Sudbury
Neutrino Observatory

Calibration Source Manipulator

User's Manual

Fraser Duncan
Queen's University
fduncan/sno/manipulator/tex/manipulator_user_manual.tex
March 13, 1999

Contents

List of Tables

List of Figures

Chapter 1

Operations

1.1 Controlling and Monitoring the Manipulator From MANMON

MANMON is a standalone Tcl/Tk program that runs on surf that can be used to either monitor or control the manipulator. It is not intended as the primary control program for the manipulator. Rather it is to be used to display strip charts of manipulator systems and to periodic monitoring without interfering with the DAQ. Also it can be used to control the manipulator and laser from surface if necessary.

1.1.1 Starting MANMON

1. Log onto `surf` as user `manipulator`
2. go to the current manmon directory,

   ```
   cd manmon
   ```

   the directory `manmon` is a softlink to the current version of the manmon code. If there is a problem, usually an older version will solve it.
3. start the **manmon** program by typing

   ```
   manmon
   ```

   A GUI user interface will pop up (figure 1.1).
4. Connect to the manipulator computer by clicking on the **connect** button. A window will pop up (see figure 1.2) asking if you wish to make this a control connection (to operate the manipulator and laser) or a monitor connection (to view but not affect the calibration system). The default is to make a monitor only connection. To make this a control connection, click on the **monitor only** button to deselect it. The window will disappear and the connection will be attempted. If the connection is accepted properly, the message

   ```
   Connection Accepted
   ```

   will appear in the **from server:** window and in the **Connections** panel of the display (top right) a line indicating the connection will appear. This line contains the *ID* of the process, the *Address* of the machine that **manmon** was started from and the *Idle Time*. Because **manmon** is constantly polling the manipulator the idle time should always be zero. If a different process connected to the manipulator computer becomes hung, then that process's idle time will continually grow.

1.2 Running Manipulator codes from PC

In directory

```
c:\motors\manip\
```

run program

```
newmot
```

(this may change name to manip or something). Basic Commands

help

list lists all objects

logout disconnects tcp/ip connection

quit exits program

Commands for the `prototype` object

prototype by $< x > < y > < z >$ move manipulator amout x y z in manipulator space.

prototype reset resets encoders to agree with motor position and tension

prototype locate $< x > < y > < z >$ defines the position to be x y z.

prototype to $< x > < y > < z >$ moves to absolute position

A sample session:

```
motors> prototype reset    -- resets encoders to agree with motor position
                              and tension

motors> prototype by  35 0 -40 -- moves differential amount in x,y,z

motors> prototype locate 0 0 92.8 -- defines the current position to be
                                     (0,0,92.8)

motors> prototype to  -180.0 0 32.3 -- moves to absolute position
```

A session in which the central rope was originally fully spooled and is unspooled, threaded through the pullies and attached to the carriage.

```
motors> centralrope reset   -- to reset the encoder on the central rope

motors> centralropemotor setcruise 2   -- change from maximum 4cm/c to 2cm/s
                                          so it feeds off the drum slower.

motors> centralrope down 10000         -- feed out string

motors> stop                           -- stop when you have enough

motors> centralropemotor setcruise 4   -- change speed back to max.
```

A session where the prototype is disconnected and reconnected.

```
motors> prototype disconnect
motors> prototype connect eastrope centralrope westrope
motors> show prototype
```

Note that the `show` command has a different syntax. This is because it is a system wide command unlike the others which are object commands.

1.3 Running the Manipulator from the MAC DAQ computer

You run the manipulator through the data acquisition program. But first make sure that the manipulator program is running on the PC. Phil uses the minimal version of the DAQ located in:

```
hardisk/Programming/DAQ3.6/MinDev/
```

Start the program by clicking on

```
MinDev
```

and this will pop up two windows, the status window and the configuration window. It will be necessary to add the manipulator module,

```
File -> Add Module -> Module Group -> MANI-MAIPULATOR
```

You can also add a SPLITTER and a DISK etc. To see what options are available with the module, hold down the **option** key (lower left on mac keyboard). To connect to the manipulator,

1. hold the apple key (the one with the bite out of it). You get a menu:

   ```
   Configure
   Basic Ops
   Special Ops
   ```

   select `Configure` and select the auto updating (or whatever it is called) on.

2. Select `Basic Ops` and a window with the manipulator status will pop up. This window has places to input commands to the manipulator and readback.

3. (I think) you can get a graphical display of the AV and the manipulator position from the `Special Ops` option.

4. To shut down the GUI interface to the manipulator,

   (a) shut down the DAQ. MAC will wait forever trying to close the TCP/IP connection.

   (b) close the TCP/IP connection from the PC by using either the `logout` command or by quitting.

