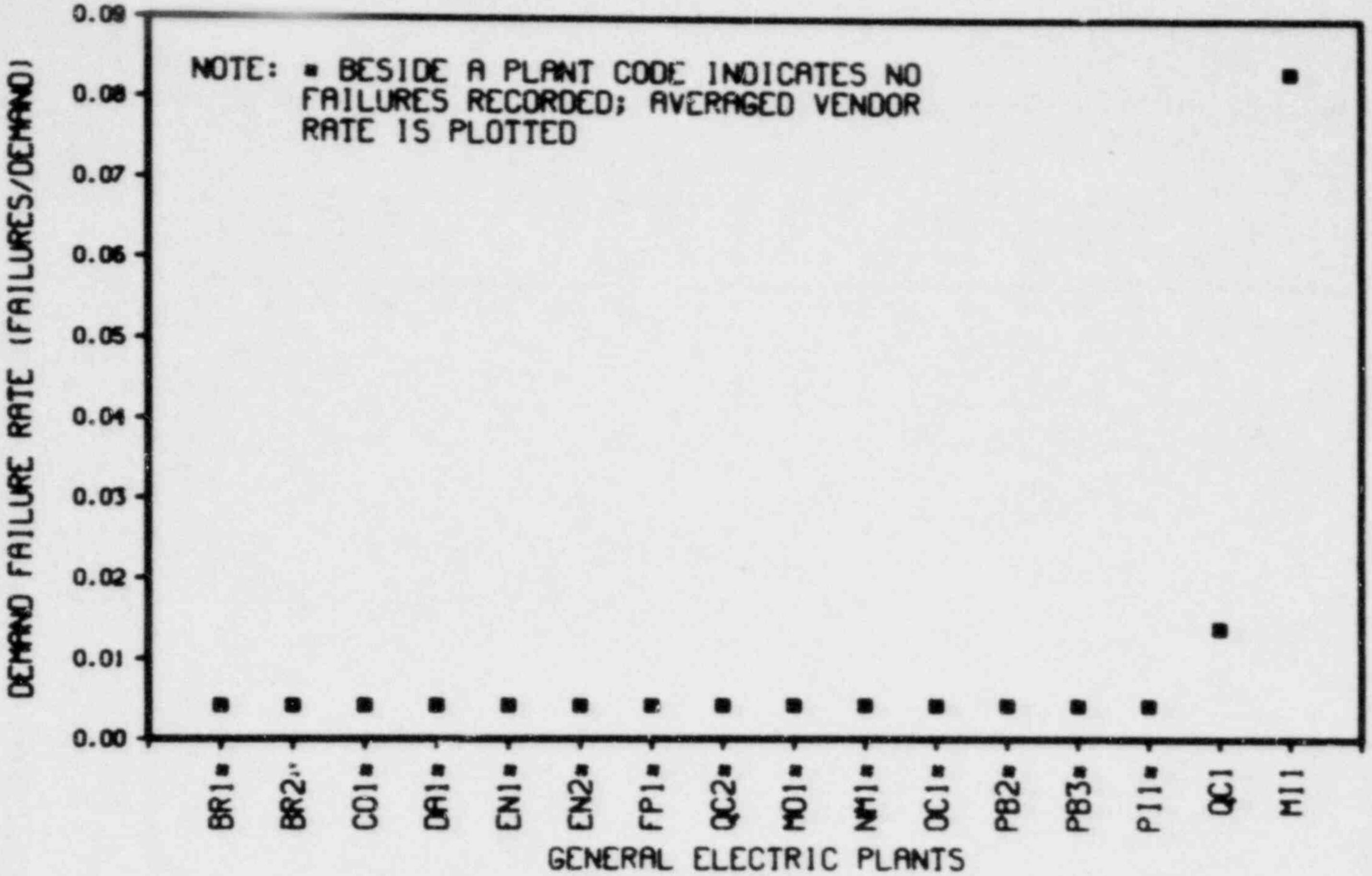

Figure 13c. Scatter plot of demand LER rates for "Valve--Operator (Air)--Fail to Operate (Command Faults Included)" in General Electric plants.

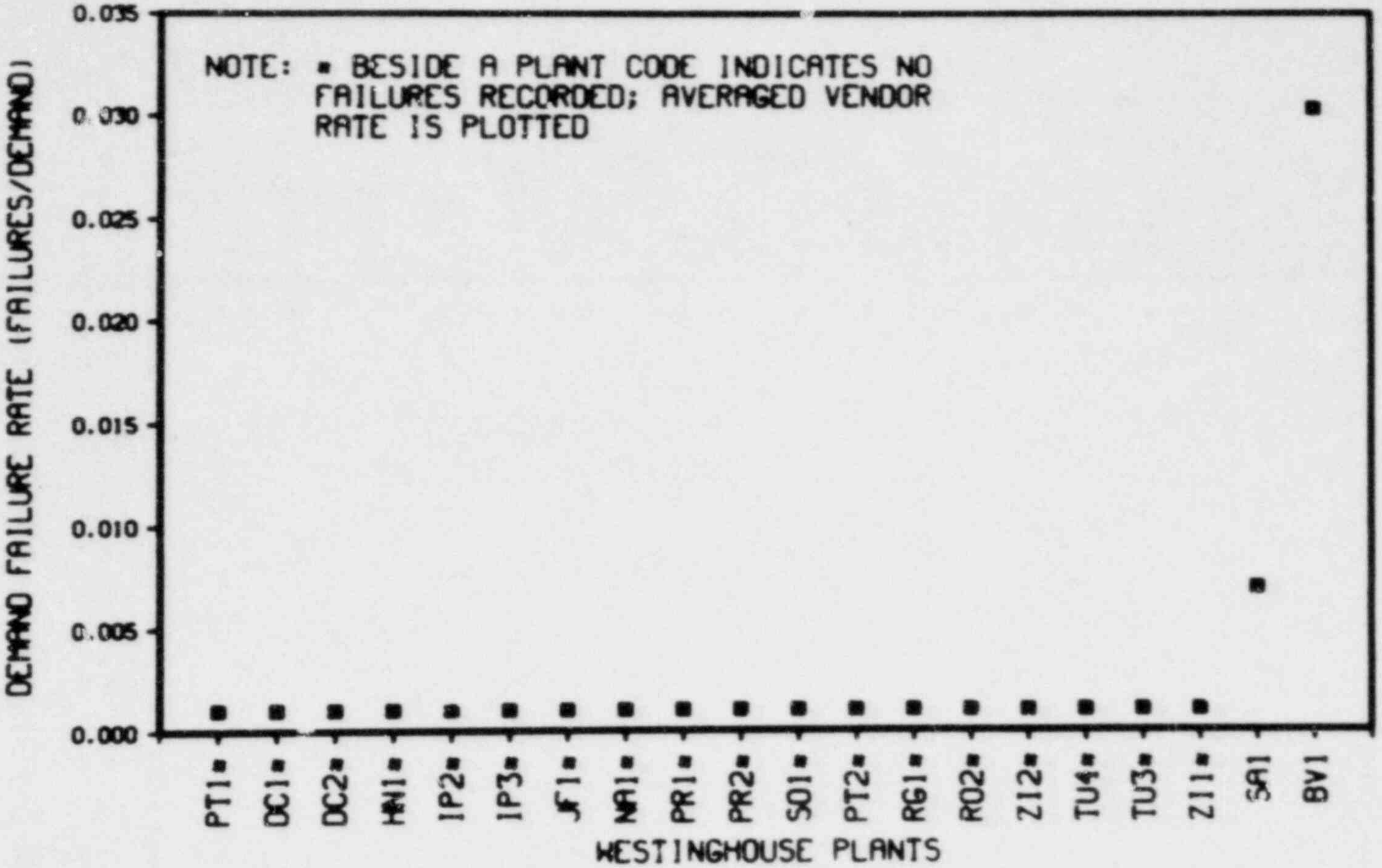

Figure 13d. Scatter plot of demand LER rates for "Valve--Operator (Air)--Fail to Operate (Command Fault Included)" in Westinghouse plants.

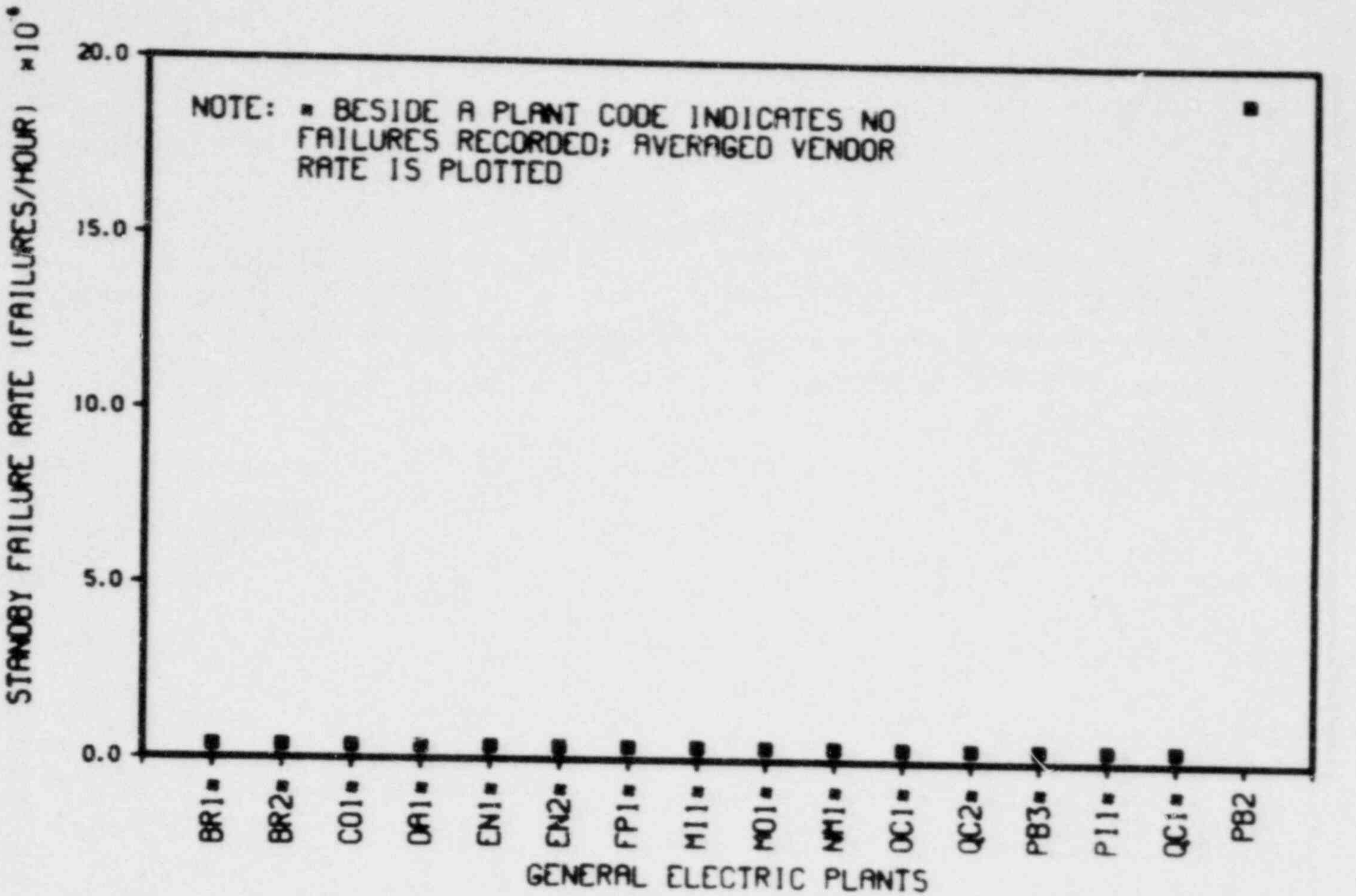

Figure 14a. Scatter plot of standby LER rates for "Valve--Operator (Air)--Leak Externally" in General Electric plants.

