The Design of the SNO NCD Construction Hardware In Situ Monitoring Experiment (CHIME)

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Abstract

The use of ultra-low background ^{3}He proportional counters in the SNO detector will provide a means of measuring neutrons from the neutral-current interaction rate of solar neutrinos. Since the binding energy of the deuteron is only 2.2 MeV, gamma rays from natural decay chains in the proportional counters may photodisintegrate the deuteron and thus simulate the neutral-current signal. This poses stringent limits on the radiopurity requirements for the counters.

We propose to perform an *in-situ* background measurement of the construction materials used in the Neutral Current Detector (NCD) array prior to its deployment in SNO. An *in-situ* measurement of the background from seven Neutral Current Detectors will determine the activity of ^{232}Th in the Neutral Current Detectors and thus determine an upper limit on the photodisintegration background generated by the radioactivity in the NCD array. In this STR we describe the design, construction, and preparations for deployment of this background test source.

1 Introduction

To ensure that the photodisintegration background due to the presence of the NCD array in the D_2O volume is low, we plan to perform an *in-situ* measurement of the materials used in the construction of the array prior to its deployment. The background test source in this measurement must meet the following criteria:

- The construction materials of this source must be identical to those in the real NCD array. This will allow us to set a limit on the photodisintegration background from the entire NCD array.
- The background test source source can be deployed using the calibration source manipulator system. This will minimize the time required to deploy the source.
- This source must have a negative buoyancy.

In this design note we shall describe the design and construction of this source in detail.

2 Design

The Neutral Current Detector (NCD) array consists of 770 m of ^{3}He proportional counters arranged in 96 strings with 300 counters. The counter bodies are made of about 450 kg of ultra-pure CVD nickel which contains natural Uranium and Thorium at about the 1-2 ppt level. The photodisintegration gammas are produced in the decays of the ^{232}Th (^{208}Tl $\rightarrow$ ^{208}Pb, E_γ=2.615MeV) and ^{238}U (^{214}Bi $\rightarrow$ ^{214}Po, E_γ=2.445MeV) chains and in the decay of ^{56}Co (^{56}Co $\rightarrow$ ^{56}Fe, E_γ >2.224 MeV)

A Construction Hardware In Situ Monitoring Experiment (CHIME) has been designed to measure the NCD originated background in the presence of the D_20 contribution prior to the deployment of the entire NCD array. Seven individual counters (Figures 1 and 2) arranged in a close-packed configuration (Figure 3) will be deployed as a background test source in the SNO detector. The construction materials and procedures for the CHIME counters are essentially identical to those in the real NCD array with the difference being that the CHIME counters are not active. The CHIME counters are not designed to be active neutron counters because of the additional background associated with the readout cable.

Initially, it was considered to deploy a single active NCD for this background measurement [1]. However, the background due to radioisotopes in the readout cable would completely mask the photodisintegration background due to the proportional counters themselves. In case of the NCD array in SNO, the background associated with the readout cables is not a problem since the NCD cables do not extend much into the main detector volume and connect to the top end of the neutral-current detector strings near the chimney of the acrylic vessel.

The construction of each CHIME counter in the septet is identical. The diameter and the total length of each counter are 2" and 45.1" respectively and its mass is about 715 g. Each CHIME counter is similar to a string of 2 proportional counters. Figures 1 and 2 show the schematic and a technical drawing of a CHIME counter, while Figure 3 illustrates the close-packed configuration of the septet.

3 Construction and Assembly of CHIME

3.1 General Construction

The total length of each CHIME counter is 45.1", which consists of two CVD nickel tubes of lengths 9.4" and 34.7" laserwelded together. These tubes are electropolished and chemically cleansed in the manner described in Sec. 2.1 of [2] prior to the construction of the individual counters. Two 0.5" holes, separated by 180 degrees, are drilled in the long Ni tube as indicated in Figure 1. These two holes will server as pressure relief once the counters are submerged in the heavy water during the *in-situ* measurement.

An anchor endcap is laser-welded to one end of the short nickel tube (D1 in Figure 1). Another endcap with its outer flange removed is laser-welded to the other end of the tube (D5 in Figure1). Since these endcaps seal the inner volume of the CHIME the two welds are required to be vacuum leak tight to 10^{-5} std cc/s. In comparison, the standard constraint for leak rates in Neutral Current Detectors is 10^{-9} std cc/s [2] .