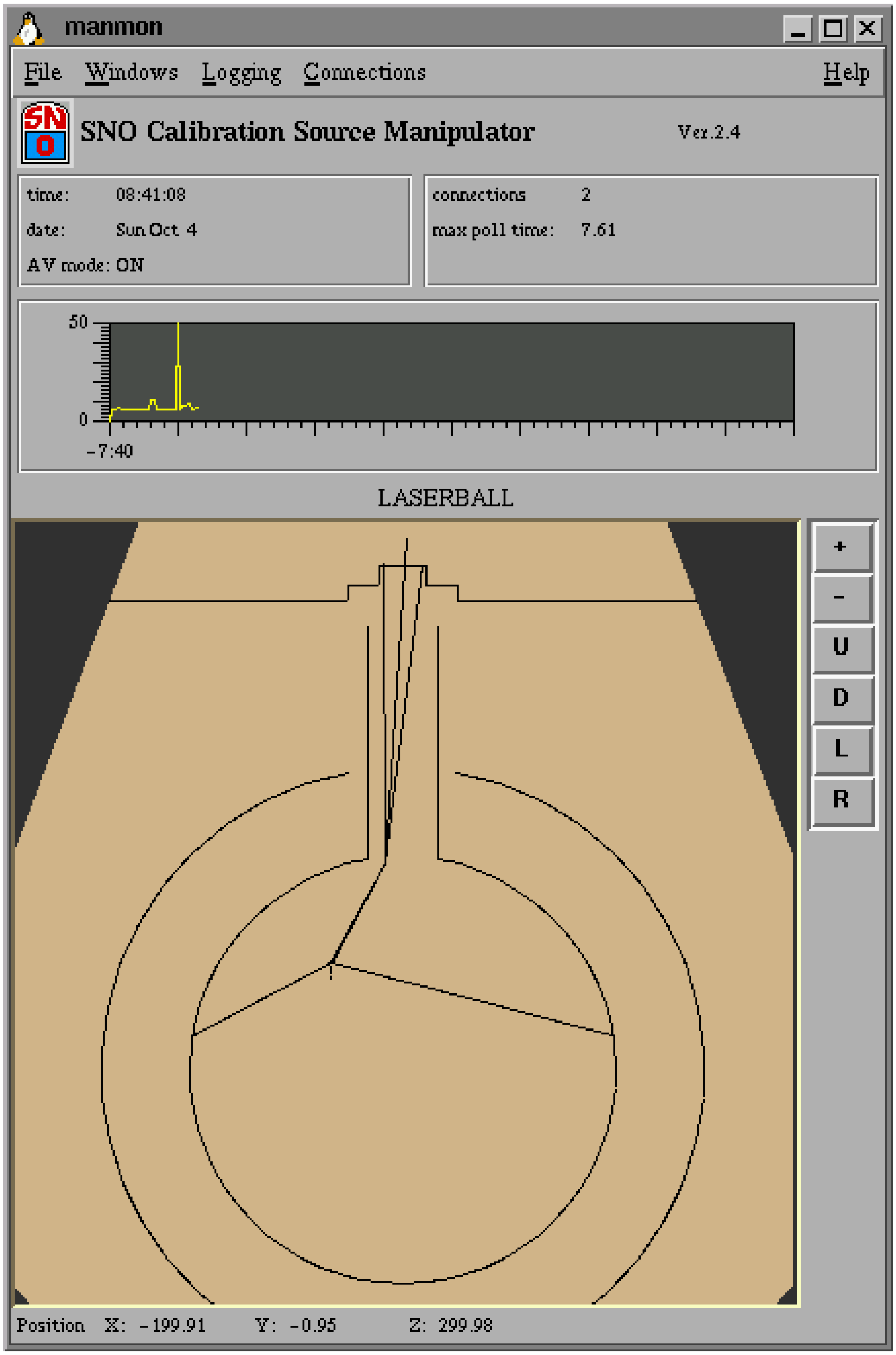


Figure 1.1: manmon main window

Figure 1.2: manmon connection dialog

Chapter 2

Overview

The SNO calibration source manipulator is a positioning device used to place calibration sources inside the Acrylic Vessel of the SNO detector or down special calibration guide tubes in the region between the AV and the PSUP. By using a system of three ropes, a central and two side ropes, the manipulator is able to position a source on either an east west plane or north south plane inside the AV. About 3/4 of the plane inside the AV can be reached by the manipulator, the remaining quarter is off limits due to the geometry of the manipulator system. In addition to the manipulator ropes (referred to as **axes**) there is an **umbilical** attached to the manipulator that provides the necessary services for the source (electrical signals, fibre optics, gas lines etc).

Each calibration source is stored in an **Umbilical Retrieval Mechanism** or **URM**. A URM consists of a block and tackle mechanism for taking up the source **Umbilical** used to provide services to the source and a **central rope** used to support the weight of the source. Below the URM is the **source tube** which is a 4' long stainless steel pipe used to store sources when not deployed in the vessel. Normally, the URM and source tube are mounted on a calibration port on the **glovebox** which is located on the **universal interface** located directly over the neck of the acrylic vessel. When not in use, the source is stored in the source tube and a gate valve on the glove box seals off the detector. The central rope in the URM is instrumented with a **shaft encoder** which determines the length of rope played out and a **load cell** used to measure the tension in the rope. The umbilical is similarly instrumented.

Sources can be deployed in a **single axis mode** which consists of lowering a source straight down from the URM on just the central rope and umbilical. The horizontal position of the source is determined by the location of the URM. The vertical position of the source is determined by the measured length of central rope played out. The single axis deployment mode is useful for operation along the central axis of the detector and for deployment of sources down the guide tubes.

The main purpose of the manipulator however, is to deploy a source *off* the central axis of the detector inside the acrylic vessel. This is done attaching two **side ropes** to the manipulator carriage once it is deployed into the glovebox. The side ropes are attached at one end to **anchor blocks** in the AV are anchored at the other end by feedthroughs on the glovebox. The side ropes go over pullies on the manipulator carriage. Once the source is lowered into the vessel, it can be pulled off the central axis by shortening one side rope and lengthening the other. Because only two side ropes are attached at a time, the source can only be moved in a plane. There are two sets of side ropes allowing motion in an east-west plane or a north-south plane. The side ropes are instrumented in the same fashion as the central rope with the side rope motor mounts located on the roof of the DCR. The ropes pass through the roof of the DCR into the glovebox through stainless steel tubes.

The manipulator is controlled by the manipulator computer, a DOS based PC. The manipulator computer runs a C++ based program called **manip** which monitors the instrumentation on the manipulator, calculates the positon of the source and accepts commands to control the manipulator. **manip** can be accessed both from the console in the DCR and remotely via TCP/IP. When taking data control of the manipulator is nominally done through the SNO DAQ. The reason for this is that the DAQ then automatically incorporates any change in the calibration source configuration into the data stream. In addition there is a standalone unix utility called **manmon** which allows remote monitoring of the manipulator and is useful for diagnostics.

