TR-06-xxxx

HRSG Reliability Report

for <Name> Power Project

December 2005

Tetra Engineering Group, Inc.

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1. Executive Summary

This HRSG Reliability Data Report provides <Owner Name> with a comparison of HRSG reliability for <Name> Power Project with similar units in operation behind similar gas turbines. The focus of the December 2005 report is with HRSG Tube Failures. Future reports will also address the following components: drums, piping, duct burner systems, desuperheater attemperators and structures including ducting, supports and stacks.

HRSG Reliability for <Name> Power Project is summarized as follows:

Unit	RDB Code	Overall Reliability
U1	Axxxx	Average
U2	Bxxxx	Average
U3	Cxxxx	Average

Detailed HRSG Reliability Metrics for <Name> Power Project are described in Section 2. <Name> Power Project has experienced a moderate number of failures; many large frame combined cycle plants of similar design & similar operation have experienced fewer HRSG tube failures and fewer failures of piping, headers and valves, overall.

2. Overview of HRSG RDB

Tetra Engineering initiated the HRSG Reliability Project in 2005 to address an industry need for more access to reliability metrics for heat recovery steam generators, particularly for newer units that operate behind large frame gas turbines. This need arose as owners/operators of new large frame plants have experienced numerous early life failures in pressure parts, supplemental firing systems and related HRSG auxiliaries. Tetra Engineering has created a database to maintain these data. Two forms are used to describe HRSG design characteristics and to provide annual updates to failure experience.

Reporting of reliability data is voluntary; there are no current requirements for reliability reporting at the level of detail addressed by the HRSG Reliability Data Base. As such, the reliability data are not exhaustive but are considered representative of current HRSG reliability for typical operating configurations and conditions. Data have been contributed from many combined cycle plants in North America, Central America, Europe, North Africa, Central Africa and Asia. As of December 2005, the HRSG reliability data base contains data from 50 combined cycle plants and includes data for more than 100 large frame HRSGs.

Summary statistics are provided in Figure 2-1 and Figure 2-2 to show the distribution of data in the HRSG Reliability Data Base by HRSG OEM and Gas Turbine OEM. These graphs show that the HRSG Reliability Data Base spans almost all modern HRSG OEMs and all large frame GT OEMs.

Figure 2-3 and Figure 2-4 also show the distribution of commercial operating date and all failures by GADS code. These graphs indicate that most HRSG Reliability Data is for early life conditions (predominantly for operations less than 5 years). While no direct comparisons between specific HRSG OEMs are provided in this report, various (anonymous) comparisons are provided to assess “performance in class.” It should be kept in mind that the database is not mature and that these comparisons are a direct result of reported information. As more information is accumulated, the relative accuracy of all comparisons will improve. These summary graphs also indicate the importance of continued data collection as the bulk of the HRSGs have operated for only a short time. Failures that occur early in the plants' lifetime are considered wear-in or early life failures and are characteristic of failure processes which cause premature failures of components. Such failures can be caused by fabrication errors, overstress, grossly poor water chemistry control and design related causes such as quench caused by poorly designed or malfunctioning desuperheater/atttemperator spray systems and drain systems.

As the fleet of large HRSGs ages, there will be more component failures attributable to traditional later-in-life causes such as fatigue, cavitation and wear, underdeposit corrosion and FAC (flow accelerated corrosion). Most of the component failure information that has been initially reported is related to HRSG tube failures; primary contributors to HRSG unreliability and lost availability. Some tube failures occur as isolated events (that is, a single tube leaks/fails and the repair is effected at the next possible time).

Other tube failure events consist of more significant damage or simultaneous failures where a plant trip or immediate orderly shutdown commences. In either instance, downtime for repairs is measured in terms of hours and possibly days, depending on the extent of damage and location of tubes that require repair.

