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MINISTRY OF SCIENCE AND TECHNOLOGY
सत्यमेव जयते

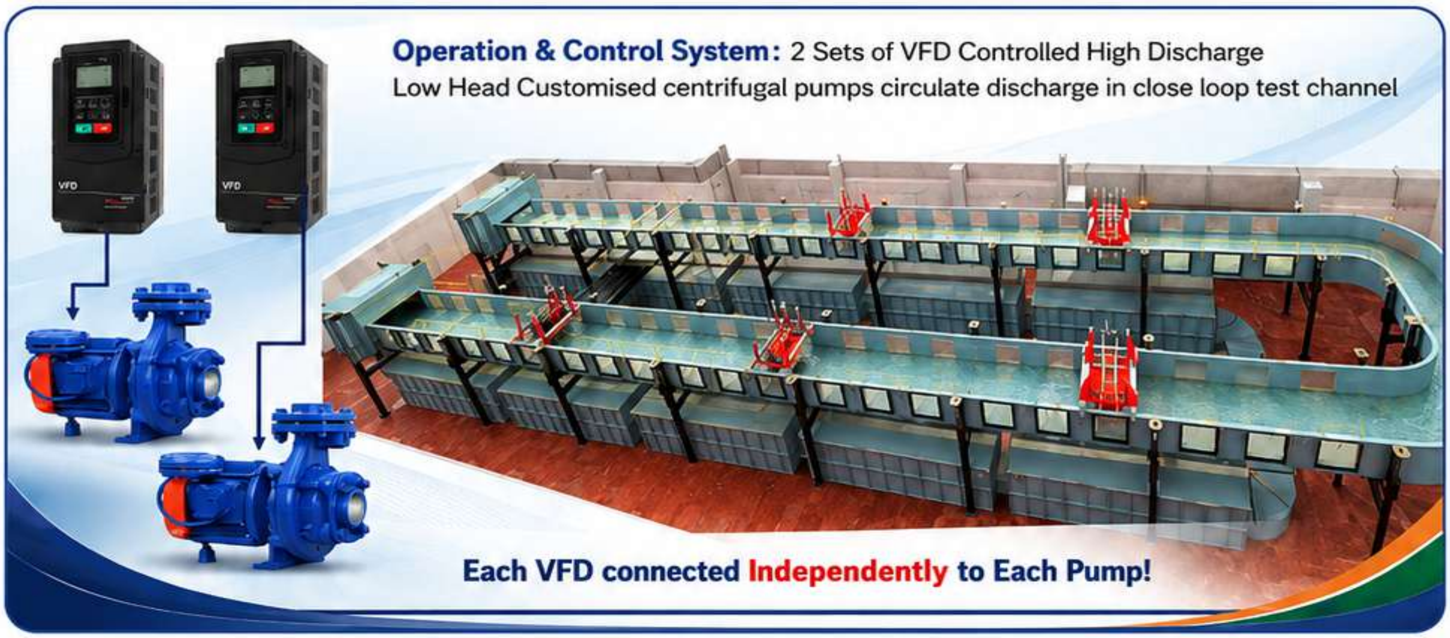
DSIR RECOGNISED
Department of Scientific & Industrial Research
Ministry of Science & Technology, Government of India

SHK TURBINE TESTING LABORATORY

STATE-OF-THE-ART

SHK TURBINE TESTING FACILITY

A First-of-its-Kind Double-Loop Hydrokinetic Research, Validation and Demonstration Platform



Inaugurated on 7 August 2026 by the Hon'ble Chairperson, Central Electricity Authority (CEA), Ministry of Power, Government of India

MACLEC Headquarters | A-1/153, Safdarjung Enclave, New Delhi

FACILITY MISSION

To provide controlled, observable and repeatable testing of Surface Hydrokinetic Turbines (SHKTs), multi-turbine arrays, environmental interactions and low-head SHK-PSP energy-recovery concepts under independently varied flow, water-level, gradient and loading conditions.

TECHNICAL FACILITY REPORT • AUGUST 2026

Executive Summary

MACLEC has developed a dedicated SHK Turbine Testing Facility at its New Delhi headquarters to accelerate the scientific validation, engineering optimisation, demonstration and commercial deployment of Surface Hydrokinetic Turbine technology. The facility was inaugurated on 7 August 2026 by the Hon'ble Chairperson, Central Electricity Authority (CEA), Ministry of Power, Government of India.

The installation is conceived as a first-of-its-kind double-loop, recirculating hydrokinetic test channel. More than fifteen transparent observation panels enable direct visual and camera-based examination of turbine blade profiles, swept area, rotor submergence, free-surface response, upstream and downstream water levels, wake formation and recovery, sediment transport, debris interaction and aquatic-life behaviour. The two loops allow controlled test conditions to be created in parallel and support simultaneous testing of up to eight SHKT scale models, subject to the selected mounting, blockage ratio and research protocol.