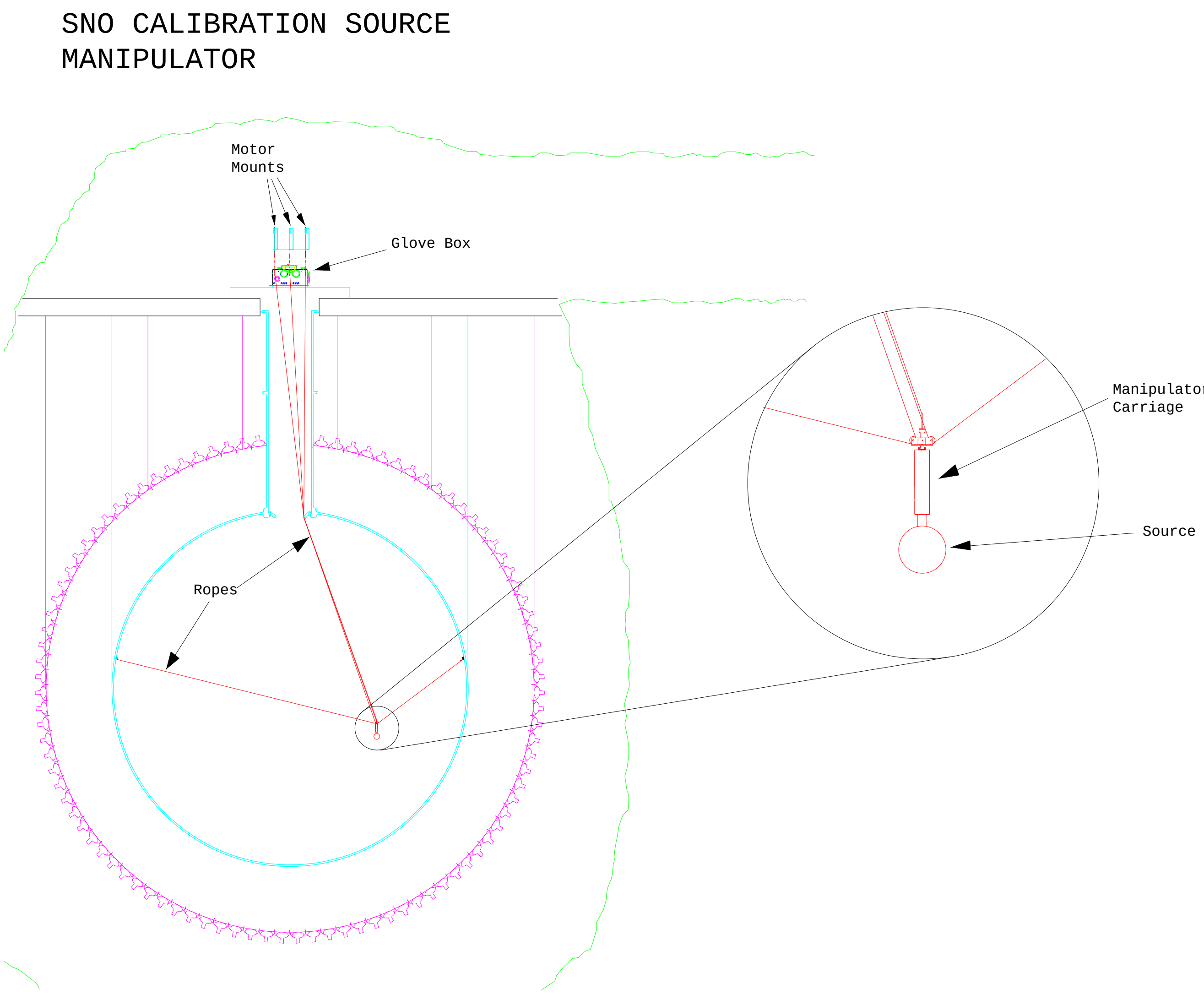


Figure 2.1: SNO manipulator

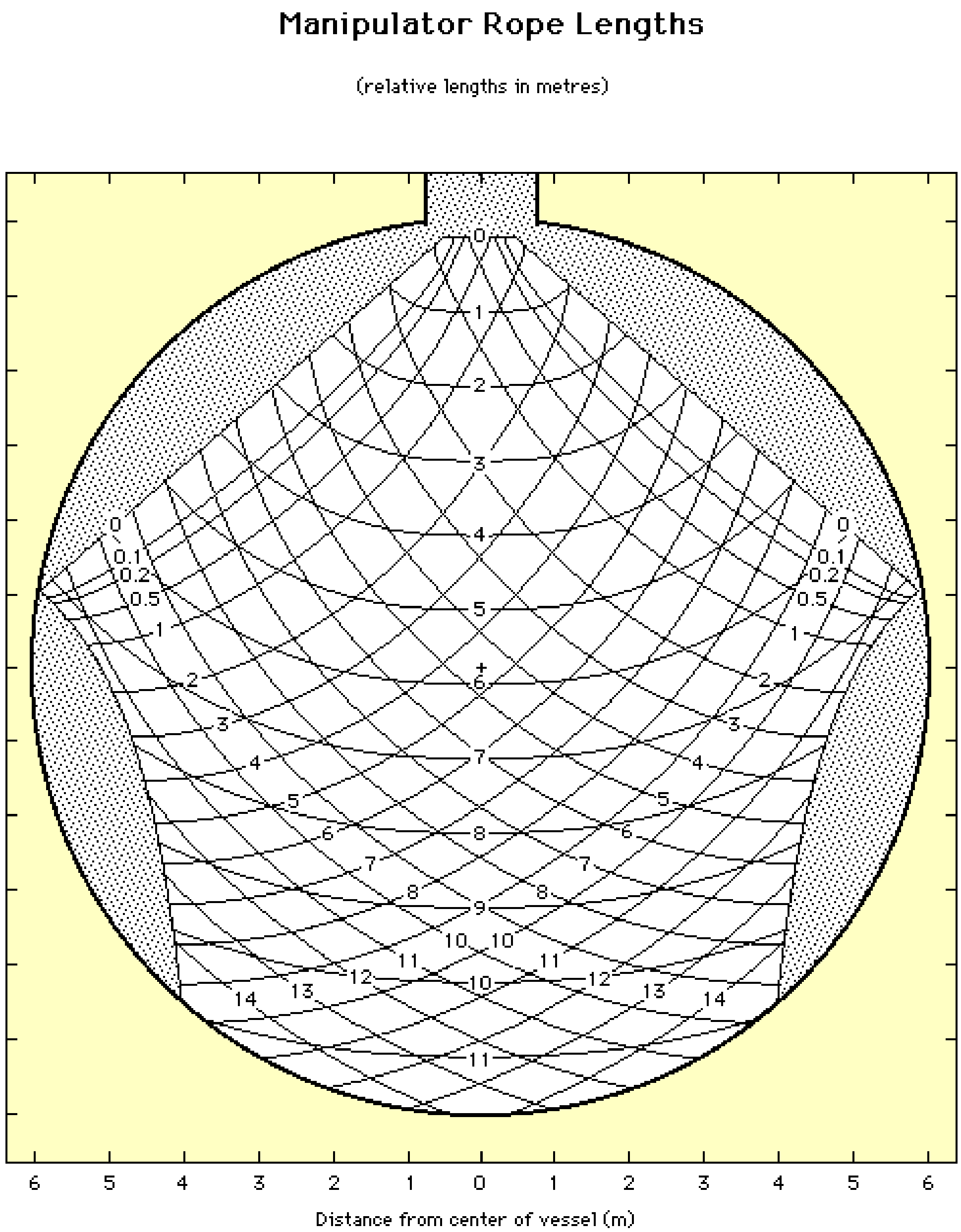


Figure 2.2: Rope Lengths

