OPERATOR'S MANUAL FOR SHEBA POWERED TETHER BALLOON SYSTEM

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Abstract

The Surface Heat and Energy Budget of the Arctic (SHEBA) was an intensive field project which took place in the Arctic Ocean from October 1997 through October 1998. Its purpose was to measure as many facets of the Arctic environment as possible so that we would be able to better understand the interaction between the ice, atmosphere, and ocean and their interactions with global climate. One aspect of the atmospheric field component was launching tethered balloons to monitor the profiles of temperature, wind, pressure, and humidity, as well as examine the vertical structure of cloud droplet sizes and distributions. The tethered balloon that we used was one specially designed for use in freezing climates by SPEC Corporation in Boulder, Colorado. A special winch that was able to withstand Arctic temperature and weather became necessary when the testing of simple winch systems used in warmer climates failed under these extreme conditions.

The purpose of this manual is to acquaint any new user to the powered tethered balloon system deployed at the The Surface Heat and Energy Budget of the Arctic (SHEBA ice camp. It includes a description of the preparations necessary to get ready for a launch, the mechanics of the actual launch, and an account of the proper procedure for taking down the equipment when finished. It will also include tips on how to minimize potential equipment failures, some trouble shooting, and some safety ideas. This manual is designed so that new operators can use the system with minimal previous training. At the end of this manual, the reader will find a quick checklist.

I. Introduction

The Surface Heat and Energy Budget of the Arctic (SHEBA) was an intensive field project which took place in the Arctic Ocean from October 1997 through October 1998. Its purpose was to measure as many facets of the Arctic environment as possible so that we would be able to better understand the interaction between the ice, atmosphere, and ocean and their interactions with global climate. One aspect of the atmospheric field component was launching tethered balloons to monitor the profiles of temperature, wind, pressure, and humidity, as well as examine the vertical structure of cloud droplet sizes and distributions. The tethered balloon that we used was one specially designed for use in freezing climates by SPEC Corporation in Boulder, Colorado. A special winch that was able to withstand Arctic temperature and weather became necessary when the testing of simple winch systems used in warmer climates failed under these extreme conditions.

The purpose of this manual is to acquaint any new user to the powered tethered balloon system deployed at the SHEBA ice camp. It includes a description of the preparations necessary to get ready for a launch, the mechanics of the actual launch, and an account of the proper procedure for taking down the equipment when finished. It will also include tips on how to minimize potential equipment failures, some trouble shooting, and some safety ideas. This manual is designed so that new operators can use the system with minimal previous training. At the end of this manual, the reader will find a quick checklist.

The system simply consists of a winch, a special tether-line, a balloon, and a power supply rack. The following sections will give a brief description of each of these three components and the subsequent material will describe how to get the system connected and functioning as a unit.

II. The Winch and Tether

II-A. General description

The winch is designed to handle 1.0 km of electrically and thermally hot tether. It has a large drum onto which the tether is spooled in a single wrap (F: Fig 1). The design of such a large drum is such that heat generated by voltage running through the tether can be easily dissipated. The winch is powered with a 440 VAC-3 phase drive motor (D: Fig 1). This power supply plugs directly from the wall on the port side of the ship to a power rack (discussed in Section IV) in the hangar. The power rack then has a 440VAC cord which goes from it to the variable frequency driver (VFD) controlling the winch motor (E: Fig 1). The power rack contains the main power switch for the rack and the winch and a breaker switch just for the winch itself (See Figures 3 and 4.). It also contains a plug-in for an EMI high voltage power supply (which runs to the tether to supply the instruments with power when the power supply is being used), a cooling unit for this power supply, and a multiplexer box (to facilitate communication between various components of the system). NOTE: Currently (04-01-98), we have no high voltage power supply so we are not using this aspect of the system.

A variable frequency driver (VFD) is used to control the speed and direction of the winch motor (Section II-H). Limit switches control the amount of tether that can be let out or let in (Section II-F). A thermostatically controlled heater warms the VFD to make sure it is operating within

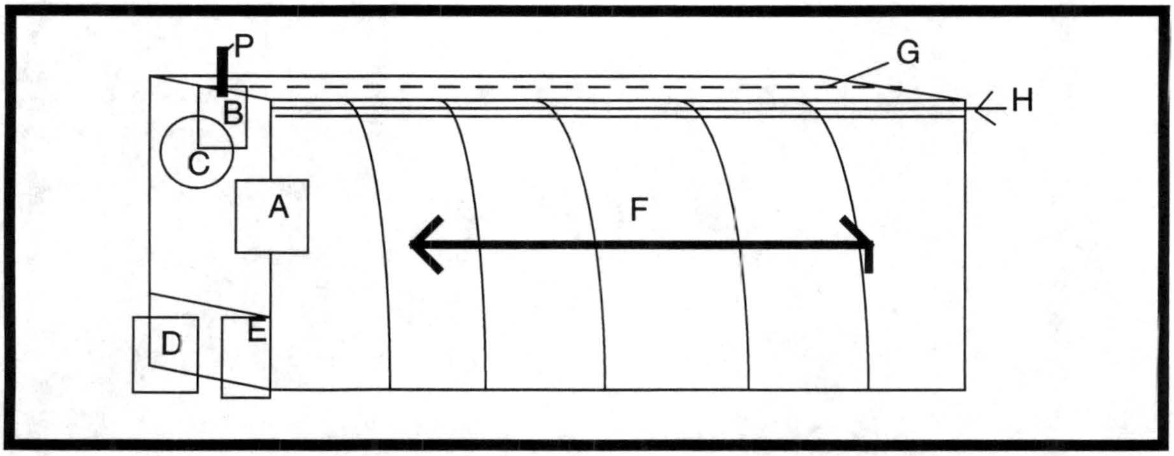

Figure 1: **Crude drawing of the winch system, meant only to show the relative locations of parts. A- control panel (blown up in Figure 2); B -magic tether box with clutch; C- wheel to tighten threaded rod; D- VFD motor; E- winch control box; F- tether on the drum; G-(dashed line) threaded rod; H- yellow measuring tape; P- tether connection.**

its proper temperature range. In addition, the winch motor has an emergency brake which can be set to stop the tether in case of emergency (Section II-K).

