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DATA REPORT

**DESIGN, CONSTRUCTION, AND INITIAL OPERATION
OF THE BNL-COASTAL TRANSPORT AND DIFFUSION,
AIR/SEA INTERACTION RESEARCH BUOY**

D. HUSZAGH, W. RIPPERGER, AND S. FINK

October 1979

**ATMOSPHERIC SCIENCES DIVISION
DEPARTMENT OF ENERGY AND ENVIRONMENT**

**BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.**

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ABSTRACT

Design features of the Brookhaven National Laboratory (BNL) Air/Sea Interaction (A/S-I) buoy are described, and construction, testing, and deployment experiences are related. This two-attitude buoy is similar to the MIT/Navy buoy which it replaces, but it accommodates more instruments and can be towed through shallower water. The BNL A/S-I buoy can be broken down into two, three, or four sections to facilitate overland transport. Compressed air is stored aboard and the controls for deploying, trimming, and recovering the buoy are centralized on the superstructure and are perpetually above water level. The ballast control plumbing is entirely within the hull for maximum protection. The buoy also has a propane storage and distribution system and a 40-watt thermoelectric generator for powering instruments.

Two buoys were built and tested in 1978, and one buoy was deployed in 1979 and is in operation off the south coast of Long Island.

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INTRODUCTION

The BNL-A/S-I buoy was conceived as a replacement for the Massachusetts Institute of Technology (MIT)/Navy buoy previously used by BNL for air/sea interaction studies (Huszagh and Fink, 1976; SethuRaman et al., 1978; SethuRaman, 1978, 1979). Like its predecessor, the A/S-I buoy is primarily intended to provide a transportable stable platform in coastal waters on which atmospheric and oceanographic observations can be made.

It was decided to introduce some conceptually insignificant but physically important changes to the basic MIT design for the intended BNL application. These changes were desirable to accommodate the vastly increased complement of instruments and to suit the special conditions involved in transporting, launching, and deploying the buoy along the South Coast of Long Island. Some operational refinements were added to simplify deployment, recovery, and trim adjustment. The mechanical features of the buoy are described in the following sections.

Design of the buoy commenced in November 1977 and was completed in March 1978. A contract for hull fabrication was let in May 1978, and two finished hulls were delivered in September 1978. One hull was outfitted for sea trials in October 1978, and the preliminary hull trials were undertaken in November 1978. Over the winter of 1978/79, one buoy was outfitted with instrument supports and the fuel system for in situ power generation. The fully outfitted buoy was launched in April 1979 and underwent a period of testing and in situ adjustments. Instruments were installed and the buoy went into full operation in late April 1979. The buoy has been "on line" and collecting data ever since.

BUOY DESIGN

The buoy hull is comprised of four sections which measure 77 feet in overall length when assembled. The sections are joined by bolted and gasketed 24-in. pipe-size flanges. The flange at the lower end of each individual section is "blind" (or closed bore) whereas the upper is open bore. Thus, when the sections are joined, four isolated compartments are formed. Access to the interior of each section is provided by the open-bored flange for inspection and for installation and repair of interior plumbing. The air lines associated with the ballast control system are installed inside the hull sections, and are coupled between sections at the flanged joints when the hull is assembled.

The 24-ft-long bottom section of the buoy is the primary ballast tank (see item 4 of Figure 1). Its lower end is fitted with an 8-ft-diameter damper plate with a removable central access plate to which the seacock assembly is attached on the inside, and a sea strainer on the outside. The upper three-fifths of this section is formed of 24-in. pipe whereas the lower two-fifths is of 30-in. pipe. A conical transition piece connects the two sections. The purpose of the enlarged hull extremity is to provide extra floatation at the lower end to compensate for the weight of the damper plate. This allows the buoy to float with an even keel in the towing position, and to pass over shoals which were impassable to the old MIT buoy.

