DESIGN OF A POWERFUL AND PORTABLE MULTIDIRECTIONAL WAVE GENERATOR

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ABSTRACT

A new multidirectional wave generator with 72 independent paddles has been designed, fabricated and is in the process of being commissioned at the National Research Council labs in Ottawa, Canada. The wet-back piston-mode machine is being installed in a new 50 m long by 30 m wide rectangular wave basin, where water depths can be varied over the range from 0 m (dry) up to 1.3 m. The new machine is unique in the world in that it combines the power and stroke required to generate large waves with heights exceeding 0.6 m with the modularity and ease of portability required to support a wide variety of research and consultancy studies, including studies with seas and swells approaching from very different directions. The new wave generator features lightweight, composite materials, energy efficient regenerative power supplies, state-of-the-art software and control systems, including capabilities for active wave absorption (reflection compensation), second-order wave generation (sub- and super-harmonics), side-wall reflection (long-crested and short-crested seas), and more. The design of this new directional wave generator is described and several of the more innovative features are highlighted in this paper.

KEYWORDS: wave generator, wavemaker, multidirectional waves, control system, physical modeling

1 INTRODUCTION

Physical model studies of coastal processes, coastal and port structures and marine vehicles depend on the ability to reproduce a wide range of realistic wave conditions within test facilities. Unfortunately, the quality and usefulness of such studies are often limited by the capabilities of available wave generation equipment. Many wavemakers can generate only small amplitude waves, which forces the modeller to work at a small scale when simulating storm conditions. This limitation has serious consequences, since scale effects related to distortions in Reynolds number and surface tension become increasingly important in small scale models. Many wave generation systems are unable to generate multidirectional waves or correctly reproduce infra-gravity (long) waves or compensate for waves reflected from a test structure. All of these deficiencies can degrade the quality of physical model studies of processes dominated by wave action, and increase the risk of failure for real structures whose designs were confirmed in physical model studies.

This paper reviews the design and fabrication of a new multidirectional wave generator (see Figure 1) that includes many essential features required to maximize the quality of physical model experiments and studies. The new wet-back type wavemaker has been designed to have the power and stroke required to generate regular waves over 0.6 m high, sufficient to simulate 9 m high waves at a length scale of 1:15. It also features state-of-the-art software and control systems, including capabilities for active wave absorption (reflection compensation), second-order wave generation (sub- and super-harmonics), side-wall reflection (long-crested and short-crested seas), and more. Moreover, the new wave generator features a highly modular design and is fully portable. The stiffness to weight ratio of several key components, including the wave boards, has been maximized through extensive use of high strength aluminum and composite materials, while power consumption has been minimized by incorporating energy efficient regenerative power supplies. Each module supports eight wave boards moving in piston-mode, and the modules can be arranged in various configurations to support project requirements. For example, the modules can be arranged to form one long wave generator or several shorter wavemakers.
This innovative and capable new machine has been developed for the National Research Council of Canada (NRC) by Akamina Technologies (Canada) in partnership with +D (Spain) with support from Respect Industries (Canada), Bosch-Rexroth (Canada), IH Cantabria (Spain) and M.D. Miles (Canada).

The new wave generator has been developed for use within a new 50 m by 30 m rectangular wave basin at the NRC labs in Ottawa, Canada. Nine modules each with eight wave boards have been fabricated to date. The new wave generator is presently undergoing commissioning trials and will soon be available for use in physical model experiments and studies.

2 SPECIFICATIONS

The new wave generator has been designed to satisfy a long list of specifications and performance requirements, including those listed below.

- The system must be a wet-back piston-type segmented directional wave generator
- The system must include no less than 72 wave boards (segments)
- The wave board width must be within 0.4m to 0.45m.
- The wave board height must be no less than 1.4 m.
- The gap between adjacent wave boards must be no more than 5 mm.
- The minimum useful wave board stroke shall be at least 1.0 m.
- The system must be able to generate the full range of regular wave conditions shown in Figure 2.
- The system must be modular in construction and the maximum weight of each module must not exceed 2,350 kg.
- The wave generator must be portable. It shall be possible for two technicians to move the entire wave generator to a new location and secure it within a single 7.5 hour workday.
- Lifting points shall be provided to facility safe and efficient movement of the modules by forklift.
- It must be possible to arrange the modules to form one continuous wave generator or two shorter wave generators in two locations. The ability to operate the two shorter generators individually or simultaneously is required.
- For stability during wave generation, the design must support a) placing ballasting weights on top of the modules and/or b) securing the modules to the concrete floor.
- The system must employ AC servo motor drive systems capable of operating at velocities between 0 up to 0.9 m/s.
- The maximum peak power consumption of the system shall be less than 750 kVA @ 460 Volts 3 Phase.
- The system must include redundant safety features to minimize the risk of damage and accidental injury.
- The system must support the synthesis and generation of regular waves, irregular unidirectional waves (normal and oblique) and irregular multidirectional waves.
- The system must support active wave absorption, side-wall reflection and the synthesis and generation of waves consistent with second-order wave theory.
- The design life of the system must exceed 20 years, assuming operation for 500 hours/year.