A drive wheel through a one-directional clutch pulls the tether from the drum when the tether is being let out and free-wheels when it is being reeled in (Section II-E). This clutch is located in box B in Figure 1. Box (B) is the magic tether box which influences the action of the tether in two ways: (i) how quickly the balloon receives the tether, and (ii) how quickly the drum releases the tether. These two must correlate exactly in order for the tether to remain tight and function properly. Thus, what happens in this box determines the ultimate fate of the tether (see Section II-C).

There is a control panel (A: Fig 1) for the winch motor and a power supply rack (See Section IV.). It controls the direction and speed of the tether as well as the power of the winch motor and the VFD. Figure 2 shows a blow-up of this box and Section II-B discusses the box in greater detail.

These are the main components of the winch system. I will describe each in more detail in the sections below. In these descriptions, I will provide guidelines for fixing and tuning the winch as well as guidelines on how to recognize when an adjustment is in fact necessary. I will recommend what to look for, how much to adjust the components, and how to do the adjustment. These guidelines are the basic skills and precautions any operator needs to operate the system without suffering injury or damaging the equipment.

II-B. Winch control Panel (A: Fig 1)

This panel controls the motion of the winch, the VFD, and a fan motor. It also contains a protection override switch and an input power indicator light (see Figure 2). Thus, this panel

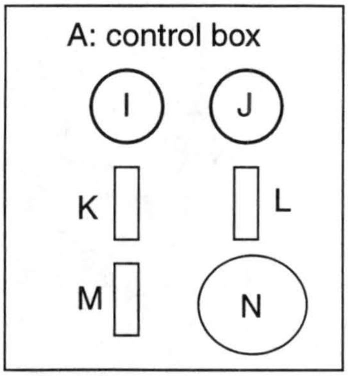

Figure 2: **The control panel for the winch operation: I- input power indicator; J- protection override button; K- fan switch; L- VFD switch; M- winch bi-directional switch; N- winch speed control adjuster.**

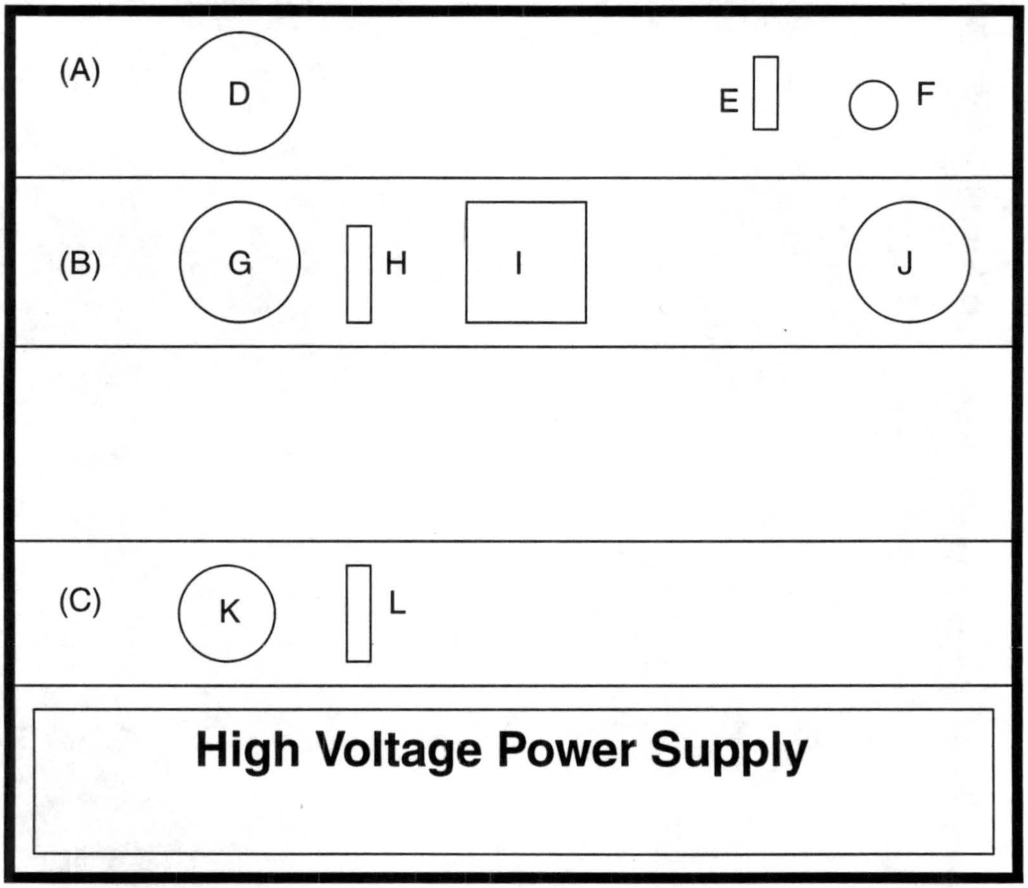

Figure 3: **Front of the power rack- Row (A): High Voltage, Data, and Multiplexer Panel: D-Power (green); E-small pin switch; F-small knob (not used). Row (B): Power Distribution board: G-Input power indicator (red); H- Power switch for the rack; I-Winch circuit breaker; J-Output power indicator (red). Row (C): Cooling system indicators: K- Flow meter indicator (green); L-Fan control switch.**

protection override switch and an input power indicator light (see Figure 2). Thus, this panel shows the current status of the equipment as well as determines what happens next. When following the checklist for a balloon launch (Section V), the first thing one is asked to do is to turn on the winch power. A 440VAC power cord already wired into the ship's power is available in the hangar. As mentioned in Section II-A, this gets plugged into the power rack (R: Fig 4) and a separate cord runs from the power rack (T: Fig 4) to the VFD grey box (E: Fig 1). When this cord is plugged into the VFD box, the red light on the control panel should illuminate (I: Fig 2).