Two specialised VFD-controlled, high-flow, low-head pumps provide variable circulation. Flow-conditioning devices, head/level regulators, adjustable channel-bed gradient arrangements, instrumented turbine mounts and underwater cameras enable repeatable experimentation. The platform supports power coefficient (Cp), tip-speed ratio (TSR), torque-speed-power, load, thrust, wake, blockage, submergence, gradient, sediment, debris, environmental and endurance studies.

The same facility also serves as a live physical demonstration of the energy-recovery principle proposed for low-head Surface Hydrokinetic Pumped Storage Plants (SHK-PSPs). A controlled loop-canal section can be configured to demonstrate how multiple SHKTs recover energy from moving water after pumping or release, with turbine spacing, available swept area, designed bed slope, local depth and wake recovery selected to maximise recoverable energy without unacceptable hydraulic loss.

Facility attribute	Reported capability / purpose
Configuration	Closed recirculating double-loop hydrokinetic test channel; each loop can be operated as a controlled test stream.
Visual access	More than 15 transparent panels plus underwater imaging for observation of rotor, flow and material/biological interactions.
Parallel testing	Up to 8 scale SHKT models in different combinations of velocity, level/depth, gradient, loading and array spacing.
Flow generation	2 specialised VFD-controlled, high-flow, low-head pumps with individual operating control.
Primary variables	Velocity, discharge, water depth/level, gradient, rotor RPM, applied torque/load, submergence, blockage and spacing.
Extended variables	Turbidity/silt, debris/garbage type and concentration, water temperature, ambient airflow and aquatic-life interaction.
Core outputs	Cp-TSR curves, torque-RPM-power curves, load response, efficiency, thrust, wake recovery, head/level effect and reliability data.
Demonstration use	Live SHKT generation and low-head SHK-PSP energy-recovery demonstration, training and stakeholder familiarisation.

1. Background, Development and Inauguration

Surface Hydrokinetic Turbines convert the kinetic energy of flowing water into mechanical and electrical energy without requiring a conventional dam or a large static head. Their practical deployment depends on the combined effects of flow velocity, depth, turbulence, submergence, blockage, mounting, rotor geometry, generator/load control, debris and sediment conditions, and multi-turbine spacing. MACLEC developed this facility to bring those variables into a controlled, measurable and visible laboratory environment.

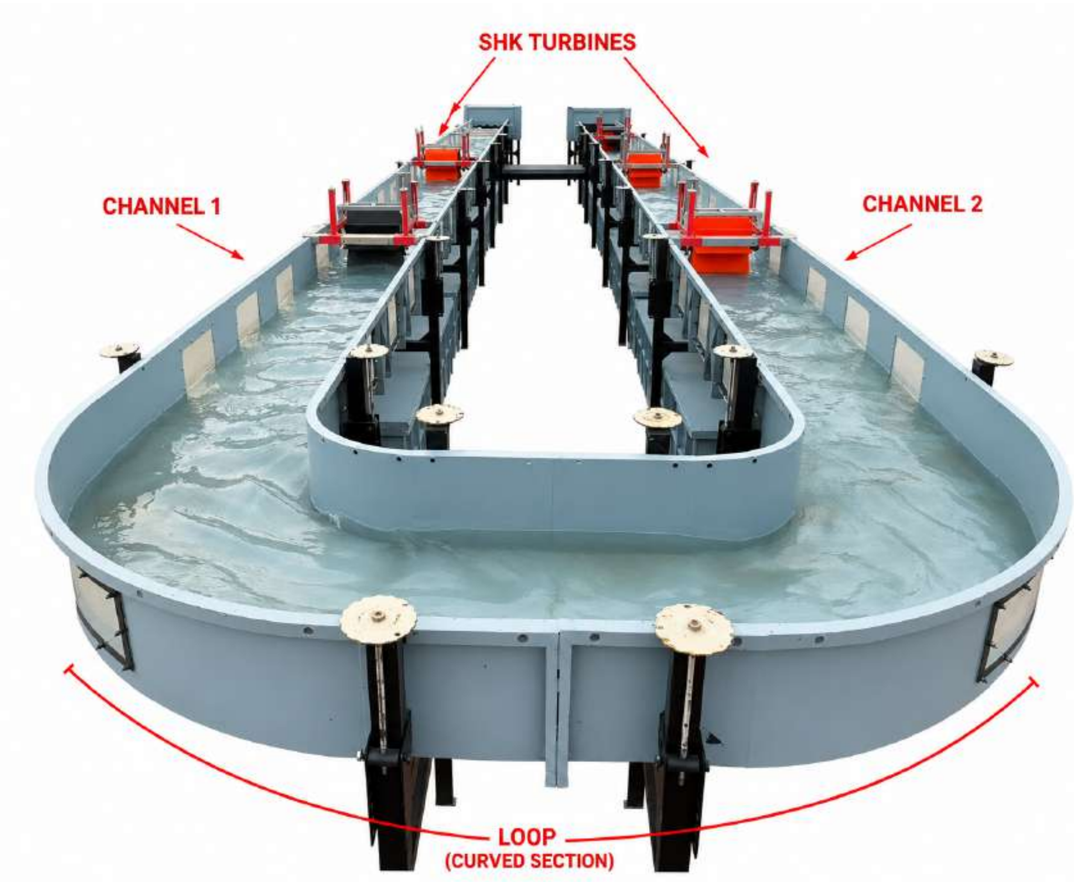
The inauguration by the Hon’ble Chairperson, CEA, represents institutional recognition of the need for indigenous research infrastructure capable of supporting hydrokinetic technology development, site-specific engineering, performance validation and stakeholder demonstration. The facility is intended to serve MACLEC’s engineering programmes and, through structured collaboration, the wider ecosystem of ministries, utilities, PSUs, private developers, academic institutions and research organisations.