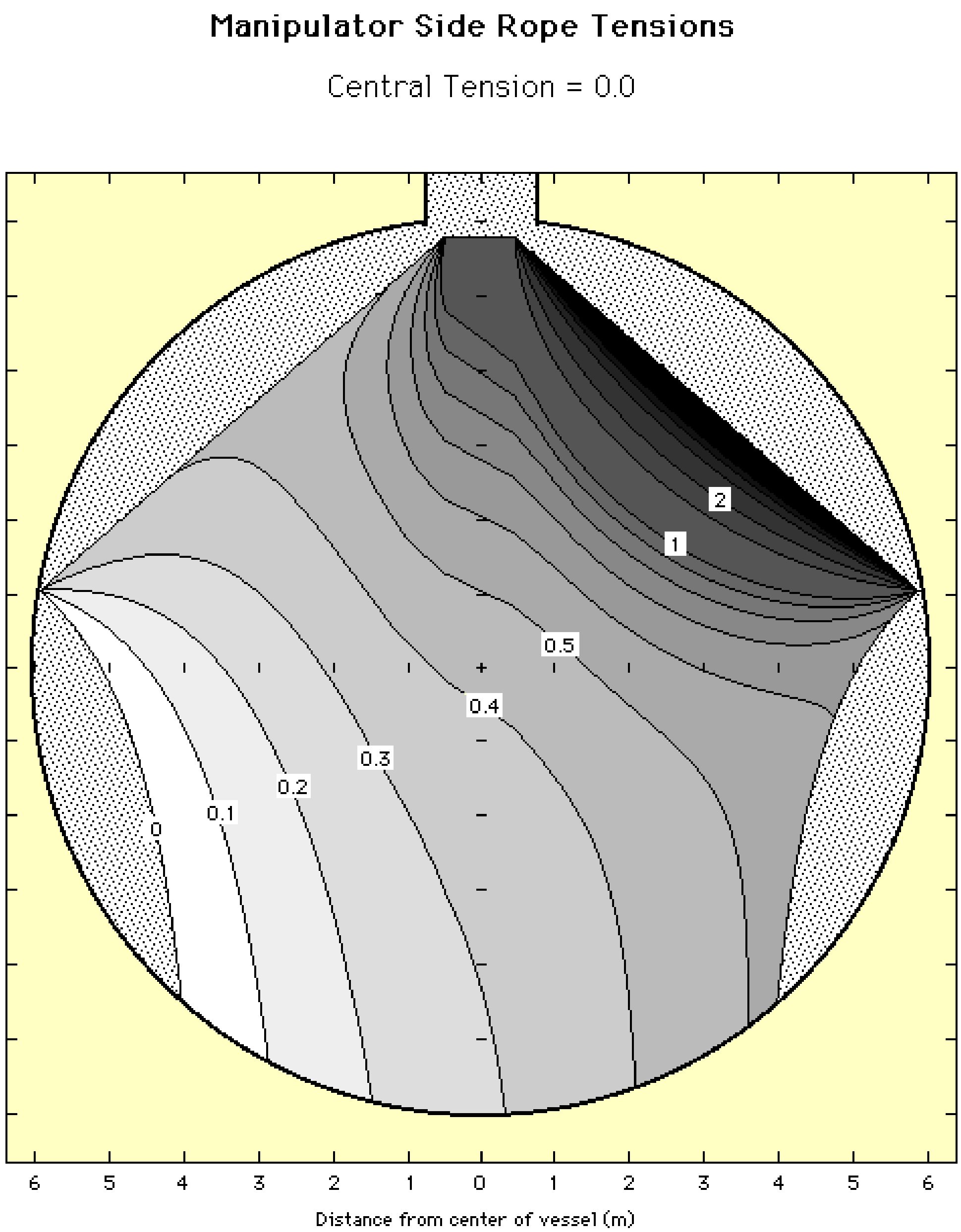


Figure 2.3: Rope Tension

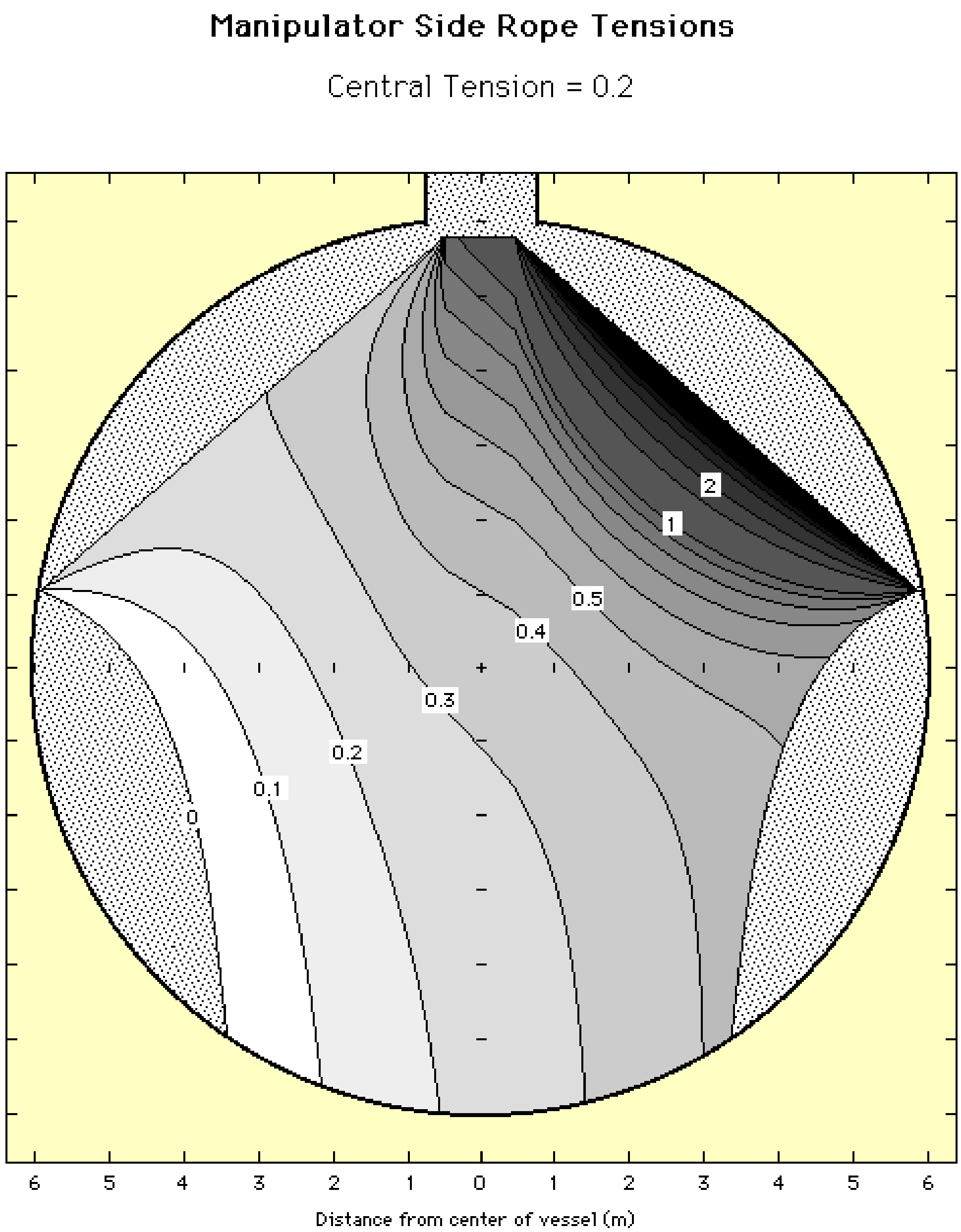
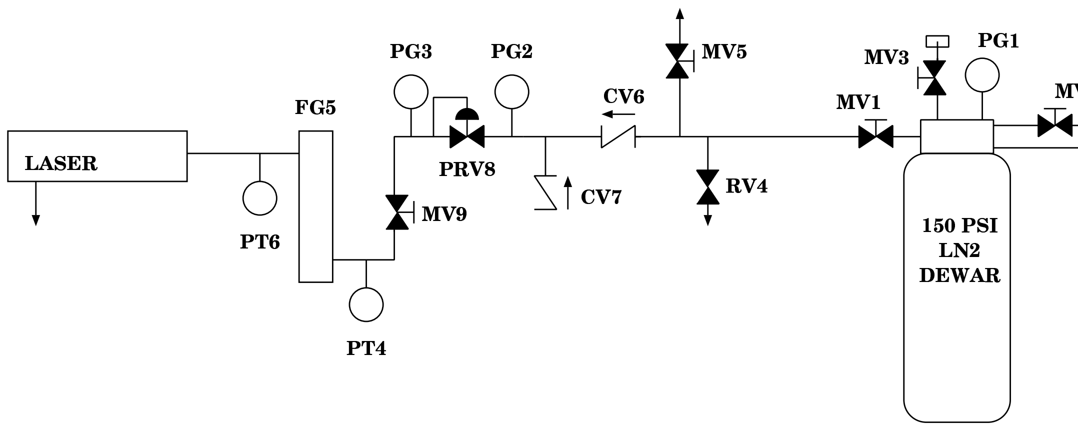


