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Calibration Source Deployment Inside the Acrylic Vessel

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Introduction: The calibration of the SNO detector requires that sources be deployed inside the acrylic vessel. Ideally these sources can be deployed without seriously effecting normal data acquisition and can be moved throughout the entire volume of the vessel. In the presence of discrete neutral current (NC) detectors the latter requirement may be difficult to satisfy. We are assuming here that sources include light balls, solid radioactive sources, and gas sources fed by capillary lines. One must also consider the requirement that deployment hardware permanently mounted in the acrylic vessel must have acceptable levels of radio impurities.

Three possible solutions to source deployment are presented along with the advantages and disadvantages of each. It is assumed that the knowledge of the source position is better than 20cm (the accuracy required by the NC calibration source). It may be that other sources require greater accuracy which may in turn eliminate some solutions.

Option 1. Loop System: The basic configuration of the hardware for this system is illustrated in figure 1 which shows four loops entering the neck of the vessel and passing around pulleys attached at the equator. In this view, the source is shown deployed on a single line allowing it to move vertically. This may be the configuration normally employed for the more frequent "coarse" calibration. The assumption in all of the figures is that the calibration sources have negative buoyancy.

Figure 2 shows the source again in the vertical position but with the four loops attached. The loops are attached by raising the source into the universal interface, and by means of a glove box type arrangement built into the universal interface, the loops are attached to the source. In figure 3, these loops are shown pulling the source off axis to other regions of the vessel. The regions accessible in this manner are shown in figure 4. The loops are driven by encoded motors that allow one to position (and hence determine) the source location by computer control.

For calibrations with discrete NC counters in the vessel, one would only use two of the four loops at a time (pairs of loops located 180 degrees apart). This would allow one to map two orthogonal planes cutting through the center of the detector.

Advantages: This is a relatively simple arrangement which allows various sources to access almost the entire volume of the vessel. One can minimize the impact of the radioactivity of the material in the loops by using positive buoyancy lines that would float up against the surface of the acrylic vessel while not in use. Using loops also allows for inspection of the lines for wear before deploying a calibration source. Any worn loops can be easily replaced.

Disadvantages: The principal disadvantages are that the system requires fixtures on the wall of the vessel and when the NCD strings are in position it is only possible to move the source in one of two orthogonal planes. Also, since the negative buoyancy source cannot access the entire volume, it must be shown that this allows acceptable calibration to take place. (One might consider using a positive buoyancy source to map out this other region, but use of such a source may be very difficult to control). Finally, if lines or pulleys became jammed or entangled, one would probably require the use of a remote operating vehicle to fix the problem.

Actions: It must be demonstrated that the loads that the loops impose on the shell of the vessel are acceptable. It must be shown that stretch in the lines doesn't result in a significant uncertainty in the position of the source. One must also verify that the eight reels to hold the lines can be accommodated at or near the universal interface and that the source attachment can be accomplished without light disturbing the PMT's. Since the source cannot access the entire volume of the vessel it must be shown that this will allow adequate calibration.

Option 2. Boom System: This solution is illustrated in figure 5. A thin acrylic boom of just over 6 meters length is attached to two lines which pass up the neck of the vessel. Where the lines attach to the boom, weights are located, which provide inertia and better control over the boom and also counterbalance the weight of the source which is attached to the tip of the boom. Since the density of acrylic is 1.9, the effective weight of the boom once immersed in D_2O will be small. When not in use the boom is stored vertically in the neck, the source end uppermost, allowing easy attachment of the source using a similar type of glove box arrangement in the universal interface as used by the loop technique. The source can be moved in a plane passing through the axis of the vessel by adjusting the length of the lines using motorized reels. The reels are mounted on a circular track located in the universal interface, by rotating this track a new plane can be selected. The position of the source is known from the readings of the encoded motors driving the reels and the circular track. Figure 6 shows the regions accessible to the boom.

Advantages: In the absence of the NCD's the boom may access the entire volume of the vessel. The operation of the boom does not impose loads on the sphere. When not in use it is removed from the sensitive volume of the detector.