![Figure 1. New 72-segment portable directional wave generator](image)

![Figure 2. Specified minimum performance curves (regular waves)](image)
3 MECHANICAL DESIGN

The new wave generator uses a modular design to allow the individual modules to be arranged in various configurations to support project requirements. The basic module consists of 8 electrically actuated wave boards supported on a rigid stainless steel frame (see Figure 3). Nine modules, each supporting eight wave boards have been fabricated so far. Each of the 0.41 m wide by 1.7 m tall wave boards is driven by a synchronous AC servo-motor connected to a ball screw via a backlash-free coupling. The servo drives for the motors, the control computer and all internal cabling is enclosed in a IP65 servo drive cabinet mounted on the top of the module. The number of cables feeding into each servo drive cabinet has been minimized to make it easier and quicker to rearrange the wave generator modules into various configurations. The nine modules built to date can be arranged in various configurations: to form a single 29.5 m long wave machine (with 72 paddles) at any location in the 50 m by 30 m basin; to form an “L” configuration along two adjacent walls; or even to form two or more independent wave machines having a combined length of 29.5 m.

To ensure precise control over wave board motion, the wave boards and support frames have been designed to have extremely high rigidity while the drivetrains feature a backlash-free ball-screw that converts rotational motion to very precise linear motion. Each wave board has a working stroke of ±0.55 m and a rated maximum velocity of 1.0 m/s, and can generate peak forces over 2.5 kN, sufficient to generate regular waves with heights up to 0.6 m and waves with periods from 0.5 s to 5 s, with considerable reserve capacity for active wave absorption (reflection compensation). The total weight of each module was kept below 2,350 kg to ensure that it could be moved easily within the basin using only a forklift or hydraulic lift truck. To ensure stability when generating large waves, the modules can either be fastened to the basin floor using specially designed clamps, or stabilized by placing ballasting weights on top of the sturdy steel support frame. No anchoring or ballasting is required when generating smaller waves.

![Figure 3](image)

Figure 3. Each wave generator module has four distinct levels and supports eight 0.41 m wide by 1.7 m tall wave boards.

Each wave generator module has four levels as shown in Figure 3 (see also Figure 4a).
- The floor level. The levelling feet and the lower module integrated connection clamps are located in this lower level. The feet are equipped with high-friction pads, a ball joint and vertical adjustment to account for unevenness in the floor.
- The support level. This is the main structure that supports the upper levels including the powertrain and wave board main beam guiding system, while providing overall strength and rigidity. The main frame (see Figure 4b) is made entirely of stainless steel and designed for high strength and high rigidity with negligible corrosion. The steel frame includes lateral locating fixtures to facilitate rapid assembly and clamping of several adjacent modules into a single wave generator unit. The support frame is fitted with expanded perforated metal sheets which serve to dissipate wave energy behind the wave boards.
- The motor drive level. The servo motors, lead screws and backlash-free transmissions are located on this level (see Figure 4d). Each wave board is powered by a Bosch Rexroth IndraDyn S MSK061C synchronous servo motor.
acting through the backlash-free transmission. The MSK family features a wide power spectrum, high torque density, a range of encoder options, brake options and IP65 protection. The selected motor has a maximum speed of 6,000 RPM, a continuous torque of 12 Nm and a maximum torque of 32 Nm. The wave boards themselves are comprised of aluminum sandwich panels offering very low weight together with extremely high rigidity and dimensional stability. Additional stiffness is provided by an inner “skeleton” structure, also in high strength anodised aluminium alloy (see Figure 4c). The wave board design represents an ideal balance between high stiffness, light weight and durability. Each wave board is rigidly bonded to a lightweight and rigid anodized aluminium main box beam that travels horizontally on a monorail guidance system (see Figure 4e). The linear guide rail and ball-bearing carriages are coated to withstand continuous splashing, although no wetting is expected under normal operating conditions. Each wave board is fitted with a capacitance-wire wave gauge to sense the local water level; information required to support active wave absorption (reflection compensation).