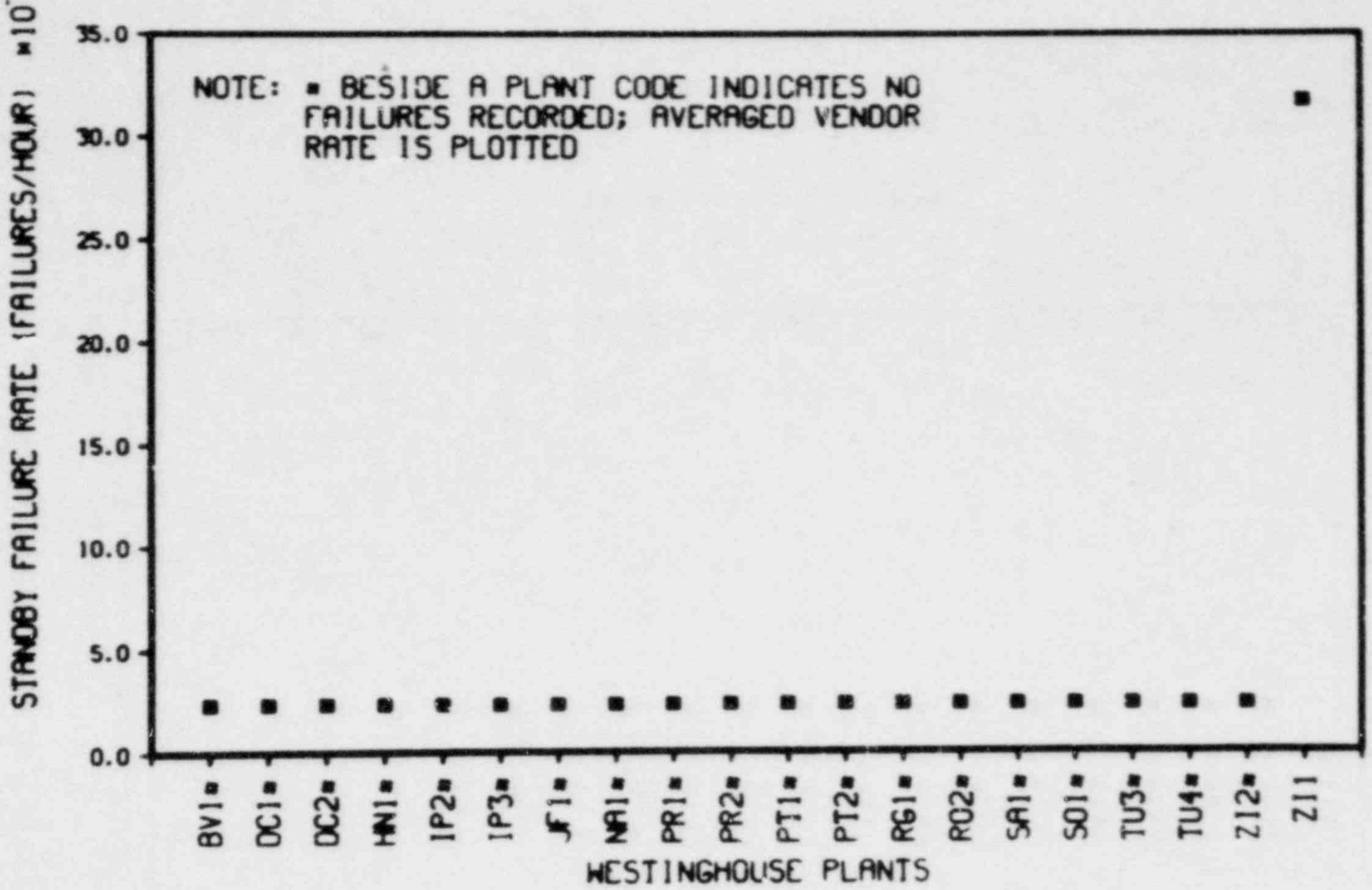

Figure 14b. Scatter plot of standby LER rates for "Valve--Operator (Air)--Leak Externally" in Westinghouse plants.

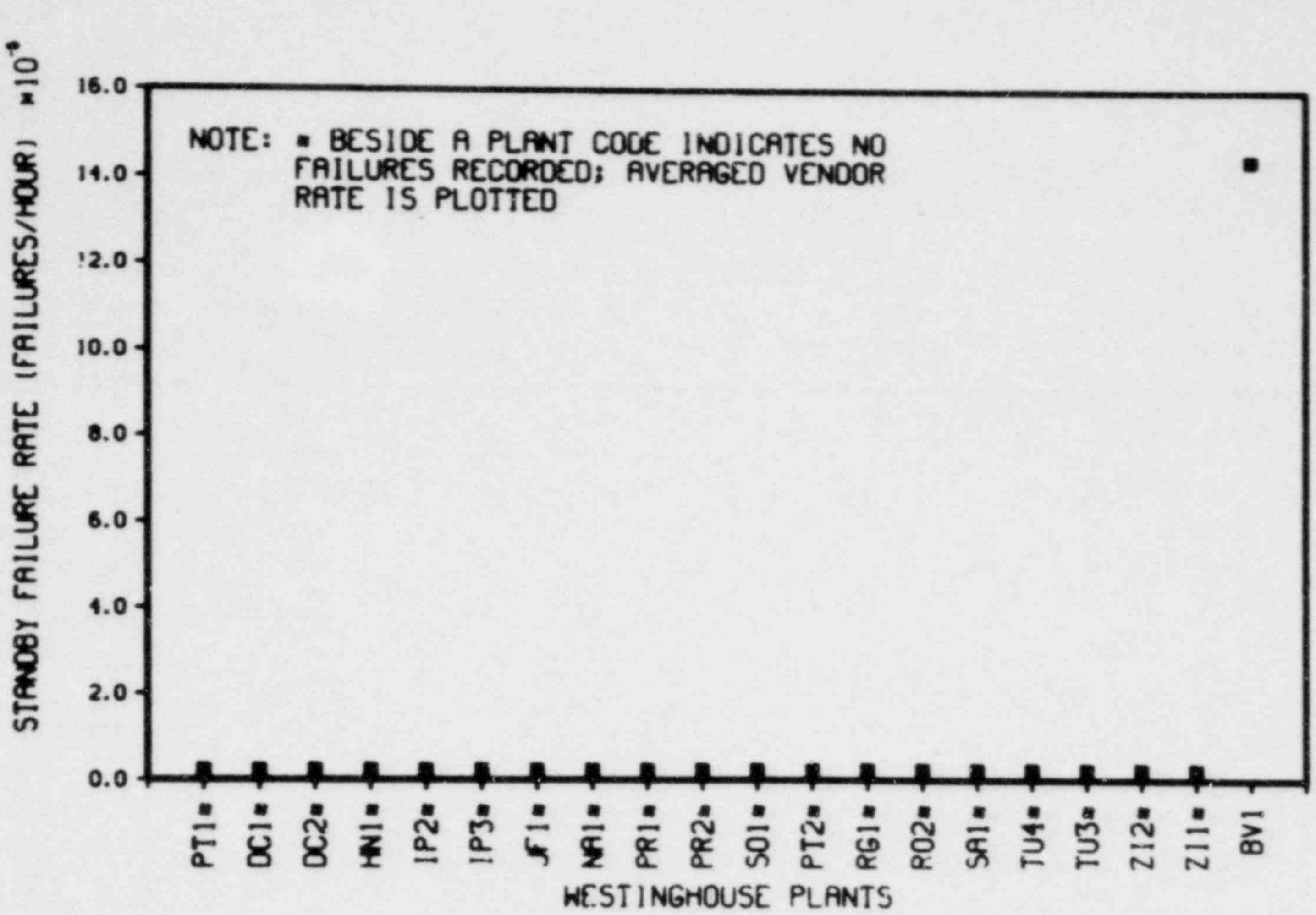

Figure 15. Scatter plot of standby LFR rates for "Valve--Operator (Air)--Plugged (Command Faults Included)" in Westinghouse plants.

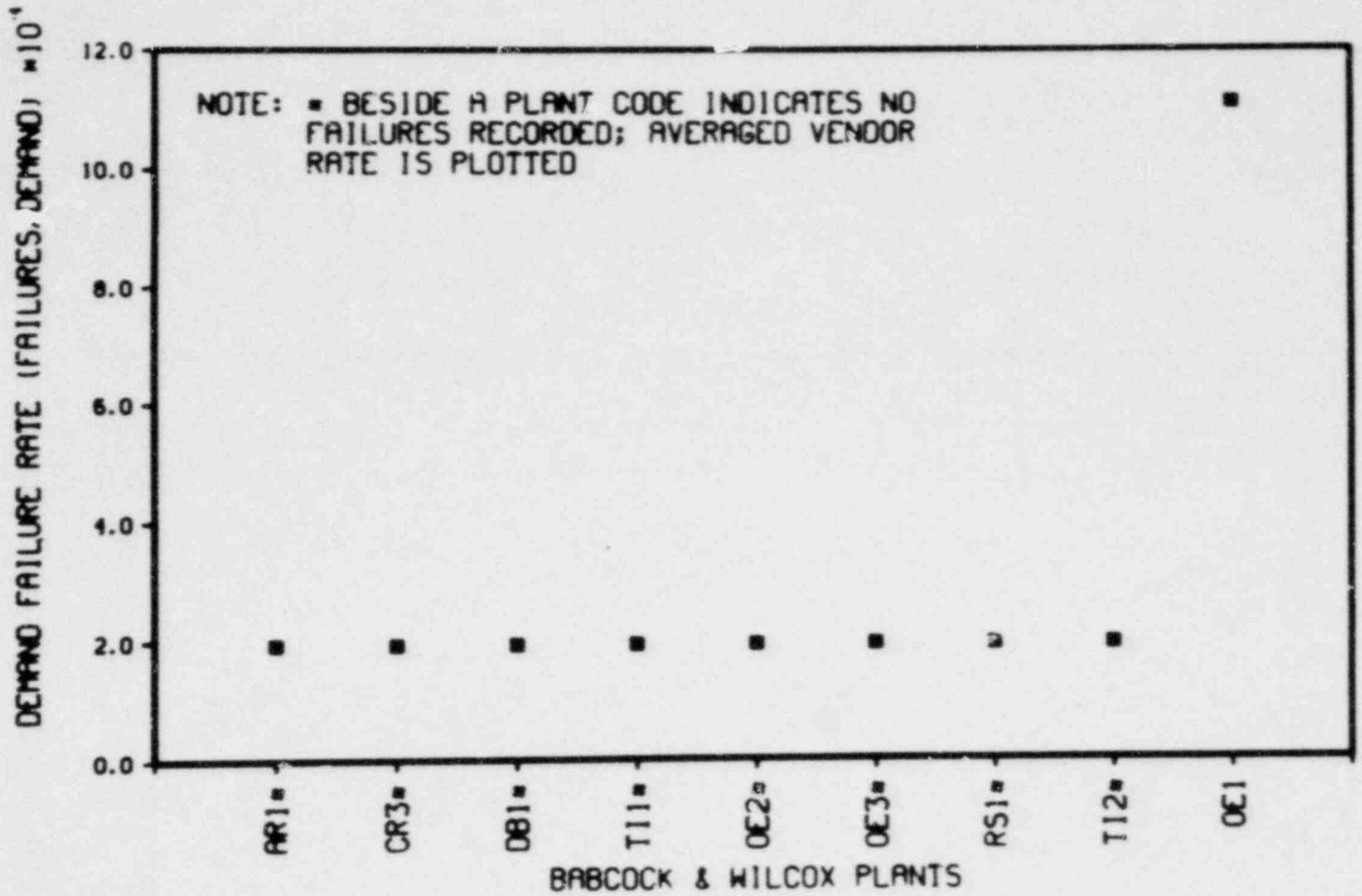

Figure 16a. Scatter plot of demand LER rates for "Valve--Operator (Manual)--Fail to Operate" in Babcock & Wilcox plants.

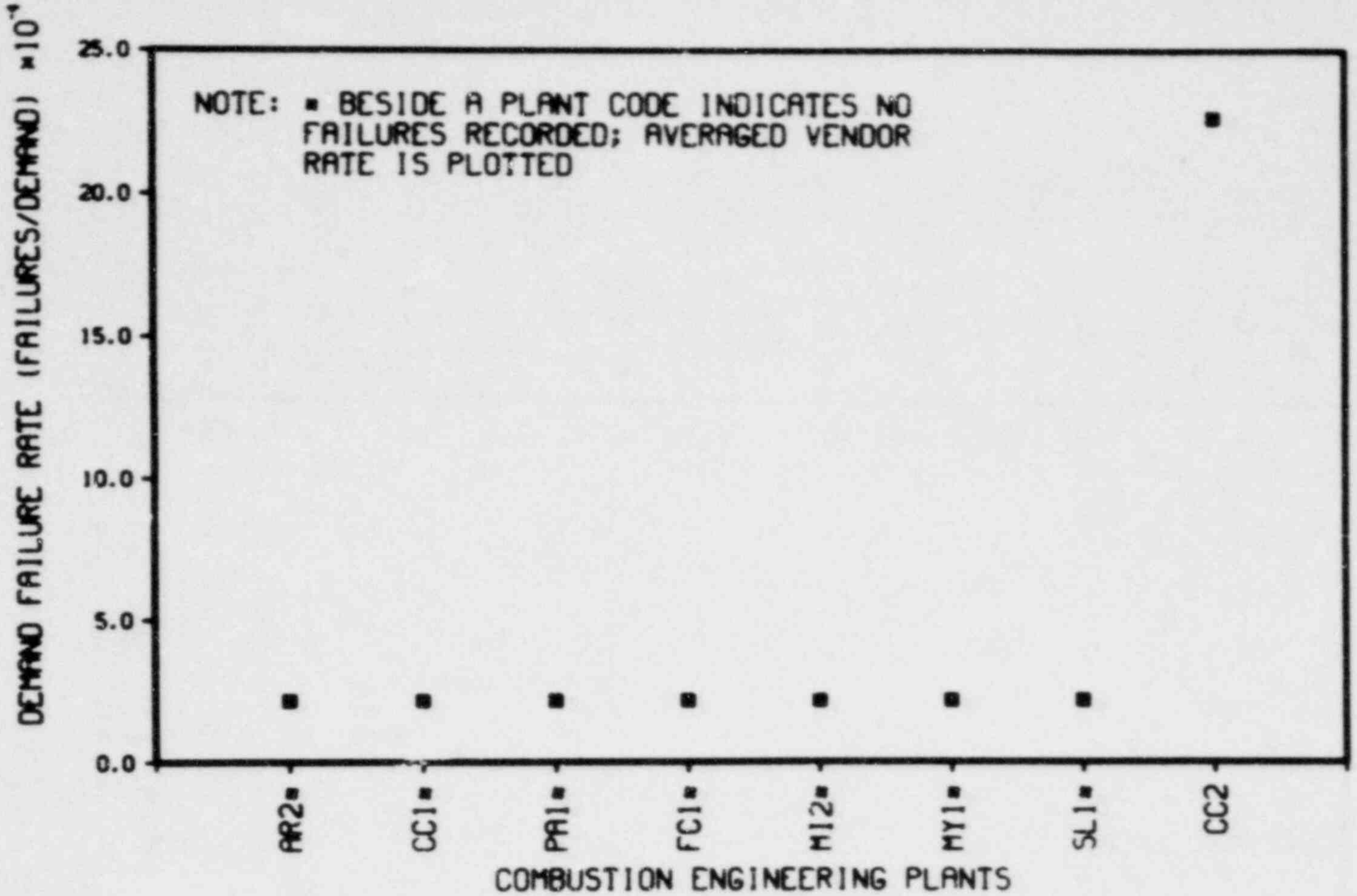

Figure 16b. Scatter plot of demand LER rates for "Valve--Operator (Manual)--Fail to Operate" in Combustion Engineering plants.

