

Application Solution Guide

CONCENTRATED SOLAR POWER



Experience In Motion



TABLE OF CONTENTS

THE GLOBAL CONCENTRATED SOLAR POWER

LANDSCAPE

- Market Overview 3
- A Closer Look at Concentrated Solar Power Technology . 4
 - Basics 4
 - Plant Configurations 5
 - Plant Sizes/Temperatures 7
 - Hybrid Cycles 7
 - Integrated Solar Combined Cycle (ISCC). 7
 - Integrated Solar and Desalination Plant 9
 - Concentrated Solar Power Project Models 10

THE CONCENTRATED SOLAR POWER-FLOWSERVE INTERFACE

- Business Impact and Focus Areas 12
 - The Big Picture 12
 - The Flowserve Fit in Concentrated Solar Power 13
- Products for Concentrated Solar Power – At a Glance . . 13
 - Pumps 13
 - Valves 14
 - Seals 14

FLOWSERVE OPPORTUNITIES IN CONCENTRATED SOLAR POWER – PRODUCTS AND CAPABILITIES INFORMATION

- Overview 15
- Flowserve Products in Concentrated Solar Power 15
 - Molten Salt Pumps 15
 - Parabolic Trough Pump Applications (PFD167) 15
 - Power Tower Pump Applications (PFD168) 15

- Valves for Concentrated Solar Power 16
- Parabolic Trough Valve Applications (PFD167). 17
- Power Tower Valve Applications (PFD168). 21
- Actuators for Concentrated Solar Power 25
- Seals for Concentrated Solar Power 26

COMMUNICATING OUR VALUE

- Flowserve Value Proposition in Concentrated Solar Power 28
- Innovative Ways Flowserve Addresses Customer Challenges 29

APPENDIX

- Terminology 31
- Acronyms 31

FIGURES

- Figure 1: Parabolic trough mirror and receiver 3
- Figure 2: Tower or central receiver 4
- Figure 3: Fresnel mirrors and receiver 4
- Figure 4: Parabolic trough with molten salt as the HTF 5
- Figure 5: Parabolic trough with thermal oil as HTF and molten salt TES 6
- Figure 6: Tower with molten salt as HTF and TES 6
- Figure 7: Simplified integrated solar combined cycle plant 8
- Figure 8: CSP integrated with MED desalination plant 9
- Figure 9: Global renewable power market additions (MW), 2017–2030 12

THE GLOBAL CONCENTRATED SOLAR POWER LANDSCAPE

Market Overview

There are two major classifications of solar power generation: solar photovoltaic (PV) and concentrated solar power (CSP). In solar photovoltaic power generation, the sun's energy is directly converted to an electric current. CSP involves the sun's heat energy being concentrated and transferred to a fluid, which will facilitate the use of the Rankine (steam) cycle for power generation. This document deals with the latter, as the solar photovoltaic method does not require pumps, valves or similar process control equipment.

An advantage of CSP is that there is inherently some stored thermal capacity in the system, which helps

maintain generation capacity, even when sunlight is not available. The stored thermal capacity of the system is often increased using molten salt as a heat transfer agent. This is referred to as *thermal energy storage* (TES). Depending upon the TES system employed, the ability of CSP to run without the sun's energy can range from just a few minutes to overnight.

Despite the falling costs and simplicity of solar photovoltaic, CSP systems are being built because of their ability to more predictably generate electricity.



Figure 1: Parabolic trough mirror and receiver

A CLOSER LOOK AT CONCENTRATED SOLAR POWER TECHNOLOGY

Basics

Concentrated solar power plants are similar to a combined cycle gas turbine plant. Instead of using exhaust heat from a gas turbine to generate steam, CSP plants use sunlight as the heat source to generate steam, which is the motive force for the steam turbine generator set.



Figure 2: Tower or central receiver

Central Receiver or Solar Tower — The second most common form of CSP. An array of large individually tracking mirrors (heliostats) focus solar radiation onto a central receiver mounted on top of a tower. Water or molten salt are the typical heat transfer mediums, which employ multiple heat exchangers to produce steam to be used in a Rankine cycle. Air can also be utilized as the heat transfer medium, which can be used directly in a gas turbine. Typically limited to 650°C (1202°F) with potential beyond 1000°C (1832°F).



Figure 3: Fresnel mirrors and receiver

To provide heat energy of sufficient temperature for power generation, the sunlight must first be focused or concentrated. Multiple technologies have been developed, but there are four main technologies that have been commercialized:

Parabolic Trough — The most common form of CSP. Parabolic mirrors focus the sun's energy onto an absorption tube at the focal point running the length of the parabola. Heat transfer fluids (HTF) running through the pipe transfer the heat energy to the water/steam in heat exchangers, which is then used in a Rankine cycle. Typically limited to 400°C (204°F) with potential to 500°C (932°F).

Fresnel — Similar to a parabolic trough. Flat or slightly curved mirrors mounted on trackers reflect sunlight onto an absorber. A thermal transfer fluid can be used or it can directly produce steam. Not as efficient as parabolic trough or tower systems, but the structural and reflector costs are lower. Typically limited to 400°C (204°F).

Parabolic Dish System — A parabolic dish-shaped mirror reflects sunlight onto the central focal point of the dish. A thermal fluid or gas is used to receive the energy and then power a small piston, turbine or sterling engine. This is generally used for small and stand-alone, off-grid systems. Although it has high conversion efficiency, it has limited thermal storage capacity. There are no pump or valve applications for this technology.

Plant Configurations

Whether parabolic trough, central receiver or fresnel, during normal operation, a heat transfer fluid carries heat from the absorber (receiver) to a heat exchanger and steam generator system where the heat energy is used to raise steam and power a steam turbine. Whenever a thermal oil HTF is utilized, as is typically the case in parabolic trough systems, the maximum temperature of the system is about 400°C (752°F). When molten salt is used exclusively as the HTF, such as in a central receiver configuration, the maximum temperature of the system can be raised to 600°C (1112°F) and higher (see Table 1). Cold molten salt is returned to a cold tank at approximately 290°C (554°F), but this temperature varies based upon the system's design.

Because of the variability in the sun's energy at different times of the day, many plants utilize molten salt TES. When TES is implemented, for the part of the day when the sun is at its most intense position, collectors provide more heat than is needed to power the turbine. The excess power is stored by transferring the HTF through a heat exchanger to heat molten salt.

Once heated, the molten salt is stored in a hot tank. During periods of low sun intensity, or during hours of darkness, the stored heat can be used in lieu of heat from the sun to generate steam and drive the plant turbine, thus providing for much more operational flexibility.

