BiSS Spark Plasma Sintering (SPS) / Hot Press Machine features high-stiffness, precision-aligned annular load frame. The basic system consists of single or dual vertical loading, single axis load frame, pressurization mechanism, specially designed punch electrodes incorporating water cooler, water-cooled vacuum chamber, vacuum/air/argon-gas atmosphere control unit, pulsed/direct current or induction or furnace heating system, a cooling water unit, press with position measuring unit, load measuring unit, temperature monitoring unit, safety interlocks and servo controller. The 2370MS controller provides the required control on stroke, load, vacuum and temperature.

**Standard Features**

- Fully integrated and independent programmable pulsed or direct DC-power generator
- Working temperatures up to 2400°C with maximum temperature to 2500°C
- Digitally servo controlled induction heating system up to 1200°C
- Furnaces for atmospheric operations up to 1200°C
- Optical pyrometer integrated with the system for remote temperature measurement
- Double walled water cooled stainless steel vacuum chamber with vacuum levels to $1 \times 10^{-5}$ milli bar (optionally to $10^{-7}$ milli bar)
- Cylindrical or box type construction vacuum chambers
- Various geometry graphite / metallic moulds / dies
- Custom design for graphite / metallic punches
- Fully self-reacting load frame from 50 to 600kN force rating systems
- Actuator ram stroke up to 250mm
- Low friction and wear resistance actuators
- Servo controlled force and displacement
- Green and energy efficient hydraulic pump
- Contamination insensitive hydraulics
- Virtually noiseless
- 3648 MIPS DSP with 24-bit analog data conversion, 32-bit data acquisition and 40 bit servo-loop calculations.
- Data acquisition rates up to 40 kHz.
- User friendly application software.
What is Spark Plasma Sintering?

Spark plasma sintering (SPS), also known as field assisted sintering technique (FAST) or pulsed electric current sintering (PECS), is a sintering technique.

Spark plasma sintering (SPS) is a form of sintering where both external pressure and an electric field are applied simultaneously to enhance the densification of the metallic/ceramic powder compacts. This densification uses lower temperatures and shorter amount of time than typical sintering. For a number of years, it was speculated that the existence of sparks or plasma between particles could aid sintering; however, Hulbert and coworkers systematically proved that the electric parameters used during spark plasma sintering make it (highly) unlikely. In light of this, the name "spark plasma sintering" has been rendered obsolete. Terms such as "Field Assisted Sintering Technique" (FAST), "Electric Field Assisted Sintering" (EFAS), and Direct Current Sintering (DCS) have been implemented by the sintering community. Using a DC pulse as the electrical current, spark plasma, spark impact pressure, joule heating, and an electrical field diffusion effect would be created.
Principle of Operation:

The main characteristic of SPS is that the pulsed DC current directly passes through the graphite die, as well as the powder compact, in case of conductive samples. Therefore, the heat is generated internally, in contrast to the conventional hot pressing, where the heat is provided by external heating elements. This facilitates a very high heating or cooling rate; hence the sintering process generally is very fast (within a few minutes). The general speed of the process ensures it has the potential of densifying powders with Nano size or nanostructure while avoiding coarsening which accompanies standard densification routes. While the term "spark plasma sintering" is commonly used, the term is misleading since neither a spark nor plasma is present in the process [Hulbert]. It has been experimentally verified that densification is facilitated by the use of a current.

Methods of Heating used in Sintering Process:

A. Direct Heating (in vacuum)
   1. Joules heating with Direct current
   2. Heating with pulsed DC current

B. Induction heating (hot press in vacuum)

C. Resistance heating (With atmosphere pressure)

A. Direct Heating:

1. Joules Heating with Direct current:

   Joule heating due to the passage of electric current through particles assists in the welding of the particles under mechanical pressure. The intense joule heating effect at the particle conducting surface can often result in reaching the boiling point and therefore leads to localized vaporization or cleaning of powder surfaces. Such phenomenon ensures favourable path for current flow.
2. Heating with pulsed – DC current:

The SPS process is an electrical sintering technique which applies an ON-OFF DC pulse voltage and current from a special pulse generator to a powder of particles and in addition to the factors promoting sintering described above, also effectively discharges between particles of powder occurring at the initial stage of the pulse energizing for sintering. High temperature sputtering phenomenon generated by spark plasma and spark impact pressure eliminates adsorptive gas and impurities existing on the surface of the powder particles. The action of the electrical field causes high-speed diffusion due to the high-speed migration of ions.

The Joules heating and DC-pulse heating technique require special power generator. The DC pulse power generator has programmable option to generate direct current without pulse mode.

