RSI Technical Note 049

Tow-yoing with the VMP-250-IR

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1 Introduction

In the ever expanding world of turbulence measurements it has come to the attention of Rockland Scientific that several research groups have successfully collected turbulence measurements with the Rockland VMP-250-IR (VMP) using non-traditional rapid recovery equipment in tow-yo configurations. Tow-yoing provides an opportunity to collect turbulence data while a vessel is underway, therefore increasing the spatial resolution of the measurements. This technical note outlines the equipment options and recommendations, as well as highlights lessons learned from previous deployments.

1.1 What is Tow-yoing?

Tow-yoing is a method of vertical profiling in a "yo-yo" pattern while towing the profiling instrumentation with the vessel underway. This results in the instrumentation following a saw tooth pattern through the water (Figure 1). The term "underway profiling" is also used in place of "tow-yoing" and the phrase Underway Vertical Microstructure Profiler (UVMP) has been used to describe a Rockland VMP in this configuration (Nagai et al 2017).

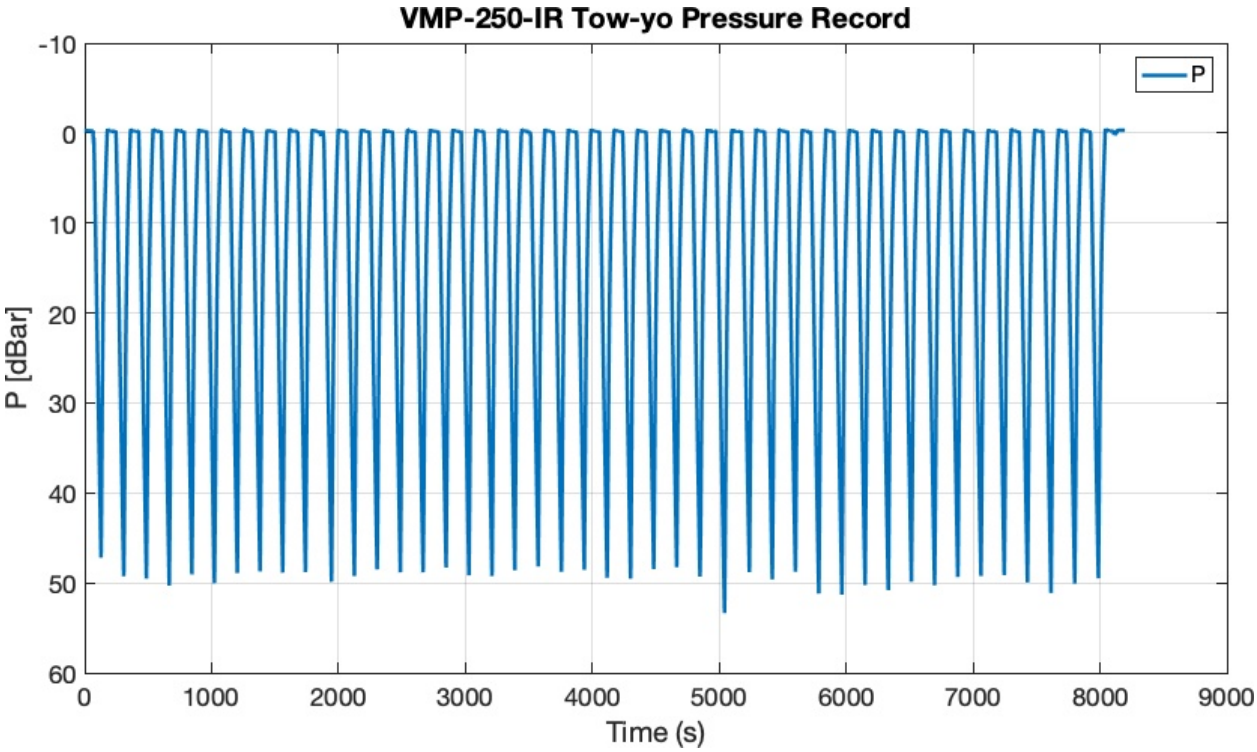

Figure 1: Example pressure record from a LP S-1200 and VMP-250-IR tow-yo operation. Vessel speed was aproximately 2 knots.

2 Equipment

To successfully obtain measurements using the tow-yo technique, a rapid recovery system is necessary. For the VMP-250, this can be achieved using an electric fishing reel or other althernative rapid recovery systems, such as the Teledyne Oceanscience UnderwayCTD^{TM}. However, the benefit of a conventional winch is that it can accommodate a much larger tether, which provides increased breaking strength, therefore reducing risk of losing the VMP due to the tether breaking under load.