The second-from-bottom section is called the mooring section (see item 3 of Figure 1). It is formed of 24-in. pipe throughout, and is only 15 ft long. This section has a mooring tongue attachment rail fitted to it. The

8-ft-long rail allows positioning of the mooring tongue anywhere along its length. The calculated and actual center of buoyancy of the deployed buoy falls within the span of this rail with both large and small instrument payload, and at all usual conditions of buoy freeboard. Two 80-gal compressed air storage tanks, and two 60-gal liquefied propane storage tanks are also attached to this section. These tanks are paired on opposite sides of the hull section, and are normal to the mooring tongue attachment rail. In addition to their air and fuel storage functions, these tanks provide added floatation and act as powerful anti-roll stabilizers while towing. Their close proximity to the mooring attachment point tends to reduce their contribution toward "tilting" the buoy in response to underwater currents. The air tanks are fitted with mechanical supports for instrument towers.

The 19-ft-long main float section (see item 2 of Figure 1) is directly above the mooring section. The ends are formed of 24-in. pipe while the 10-ft central section is 42-in. pipe. Conical transition pieces connect the central section with the ends. Mechanical supports for instrument towers are fitted to the enlarged central section. Two 30-gal tanks just below the bulge can be used for extra fuel or compressed air storage, as needed.

The 19-ft-long top section of the buoy (see item 1 of Figure 1) is only 18 in. in diameter in the lower wave zone portion. The upper 6-1/2 ft is abruptly expanded to 30-in. diameter to accommodate the electronic accessories for the atmospheric and oceanic measurements. A 6-ft diameter circular work platform with an open grillwork floor and a surrounding guard rail encompasses the top. Access is gained by ladder rungs running up one side and leading to a trap door in the floor grill. Entry is gained to the enlarged upper chamber by a 24-in. diameter quick-closing watertight door. Four triangular antenna-type instrument support towers are fastened to and terminate at or above the work platform periphery. Two of these extend down to the air tanks on the mooring section, while the other two extend only to the main subsurface float (see items 5 and 11 of Figure 1).

The mooring tongue (see item 14 of Figure 1) can be positioned anywhere on the mooring attachment rail by aligning the holes in the tongue base with appropriate threaded holes in the rail, and bolting the two together. Holes are spaced 3 in. apart along the entire length of the mooring tongue attachment rail.

Important physical and hydraulic statistics of the buoy include:

Length overall	97 ft
Hull length	77 ft
Gross weight, less ballast and instruments	17,129 lb
Total volumetric displacement	404 ft ³
Water ballast capacity	645 gal
Draft with no ballast (horizontal)	4.75 ft
Draft with full ballast (vertical)	69.5 ft
Range of working drafts	63 ft. to 68 ft
Metacentric height at 63 ft draft	3.61 ft*

The buoy's attitude (horizontal or vertical) and draft are regulated by ingesting and expelling ballast water, with power provided by the self-stored compressed air. The two 80-gal air tanks are charged to 190 lb gauge

*Increases to 4.42 ft when stabilizing weights are added.

pressure. An electropneumatic control system (see Figure 2) is used to govern the action. All operating controls are centralized on the buoy work platform. The system-charging connection, pressure regulator, battery power pack, and all electric and pneumatic pilot controls are housed in or on a padlockable watertight cabinet. The manual air distribution valves are below this cabinet.

Seawater enters the ballast tank through a manifold leading to a 2-in., all-plastic, air piston-operated valve. This valve is operated by the pilot controls in the cabinet on the work platform. Seawater can be expelled through this valve, or through a 2-in. galvanized steel "foot" valve which is connected by flexible "suction" hose to the manifold. The purpose of the hose is to allow the foot valve to lie in the lowest portion of the ballast tank when the buoy is raised to the horizontal position. This insures that nearly all the ballast will be expelled. (When raising the buoy to the horizontal position, the piston valve must be closed to prevent bypass exit of air before all the water is expelled.) Opening the piston valve by itself is not enough to cause the ballast tank to flood. The trapped air must be vented from the tank as well, and this is controlled by proper alignment of the air distribution valves on the work platform. All air going into or out of the ballast tank via the air distribution system must pass through a 15-gal "metering" tank (see item 20 of Figure 1). This is used as a "batch" or "weigh" station in trimming the deployed (upright) buoy. It permits injection or release of discrete amounts of air into or out of the ballast tank which, in turn, causes the ejection or admission of discrete amounts of ballast water. Precise trimming, without overshooting and waste of air reserves, is easily accomplished using this tank.

