Current Meter Calibration Using Plint Tow Trolley

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1. Current Meter Calibration Facility at CEWRE

Model Tray Hall of Centre of Excellence is equipped with current meter calibration setup. It consists of PLC control panel, electrically driven trolley, and water channel. The trolley moves on rails mounted on side walls of water channel as shown in **Figure 1** and **Figure 2**. Maximum speed limit of trolley has been restricted to 2 m/s. Trolley covers a distance of 25m in each run. The total length of water channel is 44 meters. Water channel's maximum depth is 1.2m and its width is 1m. Four photoelectric sensors are installed on each end of rail track to stop the movement of trolley as soon as the trolly reaches the sensors, automatically. Rope buffers on each end of rail track are also provided to stop the movement of trolley in case of failure of trolley breaks and sensors.

Figure 1: Channel and rail track of trolley

Figure 2: View of the Trolley on rail track of calibration channel and the control room

2. Trolley Operation Procedure

Following stepwise procedure is adopted to operate the trolley:

1. To activate the power supply to trolley, motor power button of green color is pressed form trolley drive control panel.
2. Before operating the trolley, check that track is clear and no person on trolley. Now press the green “Drive Power” start button providing power to the thyristor drive.
3. Note that the “Emergency Set” red lamp will be lit, indicating that the emergency trip circuit is not reset.
4. Place the key in the “Emergency Reset” switch and turn clockwise, the set lamp will be extinguished indicating that the emergency trip circuit is now reset. The key cannot be removed until it return to vertical.
5. The key can now be positioned in the “Enable” switch, turning the key will enable the trolley controls to be operational.
6. Before moving the trolley, switch the “Trolley Auxiliary Power” on, this activate the rail brush motors.

7. Select the desired running speed from “Speed Set Knob”. PLC panel will indicate the selected speed of trolley.
8. “Run Forward” or “Run Reverse” buttons on PLC panel will cause the trolley to move to the desired nominal set speed in the direction selected.
9. The trolley may stopped at any point of the operation by pushing the “Stop” button.
10. The trolley will automatically stop at the end of track by utilizing the photo-electric sensors. When this occurs the “Run” buttons will not operate for same direction as trolley was originally travelling. However the “Inch” buttons will enable trolley movement within these restricted regions to allow for maximum utilization of channel length.

3. Description of Control Panel

Control panel consist of “Trolley Drive Control”. It has motor power button, drive power button and emergency set and reset switches with red and green lights as shown in **Figure 3** (a). Trolley speed is adjusted by using a black color “Knob”. The movement of trolley on track is controlled through “PLC Panel”. Moreover, data regarding adjusted speed of trolley, constant speed of trolley, revolution counter, working of photoelectric sensors and time of travel are also acquired from “PLC Panel” as shown in **Figure 3** (b).

(a) (b)

Figure 3: (a) Control panel of Trolley **(b)** PLC panel

4. Calibration Procedure of Current Meter

In order to find out the velocity of water from revolutions of rotor of a current meter, a relation must be established between angular velocity of rotor and velocity of water turning it. The establishment of this relation is known as 'rating the current meter'. The relationship between flow velocity and rotational speed of rotor of current meter is shown below.

$$V = a + KN \qquad (1)$$

In above relation 'V' denotes the flow velocity while 'N' denotes the revolution per unit of time. Whereas 'a' and 'N' are constants.

At CEWRE current meter calibration is carried out in 44m long, 1m wide and 1.2m deep channel. The trolley carries the current meter at a constant speed through stationary water in channel. The average velocity of moving trolley is determined for each run by making a measurement of distance it travels during the time that the revolutions 'N' of the rotor of current meter counted through counter. United States Geological Survey (USGS) recommends that current meter is rated by towing it through trolley at eight different velocities (0.25, 0.50, 0.75, 1.10, 1.50, 2.20, 5.00 and 8.00 ft/sec). A pair of runs is made for each velocity. The data thus consist of 16 observations for selected velocity (0.25, 0.5, 0.75, 1, 1.25, 1.50, 1.75 and 2 m/s) of trolley (V) and revolutions (N) per unit of the time of rotor. The current meter rating is determined using these data and expressed in the form of linear equation as shown in **Table 1**, **Table 2**, **Table 3** & **Table 4**.