Figure 1. Inauguration ceremony at the MACLEC SHK Turbine Testing Facility, New Delhi.

2. Facility Objectives

- Develop and optimise SHKT rotor, blade, shaft, support, submergence and power-take-off configurations.
- Generate repeatable performance maps across controlled velocity, water-level, discharge, gradient and loading conditions.
- Quantify turbine interaction with the free surface, channel bed, sidewalls, sediments, floating/submerged debris and garbage.
- Assess single-turbine and multi-turbine wake behaviour, row spacing, lateral spacing and array-level energy capture.
- Study aquatic-life approach, avoidance, passage and contact behaviour using underwater and transparent-panel imaging.
- Validate controls, instrumentation, data acquisition, generator/load response and rapid operating transitions.
- Demonstrate the SHK-PSP energy-recovery mechanism in a specially configured low-head loop canal.
- Provide a live education, training and technology-demonstration platform for government, utilities, industry and academia.

3. Double-Loop Test Channel Architecture



The complete facility comprises two recirculating hydrokinetic loops. Water is circulated by independently controllable high-flow, low-head pumps. The double-loop architecture permits either (a) two simultaneous research programmes, (b) a control loop and an experimental loop, (c) different velocity/depth/gradient combinations, or (d) coupled demonstrations in which one loop represents the pumping/conditioning leg and the other represents the energy-recovery leg.

OPERATING INTERPRETATION The facility is described as a double-loop system. References to a "single-loop setup" mean that either individual loop can independently serve as a complete SHKT test and SHK-PSP demonstration stream. Final capacity in any test is governed by safe blockage ratio, pump envelope, mounting arrangement and approved test protocol.

Subsystem	Function	Controllable / observable parameters
Loop channels	Provide recirculating open-channel test sections	Water level, velocity, discharge, gradient, bed condition, sidewall effect
Transparent panels (>15)	Direct optical access to the wetted test section	Blade passage, swept area, submergence, wake, bubbles, silt, debris, fauna
Two VFD pump trains	Generate variable high-flow, low-head circulation	Pump speed, ramp rate, discharge, test duration, transient flow
Head/level regulators	Set upstream/downstream control levels and stabilise depth	Local afflux, drawdown, water-surface profile, head/level difference
Flow streamliners	Reduce swirl and condition inlet flow	Uniformity, turbulence intensity, approach angle
Adjustable gradient/bed	Represent canal slope and different bed levels	Bed slope, effective flow area, clearance, near-bed velocity
Instrumented mounts	Support turbine and transmit forces/load	Submergence, position, torque, thrust, vibration, alignment
Data and imaging system	Synchronise measured and visual evidence	Time histories, videos, event markers, processed performance curves

4. Unique Transparent Observation and Imaging System

More than fifteen transparent panels convert the channel into an observable experimental environment. This is especially valuable for partially submerged hydrokinetic turbines because important phenomena occur simultaneously above, at and below the water surface. Fixed external cameras and underwater cameras can record these events synchronously with sensor data.