The electric portion of the pilot system, which includes a battery pack, solenoid valve, watertight push-button switch, and watertight remote control jack, serves one operating and three control functions. The operating function is to supply air, via the solenoid valve, to a position selector valve which governs the opening and closing of the seacock "piston" valve. Tamper-proofing is the first control function provided. Removing a dry cell from its clip in the battery pack effectively "locks" the seacock in its last operated position. A second function is remote control via the remote control jack. The seacock valve can be opened and the buoy deployed in response to a radio or acoustically actuated remote switch closure of about 3 seconds' duration, which is the time required for full operation of the seacock-actuating piston. The push-button switch permits manual operation of the seacock from the work platform. A bicycle-type tire valve on the surface of the watertight control cabinet provides a backup means of operating the seacock valve in case of total electric failure. Injecting air from any source into the bicycle valve will operate the seacock valve.

Protection against the severest effects of unauthorized boarding and tampering with the controls is provided in several ways. Ballast tank flooding and loss of freeboard are guarded against by closing the seacock valve, removing a battery from the power pack, and locking the control cabinet. Raising the buoy and exhausting the air reserves are guarded against by closing the main supply valve in the cabinet before locking it. As an added measure, a tight plug is inserted in the main vent valve.

Provisions have been made for the in situ attachment of stabilizing weights to the towing bridle under the deployed buoy. This might be necessary in case a very heavy instrument load, with exceptionally large wind or current

resistance, causes unacceptable tilting. It is necessary to add solid ballast in situ rather than having it permanently attached because of our need for shallow draft in the towing position. The weights are stowed in a large sieve-like bucket with a capacity for 1100 lb of steel scrap with 20% voids. This is lowered on a hoist line and guided by a leader attached to a messenger cable on the back side (opposite from mooring tongue) of the buoy. When fully lowered, the bucket is supported by the leader which rests against the damper plate. The bucket will hang about 4 ft below the damper plate in a position where a diver can swing the towing bridle over to it and couple the bucket bail to the bridle ring. Then, slacking the messenger cable to which the leader is attached will take the strain off the leader and allow it to be released. A "tip over" eye is provided on the weight bucket to allow it to be emptied quickly (windless or hoist rope needed), in case the buoy must be raised in a hurry. The lightweight bucket can be recovered easily when the buoy is on the surface.

Because of the heavy power drain of the projected instrumentation and communications equipment, power generation equipment and a propane storage system are necessary. Figure 3 describes the system schematically. Figure 4 shows the generator installation. Both supply and 'purge-piping are run along the exterior surface of the buoy hull inside protective steel raceways welded to the hull. Hull joints are spanned with armored hoses. The propane-fueled generator can deliver 40 watts of power at 12 V dc continuously. Fuel storage capacity is sufficient to allow up to 8 weeks of uninterrupted operation. The system can be refueled in situ using a slightly modified (type-420) liquid propane transfer tank, which is carried on the buoy tender. The transfer tank is connected to the fill fitting on the buoy with a grounded high pressure hose, and the liquefied propane is forced over with pressurized nitrogen. The type-420 transfer tank is fitted with the customary liquid withdrawal-type multivalve and a "magnetometer"-type liquid level gauge. A separate injection nozzle with antireverse flow check valve was added for admitting the nitrogen.

Figure 5 shows the mooring that is used in shallow water with the A/S-I bouy. This mooring is suitable for water depths ranging from 15 to 25 fathoms. The mooring string is coupled to the buoy prior to launching and towing. The chain at the buoy end of the mooring is lashed with breakaway lines, festoon fashion, to the buoy hull leading back to the damper plate. The nylon hawser from the chain end passes under the towline to the towing vessel. The anchor and the remainder of the mooring are carried fully assembled aboard the towing vessel. At the deployment site, the towline is disconnected and the mooring anchor is lowered by a messenger line while the buoy is allowed to drift back and away from the towing vessel. Control of the buoy is maintained during this operation by snubbing the lengthy nylon hawser portion of the mooring. The breakaway lashings on the upper chain are parted before the buoy is righted. Submersible floats are attached to the nylon hawser close to the junction with the anchor chain to prevent fouling the nylon hawser in the chain. A clump weight at the chain end serves to counteract the pull of the floats and keeps the chain on the bottom when the mooring is slack.