Table 1: Calibration of Current Meter (Propellor # 44637)

Calibration of Current Meter (Revolution recorded with counter)								
Propellor # 44637						**Date of Calibration= September 29,2020**		
Equation of current meter= V= 0.0923n+0.0505 ("n" in rev/s, "v" in m/s)								
Pair of transects	**Trolley Velocity**		**Time**	**Average Time**	**N=No. of Revolutions**	**N=Avg. no. of Revolutions**	**n= No. of revolutions per second**	**y =0.0923x+0.0505**
	m/s	**ft/s**	**second**	**second**	**rev**	**rev**	**rev/s**	**m/s**
2	0.25	0.820	93.5	94	217	218	2.33	0.27
			93.5		218			
2	0.5	1.641	46.4	46	226	227	4.89	0.50
			46.4		228			
2	0.75	2.461	30.8	31	231	231	7.49	0.74
			30.9		231			
2	1	3.281	23	23	234	234	10.15	0.99
			23.1		234			
2	1.25	4.101	18.4	18	238	238	12.91	1.24
			18.4		237			
2	1.5	4.922	15.3	15	241	241	15.70	1.50
			15.4		241			
2	1.75	5.742	13.2	13	245	244	18.48	1.76
			13.2		243			
2	2	6.562	11.6	12	246	246	21.21	2.01
			11.6		246			

Table 1 illustrate the measured key parameters, required to (Calibrate the Current Meter) develop the linear equation for establishment of relationship between angular velocity of rotor and velocity of water turning the propeller.

Results of calculated flow velocities by current meter are admirable. Two pair of transects are performed against each selected velocity of trolley to estimate the average time of trolley travelling and average number of rotor revolutions, to calculate the per second revolution of current meter rotor. It is prominent that number of revolutions per second are increasing as the trolley velocity increases which indicates a direct relationship between both parameters. To establish a relationship between both parameters (rotor per second revolutions and trolley velocity) a liner equation is developed "V=0.0923n+0.0505" by plotting a graph as shown in **Figure 4**, and water velocity can be calculated using current meter rotor "per second revolutions". It is shown that estimated velocities by linear equation are approximately same as the trolley velocity. Overall, the current meter is accurately measuring the flow velocity and linear equation can be applied to calculate the actual velocity of flowing water in open channels.

Table 2: Calibration of Current Meter (Propellor # 44922)

Calibration of Current Meter (Revolution recorded with counter)								
Propellor # 44922						**Date of Calibration=August 24,2020**		
Equation of current meter= V= 0.5038n+0.0203 ("n" in rev/s, "v" in m/s)								
Pair of transects	**Trolley Velocity**		**Time**	**Average Time**	**N=No. of Revolutions**	**N=Avg. no. of Revolutions**	**n= No. of revolutions per second**	**y =0.467x+0.0635**
	m/s	**ft/s**	**second**	**second**	**rev**	**Rev**	**rev/s**	**m/s**
2	0.25	0.820	94	94	41	41	0.43	0.27
			94.6		41			
2	0.5	1.641	45.9	46	40	42	0.89	0.48
			46.9		43			
2	0.75	2.461	31.1	31	46	46	1.48	0.76
			31		46			
2	1	3.281	23.3	23	46	46	1.98	0.99
			23.2		46			
2	1.25	4.101	18.6	19	47	47	2.53	1.24
			18.6		47			
2	1.5	4.922	14.9	15	46	47	3.16	1.54
			14.5		47			
2	1.75	5.742	13.2	13	47	47	3.55	1.72
			13.3		47			
2	2	6.562	11.6	12	48	48	4.16	2.00
			11.5		48			

Table 2 illustrate the measured key parameters, required to (Calibrate the Current Meter) develop the linear equation for establishment of relationship between angular velocity of rotor and velocity of water turning the propeller.

Results of calculated flow velocities by current meter are admirable. Two pair of transects are performed against each selected velocity of trolley to estimate the average time of trolley travelling and average number of rotor revolutions, to calculate the per second revolution of current meter rotor. It is prominent that number of revolutions per second are increasing as the trolley velocity increases which indicates a direct relationship between both parameters. To establish a relationship between both parameters (rotor per second revolutions and trolley velocity) a liner equation is developed "V=0.5038n+0.0203" by plotting a graph as shown in **Figure 5**, and water velocity can be calculated using current meter rotor "per second revolutions". It is shown that estimated velocities by linear equation are approximately same as the trolley velocity. Overall, the current meter is accurately measuring the flow velocities and linear equation can be applied to calculate the actual velocity of flowing water in open channels.