Fig. SHK Turbine testing Channel's observation screen

Observation zone	What can be studied / recorded	Engineering use
Blade profile and rotation	Entry/exit angle, blade wetting, splash, ventilation, attached/separated flow indicators	Blade geometry screening; submergence and RPM optimisation
Swept area	Effective wetted rotor area at different levels and immersion settings	Input-power calculation and Cp normalisation
Free surface	Wave formation, drawdown, local rise/afflux, air entrainment and oscillation	Minimum depth; freeboard; stable operating envelope
Upstream/downstream levels	Local water-surface elevation before and after turbine/array	Blockage, energy extraction and channel-impact assessment
Near-bed region	Bed clearance, boundary layer, scour/deposition tendency and bed-form interaction	Mounting height; bed protection; sediment management
Wake region	Velocity deficit, swirl, turbulence, free-surface recovery and mixing	Longitudinal/lateral spacing and downstream-row placement
Silt/sediment	Suspension, deposition, blade impingement, abrasion paths and flushing	Material selection, coatings, maintenance and site suitability
Debris/garbage	Approach, interception, deflection, entanglement, passage and release	Trash-management devices, blade shape and O&M strategy
Aquatic life	Approach, avoidance, passage route, contact and post-passage behaviour	Fish-friendly design and environmental safeguards

5. Instrumentation and Measurement System

The facility integrates hydraulic, mechanical, electrical, environmental and visual instrumentation. All measuring instruments should be uniquely tagged, calibrated and time-synchronised before formal performance testing. Accuracy, range, sampling rate and uncertainty should be stated in each approved test sheet.

Instrument / device	Measured quantity or function	Typical application
2 VFD-controlled pump systems	Pump speed and controlled circulation	Velocity/discharge sweeps, ramp tests and repeatability
Velocity meter(s)	Point/section velocity and approach-flow profile	Power input, wake deficit and flow uniformity
Discharge/flow sensor	Volumetric flow rate	Mass/energy balance and pump operating point
Level gauges / sensors	Upstream, turbine-zone and downstream water levels	Submergence, depth, drawdown/afflux and local head difference
Variable torque sensor	Shaft torque across operating range	Mechanical power and Cp/TSR calculation
RPM / rotational sensor	Rotor speed	TSR, runaway, start-up and load-control tests
Load bank / generator analyser	Electrical load, voltage, current, power and energy	Electrical output, efficiency and load response
Force / thrust measurement	Streamwise and support reactions	Structural loading, drag and anchoring inputs
Vibration sensors	Vibration amplitude and spectrum	Balance, resonance, cavitation/impact indications
Turbidity sensor	Suspended solids/turbidity trend	Silt/debris trials and water-quality tracking
Temperature sensor	Water and equipment temperature	Density correction and thermal behaviour
Air-flow / ambient sensor	Airflow near partially submerged rotor and environment	Ventilation/splash correlation and ambient documentation
Underwater cameras	Submerged visual evidence	Blade flow, fauna, silt, debris, bubble and wake observation
Head regulator / control gates	Set and stabilise loop water levels	Depth, gradient and controlled low-head demonstrations
Flow streamliners	Condition approach flow	Reduce swirl and improve repeatability

6. Hydrokinetic and Open-Channel Test Programme

A test point is defined by a stable combination of channel geometry, bed gradient, water level, discharge, approach velocity, rotor submergence, rotor speed/load and environmental condition. The programme may use one-factor-at-a-time screening followed by a factorial or response-surface design to reveal interaction effects.

Test family	Variables varied	Key measurements / outputs
Velocity sweep	Pump VFD setpoint; discharge; approach velocity	Cut-in velocity, torque, RPM, power, Cp, TSR, thrust
Water-level/depth sweep	Upstream control level; downstream regulator; depth	Swept area, submergence ratio, free-surface effect, power stability
Discharge sweep	Pump speed and control setting	Velocity profile, hydraulic capacity, power response
Gradient/bed-level sweep	Channel bed slope or stepped/adjustable bed condition	Depth-velocity redistribution, Froude response, rotor-bed clearance
Submergence sweep	Vertical turbine position or controlled level	Optimum immersion, ventilation, splash, load and power
Blockage sweep	Rotor/channel area ratio; side and bed clearance	Afflux, bypass flow, thrust, corrected Cp and safe array density
Inlet conditioning	Streamliner configuration; approach turbulence	Repeatability, yaw sensitivity and profile non-uniformity
Transient flow	VFD ramp, rapid load step, simulated surge	Acceleration, control stability, overspeed and structural response
Head/level impact	Upstream/downstream level measurements across turbine	Local water-surface effect and energy extraction indicator

7. Mechanical, Performance and Load Testing

The mechanical programme converts measured flow and shaft quantities into performance curves and design loads. Torque and RPM should be measured simultaneously; shaft power is calculated as $P_m = T\omega$, where T is shaft torque and $\omega = 2\pi N/60$. The available kinetic power through the wetted swept area is $P_k = 0.5\rho AV^3$. The power coefficient is $C_p = P_m/P_k$ (or electrical power may be separately reported with drivetrain/generator efficiency clearly identified). Tip-speed ratio is TSR or $\lambda = \omega R/V$.