Inside this enclosed volume are four endcaps that were processed by IJ Research as described in Sec. 1.6 of [2]. Endcap D2 is a regular counter endcap with a sealed copper endplug and copper pinch-off tube. The volume enclosed between the endcaps D2 and D5 is filled with ^{4}He according to the gas fill procedures [3] for Neutral Current Detectors and then evacuated to simulate counter handling during gas fill. The endcaps D3 form a normal counter-to-counter coupling, with the only exception that the anode wire feedthrough holes in the copper endplugs are not sealed in these two endcaps.

That is, the anode wire in the normal NCD counter is not strung in the CHIME counter. It is placed inside the enclosed volume instead. Because of the physical constraint on the length of the enclosed volume in the CHIME counter, one of the endcaps (D4) has a shortened quartz tube. These endcaps were selected from our inventory of endcaps that have quartz tubes damaged during the endcap production and handling processes. These four enclosed endcaps (D2, D3, and D4) are laser-welded to the short Ni tube. The primary purpose of these welds is to hold the four endcaps in place. Therefore, these welds do not need to be leaktight.

Since the CHIME counters are not active the criteria for the quality assurance of some counter components are less stringent. Components are chosen from our inventory to meet all specifications and requirements of the CHIME design. They would not necessarily meet all of the QA criteria for NCD components. Amongst these components are endcaps that do not pass the high voltage tests and counter tubes that show signs of pinholes and do not meet the standard specifications for leak rates. Appendices B, C, and D describe the construction anomalies and summarize the characteristics of the CHIME components and their QA results.

3.2 Assembly of CHIME Counters

The septet of CHIME counters is a close-packed configuration held together by CVD nickel rings that connect the seven counters at the top through the holes on the outer ring in the anchor endcap D1 (Figure 4) and at the bottom of the CHIME tubes through additional holes of the same diameter. The CVD nickel rings are the same as the ones used in the assembly of the NCD anchors and thus a NCD production component. A band of CVD nickel across the top of the central CHIME counter serves as an attachment point for the vectran rope. This is not a standard piece. However, since it is made from CVD nickel following standard handling and manufacturing procedures it conforms with our cleanliness requirements and will not affect the proposed background measurement

3.3 Constraints on the CHIME Leak Rate

The use of porous nickel tubes in the construction of the CHIME makes it necessary to consider the leak rate constraints for the CHIME. The two cases of heavy water getting into the counters and counter gas leaving the counter volumes need to be considered:

According to the NCD blind weld leak test report [4] an interspace leak rate of 10^{-7} std cc/s will result in condensed water after 10 years in SNO. The CHIME does not need to be electrically sound so water is less of an issue. If the CHIME spends 2 months in SNO (upper limit), and we scale the result from the leak test by the ratio of times this leads to a limit of 10^{-5} std cc/s. However, this is a very conservative limit since even a gram of water would not matter in the CHIME.

The condensed water criterion [4] considers droplets and therefore it has been assumed that a leak rate even one order of magnitude greater than this would be acceptable. Therefore, we chose 10^{-4} std cc/s as the leak rate constraint in the construction of the CHIME. A total leak rate of 10^{-4} std cc/s is considered to be acceptable and hence for each CHIME counter the leak rate needs to be less than 10^{-5} std cc/s.

In the initial design of the CHIME counters, ^{4}He was used as a fill gas. Exiting ^{4}He gas is only a problem if it ends up in the phototubes. At 10^{-4} cc/s and after 2 months, one has about 40 cc of gas. Dispersed into the cavity, this amount would represent 10^{-3} of the natural atmospheric abundance of He. Nevertheless, it was decided to go through the motions of filling with a ^{4}He-CF_4 gas mix according to the NCD gas fill procedures [3] but as a last step to evacuate the CHIME counters. Thus even if the CHIME counters do leak, no ^{4}He will emerge into the heavy water and the SNO detector.

3.4 Additional Backgrounds from CHIME Construction

The ^{3}He proportional counters are made by the chemical vapor deposition of nickel from nickel carbonyl, $Ni(CO)_4$. This produces almost pure nickel with almost no Uranium or Thorium. However, although the counters can be produced with very low activity any exposure to cosmic ray neutrons produces activity from spallation products. ^{56}Co can be formed as a spallation product of nickel with cosmic ray neutrons through ^{58}Ni(n,p2n)^{56}Co and ^{60}Ni(n,p4n)^{56}Co.

