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BLISS
Boundary Layer Inline Separator Scrubber

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Abstract

A new compact, low cost, and high performance separator is being developed to help reduce the installed and O&M cost of geothermal power generation. This device has been given the acronym "BLISS" that stands for "Boundary Layer Inline Separator Scrubber". The device is the first of a series of separators, and in the case of injectates, scrubbers to address the cost-reduction needs of the industry.

The BLISS is a multi-positional centrifugal separator primarily designed to be simply installed between pipe supports, in a horizontal position. This lower profile reduces the height safely concern for workers, and significantly reduces the total installation cost. The vessel can demand as little as one-quarter (25%) the amount of steel, traditionally required to fabricate many large vertical separators.

The compact nature and high separating efficiency of this device are directly attributable to a high centrifugal force coupled with boundary layer control. The pseudo isokinetic flow design imparts a self-cleaning and scale resistant feature. This polishing separator is designed to remove moderate amounts of liquid and entrained solids.

Introduction

Geothermal separators and scrubbers are the most expensive pieces of hardware between the wellhead and the power plant. The total installed cost per project can not only represent millions of dollars in capital expenditure, but the synergistic effects can represent a ten (10x) fold or greater financial impact on the project. Poor separating efficiencies have slugged, scaled, clogged, or eroded various components, reducing power generating efficiency; has significantly increased maintenance expenditure; and has even destroyed turbines.

High-pressure drop across separators reduces a depleting reservoir's ability to deliver steam to the turbine. In many instances, this choke effect in pipeline and separator strategy can reduce the amount of steam flow by up to ten percent (10%) or more in extreme cases. Better separators and scrubbers can help reduce the number of wells drilled to support the plant, enhance resource recovery, and reduce operating and maintenance cost. Today, where cost is critical, better and lower cost geothermal steam processing technology can save the industry millions of dollars, and improve its competitiveness relative to other energy sources.

The geothermal industry in the majority of cases utilizes large vertical separators and scrubbers to remove liquid, and dissolved and entrained solids from the vapor fraction. Alternative low cost separators and scrubbers have been conceived to address the needs of the Geothermal Industry. The new technology development will target total *installed cost-savings in excess of 50%*; with an overall *pressure loss saving to 75%*; with an *improved steam quality and purity* into the *turbine in excess of 10 fold*. This paper will focus only on the BLISS.

BLISS Concept

The "Boundary Layer Inline Separator Scrubber" is a geothermal steam purifier that utilizes the pipeline as part of the separator. This approach enhances removal efficiency, conserves steel and reduces installation cost. A spin inducer can be installed within the pipeline to reduce the vessel size, impart a higher centrifugal force, and reduce the transitional particulate migration distance to enhance removal. The conditioned flow forms an annulus, with the liquid held by the high centrifugal force against the conduit wall, while the vapor flows through the core. This annular liquid profile enters a perforated liner where the denser material is squeezed through and isolated. This liner protects the isolated liquid from re-entrainment. The shielded liquid is drained from the separator body. Fig. 1 depicts BLISS operation.

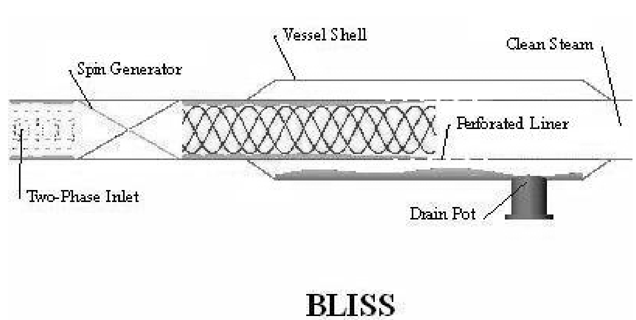

Fig. 1

The feature of this approach is especially advantageous in large diameter conduits where increased vessel size is costly. The key focus is controlling the boundary layer at high velocities. Conventional separators encounter abrupt transitions and collisions creating considerable particulate shatter and re-entrainment. This atomizing spray nozzle effect can significantly reduce the catch efficiency as smaller particles, coupled with a reduced centrifugal force in larger pipe diameters; and longer particulate travel distance yields lower performance. Furthermore, re-entrainment from high vapor flux is a serious problem in conventional centrifugal separators.

Re-entrainment, the mechanism of isolated solid or liquid reentering into the vapor stream is a concern addressed by the BLISS. The centrifugal force moves the liquid layer through the liner shell. The liner allows the liquid to be ejected without creating high shear and uncontrolled gas recycling. The protective liner isolates the liquid from the bulk vapor stream mitigating high transitional shearing and re-entrainment.

The pseudo isokinetic characteristic of the design helps to prevent liner and vessel scaling and plugging. Many traditional separators act as if they are a “throttling calorimeter”. High velocity, shearing, pressure drop, gradients coupled with the transition from high velocity inlet to low superficial vessel velocity evaporate or concentrate dissolved solids causing, precipitating and scale. The BLISS maintains a high velocity and pressurizes the liquid isolation chamber to prevent flashing.

This isokinetic effect does not mean no scaling will occur should supersaturation of the brine be reached. This implies that the design will not exasperate these scaling effects through thermodynamic action. Early prototypes have shown to exhibit no scaling whereas vertical centrifugal multitubular designs under the same conditions have been scaled shut.

The pressure drop for the BLISS is moderately low; about equivalent to the differential pressure generated across a .8 beta ratio orifice plate. A target rate could be less than 0.1 bar. The superficial vapor operating range based on the inlet could be from 10 m/s to greater than 50 m/s. Inlet quality is highly variable but could be targeted for 50 percent or greater. A custom design could focus on minimizing pressure loss, maximize liquid removal or maximize exit steam quality.

