SRM Sample Changer
Blueprints

Supplementary Material to:


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Please visit http://paleomag.caltech.edu/ for the most recent version
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Quartz-glass vacuum tube
Sample changer base plate assembly
Suspension coil
Magnetic Shielding
Helmholtz pair for AF
Lee-Whiting ARM bias Coils
Axial solenoid for AF & IRM
DC Servo Motor to change samples
Vacuum control assembly, up/down and turning motors
Superconducting Rock Magnetometer
I. Changer Base Plate Assembly

I. 1. Changer Base Plate

The changer base plate is the Teflon-coated aluminum plate on which the snake chain assembly slides. First, fabricate the base plate. (You can modify the layout to see fit, but the drive belts underneath the plate will have to be adjusted to fit alternate schemes). Next, you should roughen the surface which will be bonded to the Teflon using sand paper or a shop sand-blasting tool. We recommend using a Teflon sheet that comes chemically treated on one side to stick with a special epoxy (see purchase list). Roll it smooth with a small wooden roller tool. When the epoxy hardens, trim the excess Teflon away using a razor knife, being sure to clear the holes appropriately.
Both of these drive cog holes should be ~2.05" in diameter, centered as shown, for snug fit of bearing assembly, with four holes around them to fit the 8-32 threaded bolts on the drive assemblies.

Each of the 2" holes should have 4 small holes 0.13" in diameter for the 8-32 bolts surrounding them as shown, so that the aluminum supporting rings will fit.

These 4 slots are for adjusting the motor tension on the belts, and should be 1.5" long, 0.17" wide, and centered as shown.

The two central nanocogs wheels are on a 1.5" long 1/4" wide adjustable slot to control belt tension.

All small holes ( ) and slots in the bottom half of this figure are 1/4" diameter,

Scale: 0.4" = 1"

Dec. 08, 2006

These holes should be machined on a solid piece of Aluminum plate, 3/16" thick, 35" long, and 22.8" wide.

The two central nanocogs wheels are on a 1.5" long 1/4" wide adjustable slot to control belt tension.
I. 2. Changer Cups

These systems were designed for standard paleomagnetic core samples: flat-ended right circular cylinders with a diameter close to 2.54 cm (1”), as used in most paleomagnetic laboratories. For vertical systems, every tenth cup (made from the plastic Delrin) in the snake chain is type 1 (with a hole in the bottom, allowing access to the measurement region of the 2G SRMs). For the untested horizontal design, all will be type 2 (with bottoms, including rubber O-ring). The cups are held together with brass #16 pins and connected in a continuous loop. Cogs guide the snake chain smoothly over the Teflon surface.
Sample Holders for the Sample Changer Snake Chain
Type #1 -- without bottoms (pass-through hole)

1" = 1"

id is 1.16", od is 1.36" wall thickness 0.1", except for edge warts which are 0.2" diameter blebs on the edge.

These sample holders should fit together in a long, sinuous snake chain on a flat surface.

18 February 2002
Sample Holders for the Sample Changer Snake Chain Type #2 -- with bottoms to hold samples. All external dimensions are the same as Type #1. These differ in that they have a tapered bottom:

1" = 2" (blowup)

Main outer circle 1.36" diam.

Hole for brass pin .07" diam.

The bottom in these sample holders should be 0.1" thick for the central circular area 1.0" in diameter, and then taper up to the sides at ~ 60 degrees.

Cross-section of type#2 holder perpendicular to snake axis

60 deg. taper around edge

- 0.5"
- 1.05"
- 0.1"
- 1.36"
- 0.2"

October 18, 2002
Brass Pin at Junctions

Outer Ring of Sample Changer snake chain

Clear Polyethylene spacer on inside of ring

White Plastic Bottom of Sample holder

Black Rubber flat 'O' ring

Each sample should be tangent to the leading brass pin, but no closer than the width of the polyethylene spacer. This minimizes jamming problems.