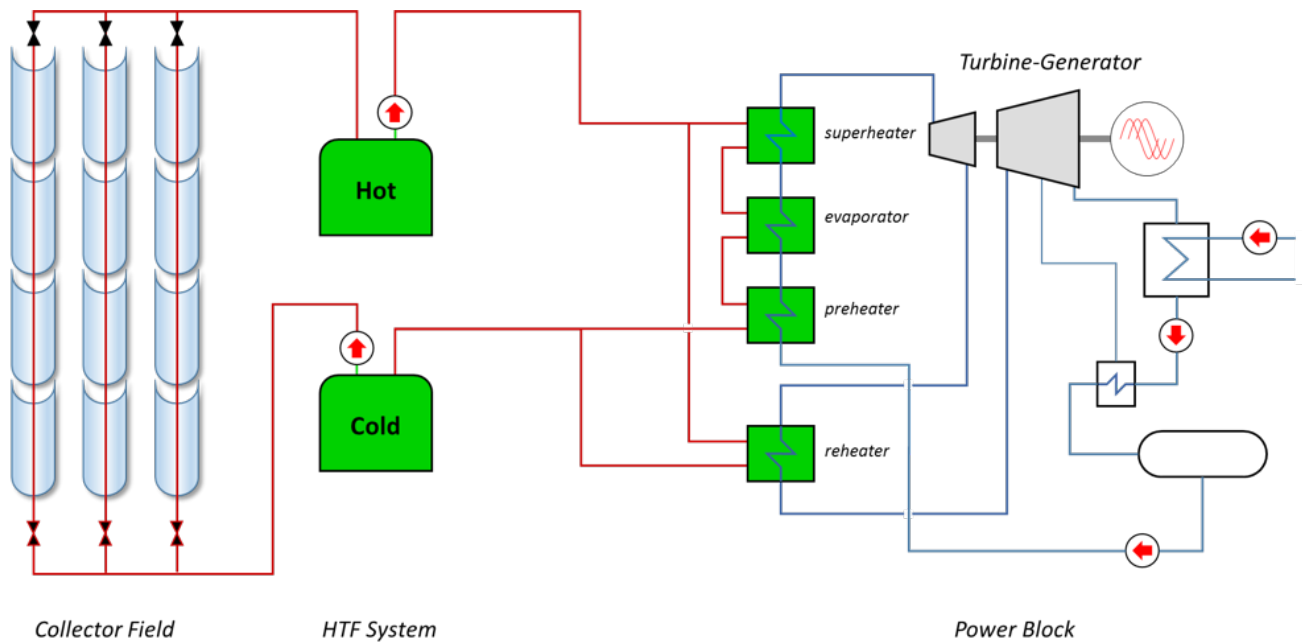


Figure 4: Parabolic trough with molten salt as the HTF

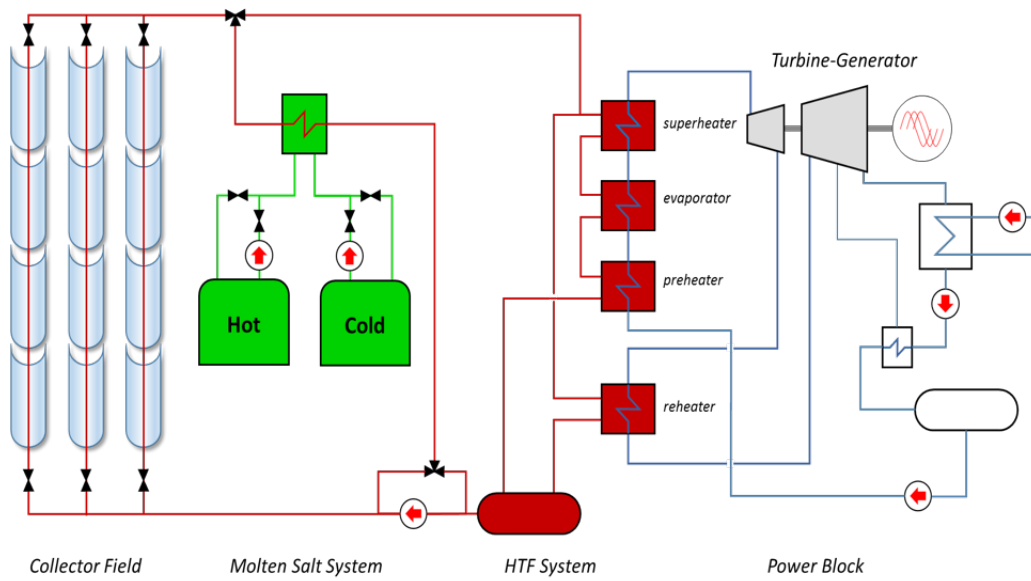


Figure 5: Parabolic trough with thermal oil as HTF and molten salt TES

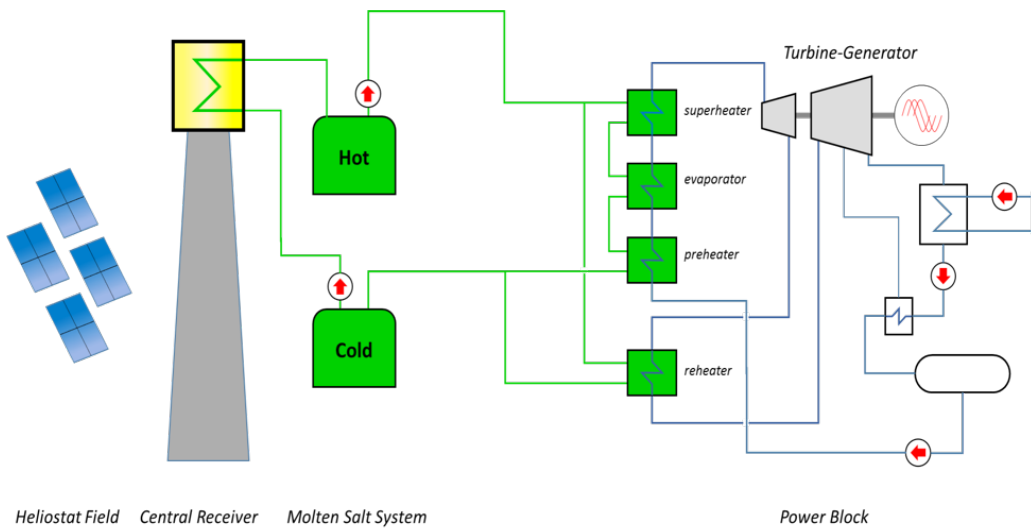


Figure 6: Tower with molten salt as HTF and TES

Plant Sizes/Temperatures

Configuration	Normal/Maximum Temperature	MW Rating
Parabolic Trough With Thermal Oil HTF and Molten Salt TES	387/400°C (729/752°F)	20 to 280
Parabolic Trough With Molten Salt as HTF (limited applications)	565/600°C (1049/1112°F)	5 to 120
Tower Receiver With Molten Salt as HTF	565/600°C (1049/1112°F)	20 to 120

Table 1: Plant sizes/temperatures

Hybrid Cycles

In addition to the conventional CSP technologies previously mentioned, other uses of concentrated solar power are in various stages of development, testing and deployments. The following represent some examples.

Integrated Solar Combined Cycle (ISCC)

One recent study concluded that integrating CSP with a CCGT plant can reduce the levelized cost of the solar-generated electricity by as much as 35% to 40%. This technology, known as ISCC, is ideally suited to operations in the Middle East and parts of North Africa, where sunlight and natural gas are abundant.