Calculations show that 32% of ^{56}Co decays result in gamma rays with energy greater then 2.224 MeV [5]. These gamma rays can break up a deuteron and thus contribute to the photodisintegration background. Since the tubes used for the construction of CHIME were manufactured in 1997 we can assume that the level of ^{56}Co in the CHIME counters has saturated. The CHIME was stored underground on December 20, 1998 and we expect that by the end of April 1999, ^{56}Co and ^{208}Tl are equal in gross neutron production rates if neutron production rate from Thorium is 20% of the Standard Solar Model (SSM). There is then a strong incentive to do 2 CHIME measurements, one early on (possibly in July or August of this year), and one later on.

All NCD construction materials have been radioassayed to assure the cleanliness of the individual NCD components. Although the CHIME has been designed to measure the photodisintegration background, the NCD neutron background can be estimated from the preliminary results of the NCD radioassay program [6]. Table 1 summarizes preliminary results. The contribution from ^{238}U is not included.

Another concern and source of background is the exposure of the NCD and CHIME construction materials to radon in the laboratory air. In addition, laboratory air is a source of particulate matter. While most of the construction is done under clean room conditions some of the components for the CHIME counters were exposed to laboratory air during construction. This was mainly because of the increased complexity associated with the construction of CHIME and some of its non-standard assembly procedures. It is estimated that the air exposure of the CHIME counters exceeds the air exposure of standard NCD's by a factor of 2. While we are confident that this will not make this background measurement impossible we hence expect that this measurement will give us an upper limit on the photodisintegration background from the entire NCD array.

Component	*Contained Mass Th* (in μg)	*Effective Mass Th* (in μg)	*% SSM*
Uniform Constributions			
Counters	0.3±0.5	<0.8	<1.6
Endcaps	0.1±0.9	<1.0	<2.0
Near AV Contributions			
Delay Lines	-1.1±1.9	<0.2	<0.4
Wet-end connectors	0.2±0.6	<0.2	<0.4
Cable	2.4±2.7	<1.3	<2.6
Total	0.8±1.4	<2.2	<4.4

Table 1: Preliminary results from the NCD radioassay program.

3.5 Construction Summary

Due to the complexity and non-standard dimensions of the CHIME counters some minor problems were encountered during the construction and assembly of the CHIME. These are described in Appendix B of this document. However, the cleanliness requirements for the CHIME counters and the standards for building Neutral Current Detectors were met at all times. Given the repairs and construction irregularities we encountered during the assembly of CHIME we expect that any measurement we make will represent an upper limit on the photodisintegration background from the actual NCD array.

4 Storage and Handling Underground

Currently, the CHIME is stored underground in the NCD cooldown rack in the control room. The procedures for handling the CHIME underground are similar to those for receiving and handling NCD's underground. The CHIME is sealed in a nylon bag under nitrogen to prevent contamination through radon contaminants from air. During deployment the calibration source procedures will be followed closely.

The CHIME will be subject to the same review and approval process as all objects that are lowered into the heavy water in the acrylic vessel (see Source Certificate, Hardy Seifert, August 1998).

4.1 Radon Emanation Test

A radon emanation test will be conducted on the CHIME while it is underground to assure its cleanliness before deployment. The CHIME leach tank will be 48" long by 7" (minimum) ID. It is made by the same fabricator that made the ROV leach tank. A teflon (all wetted parts) bellows pump will circulate ultrapure water over the CHIME assembly and through a trap containing a cation exchange resin.

Preliminary studies with the similar ROV leach system indicate that the detection limits for ^{228}Th and ^{226}Ra are about 5000 atoms (5 disintegrations/day) and 2x10^6 atoms (2.5 dpd) respectively. The overall detector burdens for these species are 2x10^5 atoms ^{228}Th (210 dpd) and 2x10^9 atoms ^{226}Ra (2100 dpd). These are the amounts that would be in secular equilibrium wit 0.6 micrograms ^{232}Th and 2 micrograms ^{238}U respectively. These detection limits correspond to approximately 3 times the standard deviation of the background count rate in the alpha energy range of interest [7].

The radon emanation test hardware is currently being tested at LANL and will be shipped to Sudbury by June. It is anticipated that one month will be required to establish the equipment underground and conduct the emanation tests.