The sample's orientation mark should be aligned with the brass pin; the direction of the arrow (up or down) depends upon which measurement is being done.
I. 3. Nonacogs

These are two flavors of Delrin plastic gears and hardware to hold them in place. By playing around with the sample cups described above, we found that the 9-hole design was the most efficient we could produce. On each of the sample changing systems, we need to have two drive gears connected to a DC Servo motor via a brass or aluminum drive shaft to control the position of the paleomagnetic samples under the quartz-glass vacuum tube. For a 200-hole system, we need 7 unpowered idling gears arranged as shown on the base plate assembly above. (Feel free to design a bigger sample queue, if needed!)
Sample Changer 9-cog drive wheel, made from plastic, with the rod made from 1/4" brass

1" = 1"

Inner cusps are 1.19" from the center (tangent circle is 2.38")

The radius of each of the 9 cusps is 0.68", to fit the sample cups of the snake chain. (Drill with 1.36" diameter mill)

Cusp centers are located 1.19" + 0.680", or 1.87" from the center, for the first 0.5" of penetration. Move drill out 0.07" to drill remaining 0.1".

The top 0.1" of the nanocog assembly should be sloped slightly so that the sample cup snake chain holding the samples does not work its way up off of the drive assembly. It will stick out slightly from the base, as shown. (dimensions above are for the curved section).

1" = 2"

This brass rod is ~ 1/4" in diameter for attaching the no-slip gear, but with one side slightly flattened to allow the set screw to grab securely. (Note: only 3 of 7 nonacogs per changer need this)
Sample Changer 9-cog Drive wheels (4 per sample changer)

The radius of each of the 9 cusps is .68", to fit the sample cups of the snake chain.

Inner cusps have a minimum distance from the center of 1.19"

40 degrees between cusps

1" = 1"

KMS Plastic Raceway Double Row ball bearing assembly AR16DR-G, 1" ID, 2" OD, .75" high, Plastic non-magnetic bearings w/ glass balls

No-slip sprockets from PIC Design FRG6-050, shaft size 0.2498", OD 2.116", fits with PIC FRA-190 or similar Aramid (Kevlar) belt. Two assemblies have two sprockets, the other two (on the outside), one.

No-slip sprockets from PIC Design FRG6-050, shaft size 0.2498", OD 2.116", fits with PIC FRA-190 or similar Aramid (Kevlar) belt. Two assemblies have two sprockets, the other two (on the outside), one.
Sample Changer 9-cog drive wheel, Lip Assembly Detail
(Lip assembly is the same for both types of nonacogs) 2/27/2003

The lip edge should be 0.07"

(Use the same technique for both the drive and idling nonacogs)

To make the lip, mill down on the plastic exactly 0.5", then move radially out from the center 0.07", and finish drilling. Rotate 40 degrees, and do again for each of the 9 holes.
Sample Changer 9-cog Idle wheels
(7 needed per system)

1" = 1"

Inner cusps have a minimum distance from the center of 1.19"

The radius of each of the 9 cusps is .68", to fit the sample cups of the snake chain.

40 degrees between cusps

Inner diameter of the plug is ~1", to fit snugly inside the ball bearing assembly. The outer part is 1.18", to grip the inner sleeve of the ball bearing and hold it to the base plate firmly. The nanocog plastic rim is milled so that the bearing holds it up enough to clear the teflon base plate with a snug fit.

McMaster-Carr Supply Co., thermoplastic semi-precision ball bearings. standard open Delrin Raceways with glass balls PN- 6455K88

Plastic plug to hold bearing assembly firmly to base plate, with 1/4" hole to anchor to base plate.

0.05" Teflon (bonded to Aluminum)
0.125" Aluminum
mu-metal

1.6" od
1" id

Machine from 0.6" thick Dalran plastic.

1" id
Sample Changer Idle wheel Plugs (25 needed)

Inner diameter of the plug is ~1", to fit snugly inside the ball bearing assembly. The outer part is 1.18", to grip the inner sleeve of the ball bearing and hold it to the base plate firmly. The nonacog plastic rim is milled so that the bearing holds it up enough to clear the teflon base plate with a snug fit.