- The ballast level. Ballast weights made of lead, steel or concrete can be placed on top of the module for added stability during wave generation. The forklift lift points and the electrical cabinet containing the servo-drives and distributed control computer are also located on this upper level together with an accessible marine plywood service deck.

Both the wave board and its sub-structure are exclusively built in lightweight materials (aluminum alloy and composites). High rigidity with low weight has been achieved by applying a design philosophy based around structural box sections and by using aerospace construction techniques. The design achieves a very high ratio of rigidity/strength to weight that delivers improved frequency response and requires less energy to overcome machine inertia and friction, leading to improved precision control of wave board movement. The lightweight wave boards can be easily removed (7 screws) for maintenance, or to avoid accidental contact when maneuvering adjacent modules into position.

![Figure 4. 3D CAD modelling: a) module assembly; b) stainless steel frame; c) wave board sub-assembly; d) powertrain sub-assembly; e) monorail guide system sub-assembly.](image-url)
4 CONTROL SYSTEM DESIGN

Figure 5 shows a high-level top-down view of the wave generation system. A brief description of each of the main components is given below.

- **Operator’s Console** - a PC that runs the interface to the wave generation system. Additional Operator’s Consoles can be added to support situations in which the models are grouped to form two or more separate wave generators.

- **Remote Control Console** - a rack-mounted console that provides basic visual status information and for managing basic operations. Status information such as power on/off indications and control interlock loop state are visible on the console. The operator can turn on and off AC power, reset the control system and turn on and off the high voltage DC bus that powers the servo drives from the console. There are also network connection points for the Operator’s Console as well as connectors for extending the control interlock loop as well as the AC power interlock loop.

- **3-Phase AC Central Power** - transformers and control circuitry required to provide the main AC power to the system. The power to the system is turned on and off from the Remote Control Console.

- **AC Interlock Loop** - one of two independent safety interlock loops in the system. The AC power interlock loop controls the main AC power to the system. The AC power to the servo drive cabinets is immediately cut if the interlock loop is opened using any of a number of red emergency pushbuttons strategically located around the facility.

- **AC Power Outlets** - a series of 18 AC power outlets distributed along two walls of the basin. Each outlet provides sufficient 3-phase, AC power for a single Servo Drive Cabinet.

- **Servo Drive Cabinet** - all of the components required to provide the controlling pulse-width modulation (PWM) power signals to the servo motors on a module of 8 segments are enclosed within a cabinet. One cabinet is mounted on top of each of the mechanical modules.

- **Synchronization, Network, Management and Interlock** - these signals are combined into a single, multi-drop cable that starts at the Remote Control Console and ends at a terminator after the last Servo Drive Cabinet in the chosen configuration.

- **Control Interlock Loop** - this is the second interlock loop in the system. The control interlock loop is carried in the Synchronization, Network, Management and Interlock Cable. The drives are programmed to execute a motor-assisted stop procedure if this loop is opened. The control interlock loop can be opened using any of a number of yellow emergency pushbuttons located around the facility or by the control system itself.

- **8-Segment Module** - the 8-segment module consists of the stainless steel frame, wave boards, transmission systems and motor drives for the 8 segments in the module.

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4.1 Operator’s Console

The Operator’s Console is a PC running the Windows 7 operating system. The wave generator is operated and controlled through the WaveGen-Studio software developed by Akamina Technologies. WaveGen-Studio is a feature-rich, powerful system designed for managing hydrodynamic experiments and physical model studies. It combines the four components of data acquisition, wave synthesis, wave generation and wave data analysis in a seamless, intuitive graphical interface.
interface designed to allow users to easily manage even the most complex experiments. Figure 6 shows a screen shot of the operator’s interface during wave generation.

Figure 6. Screen shot of the user interface.

The wave generation system uses a network of connected controllers to provide the necessary control capabilities. One controller is housed within each of the Servo Drive Cabinets with the controllers and the Operator's Console connected on a Gigabit Ethernet network.

The wave synthesis, wave data analysis and plotting functionality within WaveGen-Studio are based on the GEDAP software system developed at the National Research Council, Canada (Miles, 1989, 1997). GEDAP is a well-proven, complete software solution for physical modelling in hydrodynamic laboratories. Commonly used GEDAP programs have been integrated into WaveGen-Studio for interactive use. Other GEDAP programs, the G PLOT plotting package, customized scripting and batch file processing are also available through the Windows Command Prompt.