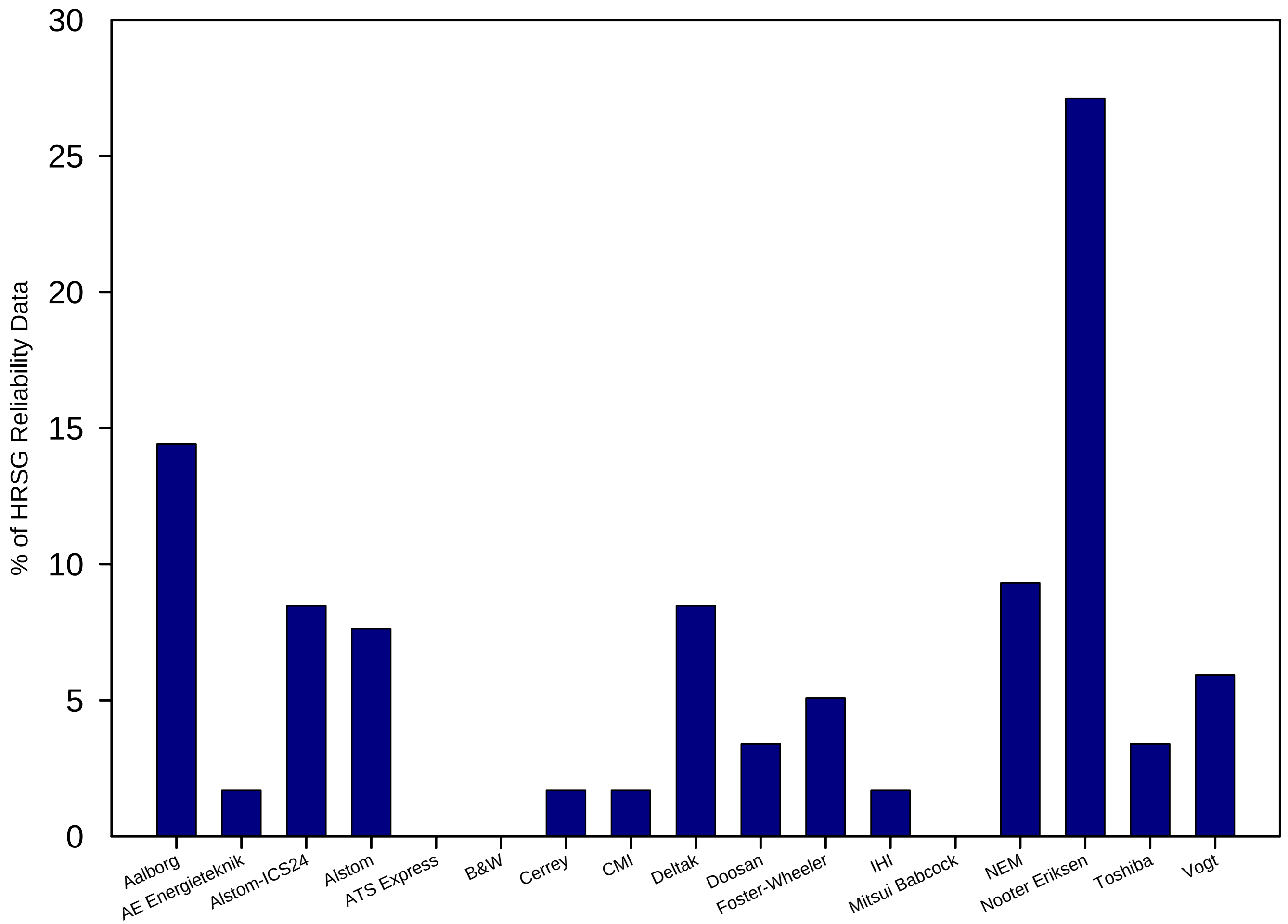

Figure 2-1 HRSG Reliability Data Base by HRSG OEM

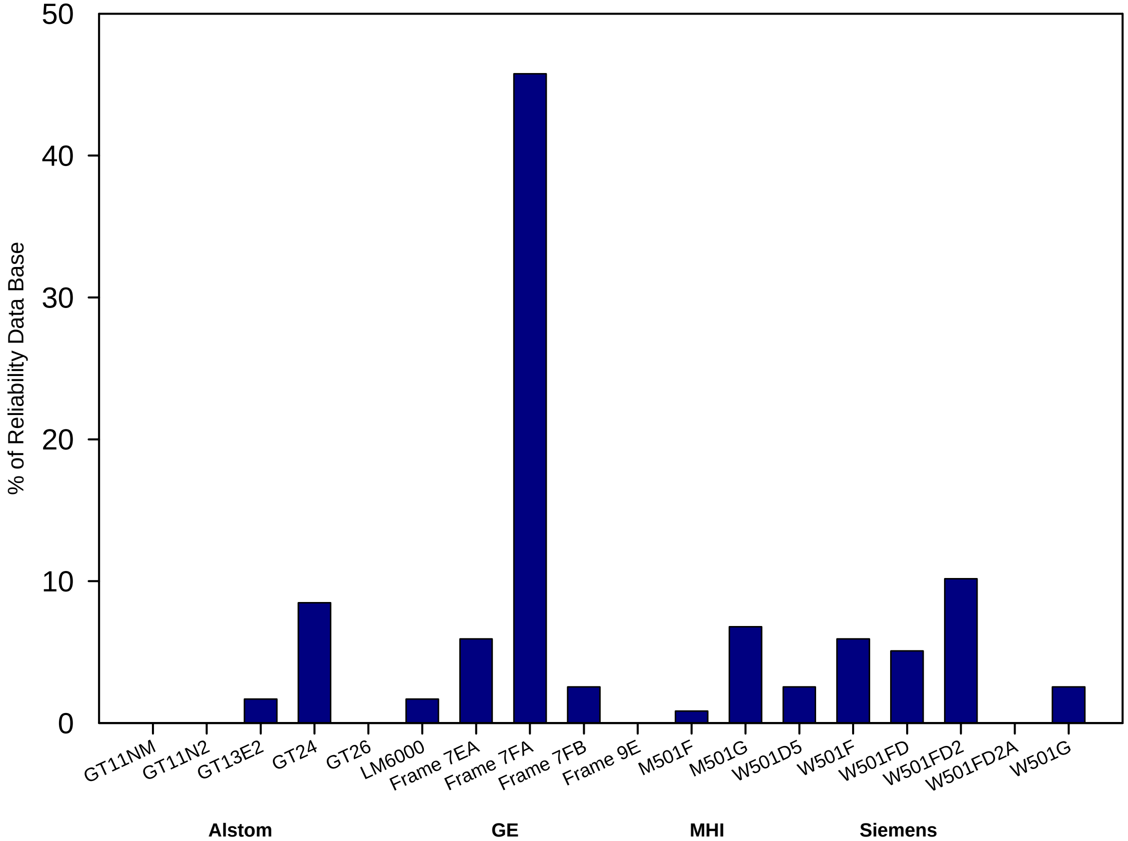

Figure 2-2 HRSG Reliability Data Base by GT Model

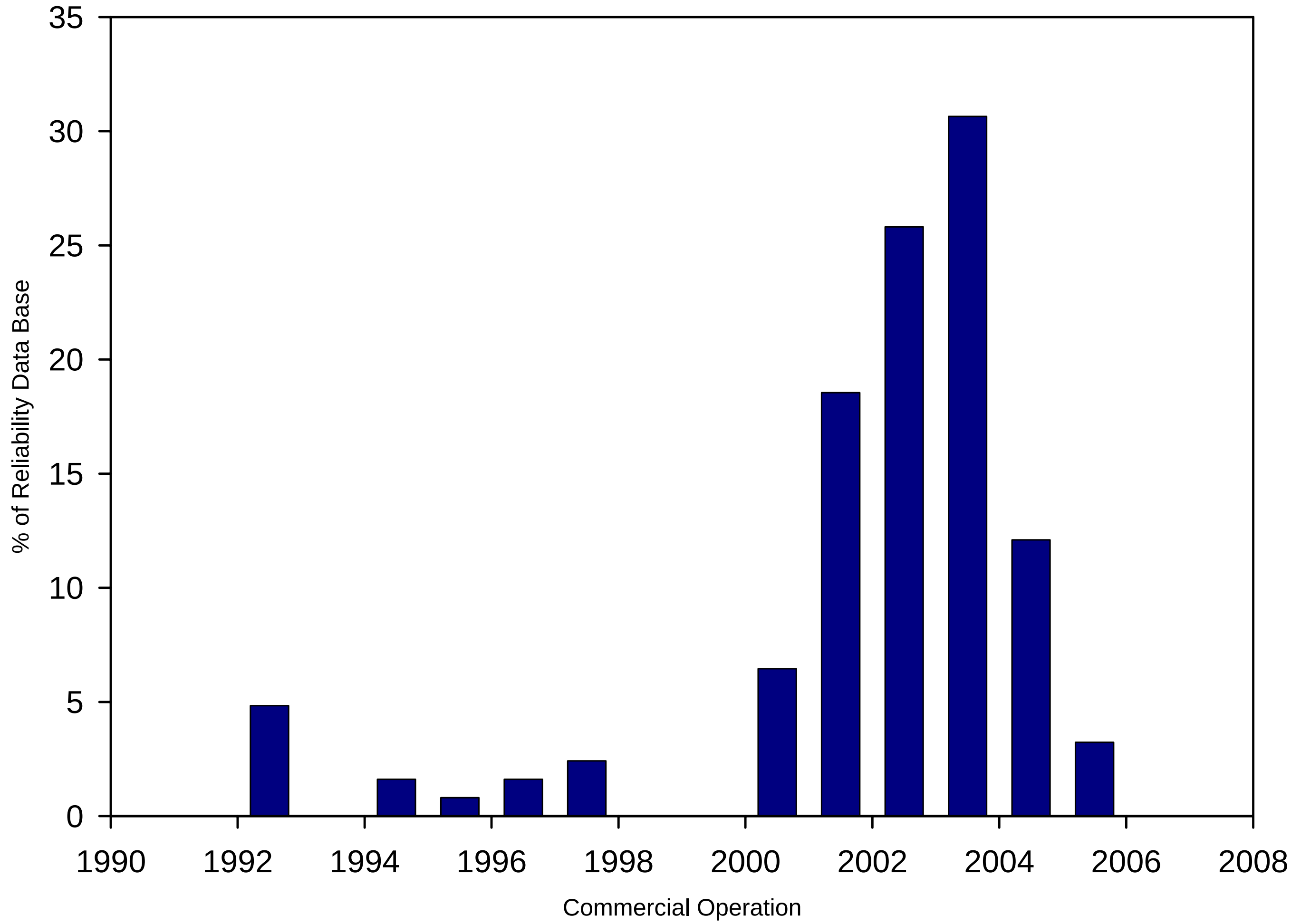

Figure 2-3 Commercial Operation for RDB Plants

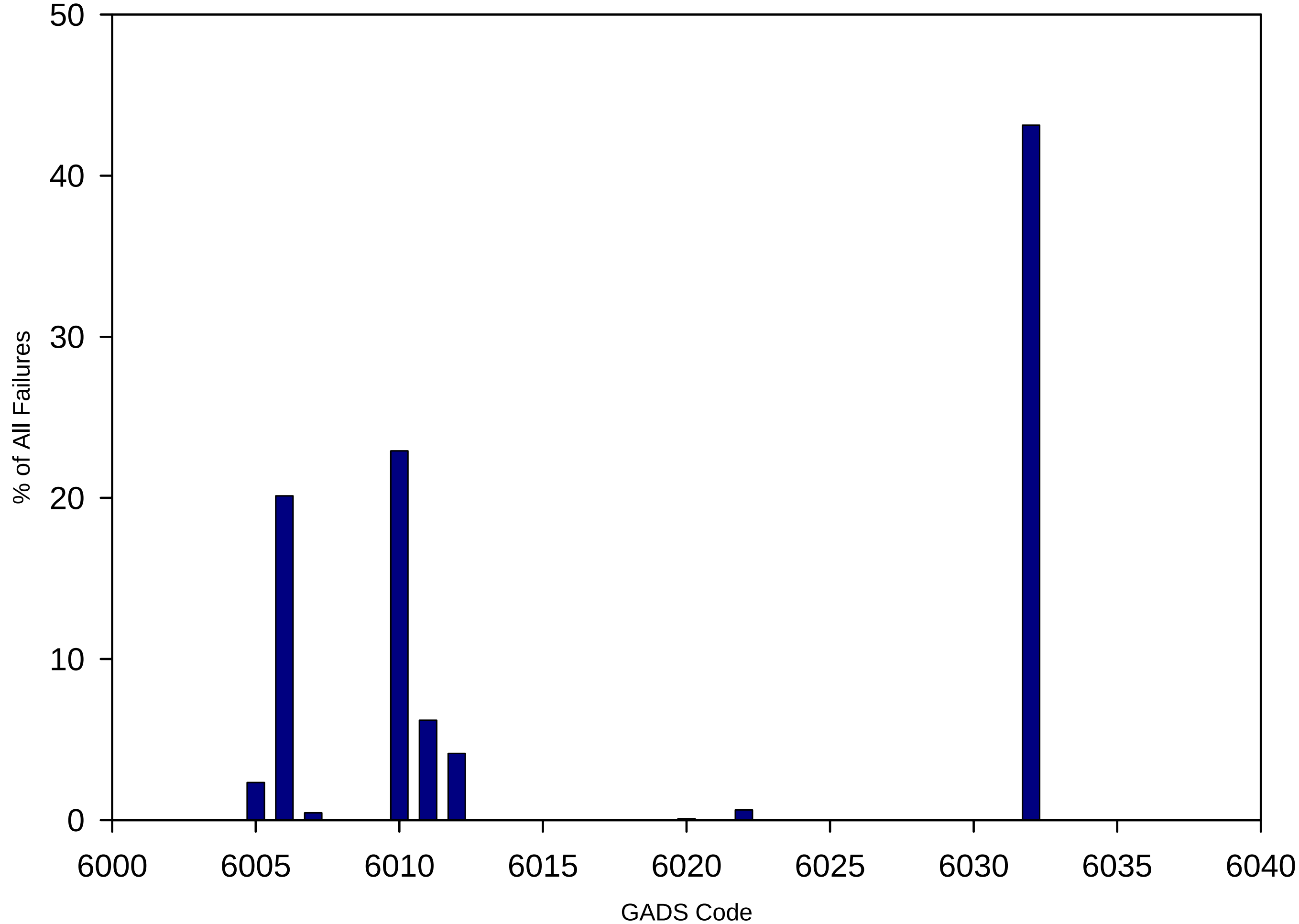

Figure 2-4 All Failures by GADS Code

3. Reliability Metrics

3.1. Overview

This report addresses the important contribution to HRSG unreliability due to HRSG tube failures. HRSG tube failures continue to be the leading cause of combined cycle plant unreliability. The modular designs of modern HRSGs do not lend themselves to easy access for repairs.

Figure 3-1 and Figure 3-2 provide a general overview of the frequency of HRSG tube failures at plants in the HRSG Reliability Data Base ("RDB"). From these graphs it is seen that many plants have experienced at least a few tube failures while an isolated few have experienced many typically requiring module replacement. More than 2/3 of the plants whose data are in the RDB have experienced tube failures.

The time to first tube failure is shown in Figure 3-3 where a classic early life failure pattern with operating time is indicated. The decreasing trend of time to first failure with operating time suggests these early life failures will decrease in frequency with longer operating. However, the same graph shows that the decreasing trend abruptly changes after 8-10 years of operation. This is when longer term corrosion damage such as FAC can occur for a HRSG that otherwise has had few problems with pressure parts.

Data currently in the HRSG RDB do correspond to relatively new plants overall as indicated in Figure 3-4. These units entered commercial service in a time pattern that is consistent with the overall introduction of large combined cycle plants into baseload, merchant and voltage support service throughout the world. Most of these new, large plants were designed in the late 1990s, entering service as indicated in the graph. As such, there is only very little long term data for operation beyond 5 years or so.