CONSTRUCTION

A contract for the fabrication of two complete buoy hulls was let to Eastern Tank Fabricators Inc. 73 Plandome Rd. Manhasset, N.Y., on May 4,

1978. The contract called for fabrication, pressure testing, mechanical outfitting, protective coating, cosmetic finishing, and delivery to BNL of the completed subassemblies. During the course of fabrication BNL agreed to purchase the assembly and shipping cradles which Eastern Tank Fabricators devised and built to aid in the assembly and testing of the hulls at their plant.

BNL provided detailed construction drawings and specifications, which were adhered to with exceptional precision. The fasteners, the joint flanges, the watertight instrument well door, the air and propane tanks, and the instrument support towers were the only purchased parts. All other portions of the hulls and accessories were formed and fabricated from steel plate and sheet stock at the contractor's own shop. Fabrication work was completed in early September 1978, and mechanical acceptance tests were started on September 12, 1978. Measurements of actual dimensions, weights, and centers of gravity were taken on each hull section, side tanks, and instrument towers. Each buoy was then assembled and pressurized to 20 psig with shop air on 9/13/78. Twenty-four hours later, on 9/14/78, after no detectable loss of internal pressure, the two buoys were accepted for leak tightness and mechanical completion.

Following these mechanical measurements and tests, the buoys were disassembled and shipped to a subcontractor for application of the protective and cosmetic finishes. The protective finish is "Interlux" coal-tar epoxy, and was applied to the three lower buoy hull sections and to the lower third of the upper section.* Conventional metal primer was applied to the top of the upper section. The final finish on the three lower sections is an "Interlux" coal-tar compatible antifouling paint in the customary dark red color. Alternating foot-bands of red and white "Interlux" coal-tar-compatible hull and superstructure enamel were applied to the upper hull section. The work platform and superstructure fittings were finished in white. The mechanically complete and freshly painted buoys were delivered to BNL on September 27, 1978. Outfitting for sea trials commenced immediately. All outfitting, system testing, and touch-up painting were completed in October and arrangements were made to conduct the sea trials with one buoy in Long Island Sound from the Northville Oil Company's terminal facility at Port Jefferson Harbor. Heavy fuel barge traffic at the terminal caused severe scheduling difficulties and repeated postponements of the trials. Towing trials were finally conducted in mid-November 1978, but full deployment and mooring trials had to be abandoned for the season because of prevailing foul weather and the sudden unavailability of the primary support vessel. The buoy was returned to BNL in December 1978.

During the winter months of 1978/79, outfitting for instrumentation of one buoy was completed. Electronic chassis supports, sensor mountings, and the propane fuel system plumbing were installed during this period.

LAUNCH AND DEPLOYMENT

With all preparations completed, one buoy was transported in two sections to the U.S. Coast Guard (U.S.C.G.) station at Shinnecock, N.Y., for launching on April 3, 1979. The buoy was assembled, leak tested, and lowered into the

*Metal surfaces must be sandblasted and bright before application of coal-tar epoxy.

water at dockside that same day. At 6:30 a.m. on April 4, 1979 (the time of high slack tide at the inlet), the buoy was towed through the Shinnecock inlet by the BNL LCM and proceeded toward the deployment site 7 miles due south of the inlet sea buoy. The BNL R.V. COBOLT (a 32-ft Maine fisherman-style skiff) acted as an escort and diver support vessel. The deployment site was reached at 10:05 a.m. and the buoy's mooring was deployed by the LCM with the buoy still in tow. After testing the mooring anchor, the buoy was cast adrift and was boarded by divers who severed the "breakaway" lashings on the upper chain portion of the mooring. The buoy was then righted and boarded for the purpose of increasing the freeboard from the natural 7-ft level to the more desirable 12-ft level. All operations were completed by 11:35 a.m. and both vessels returned to port.