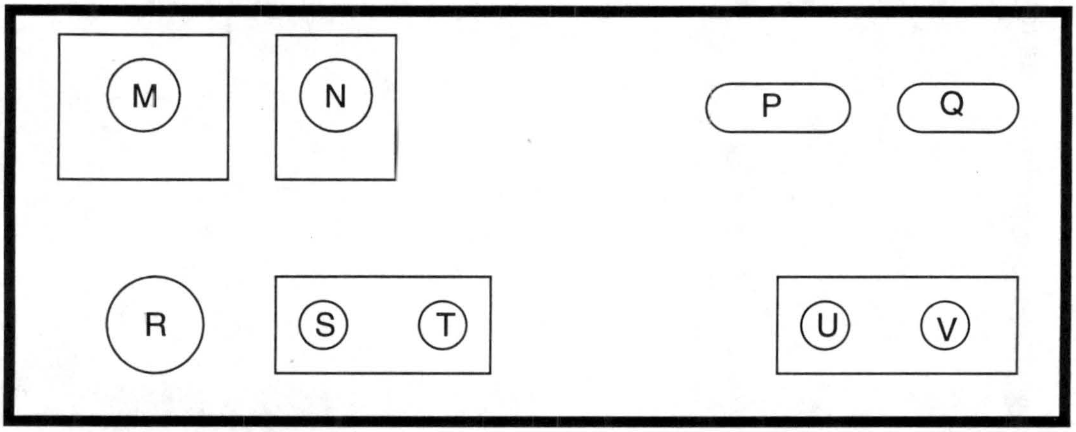

Figure 4: Electrical outlet board inside the power rack- M- High voltage and data; N- High Voltage to instruments; P- Link status (not used); Q- Probe data (to PC); R- Input 440 VAC; S- EMI Power supply plug-in (440 VAC); T- Winch plug in (440 VAC); U- Cooler (110 VAC); V- Mux (110 VAC for multiplexer).

If this does not occur, check that the plug has been twisted when inserted into the side of the grey VFD control box (E: Fig 1). This plug must be inserted and twisted clockwise for the power to be connected. If this does not fix the problem, check to make sure that the power switch (H: Fig 3) on the power rack in the hangar is turned on and that the winch breaker on this rack (I: Fig 3) is pushed all the way to the right. If the red light still does not respond to any of these remedies, check to see if the breaker switch on the port side of the ship has been tripped or turned off. If none of these work, there is likely a serious problem with either the winch motor or the VFD. Note: If the operator is using the high voltage power supply for the launch, also check that the green cooling pump indicator light (K: Fig 3) is illuminated. If this is not illuminated, follow the procedure outlined in IV-D to jump that switch.

Moving to the right on the control panel, one can see the protection override button. This button is ONLY to be used in the following circumstance: For some reason, the non-adjustable limit switches have been triggered. (This should theoretically NEVER occur) (see Section II-F.) When they are triggered, you must reverse the tether direction switch (M: Fig 2), set the speed control to zero (N: Fig 2), hold down this button, and cycle the VFD switch (L: Fig 2) to on. This will restart the system. Other than that, this button should NEVER be used. Any other problem with the winch not responding to the 'out' or 'in' command can be alleviated as described in the winch control device paragraph below.

The switch in the middle of the left-hand column of the controls (K: Fig 2) sets the use desired of a cooling fan motor - On the end of the drum opposite the control panel, there is a large fan blade- this button controls the use of this fan. The purpose of this fan is to prevent the electrically heated tether drum from becoming too hot. With temperatures in the Arctic, there is virtually no chance of this occurring. Thus, it is unnecessary to use this switch- leave it off!

Moving right, one sees the VFD control switch (L: Fig 2). It has two positions: 'on' or 'off'. You will see in the checklist that the VFD gets switched on after the winch has power but before you start to wind or unwind the tether. NOTE: This switch should always be in the off position when the drum is not moving- including the time when the winch is unpowered. This will prevent the drum from accidentally winding or unwinding without warning and causing damage to the system. Check that this as well as the tether switch is OFF before plugging in the 440 VAC to power the winch.

On the bottom row of the control panel, one finds the tether control devices. The switch on the left (M: Fig 2) controls the direction the that the drum will spin and the knob on the right (N: Fig 2) controls the speed of the drum. The switch has three settings: 'in', 'out', and 'stop'. This should ALWAYS be in the 'stop' position when the drum is not rotating! WARNING: Turning the speed knob to zero (which incidentally is counter-clockwise) and not turning this switch to 'stop' will stop the drum from spinning BUT is an extremely bad habit. The speed knob does not lock in the off position and a very slight bump of the winch can knock this knob from the zero speed position and start the drum reeling again without warning. If the drum is unattended because the operator took a break thinking that the rotating drum was shut off, it is obvious that the situation could prove disastrous. Thus, if the operator wishes to temporarily suspend the winding or unwinding of the drum, he/she MUST set the speed to zero, switch the tether control to the 'stop' position, AND switch the VFD to the 'off' position. This is a threefold way to insure that the drum will not start unintentionally!

As indicated above, the direction that the tether is spooling is determined by a small switch located on the control panel (M: Fig 2) with positions 'in', 'out', or 'stop'. In or out indicates which direction the balloon is going. If the winch will not wind or unwind in the direction chosen, turn the switch to 'stop' and try to spin the drum in the opposite direction (i.e., if you are trying to get it to go out, switch it to 'in' for a moment). If this is successful, turn it back to the 'stop' position and try the desired direction again. If this remedy does not work, unplug or completely turn off the power supply for the winch, wait a few minutes, and then turn it back on- the system should naturally reboot itself. If this doesn't work, the balloon may have to be reeled in by hand (have fun)- there is likely a serious problem.

II-C. The Magic Tether Box and the Tether Path

The magic tether box influences the action of the tether in two ways and thus what happens in this box determines the ultimate fate of the tether. The tether enters the box through the top and then exits out the side of the box toward the drum. When it emerges from the top, it attaches to a one inch thick metal ring. This metal ring contains an affixed screw. We secure the tether to this ring as follows: We wind it around the ring three or four times and then (via a loop already in the tether) attach it to the screw. This screw marks the very end of the tether and the ring itself marks the point where one attaches the balloon to the system (see Section II-J for a more detailed description).