2.1 Conventional Winches

Conventional winches (e.g. Figure 2) are designed to conduct single profile measurements while the vessel is not underway, and are not ideal for tow-yo applications with the VMP. Rockland Scientific is not aware of any tow-yo applications using conventional winches, however, theorectically, it may be possible. Conventional winches provide the benefit of large capacity drums capable of housing larger diameter tethers with significant breaking strength, that can increase the success of instrumentation recovery. Conventional winches also provide increased power allowing for deployment of larger profiling packages and/or in situations where high loads may be placed on the winch and tether. The limitations of conventional winches include the requirement of a larger sized vessel, an A-frame, davit or crane, and power to be supplied by the vessel.

Figure 2: An A.G.O. Environmental CSW-7 Conventional Winch installed amidships to deploy a VMP-500-RT

2.2 Lindgren-Pitman Electric Fishing Reel (LP S-1200)

The LP S-1200 Fishing Reel produced by Lindgren-Pitman has been used by multiple VMP users for tow-yo operations. In 2017, Rockland purchased a LP S-1200 for testing and field service. Rockland recommends using the wishbone rod, however a conventional rod has also been shown to be viable. Consult the Lindgren Pitman S-1200 User Manual before operating.

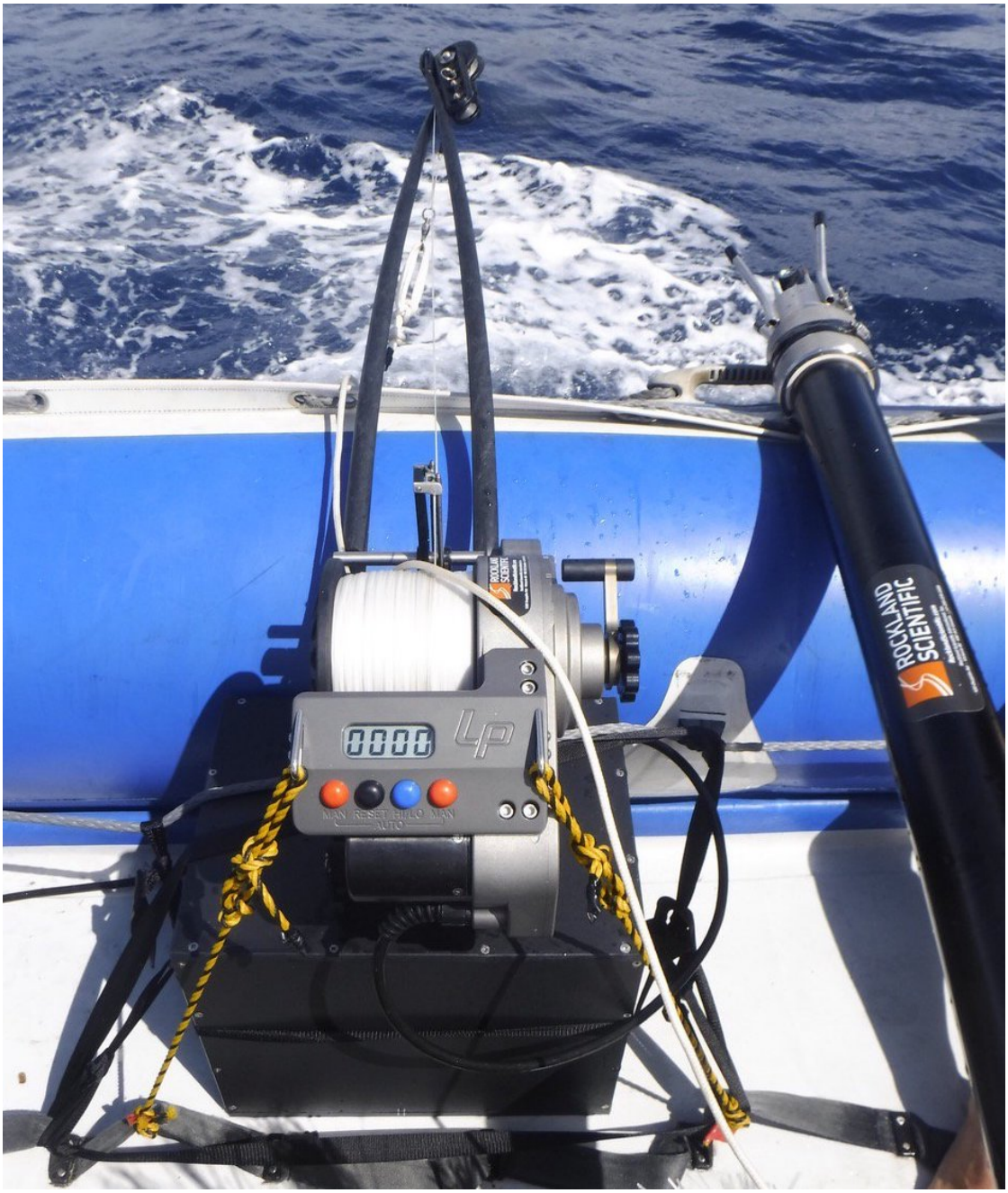

Figure 3: A VMP-250-IR and LP S-1200 Electric Reel mounted amidships on a Rigid Hull Inflatable Boat for single point measurements.

2.2.1 Operating the LP S-1200

Basic deployment instructions for the VMP-250 and LP S-1200 tow-yo system:

1. Before deploying the VMP, review Section 4 to ensure the tether is securely attached to the VMP.
2. Once the VMP has been lowered into position just below the surface, press the black RESET button to set the line counter to zero (as seen in Figure 3).
3. To deploy the VMP, release the LP S-1200 clutch so that the VMP can freely pull the line off the LP S-1200 drum. Ensure the line is running freely. The line counter displays length of line deployed in feet (ft).
4. Once the desired amount of line has been deployed, engage the LP S-1200 clutch to stop the line from paying out further.

Basic recovery instructions for the VMP and LP S-1200 tow-yo system:

1. Begin by pressing one of the red MAN buttons. Confirm the tether is being retrieved smoothly and is not caught on anything in the water.
2. Press the two red MAN buttons together to start automatic recovery. The built in automatic recovery mode will allow the LP S-1200 to recover the VMP hands free.
3. Adjust the LP S-1200 clutch, see section 2.2.3.
4. The recovery speed of the LP S-1200 can be adjusted by pressing the blue HI/LO button.