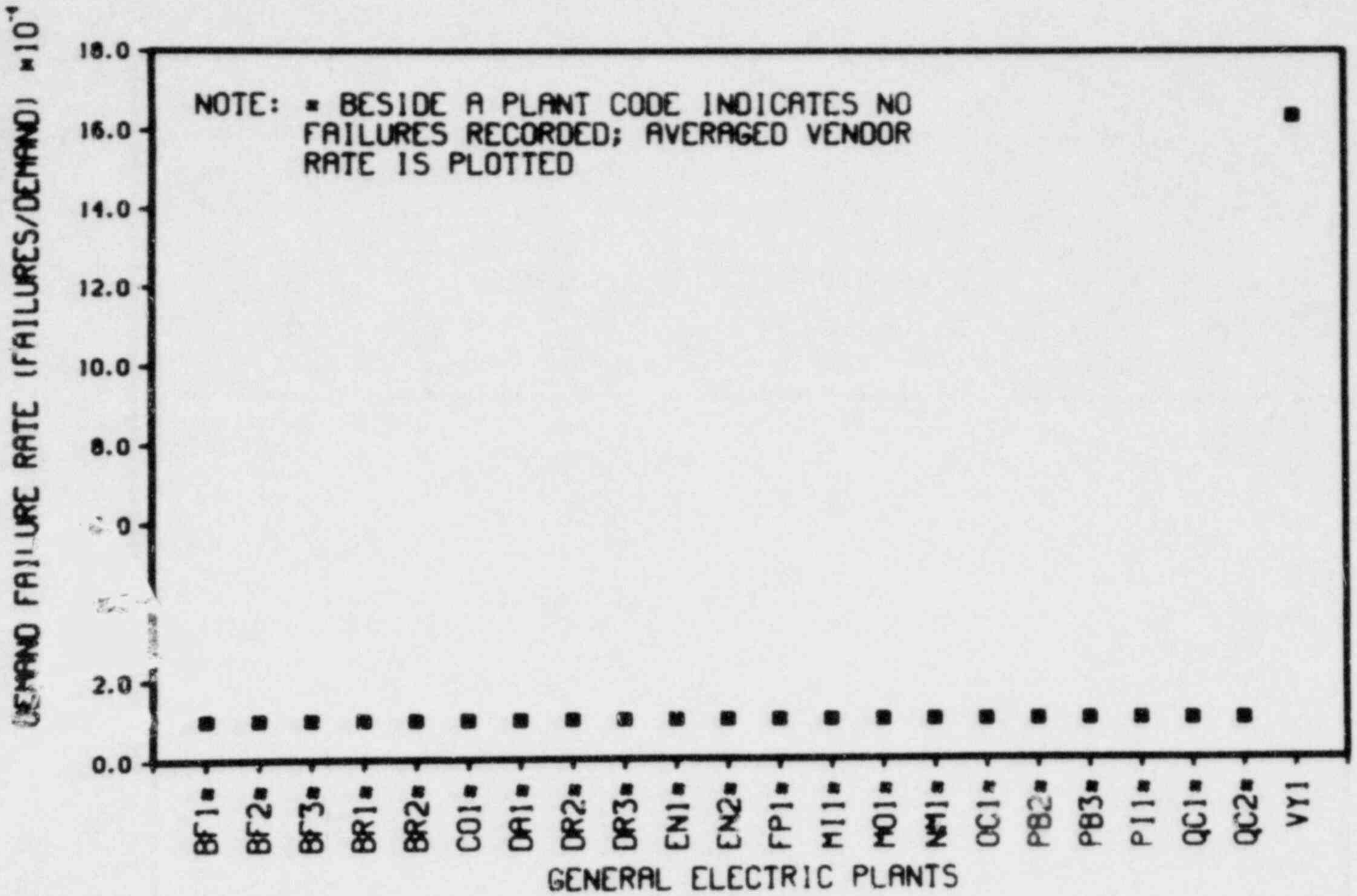

Figure 16c. Scatter plot of demand LER rates for "Valve--Operator (Manual)--Fail to Operate" in General Electric plants.

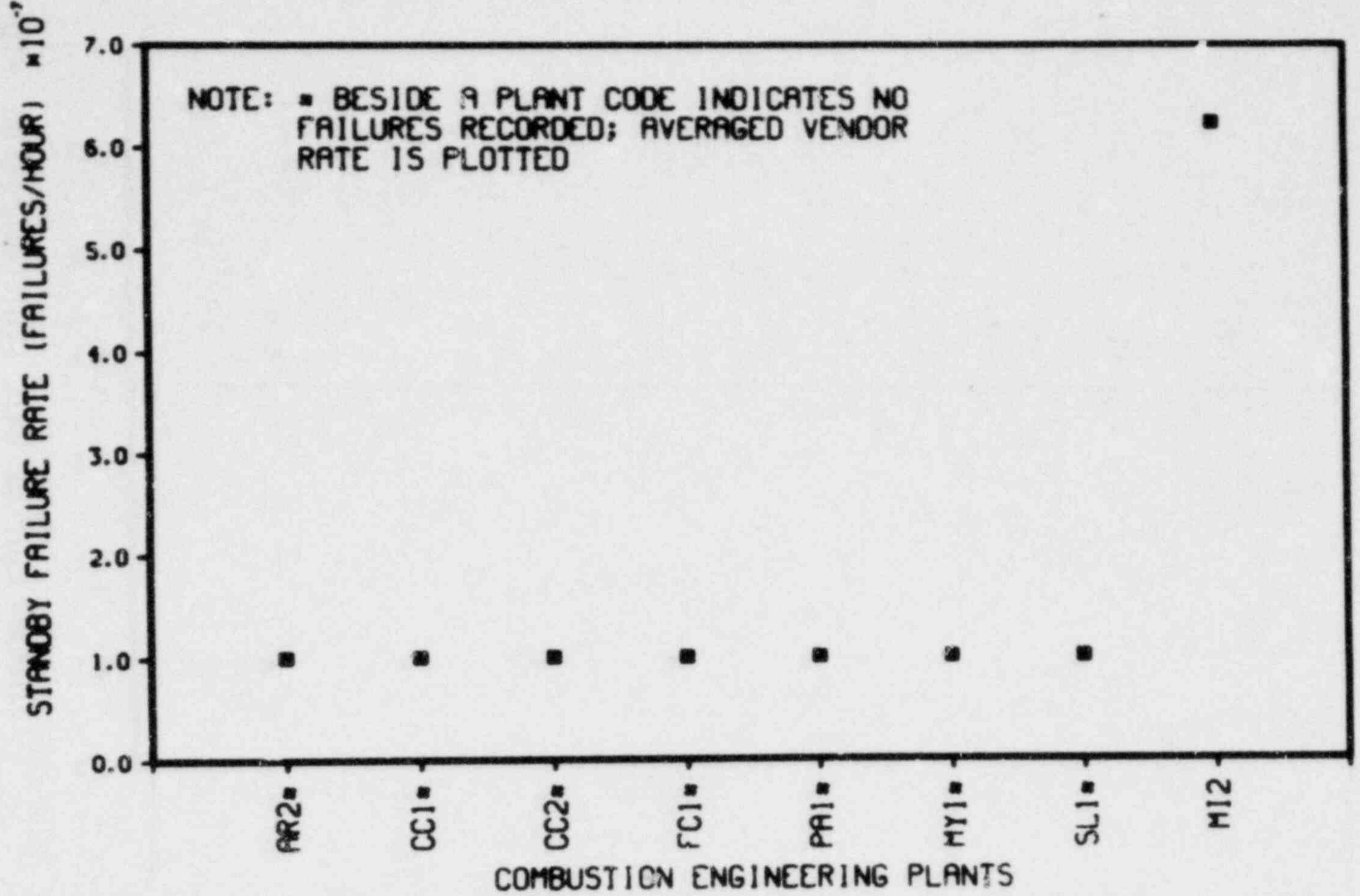

Figure 17. Scatter plot of standby LER rates for "Valve--Operator (Manual)--Leak Externally" in Combustion Engineering plants.

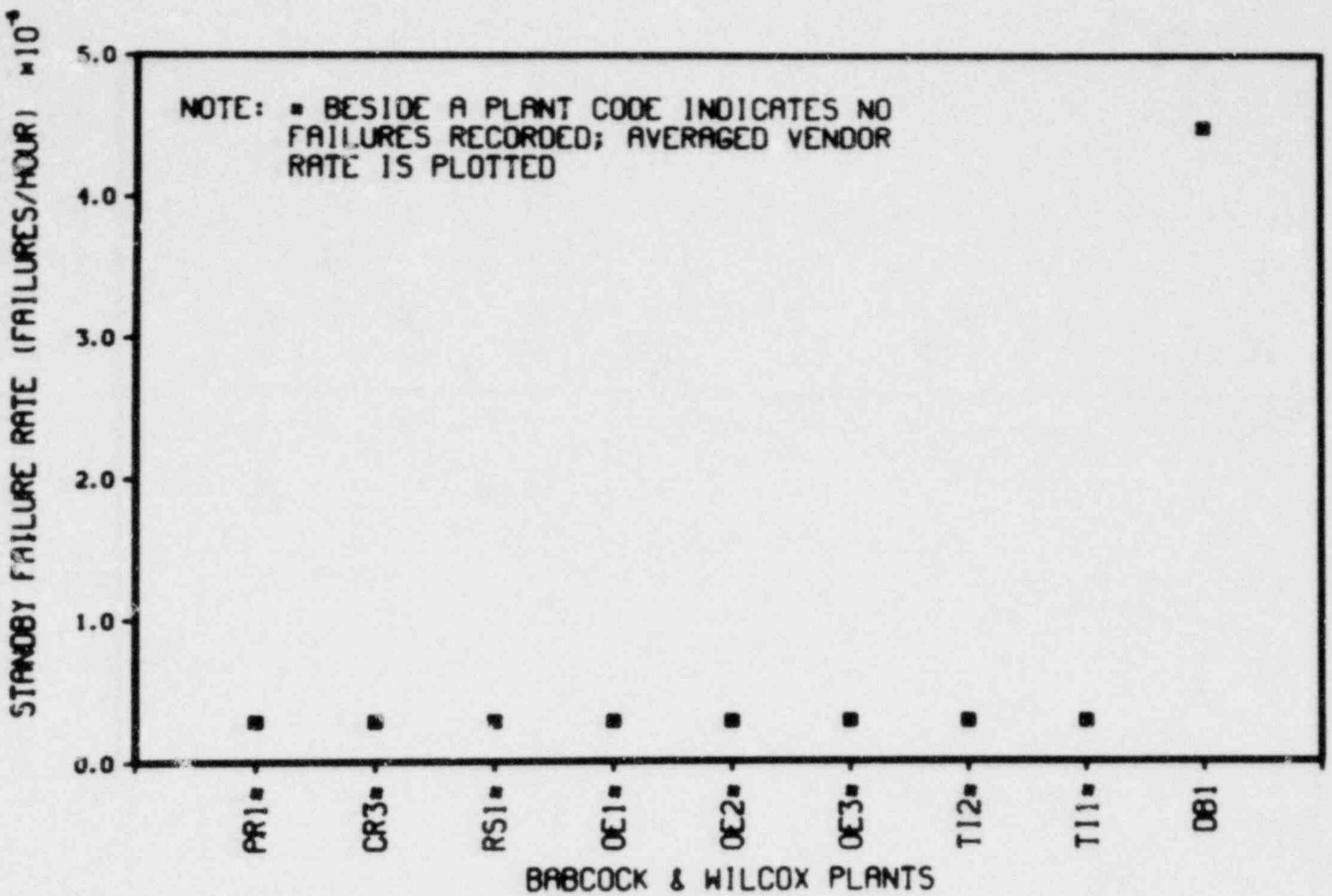

Figure 18a. Scatter plot of standby LER rates for "Valve--Check--Leak Externally" in Babcock & Wilcox plants.