Mechanical / performance test	Procedure variation	Principal result
No-load and free-running	Increment velocity with unloaded rotor	Start-up velocity, free RPM, runaway/overspeed envelope
Controlled load test	Step or ramp torque/electrical load at fixed V, depth and gradient	Torque-speed curve, stable operating range, maximum power point
Cp curve	Sweep load/RPM at multiple velocities and submergence ratios	Cp versus TSR; peak Cp and optimum TSR
Load × velocity matrix	Repeat load sweep at each velocity setpoint	Power, torque, thrust and efficiency surface
Load × water-level matrix	Repeat at controlled depth/submergence	Optimum immersion and free-surface sensitivity
Load × discharge matrix	Repeat across discharge values	Channel-flow dependence and scale correlation
Load × gradient/bed level	Repeat at selected slopes and rotor-bed clearances	Slope/clearance effects and site-specific setting
Static/structural load	Apply or derive design support loads with safety controls	Frame, shaft, bearing, mounting and anchor validation
Dynamic/load-change	Rapid load application/rejection and VFD transient	Torque peaks, overspeed, control response and fatigue inputs
Endurance/fatigue	Extended operation at rated and cyclic conditions	Temperature, wear, vibration drift, reliability and maintenance interval

8. Multi-Turbine and Eight-Condition Testing

The double-loop facility can accommodate simultaneous testing of up to eight scale SHKT units, subject to approved blockage, safe access and mounting constraints. Units may be installed as longitudinal rows, lateral arrays, staggered formations or control-versus-experimental groups. Different velocity, water-level and gradient conditions can be established by loop and test section, while each turbine can be assigned a distinct load or submergence setting.

Illustrative unit	Velocity condition	Water level / submergence	Gradient / bed condition	Research purpose
SHKT-1	V1	D1 / S1	G1	Baseline control
SHKT-2	V1	D2 / S2	G1	Submergence effect
SHKT-3	V2	D1 / S1	G1	Velocity sensitivity
SHKT-4	V2	D2 / S2	G2	Combined interaction
SHKT-5	V3	D3 / S3	G2	High-flow performance
SHKT-6	V3	D2 / S2	G3	Gradient/clearance effect
SHKT-7	V4	D3 / S3	G3	Wake/array optimisation
SHKT-8	V4	D4 / S4	G4	Extreme/validation point

For multi-turbine arrays, the velocity deficit and turbulence behind each rotor are mapped against downstream distance. Wake-recovery distance is then selected where the downstream unit receives sufficient flow quality without excessive cumulative head loss. Tests should evaluate lateral bypass flow, stagger, row spacing, rotor rotational direction, phase effects, array blockage and power-per-channel-width.

9. Silt, Sediment, Debris and Garbage Interaction

The loop enables controlled introduction of representative suspended or discrete materials under a risk-assessed test plan. Transparent panels and underwater cameras allow direct observation of impact, deflection, passage, trapping, recirculation and deposition. Trials may represent fine silt, sand, leaves, grass, twigs, cloth, flexible plastic, floating litter and other site-relevant material; hazardous or damaging objects require separate containment and approval.

Test category	Variables	Evaluation criteria
Suspended silt	Concentration, particle size, velocity, duration	Turbidity, deposition, abrasion indicator, power/vibration change
Bed sediment	Bed material, depth, gradient, rotor clearance	Scour, deposition, resuspension and support exposure
Floating debris	Type, size, buoyancy, arrival angle and rate	Deflection, capture, passage, entanglement and power interruption
Submerged debris	Density, depth, trajectory and stiffness	Blade contact, impact load, release and damage risk
Garbage accumulation	Mixed material and repeated exposure	Trash-rack need, self-cleaning ability, shutdown and cleaning time
Post-event recovery	Restart and inspection after interaction	Residual imbalance, vibration, power recovery and maintenance action

10. Aquatic-Life Interaction and Eco-Hydraulic Studies

The facility can support controlled, ethics-approved aquatic-life interaction studies. Transparent panels and underwater cameras may record approach paths, avoidance response, entrainment, blade contact, passage route and post-passage behaviour. The purpose is to improve rotor geometry, rotational speed, blade leading edges, screening, bypass and operating protocols for safer deployment.

- Approach and avoidance distance at different velocities, rotor RPM and light conditions.
- Preferred passage route: above, below, around or through the rotor swept area.
- Contact probability and contact location relative to blade speed and geometry.
- Post-passage swimming, orientation and visible stress/injury indicators.
- Influence of turbine colour, lighting, acoustic/vibration signature and protective guidance devices.
- Fish-friendly operating windows, low-RPM start-up, bypass provision and seasonal operation strategies.
- Interaction with non-fish aquatic organisms or surrogate models where appropriate.

ETHICS AND BIOSAFETY Live-organism studies must be undertaken only with competent aquatic-biologist/veterinary oversight, applicable institutional approvals, humane handling, water-quality control, species-appropriate containment and a documented release/recovery protocol. Surrogate models and computational/visual studies should be used before live trials.