Following this tether end down from the ring and into the box, one will see that the tether gets guided along a pulley oriented vertically. This pulley is attached to a clutch (see Section II-E) which controls the amount of tether that the drum is fed. After passing through this pulley, the tether gets guided by another pulley wheel which is oriented horizontally lower in the box. After passing through this lower pulley wheel, the tether exits the magic box into the drum area. Next, it gets taughtly strung along the top of the drum to the far side where it is guided by another pulley wheel onto the drum. This far wheel is attached directly on to the threaded rod (G: Fig 1). (see Section II-D). The threaded rod and pulley wheel act together as a unit which is responsible for physically winding and unwinding the tether from the drum (see Section II-D).- One can align the tether on the drum if it is not functioning properly with wheel (C) in Figure 1 (see Section II-D).

Each time that the operator prepares for a launch, this box should be opened and its components inspected. To open the box, flip down the gold-colored pin on the front of the box to unlatch the top of the box. Inside the box, you should be able to follow the tether from its end on the ring above the box through the pulleys to its side exit to the drum. This should all be visible. To inspect these components, do the following: Make sure the tether is in the groves of the pulleys, and that all the components are free of snow, ice, and debris. Often times after a launch (especially one into a cloud) the tether line becomes rimed with snow and ice. When reeling in the tether, the line going through this box and thus the pulleys that the line is riding on, become clogged with snow and ice. This snow and ice will not melt in these cold temperatures and will likely still be there the next time the winch is operated. If the components in the magic tether box are not cleared of any obstructions before launching, the tether could get off track or bind up and components will be damaged.

After the operator is sure that the pulleys can run freely and that the tether is properly in the pulley groves, the gold pin to secure the lid MUST be re-attached! If this is not reattached, the tether line which comes out the top of the lid (P: Fig1) will be stressed and will likely kink and/or snap on the sharp edge of the box lid. If this happens, run to the nearest lead and jump in. Do not radio the bridge. Thus, unless you have a death wish, DO NOT start the winding or unwinding process if this lid is not secured!!!

II-D. Threaded Rod (G: Fig 1) - Wheel for correcting a misaligned tether (C: Fig 1)

At the bottom of the magic tether box (B: Fig 1), the tether emerges from the pulley system within the box, stretches to the far end of the drum where it gets wound around a pulley wheel which is attached to a threaded rod (G: Fig 1) which also runs along the top of the winch. Two smooth rods above and below the threaded rod guide this pulley wheel with the tether around it up and down the length of the drum. Essentially the motor turns a thick drive (Section II-I) belt which turns a smaller drive belt which spins the threaded rod, along with its attached clutch inside the magic box and its associated adjustment wheel outside the magic box. The whole system of the adjustment wheel, the clutch, and the threaded rod spin in a way to either unwind or wind the tether at the appropriate speed onto or off of the drum.

Care should be taken so that there is absolutely no overlap or gaps in this single wrap. Overlaps and spaces will typically occur when the balloon is being reeled in. Thus, one should be very cautious and pay close attention during this phase of operation. If an overlap or a large gap occurs during the reeling in of the tether, the threaded rod on top of the winch (G: Fig 1) must be hand adjusted at once (before even one more wrap of tether occurs around the drum) to place the displaced tether in the correct position.

This is done as follows in order: Shut down the drum immediately by turning the speed adjuster to zero (N: Fig 2), push the winch direction switch to 'stop' (M: Fig 2), and turn the VFD switch (L: Fig 2) to 'off'. The system is now shut down.

Then, there is a jointed handle with a plastic wheel on the end of it which is the last thing the tether rides through before hitting the drum. Lift up this handle by straightening the joint in it so that the plastic wheel is no longer resting on the drum. Proceed to the side of the winch where wheel (C) is located. There is a handle (a thin rod perpendicular to the plane of the wheel) and a small metal L-shaped bracket protruding from this wheel. On the bracket, there are 2 tiny screws. Take off the screw furthest from the protruding part of the bracket- don't touch the other screw. Wheel (C) will now spin by hand- clockwise moves the rod toward the right and will carry the tether end that you are trying to adjust along with it. Thus, if the tether is wound too tightly, the wheel should be spun in the clockwise direction.

If the tether is wound such that gaps are forming on the drum, the wheel should be turned counter-clockwise to move the tether end the other way. After the pulley wheel with the tether has moved along the threaded rod to the point where the tether is wound tightly on the drum again, the screw should be returned to the bracket. Finally, release the hinge on the jointed bracket so that the plastic wheel is once again resting on the drum and guiding the tether onto the drum. Start up the system again as done in the original launch.

NOTE: If this problem occurs again, the clutch located in (B: Fig 1) may need to be adjusted (see next section).

One final note about the threaded rod is that it contains the pointer which indicates on the yellow measuring tape how much tether has spooled off the drum. This indicator should be pointing to zero at the beginning of the launch. If it is not, it needs to be adjusted (see Section II-G).

II-E. Drive Clutch

A drive wheel through a one-directional clutch pulls tether from the drum when the balloon is being let out and free wheels when the balloon is being pulled in. This drive wheel is located in the magic tether box (B: Fig 1) on top of the drum. The clutch can be adjusted by loosening the set screws on the side of the clutch and physically turning the clutch disk a quarter of a turn or so clockwise and re-tightening the set screws. This will need to be adjusted if the small belt begins to skip. This may also need adjustment if the tether continuously misaligns on the drum while being wheeled in.

II-F. Limit Switches

There are two sets of limit switches which will stop the drive motor when reached. One set is permanently affixed at the ends of the threaded rod. This set serves as a final shut down for the system. The designers positioned them so that they will never allow the drum to spin beyond either end of the tether. One should never tamper with these switches under any circumstance- they are a last resort shut down in the case that the other limit switches fail and the operator has taken a nap during the launch.

The second set of limit switches attach to the rod that the yellow tape measure is mounted on. These switches are adjustable and should always be set but never depended upon. (The ONLY limit switch that should be DEPENDED upon is an alert operator. All else are mechanical back-ups which can fail!) These adjustable switches are meant to stop the drum after amount of desired tether has been let out or in. To adjust these switches, simply unscrew the screw holding them down, slide them to the desired position and re-tighten the screws. It is a good idea always to set these switches even if the operator intends to let out the entire tether and does not wish to stop en-route.