Table 3: Calibration of Current Meter (Propellor # 46862)

Calibration of Current Meter (Revolution recorded with counter)								
Propellor # 46862						Date of Calibration= September 24,2020		
Equation of current meter= V= 0.0922n+0.0607 ("n" in rev/s, "v" in m/s)								
Pair of transects	Trolley Velocity		Time	Average Time	N=No. of Revolutions	N=Avg. no. of Revolutions	n= No. of revolutions per second	y =0.0922x+0.0607
	m/s	ft/s	second	second	rev	rev	rev/s	m/s
2	0.25	0.820	93.3	95	203	204	2.15	0.26
			96.1		204			
2	0.5	1.641	46.6	47	222	221	4.74	0.50
			46.5		219			
2	0.75	2.461	31	31	227	229	7.38	0.74
			30.9		230			
2	1	3.281	23	23	232	233	10.11	0.99
			23		233			
2	1.25	4.101	18.5	18	237	238	12.90	1.25
			18.4		239			
2	1.5	4.922	15.3	15	244	242	15.82	1.52
			15.3		240			
2	1.75	5.742	13.3	13	240	241	18.22	1.74
			13.1		241			
2	2	6.562	11.6	12	243	244	21.03	2.00
			11.6		245			

Table 3 illustrate the measured key parameters, required to (Calibrate the Current Meter) develop the linear equation for establishment of relationship between angular velocity of rotor and velocity of water turning the propeller

Results of calculated flow velocities by current meter are admirable. Two pair of transects are performed against each selected velocity of trolley to estimate the average time of trolley travelling and average number of rotor revolutions, to calculate the per second revolution of current meter rotor. It is prominent that number of revolutions per second are increasing as the trolley velocity increases which indicates a direct relationship between both parameters. To establish a relationship between both parameters (rotor per second revolutions and trolley velocity) a liner equation is developed "V=0.0922n+0.0607" by plotting a graph as shown in **Figure 6**, and water velocity can be calculated using current meter rotor "per second revolutions". It is shown that estimated velocities by linear equation are approximately same as the trolley velocity. Overall, the current meter is accurately measuring the flow velocities and linear equation can be applied to calculate the actual velocity of flowing water from in open channels.

Table 4: Calibration of Current Meter (Propellor # 47636)

Calibration of current meter (Revolution recorded with counter)								
Propellor # 47636						**Date of Calibration= October 06,2020**		
Equation of current meter= V= 0.2268n+0.0562 ("n" in rev/s, "v" in m/s)								
Pair of transects	**Trolley Velocity**		**Time**	**Average Time**	**N=No. of Revolutions**	**N=Avg. no. of Revolutions**	**n= No. of revolutions per second**	**y =0.2268x+0.0562**
	m/s	**ft/s**	**second**	**second**	**rev**	**rev**	**rev/s**	**m/s**
2	0.25	0.820	94	94	88	88	0.94	0.27
			93.6		88			
2	0.5	1.641	46.2	46	92	92	1.99	0.51
			46.2		92			
2	0.75	2.461	30.7	31	93	93	3.03	0.74
			30.7		93			
2	1	3.281	23.1	23	94	94	4.07	0.98
			23.1		94			
2	1.25	4.101	18.4	18	96	96	5.22	1.24
			18.4		96			
2	1.5	4.922	15.4	15	97	97	6.30	1.48
			15.4		97			
2	1.75	5.742	13	13	98	98	7.51	1.76
			13.1		98			
2	2	6.562	11.5	12	99	100	8.65	2.02
			11.5		100			

Table 4 illustrate the measured key parameters, required to (Calibrate the Current Meter) develop the linear equation for establishment of relationship between angular velocity of rotor and velocity of water turning the propeller

Results of calculated flow velocities by current meter are admirable. Two pair of transects are performed against each selected velocity of trolley to estimate the average time of trolley travelling and average number of rotor revolutions, to calculate the per second revolution of current meter rotor. It is prominent that number of revolutions per second are increasing as the trolley velocity increases which indicates a direct relationship between both parameters. To establish a relationship between both parameters (rotor per second revolutions and trolley velocity) a liner rating equation is developed "V=0.2268n+0.0562" by plotting a graph as shown in **Figure 7**, and water velocity is recalculated using current meter rotor "per second revolutions". It is shown that estimated velocities by linear equation are approximately same as the trolley velocity. Overall, the current meter is accurately measuring the flow velocities and linear equation can be applied to calculate the actual velocity of flowing water from in open channels.