Disadvantages: The movement of the boom is ***possibly*** limited to two orthogonal planes in the presence of the NCD's. It must be shown that the boom cannot be used like a jousting pole to damage the vessel or the NCD's. It must not be possible to lodge the boom in the neck of the vessel by entangling it in the fixtures (NCD cables, pipes etc.) passing down the neck. There are concerns with the boom shadowing the source.

Actions: It must also be demonstrated that the boom can be precisely controlled and that boom failure will not endanger the shell. The pendulum modes that can be induced in the boom system should be studied along with their rate of damping. It must be shown that the water speed does not result in the boom being displaced significantly giving rise to an uncertainty in the position of the source. It must be shown that any lines associated with a particular source (e.g. fiber optics or ^{16}N capillary gas lines) do no result in a displacing drag on the boom. It must be shown that it is possible to accommodate the ring and reels in the region of the universal interface. Since the movement is restricted in the presence of the NCD's it must be shown that adequate calibration of the NCD's is possible.

Option 3. ROV System: A ROV source transport system has the potential advantage of great flexibility. A candidate ROV to fulfill this task is the "Seaball" made by Inukton Services, Nanaimo, BC. This ball has a diameter of only 18 cm. When not in use the ROV is stored in the region of the universal interface where different sources may be attached using the glove box type arrangement described above. Control and power to the ROV is provided by means of an umbilical. Navigation uses an on board video camera, precise knowledge of it's position is by means of a transponder located in the ROV plus receivers probably mounted on the PSUP.

Advantages: In the absence of the NCD's the ROV can access the entire volume of the vessel and in the presence of the NCD's it can potentially access a larger volume than the above schemes although with the increased possibility of fouling or damaging the NCD's. There may also be advantages in having a small remote controlled vehicle to be able to access the outside of the vessel. The use of a ROV can also be considered if either of the above schemes prove inadequate, most likely without modification of the interface.

Disadvantages: Even a small ROV will shadow part of the source, thus making reconstruction of the detector response more difficult. It may also be possible that an out of control ROV can threaten the integrity of the vessel or become entangled with the NC detectors.

Actions: It must be demonstrated that the ROV does not threaten the integrity of the vessel, become entangled with the NC detectors, or contaminate the water. A satisfactory transponder location device must be developed . Finally, one must also select an illumination system for the camera that will not interfere with the PMTs.

Summary: The following table summarizes the pertinent features of each scheme.

	LOOPS	BOOM	ROV
Access to vessel	60% of volume	100% of volume	100% of volume
Access to vessel (with NCD's)	2 partial planes	Possibly up to 24 planes	Possibly 100% of volume
Material	Nylon	Acrylic	Metals + Plastics
Radioactivity	Low	Low	High
Storage	In vessel	In neck	Outside vessel
Cleanup before each use?	No	No	Yes
Attachment points needed?	Yes	No	No
Guides at neck needed?	Yes	No	No
Permanent installations?	Yes	No	No
Windlasses	8	2 (lines) 2 (rotation)	1 (umbilical)
Encoders	8	2 (lines) 2 (rotation)	Sonar
Obstruction of neck	High	High	None
Precision of location	High	Medium	Unknown
Source loading procedure	Remove top cover	Thru' glove box	Thru' glove box
Load capacity	Medium	Low	High

In order to make a decision on which (if any) of these three schemes to develop further, additional, basic information is required:

- **Calibration definition:** A more complete description of the calibration requirements is needed, including accuracy of calibration for various physics goals, source description (intensity, size, weight, etc.), frequency and duration of deployment, regions to be accessed inside (and outside) the vessel and precision of location. The feasibility/desirability of using an internal calibration source on each NCD should also be decided.
- **Universal interface requirements:** All systems must enter the acrylic vessel via the universal interface and any changes to the source must be carried out via the interface, since the design of the interface is almost complete, changes to accommodate the source transport may be non-trivial and the requirements of each scheme should be reviewed as soon a possible.
- **Impact on vessel:** The calibration scheme has to co-exist with several other systems in the vessel, particularly in the restricted

region of the neck. A failure analysis for each scheme should be developed.