Central hole ~ 1/4" for brass bolt, countersunk at top for flat-head of bolt.
Aluminum Ring to hold bearing assemblies (4 per sample changer)

1"=2"

Outer diameter 2.5"

0.5"   0.25"   0.560"   0.125"

The lip diameter is just enough to support the outer bearing without interfering with its operation ~ 1.66"

Drill & tap 4 8-32 holes around the margin as shown,

inner diameter ~2.0", for snug fit of bearing assembly

May 29, 2003
Main Gear Mount Concept (Paleomag II)

- Non-Magnetic bearings that are held in place by the base plate and aluminum collar
- Aluminum base plate
- Gear connecting to drive belt from stepping Motor
- Aluminum ring spacer to hold bearings rings in place
- Teflon (bonded to Aluminum)
- Aluminum
- Mu-Metal

C7B 2/5/03
1. 4. Plexiglas Alignment Plate

On top of the base plate, where the quartz tube moves down and senses the top of each sample, it is necessary to have an alignment plate to position the tip of the quartz tube exactly over the center of the sample as it moves into position. That is done with two simple aluminum blocks that support a plexiglass plate. Note that the hole in the plate needs to be sanded slightly with 600 mesh sandpaper to allow the quartz rod to slide smoothly.
Sample Changer

Plexiglass Alignment Plate

Dec. 8, 2006

These plates position the 3/4" quartz glass vacuum rod over the center of the samples for pickup.

3/16" thick Plexiglass

The 4 small holes are 3/8" diameter, and the big hole is 3/4"

Please round the 4 corners slightly so they are user friendly
Sample Changer  Aluminum Plexiglass supports
(2 needed)

1" = 1"

These are simply aluminum blocks, 3" x 1.5" x 0.75", with four 1/2" deep tapped and threaded (10-24) holes on the top and bottom as shown. They support the plexiglass alignment plate.

End View

3" high
1.5" wide

Top View

3/4" thick

Drill and tap four 10-24 holes top and bottom, spaced 1" apart.
II. DC Servo Motor Positioning Hardware

Because the DC servo motors generate a strong magnetic anomaly, it is desirable to place them as far away from the samples being loaded on the tray as possible. In many labs, we have put layers of mu-metal shielding around the motors to knock down the residual magnetic fields. (In some labs, we have also mounted a mu-metal plate beneath the aluminum base plate as extra shielding, but that sometimes causes additional problems.). The following figures show how we solved this problem by dangling the motor below the plate and transferring torque up through a drive.
Sample Changer Motor Drive Shaft

1" = 2"

Made from 1/2" diameter brass or Aluminum rod, total length should be 1/2" shorter than the vertical support rods.

- 1/4" diameter to fit PIC no-slip gears
- 1/2" diameter shaft to fit snugly into the McMaster-Carr bearing in the top 2"
- 0.7" depth to fit snugly the 1/4" shaft of the DC Servo Motor
- Cotter Pin to anchor drive shaft to motor shaft semi-permanently

DC Servo Motor (Bottom)

Drill a hole 0.7" deep to fit snugly the 1/4" shaft of the DC Servo Motor.
Sample Changer Motor Support Bracket (2 needed)

April 12, 2007

1" = 1"

The motor bracket is cut from a 1/4" thick aluminum rectangle, 6.25" x 3.0"

Top View

these dots are (untapped) holes for 8-32 bolts, which will hold the two 1/4"L-shaped angle brackets (3" x 2") tightly.

Please tap 4 8-32 holes on a square 1.85" on edge, on center for holding motor.

Cut out a hole 1 & 5/8" in diameter centered in the middle, for the motor shaft to poke through.

Note: the SilverMax motor will be bolted to the bottom of this plate
Part #1: A 3/8" thick aluminum base plate with holes as shown - Please make TWO of these.

The two small holes in the center, on opposite sides of the center 1.1" diameter hole, should be drilled and tapped for 8-32 holes.

Note that the plate must be long enough so that the 8-32 holes in the vertical support brackets are EXACTLY 6" apart, so that they will align with the slots in the bottom of the base plate of the sample changer.

