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CONCENTRATED SOLAR POWER (CSP) CODES AND STANDARDS GAP ANALYSIS

ASME STANDARDS TECHNOLOGY, LLC

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CONCENTRATED SOLAR POWER (CSP) CODES AND STANDARDS GAP ANALYSIS

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FOREWORD

The report provides an analysis of the ASME codes and standards that apply to Concentrated Solar Power (CSP) technologies to determine the gaps in the codes and standards and where there may be additional codes and standards work required to implement and commercialize CSP.

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ABSTRACT

Numerous concentrated solar power (CSP) facilities have been in successful commercial operation for the past 25 years. Recently, government incentives and advances in cost reduction have brought many new players into the field. An accelerated deployment of CSP is currently being seen worldwide. Many of the developing technologies in CSP have failure modes and effects different from those treated by existing boiler and pressure vessel codes. This study is a gap analysis to identify differences between the safety regulation needs of emerging CSP technologies and existing ASME Boiler and Pressure Vessel codes (BPV). Six leading CSP technologies are examined. The safety related failure modes of these systems are identified and compared with existing Code rules to identify gaps in code coverage. Recommendations for actions to close these gaps are proposed.

1 INTRODUCTION

Concentrated solar power (CSP) systems focus solar radiation collected from a large surface area to a smaller area to heat a medium to an elevated temperature. The collected heat is then used for process purposes or for the generation of electric power. A wide variety of heat transfer media are being explored for use in CSP systems. These media include water, steam, heat transfer oils, air or other gases, and even solid particles. This study examines a select subset of six CSP technologies being developed today with the objective of identifying gaps between the technologies and current ASME Boiler and Pressure Vessel (BPV) Codes.

This study is not a comprehensive review of the entire field of concentrated solar power. Because of the wide scope of active work in the field, only the most visible technologies are reviewed here. Although some of the advantages and disadvantages of the various systems are mentioned here, it is not the goal of this report to make any judgments about the economic viability of any of the systems. There are commercial plants that have been operating for as long as 25 years; nonetheless, this field is in its relative infancy. There are myriad researchers following a multitude of paths. The industry does not yet appear to be narrowing its technology choices. It would be premature at this point in time to try to sort the winners from the losers.

The common elements in all CSP systems are the collector system and the receiver system. The collector system consists of the mirrors, lenses, or other devices that focus and concentrate the solar radiation on the receiver. The receiver system is a heat exchanger that converts the focused solar radiation to another form of energy that can be used either for process heating or to generate electric power. This paper focuses on CSP power generation.

The CSP technologies reviewed for this study are:

- Dish systems
- Linear systems
    - Parabolic trough reflector systems
    - Linear Fresnel reflector systems
- Power towers
    - Direct steam (Rankine cycle) systems
    - Volumetric expansion (Brayton cycle) systems
    - Molten salt systems

These three categories are based on the physical architecture of the collector systems. A wide variety of receiver systems are being explored by developers. Receiver systems can be generally be coupled with a variety of different collector systems which results in a large domain of collector/receiver pairings.

Dish systems have a physical architecture employing a parabolic reflector, generally multi-faceted, as the collector. The receiver, located at the focal point of the reflector, is generally a reciprocating Stirling engine. There has been some research of dish systems employing a gas turbine as the engine. Dish receiver systems that export a heated fluid are also possible.

Linear systems consist of linear, fluid-filled receiver tubes running parallel to grade at a relatively low elevation. The collector system employs linear reflectors of parabolic shape or multi-element Fresnel arrangements in a common plane to focus sunlight on the receiver tubes. Thermal heat transfer fluids, air or molten salt can be heated in these systems. Some systems are generating steam that can directly power a turbine.

Power towers are point focus systems that consist of a collector field of flat or slightly curved mirrors with two axis pointing systems that focus the solar radiation onto a receiver located on a tall central tower. The mirrors and their pointing drives are referred to as heliostats. The receivers in power tower systems can be designed for direct steam generation, for expansion of air or gas, or to heat a mass storage medium such as molten salt. There have even been experimental systems tested that heat a fluidized curtain of falling solid pellets or spheres which could be stored for subsequent extraction of heat for process or power generation purposes.

Each of these systems is described more specifically in Section 2. The major components and their relationships are explained with emphasis placed on identifying system components that contain pressure or provide a heat transfer function. It is these components that may fall under BPV jurisdiction.

Section 3 examines the BPV Code issues related to each system. First, the code section having the system within its scope is identified. This exercise is not trivial as the definition of a boiler varies between jurisdictions. Some jurisdictions classify all of these CSP systems as boilers while others classify none of them as boilers. The confusion in definitions is largely because current regulations were written before the advent of current CSP technologies.

Section 3 then examines the safety related failure mechanisms of the systems. For each failure mechanism, two questions are posed:

1. Are these failure mechanisms adequately covered by present codes? (i.e., what are the code gaps?)
2. Are there BPV Code requirements imposed on the system that serve no safety related purpose?

Section 4 provides provisional suggestions of future BPV code development initiatives. Some judgment will be needed to choose which of the suggestions to pursue. At this time, a wide variety of technologies are being pursued. The industry has not settled on a favored or best technology yet. Some of the technologies may not prove to be economically viable and will fall out of the marketplace; developing rules to address these systems may waste limited code committee resources. However, the number of gaps between the industry's needs and the BPV codes is small, so the burden of addressing the gaps is not great.

Section 5 touches on the future in the development of PTC technologies. The ASME PTC 52 committee is developing a performance test code for concentrated solar thermal power systems. Among the technologies that will be covered by this code are linear Fresnel collectors, parabolic troughs, power towers, and thermal storage. The committee members were drawn from various countries and interest areas.