Figure 3-5 provides a comparison of the number of starts per year vs. the number of operating hours per year for large HRSGs in baseload, cycling and voltage regulation service. From this graph it is clear that cycling units, such as typically operate in merchant service, are often subjected to very large numbers of starts. While the total numbers of starts is large, the critical variable is the number of cold starts as these are significantly more damaging to HRSG pressure parts than warm starts. Differences such as these are typically addressed in HRSG Cost of Cycling evaluations and Remaining Life Assessments.

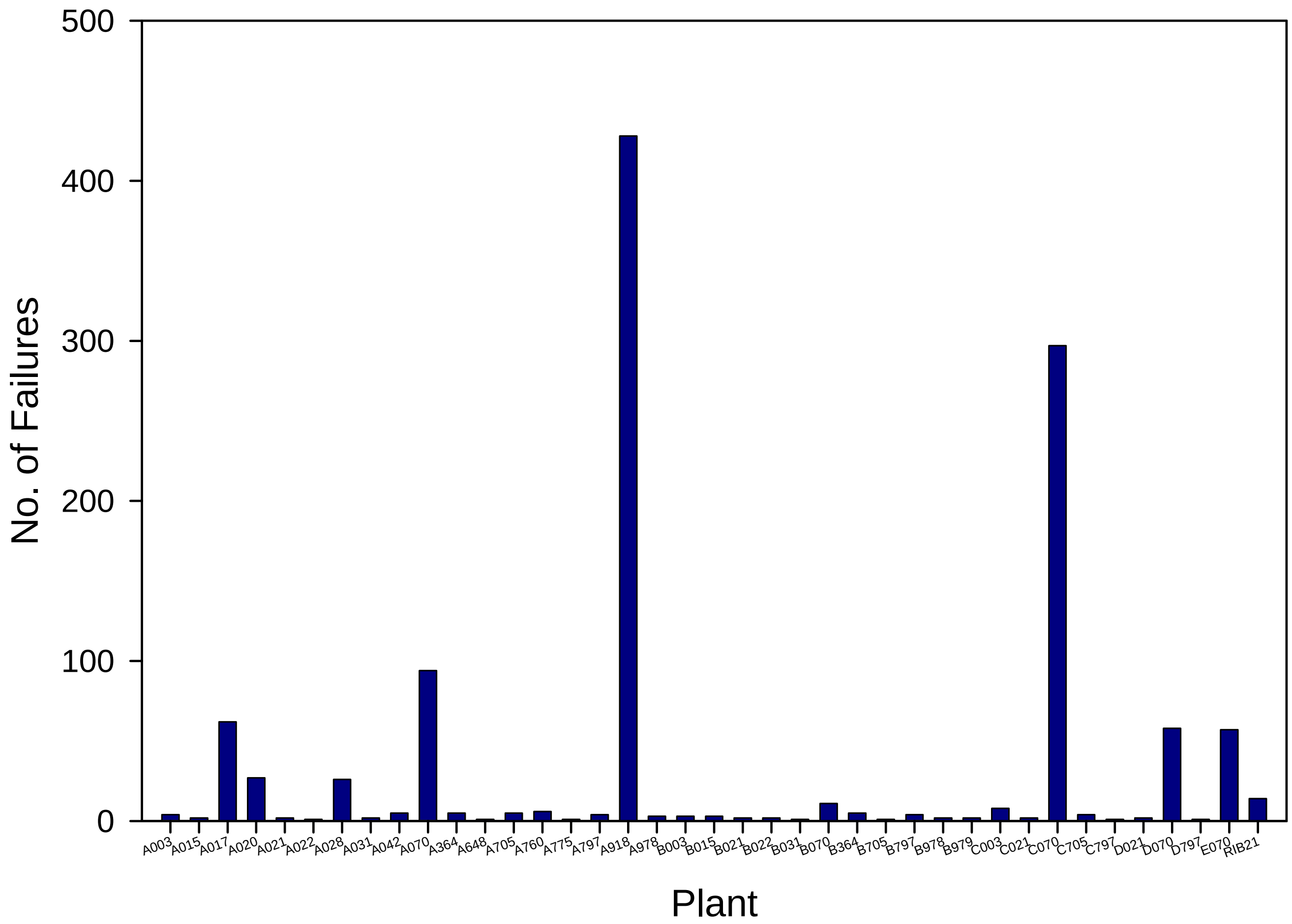

Figure 3-1 All HRSG Failures by Plant

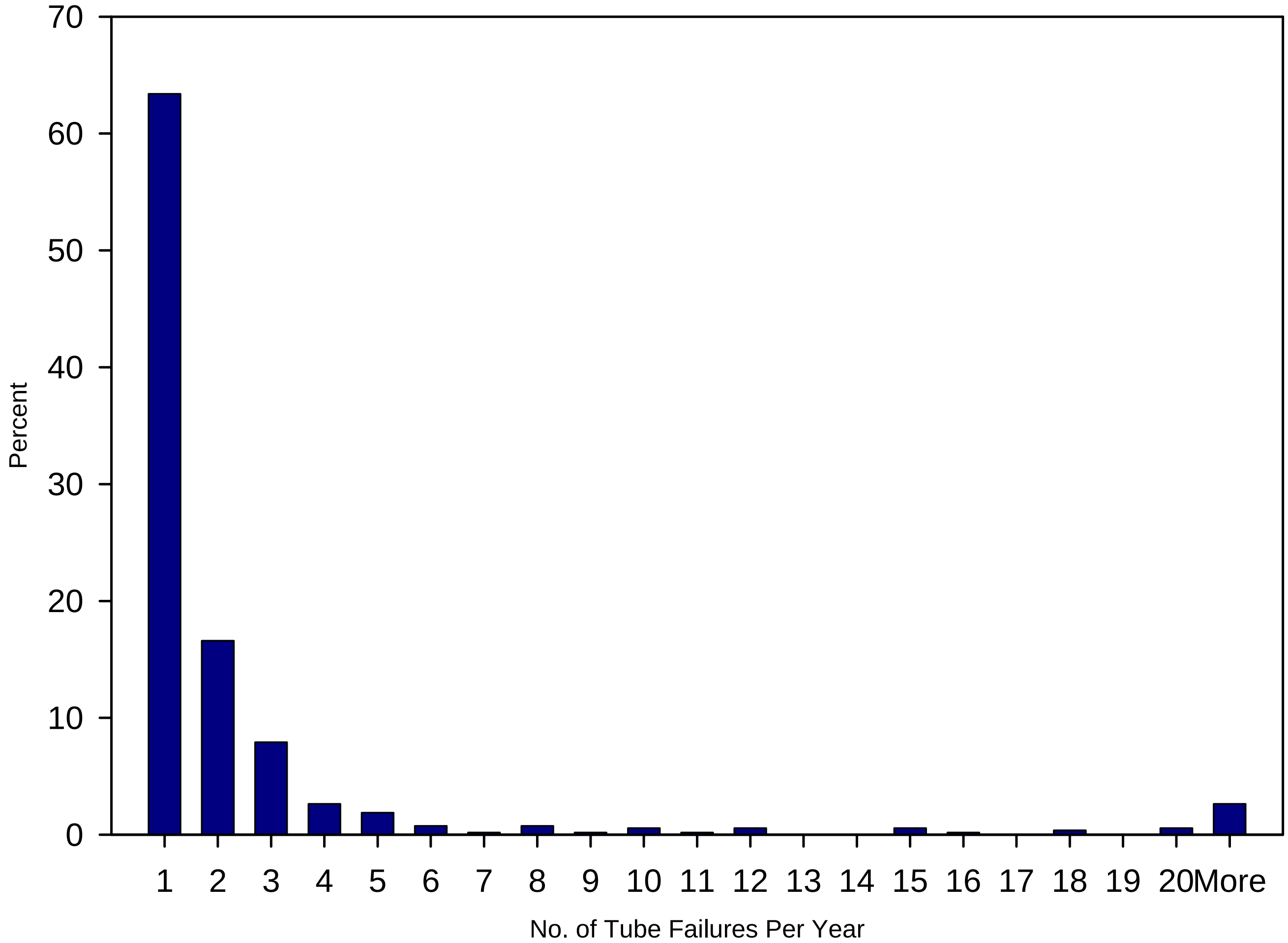

Figure 3-2 No. of Tube Failures Per Year (Plants with Failures)