- **Light sensitivity:** Changing the source on the loop and boom schemes requires an operator to access the mechanisms which may allow the possibility of light entering the vessel. We must consider methods that allow one to change sources at the universal interface without allowing light into the detector (red light may be acceptable), alternatively the PMT's would have to be powered down which introduces dead time and possible stability problems.

With the above information in hand it will be possible to select a calibration scheme and focus on addressing the problems in implementing it.

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DEPLOYMENT COST ESTIMATES

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1) LOOP SYSTEM:

Buoyant Kevlar Lines (500m)	10.0
4 Equatorial Pulleys	4.0
8 Neck Pulleys/Guides	4.0
Source Housing (Neutron, Gamma, Light Pulsar)	5.0
Sources	?
9 Encoded electric(?) motors (2/loop, 1 axial)	22.5
9 torque clutches	4.5
Motor/clutch mounting (in universal interface)	10.0
"Glove box" (in universal interface)	15.0
Additional modification to universal interface	10.0
Computer interface	15.0
Computer	10.0
Commercial software (encoders)	5.0
Custom software	?
TOTAL:	$115.0k

2) BOOM SYSTEM:

7 meter acrylic(?) boom	5.0
2 encapsulated weights/line attachments	2.0
Kevlar lines (2x25 meters)	1.0
Sources	?
Source housing (neutron, Gamma, light pulsar)	5.0
4 encoded electric(?) motors	10.0
4 torque clutches	2.0
Motor/Clutch mounting Ring (in universal interface)	20.0
"Glove Box" (in universal interface)	15.0
Additional modifications to universal interface	10.0
Computer interface	15.0
Computer	10.0
Commercial software (encoders)	5.0
custom software	?
TOTAL:	$100.0k

3) **ROV SYSTEM:**

Basic "Seaball" ROV	50.0
Infra red(?) camera system	10.0
ROV control console + video	30.0
Source holder + transponder modification	10.0
Sources	?
Transponder system	50.0
Transponder installation hardware on PSUP	10.0
Modifications to universal interface	15.0
Commercial software (transponder etc.)	10.0
Custom software	?
Computer interface	15.0
Computer	10.0
TOTAL:	$210.0k