**Standard Features**

- Thyristor controlled power supply
- Suitable for resistive, inductive and capacitive loads
- Output current up to 10,000 Amperes
- Output voltage up to 600 Volts
- Residual ripple < 0.02% pp
- Current stability < 0.03% over 8h
- Setting of output voltage with ten-turn potentiometer
- Setting of output current with ten-turn potentiometer
- For temperatures to 2500°C Max.
- Thermocouple / pyrometer based temperature measurement
- Temperature accuracy ± 2 ºC
- Allows heating rates* > 400 ºC/min
- Cooling rates* > 200 ºC/min
- Programmable unit for pulsed or direct current generation
- Digital display for voltage & current
- Digital interface (optional)
- Short-circuit proof for continuous operation
- Internal and external interlock
- Customized versions are available to meet specific requirements

* Rates depend on type of material under heating
B. Induction Heating:

Induction heating is a conventional process used in hot press. This direct way of heating allows the application of very high heating and cooling rates, enhancing densification over grain growth promoting diffusion mechanisms allowing maintaining the intrinsic properties of nano powders in their fully dense products. This can be used in vacuum chamber.

- Temperature range from 300 - 1200°C
- Efficient heating of many geometries
- Heating rates* 1-20°C/sec
- Cooling rates* 1-10°C/sec
- Thermocouple K type or R type
- Temperature accuracy ± 2°C
- PID controller with profile program
- Round or helical heating coil geometry with suitable diameter
- Remote work head with flexible cable with optional extension
- Power rating 1kW to 2.5kW
- Efficient operation for repeatable and reliable heating
- Frequency range 50 to 450kHz
- RF coil current max 400 A
- Ground leakage protection through isolation transformer
- Serial communication for PC interface (optional)
- Cooling water requirement:
  i. Flow rate up to 3 ltr/min
  ii. Pressure differential 2.8 to 5.5 bar
  iii. Max water temp 35°C

C. Resistance Heating (Only atmospheric pressure):

Resistance heating is a conventional process used in hot press. This is similar to heating the mould with induction coil but the heating element is located away from the mould. The rate of heating is slow compared to other heating methods. This can be used only in atmospheric conditions and with inert gas purging. Temperatures from 300 - 1200°C with heating rates up to 20°C/min. It offers temperature accuracy ± 2°C with K-type or R-type thermocouple.
Vacuum Chamber with Pump

Ultra High Vacuum chambers and systems are designed and manufactured for a wide variety of customers and applications, meeting the difficult demands of advanced processes and stringent specifications.

Vacuum chambers are attached to loading frame for sintering / pressing below atmosphere. These chambers are of double walled and water cooled design with stainless steel body. Leak test is performed to measure and distinguish between real leaks, virtual leaks, permeation and vacuum integrity issues related to cleanliness, providing our customers with the confidence of trouble-free operation.

These chambers are coupled with various types of pumps for efficient, effective and leak free pumping. A commonly used efficient and economic type is Diffusion pump.

Diffusion Pumps are designed and manufactured to suit the needs of both industrial and laboratory applications. These pumps are offered in sizes 65 mm, 114 mm, 150 mm, 250 mm, 500 mm and 1000 mm diameters. The superior pumping speed makes them suitable for Vacuum Chambers, Space Research, Vacuum Coating of lenses, Thin Film Deposition and several other industrial & research applications. These pumps are capable of achieving vacuum in the range of $10^{-6}$ to $10^{-7}$ milli bar. The main body is fabricated from stainless steel in the shape of a cylinder and water cooling copper coils are wrapped around the body. The jet assembly consists of metallic nozzles aimed downwards facing the pump inner body so as to cool the vapor molecules emerging from these nozzles. The oil boiler, with external flat type heating coil for burst free evaporation, is located at the bottom of the pump and it holds specified quantity of oil for efficient working of the pump. An ultimate vacuum in the range of $1 \times 10^{-7}$ m.bar can be achieved by using Dow Corning 704 Silicon Fluid, as this fluid does not oxidize by air and is chemical resistance which eliminates frequent replacements.

These pumps are built in with water cooled cap over the jet assembly so as to trap the back streamed oil vapors thus producing clean and better ultimate vacuum over conventional Diffusion pump. Other features are, pump is built in with High vacuum valve such that it can be used as high vacuum pumping unit with suitable backing pump.

### Standard Features

- Double walled construction
- Cylindrical type, horizontal orientation, one side welded dished end
- Box type, vertical construction
- Materials: Chamber body and door made from stainless steel
- Stainless steel door with hinges and quick clamps to pre-stress the door seal
- Chamber ports available for valves, gages and other devices connection
- Facility to purge with inert gas for positive pressure in inert atmosphere
- Pressure range: $1 \times 10^{-7}$ milli bar to ambient pressure
- Tightness: $< 1 \times 10^{-9}$ Pa m$^3$/s
- Customized view ports on front door
- Chamber with fittings to mount on to the loading frame
- Diffusion pump with 700 ltr/sec air speed, 250cc fluid charge, water cooled
- Other types of pumping systems are available viz. Rotary vane type, Turbo molecular type etc are available on request.
BiSS Sintering / Hot Press Machines are built around the Digital Signal Processor based control technology for precise control on movement of test piece and vertical loads.