5. The LP S-1200 will end automatic recovery when the line counter reaches zero, so remember to set the line counter to zero with the VMP on the surface, not when the VMP is at the end of the rod.
6. The LP S-1200 should be monitored at all times during deployment and recovery of the VMP.

2.2.2 Mounting the LP S-1200

The LP S-1200 is easily installed using conventional fishing rod holders and equipment available on recreational and commercial fishing vessels. It is recommended to tie the LP S-1200 securely to the vessel as the LP S-1200 sits in place due to gravity and it is possible it will be knocked out of the holder in high seas. For tow-yo operations the LP S-1200 should be mounted on the stern rail of the vessel immediately above the transom. Rockland designed a mounting system for use on vessels such as Rigid Hull Inflatable Boats (RHIBs) where hard mounting points are limited (Figure 3). When mounting the LP S-1200, the unit should be tied to the vessel using the tie down points. This prevents the LP S-1200 from over-rotating or from slipping out of the mounting box. The wishbone rod should extend over the rail as much as possible with unimpeded access to the waters

astern of the vessel. If mounting the LP S-1200 on a RHIB, the mounting system should be well secured to the deck of the vessel. The LP S-1200 should be positioned amidships. When deploying from a RHIB equipped with outboards engines or propulsion mechanisms aft of the transom, tow-yoing is not advised; instead use standard profiling practices, i.e. let the vessel drift broadside to the wind with the tether deployed amidships, away from the propellers, off the windward side.

2.2.3 LP S-1200 Clutch

During retrieval, the clutch on the LP S-1200 should be adjusted. The clutch can be adjusted using a coarse tuning dial and a fine tuning lever. The clutch should be engaged to a minimum in case the VMP or line is caught on something and needs to pull line off the drum during recovery. When the clutch is engaged to a minimum the LP S-1200 will not continue retrieval during moments of high tension due to the heave of the vessel. Keeping the clutch engaged to a minimum can prevent the loss of your instrument, it is a safety feature that will help reduce risk of the line snapping in the event of sudden high tension on the tether due to heaving in high seas or in the unfortunate event the VMP is caught on something in the ocean. To set the clutch when the VMP is in automatic recovery mode:

1. Begin by releasing the clutch until you hear the LP S-1200 motor is turning but the drum is not spinning.
2. Next, engage the clutch until the drum begins to turn, pulling in the tether. The clutch can be further engaged a very small amount for good measure.

