PELTON WHEEL TURBINE LAB

PURPOSE: The main purpose of this lab is to measure the power output of a Pelton Wheel turbine and to compare this to the theoretical power output. Another purpose of the lab is to check turbine scaling laws.

PROCEDURE: Set the driving pressure at a low level. Measure the flow rate through the turbine. Set the brake at some level and measure the brake load using the load cell and the rotor speed using a tachometer. Repeat for various brake settings. Set the driving pressure at a high level and repeat the experiment.

REPORT: Using the measured data, calculate the brake torque and the bucket speed: then calculate the brake power output of the turbine. Plot Power **P** versus RPM for each driving pressure. Plot Power Coefficient $C_{\mathbf{P}}$ versus Speed Coefficient $C_{\mathbf{S}}$. Compare Actual Power with Theoretical Power. Comment on the results.

MEASUREMENTS

The brake power output of the turbine is:

$$\mathbf{P} = T\ \omega$$

where T is the torque on the rotor and ω is the rotational speed of the rotor. The torque is:

$$T = L\ d$$

where L is load measured by the brake load cell and d is the moment arm of the cell from the rotor axis. The rotor speed ω is measured using a tachometer.

The theoretical power is a function of the bucket speed V_B and the jet speed V_J. The bucket speed is:

$$V_B = R\ \omega$$

where R is the distance out to the bucket from the rotor axis. The jet speed is approximately:

$$V_J = k\ \sqrt{[2P/\rho]}$$

where k is a nozzle loss factor, ρ is the density of water and P is the jet driving pressure: this is measured using a pressure gage. For the lab turbine, k is 0.97, d is 15cm and R is 5cm.

PELTON WHEEL TURBINE THEORY

The power output of the turbine is:

$$\mathbf{P} = T\ \omega$$

where T is the torque on the rotor and ω is the rotational speed of the rotor. The torque is:

$$T = \Delta\ (\rho Q\ V_T\ R)$$

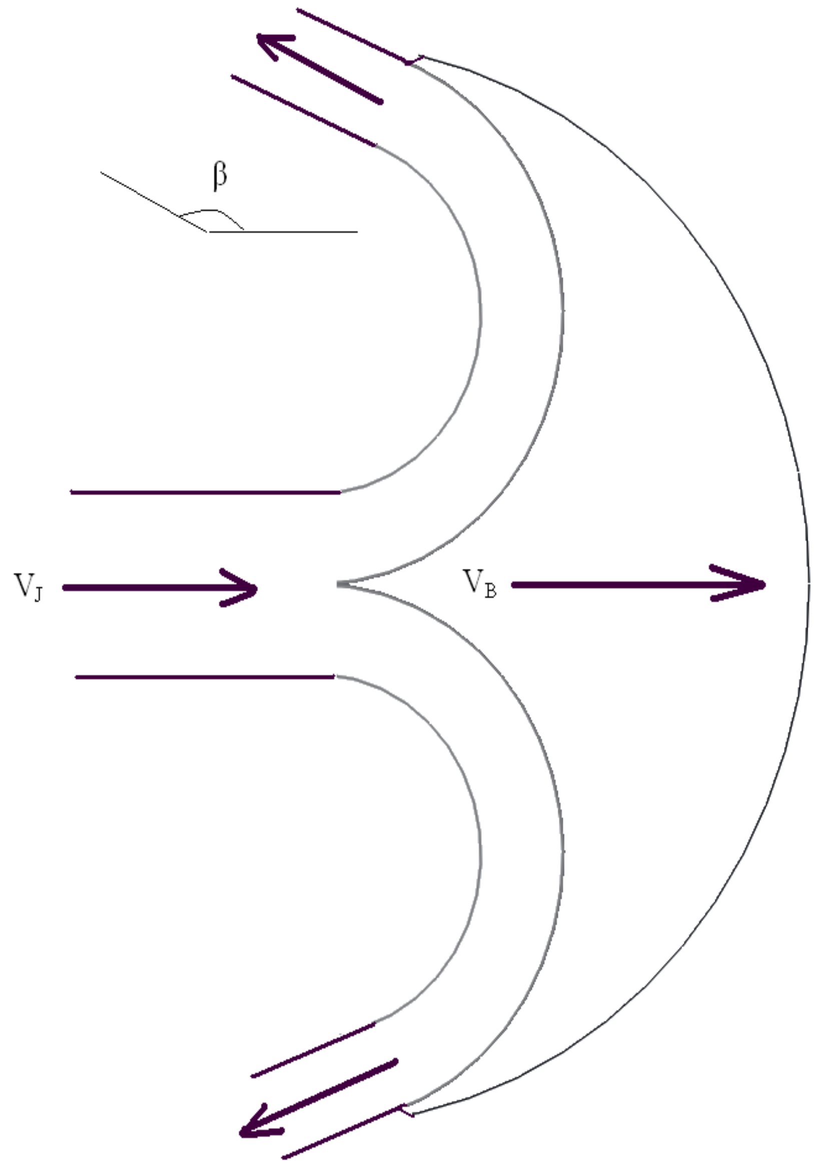
where Q is the volumetric flow rate through the turbine and V_T is the tangential flow velocity. The tangential flow velocities at inlet and outlet are:

$$V_{IN} = V_J \qquad V_{OUT} = (V_J - V_B)\ K\ \cos\beta + V_B$$

where, relative to the tangential direction, β is the angle of the relative velocity vector and K is a loss factor. So power becomes:

$$\mathbf{P} = \rho Q\ (V_J - V_B)\ (1 - K\ \cos\beta)\ V_B$$

For the lab turbine, β is 168° and K is 0.8. In the lab, the flow rate Q is measured using a V Notch Weir.



β
V_J
V_B

SCALING LAWS FOR TURBINES

For turbines, we are interested mainly in the power of the device as a function of its rotational speed. The simplest way to develop a nondimensional power is to divide power $\mathbf{P}$ by something which has the units of power. The power in a flow is equal to its dynamic pressure P times its volumetric flow rate Q:

$$P \; Q$$

So, we can define a power coefficient $C_{\mathbf{P}}$:

$$C_{\mathbf{P}} = \mathbf{P} \, / \, [P \; Q]$$

For a Pelton Wheel turbine, the dynamic pressure P is approximately equal to the driving pressure.

To develop a nondimensional version of the rotational speed of the turbine, we can divide the tip speed of the blades $R\omega$ by the flow speed U. For a Pelton Wheel turbine, the flow speed U is equal to the jet speed V_J. So, we can define a speed coefficient $C_{\mathbf{S}}$:

$$C_{\mathbf{S}} = R\omega \, / \, V_J$$

DATA SHEET FOR PELTON WHEEL TURBINE

JET PRESSURE =

FLOW RATE =

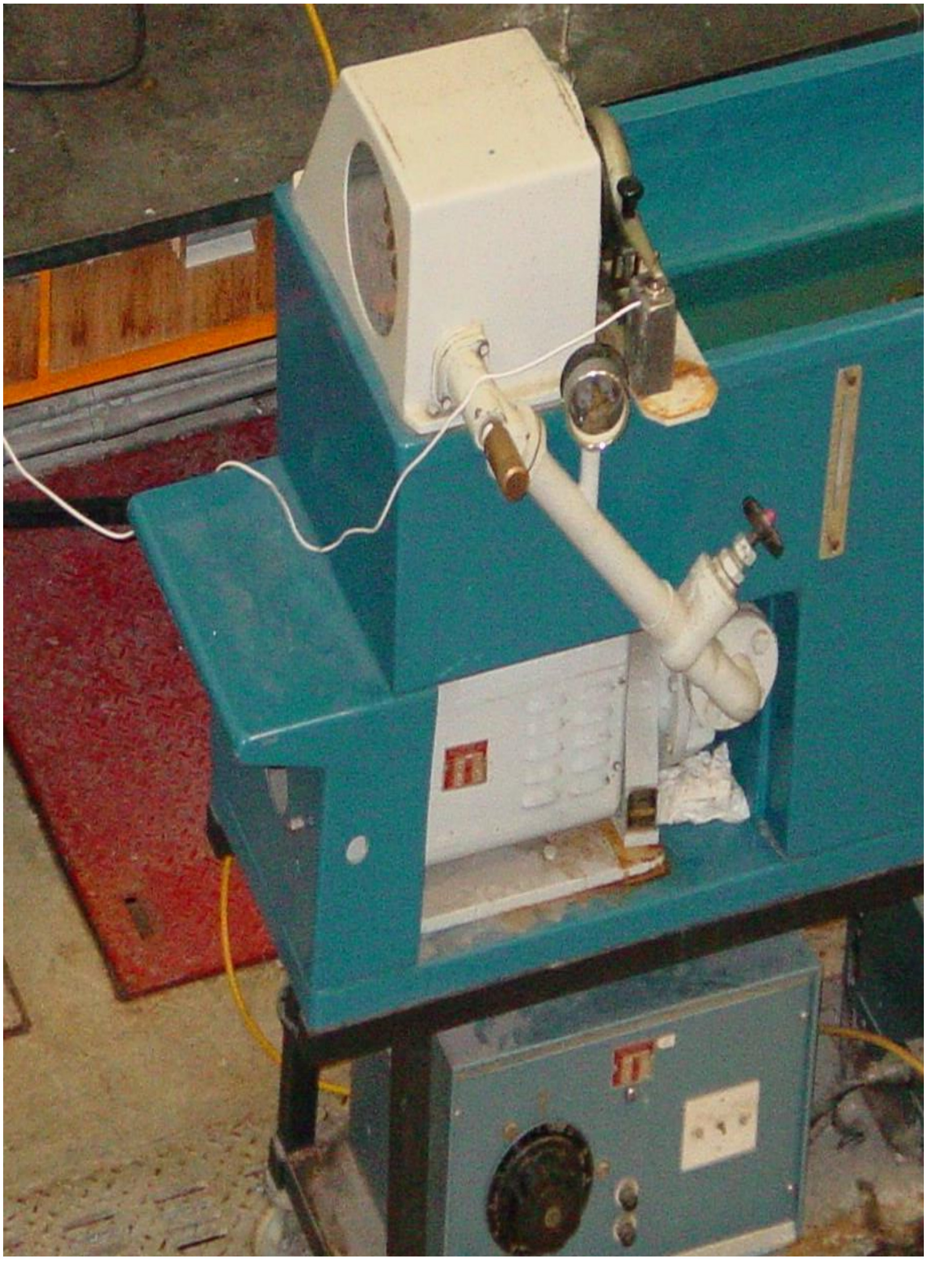
RUN	BRAKE LOAD	ROTOR RPM

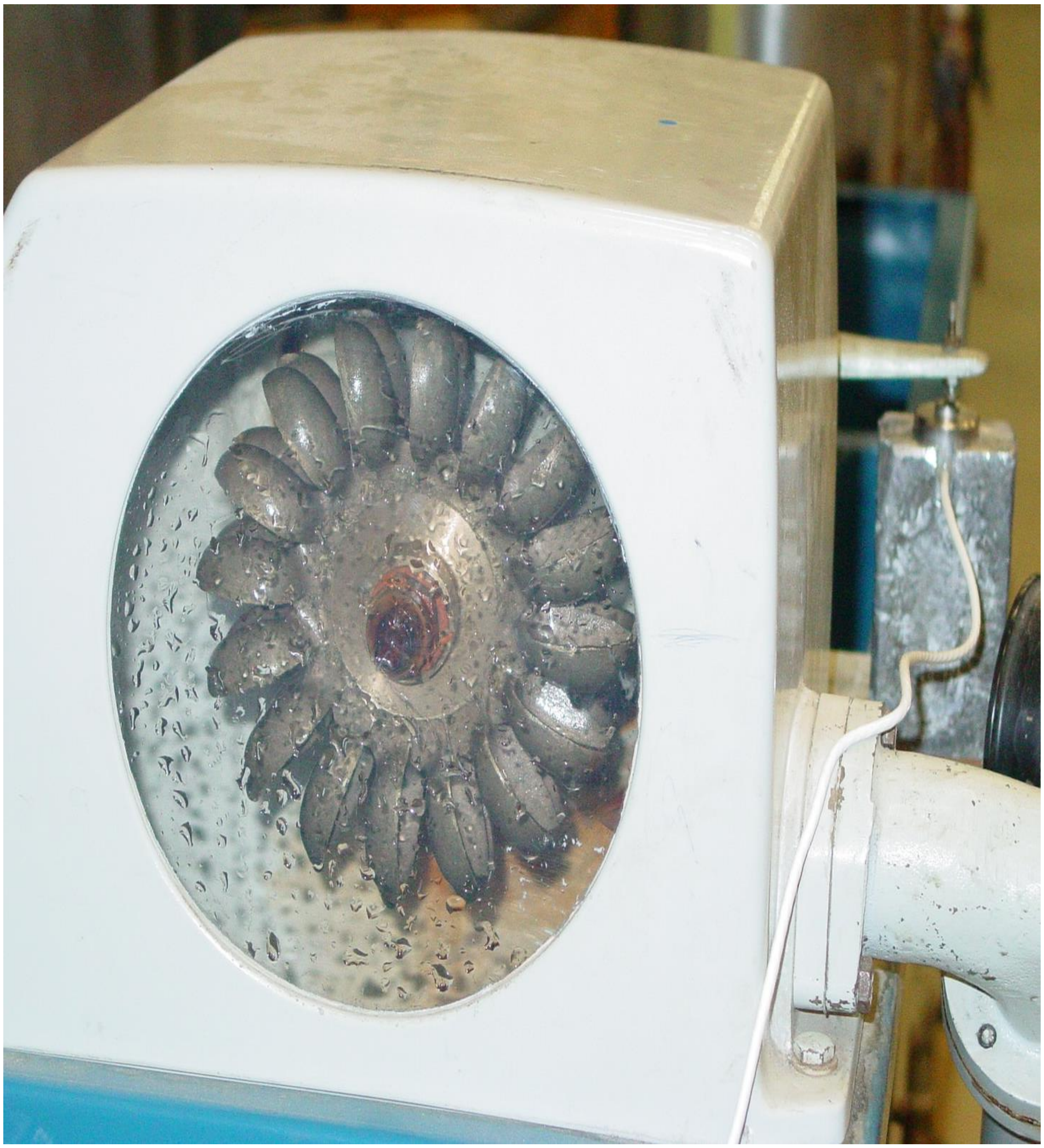
DATA SHEET FOR PELTON WHEEL TURBINE

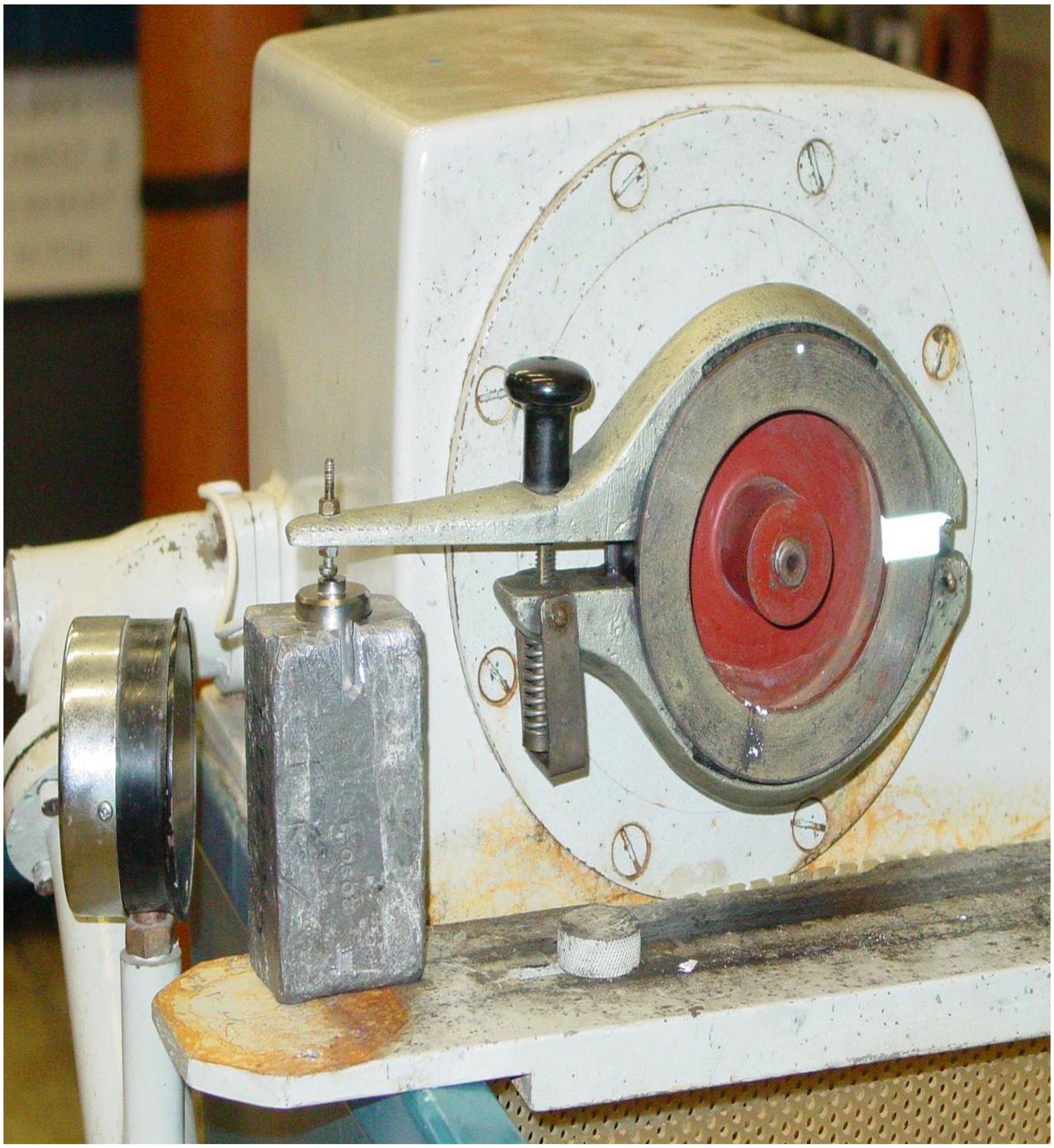
JET PRESSURE =

FLOW RATE =

RUN	BRAKE LOAD	ROTOR RPM







STRAIN AMPLIFIER/SIGNAL CONDITIONER MODULES
FOR STRAIN GAGES, LOAD CELLS, AND TRANSDUCERS

DMD-460 Series

Starts at **$350**

Up to 2 kHz Dynamic Response DMD-465WB

DMD-465, $350, shown smaller than actual size.

- Bridge Excitation 4 to 15 Vdc Up to 120 mA
- Works with 120, 350, 500 Ω and Greater Bridge Circuits
- Adjustable Gain and Offset
- 6-Wire Bridge Connections
- Voltage and Current Output Versions
- 115 and 230 Vac, and DC-Powered Models

The DMD-460 Series bridge amplifiers are self-contained, AC- or DC-powered, signal conditioning modules for strain gages, load cells, and bridge-type sensors. The DMD-465 contains a precision differential instrumentation amplifier with voltage output. The similar DMD-465WB has a frequency response to 2 kHz, while the DMD-466 has a 4 to 20 mA output instead of a voltage output.