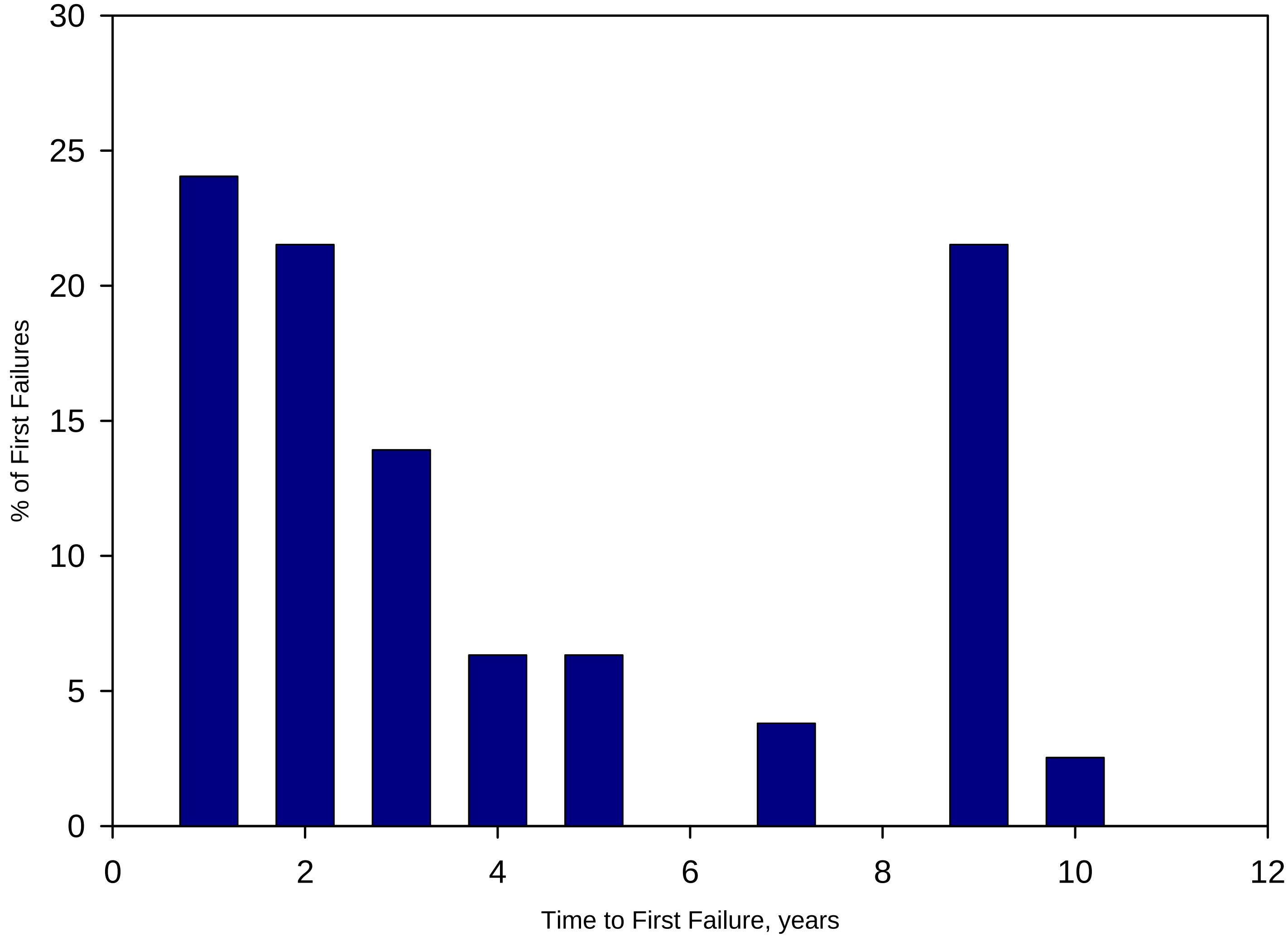

Figure 3-3 No. Years to First Tube Failure

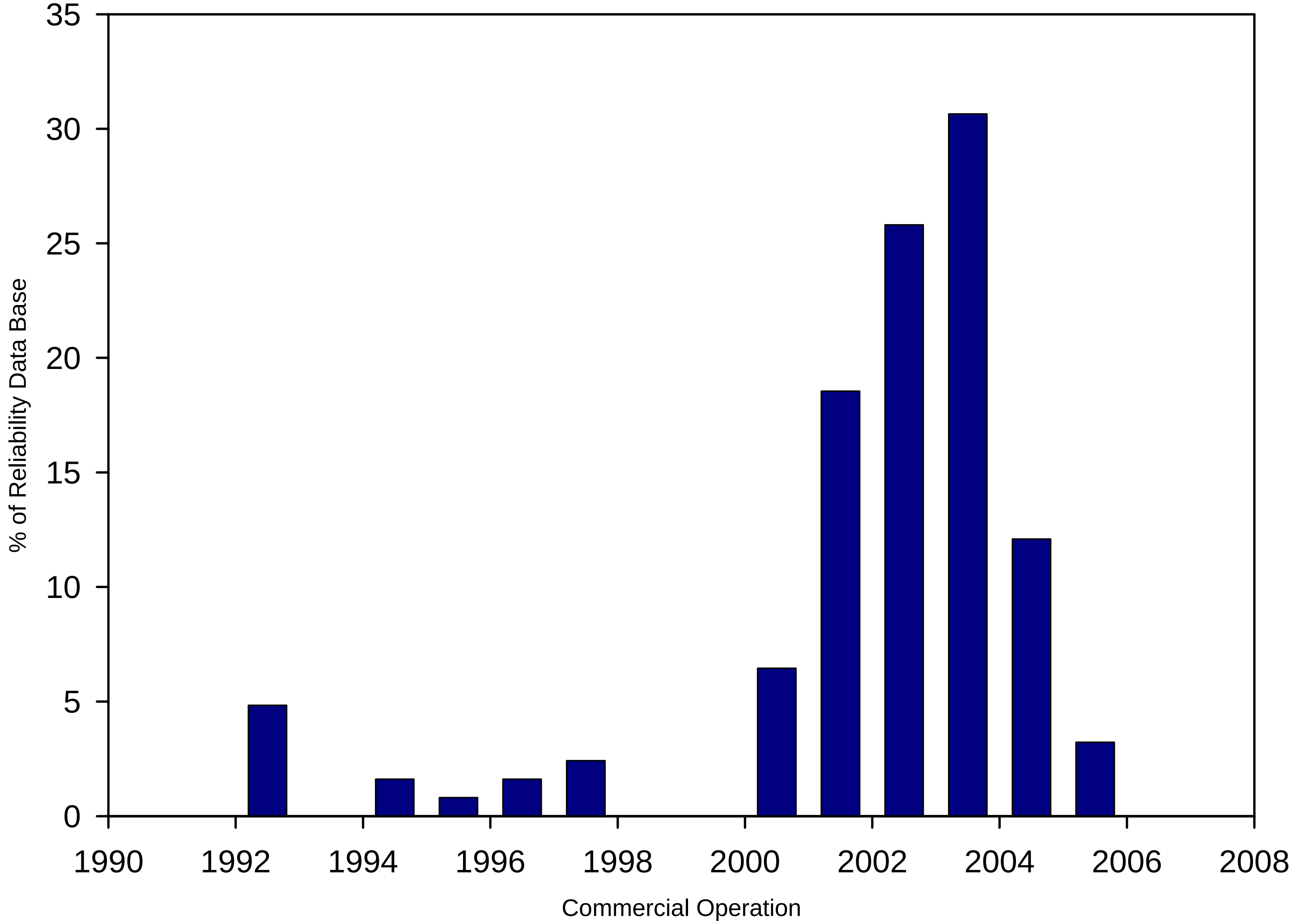