11. Electrical, Control and Power-Quality Testing

Test area	Possible tests	Outputs
Generator/load matching	Resistive/electronic load sweeps; controller settings	Maximum power point, conversion efficiency, thermal response
Start/stop control	Flow start, cut-in, synchronisation logic, controlled shutdown	Sequence timing, inrush, overspeed and safe-state verification
Load change/rejection	Step load, ramp load, sudden disconnection	Voltage/frequency excursion, torque transient and braking need
Power quality	Voltage, current, frequency, harmonics, power factor	Compliance evidence and conditioning requirements
PLC/SCADA	Setpoint control, alarms, interlocks, logging and remote operation	Functional verification, event trace and data integrity
Submergence adjustment	Position command versus measured level/power	Control accuracy, response time and energy optimisation
Multi-unit control	Coordinated loading and dispatch of several turbines	Array power smoothing and optimum channel operation

12. SHK-PSP Low-Head Energy-Recovery Demonstration

The facility can physically demonstrate the energy-recovery stage of a low-head Surface Hydrokinetic Pumped Storage Plant. In a practical SHK-PSP, water moved or released between storage levels is guided through a specially engineered low-head/open-channel path. SHKTs placed in the moving stream recover part of the hydraulic energy as electrical energy. The laboratory loop does not create net energy; pump input and system losses remain fully accounted for. Its purpose is to demonstrate conversion, control, array placement and recovery behaviour in a measurable closed circuit.

Demonstration element	Facility representation	Evidence generated
Pumped/released flow	VFD pump establishes controlled flow and level	Pump power, discharge, velocity and stored/flow condition
Low-head canal	Regulated loop section with selected gradient and bed level	Depth, water-surface profile and available flow area
Energy-recovery units	One or more SHKTs in calculated swept area	Torque, RPM, electrical output and recovered energy
Array design	Variable longitudinal/lateral spacing and stagger	Wake recovery, cumulative power and cumulative level effect
Control strategy	Coordinated pump, level regulator, turbine load and bypass	Stable operation, transient response and optimum recovery point
Energy accounting	Simultaneous pump-input and turbine-output measurement	Gross recovery, parasitic loads, losses and loop energy balance

The demonstration can vary canal gradient, local depth, swept-area ratio, number of turbines, row spacing and load distribution. This allows optimisation of (i) energy recovered per unit flow, (ii) power per metre of channel width, (iii) acceptable cumulative afflux/head loss, (iv) wake recovery between units, and (v) overall round-trip-energy implications when integrated into a full storage-cycle model.

13. Test Variables and Experimental Design Matrix

Independent variable	Illustrative levels / modes	Dependent responses
Approach velocity V	Low / medium / high / site-specific profile	RPM, torque, power, Cp, thrust, wake
Discharge Q	Pump/VFD and control-gate setpoints	Velocity distribution, depth and hydraulic capacity
Water depth D	Multiple stable levels	Swept area, submergence, free-surface response
Submergence ratio S	Vertical rotor settings	Cp, ventilation, splash, load stability
Gradient G	Level/bed-slope configurations	Depth-velocity regime, bed clearance, Froude behaviour
Load / torque	No-load to rated/overload within safe envelope	RPM, mechanical/electrical power and temperature
TSR λ	Controlled by load/speed for each velocity	Cp-TSR performance map
Array spacing	Longitudinal, lateral and staggered	Wake recovery, total power and cumulative head effect
Turbulence/profile	Streamliner and inlet-condition variants	Yaw sensitivity, cyclic load and repeatability
Silt/debris	Type, size, concentration and exposure time	Power loss, vibration, blockage, passage and wear
Temperature	Water/ambient range during trial	Density correction, bearing/generator thermal performance

14. Data Reduction and Key Performance Outputs

- Velocity and discharge profiles corrected for channel geometry, sensor position and calibration.
- Effective wetted swept area for each submergence and water-level condition.
- Torque-RPM, mechanical-power and electrical-power curves at each test point.
- Cp versus TSR curves, including peak Cp, optimum TSR and uncertainty bounds.
- Thrust/drag and structural reaction loads versus velocity, load and blockage.
- Upstream/downstream water-level difference, local afflux/drawdown and channel impact.
- Wake velocity deficit and recovery against downstream distance and array configuration.
- Turbulence, vibration, temperature, noise and power-quality trends.
- Silt/debris passage, entanglement, deposition and performance-recovery records.
- Aquatic-life behaviour maps and interaction-event statistics under approved protocols.
- SHK-PSP loop energy balance: pump input, turbine recovery, auxiliary consumption and losses.