SPECIFICATIONS

COMMON

Power: Standard 115 Vac or optional 220 Vac ±10% 50/60 Hz or 10 to 35 Vdc 0.7 A @ 10 V, 0.17 A @ 36 V at maximum excitation load

Operating Temperature: 0 to 70°C (32 to 158°F)

Storage Temperature: -25 to 85°C (-13 to 185°F)

Weight: 510 g (18 oz)

Size: 96 L x 51 W x 73 mm H (3.75 x 2 x 2.87")

BRIDGE SUPPLY

Excitation Voltage Range: 4 to 15 Vdc

Current Output: 120 mA max

Line and Load Regulation: (0 to 100 mA) 0.05% max

Output Noise: 0.5 mVrms

VOLTAGE OUTPUT DMD-465 and DMD-465WB

Gain Range: 40 to 250 (up to 1000 with external resistor on DMD-465 only)

Dynamic Response:
DMD-465: DC to -3 dB = 3 Hz
DMD-465WB: DC to -3 dB = 2 kHz

Max Output (2 kΩ Load): ±10 Vdc

Output Impedance: 0.01 to 1 Ω

Output Offset: -5 to 2 V (DMD-465WB only)

Gain Temp Coefficient: 200 ppm/°C

Input Bias Current: 30 nA

Input Impedance: 3000 MΩ

Output Noise (RTO): @ gain = 100
DMD-465: 120 μVrms
DMD-465WB: 1 Hz to 2 kHz = 2 mV

Input Noise Line Frequency: 15 μV p-p

Common-Mode Rejection: 90 dB @ gain 40, 100 dB @ gain 250

Common-Mode Input Voltage: ±15 V

4 to 20 mA Transmitter DMD-466

Output: 4 to 20 mA, 0 to 20 mA

Input Range for 20 mA Output: 10 mV min, 50 mV max

Zero Adjust: 0 to ±12 mA

Linearity: ±0.05% FS

Temperature Stability: 200 ppm/°C

Input Impedance: 1000 MΩ

Common-Mode Rejection: 90 dB

Common-Mode Input Voltage: ±15 V

Compliance Voltage: 10 Vdc

Output Noise: 1 μA rms @ gain 0.2 mA/mV, 1 to 100 Hz

Dynamic Response: DC to -3 dB = 3 Hz

Response Time: To 99% of final value 200 ms, typical; to 99.9% of final value 300 ms, typical

MOST POPULAR MODELS HIGHLIGHTED!

To Order *(Specify Model Number)*

MODEL NO.	PRICE	DESCRIPTION
DMD-465	$350	Voltage output
DMD-465-220V	350	220 Vac powered DMD-465
DMD-465WB	350	High-frequency voltage output
DMD-465WB-220V	350	220 Vac powered DMD-465WB
DMD-466	350	Current output (4 to 20 mA)
DMD-466-220V	350	220 Vac powered DMD-466
DMD-466-DC	395	10 to 36 Vdc powered DMD-466

Comes with complete operator's manual.

***Ordering Example:** DMD-465WB, wide bandwidth amplifier/signal conditioner module with 115 Vac power, $350.*

ACCESSORY

MODEL NO.	PRICE	DESCRIPTION
EE-2454	$160	Reference Book: The Industrial Electronics Handbook