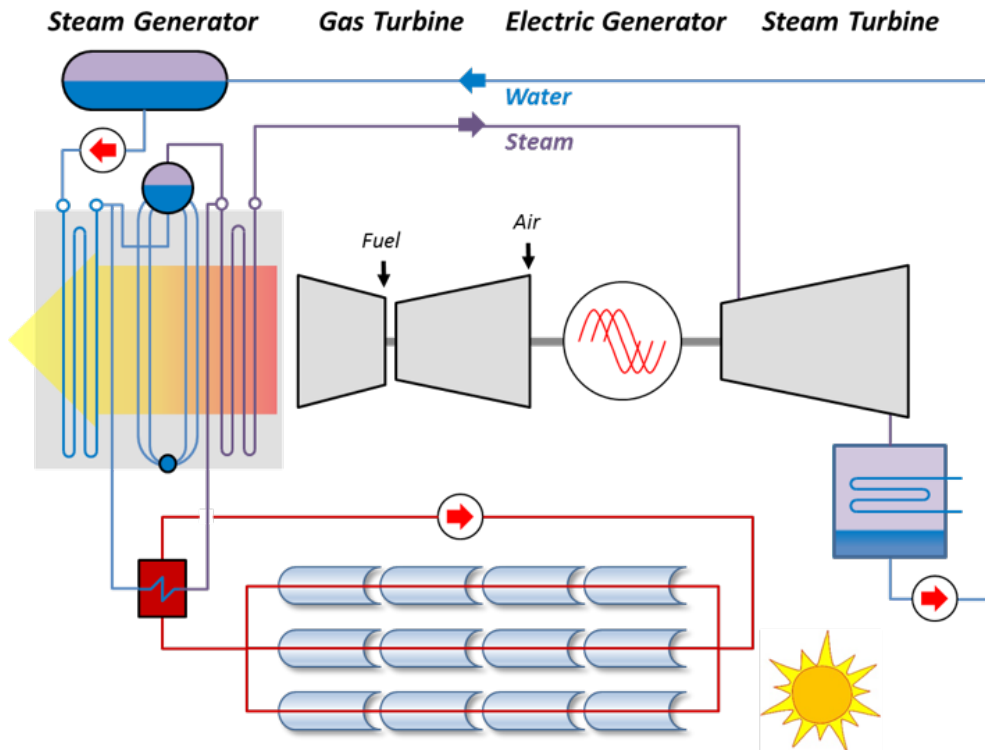
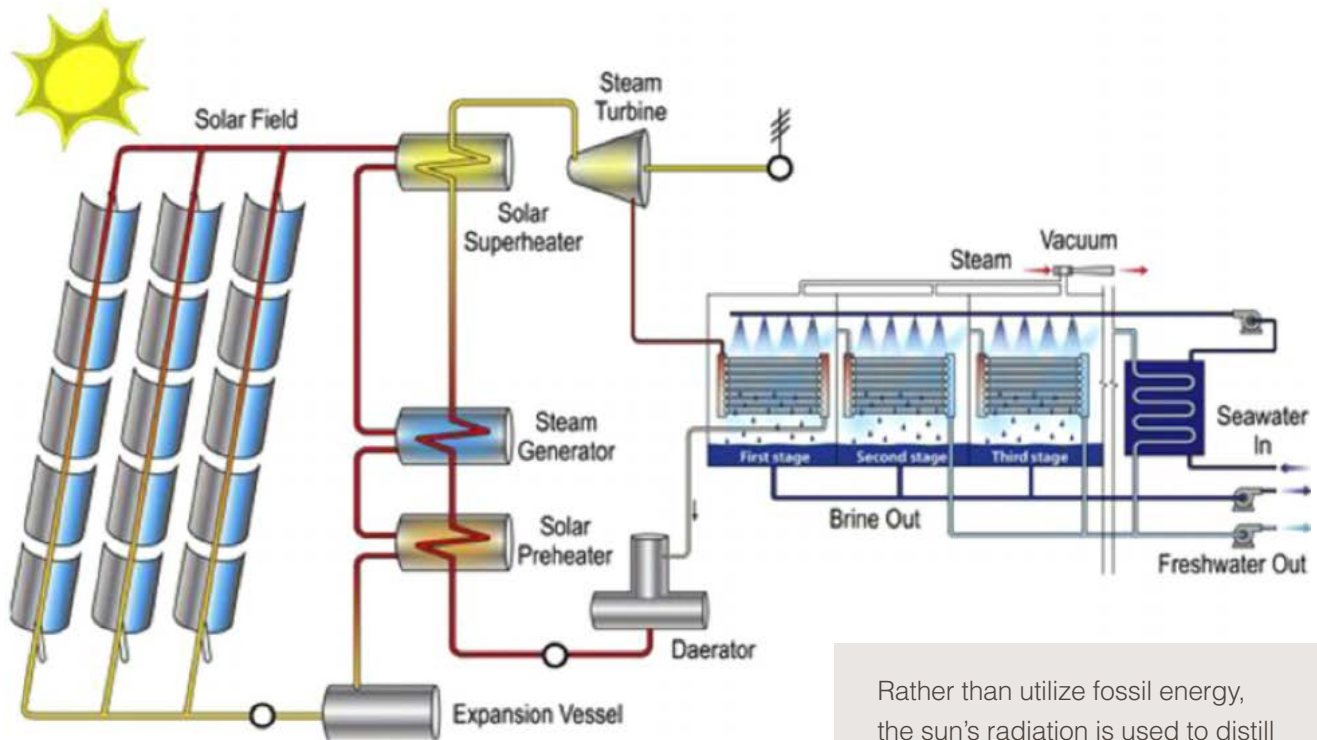


Figure 7: Simplified integrated solar combined cycle plant

There are several ways in which CCGT and CSP plants can be integrated. **Figure 7** shows a highly simplified illustration of perhaps the most common configuration. Here HTF is circulated through the solar field and passed through a heat exchanger to generate saturated steam. The feedwater for this solar steam generator comes from the economizer section of the heat recovery steam generator (HRSG). The saturated steam produced by the CSP plant returns to the superheater section of the HRSG. In effect, there are two evaporator sections in the system operating in parallel: one uses heat from the gas turbine exhaust gas and the other uses the heat from the solar field. The two parallel heat sources use a common economizer as well as a common superheater, which are both located in the HRSG. An example of this type of plant is GE's facility in Waad Al-Shamal, Saudi Arabia. The plant produces 650 MW in combined cycle plus another 50 MW from the solar field; Flowserve is a major supplier on this project.



Rather than utilize fossil energy, the sun's radiation is used to distill seawater and produce potable fresh water.

Figure 8: CSP integrated with MED desalination plant

Integrated Solar and Desalination Plant

Another application of concentrated solar energy is in the use of desalination. There are many types of desalination (which are covered in a separate application selling guide), but a combination CSP/multiple effects distillation desalination plant is being implemented in California. A simplified schematic can be found in **Figure 8**.

Concentrated Solar Power Project Models

CSP power plants are conceived and constructed under varying financial, regulatory and market circumstances. Understanding these can be vital to developing a successful sales strategy.

Power plant ownership and operation take many different forms. One is the publicly owned utility that operates in a rate-based regulated market and is vertically integrated, owning not only the generation assets but also the transmission and retail distribution network. Many developing countries have national utilities of this type. In developed countries, this type of utility — if it exists at all — generally occurs at a state or municipal level. Regulated rate-based utilities can also be privately owned; this is very common in many parts of the U.S. National, regional or state-based regulated utilities, whether publicly or privately owned, often have large experienced engineering, operations and maintenance organizations. They are much more likely to take an active part in the specification of equipment and in the evaluation of equipment proposed by project EPCs. Equipment specifications may have been developed over many years; as such, it can be very difficult to have any proposed deviations accepted. While EPCs generally operate under lump sum/fixed-price contracts, utilities can exercise important control on equipment purchased by them by including approved vendor lists in the bid specifications.

However, the situation with power plant owners in deregulated markets is somewhat different. One common project model is the power purchase agreement (PPA) between an independent power

plant (IPP) developer and an offtaker or purchaser of the power. PPAs guarantee the quantity and price of the power to be purchased for an extended time period and thus facilitate project financing. The offtaker is typically a public utility. These projects tend to be very sensitive to the overnight costs (i.e., capital cost of the plant with no finance charge, as if the plant was built overnight) of the project because the PPA is often awarded on a competitive auction basis. IPPs are often owned by groups of investors who do not have an extensive portfolio of generating assets or a great deal of engineering and operating expertise. As a result, they may tend to take a more “hands off” approach to equipment selection on a project. However, PPAs often have penalties tied to plant availability and project completion dates, so developers are not indifferent to reliability and quality.

Another utilized model is the merchant power plant. Merchant plants by definition do not have long-term PPAs and pre-identified customers. Financing projects with no guaranteed revenue streams can be difficult; these arrangements are generally applicable to existing older power plant assets.

Power plant developers and owners typically hire a consulting engineering company or companies (also known as *owner's engineer*) that will be involved in project planning, basic design, siting and permitting activities as well as the development of detailed project specifications for EPC bidding. The owner's engineer will not actually procure anything but may substantially impact the specifications, so it is important for Flowserve to be engaged with them by providing strong technical

A CLOSER LOOK AT CONCENTRATED SOLAR POWER TECHNOLOGY

support regarding pumps and valves. In some cases, the owner's engineer may also be involved in the bid evaluation and purchase decision and provide technical advice to solve problems during manufacturing, startup and commissioning.

Concentrated solar projects are frequently constructed under lump sum, turnkey, engineer, procure and construct (EPC) contracts awarded to large EPC contractors by the project owners. The EPC contractor may be a pure EPC company, or joint venture or the OEM supplying the major equipment for the project (power tower, parabolic trough, steam turbines and generators). In some cases, there may be more than one EPC contractor, each handling a specific part of the scope.

EPCs conduct business in a highly competitive market, and EPC contracts can involve substantial risk. The EPC contracts are fixed price; the potential for cost overruns is high. EPC contracts typically include guarantees on plant performance and project milestones that are subject to liquidated damages. As a result, sub-vendors that provide competitively priced products and strong sales support at the contractor bidding phase as well as strong project and supply chain management during order execution, erection, commissioning and warranty are well-suited to succeed in this market. The ability to source multiple packages from a single supplier can also reduce project management costs.

When major OEMs act as the EPCs, they share many of the same concerns as pure EPCs (as noted above), but other factors may enter into their decision-making processes. For example, their reputation for supplying high-quality steam turbines or solar thermal collection equipment cannot be compromised by the failure of a pump or valve. They also may

be more inclined to develop long-term agreements with fewer key equipment suppliers to enhance their overall equipment portfolio as they go to market. This would be particularly true the more standardized the component.

Because CSP is an emerging technology, the major OEM for the tower or parabolic trough equipment may take on an expanded role. Many of these projects start with the developer also being the owner (BOO [Build, Own, Operate]) or they may have a customer who eventually will take ownership (BOOT [Build, Own, Operate, Transfer]).