PLEASE MAKE 2 OF THESE!
Sample Changer Motor Vertical Support Brackets (2 needed)

These are machined from stock aluminum channel, 3" wide, 3/8" thick, length to match drive shaft

TOP End

1" = 1"

BOTTOM End

All holes on the ends are threaded 8-32, ~ 1/2" deep as shown

View of top end of U-channel only ........

These two unthreaded holes are to fit 8-32 screws that hold the bearing plate 2" from the top end of the support brackets.

2.0 "

many inches to the bottom End
III. Up/Down Arm and Vacuum Valve Assembly

For the Up/Down arm, we rely on 2G Enterprises to build the sliding assembly, but have them mount the smaller DC Servo motor on it to do the sample rotation. (We do NOT use the stepping motor systems 2G have employed for many years). We plumb in a vacuum-interconnect system with a 0.75” copper pipe system, and drill several 0.25” holes in their rotating shaft assembly to connect the vacuum system to the vacuum blower motor.
IV. Locating the Vacuum Blower Motor

The vacuum blower motor is rather noisy, so it is best to locate it in an area that humans do not inhabit frequently (like a roof or steam tunnel room), and run the vacuum tube and power cord back to the lab area. A good example of how to mount the vacuum blower is shown here from Occidental College.
V. DC Servo Motor Control Components

A major advance for the present system was the switch to DC Servo Motors with optical encoding (accurate to 1/8000 of a revolution), rather than the old stepper-motors used on most paleomag sampling applications. Software for controlling the motors produced by QuickSilver Controls of San Dimas, CA, were particularly easy to implement. Three motors are required: two hefty ones to move the sample dolly assembly and change the samples, and a smaller one to rotate the quartz-tube vacuum system. One limit switch is used on the system to sense when the up/down motor has reached the top of its range.

The wiring is simple. Going from the N2 (SilverNugget) controllers to the RS-232 input lines only involves 9-pin D connectors to the 48 V DC power supply.
Back of box, Outside facing forward. Use D-punch to open holes below, after drilling holes

Front of Box, facing Inward. Only hole here is for the power switch

Power Supply - no holes here!

The Aluminum box is from LMB, 2946 E. 11th St., LA 90023
a 'Modernistic Enclosure (M-E)'
4" high, 11" wide, 7" deep
pin #1 of the power switch connects to the hot lead from the +110 V AC supply

pin #2 of the power switch (center) goes to the "L"ine ac input of the Mean Well Power supply

pin #3 of the power switch goes to the "N"eutral ac input of the Power Supply

The neutral line from the AC cord also goes to the "N"eutral ac input of the Power Supply

The +48 V line goes to the center of the +48V terminals, and the ground lines all go to the center of the three -V lines of the MeanWell power supply
VI. AF and Rock Magnetism Coils

The coils for alternating fields and rock magnetic experiments are mounted in line between the bottom of the base plate and the top of the magnetometer, as shown in the overview diagram.
Make from thermally-resistant plastic

1" = 1"

The red shaded areas show the maximum extent of the transverse coils, which have 1.5" x 1.5" cross-sections. They are tangent to the central hole.

Inside Diameter tapers from 1.26" to 1.625" across the bottom.

Outside Diameter 2.0", to fit in the base support ring

Inside Diameter at base 1.625"

3.0" long groove for winding axial coil, o.c. with radial coils

3.75" from base plate level to center of coils

7.5" from top to base plate Level

Base Plate Level

0.35"
Make from thermally-resistant plastic (Phenolic)

AF Transverse Coil Support tube

Inside Diameter

1.26"

Outside Diameter
2.50" everywhere

7.5" from top to base plate Level

3.75" from base plate level to center of coils

Inside Diameter tapers from 1.26" to 1.625" across the bottom 1/4"

7.0" Radius circle

Outside Diameter 2.0", to fit in the base support ring

3.0" long groove for winding axial coil, o.c. with radial coils

4.0" Radius circle

.5"

1" = 1"

April 22, 2005
Alternating Field Coil Base Plate

1/2" = 1"

Made from a disk of plastic 9.375" in diameter, 1.25" thick

0.25" deep, 2.500" diam.