FIGURE 1: BASIC CONFIGURATION OF LOOP SYSYEM

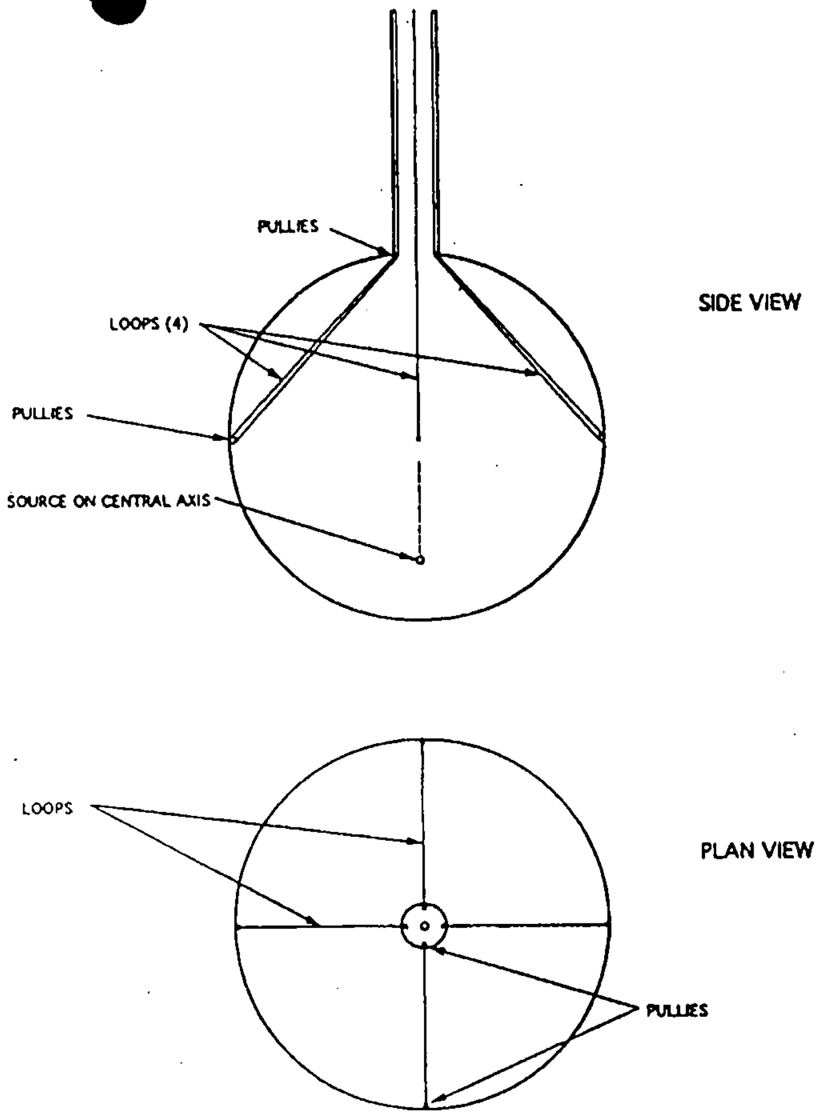

FIGURE 2: SOURCE ATTACHED TO LOOP SYSYEM