Table 5: Calibration of Current Meter (Propellor # 46353)

Calibration of current meter (Revolution recorded with counter)								
Propellor # 46353						**Date of Calibration= September 29,2020**		
Equation of current meter= V= 0.0502n+0.0498 ("n" in rev/s, "v" in m/s)								
Pair of transects	**Trolley Velocity**		**Time**	**Average Time**	**N=No. of Revolutions**	**N=Avg. no. of Revolutions**	**n= No. of revolutions per second**	**y =0.0502x+0.0498**
	m/s	**ft/s**	**second**	**second**	**rev**	**rev**	**rev/s**	**m/s**
1	0.25	0.820	93.7	94	385	385	4.11	0.26
			93.6		385			
2	0.5	1.641	46.4	46	412	413	8.91	0.50
			46.3		414			
3	0.75	2.461	30.8	31	426	428	13.88	0.75
			30.8		429			
4	1	3.281	23.1	23	435	434	18.79	0.99
			23.1		433			
5	1.25	4.101	18.4	18	443	443	24.08	1.26
			18.4		443			

Table 5 illustrate the measured key parameters, required to (Calibrate the Current Meter) develop the linear equation for establishment of relationship between angular velocity of rotor and velocity of water turning the propeller

Results of calculated flow velocities by current meter are admirable. Two pair of transects are performed against each selected velocity of trolley to estimate the average time of trolley travelling and average number of rotor revolutions, to calculate the per second revolution of current meter rotor. It is prominent that number of revolutions per second are increasing as the trolley velocity increases which indicates a direct relationship between both parameters. To establish a relationship between both parameters (rotor per second revolutions and trolley velocity) a liner rating equation is developed "V=0.0502n+0.0498" by plotting a graph as shown in **Figure 8**, and water velocity can be calculated using current meter rotor "per second revolutions". It is shown that estimated velocities by linear equation are approximately same as the trolley velocity. Overall, the current meter is accurately measuring the flow velocities and linear equation can be applied to calculate the actual velocity of flowing water from 0.25 m/sec to 1.25m/sec in open channels.

Table 6: Calibration of Current Meter (Propellor # 47598)

Calibration of current meter (Revolution recorded with counter)								
Current meter # 47598						Date of Calibration= September 25,2020		
Equation of current meter= V= 0.0497n+0.0606 ("n" in rev/s, "v" in m/s)								
Pair of transects	**Trolley Velocity**		**Time**	**Average Time**	**N=No. of Revolutions**	**N=Avg. no. of Revolutions**	**n= No. of revolutions per second**	**y =0.0497x+0.0606**
	m/s	**ft/s**	**second**	**second**	**rev**	**rev**	**rev/s**	**m/s**
1	0.25	0.820	93.8	94	367	369	3.93	0.26
			93.8		371			
2	0.5	1.641	46.6	47	407	407	8.72	0.49
			46.6		406			
3	0.75	2.461	30.9	31	421	421	13.65	0.74
			30.8		421			
4	1	3.281	23.2	23	465	448	19.33	1.02
			23.1		430			
5	1.25	4.101	18.4	18	438	439	23.77	1.24
			18.5		439			

Table 6 illustrate the measured key parameters, required to (Calibrate the Current Meter) develop the linear equation for establishment of relationship between angular velocity of rotor and velocity of water turning the propeller

Results of calculated flow velocities by current meter are admirable. Two pair of transects are performed against each selected velocity of trolley to estimate the average time of trolley travelling and average number of rotor revolutions, to calculate the per second revolution of current meter rotor. It is prominent that number of revolutions per second are increasing as the trolley velocity increases which indicates a direct relationship between both parameters. To establish a relationship between both parameters (rotor per second revolutions and trolley velocity) a liner rating equation is developed "V=0.0497n+0.0606" by plotting a graph as shown in **Figure 9**, and water velocity can be calculated using current meter rotor "per second revolutions". It is shown that estimated velocities by linear equation are approximately same as the trolley velocity. Overall, the current meter is accurately measuring the flow velocities and linear equation can be applied to calculate the actual velocity of flowing water from 0.25 m/sec to 1.25m/sec in open channels.