2.2.4 LP S-1200 Tether

The LP S-1200 drum can hold 500 yards (457 m) of 500 lb test single braid Spectra®1.5 mm diameter tether. Stronger lines are available but typically have a larger diameter, leading to reduced length that will fit on the drum. It is recommended to use stronger line if the target deployment depth does not require 457 m of line. See section 3.3.1 to determine the length of line required for a deployment. Rockland does not recommend using tethers with a test strength below 500 lbs.

It is important to consider that the deployment tethers used with the LP S-1200 are not as strong as conventional (>6 mm diameter) deployment tethers and, therefore, may increase the risk of instrument loss compared with standard VMP deployment techniques.

2.3 UnderwayCTD Winch

The UnderwayCTD Winch is well suited for tow-yoing the VMP, as referenced in Nagai et. al., 2017 & 2019. The UnderwayCTD manual must be consulted and considered before operation with the VMP. The UnderwayCTD may be supplied with a 1.2 mm 300 lb

test single braid Spectra deployment tether, however, **Rockland recommends upgrading to at least a 1.5 mm 500 lb test tether or stronger for use with the VMP.** The UnderwayCTD system considers the CTD units semi-expendable, therefore, they do not securely tie off the tether to the UnderwayCTD winch drum. In the event the instrument is caught on something in the water, the line will be pulled off the UnderwayCTD winch and the winch will not be damaged. The user must consider if the same approach is warranted with the VMP. It may be best to securely tie the tether to the UnderwayCTD winch. Tether terminations recommended in the UnderwayCTD manual may not be appropriate for the VMP; refer to the UnderwayCTD winch manual and section 4.

2.4 rapidCAST™ System

The rapidCAST system by Teledyne Oceanscience is a more advanced version of the UnderwayCTD. Rockland is not aware of any deployment yet of this system with the VMP, however, testing may occur in the near future. Rockland expects rapidCAST is well suited for tow-yoing the VMP. Similar to the UnderwayCTD system, the tether strength and tether terminations should be carefully considered before operating the rapidCAST system with the VMP. The rapidCAST user manual must be consulted and considered before operation with the VMP. Tether terminations recommended in the rapidCAST manual may not be appropriate for the VMP; refer to the rapidCAST manual and section 4.

3 Vessel Considerations for Tow-yoing

3.1 Propeller Location

Careful consideration of the deployment vessel should be made to maximize tow-yoing capabilities. Vessels of any size can be used, however to prevent the deployment tether from interacting with the vessel's propellers, a vessel with the propellers well forward of the transom should be employed.

The tow-yo recovery system should be mounted on the aft rail of the vessel with the davit or wish bone rod extending over the transom of the vessel. When the tether enters the water near the transom it should be sufficiently clear of the ship's propulsion mechanism to avoid any risk of damage to the tether.

Vessels with outboard motors are not ideal for tow-yo applications because there is no clear path for the deployment tether aft of the vessel. Small vessels such as RHIBs have been used with the Rockland mounting system and LP S-1200 installed amidships (see Figure 3); in this case tow-yoing is not used and instead a conventional single profile deployment method is employed.

3.2 Powering the Recovery System

The LP S-1200 can be wired to a vessel's electrical system or powered from a conventional marine or automotive battery. Check with the vessel operator ahead of your deployment for the best method to power your equipment. If an independent battery is used to power the LP S-1200, ensure the battery has sufficient capacity for the deployment duration. Recharging the battery may be required for longer deployments.

3.3 Vessel Operations

It is critical that the tow-yo system operator and the vessel operator to maintain good communication at all times. The suggested best practices include the following:

1. The tow-yo tether and instrument should be kept well clear of the propellers at all times during operation.
2. The vessel should never operate in reverse while the instrument or tether is in the water.
3. The vessel should avoid marine traffic, fishing equipment and any other obstacles that may entangle the tow-yo equipment.
4. At the discretion of the vessel operator, the vessel should use the appropriate lights or day shapes indicating the vessel is restricted in maneuverability as per the International Collision Regulations.

3.3.1 Vessel Speed

Vessel speed during underway profiling is an important consideration. Vessel speed will determine the spatial resolution of the measurements, the loads on the tether and winch, and may limit the profiling depth.