The 2370MS controllers require a separate host computer running MS Windows. All operations including system setup, calibration and tuning are performed from this computer. BiSS hardware is designed to deliver high-speed closed loop servo control and fast data acquisition.

A unique feature of the 2370MS controller is the global data sharing (GDS) environment. The GDS environment effectively converts the control system into an application server, permitting the connection of additional networked MS-Windows terminals, each with its own keyboard and mouse and windows desktop.

**Standard features:**

- 3 GIPS DSP, 32-bit data acquisition
- Three stage data filtering and oversampling and user selectable digital filters
- Up to 16 control channels on 2370MS
- Up to 4 feedback channels and up to 80 feedback channels on option
- Digital loop update frequency between 40 kHz depending on number of control channels configuration on controller
- Data acquisition rates up to 40kHz
- Variable servo controlled stroke rates from 0.05 to 250mm/min
- MTL32 kernel software for basic operations including system set up
- Watch dog facility for continuous communications monitoring
- Wide choice of single and multi-channel GDS applications
- Open source code in MS-Office environment for many applications
## Specifications of Spark Plasma Sintering / Hot Press Machine

<table>
<thead>
<tr>
<th>Model No</th>
<th>SP 50</th>
<th>SP 100</th>
<th>SP 150</th>
<th>SP 200</th>
<th>SP 250</th>
<th>SP 300</th>
<th>SP 500</th>
<th>SP 600</th>
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<tbody>
<tr>
<td>Catalog No</td>
<td>SP-05-0050</td>
<td>SP-05-0100</td>
<td>SP-05-0150</td>
<td>SP-05-0200</td>
<td>SP-05-0250</td>
<td>SP-05-0300</td>
<td>SP-05-0500</td>
<td>SP-05-0600</td>
</tr>
<tr>
<td>Axial Force Capacity, kN</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>300</td>
<td>500</td>
<td>600</td>
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<td>Column clearance, mm</td>
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<td>Max. Vertical daylight, mm</td>
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<td>1500</td>
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<tr>
<td>HPS flow, LPM</td>
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<tr>
<td>Stroke, mm</td>
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<td>Up to 250</td>
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<tr>
<td>Total weight, Kg</td>
<td>1000</td>
<td>1400</td>
<td>2000</td>
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<tr>
<td>Piston stroke rate, mm/min</td>
<td>0.05 to 250</td>
<td>0.05 to 150</td>
<td>0.1 to 100</td>
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<tr>
<td>Loading rate, kN/min</td>
<td>0.1 to 200</td>
<td>0.1 to 150</td>
<td>1 to 100</td>
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<tr>
<td>Stroke accuracy</td>
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<td>±0.5% of readout value</td>
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<td>Load accuracy</td>
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<td>±0.5% of readout value down to 1/500 of capacity</td>
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<tr>
<td>Data acquisition</td>
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<td>32 bit, 40kHz</td>
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<tr>
<td>Vacuum chamber</td>
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<td></td>
<td>1 x 10^-6 m bar (optionally up to 1 x 10^-7 m bar)</td>
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<td>Double walled tubular/box, horizontal/vertical, stainless steel construction</td>
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<td>Ports for connecting pressure gages and valves, Large view port on front door</td>
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<td></td>
<td>Integrated with suitable vacuum pump for various applications</td>
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<td>Heating system</td>
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<td></td>
<td>Direct current heating for temperatures up to 2500°C</td>
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<td></td>
<td>Pulsed current heating for temperatures up to 2500°C</td>
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<td></td>
<td>Induction heating for temperatures up to 1200°C</td>
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<td></td>
<td>Resistance heating with Split tube furnace for temperatures up to 1200°C</td>
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<tr>
<td>Safety system</td>
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<td>Electronic safety limits on stroke and load channels for system stop on limit hitting</td>
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<td>Mechanical safety limit switch to stop actuator preventing accidental hitting of mould</td>
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<td>Vacuum safety alarm</td>
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<td>Over current or over temperature alarm with tripping option</td>
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<td>Cooling system</td>
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<td></td>
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<td></td>
<td>2 - 4 TR Chiller unit for water cooling</td>
</tr>
</tbody>
</table>

### Notes:
1. Dimensions and ratings are subject to minor variations based on specific ratings.
2. Custom options are available.