THE CONCENTRATED SOLAR POWER-FLOWSERVE INTERFACE

Business Impact and Focus Areas

The Big Picture

Global CSP generating capacity increased from 355 MW in 2006 to 5094 MW at the end of 2017. In addition, there were 8273 MW announced, 7507 MW in planning, 5952 MW in development and 1926 MW under construction. Installed generating capacity is anticipated to grow to 19 786 MW by 2030. This is the equivalent capacity of adding 15

AP1000 nuclear power plants, but is only a very small percentage of the total capacity expected to be added in renewable power (see **Figure 9**). However, Flowserve has historically been able to capture a large share of CSP projects, and the sector remains a significant part of the company's power generation business.

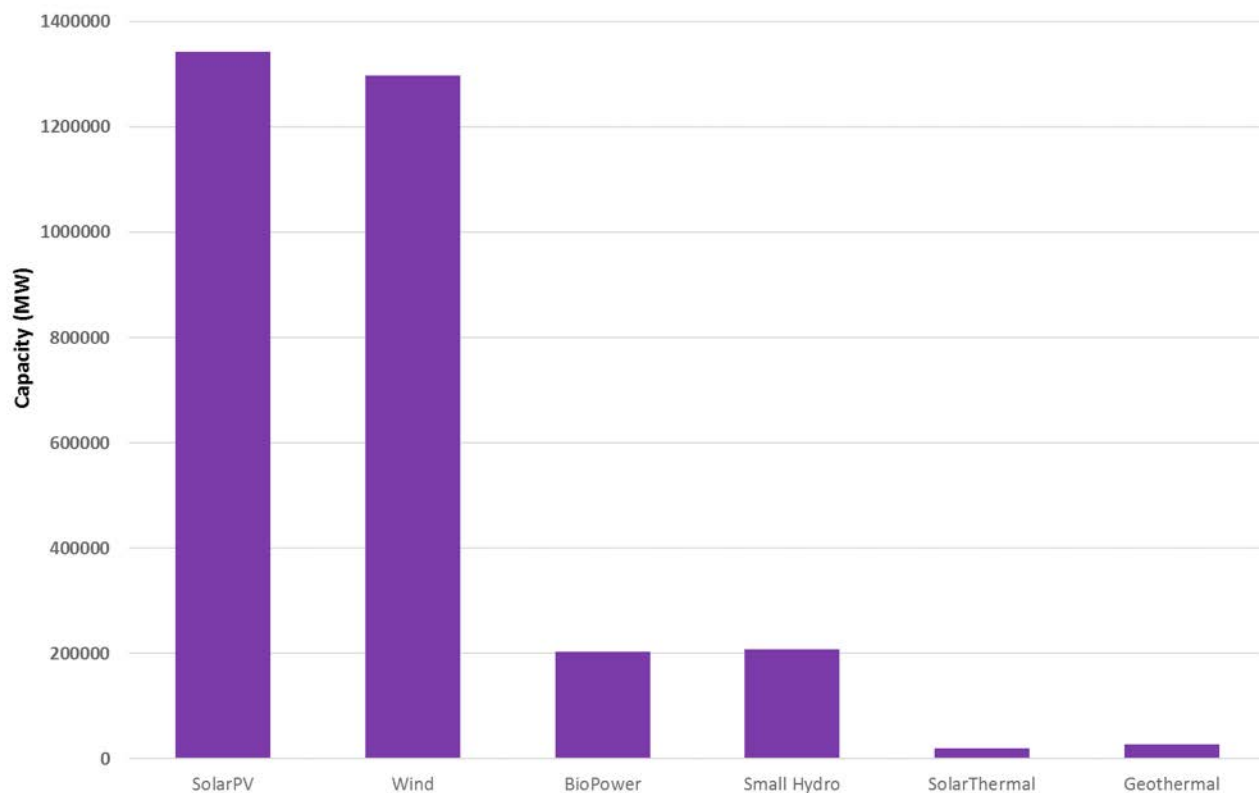


Figure 9: Global renewable power market additions (MW), 2017–2030

Table 2 illustrates the forecasted capacity gains from 2016 through 2030 by country.

Country	2017	2030	MW Change (2016-2030)
United States	1743	3943	2200
Chile		1865	1865
China	156	1790	1724
South Africa	400	1830	1630
Saudi Arabia		1500	1500
Morocco	381	1631	1451
Israel	127	1300	1294
United Arab Emirates	100	1100	1000
Algeria	25	925	900
India	251	1028	797
Egypt	20	570	550
Australia	6	484	481
Italy	5	418	413
Greece		175	175
France	14	69	68
Turkey		50	50
Germany	2	2	0
Iran	17	17	0
Mexico	14	14	0
Spain	2300	2300	0
Thailand	5	5	0

Table 2: Forecast capacity gains by country

The Flowserve Fit in Concentrated Solar Power

Flowserve has been a leader in the power generation industry for nearly 100 years. The company's reputation as a provider of engineered equipment is largely based on its participation in the [power](#) and [oil and gas](#) markets, and power represents about 15% of its annual sales. Flowserve is a significant player in all sub-segments of the thermal power market, including conventional fossil-fired steam, nuclear, combined cycle, biomass, concentrated solar power and geothermal. Regarding [CSP](#), Flowserve has industry-leading experience and expertise in working with molten salt for TES and thermal transfer oils.

Products for Concentrated Solar Power – At a Glance

Concentrated solar plants offer difficult challenges for pumps, valves and seals. In addition to the high operating temperatures and pressures characteristic of many applications utilizing steam turbines, CSP plants also work with unusual working fluids such as thermal oil for the thermal transfer of heat and molten

salts for thermal transfer and energy storage. As a result, pumps, valves and seals must be designed and selected to handle severe operating conditions and special operating fluids.

Pumps

A typical concentrated solar plant may use 50 to 100 pumps. A few key services (molten salt, main feedwater, condensate extraction and condenser cooling) collectively account for a very high percentage of the total pump value.

- Molten Salt (VTP)
- Main HTF (HDX)
- Freeze Protection (HPX)
- Solar Field Recirculation (HPX)
- Condensate Extraction (APKC/MPC)
- Main Feedwater (WXH)
- Condenser Cooling (VTP/VCT)
- Attenuator (VTP)
- Drain Tank (VTP)
- Ullage Circulation (HPX)
- Ullage Discharge (HPX)
- Overflow (HPX)
- HTF Filling (HPX)

Valves

There can be more than 5000 valves in a CSP plant. A large share of these are small bore general service valves, which are not discussed in this guide. Flowserve targets the severe service and control [valve applications](#) in CSP plants. These account for as much as 50% to 60% of the valve spend, even though the quantity of valves may be a small percentage of the total.

- Molten Salt — Mark One™ control valves with Flowserve's Self-contained Thermal Management System (STMS)
- Thermal Oil — Mark One and FlowPro globe valves with bellows seal, TX3 triple offset butterfly valves, Univalve®, Flite-Flow®
- Steam & Condensate — Valtek™ general and severe service control valves, Edward® gate, globe and check valves
- Actuation — Limitorque® MX multi-turn, non-intrusive electric actuators, Limitorque LPS and LPC Scotch yoke rotary actuators, spring return cylinder actuators and diaphragm actuators

Seals

[Flowserve pumps](#) are sold into the CSP industry in tandem with [Flowserve mechanical seals](#), unless the purchaser specifies otherwise. Virtually all applications can be handled with the following products:

- BXRH, BRCSRW and HSH for HTF pumps
- QB for main feedwater, boiler circulating water and condensate extraction applications
- PSS III split seal for condenser cooling, though packing is still the most popular solution
- ISC2-P pusher seals can be used for most other applications

FLOWSERVE OPPORTUNITIES IN CONCENTRATED SOLAR POWER – PRODUCTS AND CAPABILITIES INFORMATION

Overview

In this section, you will find a detailed listing and description of the key products and capabilities Flowserve offers for concentrated solar power plants.

Flowserve Products in Concentrated Solar Power

Molten Salt Pumps

Molten salt for the concentrated solar power market is typically a combination of sodium nitrate (NaNO_3) and potassium nitrate (KNO_3). It possesses high thermal conductivity, allowing temperatures to reach 600°C (1100°F). Specially designed vertical turbine pumps (molten salt VTP) are used to transfer the salt throughout the solar field. These pumps allow for reduced submergence levels and heat dissipation, which help maximize plant efficiency.