As part of the cleanliness review process, technical drawings of the CHIME along with a list of materials exposed to the heavy water (nickel and vectran) will be submitted. The CHIME handling and deployment procedures will also be available for review.

4.2 Manpower Requirements

Establishing the emanation hardware underground is expected to require 2 people working 1 shift per day for a total of 2 weeks. It is expected that during the emanation test one person per shift would be adequate to monitor the experiment, which would last 2 weeks.

5 Deployment

5.1 Deployment Procedures

The septet of CHIME counters is negative buoyant and can be deployed as a background test source along the central axis of SNO using the existing calibration source deployment hardware and manipulator system. Since the CHIME is negatively bouyant itself, anti-buoyancy weights are not needed in the deployment. The mass of the CHIME septet is 4947 g, and its free fall weight is 9% over its buoyancy in heavy water.

A 100-foot 1/16" Vectran rope will be tied to the septet of counters. The loose end of this rope will be stored in the rope winder in the manipulator system [1]. Since the existing source umbilical is too radioactive it cannot be used as a backup retrieval device. The umbilical will be replaced with a vectran line. If this is not feasible the source deployment hardware will be replaced with the NCD hauldown hardware which mounts directly on the top of the existing 48" source deployment tube. If it is necessary to use the NCD hauldown hardware, performance test results, procedures, and technical drawings of the hardware will be provided for review.

Deployment of the CHIME will follow closely the procedures for handling and deploying standard SNO calibration sources. Detailed, CHIME specific procedures and instructions will be finalized in April when the CHIME emanation tests are conducted underground and all the calibration source deployment hardware is in place. The CHIME deployment procedures will be made available for review before deployment. These procedures will cover the handling of the CHIME, the first deployment in SNO, the removal of the CHIME, and any necessary cleaning and drying procedures when the CHIME is removed from SNO. The case of a second deployment will be considered separately depending on the outcome of the first CHIME background measurement.

[1] This rope winder is not the umbilical winder. The rope winder is used in parallel to the umbillical system in the calibration deployment hardware

5.2 Impact on SNO Operations

The deployment of CHIME is expected to be no different than that of a standard calibration source and will have minimum impact on the SNO operating schedule. Monte Carlo studies show that the presence of the CHIME will have no measurable impact on the physics goal of SNO [8]. It should be noted by the physics scheduling committee that while the CHIME is deployed it will not be possible to deploy other calibration sources.

5.3 Safe Procedures

Deployment of CHIME will follow approved procedures which will be similar to those for deployment of a standard calibration source. Use of the existing source deployment tube, gate valve, and deployment procedures will prevent light or laboratory air debris entering the detector. The usual cleanliness procedures applicable to handling sources will be observed during the CHIME deployment.

5.4 Failure Modes and Worst Case Scenario

The failure modes are similar to those associated with deployment of a simple source along the axis of the acrylic vessel. Two independent tether lines will be employed. The failure of both systems is considered extremely unlikely and will have been tested beforehand. The worst case scenario is considered to be that in which the CHIME breaks free of both tether lines and falls to the bottom of the vessel. The weight of the CHIME in heavy water is less than 0.5kg and the terminal velocity so low that it is not expected to damage the acrylic vessel. Since the radioactivity and light obscuration of the CHIME is low it could remain in the heavy water until deployment of the NCD's in which case it would be removed by the NCD ROV, the remote-operated vehicle which will be used during the installation of the NCD's.

5.5 Manpower Requirements

Deployment of CHIME is expected to take 2 people, one NCD CHIME expert and one manipulator expert. The entire deployment procedure can be completed in 2 shifts. Retrieval is expected to require a similar effort. One representative will be on shift during the 10-30 days of data taking. The NCD collaboration will be responsible for meeting all of the manpower needs of the CHIME program.

6 MC Simulations and Data Analysis

The complete geometry of CHIME, the SNO detector response, and all important decay schemes can be simulated using the SNO Monte Carlo code. Preliminary studies of the reconstruction distribution and the energy spectra have shown that an analysis approach based on fiducial cuts and the shape of the ^{56}Co energy distribution will allow us to discriminate the ^{56}Co contribution to the photodisintegration background with high enough accuracy. In addition, further techniques will be developed to distinguish reconstructed events in the fiducial volume due to the ^{208}Tl decay in the CHIME and ^{208}Tl decays in the D_20. Detailed results of our MC studies will be described in another SNO Technical Report [8].