Figure 2.4: Rope Tension

Chapter 3

Operating the Laser



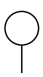


Figure 3.1: Laser Gas System

3.1 commands

n2laser
  Lists commands for n2laser

n2laser monitor
  displays status information on the n2laser.

n2laser poweron
  Turns on the power to the laser

n2laser poweroff
  Turns off the power to the laser

dyelaser
  display dyelaser commands

dyelaser init
Initialize the dyelaser. Must be followed by `dyelaser findzero`

dyelaser findzero
Find the zero position of the dyelaser mirror. The mirror travels down it's track till it hits a stop.

dyelaser cell ¡0-4¿
Select the dyelaser cell between 0 and 4.

filterwheela
Show commands for filterwheela.

filterwheela init
Initialize filterwheela.

filterwheela findtab
Find the calibration tab on filterwheela.

3.2 Procedures

3.2.1 Starting the Laser

1. Open MV1 the manual valve on the LN_2 dewar.
2. Open MV2 the pressure builder valve on the LN_2 dewar.
3. Note pressure on PG1, the pressure gauge on the dewar. The pressure should be at least 120 psig.
4. Note time. **The laser must NOT be turned on until 20 min after gas flow has started.**
5. Enter DCR and note values on PG2 and PG3 and FG1. PG2 should be at least 120 psig, PG3 should be at least 100 PSIG FG1 should be at least 40.
6. Test control of the laser by changing the mirror position
7. Using either manip computer or manmon determine PT4 and PT5. PT4 should be at least 80 psi.

3.2.2 Calibrating the Filter Wheels

The control system can sometimes loose track of where the filter wheels are positioned. To fix this follow this procedure. This example is for `filterwheela`, replace with `filterwheelb` for the 2nd filterwheel.

1. Reinitialize the filterwheel

   ```
   filterwheela init
   ```

2. Find the tab on the wheel

   ```
   filterwheela findtab
   ```

3. select the desired filterwheel position using the `n2laser setnd` command.

3.2.3 Calibrating the Dye Cell Mirror

1. Reinitialize the mirror

```
dyelaser init
```

2. Find the zero of the mirror

```
dyelaser findzero
```

3. Select desired wavelength

```
dyelaser cell <0-4>
```

Chapter 4

What If...

4.1 While Operating Laser

Chapter 5

Manipulator Geometry

5.1 Global Coordinate System

When positioning the manipulator the user is in fact positioning the carraige pivot of the manipulator in the **global coordinate system** which is located at the designed centre of the PSUP and the AV. Be warned that neither the PSUP nor the AV are actually expected to be centred on the global origin. In fact it is known that the PSUP has shifted by at least 2" and the AV shifts depending on the load. Because the exact location of the AV is needed to position the manipulator (need to know the location of the anchor blocks in the AV) there are neck monitors used to measure the position of the top of the AV neck and thus infer the position of the centre of the AV.

From the construction drawings the deck of the DCR floor is located at

```
100' = 1200 in.
```

by definition. The nominal centre of the AV and thus the origin of the global coordinate system is located at a height of

```
56' 7 1/2 '' = 679.5 in.
```

Therefore the distance from the global origin to the deck is

$$520.5in. = 1322.07cm$$

by design.

measurement	dim (in)	dim (cm)	from
height of DCR floor	100'= 1200"	3048.00	definition
height of global origin	56' 7 1/2" = 679.5"	1725.93	design
d(global origin to DCR floor)	520.5"	1322.07	calc

Table 5.1: Global Coordinate System

5.2 Glovebox and Universal Interface

The dais of the universal inteface is located 17 and 1/8 " above the floor of the cleanroom. Taking the nominal height of the DCR floor as 1322.07 cm, the UI Dais is located at 1384.30 cm and the top of the glovebox is located at 1427.80 cm in global coordinates.

	coord system	location	source of measurement
DCR Floor	global	z = 1318.47 cm	
Bottom of Tube Flange on URM-1	global	z= 1504.43	
Height of side rope feedthroughs on glovebox	global	z = 1424.22	

Table 5.2: Manipulator Geometry

measurement	dim (in)	dim (cm)	from
DCR floor to UI Dais	17 1/8 "	43.50	measurement
UI Dais to top plate of glovebox	24 1/2 "	62.23	measurement
Nominal height of UI Dais		1384.30	measurement
Nominal height of glovebox top		1427.80	measurement
westrope feedthrough x	-21.000"	-53.340	Drawing
westrope feedthrough y	0.750"	1.905	Drawing
eastrope feedthrough x	21.000"	53.340	Drawing
eastrope feedthrough y	0.750"	1.905	Drawing
northrope feedthrough x	0.000"	0.000	Drawing
northrope feedthrough y	15.750"	40.005	Drawing
southrope feedthrough x	0.000"	0.000	Drawing
southrope feedthrough y	-20.250"	-51.435	Drawing
10" gate valve x	0.000"	0.000	Drawing
10" gate valve y	-8.500"	-21.590	Drawing
6" gate valve x	6.656"	16.906	Drawing
6" gate valve y	9.250"	23.495	Drawing
4" gate valve x	-6.313"	-16.035	Drawing
4" gate valve y	9.250"	23.495	Drawing

Table 5.3: Glovebox and UI dimensions

5.3 Acrylic Vessel

The thermal expansion coefficient for the acrylic is,

$$6 \times 10^{-5} C^{-1}$$

The design specs for the AV give the distance from top of chimmney to centre of vessel at 23 C

```
42' 2 3/8''
```

which is 506.375 cm. and the nominal outside radius

```
236.6''
```

which is 600.964 cm. with a nominal thickness of 2.15" (5.461cm).