Parabolic Trough Pump Applications (PFD167)

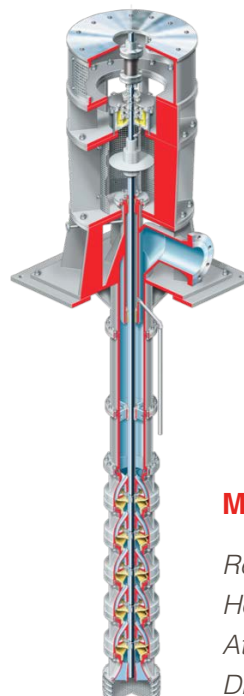
- Cold Molten Salt Pump (D)
- Hot Molten Salt Pump (E)
- Main HTF Pump (F)
- Freeze Protection Pump (G)
- Solar Field Recirculation Pump (H)
- Overflow Pumps (K)
- Overflow Pumps (J)
- Ullage Circulation Pump (L)
- Ullage Discharge Pump (M)
- HTF Filling Pumps (N)
- Overflow Pumps (K)

Molten salt is transferred from the cold storage tank through a heat exchanger to the hot storage tank. During the night, the high-temperature molten salt is used to heat the HTF, which is the heat source

for creating steam. The steam is then used to drive a steam turbine to generate electricity. Each tank typically contains three to four pumps on variable-speed drives. This configuration allows the system to be optimized during various site conditions.

Power Tower Pump Applications (PFD168)

Molten salt is pumped from the cold storage tank to the solar receiver and back to the hot storage tank. The heated salt is used as the heat source to generate steam, which drives a steam turbine to generate electricity. The cold storage tank also includes attenuation pumps, which control the SGS temperature. 100 to 150 MW plants typically consist of four receiver pumps, three hot pumps, two attenuation pumps and two drain pumps.



Molten Salt VTP

Receiver Circulating Pumps (D)
Hot Molten Salt Pumps (E)
Attenuation Pumps (I)
Drain Tank Pumps (J)

Valves for Concentrated Solar Power

A typical CSP facility may have more than 5000 valves. The largest quantity of these are small bore general service valves, which cannot be covered in detail in this guide. The following section attempts to describe the major critical service valve applications in a CSP plant with focuses on the heat transfer and thermal energy storage sections of the plant. Note that molten salt can be utilized as the thermal energy storage fluid (TES) and as the HTF. Thermal oils are used primarily as an HTF and have minimal TES capability. For detailed instructions on the sizing and specification of valves in CSP, refer to Work Instruction T019.

In general, the most critical items to note when properly sizing and specifying valves for molten salt are:

1. Corrosion
2. High temperatures
3. Molten salt crystallization and control
4. Chemical instability of the molten salt
5. Pressure pulses on critical applications
6. Sealing of the HTF

Refer to the Combined Cycle ASG for more detailed descriptions of steam and feedwater section valves. The item number after the application description refers to the location on the process flow diagram.

**Parabolic Trough Valve
Applications (PFD167)**

**Reheater/Superheater Thermal Oil
Temperature Control (11)**

FLOWSERVE SOLUTION: CavControl

**Pre-Heater/Evaporator/Superheater/Reheater
Thermal Oil Drain (12)**

FLOWSERVE SOLUTION: Univalve

Evaporator Continuous Blowdown (13)

FLOWSERVE SOLUTION: Continuous
Blowdown Valve

Evaporator Level Control (14)

FLOWSERVE SOLUTION: Valtek Mark One or
Mark 100

Isolation and Vent Valves (15)

FLOWSERVE SOLUTION: FlowPro

Heat Transfer Fluid Flow Control (16)

FLOWSERVE SOLUTION: FlowPro

Solar Field Module Flow Control (17)

FLOWSERVE SOLUTION: TX3 and CavControl or
TMCBV

This application is often specified as a TOBV with a smaller globe control valve working together in a split-range configuration; this arrangement is in principle “cheaper” than a large globe control valve. However, we propose a single TMCBV to replace both valves.

Thermal Oil NG Heater Outlet Isolation (18)

FLOWSERVE SOLUTION: TX3

Thermal Oil NG Heater Inlet Isolation (19)

FLOWSERVE SOLUTION: TX3

Freeze Protection Pump Outlet Isolation (20)

FLOWSERVE SOLUTION: TX3

Freeze Protection Pump Inlet Isolation (21)

FLOWSERVE SOLUTION: TX3

Thermal Oil Main Pump Flow Anti-Return (22)

FLOWSERVE SOLUTION: Univalve/Flite-Flow

Thermal Oil Main Pump Inlet Isolation (23)

FLOWSERVE SOLUTION: TX3

**Inlet Thermal Oil Flow Control From
TES Exchanger (24)**

FLOWSERVE SOLUTION: Mark One

**Thermal Oil Expansion Tank Inlet Main
Flow Control (25)**

FLOWSERVE SOLUTION: Mark One

**Thermal Oil Solar Field Outlet Main Flow Control
to Steam Generators Train (26)**

FLOWSERVE SOLUTION: Mark One

**Outlet Thermal Oil Flow Control From
TES Exchanger (27)**

FLOWSERVE SOLUTION: Mark One

Hot Molten Salt Tank Main Flow Control (28)

FLOWSERVE SOLUTION: Mark One or CavControl,
depending upon the actual process conditions

Cold Molten Salt Tank Main Flow Control (29)

FLOWSERVE SOLUTION: Mark One or CavControl,
depending upon the actual process conditions

Cold Molten Salt Tank Main Flow Isolation (30)

FLOWSERVE SOLUTION: TX3

Hot Molten Salt Tank Main Flow Isolation (31)

FLOWSERVE SOLUTION: TX3

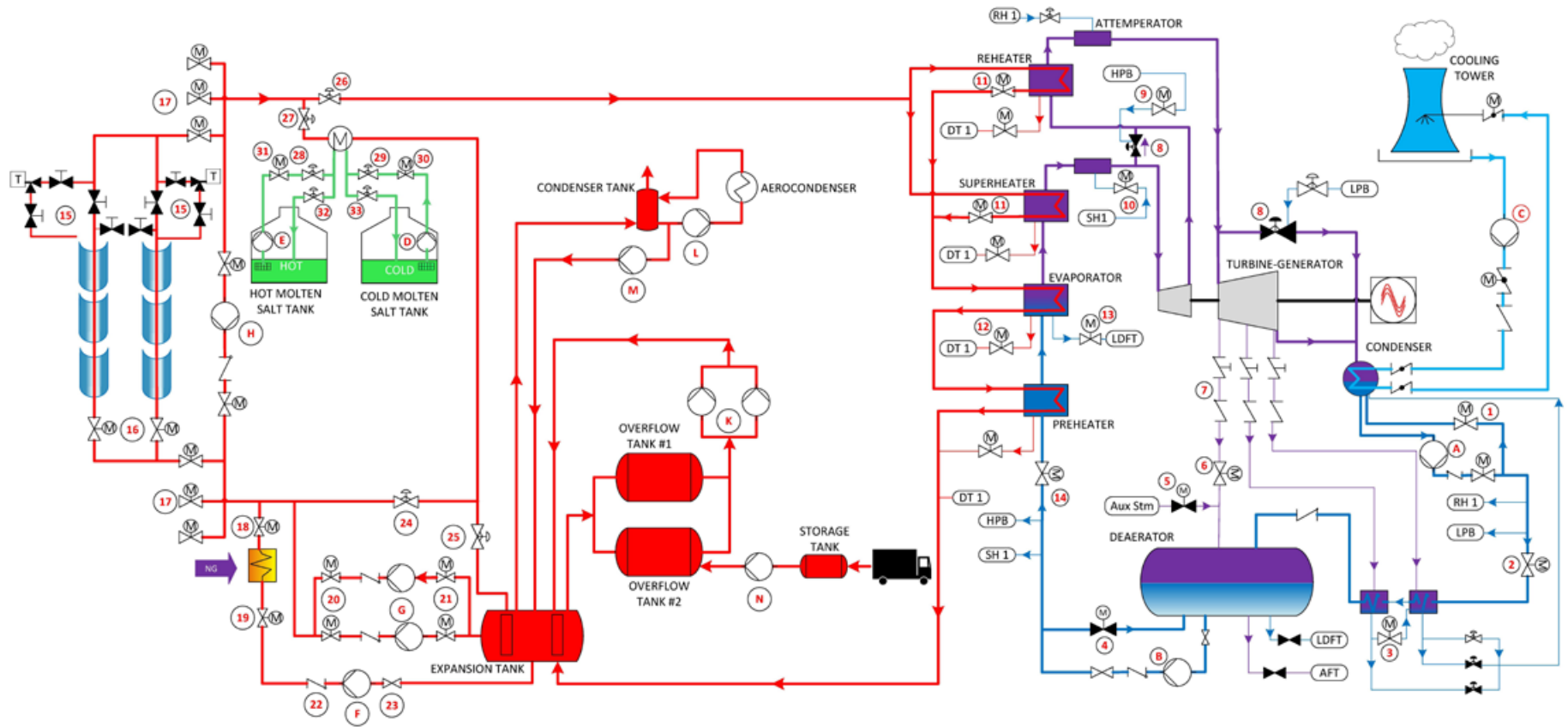
Hot Molten Salt Tank Main Flow Recirculation (32)