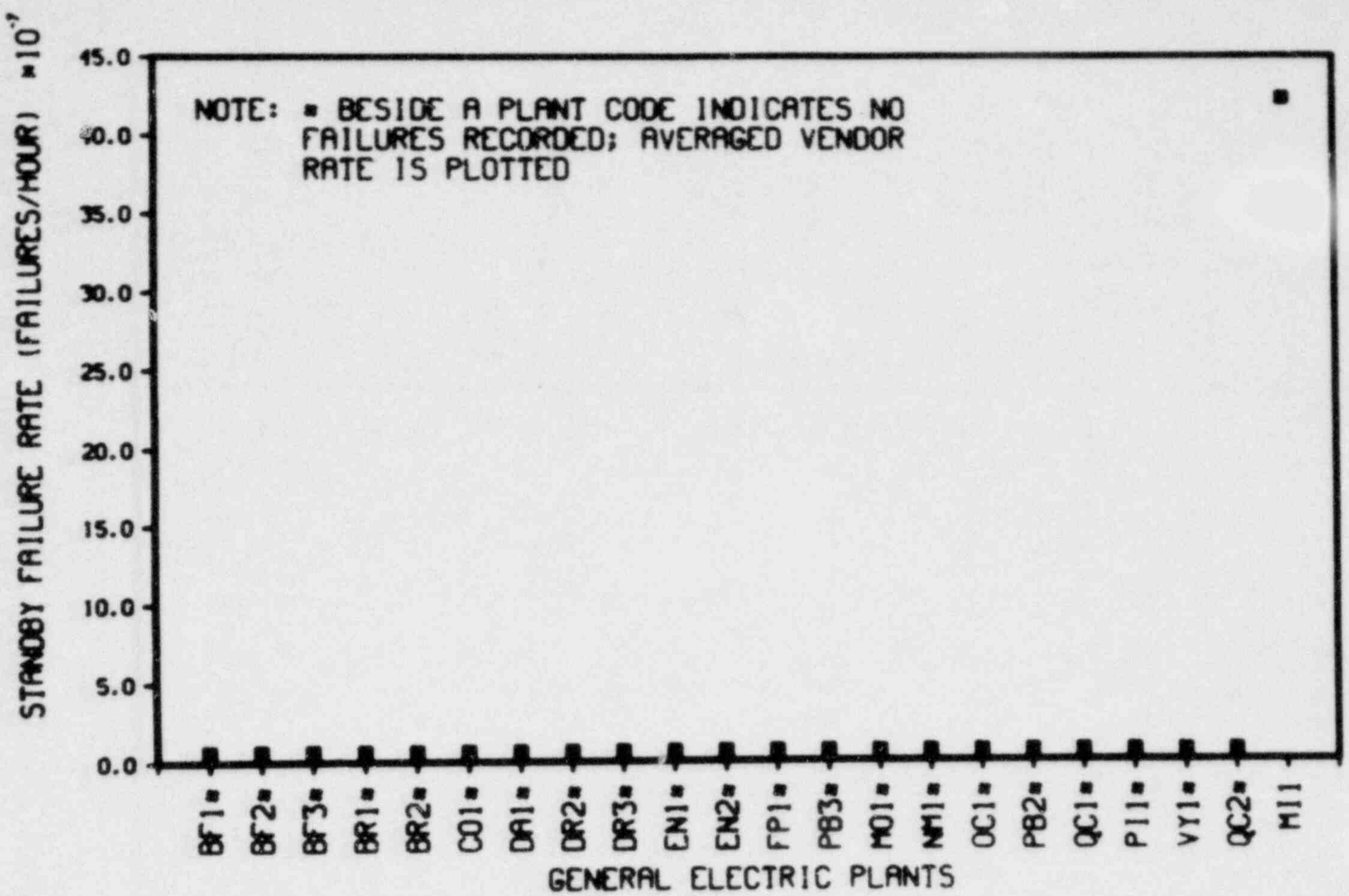

Figure 18b. Scatter plot of standby LER rates for "Valve--Check--Leak Externally" in General Electric plants.

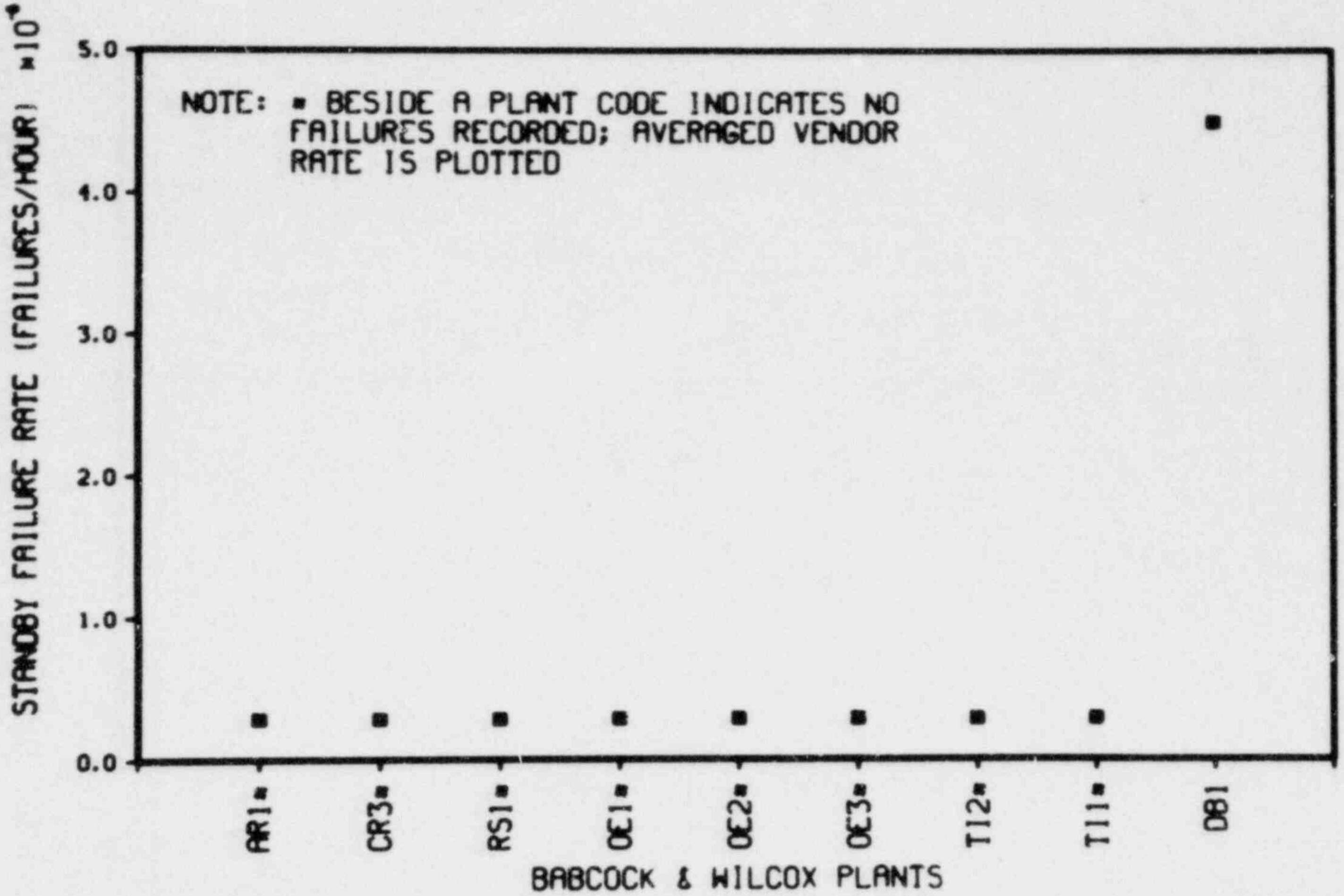

Figure 19a. Scatter plot of standby LER rates for "Valve--Check--Leak Internally" in Babcock & Wilcox plants.

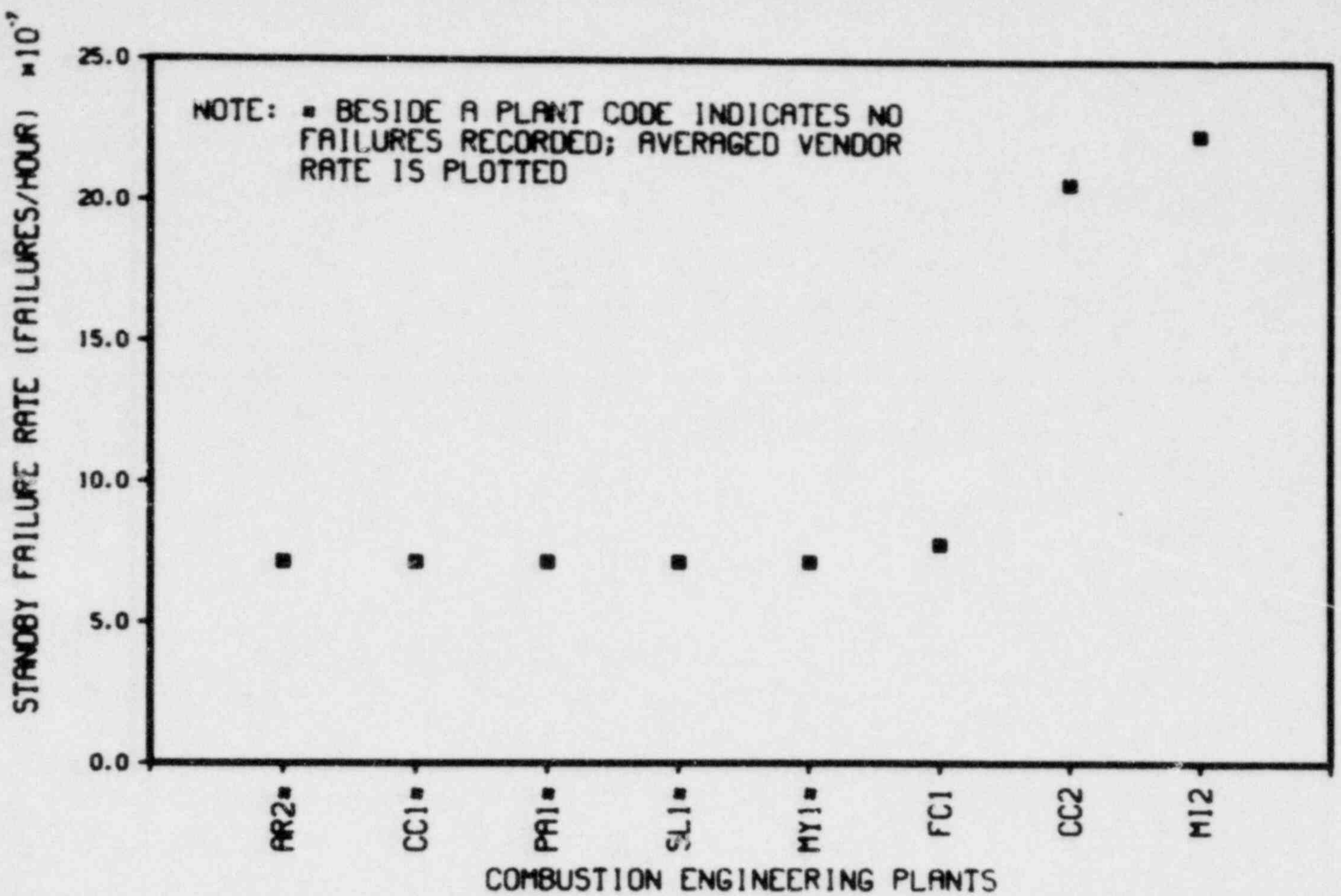

Figure 19b. Scatter plot of standby LER rates for "Valve--Check--Leak Internally" in Combustion Engineering plants.

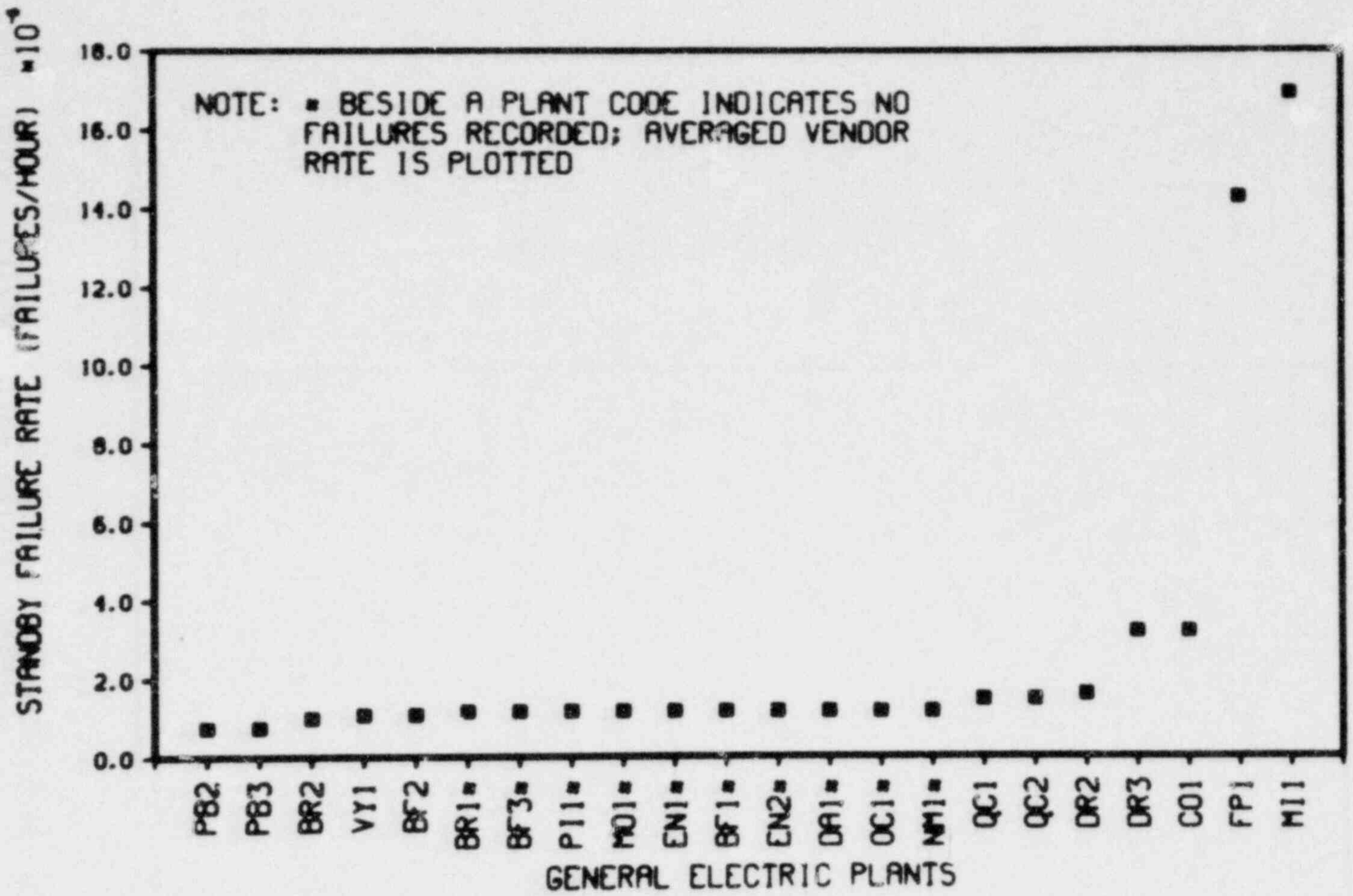

Figure 19c. Scatter plot of standby LER rates for "Valve--Check--Leak Internally" in General Electric plants.