The LP S-1200 has been successfully deployed from a vessel travelling at speeds up to 4 knots. Using the LP S-1200 system at speeds greater than 4 knots may be possible but increases risk that the tether will break as the load on the tether and winch will increase. Careful consideration of risk factors and tether breaking strength should be considered if vessel speed greater than 4 knots is desired.

3.3.2 Tether Length Requirement

The following equation can be used to determine the amount of tether (L) to let out to reach a desired deployment depth(D):

Figure 4: An LP S-1200 Electric Reel mounted for Tow-yo operations. The VMP is being towed on the surface while the vessel is underway. Photo credit: Dan Titze

$$L = D\left(\frac{W_P + U_V}{W_P}\right) \tag{1}$$

Where (W_P) is the vertical speed of the profiler and (U_V) is the speed of the vessel through the water.

Fall Speed: The typical fall speed of a standard VMP is 0.7 m/s, however, increasing the fall speed by adding ballast weight may be advantageous for tow-yo operations. The fall speed must be determined by reviewing data collected during test deployments of the instrument in safe waters. Rockland recommends deploying with test probes installed during these test deployments to determine the typical fall speed during tow-yoing.

Example: To obtain 100 m deep profiles using a VMP with added ballast (i.e. $W_P = 1\,\mathrm{m/s}$) and a vessel travelling at 4 knots (i.e. 2 m/s), 300 m of line is needed. Because the instrument is falling at 1 m/s, it will take 100 s (i.e. 100 m/1 m/s) to complete the downward profile. Experienced users of the LP S-1200 have observed that the retrieval rate is approximately constant at $\sim$ 1.25 m/s regardless of the ship speed, hence the retrieval time will be 240s (i.e. 300m/1.25m/s). The total time between tow-yos is therefore 340 s.

The main drawback to tow-yoing at faster vessel speeds, is that most of the time is spent retrieving the VMP due to the increased amount of line required to achieve a desired depth. Shallower target depths are recommended for increased vessel speeds. It is worth mentioning again, that increasing the fall speed of the VMP to nearly 1 m/s will reduce the amount of line required to achieve the target deployment depth while tow-yoing.

4 Tether Terminations

Appropriately terminating the tether to the VMP is extremely important to avoid loss of the instrument. On conventional winch recovery systems using a >6 mm diameter tether, the termination can be made using a bowline or other suitable knot. However, a bowline or similar knot must not be used with single braid Spectra or Dyneema® line typical of tow-yo recovery systems because these knots will significantly reduce the breaking strength of those specific line types. It is very common for bowlines and similar knots to slip out or untie when used with single braid Spectra/Dyneema line due to the slippery material property of the line. Splices, preferably locking splices such as the Brummel Lock-splice with one end free (Figure 5), are recommended as alternatives to knots. Splices maintain the breaking strength of the tether and are much less likely to slip un-tied.

4.1 Termination to VMP

The termination method recommended by Rockland is as follows:

1. Brummel locking eye splice, securing the tether to the winch drum. Maintain at least 20 wraps around the drum at all times.
2. Brummel locking eye splice tied in the end of the deployment tether.
3. Brummel locking eye splice tied to a 1500 lb test stainless steel swivel (Figure 6) with a cow hitch or prussic knot.
4. A 2 m length of 6 mm standard VMP deployment tether should be tied to the other side of the swivel using a bowline. Secure the tail of the bowline to the standing line with electrical tape.
5. Secure the end of the 2 m length of 6 mm standard VMP deployment tether to the VMP eye bolt using a bowline. Secure the tail of the bowline to the standing line with electrical tape.

Use a splicing tool (Figure 5) to create new splices as needed. Directions to tie the Brummel Locking Splice with One End Free can be found at this YouTube Link:

`https://www.youtube.com/watch?v=4WW7Qvg3VjI`

Contact Rockland if you require additional resources to tie a Brummel Locking Eye Splice with one end free. It is important to routinely inspect the tether for damage, fraying and particle contamination. Dyneema/Spectra line is very sensitive to heat and may lose strength and break if exposed to excessive heat. If the line has any signs of damage, or there is any reason to suspect damage, it is recommended to cut out the damaged section of line and re-terminate.

See UnderwayCTD and rapidCAST user manuals for additional tether termination directions.