FLOWSERVE SOLUTION: CavControl

Cold Molten Salt Tank Main Flow Recirculation (33)

FLOWSERVE SOLUTION: CavControl

PARABOLIC TROUGH PROCESS FLOW DIAGRAM



PARABOLIC TROUGH - Pumps

	<u>FLS Product</u>	<u>API</u>
A. Condensate Extraction	APKC / VPC	VS6
B. Main Feedwater	WXH	BB4
C. Condenser Cooling	VTP / VCT	VS1
D. Cold Molten Salt	VTP	VS1
E. Hot Molten Salt	VTP	VS1
F. Main HTF Pumps	HDX	BB2
G. Freeze Protection Pumps	HPX	OH2
H. Solar Field Recirculation Pump	HPX	OH2
K. Overflow Pumps		
L. Ullage Circulation Pump		
M. Ullage Discharge Pump		
N. HTF Filling Pump		

PARABOLIC TROUGH - Valves

	<u>FLS Product</u>
1. Condensate Pump Minimum Flow	CavControl / Diamondback
2. Deaerator Level Control	CavControl / Diamondback
3. LP Heater Drain Control	Mark One / Mark 100
4. Feed Pump Minimum Flow	ChannelStream / Diamondback
5. Aux Pegging Steam	MegaStream
6. Pegging Steam	MegaStream
7. Stop-Check/Non-Return Steam Extraction	Univalve / FliteFlow
8. HP and LP Turbine Bypass	
9. Turbine Bypass Spray Water	Diamondback / Sidewinder
10. Attemperator Spray Water	Diamondback / Sidewinder
11. Reheater/Superheater Thermal Oil Temperature Control	Diamondback / Sidewinder
12. Pre-Heater/Evaporator/Superheater/Reheater Thermal Oil Salt Drain	Univalve
13. Evaporator Continuous Blowdown	Continuous Blowdown
14. Evaporator Level Control	Mark One / Mark 100
15. Isolation and Vent Valves	FlowPro
16. Heat Transfer Fluid Flow Control	FlowPro
17. Solar Field Module Flow Control	CavControl / TMCBV
18. Thermal Oil NG Heater Outlet Isolation	TX3
19. Thermal Oil NG Heater Inlet Isolation	TX3
20. Freeze Protection Pump Outlet Isolation	TX3
21. Freeze Protection Pump Inlet Isolation	TX3
22. Thermal Oil Main Pump Flow Anti-return	Univalve / FliteFlow
23. Thermal Oil Main Pump Inlet Isolation	TX3
24. Inlet Thermal Oil Flow Control from TES Exchanger	Mark One
25. Thermal Oil Expansion Tank Inlet Main Flow Control	Mark One
26. Thermal Oil Solar Field Outlet Main Flow Control to Steam Generators Train	Mark One
27. Outlet Thermal Oil Flow Control from TES Exchanger	Mark One
28. Hot Molten Salt Tank Main Flow Control	Mark One
29. Cold Molten Salt Tank Main Flow Control	Mark One
30. Cold Molten Salt Tank Main Flow Isolation	TX3
31. Hot Molten Salt Tank Main Flow Isolation	TX3
32. Hot Molten Salt Tank Main Flow Recirculation	CavControl
33. Cold Molten Salt Tank Main Flow Recirculation	CavControl

Power Tower Valve Applications (PFD168)

Reheater/Superheater Molten Salt

Temperature Control (11)

FLOWSERVE SOLUTION: Valtek Mark One or Mark 100 With CavControl

**Pre-Heater/Evaporator/Superheater/Reheater
Molten Salt Drain (12)**

FLOWSERVE SOLUTION: Valtek Mark One

Evaporator Continuous Blowdown (13)

FLOWSERVE SOLUTION: Continuous
Blowdown Valve

Evaporator Level Control (14)

FLOWSERVE SOLUTION: Valtek Mark One or Mark 100

Solar Receiver Level Control (15)

FLOWSERVE SOLUTION: Valtek Mark One or Mark 100 With CavControl

Cold Molten Salt Pump Minimum Flow (16)

FLOWSERVE SOLUTION: Valtek Mark One With CavControl

Attemperator Pump Minimum Flow (17)

FLOWSERVE SOLUTION: Valtek Mark One
With CavControl

Reheater/Superheater Molten Salt

Temperature Control (18)

FLOWSERVE SOLUTION: Valtek Mark One
With CavControl

Hot Molten Salt Pump Minimum Flow (19)

FLOWSERVE SOLUTION: Valtek Mark One
With CavControl

Solar Receiver Inlet Vessel Air

Pressure Control (20)

FLOWSERVE SOLUTION: Valtek Mark One

Solar Receiver Vent (21)

FLOWSERVE SOLUTION: Valtek Mark One

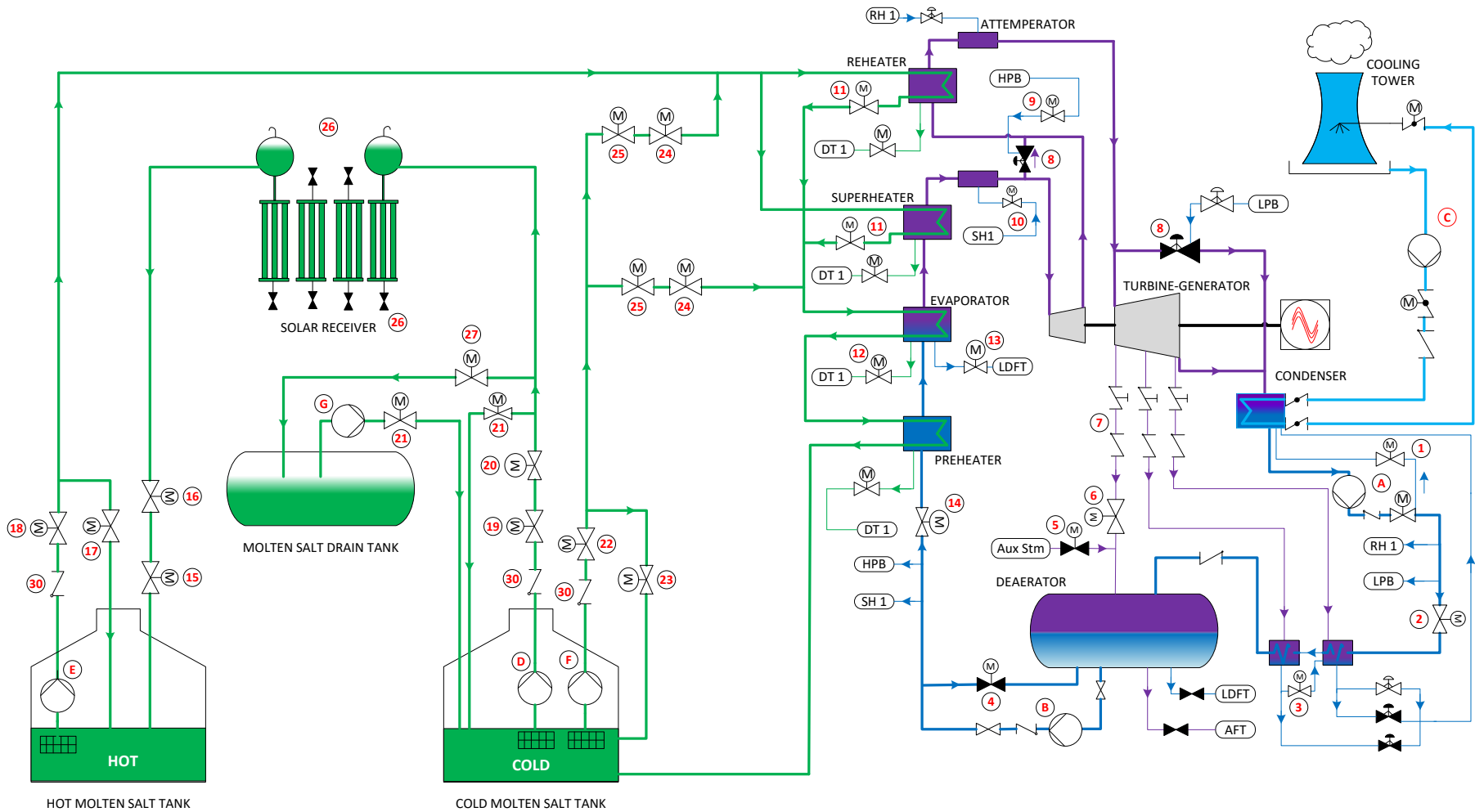
Solar Receiver Drain (22)