The first thing the operator needs to do is to make sure that the left hand limit switch (when facing the side of the drum with the exposed tether) is set so that the drum will stop just before the tape measure reads zero. In other words, align the left-hand switch so that it is positioned just to the left of the zero on the yellow tape measure. (Of course this means making sure that the yellow tape measure reads zero before the launch starts so that 0.0 meters on the tape measure corresponds to 0.0 meters of tether let out (see Section II-G for more on this procedure). The second thing the operator needs to do is to set the right hand limit switch. This switch should be set for a point just to the *right* of the 1.0 km mark on the tape measure if the whole tether is to be let out. This will ensure that before the drum runs out of tether (which is 1.0 km long), it will stop. If the operator only desires 500 meters to be let out, then this switch should be set just to the *left* of the 500 meter mark so that if he/she forgets to shut down the motor at 500 meters, the motor will shut itself off shortly thereafter.

Please note however, that the drum is often spinning at fairly high speeds and the jerk of a sudden stop will undoubtedly damage the system. The safest and least damaging way to bring an ascent or descent to a halt is to use the control knob (N: Fig 2) to slowly decrease the speed to zero, then turn off the winch motor (M: Fig 2), and finally turn off the VFD (L: Fig 2). Thus, stay awake and aware of the balloon location at all times. Do not leave the system unattended for any reason- If you must leave during a launch, shut off the motors as I indicated in the checklist as if you are taking down the system. Upon return, the system should be restarted as if from the beginning of a launch.

Finally, these switches cannot be set once and then just left alone. They must be reset each time the winch is used. The reason for this is that the drum does not wind with exactly the same amount of tightness each time it is used and small variations in the tightness will change where the zero point and the 1.0 km point of the tether rests in relation to the tape measure and the limit switches.

II-G. Tether length indicator (yellow tape)

There is a yellow indication measuring tape that runs along the top of the drum (H: Fig 1) to indicate how much tether at any given point has been reeled out. The actual indicator arrow is affixed to the threaded rod on top of the drum (G: Fig 1). This needs to be adjusted so that it reads zero at the start of a launch. It can be adjusted by sliding the indicator so that it aligns with the zero meter indicator on the yellow tape. Only if this is done correctly can one be sure that the limit switches will be set accurately at the 0.0m and the 1.0 km ends. And, accuracy is the only way to insure that the drum will hit these limit switches before running out of tether and damaging the system.

II-H. The VFD and the Winch Motor

The winch is powered with a 440 VAC-3 phase drive motor (D: Fig 1). The 440 VAC cord plugs into the side of box (E) in Figure 1 and then into the power supply rack in the hangar (T: Fig 4). Another cord connects the power rack (R: Fig 4) to a 440 VAC power supply located on a wall on the port side of the ship. The main power supply on the rack is usually left on so that it stays warm. Before a launch, check the red light indicator on the rack to make sure it is working and switch the winch breaker all the way to the right to allow the rack to run the winch (For more on the rack, see Section IV.).

A variable frequency driver (VFD) (located inside (E) in Fig 1) is used to control the speed and direction of the drive motor. These components need time to warm up. They will not be functional immediately. The circuitry in box (E) is mounted on an aluminum plate that contains thermostatically controlled patch heaters. When the winch is operated in cold conditions, this motor should be allowed to warm up with the power on for 15 minutes before attempting to operate the winch motor. There likely is nothing wrong if the winch motor and/or the VFD does not respond immediately to the switches at the beginning of the launch. The operator must sometimes leave a few minutes at the start of a launch to allow the motors (especially the VFD) to be fully operational.

Do not flick the switch on and off trying to get them to work- just give them time by leaving the VFD switch on (L: Fig 2), making sure that the drum switch (M: Fig 2) is in the 'stop' position. Try again in a few minutes. If the winch still does not respond, unplug the 440 VAC cord- remember to twist it counter-clockwise before yanking it off- wait a few minutes, and plug it back in- the system should naturally reboot itself. If this doesn't work, there may be a serious problem. Go to the nearest phone and call 1-900-WINCH-PATROL. Box (E) itself should never be touched.

Located on top of the VFD grey box (E: Fig 1) is a metal box with a four prong connector. This is where the high voltage power supply plugs in when operational.

II-I. Fan belts

There are three fan belts used by the winch system- a very short, thin belt which winds around the clutch and wheel (C) in Figure 1. The purpose of this belt is to drive the clutch wheel at 1.25 times the rate of the drum so that if the tether slackens while being wound in, the tether will spool onto the ground instead of getting caught in the winch mechanism. We have never had this problem and after snapping two belts in 10 launches, we ourselves snapped and removed this belt all together. The winch appears to work fine without it.

Of the two belts which remain, one is noticeably thinner than the other. Before starting a launch, simply check that the thinner belt is riding on track properly and that it has some tension (squeezing the belt gently together, one should not be able to get close to touching the two sides together). If this belt becomes loose or frayed, it must be replaced. There is no tensioner or adjuster on this belt. We currently have one spare. Section II-D describes how this smaller belt drives the speed and spacing of the tether onto and off of the drum. It is a critical part of the system and nothing functions without it. Thus, care should be taken to insure that this belt is in good condition.

The wider belt should also be checked at the beginning of a launch. In addition, it should be checked periodically during the launch. To check this belt, simply make sure it is flush with the top gear it is spinning on. If the edge of the belt is hanging off this gear, smack it back on so that it is flush. If it continues to do hang over with use, one can easily tighten it by loosening the bolts which hold the winch motor (D: Fig 1) in place, sliding the motor along the tracks, and retightening the bolts. This belt must be replaced if it looks frayed or in danger of breaking.

II-J. How the balloon attaches to the winch

After emerging from the top of the magic tether box (P: Fig 1), the tether attaches to a ring where it is wound three or four times before being affixed to the ring. A separate set of leads from this end have been soldered and exit the ring through a little hole terminating in an electrical connector. This connector is a direct electrical connection to whatever the tether may be transmitting. Thus, if there is a conduction through the tether wire, leads can be attached here and used as necessary and the current used as needed. Also attached to this ring is a knot which is the result of tying together four nylon strings- each of which attaches to one of the four plastic loops on the underside of the balloon. Thus, this ring serves as a coupling device to facilitate an easy connection between the four cords of the balloon and the drum tether. There is not much to be checked here at the start of a launch. Make sure the knot is well- tied and that the four lines are securely tied to the bottom of the balloon. The reason for wrapping the tether three or four times is to insure that the tether will not come loose from this coupler ring and set the balloon free. If the operator is using the electrical wires to close a switch or power any devices, check to make sure that the connection is tight and that it is working before beginning the launch.