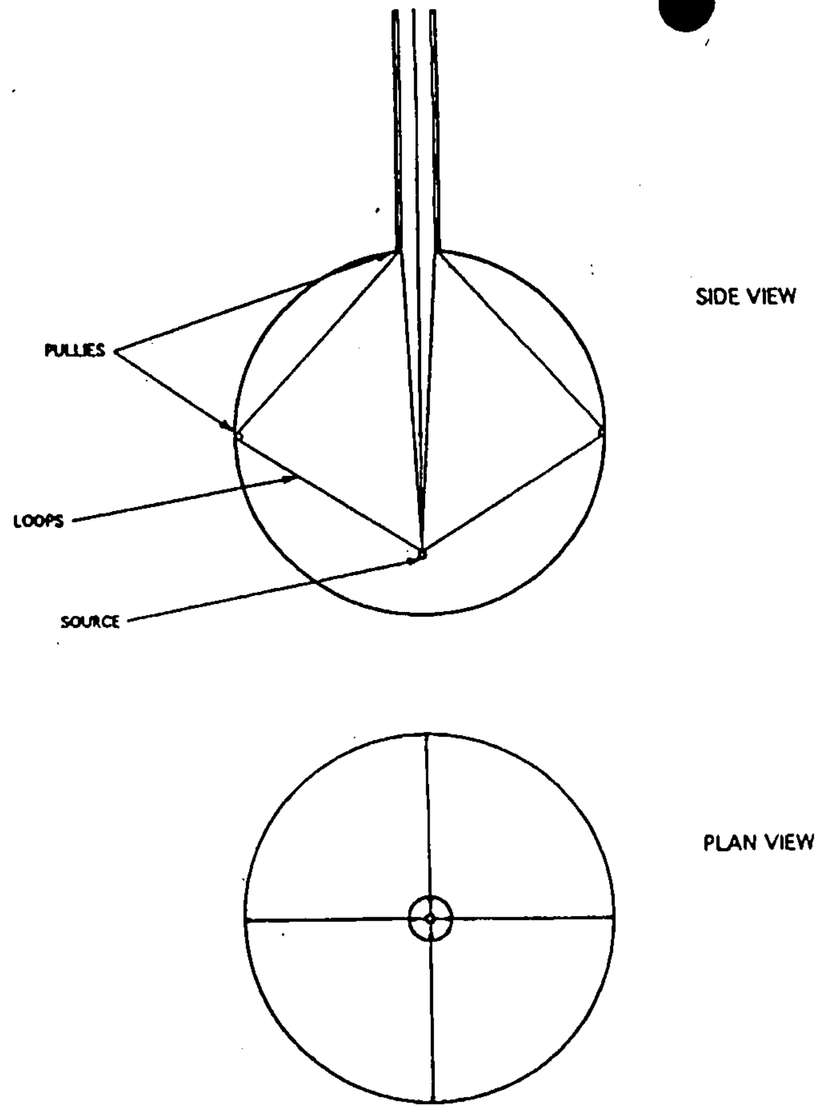

FIGURE 3: SOURCE DISPLACED OFF-AXIS USING LOOPS

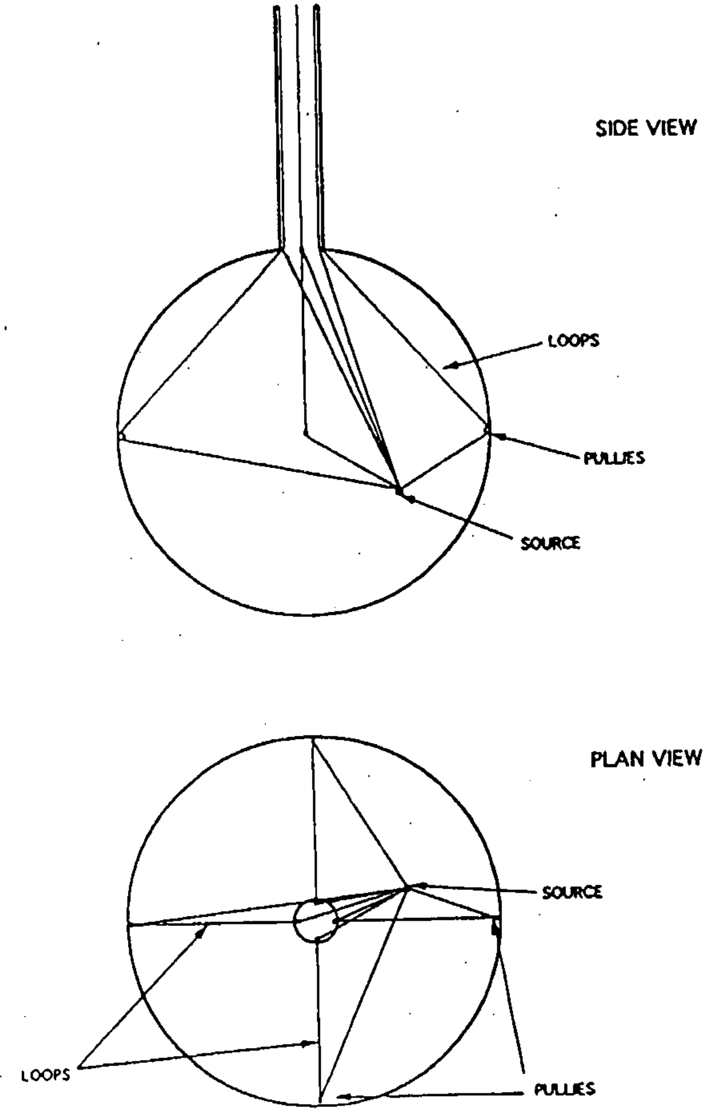

FIGURE 4: REGION ACCESSABLE TO SOURCE