FLOWSERVE SOLUTION: Valtek Mark One

Downcomer Control (23)

FLOWSERVE SOLUTION: CavControl/
ChannelStream/DiamondBack

POWER TOWER PROCESS FLOW DIAGRAM










SOLAR TOWER

- A. Condensate Extraction
- B. Main Feedwater
- C. Condenser Cooling
- D. Cold Molten Slat
- E. Hot Molten Salt
- F. Attemperator
- G. Drain Tank






1. Condensate Pump Minimum Flow
2. Deaerator Level Control
3. LP Heater Drain Control
4. Feed Pump Minimum Flow
5. Aux Pegging Steam
6. Pegging Steam
7. Stop-Check/Non-Return Steam Extraction
8. HP and LP Turbine Bypass
9. Turbine Bypass Spray Water
10. Attemperator Spray Water
11. Reheater/Superheater Molten Salt Flow Control – Mark Series
12. Pre-Heater/Evaporator/Superheater/Reheater Molten Salt Drain – Mark Series
13. Evaporator Continuous Blowdown- Continuous Blowdown Valve
14. Evaporator Level Control – Mark Series
15. Solar Receiver Down Comer Control Valves – Mark Series, CavControl, ChannelStream, DiamondBack, Hydraulic Actuation
16. Hot Salt Pump Isolation Valve – TX3
17. Hot Salt Pump Venting / Recirculation Control Valve – Mark Series
18. SGS Trains Hot Molten Salt Inlet Control Valves – Mark Series
19. Cold Salt Pump Discharge Control Valve – Mark Series, CavControl, ChannelStream
20. Cold Salts Pump Isolation Valve – TX3
21. Cold Salt Pump Venting / Recirculation Control Valve – Mark Series, CavControl, ChannelStream
22. Attemperation Pump Discharge Control Valve – Mark Series
23. Attemperation Pump Minimum Flow Control Valve – Mark Series, CavControl
24. Reheater / Superheater Molten Salt Temperature Control Valve – Mark Series
25. Reheater / Superheater Molten Salt Isolation Valve – TX3
26. Solar Receiver Venting / Draining Control Valves – Mark One Series
27. Solar Receiver Emergency Draining Control Valve – Mark One Series
30. Check Valves - Edward

**FLOWSERVE OPPORTUNITIES IN CONCENTRATED SOLAR POWER –
PRODUCTS AND CAPABILITIES INFORMATION**

The following Flowserve products handle most of the on-off applications discussed herein:

<p>Edward Blowoff Y-Pattern Globe Valves</p>	<p>Edward Angle Pattern Globe Valves</p>	<p>Edward Y-Pattern Flite-Flow Globe Valves</p>	<p>Edward Equiwedge Gate Valves</p>
			
<p>1 to 2½ in Class 300 to 2500</p>	<p>½ to 4 in Class 1690 and 2680</p>	<p>2½ to 32 in Class 600 to 2500</p>	<p>2½ to 24 in Class 600 to 2500</p>
<p>Edward Tilting Disc Check Valves</p>	<p>Valdisk TX3 Triple Offset Butterfly Valves</p>	<p>Valdisk BX Double Offset Butterfly Valves</p>	
			
<p>2½ to 24 in Class 600 to 2500</p>	<p>ANSI Class 150 to 1500</p>	<p>to 60 in Class 150</p>	

The following Flowserve products handle the majority of control valve applications:

<p>Valtek Mark One</p>	<p>Valtek Mark Two</p>	<p>Valtek Mark 100</p>	<p>Valtek Mark 200</p>	<p>STMS</p>
				
<p>½ to 36 in Class 150 to 4500</p>	<p>½ to 6 in Class 150 to 2500</p>	<p>6 to 36 in Class 150 to 600</p>	<p>2 to 30 in Class 900 to 2500</p>	<p>Environmental temperature range: -20°C to 55°C (-4°F to 131°F) Wind speed: maximum 46 km/h (fresh wind)</p>

Actuators for Concentrated Solar Power

Many Edward multi-turn globe and gate valves and their related applications as described use pneumatic piston, Scotch yoke (LPS or LPC), diaphragm and manual actuators.

Depending upon customer preference and application, they may use electrical actuation, as pictured. Flowserve offers an extensive range of electrical actuators for these applications. One such example is the Limitorque MX non-intrusive, multi-turn actuator. It provides a comprehensive network option portfolio to users, including Foundation Fieldbus, HART and DeviceNet.

The QX quarter-turn actuators would be used for any quarter-turn applications (e.g., ball valves).

On new projects, actuators are normally purchased with the valves and not directly by the EPC or OEM.



Limitorque MX
Non-Intrusive Electric
Actuators

Seals for Concentrated Solar Power

Flowserve has a full range of [seal products](#) to cover a large variety of pump applications in concentrated solar power plants.

The most challenging applications occur with heat transfer fluid. These are handled by high-temperature bellows seals, which were originally designed for the refinery and petrochemical industries.

Molten salt applications typically operate above 537°C (1000°F), which exceeds the 427°C (800°F) temperature limit for conventional mechanical seals. Pumps for molten salt are specially designed for the application and are engineered with a proprietary sealing system.

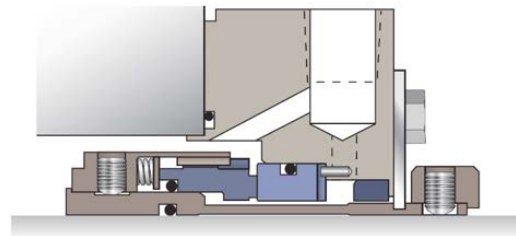
Boiler feed and condensate extraction applications commonly utilize QB series seals, which are highly reliable in these services, since the pumps are generally medium size and duty.

Most other applications in concentrated solar power plants are low duty and can be handled with the ISC2 family of products.

QB Series Balanced Pusher Seals for Main Feedwater Pumps and Condensate Extraction

- 13 to 140 mm (0.500 to 5.500 in)
- ≤ 23 m/s (75 fps)
- 0 to 51.7 bar (750 psig)
- 40°C to 204°C (-40°F to 400°F)

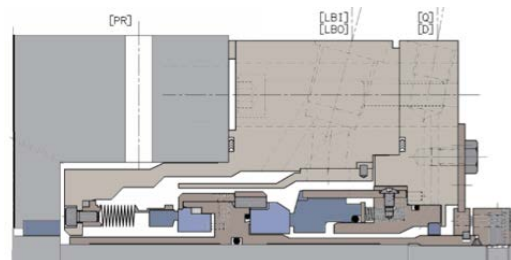
Boiler feed and recirculation applications are typically provided with Plan 23 seal flush systems. Condensate extraction applications are provided with Plans 13 and 32.



BXRH Series, High-Temperature Metal Bellows for Heat Transfer Fluid

- 22 to 127 mm (0.857 to 5.000 in)
- 0 to 20.7 bar (300 psi)
- -73°C to 427°C (-100°F to 800°F)
- To 46 m/s (150 fps)

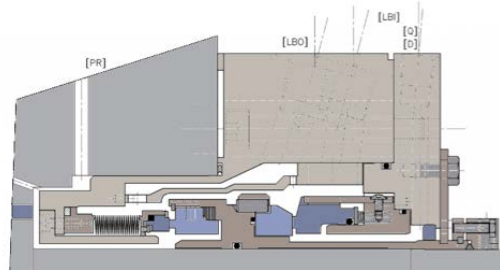
Applied in most HTF applications as a dual seal. For seal chamber pressures less than 13.8 bar (200 psig), the outer seal can be of the same or similar design as the inner seal. For higher pressures, a pusher seal is used in the outer position, as shown here. The most common piping plan is Plan 53B or Plan 54.