Seven days later the buoy was again visited for the purpose of installing the instruments. The buoy had "lost" 3 ft of freeboard during the seven days since deployment. A diver was dispatched to check for evidence of hull leakage, and reported a very slow stream of air bubbles issuing between two bolts on the mooring tongue side of the middle flanged joint. It was decided to defer instrumenting the buoy until the leak could be repaired. A few days later a team of two working divers and one standby diver repaired the leak by torqueing up the flange bolts (two of which had apparently worked loose during towing and deployment). In addition, the divers drilled and tapped two small holes adjacent to the lower flange on the partially flooded "mooring" section of the buoy. An external air line was installed in one of these, and an "exit" only" check valve was installed in the other. Compressed air was then injected into this section via the newly installed air line until a cloud of air bubbles exited through the newly installed check valve. The leaking hull section was thereby "pumped down" to the level of the check valve, just a few inches above the bottom of the section. No further leaking in the buoy hull has been experienced since that original slow leak was repaired.

By late April 1979 all instruments had been installed and were operational, running initially on battery power. The thermoelectric generator was installed next, during the first week in May 1979. The initial attempt at charging the propane storage tanks in situ was undertaken immediately thereafter. Problems were encountered. An erratic primary pressure regulator on the buoy had to be replaced. Also, severe icing of the filling line, plus an awkward mechanical procedure for effecting liquid propane transfer, resulted in excessive time being spent in fueling. A special propane transfer tank with transfer forcing provisions will be acquired, which will streamline the fueling operation and substantially reduce the time element. In the interim, all instrumentation has been kept operational with storage batteries which are exchanged and recharged on a weekly schedule.

During the brief 48 hr period when the buoy instrumentation was actually powered by the propane-fired thermoelectric generator, power output and system performance were exactly as planned. As a result, there is confidence that the eight weeks of unattended operation will be achieved after the improved fueling equipment is put into service.

MECHANICAL PERFORMANCE

The buoy was towed at approximately two knots through the two-mile serpentine channel from the U.S.C.G. station to the Shinnecock inlet. At this

speed the buoy followed smoothly behind the towing vessel. It exhibited almost no tendency to slew, roll, or plunge when traveling straight or when 90-degree course changes were effected. In the open ocean the speed was increased to nearly four knots. At this speed slewing and rolling remained negligible, although some minor plunging occurred during passage through large swells between the sand bars which skirt the inlet. But the extent of plunging was considerably less than had been experienced with the MIT/Navy buoy under similar circumstances.

After ballast tank flooding was started, the buoy took 16 minutes to right itself and settle to its natural waterline in the upright position. This was about 3 minutes faster than had been calculated, and probably was due to overly conservative estimates of pressure drop and resultant back pressure in the vent system.

The attitude, trim, and riding characteristics of the deployed buoy appear to be satisfactory for the intended use.

ACKNOWLEDGMENTS

Dr. S. SethuRaman is the chief experimenter. He established the design criteria and gave valuable assistance in resolving engineering decisions.

D. Huszagh provided the mechanical and systems engineering and the preliminary design. He also prepared the contract specifications, test procedures, and operating instructions.

W. Ripperger provided the detailed design and the contract fabrication drawings. He also designed the instrument supports and all auxiliary apparatus.

S. Fink conducted the acceptance tests, supervised assembly and outfitting, was in charge of component acquisition, and provided liaison between shop and field trades.

R. Brown planned, made the preparations for, and directed the launching, towing, and deployment operations.

E. Divis planned, made preparations for, and directed the first sea trials.

Dr. T. Hopkins gave valuable assistance in establishing basic criteria. He also assisted in mooring design evaluation and the planning of the early sea trials.

W. Jahnig captained the primary support vessel, the BNL LCM, with exceptional skill during all operations.

A. Tuthill acted as chief consultant for buoy instrumentation and related accessories.

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Figure 1. Air-Sea Interaction Buoy

Figure 2. Pneumatic Control System Schematic

Figure 3. Propane Supply System

Figure 4. Thermoelectric Generator Installation

Figure 5. Moored Air/Sea Interaction Research Buoy

Figure 6. Installing the Sea Cock Assembly (Piston Valve, Hose, Foot Valve)

Figure 7. Assembled Buoy Being Launched for Sea Trials (Nov. 1978)

Figure 8. Buoy Enroute to Sea Trials (Nov. 1978)

Figure 9. Deploying the Mooring Anchor

Figure 10. Deployment Sequence as Ballast Tank Floods

Figure 11. Buoy on Station (April 1979)