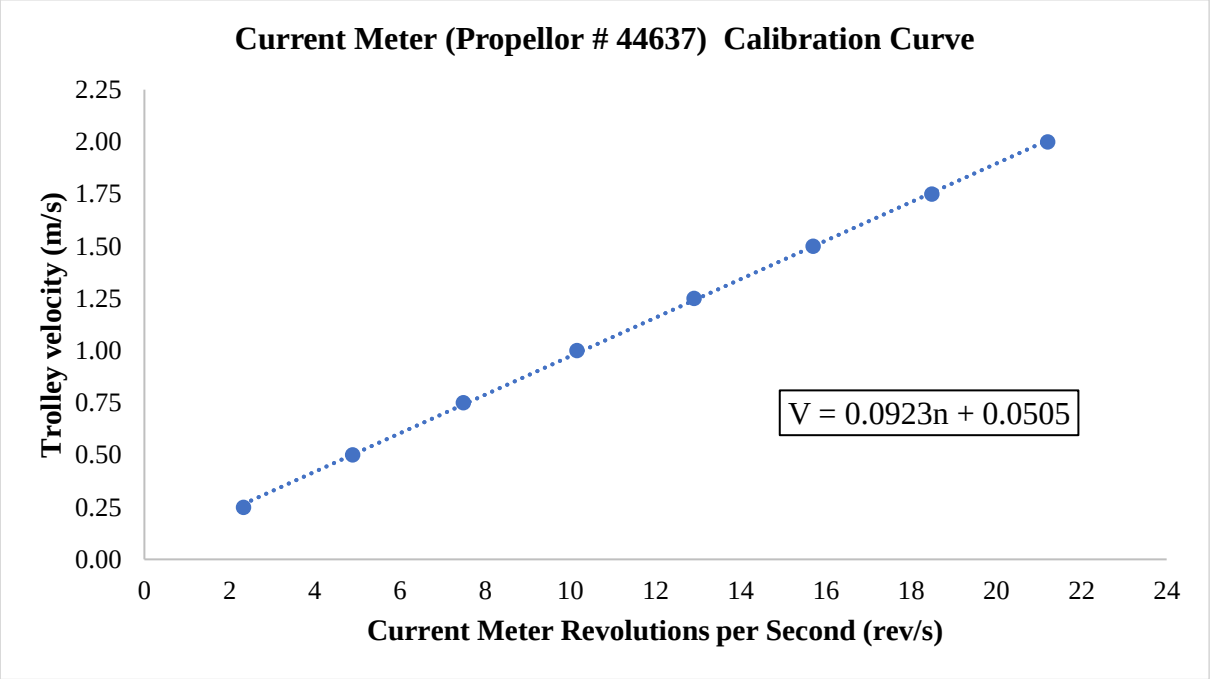

Figure 4: Calibrating Curve of Current Meter (Propellor # 44657)