BRCSRW Series, High-Temperature, Large-Diameter Metal Bellows for Heat Transfer Fluid

- 124 to 146 mm (4.881 to 5.755 in)
- 0 to 20.7 bar (300 psi)
- -73°C to 427°C (-100°F to 800°F)
- To 46 m/s (150 fps)

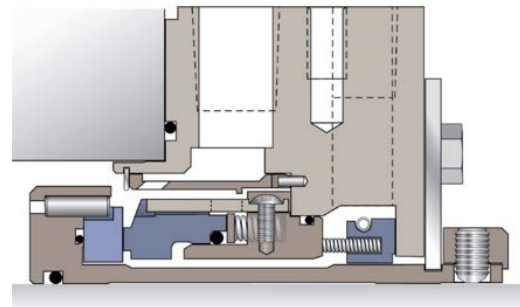
Applied in large shaft size HTF applications, most often as a dual seal. For seal chamber pressures less than 10 bar (145 psig), the outer seal can be of the same or similar design as the inner seal. For higher pressures, a pusher seal is used in the outer position, as shown here. The most common piping plan is Plan 53B or Plan 54.



HSB Seal, Balanced Pusher Seals for High-Pressure Feedwater

- 25.4 to 156 mm (1.000 to 6.125 in)
- 0 to 103 bar (1500 psi)
- -40°C to 260°C (-40°F to 500°F)
- To 46 m/s (150 fps)

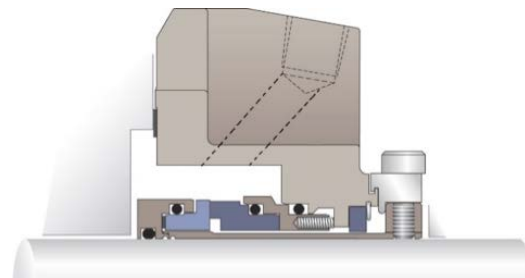
May be used in large or high-speed boiler feed applications with Plan 23. Commonly applied in HTF applications as the outer seal of a dual-pressurized seal. The most common piping plan is Plan 53B or Plan 54.



ISC2-PX Standard Cartridge Pusher Seals for General Service Applications

- 25 to 200 mm (1.000 to 8.000 in)
- 0 to 20.6 bar (300 psig)
- -40°C to 204°C (-40°F to 400°F)
- ≤ 3600 rpm

The ISC2 is the first choice for miscellaneous sealing applications such as closed cooling water, ancillary water and ANSI B.73.1 pumps.



COMMUNICATING OUR VALUE

Flowserve Value Proposition in Concentrated Solar Power

Flowserve	Proposition	Customer Benefit
Ethical Business Practices	Flowserve sets the highest standards in business integrity in its dealings with suppliers and customers.	A trustworthy partner to work toward their project success
Quality	Flowserve manufactures to the most rigorous quality standards to provide reliable products.	Satisfaction in supplier choice, on-time commissioning and project startup
Engineering Excellence	The Flowserve depth of engineering experience is unparalleled in concentrated solar power.	Optimized product and material selection for each application ensures reliable operation.
Experience	Flowserve has been a leader in CSP since the process was commercialized on a large scale.	Lessons learnt have been built into today's products, increasing reliability, maintainability and product life.
Broad Product Range	Flowserve comprises a list of world-renowned heritage brands and a wide portfolio of products and services.	A product for every service designed by specialists in their respective fields ensures low-cost, high-efficiency solutions, from intake to distribution and energy recovery.
Project Management	Dedicated project managers certified by IPMA	Professional team to handle documentation and ensure on-time delivery
After-sales Support	Dedicated after-sales support engineers	Implanted within project management, with the sole objective to resolve warranty issues quickly and painlessly
Local Quick Response Centers (QRCs)	Fully equipped QRCs in the region	Skilled team to handle upgrades and repairs; localized to reduce downtime, full access to Flowserve component drawings, procedures and standards
Aftermarket solutions	Long-term maintenance	Specialist group capable of maintaining, servicing and upgrading equipment to meet operating goals throughout

Innovative Ways Flowserve Addresses Customer Challenges

Expertise and Experience

- Flowserve has more than 80 years of experience in the power industry and has been a key supplier of pumps, valves and seals for concentrated solar power plants since the genesis of the concentrated solar power era
- Flowserve has one of the largest installed bases of pumps and valves in critical CSP molten salt, HTF and steam applications around the world
- Specialist “Virtual Centers of Excellence” ensure that expertise acquired over multiple products and manufacturing sites is shared across the global Flowserve organization

Single-source Provider

- Flowserve offers a full range of pumps, valves and seals for the CSP market, simplifying the procurement and coordination process for customers
- Global commercial operations organization ensures knowledgeable and professional review and response to customer RFQs, including those with the most complicated technical requirements

Streamlined Execution

- Each Flowserve factory has efficient and professional project management teams to ensure on-time completion of projects to customer requirements
- Where projects involve multiple Flowserve manufacturing locations, global project managers can be provided to coordinate order fulfillment. This ensures fewer errors and delays and simplifies communications between Flowserve and the customer.

Local Support Worldwide

- A large field service organization ensures technicians are available for installation, commissioning and troubleshooting without delay
- Service and maintenance contracts for highest availability and continuous efficiency optimization can be tailored to customer needs
- A global network of Flowserve Quick Response Centers means that local service and repair are always available
- Product upgrades are continuously being introduced to improve the performance and reliability of Flowserve products in the field
- Full operation and maintenance training is available to end users
- Equipment monitoring programs are also available

Optimized Efficiency

- Flowserve close involvement with the CSP market has provided the industry feedback needed to develop the range of products best suited to customer requirements, ensuring the optimal and most efficient selections are always available
- As one of the largest engineered pump manufacturers in the world, the Flowserve hydraulic engineering capabilities and resources are second to none. Flowserve is able to provide pumping equipment that consumes the least amount of power.

Collaborative R&D

- Flowserve is working with the U.S. Department of Energy on the next generation of CSP
- Flowserve is partnering with NREL and Sandia Labs to optimize plant design and lower overall costs

APPENDIX



TERMINOLOGY

Attemperator: a device for reducing the temperature of superheated steam by spraying water through nozzles into the steam line

Availability: the percentage of the hours in the year that the plant was operating or available to operate

Benson Boiler: an evaporator design that does not require a steam drum. Feedwater enters one end of the boiler, and steam comes out the other end without any separation or recirculation. Originally a license of Siemens.

Capacity Factor: the total kWh generated in a year divided by the plant nameplate net rating in kW times 8760 hours

Gigawatt (GW): 1000 megawatts

Kilowatt (kW): a unit of power (work done per unit time). 1 kW = 1000 watts.

Megawatt (MW): 1000 kilowatts. One megawatt is sufficient to provide the electricity needs of 600 to 900 homes in the developed world. Plants are typically rated in MW.

Overnight Cost: the cost of a construction project if no interest was incurred during construction, as if the project was completed “overnight”

Repowering: converting an existing conventional steam power plant to combined cycle. The steam boilers are typically replaced with new HRSGs, but the existing steam turbine is used.

ACRONYMS

BFP: Boiler Feedwater Pump

CCGT: Combined Cycle Gas Turbine (also written as GTCC)

CCS: Carbon Capture and Storage

CCW: Condenser Cooling Water, as in CCW Pump

CEP: Condensate Extraction Pump

CHP: Combined Heat and Power

EPC: Engineer, Procure and Construct

HRSG: Heat Recovery Steam Generator

IGCC: Integrated Gasification Combined Cycle

IPP: Independent Power Plant

ISCC: Integrated Solar Combined Cycle

MCR: Maximum Continuous Rating

MWe: Megawatt Electric (the electrical power output of the generator)

MWt: Megawatt Thermal (the thermal power output of the boiler)

PPA: Purchase Power Agreement

SCGT: Simple Cycle Gas Turbine (also written as GTSC)

STMS: Self-contained Thermal Management System

T-G Set: Turbine Generator Set



North America

Latin America

Europe

Middle East

Africa

Asia-Pacific

Flowserve Corporation
5215 North O'Connor Boulevard
Suite 2300
Irving, Texas 75039
flowserve.com

Experience In Motion