4.1.1. Data Acquisition

The data acquisition component of WaveGen-Studio allows data to be acquired from the control servers for which the system has been configured. The data acquisition features include:

- Acquire data from any number of control server input channels or derived data channels at the selected sampling frequency.
- Calibrate single channels or groups of channels.
- Display strip-charts with multiple channels per strip-chart in real-time.

4.1.2. Wave Synthesis

The graphical wave synthesis interface provides access to the GEDAP 2D and 3D wave generation packages. Cornett and Miles (1991) discuss the reproduction of hurricane sea states in a multidirectional wave basin using the GEDAP programs. The interface allows spectra to be created, wave height time series to be derived and wave board drive signal files to be computed and loaded into controllers for wave generation. The wave generation software includes the following capabilities, among others:

- regular, irregular and episodic wave generation,
- control over wave grouping characteristics and wave asymmetry factors,
- support for piston, hinged-flapper and combination modes of wave board articulation,
- support for elevated wave generators,
- dynamic calibration of wave generators to improve wave generation and
- spectral matching transfer functions to achieve a better match between desired and target spectra.

Target wave spectra can be specified using parametric models or by importing prototype wave spectra. Parametric models that are supported include: Pierson-Moskowitz, JONSWAP, Bretschneider, Ochi Double-Peak, Scott, TMA Shallow Water, Newmann, Mitsuyasu-Bretschneider, and Mitsuyasu (1972). Wave trains can be synthesized from target wave spectra using the Fast Fourier Transform random phase, random Fourier Coefficient or random Fourier Coefficient with matched variance methods. The GEDAP wave generation software has proven over decades of use to reliably convert wave spectra to wave height time series and wave height time series to board positions with a high degree of accuracy and precision. Moreover, it includes software tools that allow the measured wave height spectrum to be used to adjust drive
signals to better match the desired spectrum.

4.1.3. Wave Generation
Wave generation is the process of moving one or multiple actuators to generate waves. Wave generation with and without active wave absorption are supported. For this facility, a bank of controllers provide closed-loop control of the position or velocity of the single actuator that drives each wave board.

4.1.4. Wave Data Analysis
The functionality to analyse wave data in a comprehensive manner is provided through a suite of programs designed specifically for the analysis of 2D and 3D waves. The data analysis software includes a broad range of analysis tools organized in four groups:

- **time-domain**: zero-crossing analysis, trend removal, peak detection and filtering;
- **frequency-domain**: wave reflection analysis, variance spectral density analysis, filtering, differentiation and integration;
- **statistics**: basic and advanced statistics, probability distributions, and wave-by-wave statistics; and
- **miscellaneous**: data scaling, sub-record selection, and resampling.

Directional wave spectra can be computed using either the Maximum Likelihood Method or the Maximum Entropy Method (Nwogu, et al., 1987). Support for analysis of data from wave gauge arrays and co-located measurements of free surface oscillations and orbital velocities or surface slopes is provided (Cornett, et al., 1995).

4.2. Servo Drive Cabinet
The Servo Drive Cabinet (SDC) is the heart of the power and control for the wave generators. One of the important design features of the cabinet is that it uses regenerative components to reduce power consumption. When the motors decelerate, the inertia of the load causes the motor to act as a generator. The standard procedure for dealing with this generated power is to short it to ground through high current resistors. Given the rising cost of electricity and the amount of energy consumed by wave generation systems, the power system was designed to take the generated energy and return it to the grid rather than waste it as heat. The potential energy savings and the more responsible use of energy are a significant feature of the new wave generation system. The arrangement of components within the cabinet is shown below in Figure 7.

![](Figure 7. Arrangement of components within a Servo Drive Cabinet.)

4.2.1. Power Supply (PSU)
The system uses a Bosch Rexroth HMV01 regenerative power supply with a rated power of 45 kW. The regenerative power capability allows the system to recover power that would otherwise be dissipated as heat when the wave boards are being decelerated.

4.2.2. Inverter (Servo Drive)
The servo drive is the Bosch Rexroth IndraDrive Cs model HMD01 dual-axis drive with a CDB02 control card.