Experiment

An air/water system was designed and fabricated to test the various configurations of the BLISS. Blowers, spray nozzles, re-circulating pumps, compressor, air and water flow meters, temperature and pressure indicators were installed. The basic line sizes were 80mm (3 inch) and 50mm (2 inch). Air velocity varied 10 m/s up to to 60 m/s. The water injection rate was varied from a fine spray to 3500 kg/hr. See Fig 2.

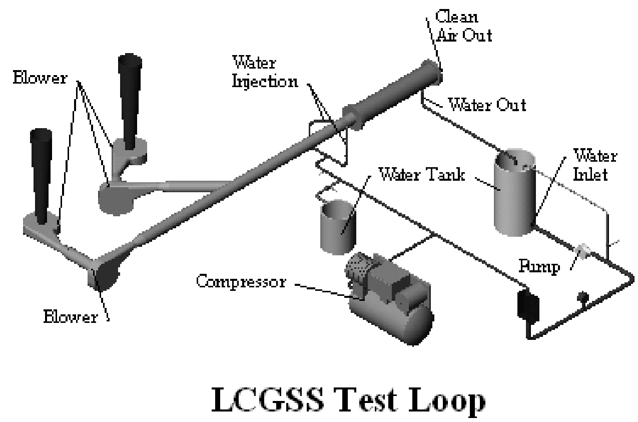

Fig. 2

The BLISS models were made primarily of Plexiglas so that visual observations could be made. Carry-over amounts were detected by visual and defraction techniques. At any specific blower setting, the water rate was increased with no carryover detected, a small amount of carryover, and maximum water injection for liner flooding. Internal inspection of the annulus could be viewed showing the cyclonic action and perforation performance as well as carryover.

An excess of 100 rudimentary configurations have been tried, zeroing in on the more promising configurations with more detailed testing reserved for the best configurations. The testing is still incomplete however, some of this information may be provided when the field testing is presented in 2001.

The configuration of the BLISS has a significant effect on performance. Some designs can only remove small amounts of liquid to perhaps 2 percent without significant carry-over. Others can remove a considerable amount of bulk liquid to perhaps 85 percent but are incapable of operating without serious re-entrainment, even with small amounts of liquid. Other designs are capable of removing large amounts of liquid with virtually no carry-over, are structurally unstable, and unacceptable for commercial use. Yet, some designs appear to be extremely rugged and are capable of removing greater than 85% liquid with very low carry-over. These test are currently being evaluated to determine the optimum configuration.

Field Plans

A BLISS field installation is tentatively scheduled for the Geysers @ the Unit 14 Power Plant. Serious erosion damage has occurred on the first and second stage turbine nozzle and blades. It is suspected that as a result of the steam wash process, and start-up operation high amounts of moisture and particulate may be entering the turbine causing these problems.

An 88" diameter high velocity multi-stage centrifugal separator is currently the final steam polisher prior to the turbine entry. A BLISS could be installed down-steam of the vertical separator to remove carry-over and condensate prior to the turbine entry. It is tentatively projected that a 54" BLISS could be used in this steam quality enhancement program. The time frame is expected in mid 2000. The success of this program could result in duplicate program at other plants at the Geysers suffering from similar difficulties.

Cost Savings

The application of BLISS technology could mean replacing a high velocity two-stage vertical cyclone 88 inches in diameter by 50+ feet high, with a horizontal separator 54-inch in diameter by 20+ feet long. It is believed this technique can reduce the separator plus installation cost involving large foundations, large vertical pipe runs, expansion loops, safety platforms, etc. by more than fifty percent (50%).

It is estimated that the installation price for an identical installed PortaTest could cost up to $700,000. A BLISS system could be totally installed for approximately $300,000. The pressure drop across the BLISS is projected to be less than that of the vertical separator, plus the fittings and inlet/outlet piping are an added bonus.

Conclusion

BLISS is a new compact separator designed to help reduce the cost of producing geothermal energy. It is a low profile device eliminating the need for large foundations, high safety platforms, and vertical pipe runs/expansion loops. It can be dropped in between sections of pipe. This lower weight, easier to install system is expected to significantly reduce the total installed costs of new or retrofit geothermal steam purifiers.

Unlike early prototypes that were only able to remove a few percent of liquid without high carry-over, these new designs are being optimized to remove moderate to large amounts of fluid. Some model configurations have shown to handle 85% liquid, although a 30% capacity may be a more practical design. Scale resistance and structural stability are concerns addressed by the new design.

A field trial will be underway to test the performance of these new separators. An update on the installation and performance will be provided as information becomes available.

References

Overview of Geothermal Separators, Jung D.B., 1989 GRC Transaction

Steam Quality Testing, Jung D.B., 1995 GRC Transaction

Drip-Pot Applications, Jung D.B., 1995 GRC Transaction

Dry Steam Scrubbing, Fisher D.W./Jung D.B., 1996 GRC Transaction

Air/Mud Drilling Separator Modification, Fisher D.W./Jung D.B., 1997 GRC Transaction

Brady Power Plant Steam Quality and Purity Enhancement, Hoffman, A./ Jung D., 1997 GRC Transaction

Production Equipment & Facilities Cost Reduction, D. Jung, 1997 GRC Transaction

Compact Portable Two-Phase Well Test Separator, Fisher D.W./ Jung, D.B., 1998 GRC Transaction

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