The backgrounds external to the CHIME measurement have also been investigated [9]. These backgrounds include mis-reconstruction of beta-gamma events originating from the PMT's, the inner H_2O, the acrylic vessel, and beta-gammas originating from the inner D_2O volume.

7 Schedule

In order to allow the cosmogenically produced ^{56}Co to decay, the CHIME must be stored underground for at least 3 months. It was placed on the 6,800' level on December 20, 1998 and will not be ready for deployment before April 1999.

The radon emanation test hardware will be shipped to Sudbury in June and set up during April. It will be accompanied with the documentation required by INCO, CSA, and SNO. It is anticipated that the radon emanation tests will be completed by July.

The deployment of CHIME will have minimum impact on the SNO operating schedule. All additional personnel required for deployment of the CHIME will be provided by the NCD collaboration. The following is a schedule of CHIME activities and milestones. The actual date of CHIME deployment will depend on the SNO detector schedule at the time.

Completion Date	*CHIME Project*
since 12/20/98	CHIME cooldown phase underground
06/01/99	Emanation hardware, procedures approved
06/01/99-08/01/99	Emanation hardware underground, tests conducted, report written and submitted
07/01/99	CHIME deployment approved
08/15/99-08/30/99	First deployment of CHIME
10/01/99-10/15/99	Second deployment of CHIME

Table 2: Projected CHIME Schedule

8 Conclusions

Provided that the hardware for deploying standard calibration sources is in place the CHIME will be ready for deployment by May 1999. During the time of the CHIME deployment manpower from the NCD group will be on site to perform the deployment, monitor the experiment, and to analyze the CHIME data online. It is expected that the Construction Hardware In Situ Monitoring Experiment will allow us to determine an upper limit to the photodisintegration background from the NCD array at the 5-10% level and hence provide an acceptance test prior to the installation of the NCD array.

A CHIME Construction Procedures

In the following, we shall outline the basic steps that have been followed in the construction of a CHIME counter:

1. **CVD Ni tube preparation**. Nickel tubes are cut in lengths of 9.4" and 34.7". Two 0.5" holes are drilled in each of the 34.7" tubes as indicated in the CHIME schematic. All the Ni tubes are chemically cleansed as outlined in [2] (same tube preparation procedures that the counter tubes go through). All ECs follow the QA/QC checks as in [2].

2. **EC D3 (with hole) preparation**. Attach a copper end plug to the D3 (with hole) EC. Then detach/remove the copper end plug. This simulates the parts and composition of copper end plugs on normal counters. Also, pinch off the copper pinch off tube on the D3 EC.

3. **Install Endcap D3 (without hole)**. Make dimple in tube at 3.42" from straight end for positioning this EC. Put"A" fixture onto positioning device and place the EC on the end of the device. Make sure the orientation of the endcap is correct (see schematic). Through the flared end, position the EC into the appropriate place in the tube. Then, take the"Laser Marks" piece, put it flush against the positioning device, and scribe mark the tube along the "A" edge. This will mark the place to weld. Remove the positioning device and take off the "A" fixture. Weld the EC. This weld does not need to be fully leak tight.

4. **Other parts samples**. Through the flared end, put in a sample of wire and the copper end plug from procedure 2 into the tube. Make sure the parts do not interfere with the quartz tube opening in the EC D3.

5. **Install Endcap D3 (with hole)**. Make dimple in tube at 6.8" from straight end for positioning this EC. Put "B" fixture onto positioning device and place the EC on the end of the device backwards. Be extra careful to make sure the orientation of the endcap is correct. Through the flared end, position the EC into the appropriate place in the tube. This endcap will be difficult to install, but once you get it into the tube, it will be able to be pushed all the way to its designated position. Then, take the "Laser Marks" piece and scribe mark the tube along the "B" edge. Remove the positioning device and take off the "B" fixture. Weld the EC. This weld doesnt need to be fully leak tight.

6. **Install Endcap D4**. Make dimple in tube at 7.52" from straight end for positioning this EC. Place the EC in the end of the positioning device. Note, no fixture is required for positioning this EC (position C). Through the flared end, position the EC into the appropriate place in the tube. Then, take the "Laser Marks" piece and scribe mark the tube along the "C-D-E" edge. Remove the positioning device. Weld the EC. This weld doesnt need to be fully leak tight.