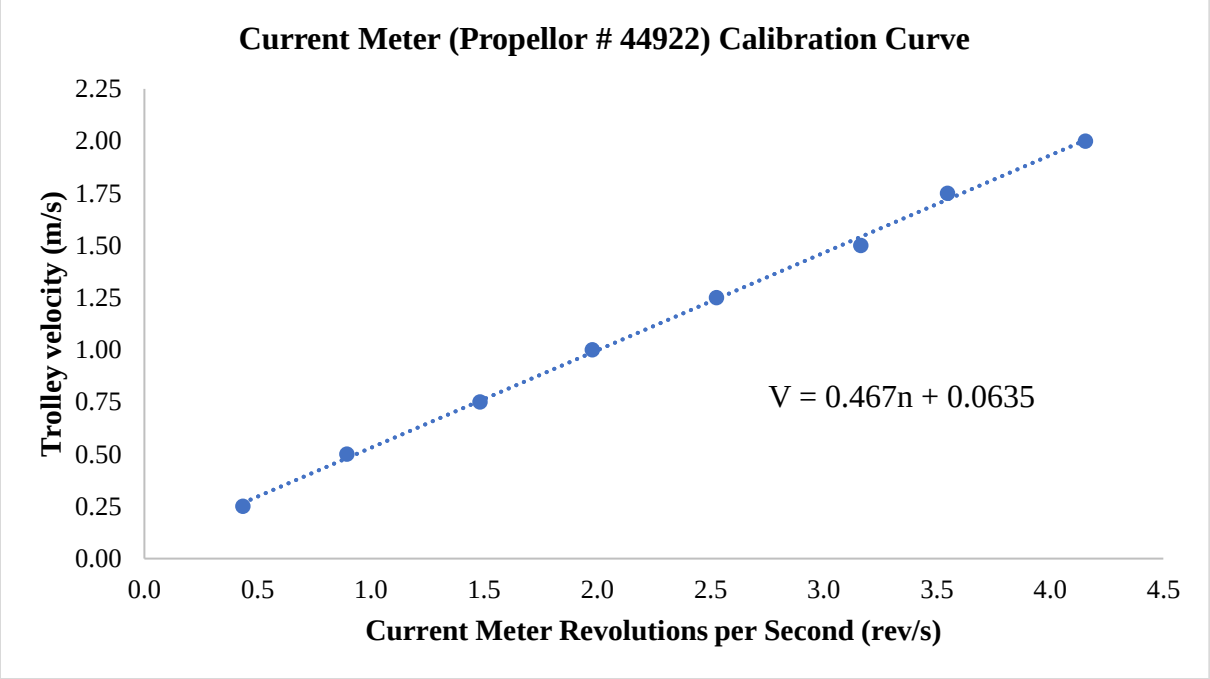

Figure 5: Calibrating Curve of Current Meter (Propellor # 44922)

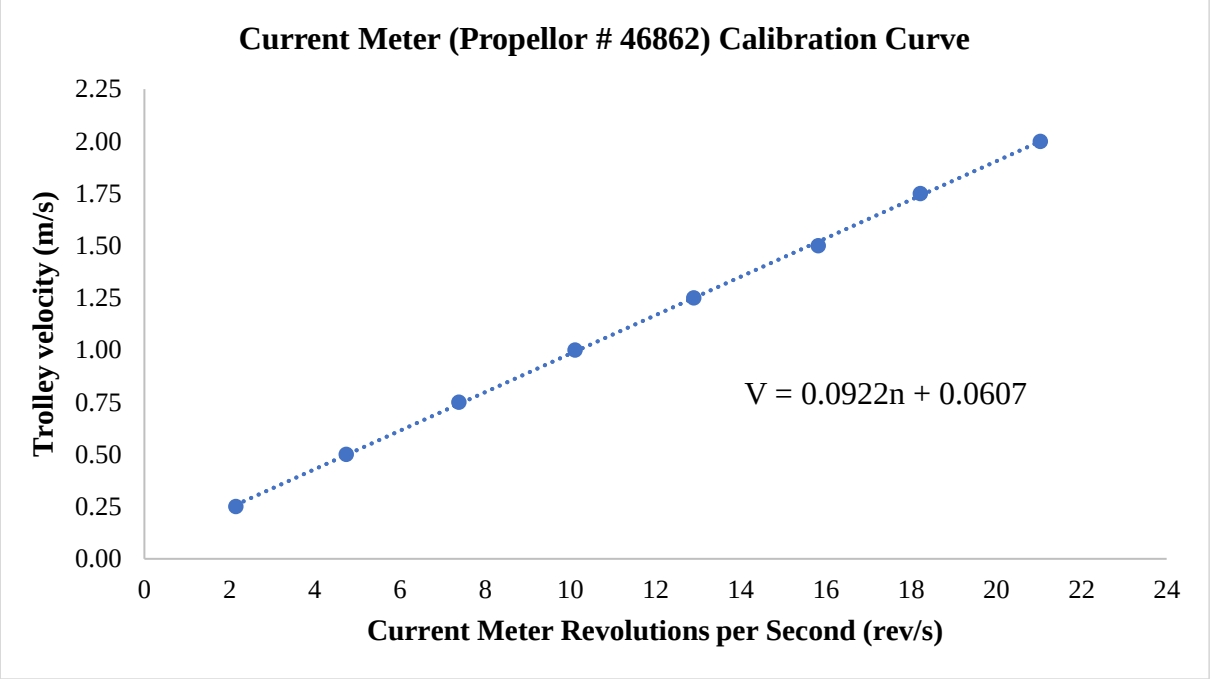

Figure 6: Calibrating Curve of Current Meter (Propellor # 46862)