4.2.3. Controller
The controller provides high-level management of the servo drives. It acquires real-time feedback from the drives from which it computes the control value that is then sent to each drive. Wave board position and velocity feedback is derived
from angular encoders integrated into each drive, while the capacitance wave gauges mounted on the face of each wave board provide additional feedback for active wave absorption (reflection compensation). The controller also manages drive signals, implements the active wave absorption algorithms, monitors the health of the drives and manages the drives based on commands received from the Operator's Console.

The controller is built on the Cannon Automata A2 all-in-one programmable automation controller platform. The A2 is based on the Intel Atom processor and has built-in CAN Bus support, digital I/O, gigabit Ethernet and hardware support for real time Ethernet communication with the servo drives. The Akamina real time Linux operating system has been ported to the hardware platform supporting control update rates up to 500 Hz. All position and velocity feedback and control signals transmitted over the Sercos III interface.

The wave generator control system provides support for active wave absorption (reflection compensation) for both unidirectional and multidirectional waves. This is accomplished by measuring the actual wave height along the surface of each wave board and comparing it to the expected wave height. The active wave absorption method used by Akamina Technologies uses a velocity controller that tracks the desired velocity and the corresponding desired wave height at the same time. When computing the desired velocity of the wave board, the control algorithm looks at the difference between the desired and measured wave height and converts this difference to a velocity correction. The velocity correction is added to the desired velocity which the controller then tracks.

Figure 8 provides additional details on the A2 Controller, the 4 dual-axis Inverters (servo drives) and the interface logic. The A2 Controller and the 4 Inverters are connected on a SERCOS III loop. Real-time data and service channel messages are exchanged between the Controller and the Inverters. Unlike common Ethernet protocols, SERCOS III provides Ethernet with a guaranteed real-time messaging capability.

![Figure 8. Each A2 Controller unit manages four dual-axis servo drives.](image-url)

Each Servo Drive Cabinet also includes a custom Interface Logic board. The circuitry on this board provides access to the synchronization and control interlock signals carried in the Synchronization, Network, Management and Interlock cables. Various relays and other components allow the A2 to close its section of the control interlock loop and detect when the control interlock is opened elsewhere in the loop. The synchronization signals guarantee that the real-time messaging loops within each of the Servo Drive Cabinets are synchronized and that wave generation starts and stops at the same instant within all Servo Drive Cabinets.

The CAN Bus interface on the Controller allows the controller to acquire wave height feedback from the Akamina AWP-300 digital wave height gauges mounted on the face of each wave board. This information is critical to the active wave absorption system, which works actively absorb waves approaching the wave generator (i.e. waves reflected from a model shoreline or structure).

4.3. Wave Generator Module

As described above, each wave generator module consists of eight 0.41 m wide by 1.7 m tall wave boards and their drivetrains mounted on a rigid steel support frame. The drive system includes an electric motor, servo-drive and ball-screw. The drivetrain components have been selected to meet the specified design criteria for wave heights and wave periods. The wave board stroke of 1.1 m and maximum velocity of 1 m/s provide the additional stroke and velocity required for simultaneous wave generation and active wave absorption (reflection compensation).
5 ADVANCED WAVE GENERATION FEATURES

Several important capabilities have been added to GEDAP and WaveGen-Studio as part of the development efforts in support of this new wave generation system. The capabilities added include:

- software enhancements to improve active wave absorption performance by including diffraction effects when computing the expected wave heights at each wave board;
- development of a new corner reflection method based on a linear diffraction model;
- development of second-order wave generation software according to the approach described by Schäffer (1993, 1996) and then modified by Schäffer and Steenberg (2003); and
- support for use of a Gaussian directional spreading function in the synthesis of 3D waves.

5.1. Active Wave Absorption Improvements

The algorithm used by Akamina to implement active wave absorption using the knowledge of the expected wave heights at each of the wave boards is based on work reported in Laurich (1994). The control algorithm adjusts the motion of the wave boards in real time to reduce the difference between the measured wave height and the expected wave height. Past experience with the generation of oblique long-crested waves with active wave absorption showed that generated wave heights can exceed the expected in certain cases.

The work done to improve active wave absorption performance included the use of a linear diffraction model to numerically simulate the effects of active wave absorption without considering linear diffraction effects. The wave synthesis software was then extended to include linear diffraction effects with the output of the synthesis software then used in a numerical simulation. The simulations showed that disregarding diffraction effects for oblique long-crested waves can indeed result in wave heights that are larger than expected. Furthermore, these errors are reduced considerably when diffraction effects are included.