1" DIAMETER STAINLESS STEEL COMPRESSION LOAD CELL
0-100 lb TO 0-10,000 lb CAPACITIES

LC304 Series

Compression
0-25 lb to 0-10,000 lb
0-11 kg to 0-4537 kg

1 Newton = 0.2248 lb
1 daNewton = 10 Newtons
1 lb = 454 g
1 t = 1000 kg = 2204 lb

All Models $295

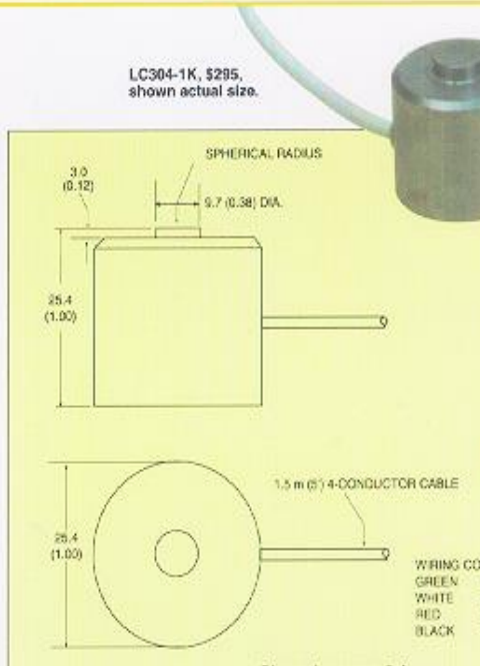
- Heavy-Duty Design
- Built-In Load Button for Easy Installation
- Miniature 25 mm (1") Diameter and 25 mm (1") High Case
- 5-Point Calibration Provided

OMEGA's LC304 Series load cells offer the highest output of all miniature load cells. Their small 25 mm (1") diameter makes it easy to mount them in a pocket or on a flat surface. The rugged stainless steel case and high-quality construction ensure reliability.

SPECIFICATIONS

Excitation: 10 Vdc, 15 Vdc max
Output: 2 mV/V nominal
Accuracy: ±0.5% FSO linearity, hysteresis, repeatability combined
5-Point Calibration: 0%, 50%, 100%, 50%,0%
Zero Balance: ±2% FSO
Operating Temp Range: -54 to 107°C (-65 to 225°F)
Compensated Temp Range: 16 to 71°C (60 to 160°F)
Deflection: 0.025 to 0.076 mm (0.001 to 0.003")
Thermal Effects:
  Zero: 0.009% FSO/°C
  Span: 0.036% FSO/°C
Protection Class: IP65

LC304-1K, $295, shown actual size.



Dimensions: mm (in)

Safe Overload: 150% of capacity
Ultimate Overload: 300% of capacity
Bridge Resistance: 350 Ω minimum
Construction: Stainless steel
Electrical: 1.5 m (5') 4-conductor cable

MOST POPULAR MODELS HIGHLIGHTED!

To Order *(Specify Model Number)*

CAPACITY lb	CAPACITY kg	MODEL NO.	PRICE	COMPATIBLE METERS*
25	11	LC304-25	$295	iSeries, DP41-S, DP25B-S
50	23	LC304-50	295	iSeries, DP41-S, DP25B-S
75	34	LC304-75	295	iSeries, DP41-S, DP25B-S
100	45	LC304-100	295	iSeries, DP41-S, DP25B-S
500	227	LC304-500	295	iSeries, DP41-S, DP25B-S
1000	455	LC304-1K	295	iSeries, DP41-S, DP25B-S
3000	1361	LC304-3K	295	iSeries, DP41-S, DP25B-S
5000	2269	LC304-5K	295	iSeries, DP41-S, DP25B-S
7500	3403	LC304-7.5K	295	iSeries, DP41-S, DP25B-S
10,000	4537	LC304-10K	295	iSeries, DP41-S, DP25B-S

Comes with 5-point NIST-traceable calibration.
* *See section D for compatible meters.*

***Ordering Examples:* LC304-100**, *100 lb capacity load cell,* **$295. LC304-5K,** *5000 lb capacity load cell,* **$295.**

ACCESSORY

MODEL NO.	PRICE	DESCRIPTION
OP-17	$15	Reference Book: Measure for Measure