MOOS MOORING FLOAT CLAMP SPECIFICATION
Revision 1.01

Rev. 1.01 – 27 JUN03

1.0 INTRODUCTION

The Monterey Bay Aquarium Research Institute (MBARI) is currently developing a deep ocean underwater science observatory. The maximum installed depth of the observatory is planned to be 4000 meters deep in seawater. The observatory design includes a wave following buoy system connected to a seafloor anchor with a synthetic electro-optical cable strength member referred to as the **Riser Cable**.

The mooring is a reverse catenary mooring that relies upon floatation attached to the riser cable to form an S-shape in the riser which provides the required geometric compliance in the system (See figure 1).

In December 2002, a prototype mooring was deployed and unfortunately broke free after 11 days of service. The riser cable failure has since been attributed to repetitive bending of the cable at the attachment point of the floatation elements. An insufficient bending strain relief was used and we are now working to develop and qualify an improved design that will provide the needed buoyancy to the cable without damage.

This document outlines the expected bending conditions seen at the float location and specifies the requirements that the new design must meet. Because of the high cost of deploying these systems at sea, test protocols that specifically mimic the expected loading conditions of the cable and float clamp are being developed and the float clamp designs will be evaluated in these tests before deployment at sea.

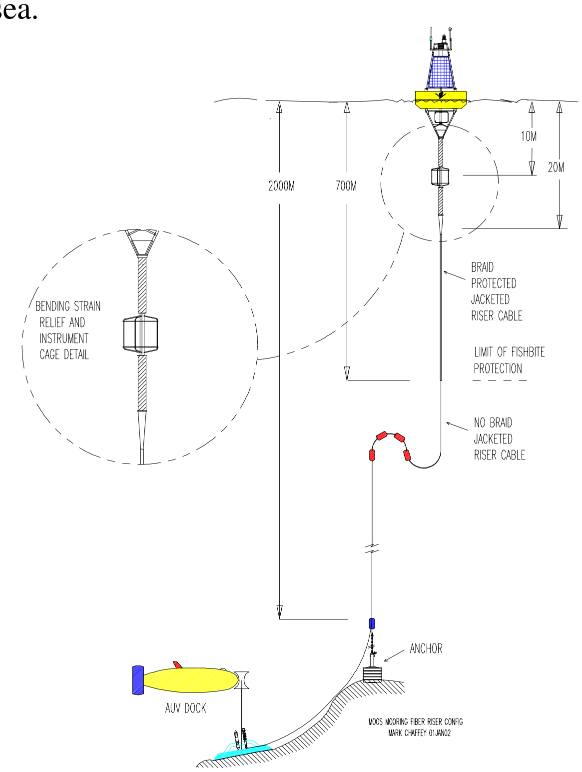

Figure 1: MBARI MOOS mooring design

2.0 FLOAT APPLICATION

The design of the MOOS mooring relies on floatation installed along the riser cable to induce the riser cable to a "reverse catenary" shape shown in figure 1. This shape provides the compliance needed for the mooring to survive the conditions expected at the deployment site, where significant wave heights may exceed 9.5 meters. A dynamic analysis using the Woods Hole Oceanographic Institute's "WHOI-Cable" software has been performed and validated to be accurate to within 10% by comparison to measured tensions in the first deployment. This analysis forms the basis for the following predictions of the load environment the system must operate in.

Cable Bending at Floatation Attachment

Failure analysis of the first deployment break has led to the conclusion that the cable parting was directly due to repeated, low tension bending at the location of the cable float. The WHOI-Cable dynamics model provides a prediction of this bending behavior near each float. Figure 2 shows typical results at a float location, the top graph illustrates the predicted angle (from horizontal) of the riser cable just below the float, at the float, and just above the float. It is clear that a significant bend is induced by the buoyancy of the float and that this bend angle changes in time as the surface waves affect the buoy. The middle graph plots the cable bend angle along with the tension in the cable, the inverse relationship between tension and bend angle is evident. The bottom graph plots this relationship between bend angle and tension for this float location in this particular sea state.