This can be compared to the results found in SNO-STR-98-003 (R. Komar) for actual measurements of the AV. Using the Komar measurements, the nominal dimensions of the AV are given in table 5.4. On

measurement	design	as built
Vessel Inner Radius	236.43"	236.38±0.23"
Top of Chimney to AV centre	506.375"	506.16±0.12"
Top of Chimney to bottom of AV	742.59"	742.59±0.05"

measurement	dim (in)	dim (cm)	from
Average Vessel Inner Radius	236.38±0.23"	600.41±0.58	measurement
Top of Chimney to AV bottom	742.59±0.05"	1886.18±0.13	measurement
Top of Chimney to AV centre	506.16±0.12"	1285.65±0.30	measured?
Neck Ring gasket	1/8"	0.3175	measured
Neck Ring plate	3/8"	0.9525	measured
AV Centre to AV top plate	506.66"	1286.92	calculated
DCR floor to AV top plate	12.4375	31.59	measured/calculated

Table 5.4: Acrylic Vessel Dimensions

top of the AV neck flange is a gasket (1/8") and a stainless steel top plate (3/8"). This gives a distance from the centre of the AV to the top plate of,

$$506.16 + 1/8 + 3/8 = 506.66in = 1286.92cm$$

The distance from the AV top plate to the UI flange on the DCR floor was measured before the UI was installed. (This flange is no longer accessable since the UI has been installed.) This was a measurement after the final installation of the AV at nominal lab temperature before any water in the AV. The distance measured on 3 April 1998 was 28 9/16". The distance of the flange from the DCR floor was measured to be 16 1/8". Therefore the distance of the AV topplate from the DCR floor

$$289/16 - 161/8 = 12.4375'' = 31.59cm$$

The distance from the DCR floor to the centre of the AV from the measurement of the topplate location and the Komar measurements of the AV are therefore,

$$1286.92cm + 31.59cm = 1318.51cm$$

which corresponds to the AV being located above the nominal position by

$$1322.07 - 1318.51 = 3.56cm$$

What was Chris's AV measurement at this time?

5.4 URM-1 (Jury Rig)

URM-1 is located on the 10" port in a jury rig. It is physically mounted 32 3/16" (81.756 cm) above the glovebox. The source tube flange is 1" thick so the tube flange is located 79.216 cm above the glovebox. The nominal height of the top of the glovebox is (table 5.3) 1427.80 cm so the location of the URM-1 tube flange is

$$1427.80 + 79.216 = 1507.02cm$$

5.5 Guidetubes

```
Hi John,
  I am currently looking at how consistant our measurement of the location
of the centre of the AV is with respect to the Deck and UI and will send
out a report when I have some numbers.  Mostly I have no knowledge of the
location of the PSUP.  However I do have one datum.

  When we put the source down guide tube number 5 (the one in the north
west corner of the DCR) we found that the exit of the guide tube into
the PSUP was out of true with the top of the guide tube in the DCR.
I am told that when the guide tubes were installed that they were aligned
by a plumb bob to better than 1/4".  When we put the source down last
spring, we found that exit of the guide tube into the PSUP had shifted
approximately 2".  This number was determined by centring a 4" diameter
cone at the exit of the tube and noting where the string holding it was
located at the top of the tube.  The bottom of the tube was shifted
in the southwest direction (-x, -y) by about 2".  I have numbers for
the nominal location of the guide tube as being at
        x = -586.6,  y = 222.2
The guide tube is supposed to enter the PSUP at z = 560.  Please note
that I have no idea if this misalignment means that the PSUP was out
of true when the guide tube was installed or if it became out of true
when AFTER the guide tube was installed.

  Cheers,
     Fraser
```

Chapter 6

Sources

There are many source designed for the SNO detector. Several of them will have dedicated URM's assigned to them.

laserball is a spherical source containing a diffusing material that isotropically distributes light from a Nitrogen laser pumped dye laser system. It is used for the optical calibration of the detector. The laser is controlled by the manipulator computer and has both adjustable wavelength and intensity.

^{16}N The ^{16}N source is a radioactive gas source used to provide monoenergetic gamma rays to measure the detector's energy response. The radioactive ^{16}N gas is created in a d-t generator located in the junction outside the control room and then piped into the DCR and down into the source through an umbilical.

Rotating Source The rotating source is a device that has a collimated flashing light source that spins on two axes. By sweeping out the detector, it can be used to verify that the locations of PMT's is correctly incorporated into the various databases. It requires electrical connections from the rotating source umbilical.

Sonoball The sonoball is a sonoluminence source operating at approximately 25kHz. It uses four wires out of the rotating source umbilical.

6.1 Laserball

weight(source and carriage)	61 N
d(pivot to centre)	62.6 cm
d(pivot to bottom)	67.7 cm
maximum diameter	10.16 cm (4")

Table 6.1: Laserball Parameters

6.2 ^{16}N

6.3 Rotating Source

weight(source and carriage)	
d(pivot to centre)	
d(pivot to bottom)	78.59 cm
maximum diameter	11.43 cm

Table 6.2: ^{16}N Parameters

Chapter 7

Misc

7.1 Control Hardware

Each of the ropes is referred to as an "axis" and each axis has a

- stepping motor to wind rope in or out.
- shaft encoder to measure length of rope.
- load cell to measure tension of rope.

The stepping motors are controlled from a National Instruments TIO 10 card in the control PC that has many clock signals. These signals are fanned out through the motor fanout box to the individual motor controllers. The readback from the axis is the load cell measuring the tension of the rope and the shaft encoder measuring the length of the rope. The input signals go into the counter boards which are gray boxes which are daisy chained together and are indvidually addressable. The address for the counters are set with jumpers on the boards as is the address for the analog circuit. Note that the analog circuit has a different address from the counter circuit. These boxes are read out by the data concentrator which is read by the computer.

7.2 Using the `see` editor on the PC

start it by typing

```
see wiring.dat
```

Now in command mode, go to insert mode by typing

```
i
```

To leave insert mode type

```
<esc>
```

When in command mode, the space bar scrolls through the commands. The page up and and page down buttons allow paging through text file.