Figure 3-4 Year Commercial Operation Commenced

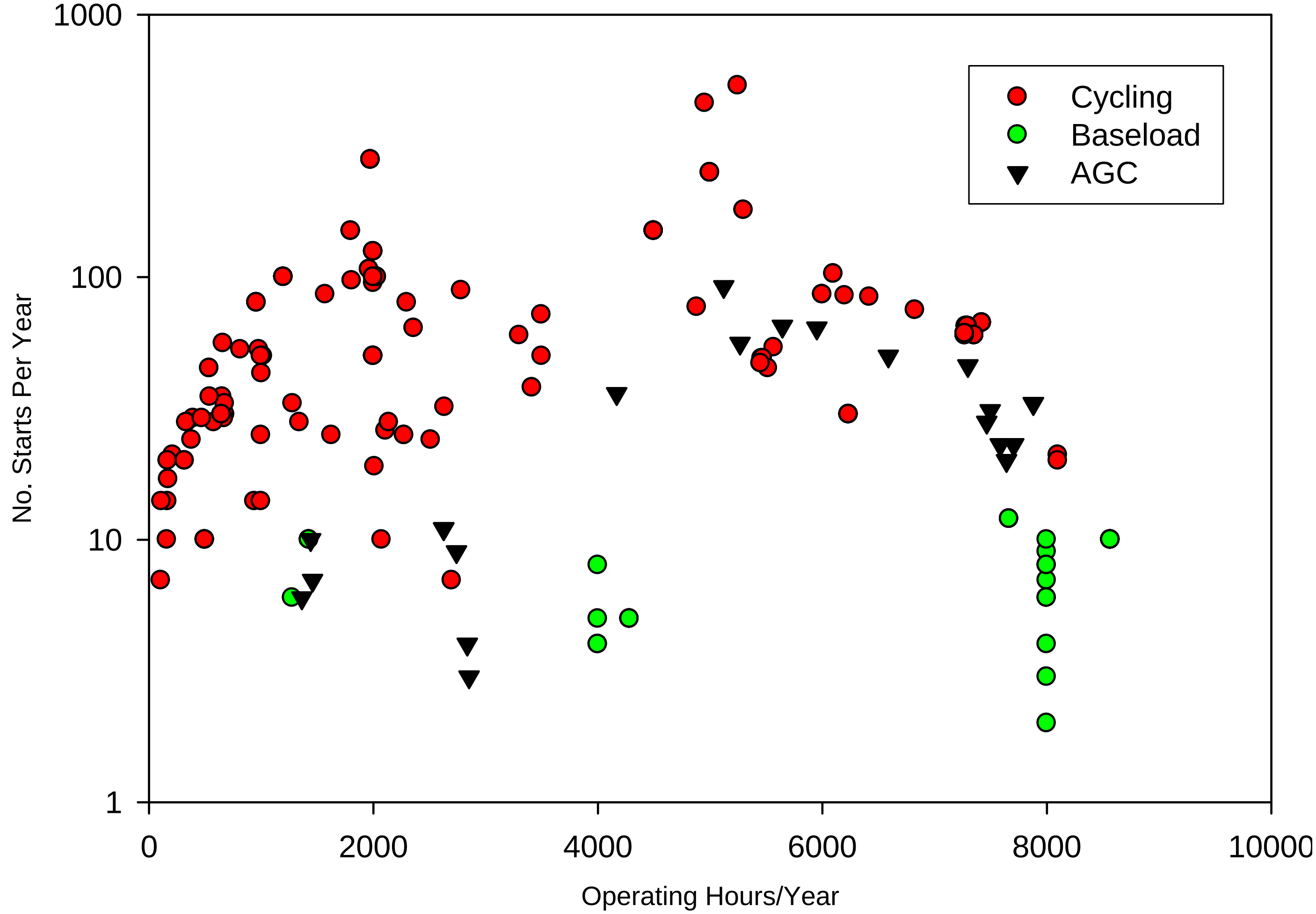

Figure 3-5 Starts vs. Operating Hours/Year