7. **Install Endcap D5**. Make dimple in tube at 8.76" from straight end for positioning this EC. Put "D" fixture onto positioning device and place the EC on the end of

the device. Through the flared end, position the EC into the appropriate place in the tube. Then, take the "Laser Marks" piece and scribe mark the tube along the "C-D-E" edge. Remove the positioning device and take off the "D" fixture. Weld the EC. This weld must be fully leak tight.

8. **Leak check**. Leak check the tube at EC D5 and around all welds.

9. **Install Endcap D2**. Note do not pinch off the Cu pinch off until after the gas has been filled. Make dimple in tube at 1.28" from straight end for positioning this EC. Put "E" fixture onto positioning device and place the EC on the end of the device. Through the straight end, position the EC into the appropriate place in the tube. Then, take the "Laser Marks" piece and scribe mark the tube along the "C-D-E" edge. Remove the positioning device and take off the "E" fixture. Weld the EC. This weld must be fully leak tight.

10. **Leak check**. Leak check the D2 EC to make sure the seal is leak tight.

11. **D2 copper end plug**. Put a copper end plug onto the D2 EC using normal end plug installation procedures. Vacuum seal the copper end plug. This must be leak tight.

12. **Leak check the end plug**.

13. **Gas fill**. Fill the tube with He-4 following the gas fill procedures outlined in [1]. You must pinch off the copper tube once the filling is done.

14. **Install Endcap D1**. Make dimple in tube at the appropriate place on end of tube from straight end for positioning this EC. Hold the tube vertical with the straight end down. Fill the space with He-4 and then insert EC D1. Weld the EC. This weld must be fully leak tight.

15. **Leak check in the whole body counter**.

16. **Weld Ni tubes**. Laser weld the 9.4" CHIME counter section to the 34.7 Ni tube as shown in D6 of the chime schematic

B Irregularities During CHIME Construction

This section describes miscellaneous irregularities that occurred during construction of the CHIME:

The order of installations and procedures as outlined in Appendix A was followed except during repairs. However, the handling of the CHIME components during construction was not always according to standard NCD procedures because of the CHIME dimensions. They required non-standard handling tools and procedures. Because of this the anode wire was not strung as usual in the CHIME counters. Instead 4 meters of copper wire and 1 endplug were put into all the CHIME counters except for in X1. There are two Cu endplugs, no wire, and a broken quartz piece. Broken quartz pieces may have been put into the other CHIME counters if one of the EC's broke its quartz during production.

In simulating the installation of Cu endplugs, the following non-standard procedure was used: The EC's were placed on a holder and a wet *Kimwipe* was wrapped around the quartz as a heat sink. The plug was put on or taken off at the same time. The areas that would have been exposed in a normal detector were cleaned of flux with alcohol. On some of them, more solder than necessary was used. Flux on the inside of the sleeve and part of the plug was not cleaned. As a result, there will be small amounts of flux exposed in the sealed volume of the CHIME.

The selection of non-standard nickel tubes and considerations regarding the leak rate constraints are described above in Sec. 3.3 of this document. Because of the necessary repairs on the CHIME the air exposure is higher by about a factor of 2 as compared to standard Neutral Current Detectors. The small parts contained in the sealed volume of the CHIME counters are listed in the table 2.

CHIME Counter	*Small Parts in Counter Volume*
X1-112-1	2 Cu endplugs, broken quartz
X2-112-1	1 Cu endplug, 4m wire
X3-112-1	1 Cu endplug, 4m wire
X4-112-1	1 Cu endplug, 4m wire
X5-112-1	1 Cu endplug, 4m wire
X6-112-1	1 Cu endplug, 4m wire
X7-112-1	1 Cu endplug, 4m wire

Table 3: Small Parts in CHIME Counters

Additional irrgularities concern the counters X1-112-1 and X3-112-1. They were brought out of the clean room for a short period time to be cut and flared for repair. The tinning of the D3 EC's was done all at once. When the counters were assembled, holes in the welds occured due to misplacement of the ECs. During a repair phase a second laser weld was placed over these holes to close them.