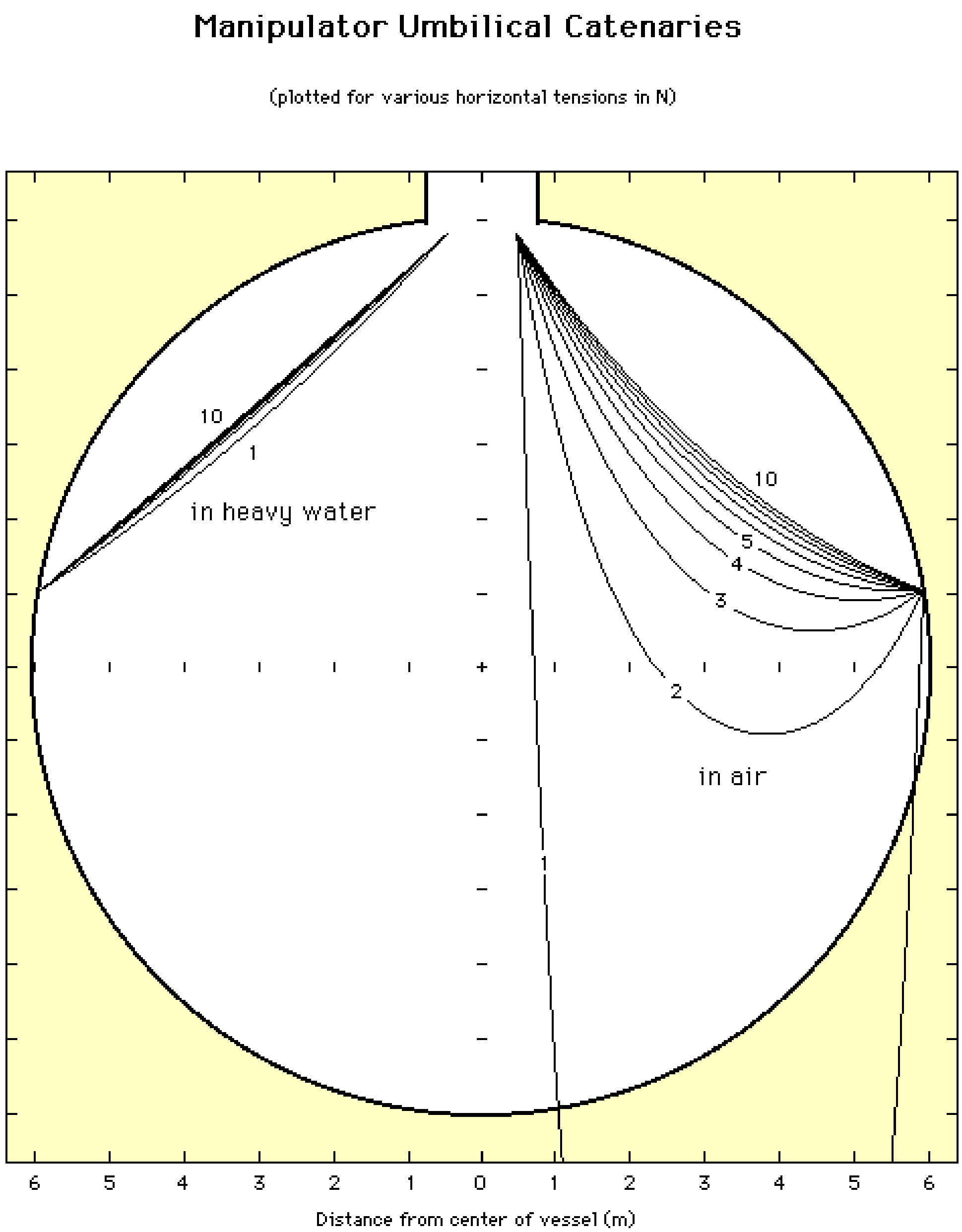


Figure 7.1: Shape of Umbilical

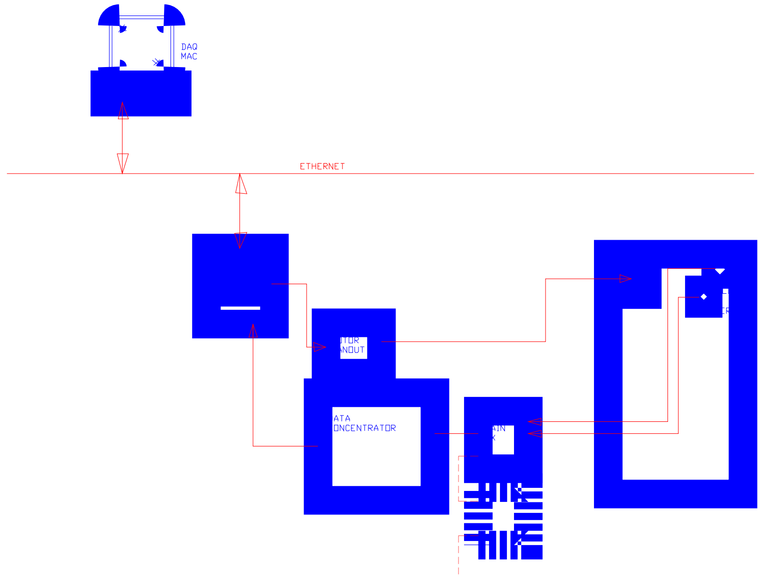


Figure 7.2: SNO manipulator control

7.3 Data files

```
On PC
-----
c:\motors\manip\

   wiring.dat  -- TIO 10 wiring map
                  counter board wiring map
                  motor fanout wiring map

       -- both the manipulator and the AV position sensors

   motor.dat    -- physical parameters for motors

   encoder.dat  -- physical parameters for encoders

   loadcell.dat -- physical parameters for load cells

   axis.dat     -- combines motor loadcell and encoder infor plus other
                   stuff (i.e. wire tension etc) to form info on axis

   polyaxis.dat -- combines 3 axes into the manipulator

   av.dat       -- information on acrylic vesel geometry
```

Chapter 8

Calibrations

8.1 Calibrating Load Cells

The loadcells on the manipulator will require calibration periodically. In particular the zero's of the loadcells are known to drift and have a significant temperature variation.

8.2 Calibrating Encoders

8.3 Hardware Loadcell Calibration

Chapter 9

Error Messages

stuck stop: <ROPE>

The manipulator has been unable to set the length of <ROPE> to the desired length. This will happen if there is static friction and as the manipulator winds in or out the rope it sticks and then jerks free. This causes the manipulator to overshoot or undershoot it's target length. After several attempts, the manipulator gives up.

Tension stop: <ROPE>

The manipulator has moved into a region where the tension of rope <ROPE> is outside the allowed range (presently defaults to 2.5 to 100 N).

Appendix A

Water Level Measurement With Manipulator

On 5 Oct 1998 at approximately 14:00, Aksel Hallin, Peter Skensved and Fraser Duncan deployed the manipulator into the D2O in the Acrylic vessel. It could easily be seen to the order of 2mm when the top of the manipulator weight cylinder contacted the D2O surface. In the manipulator coordinate system, the manipulator carriage pivot was at -285 cm when this happened. The weight top plate was located 2.5" (6.35cm) below the pivot. When the manipulator was returned to the glovebox it's calibration was checked and was found to be 1mm off. When the measurement was taken, the centre of the AV as reported by the neck monitors was located at 3.04cm in the global coordinate system. The manipulator was calibrated such that the bottom of the AV is located at -600.53 cm (at nominal lab temperature — the AV is now getting colder). Thus the depth of water in the AV (distance from water surface to bottom of AV) as measured by the manipulator is:

$$-285 - 6.35 - (-600.53 + 3.04) = 306.14cm$$

The measurements used to calibrate the manipulator position had an uncertainty of 0.16 cm. However, there is a question of reproducability of the order of 1 cm. Further the agreement between the single axis manipulator and the multiaxis manipulator is on the order of 1 cm. Thus the manipulator measurements have an uncertainty of 1 cm.

Discussion with Ken McFarlane gave a D2O AV bubbler water depth reading of 131 in. According to Dave Sinclair, the reading of that bubbler is 1of H2O density to D2O density is 62.4/69. Further, the bubbler is one inch above the bottom of the AV. Thus,

$$1.01 * 131 * (62.4/69) + 1.0 = 120.65in * 2.54cm/in = 306.46cm$$

So the manipulator and bubbler are in excellent agreement with each other, having a difference in the water position of 0.32 cm.