REPORTING PRINCIPLE All reported performance values should state the test geometry, blockage ratio, velocity definition, wetted swept area, mechanical versus electrical power basis, instrumentation accuracy, calibration status, repeat count and combined measurement uncertainty.

15. Test Procedure and Quality Assurance

Stage	Required action / record
1. Test definition	Approved objective, configuration drawing, variable matrix, acceptance criteria and safety review.
2. Instrument readiness	Instrument tag list, calibration certificates, zero checks, sampling rate and synchronisation check.
3. Channel preparation	Clean loop; verify panels, seals, streamliners, bed/gradient, regulators and emergency controls.
4. Turbine installation	Record model, blade profile, rotor dimensions, swept area, mounting, alignment and submergence datum.
5. Baseline flow	Run without turbine where required; map velocity, depth, discharge and background turbulence.
6. Stabilisation	Hold target conditions until velocity, depth, discharge and load are within defined tolerances.
7. Data acquisition	Log hydraulic, mechanical, electrical and environmental data with time-synchronised video.
8. Repeatability	Repeat selected points; include control points before/after long or debris/silt trials.
9. Inspection	Check blade, shaft, bearings, support, panels, debris and sediment after defined stages.
10. Analysis/report	Apply corrections, uncertainty, plots, event references, conclusions and configuration-specific limits.

16. Safety, Environmental and Operational Controls

- Guard all rotating shafts, couplings, belts, generators and instrumented load devices.
- Provide emergency stops, VFD trips, pump interlocks, safe electrical isolation and lock-out/tag-out.
- Verify channel structural integrity, transparent-panel condition, seals and maximum permissible level before operation.
- Control access around wet surfaces; provide drainage, non-slip walkways and safe camera/instrument mounting.
- Use screens/containment to prevent test debris, sediment or organisms from entering pump systems or escaping the test section.
- Define safe load, RPM, vibration, temperature, water-level and pressure limits with automatic alarm/trip thresholds.
- Maintain test-specific risk assessments for debris impact, live organisms, electrical generation and multi-unit arrays.
- Record water-quality conditions before, during and after environmental/aquatic trials.

17. Applications and Beneficiaries

Stakeholder / use case	Potential use of the facility
CEA / ministries / regulators	Technology familiarisation, performance evidence, policy inputs and standardisation dialogue.
State utilities and SNAs	Site-condition simulation, pilot design, DPR inputs and operator training.
Thermal and hydro PSUs	Cooling-water-channel, tailrace and discharge-channel SHKT assessment.
Canal / water-resource agencies	Hydraulic-impact, debris, sediment, mounting and array-placement studies.
Private developers / industries	Bankable design validation, captive-power concepts and O&M planning.
IITs / universities / laboratories	Joint R&D, theses, CFD validation, instrumentation and eco-hydraulic research.
Equipment manufacturers	Blade, generator, bearing, coating, sensor, control and structural-component testing.
Environmental researchers	Aquatic-life, sediment, turbulence, aeration and water-quality interaction studies.
Training institutions	Live demonstrations of hydrokinetic conversion, controls and SHK-PSP recovery.

18. Uniqueness and National Significance

- A dedicated, indigenous double-loop open-channel platform focused specifically on SHKT development and validation.
- More than fifteen transparent panels providing unusually extensive optical access to rotor, free-surface, bed, wake and environmental interactions.
- Capability for simultaneous testing of up to eight scale SHKTs under differentiated velocity, level, gradient, load and spacing conditions.

- Integrated study of hydraulic/hydrokinetic, mechanical, electrical, environmental and biological performance in one facility.
- Direct visual correlation of underwater events with time-synchronised sensor measurements.
- Ability to validate multi-turbine wake recovery and channel-density concepts rather than only a single isolated rotor.
- Live closed-loop demonstration of the low-head SHK-PSP energy-recovery mechanism with transparent energy accounting.
- A platform for indigenous blade profiles, materials, controls and deployment structures tailored to Indian canals, tailraces, cooling-water channels, rivers, STP outfalls and other flowing-water assets.

19. Proposed Research and Collaboration Modules

Module	Indicative programme
Blade and rotor optimisation	Profile comparison, solidity, diameter/width, rotational direction, Cp-TSR mapping and cavitation/ventilation observation.
Site replication	Scaled velocity-depth-gradient-blockage conditions derived from survey and hydraulic data.
Array optimisation	Wake mapping, row/lateral spacing, stagger, cumulative power and level impact.
Resilience and O&M	Silt, debris, garbage, corrosion/coating, endurance and cleaning/restart procedures.
Eco-hydraulics	Fish/aquatic interaction, bypass, rotor-speed limits, aeration and mixing effects.
Controls and digitalisation	PLC/SCADA, automated submergence, maximum-power control, alarms, remote monitoring and digital twins.
SHK-PSP demonstration	Low-head loop design, turbine density, energy recovery, dispatch/control and measured loop energy balance.
Standards development	Test definitions, calibration, uncertainty, reporting formats, safety criteria and repeatability requirements.