II-K. Emergency Brake on the Winch Motor

On the end (the end furthest from the control panel) of the VFD motor (D: Fig 1), there is a flimsy switch which seems to have a mind of its own. It is a little lever with two settings: 'set' and 'release'. This switch enables and disables a brake on the drive motor so that when the balloon is being housed, it will not free wheel to the ceiling of the hangar. ALWAYS check that this switch is in the 'release' position at the beginning of a launch and several times during the launch. The first sign you will have that this switch has been accidentally tripped to the 'set' position is the smell of smoke emanating from the motor which may be too late! The mere vibration of wheeling the winch from the hangar to the outside deck can trigger this switch. Brushing against it as you walk by can do the same. Thus, *immediately* before launching and then four or five times during the launch, the operator need to check the setting of this switch. A good practice to get into is every once in a while as the tether is spooling, walk around the winch and inspect the belts and this lever. When the winch is being stored in the hangar, this brake should be switched to the 'set' position.

III. The Balloon, the Video Camera, and the Sondes

The other components of the system are the balloon, the video camera, and the meteorology sondes. The method of preparing and monitoring each during a launch is explained briefly below. The method of preparing and initializing the sonde is written up in an attached manual.

III-A. The Balloon Preparation

The balloon is a most critical part of the tethered balloon system. Without it, nothing flies. It is imperative that they balloon be carefully prepared for launch each time. This includes making sure it has enough helium to insure maximum lift, inspecting for holes or worn spots so that the balloon will not pop or deflate in mid flight, and carefully attaching the inflated balloon to the winch system so that it is fully secured and will not detach in mid flight.

The first thing to check is that the balloon is full of helium. Each night as the balloon sleeps in the hangar, some helium is lost and thus the balloon needs to be topped off with helium prior to any launch. First make sure that there is adequate pressure in the helium tank to fill the balloon. This can be done by turning the valve slightly to release some helium. If no helium comes out, change the helium tank before proceeding. The tanks are located on the port side of the ship in the shack adjacent to the hangar. Drop the empty tank off on the stern side of this shack and pick up a new tank on the bow side of the shack.

There is a yellow plastic liquid soap bottle taped in the mouth of the balloon. After you are sure that there is helium in the tank, pop the blue cap off this yellow plastic bottle. Helium will slowly drain from the balloon. As quickly as possible, take the nozzle at the end of the helium tube and screw this in the top of the plastic bottle. It will only turn about one or two turns and should be able to be secured without a wrench. Turn on the helium valve and fill the balloon until all the wrinkles are gone and the blue tape affixed to the side of the balloon is mostly taught against the balloon. Do not over-inflate to the point where the blue tape plasters itself against the skin of the balloon. When the blue tape is taught, unscrew the nozzle from the balloon and pop the blue cap on as quickly as possible.

Next, check that any patches on the balloon are not leaking and that there are no worn or thin spots on the surface. If any patches are leaking, fix at once before proceeding with launch. Do not launch with the intention of fixing after the launch!

Finally, check to make sure that the balloon is tied to the winch from four places on the underside of the balloon. Check that the four leads from balloon are tied together in a secure knot and that this knot is secured tightly to the winch by a ring or another solid mechanism.

The balloon is now ready to go.

III-B. The video camera preparation

To prepare the video camera for launch, the following steps must be taken. This will depend of course on the video camera being used but should roughly be the same general procedure for any camera. First, the batteries on the video must be kept warm to maximize the amount of time that the video camera will work. This is accomplished by taking a booty (I used an insulated slipper), placing hand warmers in it, and sliding the video camera inside. Care must be taken that the screw which mounts the camera onto the frame under the balloon is accessible. Do not tighten the booty around the camera until just before launch. Make sure that the batteries of the video camera have access to the warmth provided from the heaters!

On the side of the instrument frame under the balloon, one will find may holes about the correct size for the screw on the video camera. It is best to mount the camera on the side of the rack from which the long arm protrudes. The reason for this is as follows: The long arm pivots from a rod (secured to the frame but able to spin). This rod has a bracket on it which protrudes below the rack. One can wedge spacers as needed between this bracket and the camera to insure that the camera points downward.

Set the camera display time to the GMT time in the digital screen. At SHEBA, GMT = local time + 8 hours. Use a 24 hour time representation if the camera allows it. Then set the VTR/ Camera switch (green) to camera. Set camera on/off switch (red) to standby. Put the screw thought the rack pointing outward, slap a washer on it and screw down the video camera with the booty attached. Then go into the pumpkin and make sure that there is a notebook, a pen, and a digital watch handy to record the camera heights (see next section)

When the system is ready to go (i.e., the winch and the balloon are outside, ALL has been inspected, you are sure that the VFD and the winch motor are warmed up and communicating, all equipment including sondes have been initialized and checked etc...), then proceed with turning on the camera- It is the last thing you will do before the actual launch commences: Press the camera on/off switch (red button) to begin recording, synch up the booty, and pray to the Arctic Gods.

There are two more things you need to do. Before launching, tie the bow line down so that it is not dangling in front of the video camera while in flight. Finally, go inside the pumpkin and look to see what is the geopotential height reading at the surface. I believe this is corrected to be zero at 1000 mb so it should read some negative number. Record this number in the notebook in the pumpkin. OK- now you can launch.

III-C. Video monitoring while in flight

Some book-keeping must be done while the video is in flight so that the picture at any point can be correlated with the height of the camera at that point. The tape measure on the winch will give you a good idea of the height of the camera, but the camera will undoubtedly be at some angle with the ground and thus this height should not be used. Every flight that is launched should have at least one sonde attached and we use this sonde for camera book-keeping. The column labeled geopotential height on the sonde output will be used for recording camera times at specified heights- namely every 100 meters. In the pumpkin, make sure there is available a note pad, pencil, and a digital watch which includes seconds. Someone should be inside the pumpkin to record the following every 100 geopotential meters: the geopotential height reading on the sonde output, the digital time (down to the seconds), the sonde wind speed and direction (which is the magnetic direction). After the balloon launch, the times on the camera can be matched to the times recorded on this note pad. Then, snappy or another computer frame grabber can grab the pictures at those times and save them as files whose names indicate the height of the picture. Don't forget to record the initial geopotential height on the sonde reading (It will not be zero and must be factored in the actual heights recorded- i.e., if it reads -70m, this value must be added on to the actual heights recorded in the notebook.).