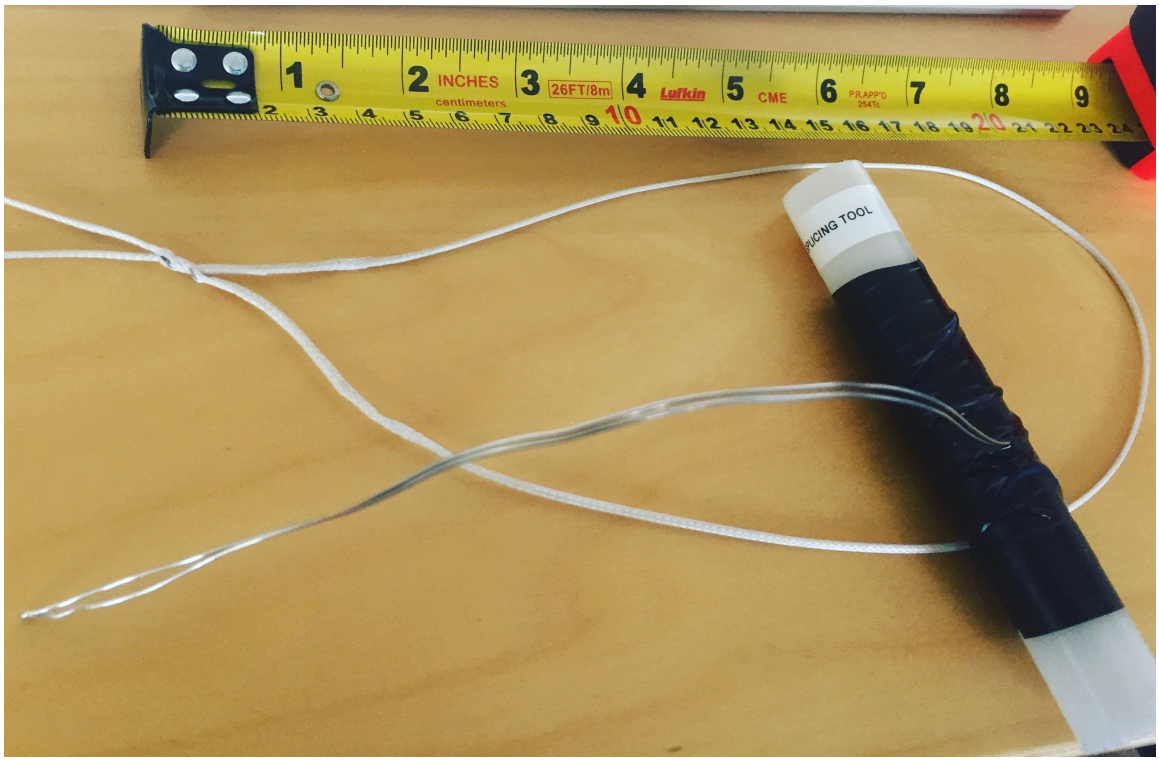

Figure 5: Partially completed splice in 1.5 mm tether and a hand made splicing tool made with a length of wire, a plastic tube and electrical tape.

Figure 6: 1500 lb test swivel

4.2 Termination to Winch

Rockland recommends creating a strong termination to the winch as the VMP is not considered an expendable probe. Always maintain at least 20 full wraps of the tether around the drum to allow sufficient friction for the winch drum to retrieve the tether. Tie off the tether with a Brummel Locking Splice tight to the drum or tied with a cow hitch. If using an UnderwayCTD for VMP measurements Rockland strongly recommends re-terminating the tether to the winch before operations.

5 VMP-250-IR Tow-yo Publications

5.1 Publications

Nagai, T., D. Hasegawa, T. Tanaka, H. Nakamura, E. Tsutsumi, R. Inoue, and T. Yamashiro, 2017: First Evidence of Coherent Bands of Strong Turbulent Layers Associated with High-Wavenumber Internal-Wave Shear in the Upstream Kuroshio. *Scientific Reports*, **7 (1)**, 14 555, doi:10.1038/s41598-017-15167-1.

Nagai, T., and Coauthors, 2019: How the Kuroshio Current Delivers Nutrients to Sunlit Layers on the Continental Shelves With Aid of Near-Inertial Waves and Turbulence. *Geophysical Research Letters*, **46**, 6726–6735, doi:10.1029/2019GL082680.

5.2 Special Thanks

Special thanks to the team at Ocean Process Analysis Lab at the Institute of Oceanography, National Taiwan University, and Dr. Sam Kelly at the University of Minnisota Diluth for sharing first-hand experiences of VMP-250-IR tow-yo deployments.

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