Appendix B

Prototype Position Survey

B.1 Manipulator Calibration Constants

parameter	value	reference
r_{NR}	2.54 cm	drawings
R_{NR}	50.662 cm	drawings
c_{NR}	(-0.364, 0, 580.835) cm	s1p108
θ_{NR}	0.320°	s1p108
p_{ABW}	(-595.391, 3.806, 97.679) cm	s1p108
p_{ABE}	(595.290, 0, 97.120) cm	s1p108
d_{AB}	1.826 cm	drawings
r_{AB}	0.635 cm	drawings
p_{GBW}	(-53.681, 0.321, 1418.496) cm	s1p108
p_{GBE}	(52.405, 0.353, 1418.391) cm	s1p108
p_{CR}	(0.0 , 12.48, 1433.06) cm	s1p111
p_{CALIB}	(0.0 , 13.75 1428.86) cm	s1p111

where

r_{NR}	radius of curvature on neckring
R_{NR}	Distance from centre of neckring to centre of curvature on ring.
θ_{NR}	tilt angle of neckring. Positive means east side is lower than west side.
p_{ABW}	bottom hole of West Anchor Block
p_{ABE}	bottom hole of East Anchor Block
d_{AB}	distance from bottom hole of anchor block to start of bevel.
r_{AB}	approximate radius of curvature of anchor block bevel
p_{GBW}	west rope feed through on glove box
p_{GBE}	east rope feed through on glove box
p_{CR}	centre rope point on pully
p_{CALIB}	calibration point in glove box

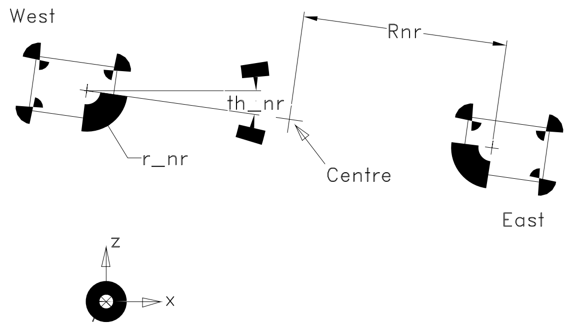


Figure B.1: Neckring

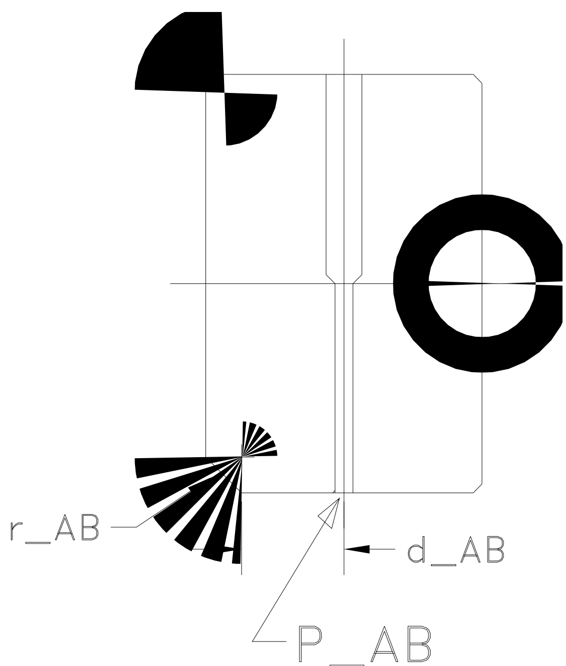


Figure B.2: Anchor Block

B.2 Coordinate Systems

The attachment points for the manipulator are given in the **prism** coordinate system, (x_p, y_p, z_p). The measurements made with the total station are given in the **theodolite** coordinate system, (x_t, y_t, z_t). The prism coordinate system is defined as follows:

1. construct the centre point,$\vec{c_{NR}}$, between the two prisms on the neckring.
2. define the prism z_p axis as passing through this point and being **parallel** to the total station z_t axis.
3. fix the height of the neckring centre, z_c point as,

   $$z_c = d_{NR} - dz_{NRE}$$

   where d_{NR} is the distance from the centre of the AV to the neckring in the real detector design,

   $$d_{NR} = 581.110cm$$

   and dz_{NRE} is the z offset from the east neckring rubbing bar to the east neckring prism,

   $$dz_{NRE} = 14.356cm$$

4. define the east AV anchor point to lie in the $x_p - z_p$ plane (i.e. the east AV anchor point has $y_p = 0$ by definition).

B.3 Offsets

offset	dx(cm)	dy(cm)	dz(cm)
neckring west	11.852	0.000	13.506
neckring east	-12.579	0.000	14.356
av west	14.181	0.000	14.131
av east	-12.861	0.000	14.155
glovebox west	-19.690	-4.050	75.820
glovebox east	7.620	-12.700	75.820

- the neckring dy offsets are set to zero. Because the ropes move on the neckring, the offset is not well defined. The value 0.0 is approximately right when the rope is low in the AV.
- the AV dy offsets are judged by eye to be 0.0 and are probably accurate to 1-2 cm.
- The AV x and z offsets were determined by sighting the exit holes of the anchor blocks and projecting the vector to the same y_p point as the prisms.
- The neckring x and z offsets were determined by sighting the point where the rope rubbed on the acrylic rubbing bar and projecting the point to the same y_p location as the associated prism.
- The glove box offsets are determined from drawings of the glove box and measurements of the prism fixture used in the glove box. The resulting position measurements of prisms hung from the glovebox are inconsistant with the glovebox drawings at the 6mm level (the xy distance between the prisms).

```
 from s1p108

 Prism Offsets
 offset_neckring_w =   11.852    0.000   13.506
 offset_neckring_e =  -12.579    0.000   14.356
 offset_av_w       =   14.181    0.000   14.131
 offset_av_e       =  -12.861    0.000   14.155
 offset_glovebox_w =  -19.690   -4.050   75.820
 offset_glovebox_e =    7.620  -12.700   75.820

average prism locations using surveys
  aksel_1
  aksel_2
  aksel_3
  970804
  970915
  970916


prism_neckring_w    -62.912(0.025)   0.709(0.019)   566.859(0.038)
prism_neckring_e     62.912(0.025)  -0.709(0.019)   566.649(0.037)
prism_av_w         -609.572(0.099)   3.806(0.156)    83.548(0.095)
prism_av_e          608.151(0.137)   0                82.965(0.125)
prism_glovebox_w    -33.991(0.167)   4.371(0.104)  1342.676(0.087)
prism_glovebox_e     44.785(0.142)  13.053(0.033)  1342.571(0.031)

The attachment points are then
neckring_w   -51.060(0.025)  0.709(0.019)   580.365(0.038)
neckring_e    50.333(0.025) -0.709(0.019)   581.305(0.037)
av_w        -595.391(0.099)  3.806(0.156)    97.679(0.095)
av_e         595.290(0.137)  0               97.120(0.125)
glovebox_w   -53.681(0.167)  0.321(0.104)  1418.496(0.087)
glovebox_e    52.405(0.142)  0.353(0.033)  1418.391(0.031)
```