III-D. The Sonde Preparation

Sondes must be prepared as per the attached sonde operations sheet. At least one sonde must be attached for every launch. On cloudy days where the video may not be useful, more sondes may be attached for more detailed vertical structure information. On cloudy days or transition days, these sondes can remain at the maximum winch height as long as their batteries allow to collect a time series of the cloud evolution.

Any sondes used should be monitored while in flight to make sure that the batteries are still functioning and that the data are being collected. A number of 9999 on the screen will indicate a malfunction in that part of the sonde. If the balloon is low enough, and 9999's appear on the output, reel the balloon in again and switch sondes- do not waste time doing a launch if data are missing.

IV. The Power Supply Rack

The power supply rack houses a power distribution box, a multiplexer box, an EMI high voltage power supply (located at the bottom of the rack- see Figure 3), and a power supply cooling unit. The status and control panels for these components are located on the front of the rack. One can view a diagram of the panel configuration in Figure 3- Row (A) in Figure 3 is the panel for the high voltage and data, and the mulitplexer; Row (B) is the main power distribution board; And, Row (C) is the panel for the cooling system. I describe all the components of the rack in the sections below:

IV-A. Power Distribution Box

The power distribution box supplies power to each of the ground units in the rack and to the winch itself. One can view the status of its various components on the panels on the front of the power rack (Rows A and B: Fig 3). A 440 VAC- 3 phase wire powers the rack and the winch as well as connects the multiplexer box to the high voltage power supply. Thus, the power rack has three 440 VAC lines- one which goes from the ship's power supply to the rack (plugging in at (R) in Figure 4), one which goes from the rack (plugging in at (T) in Figure 4) to the VFD (E: Fig. 2), and one which connect the multiplexer (S: FIg 4) to the high voltage power supply.

The outlet from the ship is located on the port side of the ship just bow-ward of the hangar. The maximum power requirement of the system is 21 KW which corresponds to 27.5 amps. When the unit is receiving power, it illuminates a red light labeled "input power" on the front of the rack (G: Fig 3). When one switches the main power supply on (H: Fig 3), another red light labeled "output power" (J: Fig 3) and a green light labeled just "power" (D: Fig 3) both illuminate. Make sure that all three of these, as well as the cooling motor indicator light (K: Fig 3) (see Section IV-D) are on before attempting a launch. The system will not work otherwise.

Other indicators on the front of the power rack include a small pin and knob located at the end of Row A in Figure 3 (E and F). We added these two components after we arrived at SHEBA. They serve no purpose now except that, in order for the power supply to work, switch (E) in Figure 3 must be pushed all the way to the left. One should leave knob (F) alone. Finally, the main winch circuit breaker is also located on this panel (I: Fig 3). This breaker must be pushed to the right for the rack and the winch to communicate (See Section II-H for more details.). Row (C) in Figure 3 deals with the cooling system and is discussed in Section IV-D.

IV-B. Multiplexer Box (MUX)

In the top of the rack, one finds the multiplexer box (MUX). As I mentioned earlier, the purpose of the MUX is to facilitate communication between various components of the system. Thus, in essence, the MUX allows all the different components of the system (the power supply, the winch, the tether line, the instruments, etc...) to "electronically" understand each another. If we look into the rack from the rear, we can see the outlets and serial ports which supply information into and out of the MUX. I have sketched a diagram of this configuration of outlets and ports in Figure 4. Below is a description of the various ports and outlets from Figure 4:

- (M): High voltage power supply line (yellow) plugs in here and goes to the junction box on top of the VFD (E: Fig 1). Line up the red dots before plugging in.
- (N): Coaxial line that goes from the high voltage power supply at the bottom of the

rack to here.

- (P): Link status serial port- this is not used
- (Q): Probe data serial port- goes from here to the RS232 port on a PC
- (R): Input power- 440 VAC line goes from the ship's power to here
- (S): EMI power supply plug-in- 440 VAC line which goes from the high voltage power supply at the bottom of the rack to here.
- (T): Winch line- 440 VAC line which goes from side of the VFD (E: Fig 1) to here- It is the thinner of the two 440 VAC cords used.
- (U): Cooler motor power - 110 VAC which powers the motor that circulates the anti-freeze-water mixture
- (V): Mux power supply- 110 VAC which provides power to the MUX

IV-C. High Voltage Power System

The high voltage power supply, located at the very bottom of the rack (see Figure 3), outputs between 300 and 3000 VDC at power levels up to 15 KW. It requires a 440 VAC- 3 phase source to operate. This supply requires liquid cooling and has a custom cooling supply (See Section IV-D.). There is one knob on the right side of the power supply unit itself. It adjusts the voltage that the tether receives. There is also a digital indicator which displays the EMF in volts and the current in amperes as one adjusts this knob. The operator should always take care that the current stays below five amps.

IV-D. Cooling System

The function of the cooling system is remove heat from the EMI high voltage power supply. There is a black tube on the top of the power supply (oriented vertically) into which one pours a 60/40 ratio of antifreeze to water. We have already done this for this rack. Thus, unless there is leakage, one should not have to add any additional anti-freeze.

The cooling system should be powered when the main power switch (H: Fig 3) on the rack is in the 'on' position. The high voltage system will *not* function if the green pump indicator light is not illuminated (K: Fig 3). We have had some problems with this aspect of the rack. When the conditions outside are cold (as they are in the Arctic), the fluid in the cooling system does not seem to be able to flow. We have rectified that problem in the following way:

Inside the rack about half-way down, there is a white cylindrical switch oriented horizontally. When the green indicator light for the cooling motor (K: Fig 3) was not illuminated, we simply jumped this cooling motor switch at the beginning of a launch just to illuminate the green light and get the power supply to function. Then, we started the launch as if there was nothing wrong. As the launch progressed, the high voltage power supply warmed up and the pump began to work on its own. At this point, we disconnected the jump we put in over the switch and the now-working pump kept the green light on. The way to avoid this procedure on every launch is to leave the power supply rack on (so that the both red lights (G and J in Figure 3) and both green lights (D and K in Figure 3) remain illuminated) at all times. Thus, the green light (K: Fig 3) never shuts off and power supply will be fully operational at the beginning of every launch.