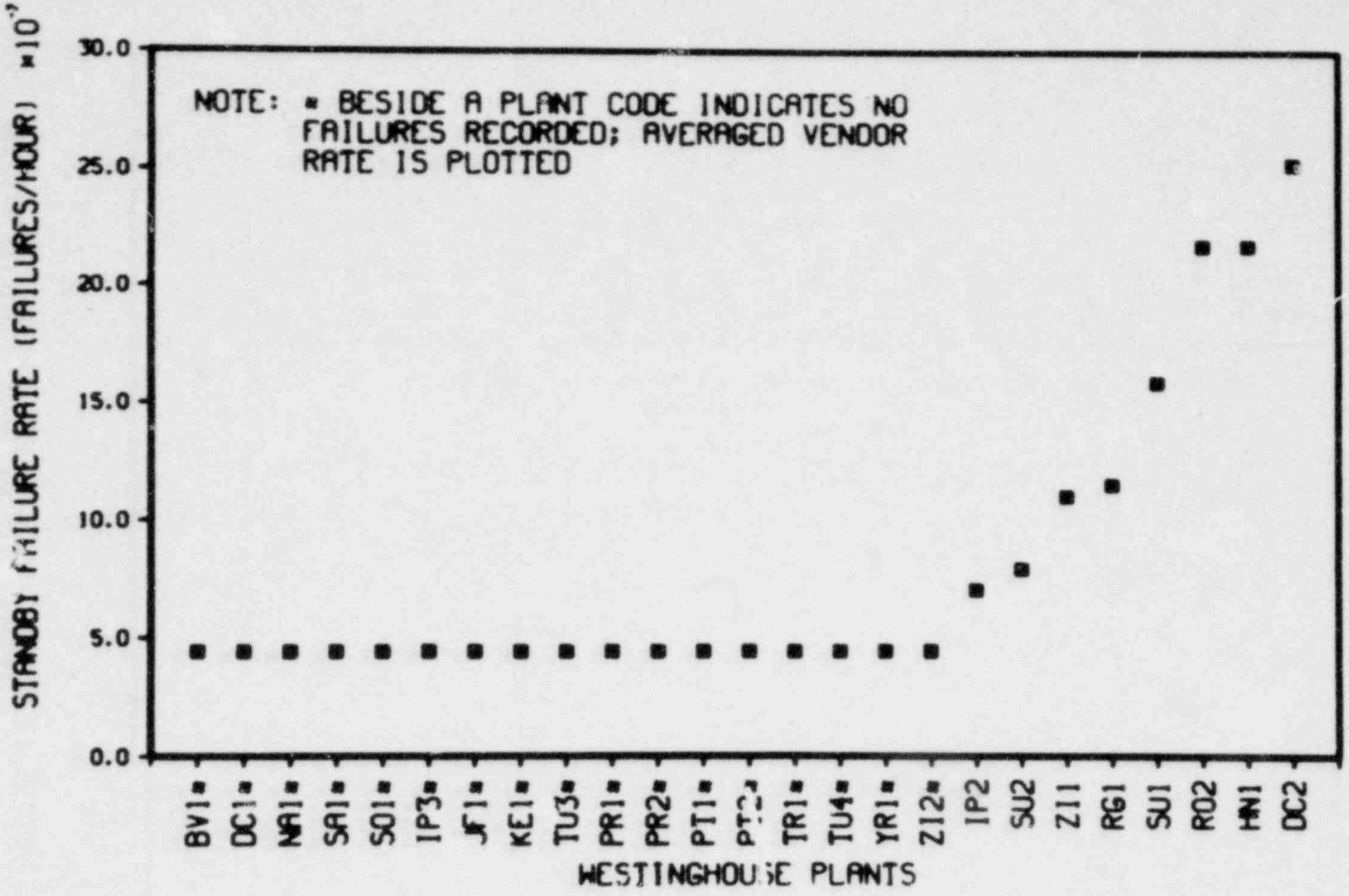

Figure 19d. Scatter plot of standby LER rates for "Valve--Check--Leak Internally" in Westinghouse plants.

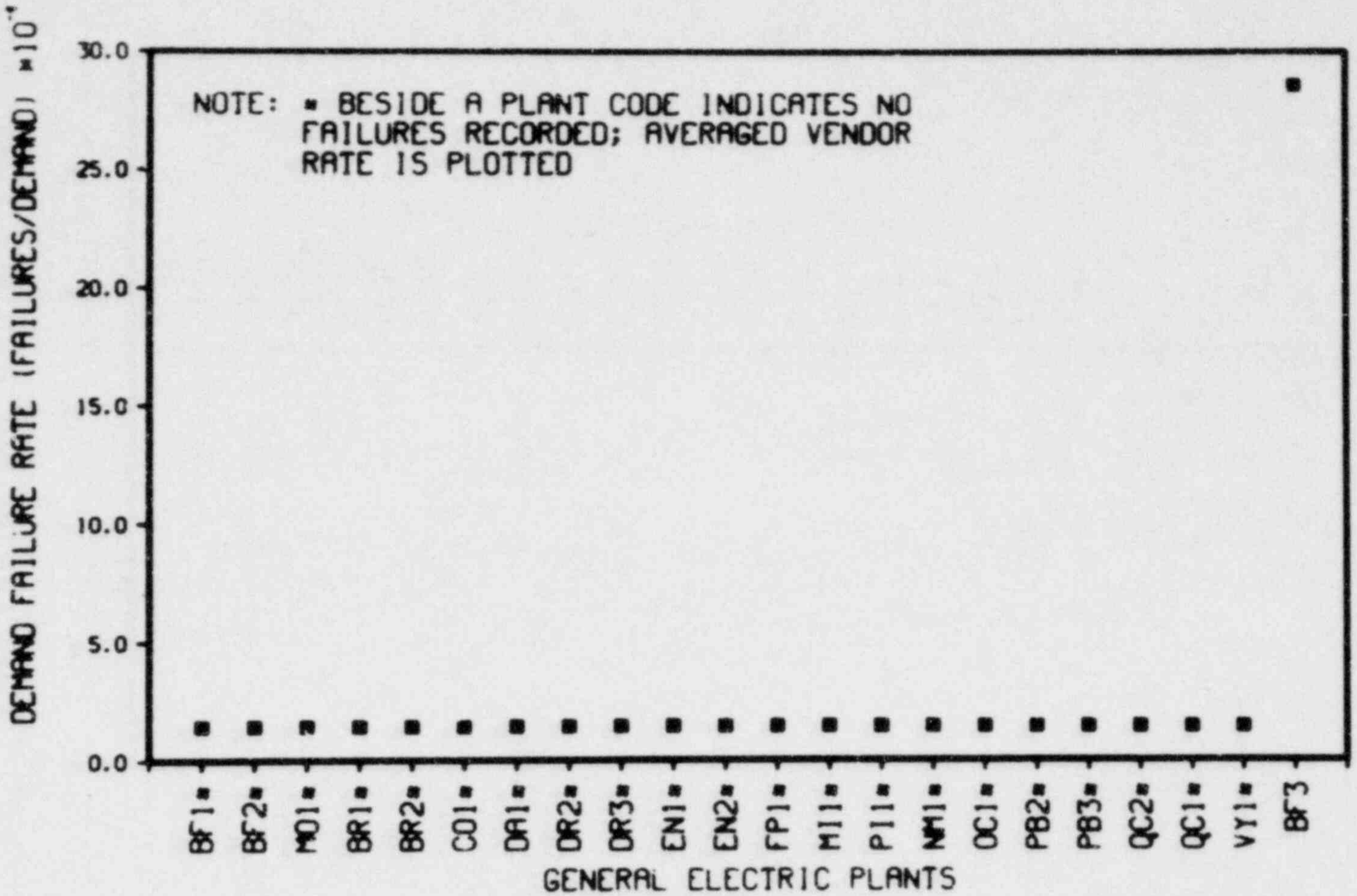

Figure 20a. Scatter plot of demand LER rates for "Valve--Check--Fail to Open" in General Electric plants.

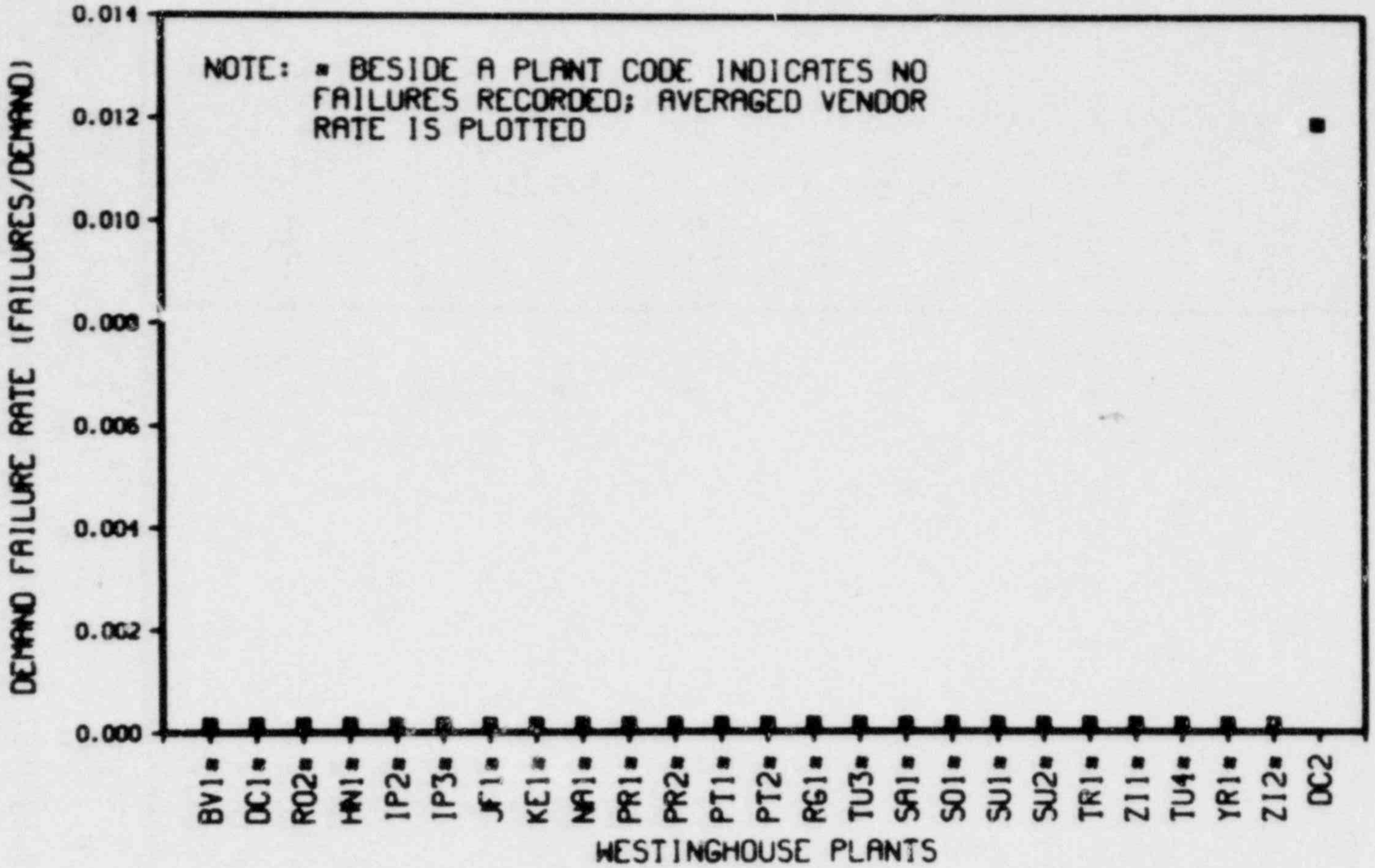

Figure 20[illegible]. Scatter plot of demand LER rates for "Valve--Check--Fail to Open" in Westinghouse plants.