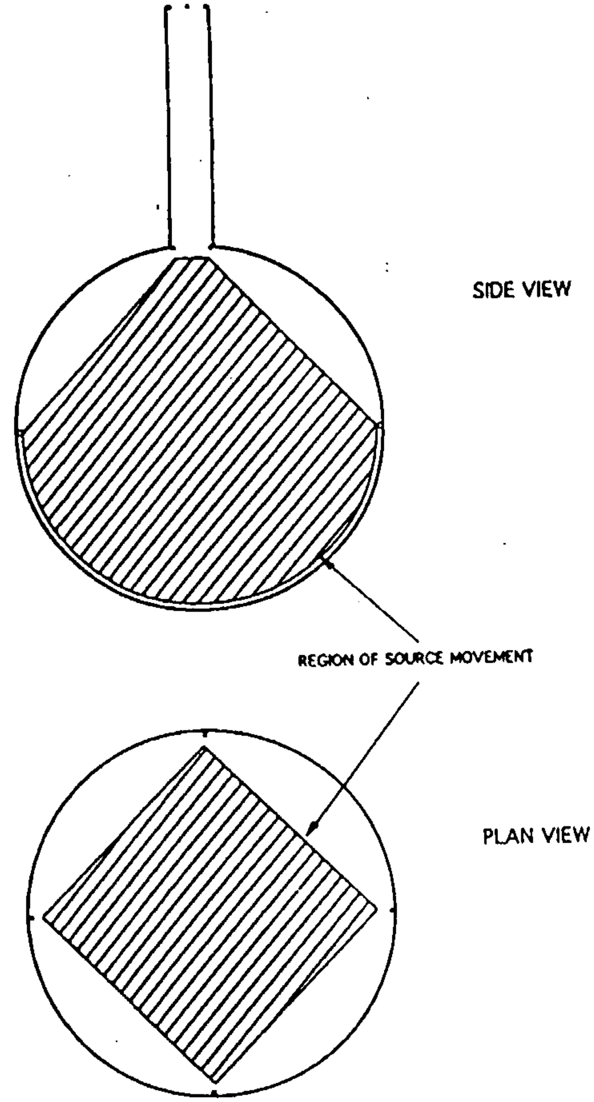

FIGURE 5: BOOM DEPLOYMENT

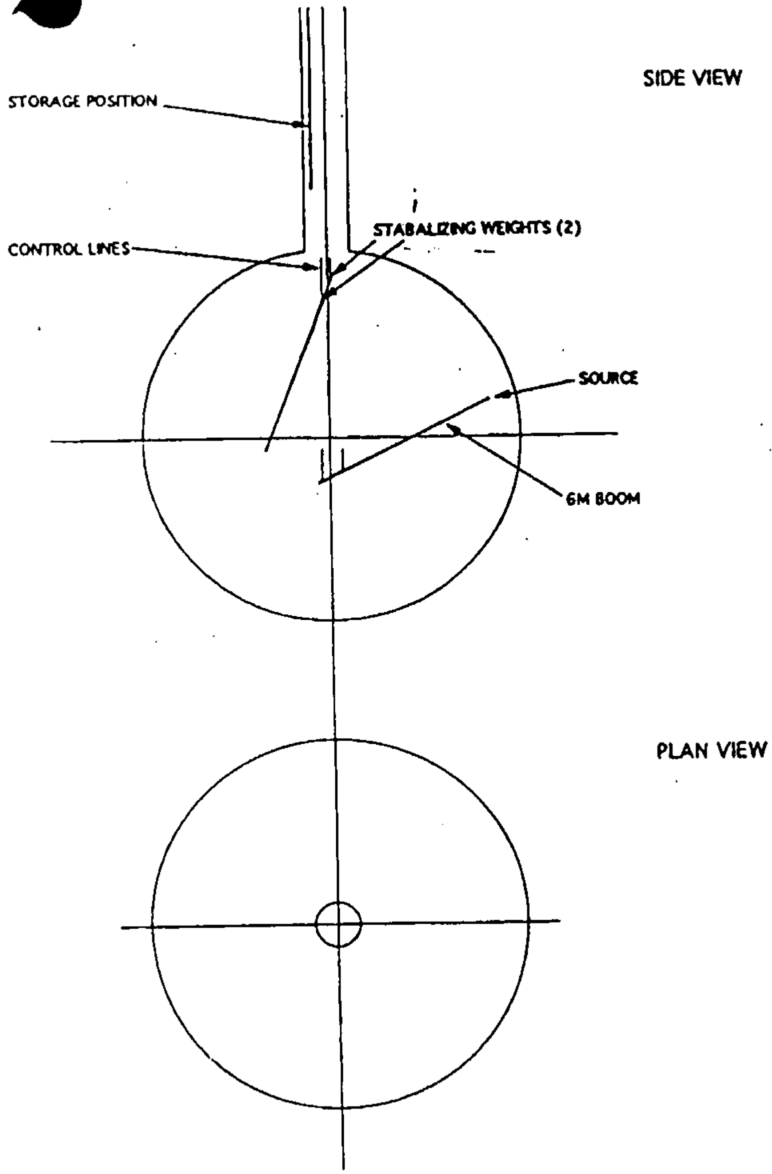

FIGURE 6: REGIONS ACCESSABLE TO BOOM