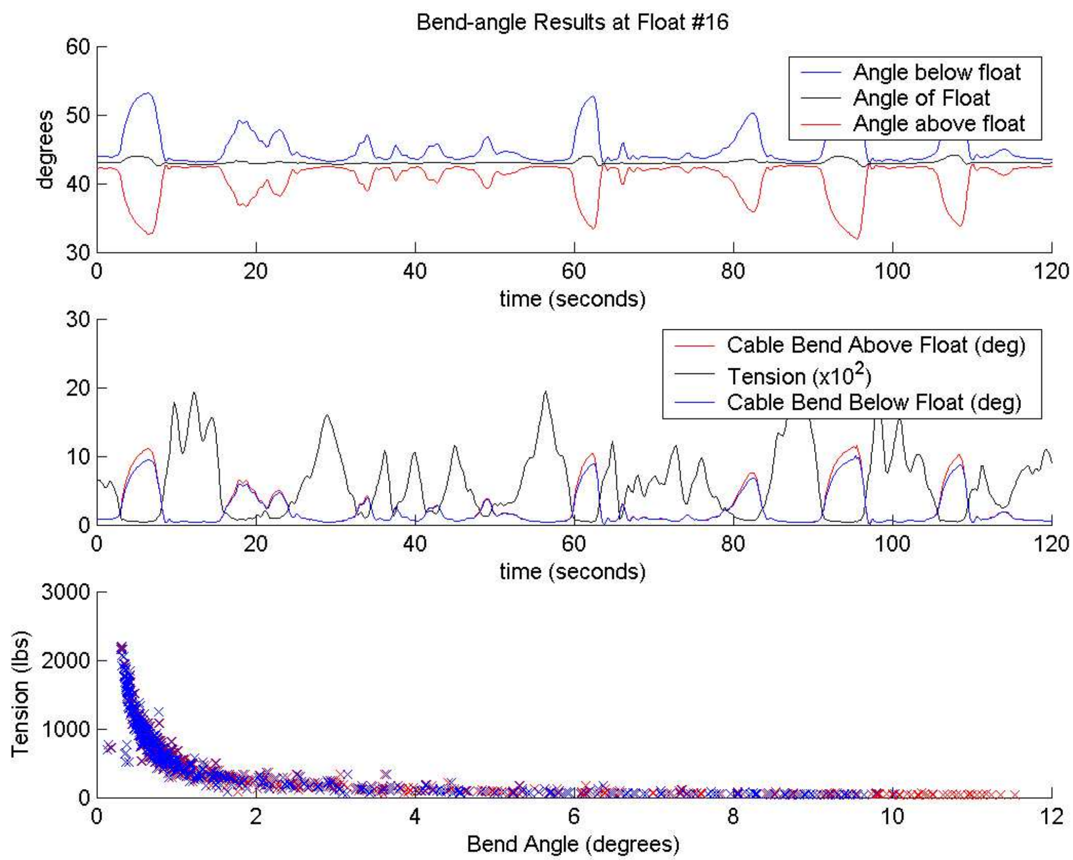

Figure 2: Cable bending at float location, 3 meter significant wave height.

These results vary with sea state and float location, figure 3 shows the superposition of the bend angle versus tension relationship for all the float locations across the entire range of expected sea conditions. The blue data points are the sea conditions that exist 90% of the time, the red data points are the storm conditions which exist 5% of the time, and the green data points are the very calm conditions that exist the remaining 5% of the time. The black dots indicate the bend-angle versus tension relationship found from static tests performed in MBARI's test tank.

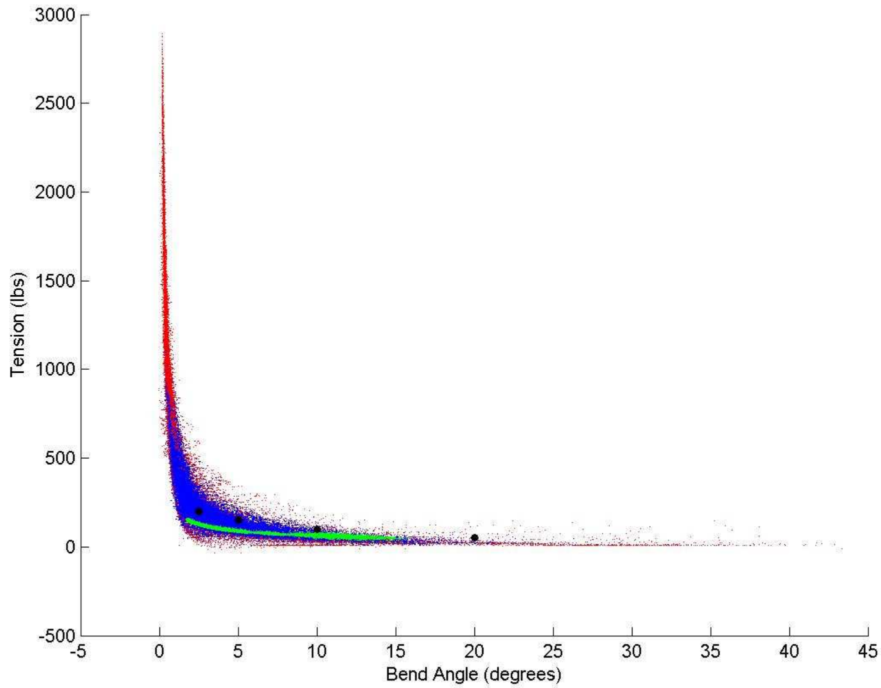

Figure 3: Tension versus bend angle for all sea conditions, note near-zero tensions at significant bend angles.

This analysis forms the basis of the requirements the float clamp strain relief system must meet. In particular, the system must maintain a specified minimum bend radius in the cable (currently 18 inches, but subject to change) across the tension versus angle relationship shown in figure 3. If the tension versus angle relationship shown in figure 3 is deemed to be too demanding, the amount of buoyancy per float can be reduced, which will reduce the amount of bending at the expense of needing more floats. The downside of this is operational inconvenience during deployment.

Finally, the riser cable system must not suffer from fatigue damage, the repetitive bending occurs at roughly the wave-exciting period (avg = 8 seconds). For the three-year design life of the system this cooresponds to 10 million bending cycles.

3.0 FLOAT, CLAMP, AND STRAIN RELIEF REQUIREMENTS

- Each float/strain-relief shall provide 15 lbs buoyancy.
- It must be possible to install the float/strain-relief during the deployment by clamping to the cable, without sliding anything over the ends.
- The strain relief must maintain an 18 inch minimum bend radius in the cable when subject to all tension versus load-angle relationships shown in figure 3.
- The system must not suffer from fatigue damage.
- All elements must remain serviceable at depths of up to 4000 meters in sea-water.