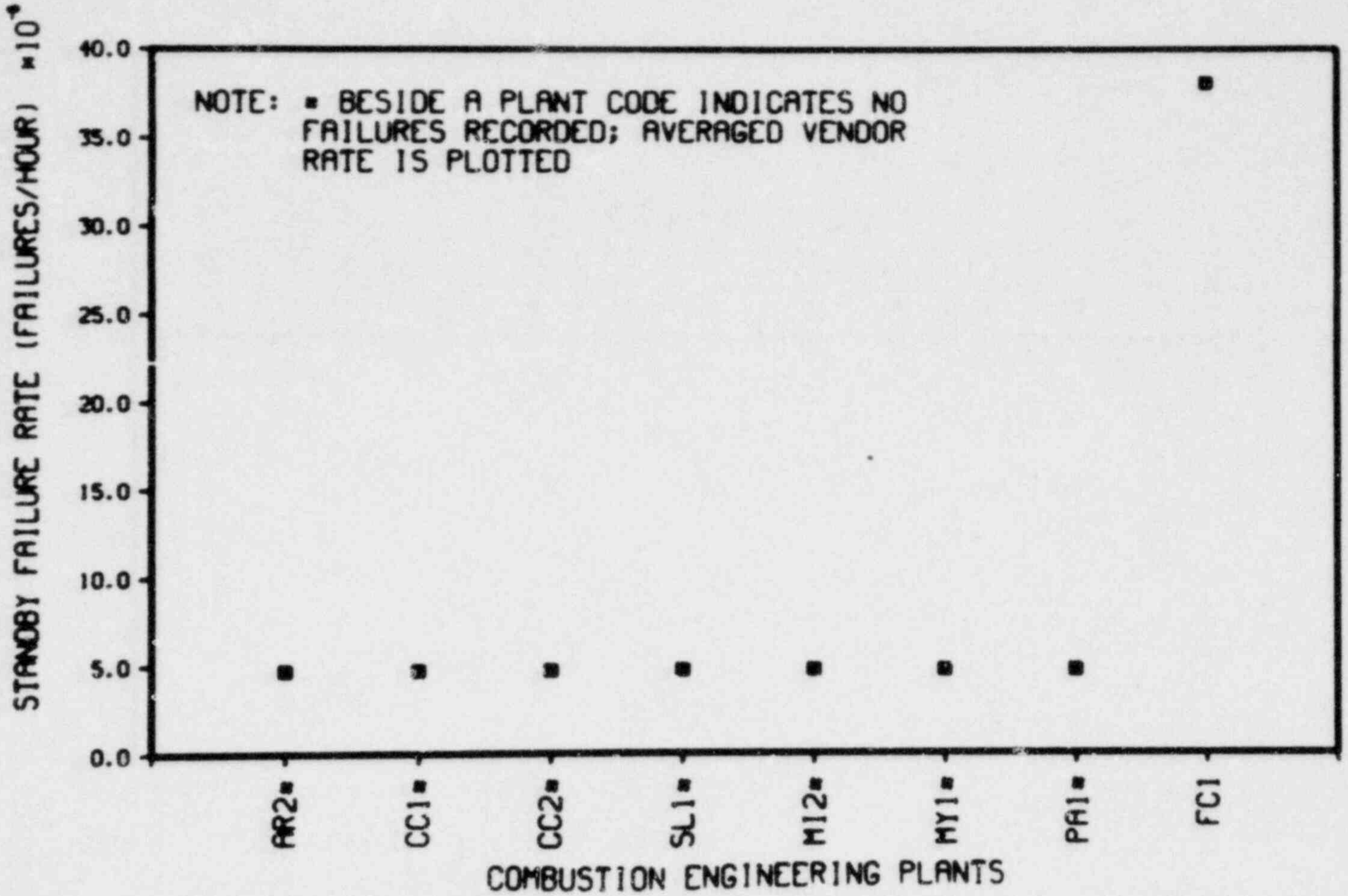

Figure 21a. Scatter plot of standby LER rates for "Valve--PWR Primary Safety--Premature Open" in Combustion Engineering plants.

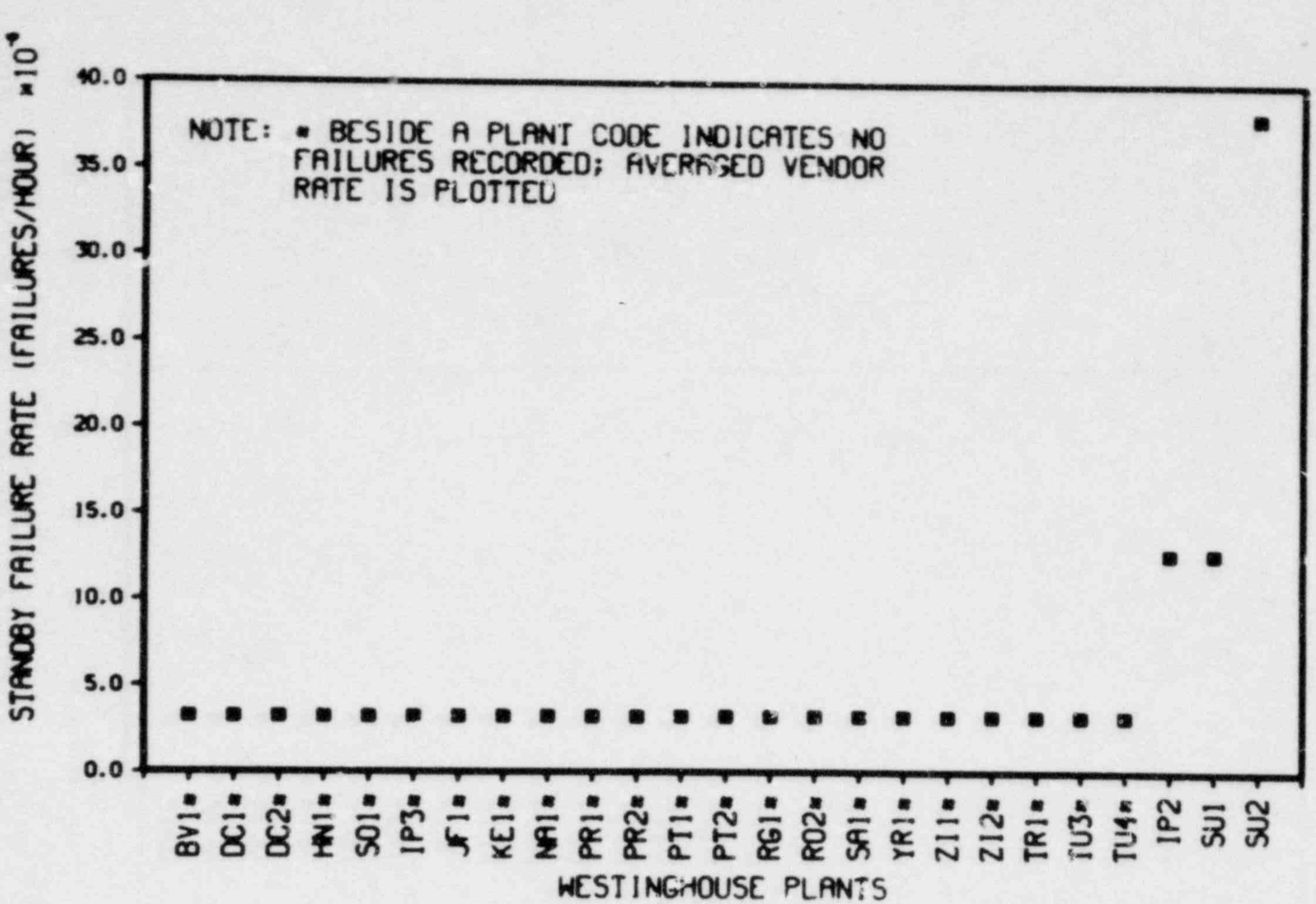

Figure 21b. Scatter plot of standby LER rates for "Valve--PWR Primary Safety--Premature Open" in Westinghouse plants.

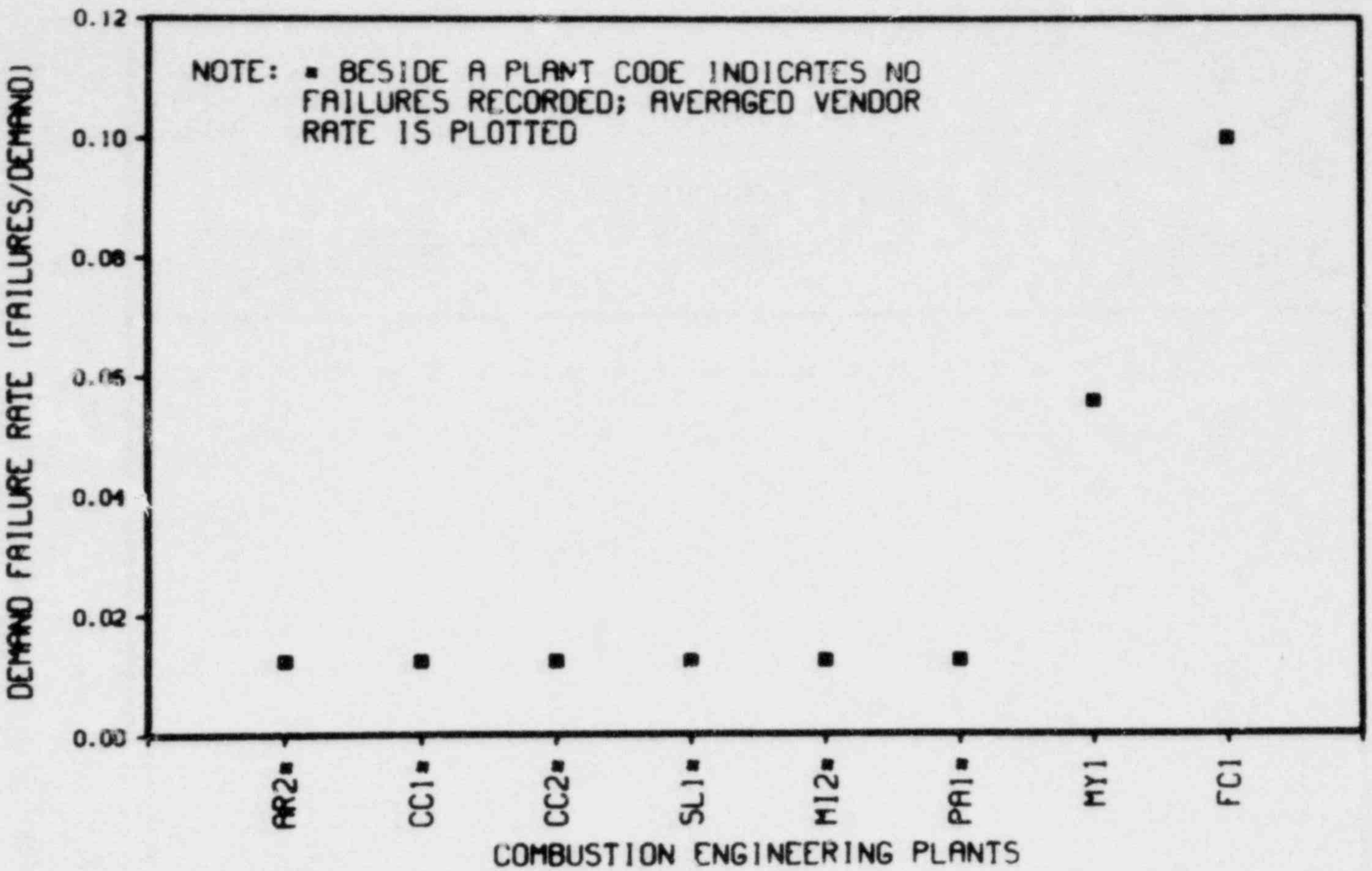

Figure 22a. Scatter plot of demand LER rates for "Valve--PWR Primary Safety--Fail to Open" in Combustion Engineering plants.