20. Recommended Standard Deliverables from Each Test Campaign

- Approved test plan and configuration drawing with channel/turbine datums.
- Instrument list, ranges, accuracy, calibration status and sampling configuration.
- Raw and processed datasets with time stamps and video/event references.
- Velocity, depth, discharge, torque, RPM, power, thrust, vibration and temperature plots.
- Cp-TSR, torque-RPM, power-velocity and load-response curves.
- Upstream/downstream level and wake-recovery assessment.
- Photographic/underwater-video record of flow, silt, debris or aquatic interaction.
- Measurement-uncertainty statement and repeatability results.
- Findings, design recommendations, operating limits, anomalies and proposed next tests.

Conclusion

MACLEC's SHK Turbine Testing Facility provides an integrated platform to observe, measure and optimise the complete interaction between a hydrokinetic turbine and its flowing-water environment. Its double-loop architecture, extensive transparent-panel access, multi-unit capacity, variable flow and level controls, adjustable gradient, mechanical loading, instrumentation and underwater imaging enable research that cannot be adequately addressed through isolated bench tests.

The facility bridges technology development and field deployment: it can reproduce site-relevant conditions; develop Cp-TSR and load-performance maps; optimise submergence and swept area; quantify wake recovery and array density; study silt, debris, garbage and aquatic-life interaction; verify control and power-quality behaviour; and demonstrate how multiple SHKTs may recover energy in a carefully engineered low-head SHK-PSP loop canal.

Inauguration by the Hon'ble Chairperson, CEA, marks an important step in advancing indigenous hydrokinetic research infrastructure. With documented calibration, test protocols, safety systems, uncertainty analysis and collaborative research programmes, the facility can support national efforts to convert suitable flowing-water infrastructure into dependable, decentralised and environmentally responsible renewable power.

Annexure A — Indicative Master Test Matrix

Test ID	Configuration	Primary sweep	Secondary factors	Core outputs
A1	Single SHKT	Velocity	Fixed depth/gradient/load	Cut-in, RPM, torque, power
A2	Single SHKT	Load/torque	Velocity levels	Cp-TSR curve
A3	Single SHKT	Submergence	Velocity and load	Optimum swept area/immersion
A4	Single SHKT	Gradient/bed	Depth and clearance	Power and near-bed effect
A5	Single SHKT	Blockage	Side/bed clearance	Afflux, thrust and corrected Cp
B1	Two SHKTs in row	Longitudinal spacing	Velocity and load split	Wake recovery and total power
B2	Lateral array	Lateral spacing	Blockage and stagger	Bypass flow and width utilisation
B3	Up to eight SHKTs	Condition matrix	V, D, G, S and load	Response surface and array optimisation
C1	Silt test	Concentration/duration	Velocity and blade material	Abrasion/power/vibration
C2	Debris test	Material/arrival mode	Rotor RPM and protective device	Passage, entanglement and recovery
D1	Aquatic interaction	Species/surrogate condition	V, RPM, light and bypass	Approach/contact/passage behaviour
E1	SHK-PSP loop	Turbine count/spacing	Gradient, flow and load	Recovered power and loop balance

Annexure B — Definitions and Symbols

Term / symbol	Meaning
SHKT	Surface Hydrokinetic Turbine.
SHK-PSP	Surface Hydrokinetic Pumped Storage Plant / system concept.
V	Representative approach velocity at the turbine test plane (m/s).
Q	Volumetric discharge (m^3/s or L/s, as stated).
A	Effective wetted rotor swept area normal to flow (m^2).
ρ	Water density (kg/m^3), corrected for temperature where required.
T	Measured shaft torque (N·m).
N	Rotor rotational speed (rpm).
ω	Angular velocity, $2\pi N/60$ (rad/s).
Cp	Power coefficient: extracted mechanical power divided by kinetic power through defined swept area.
TSR / λ	Tip-speed ratio: blade tip speed divided by approach velocity.
Blockage ratio	Defined turbine projected/wetted area divided by relevant channel flow area.
Wake recovery	Restoration of velocity/flow quality downstream of a turbine or row.
Afflux	Local upstream water-level rise attributable to an obstruction/energy extractor under defined flow.

Document Note

This report consolidates the intended configuration, capabilities and possible uses of the MACLEC SHK Turbine Testing Facility as provided by MACLEC. Exact dimensional limits, pump curves, permissible gradients, model scale, maximum test velocity/discharge, instrument ranges and declared measurement accuracies should be inserted from approved drawings, datasheets and calibration certificates before use as a formal certified test manual or third-party performance certificate.