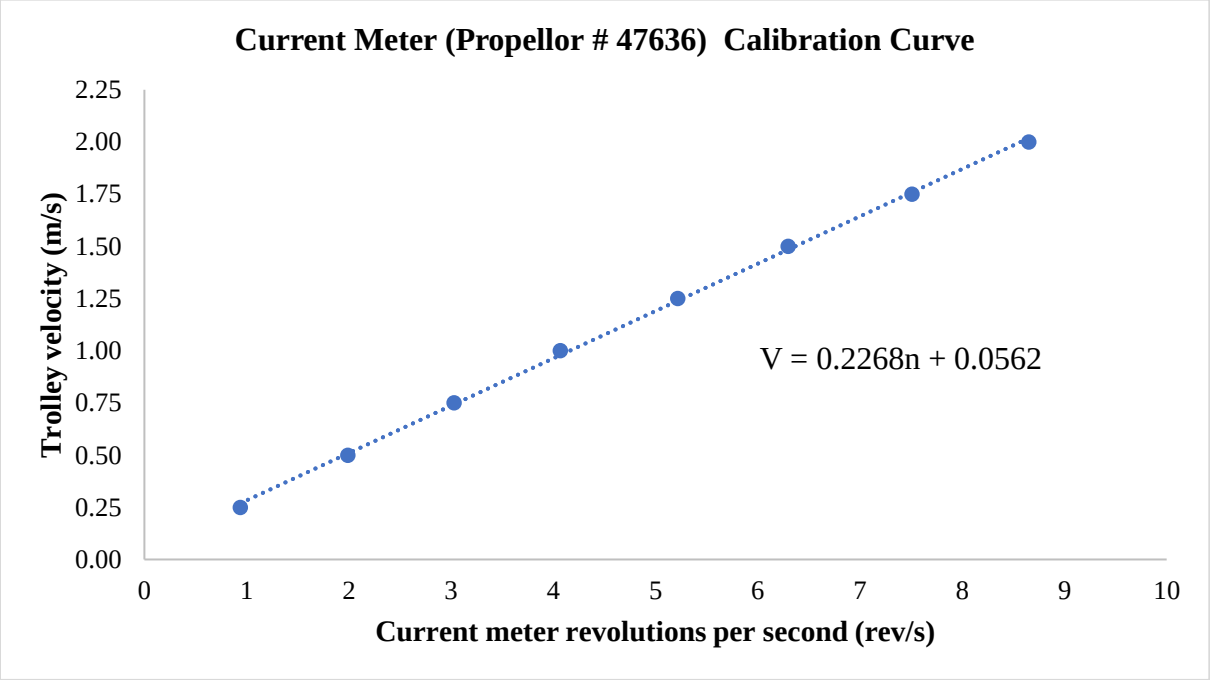

Figure 7: Calibrating Curve of Current Meter (Propellor # 47636)