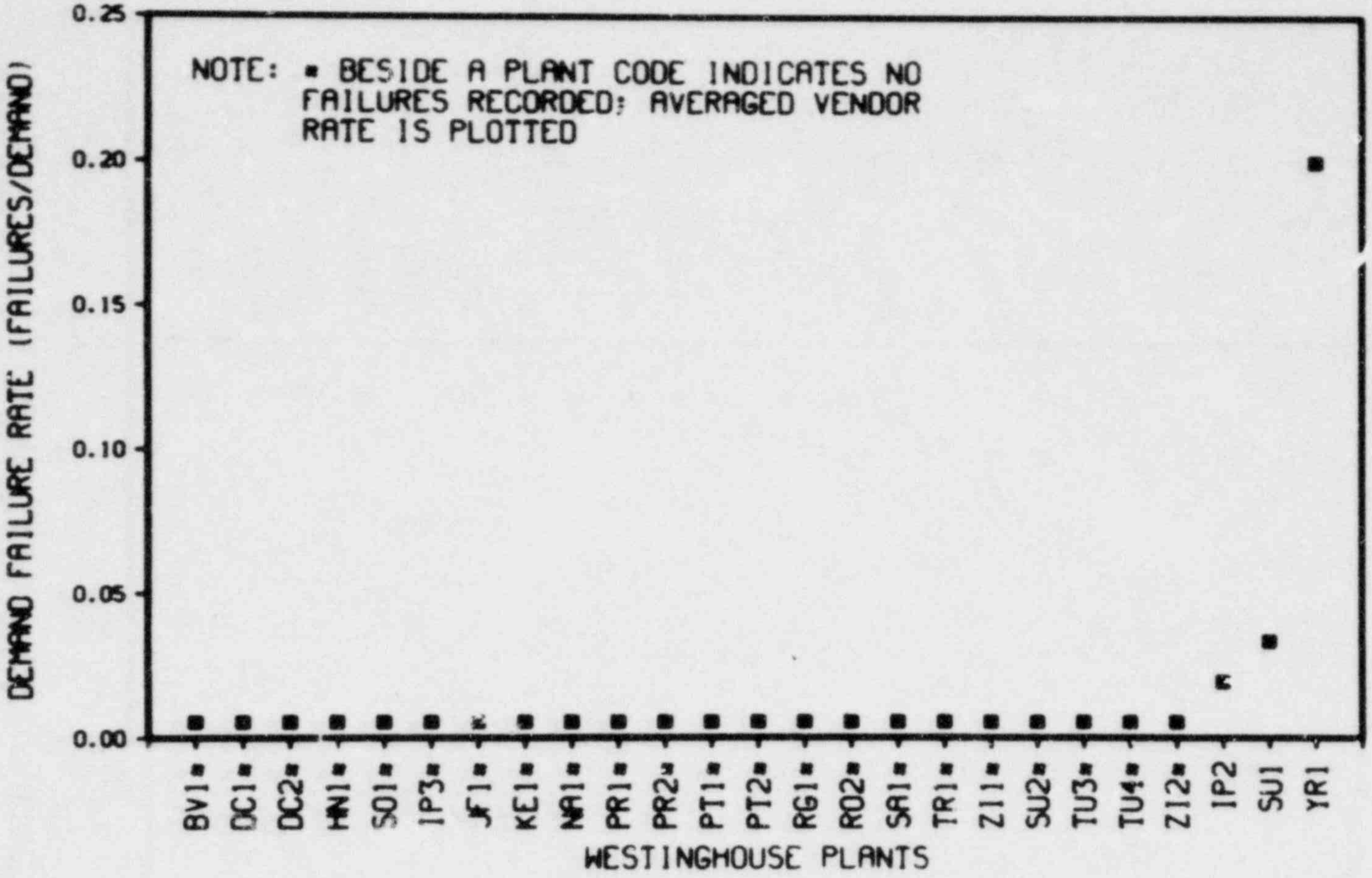

Figure 22b. Scatter plot of demand LER rates for "Valve--PWR Primary Safety--Fail to Open" in Westinghouse plants.

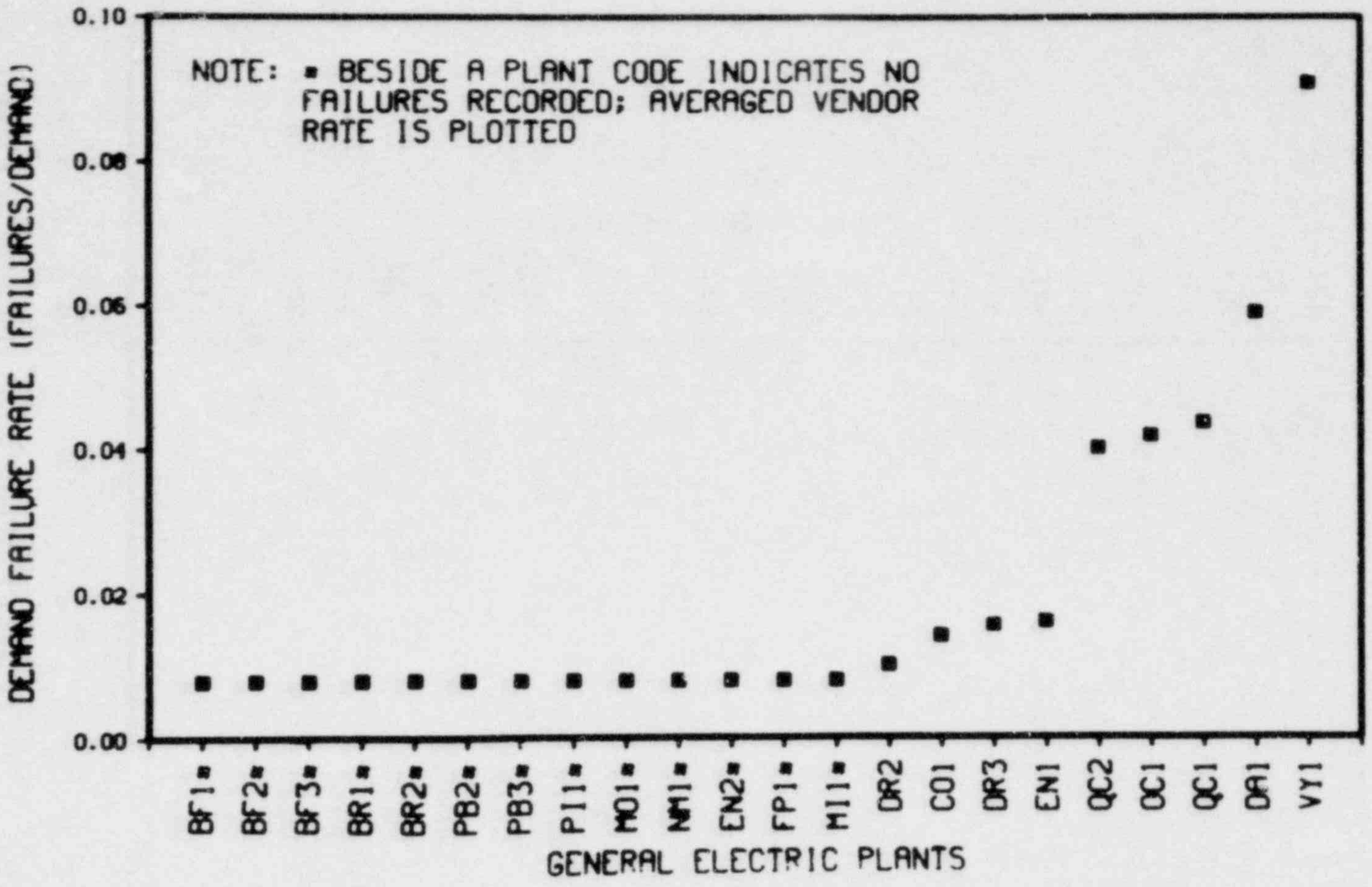

Figure 23. Scatter plot of demand LER rates for "Valve--BWR Primary Relief--Fail to Open" in General Electric plants.

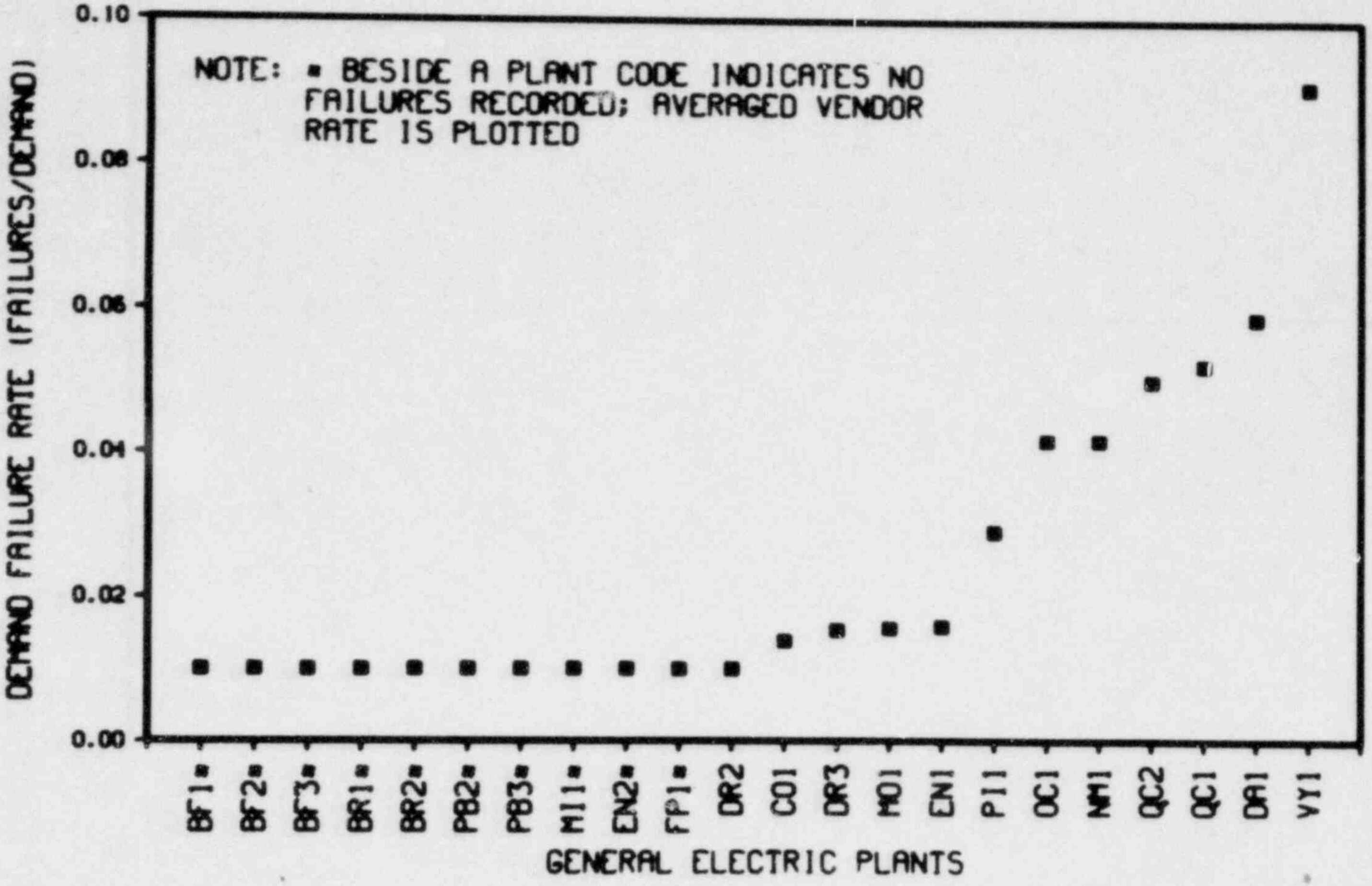

Figure 24. Scatter plot of demand LER rates for "Valve--BWR Primary Relief--Fail to Open (Command Faults Included)" in General Electric plants.

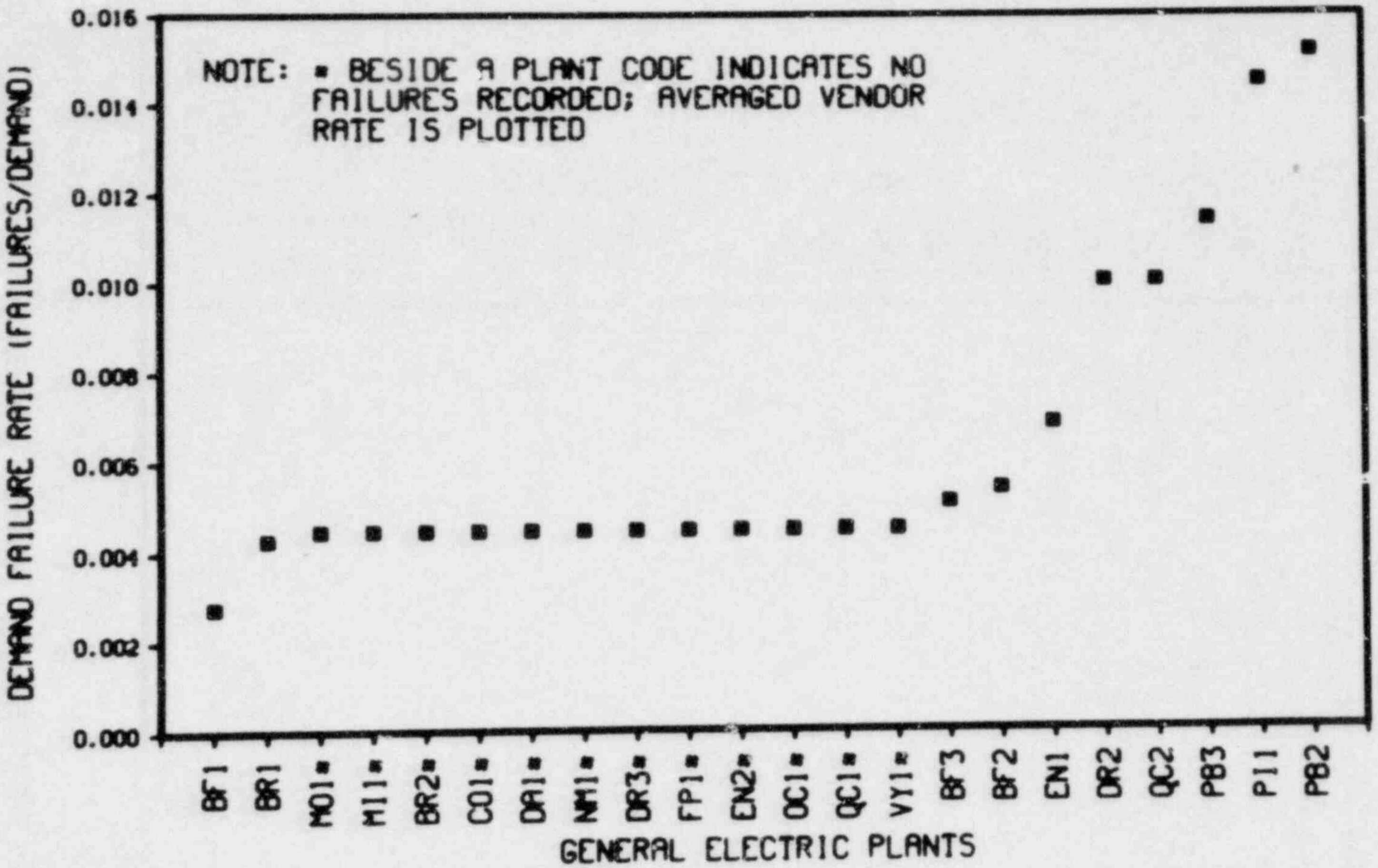

Figure 25. Scatter plot of demand LER rates for "Valve--BWR Primary Relief--Fail to Reseat" in General Electric plants.