As shown by the dotted guide lines, there should be six 1/4" holes drilled at 60 degree angles around the edge, each spaced 4" from the center.

At a distance of 3.5" from the center, there should also be two groups of 4 holes spaced as shown, which are drilled and tapped to fit 8-32 screws.

Indentation for top of magnetometer probe, 5.5" diam. 0.75" deep.

Note: this piece is highly dependent upon the magnetometer setup.
ARM Coil form for 2G systems
(5 needed)

**Top View**
- Spacing between circular cuts: 0.63" and 1.26"
- 3.0" diameter

**Edge view #1 (North Side)**
- All grooves 1/16" deep
- 1/8" wide, 1/16" deep
- 1/16"
- 1/8"

**Edge view #2 (East Side)**
- 1/16" wide, 1/16" deep
- 0.345"
- 1.333"
- 0.345"
- 3.990" Radius circle
- 1/8" wide, 1/16" deep
- 1/16"
- 1/16"
- 1/16" diameter
- 1.26"

Suggested order of machining:
First cut the grooves for the coils at the proper spacing. They should be 1/16" deep, centered as indicated.

Then make the two 3.990"-diameter cuts in from two sides, leaving a 1.26" space in the center in from each side.

(It is OK to put a mounting hole.)

Use 3" diameter cylinder with 1/8" thick walls, 5" long (made from phenolic?)
Items to order for the 200 sample automatic vacuum changer - needed for each assembly

Last updated: January 8, 2008
Prices last checked: September 2006

Estimated Cost for single system: (red items):
8.25% tax =
$36,631.01

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Precision Industrial Components (PIC Design CO):
telephone for the PIC Design is 1-800-243-6125, FAX 203-758-8271
info@pic-design.com

 PIC Part #  # needed  Unit Price  Total $  Description
FRG6-022  2  $19.19  $38.38  aluminum no-slip sprockets with 22 teeth and quarter inch shaft, for the main stepping motor.
FRG6-050  2  $17.00  $34.00  aluminum no-slip sprockets with 50 teeth and quarter inch shaft, for the nonacog drive wheels
FRA-130  2  $11.35  $22.70  Aramil no slip positive drive belts, for fitting the drive wheel spacings; includes 2 extra belts for s

total PIC=  $95.08 per system

McMaster-Carr Supply Co.

Glass bearings for idle wheels
www.mcmaster.com

 part  # needed  Unit Price  Total $  Description
PN-6455K88  7  $4.46  $31.22  thermo-plastic semi-precision ball bearings.standard open Delrin Raceways with glass balls

Glass Bearings for the gear-powered driving wheels
www.kmsbearings.com

 part  # needed  Unit Price  Total $  Description
AR16DR-G  2  $20  $40.00  1" ID, 2" OD, .75" high, Plastic non-magnetic bearings

Teflon Treating Agent for changer top and epoxy
www.berghofusa.com/be04002.htm

 Part  
Chemgrip Epoxy Cement  
Chemgrip Treating Agent

Epoxy Adhesive will bond treated fluropolymer to all common materials - regular
For making Fluorocarbon surfaces bondable.

sum:  $161.11

DC Servo Motors:
Manufacturer - Quicksilver Controls Inc (888-660-3801), contact - David Dominguez x107
Distributor - Linear Industries (408-455-2520), contacts - Tim McKay and Scott Pierce [826-303-1130 x117 (Scott)]
http://www.quicksilvercontrols.com/

 part  # needed  Unit Price  Total $  Description
QCI-A23-3-A-01  1  $280  $280.00  QuickSilver Controls I-Grade 23-3 Motor w/8000CPR Encoder
QCI-A23H-5-A-01  2  $345.00  $690.00  QuickSilver Controls I-Grade 23H-5 Motor w/8000CPR Encoder
QCI-N2-F2-04-EE  3  $595.00  $1,785.00  SilverNugget I-Grade with 3.5 Amp Driver
QCI-C-D15P-D15S-25  3  $165  $495.00  QuickSilver Controls DB15HD Motor I/F Cable 25 ft. Connects to I-Grade motor/encoder.