5.2. Side-wall Reflection Improvements

Significant progress has been made to improve the quality of waves generated using side-wall reflection techniques. A new method, reported in Miles (2015), has been developed that involves the use of a linear diffraction wave model to compute the wave board positions that result in uniform wave heights at the end of the side walls. Numerical simulations were carried out to compare the consistency of wave heights along a line at the end of side walls. The output of the simulations allowed comparisons to be made between waves generated using the Snake Principle, waves generated using the side-wall reflection methods of Funke and Miles (1987), Dalrymple (1989), and the new Linear Diffraction method described in Miles (2015). The study showed that the new side-wall reflection method based on diffraction modelling performs very well for a wide variety of frequencies, wave angles and sidewall lengths. More importantly, the new method produces a much larger area of uniform wave height in the basin for both regular and irregular waves compared with previous methods.

5.3. Second-Order Wave Generation

Support for second-order wave generation according to the approach described by Schäffer (1996) and then modified by Schäffer and Steenberg (2003) has been developed with the assistance of the Environmental Hydraulics Institute IH Cantabria. IH Cantabria initially developed second-order synthesis methods for regular and irregular waves propagating normally to the wave generator. This method was then extended to support both regular and irregular oblique waves following Schäffer and Steenberg (2003). The methods were validated using numerical simulations for both regular and irregular waves travelling perpendicularly to the wave board. Physical model tests were carried out in a 2D wave flume and a 3D facility. The resulting implementation was then integrated into GEDAP for use in the new system.

5.4. Gaussian Spreading Function

Support for synthesis of multidirectional wave fields wherein the distribution of wave energy with direction follows a Gaussian distribution has been added to WaveGen-Studio. The Gaussian spreading function is defined by the mean wave angle and the spreading width. The theoretical spreading function is normalized so that it has a unit area as it is a probability density function.

6 CONCLUSIONS

A new directional wave generator that is powerful, modular and portable has been designed and fabricated for use in a new 50 m by 30 m wave basin at the National Research Council labs in Ottawa, Canada. The new wave generator is comprised of 9 portable modules, each supporting eight 0.41m wide by 1.7 m tall wave boards. Each wave board has a stroke of ±0.55 m and can generate regular waves with heights up to 0.6 m, and waves with periods from 0.5 s to 5 s or
The 9 modules can be arranged in various configurations: to form a single 29.5 m long wave machine at any location in the 50 m by 30 m basin; to form an “L” configuration along two adjacent walls; or even to form two or more wave machines separated from each other, having a combined length of 29.5 m. The total weight of each module was kept below 2,350 kg to ensure that it could be moved easily within the basin using only a forklift or hydraulic lift truck. For stability when generating large waves, the modules can either be fastened to the basin floor or stabilized by adding ballasting weights on top of the steel support frame.

Innovative design has been combined with lightweight materials and aerospace construction methods to achieve a very high rigidity/strength-to-weight ratio that delivers improved frequency response and very precise control over wave board motions. The new wave generator features state-of-the-art software and control systems, including enhanced capabilities for active wave absorption (2D and quasi-3D), second-order wave generation (sub- and super-harmonics), side-wall reflection (long-crested and short-crested seas), and more. Regenerative power supplies have been used to significantly reduce energy consumption and operational cost. Other noteworthy features not already mentioned include:

- use of a ball-screw that eliminates backlash in the drive system,
- use of a control system that accurately tracks desired wave board position or velocity drive signals with minimal phase lag and negligible attenuation over a wide range of frequencies,
- the use of a dynamic calibration procedure that allows the electro-mechanical transfer functions of the individual segments to be computed and used to pre-compensate waves for the dynamic response of each segment,
- remote monitoring and management of individual servo drives from the Operator's Console,
- control by wire - all feedback and control signals are acquired over a communications network,
- integrated wave generation, wave synthesis, data acquisition and wave data analysis functionality through a single easy-to-use graphical interface, and
- advanced safety features including safety lock-outs plus audible and visual warnings.

This innovative and capable new machine was developed for the National Research Council of Canada by Akamina Technologies (Canada) in partnership with +D (Spain) with support from Respect Industries (Canada), Bosch-Rexroth (Canada), IH Cantabria (Spain) and M.D. Miles (Canada). The new wave generator is currently undergoing commissioning trials at the NRC labs in Ottawa, Canada, and will soon be available for use in research and consultancy studies. The results of these commissioning trials and the operational performance of the new wave generator will be described in a future publication.

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