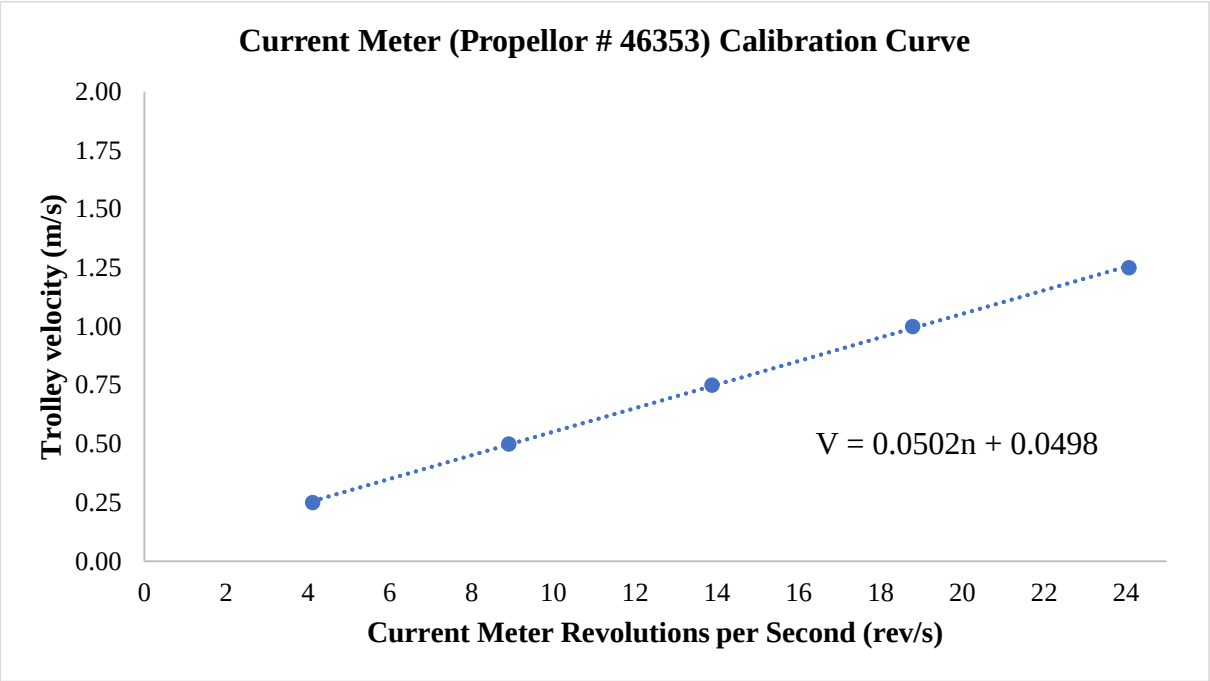

Figure 8: Calibrating Curve of Current Meter (Propellor # 46353)

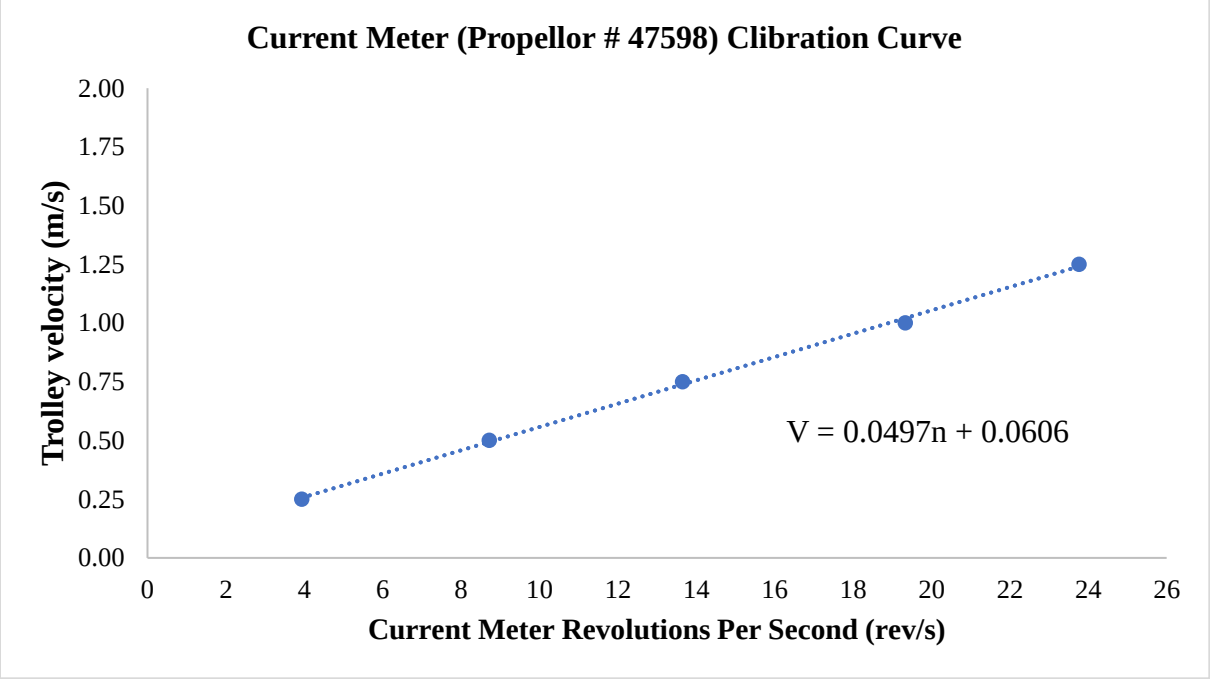

Figure 9: Calibrating Curve of Current Meter (Propellor # 47598)