48 V Power Supply for Stepping Motors:
Made by the Mean Well Company:
http://www.meanwellcentral.com/?page=products&category_id=40&CFID=4530192&CFTOKEN=64566877

 part  # needed  Unit Price  Total $  Description
SP-500-48  1  $205  $205.00  500 Watts +48 VDC, 10.5 Amps
### Aluminum Box for the Motor Power Supply Box

http://www.lmbheeger.com/products.asp?catid=33

Model# UPS 525-12-9  Uni-Pac Series 525 With Standard Sic  $101.72  $101.72  Depth: 8.875", Width 11.75", Height 5.0625"

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#### Machine Shop Items

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<td>Holder rings</td>
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**sum shop** $3,600.00

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#### Lava Octopus-550 8 RS232 9-pin connectors


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#### EE Technician

IRM and ARM controller Boxes - $7,500.00 approx. each.

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### Parts List for Paleomag Vacuum Pick-and-Place Source and Valve Controller (Paleomagnetism Lab)

#### Direct Acting Solenoid Valve, 1" Brass fittings

- Part No: Z2HNG9Y250-DA-1156-009
- Vendor: Granzow Inc.
- www.granzow.com
- QTY: 2
- Total $386.56

#### 1" Brass Tee

- Vendor: University stockroom
- QTY: 1
- Total $13.50

#### 1" x 3" Brass Fittings

- Vendor: University stockroom
- QTY: 3
- Total $2.10

#### RS-232/TTL Valve State Controller

- Part No: GPSEE0301
- Vendor: University EE Lab
- www.gps.caltech.edu
- QTY: 1
- Total $918.60

**Sub Total** $1,320.76

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#### RS-232 Controller Cost Breakdown

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**Sub Total** $918.80

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#### Vacuum Blower

- Part No: 3HV24
- Vendor: Granger
- Total $666.64

#### Vacuum hose

- Part No: 4XR62-1
- Vendor: Goodyear Spriaflex
- Total $80.88

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Grainger

1-888-361-8649 Monday-Friday, 7 a.m. – 7 p.m. (CT)

http://www.grainger.com

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Page 2 of 3
Af Coil Stuff:

- Magnet Wire: www.planetengineers.com/product.asp?id=955
  - $772.27 (55 lb spool 18.5 gauge high temp Planet Engineers 818-785-1347)
- Epoxy: Stycast 2850FT black epoxy resin 1 qt cans (3lb)
  - $150.00
  - $735.90 for spool and $36.37 for shipping
  - Planet Engineers 818-785-1347
- Epoxy hardener: 23 LV catalyst, 1 lb bottle ~$150 (resin: $86.25; cataly
  - $150.00

Local Hardware Store:
- Wheels for vacuum tube: $25.00
- Vacuum Tube: $25.00
- Hardware: $25.00
  - sum: $75.00

Measurement Computing

- PCI-DAS6030 board for controlling the Rockmag system:
  - $1,185.00
- SCB-100 connection board:
  - $199.00
- 1-meter long connection cable C100HDS-3:
  - $99.00
  - [http://www.measurementcomputing.com/cbicatalog/cb/product.asp?dept%5Fid=104&pf%5Fid=1204](http://www.measurement comput ing.com/cbicatalog/cb/product.asp?dept%5Fid=104&pf%5Fid=1204)
- 1-meter long connection cable C100MMS-1M:
  - $125.00

2G Enterprises Manual Sample Handler with modification for stepping motor

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ASC Scientific

- Craig Amerigan 800-875-4272; John Toth 800-272-4327
- Bartington MS2B dual frequency susceptibility sensor: $3247 (3102+clearance and overseas charges)
- ASC Model IM-10 Impulse Magnetizer
- External Coil accessory:
  - 1 – 380 ($350+shipping) $380.00
  - external coil accessory for ASC Model IM-10 Impulse Magnetizer