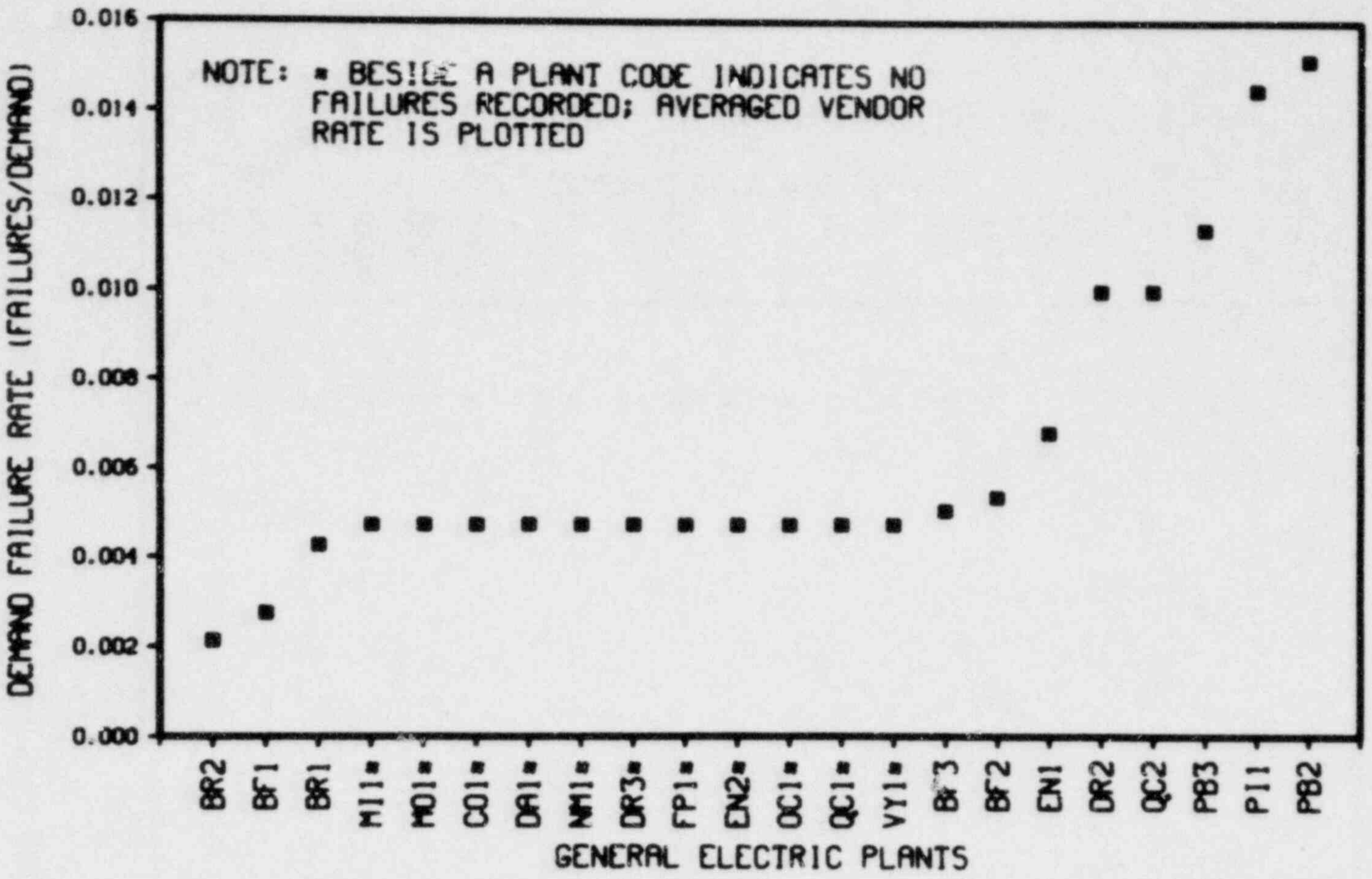

Figure 26. Scatter plot of demand LER rates for "Valve--BWR Primary Relief--Fail to Reseat (Command Faults Included)" in General Electric plants.

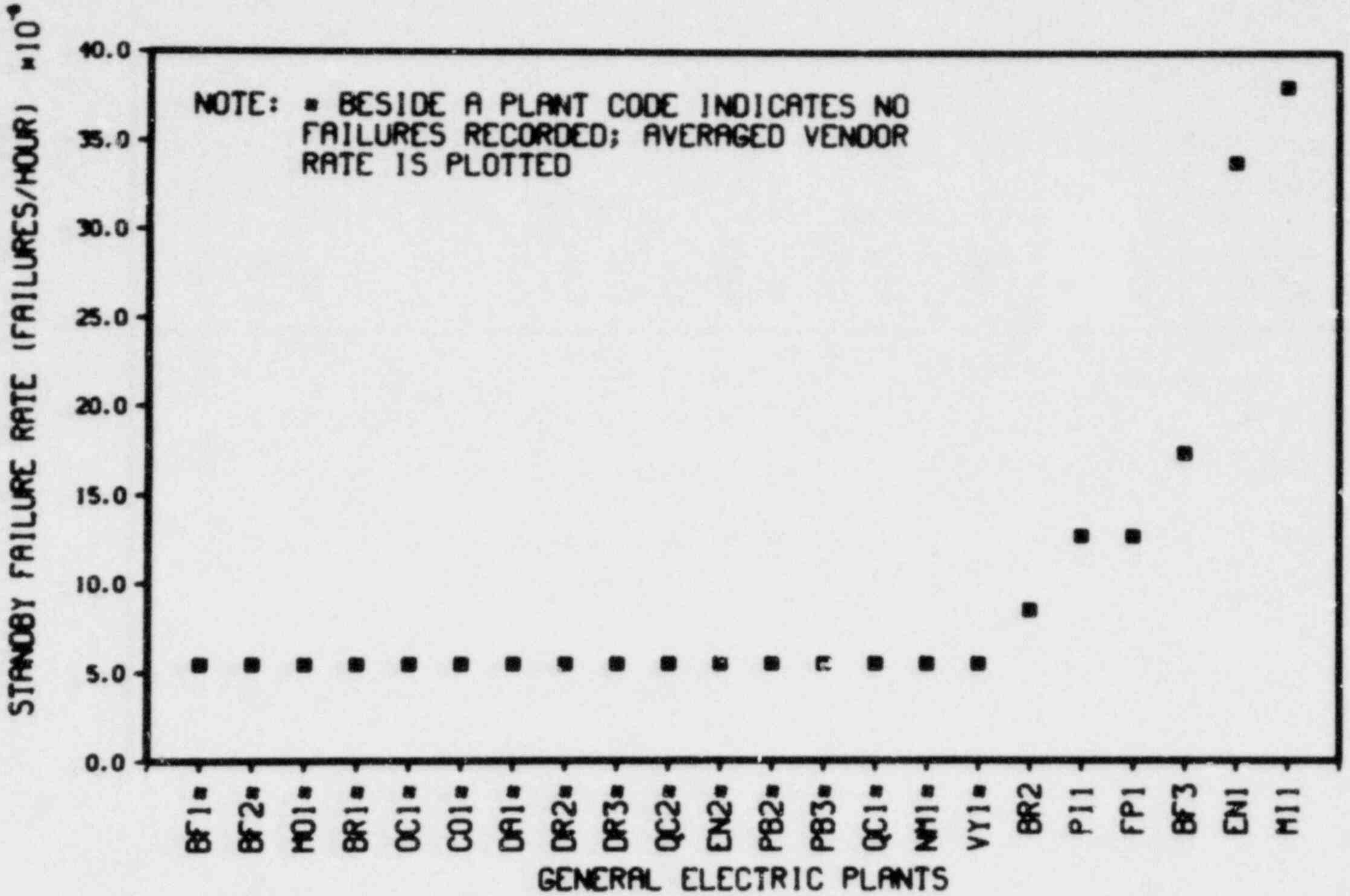

Figure 27. Scatter plot of standby LER rates for "Valve--BWR Primary Relief--Premature Open" in General Electric plants.

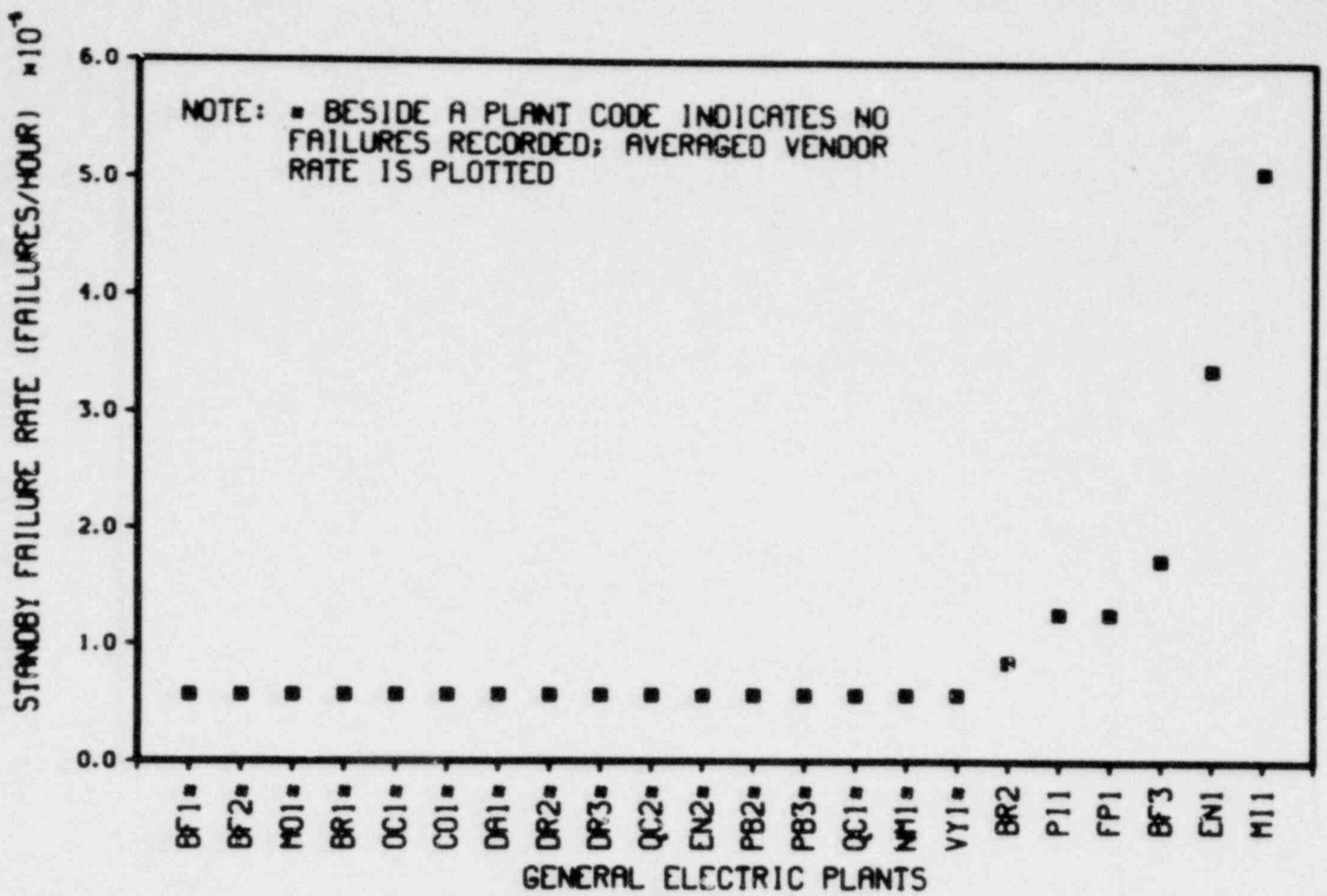

Figure 28. Scatter plot of standby LER rates for "Valve--BWR Primary Relief--Premature Open (Command Faults Included)" in General Electric plants.

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*The above-cited reports are available for purchase from the National Technical Information Service, Springfield, VA 22161

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U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

1. REPORT NUMBER *(Assigned by DDC)*	NUREG/CR-1363, Vol. 1 EGG-EA-5125 (Main Report)
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3. RECIPIENT'S ACCESSION NO.	
UTHOR(S)	arren H. Hubble harles F. Miller
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ABSTRACT *(200 words or less)*

is report describes the results of an analysis of nuclear plant valve failures. The ata used for this analysis were the Licensee Event Reports (LERs). The LERs are itten reports filed with the NRC whenever certain failures or incidents occur concerning iclear plant safety systems. The valve failures or incidents contained in the LERs were ed to calculate summary valve failure rate statistics. The report includes a variety different statistics calculated to highlight or show important failure modes or other ilure information. In addition to the quantitative failure rate information, there is so considerable qualitative information tabulated to allow the user to make additional lve failure rate calculations or inferences.

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