Finally, on the front side of the rack, at the bottom left, there is a switch for a cooling fan (L: Fig 3). This switch has three positions: 'off', 'on', or 'auto'. It is best for the operator to keep this switch on the 'auto' setting. At this setting, the fan will only come on and cool the power supply when needed. This switch should be shut off at the end of a launch.

V. Checklist Summary

1. Prepare the video camera and booty wrap with heaters (Sec. III-B)
2. Go up to the hangar to prepare the winch
3. Check to see that the main power supply switch on the rack (H: Fig 3) is on and that the rack is plugged into the ship's power supply- I.e., check that lights G,J, and D in Figure 3 on the power rack are illuminated (Sec.IV-A)
4. If the main power supply was not on already, turn it on and wait for a 15 minutes warm-up period
5. If the high voltage power supply is being used (bottom of Figure 3), check that the cooling motor flow indicator light is on (K: Fig 3). If this light is not on, follow the procedure outlined in Section IV-D for bypassing this switch.
6. If using the HV power supply and a PC for viewing data, make sure that the PC is plugged into the back of the MUX (Q: Fig 4)
7. Make sure all the controls on the winch control panel are off (A: Fig 1, Sec. II-B)
8. Make sure that the winch breaker switch on the rack (I: Fig 3) is all the way to the right so that the power supply can talk to the winch (Sec. II-H)
9. Check the balloon for the proper inflation and add helium as necessary (Sec. III-A)
10. Check balloon to insure that any patches are intact and not leaking.
11. Check all the knots and fasteners that connect the tether to the balloon- check that the balloon is securely fastened by all four lines, that these four lines tie into a secure knot, that this secure knot is securely attached to the ring under the balloon where the tether attaches AND that the tether is secured to this ring (Sec. II-J)
12. Check that the gears in the magic tether box (B: Fig 1) are clear of snow, ice, and debris and that the tether is resting in the groves of these pulleys.
13. Check that the fan belts are aligned properly and adjust the larger one if necessary (Sec. II-I)
14. Align the tether indicator located on the threaded rod with the zero meter indicator on the yellow tape (Sec. II-D and II-G)
15. Set the adjustable limit switches so that the one on the right hand side is just to the left of the 0.0 meter mark and that the one on the left hand side is just to the left of where you want to stop- If you want to stop at the end of the tether, place this switch

just to the RIGHT of the 1.0 km mark (Sec. II-F)

16. Mount the camera to the rack under the balloon. The best way to do this is to put a screw through the side of the rack, slap a washer on it, and screw it into the bottom of the camera. This should be done on the side of the rack with the protruding arm (see Sec. III-B).
17. Wedge styrofoam or any equivalent spacer as needed between the camera and the bracket of the protruding arm to insure that the camera faces downward.
18. Check to make sure that a long enough line (orange line with a clip on the end) is attached to the ring under the balloon (where the balloon cords and the tether already attach). This is where the sonde will attach.
19. Take the end of this line and wrap it around the sonde starting with the top spiral wire, continuing around through the groves at the sonde middle, and then down to the spirals at the sonde base. Make sure that the sonde is securely tied to this wire. It is a good idea to tie a knot at each of the spiral ends to insure that the sonde does not slide off.
20. Go into the pumpkin and prepare the sonde- change the 9V battery, put in 2 heaters, turn on the receiver, and start the A.I.R. program on the PC (Follow the instructions in the attached sonde preparation manual). Do not start the archive of the data yet, but make sure that the sonde is responding and that there are no 9999's (missing data) indicating bad sensors.
21. Untie the bow line inside the hangar and wheel the winch and balloon out to the far stern (past the yellow line). Use two people unless completely calm- one to wheel the winch and one to steer with the bow line.
22. Tie the bow line down outside if windy
23. Plug in the 440 VAC power cord from power rack in the hangar to the VFD grey box on the winch (E: Fig 1). Remember to twist after inserting (Sec. II-H)
24. Turn on the VFD switch (L: Fig 2) on the winch control panel and allow a few seconds for it to warm up (Sec. II-B)
25. Untie the bow line (if tied) and secure the bow line somewhere on the balloon where it will not dangle in the way of the video camera.
26. Turn the video camera on/off switch (red button) to 'on' to begin recording and synch up the booty.
27. Check the brake on the winch motor (D: Fig 1) to make sure it is set to 'release' (Sec. II-K)
28. Make sure that the winch speed control knob is turned to zero (all the way counter-clockwise) (N: Fig 2) and turn the winch switch (M: Fig 2) to the 'out' position. The balloon should not move
29. Have someone hold the prepared sonde in hand with a 1-2 foot long string which will be used to tie the sonde to the winch tether. Gently turn up the speed (N: Fig 2)

and let out enough tether so that the line that the sonde is on has no more slack.

30. Turn off the speed, turn off the winch control to 'stop' and turn off the VFD (L: Fig 2)
31. Attach the center of the sonde to the tether with the string taking special care that the sonde is free to turn around the strings and the tether without any hindrance. If the sonde is impeded from moving, the wind direction readings will be inaccurate.
32. Start archiving the sonde data (see attached balloon manual)
33. Recheck the brake on the winch motor a second time to make sure it is still set to 'release'. It could get bumped while attaching the sonde (Sec II-K)
34. Restart the winch by first turning on the VFD, then turning the winch control to the 'out' position, then increasing the speed.
35. Check to make sure that the drum is spooling accurately and smoothly
36. A second person should at this point go into the hangar to start recording on the note pad the time, and wind speed and direction each 100 geopotential meters.
37. After the balloon reaches its desired height, turn the speed knob to zero (counter-clockwise), turn the winch motor to the 'in' position, and reel back in by increasing the speed slowly.
38. Reverse the above instructions for launching to take down the system.