C CHIME Tube Assignments and Cutting Procedures

Four tubes, T179, T316, T318, and T322, were selected according to the NCD splotch density requirements [10]. These tubes were electropolished in July 1998 following standard procedures. The procedures for electropolishing tubes are described in detail in the NCD Construction Document [2]. Since then, the procedures for electroplishing raw tubes have been optimized and changed according to the cleanliness of the raw tubes, mostly because it became necessary to remove surface contamination from tubes that were stored at an underground storage facility in Index, Washington. The tubes that were selected for the construction of CHIME were never stored there and thus did not have this problem. Detailed and extensive studies of our electropolishing procedures have shown that during the entire NCD construction process the completed Neutral Current Detectors meet the same stringent cleanliness requirements.

For the construction of the CHIME counters tubes were selected that showed a high number of pinholes in the body of the tube. Since the CHIME counters are not active this will not affect the performance of the counters in the CHIME experiment. Furthermore, there is also no hypothesis that correlates a bulk or surface alpha activity with pin holes in the nickel tubes. We assume that this is true. The interpretation of CHIME data will rely on this assumption.

With regards to their aluminum splotch density [2] tubes with an average splotch density of 10% were chosen. This corresponds to the average measured splotch density [10] and allows us to represent the whole NCD array most accurately. The following table lists the tube assignments and splotch densities for the CHIME counters:

CHIME Counter	*Tube IDs*	*Splotch Density of Tubes*
X1-112-1	T179	7%
X2-112-1	T316, T179	10%, 7%
X3-112-1	T318, T316	22.3%, 10%
X4-112-1	T322, T316	0%, 10%
X5-112-1	T322, T318	0%, 22.3%
X6-112-1	T322, T318	0%, 22.3%
X7-112-1	T322	0%, 22.3%

Table 4: Tube Assignments and Splotch Density

The seven CHIME counters require 14 tube segments. The tubes were cut according to below specifications (see table 4). Note that tube 4 (T322) is cut differently than tubes 1-3 (T179, T316, T318).

[2]During the removal of a CVD nickel tube from its Al mandrel splotches of Al from the surface of the mandrel sometimes remain on the inside of the nickel tube.

Tube ID	*Section*	*Counter Assignment*
179	88cm	X1-112-1
179	88cm	X2-112-1
179	24cm	X1-112-1
316	88cm	X3-112-1
316	88cm	X4-112-1
316	24cm	X2-112-1
318	88cm	X5-112-1
318	88cm	X6-112-1
318	24cm	X3-112-1
322	88cm	X7-112-1
322	24cm	X4-112-1
322	24cm	X5-112-1
322	24cm	X6-112-1
322	24cm	X7-112-1

Table 5: Tube Cut Plan

All tube segments were scribed with tube number and counter ID. Following the general NCD Construction Document [2] all parts were etched and baked. Since the lower sections of the CHIME counters will be open to the D_2O they do not have to be leak tight. Pinholes were not repaired in these sections.

D CHIME Endcap Assignments

Table 5 lists the endcap (EC) assignments for the CHIME. As described in Section 3 of this STR, components that were sufficient for the construction of the CHIME counters but did not meet all specifications for the neutral-current detectors were chosen from our inventory. We first used EC's failing the high voltage tests and our requirements for microdischarges. Since the CHIME counters are not active this does not affect the performance of the CHIME counters in the proposed background measurement. This selection included 3 short quartz EC's. Next, endcaps with big leaks were used. These EC's have visible voids in them and cannot be pumped down on the leak detector. Finally, EC's with small leaks were used. These have leaks at the 10^{-7} cc/s level or less. Leak tight EC's were used for the the placement at D2.

SNOMAN EC ID	*Assigned EC*	*Description*
1-1 (D2)	47-06	With hole; leak tight, failed high voltage test
1-2 (D3-a)	23-15	No hole; leak tight, failed high voltage test
1-3 (D3-b)	39-11	With hole; big leak
1-4 (D4)	9-1	No hole; broken quartz
2-1 (D2)	25-15	With hole; leak tight, failed high voltage test
2-2 (D3-a)	58-08	No hole; leak tight, failed high voltage test
2-3 (D3-b)	67-03	With hole; big leak
2-4 (D4)	20-11	With hole; broken quartz
3-1 (D2)	58-01	With hole; leak tight, failed high voltage test
3-2 (D3-a)	34-08	Short quartz; leak tight, failed high voltage test
3-3 (D3-b)	45-10	With hole; big leak
3-4 (D4)	14-01	With hole; broken quartz
4-1 (D2)	72-07	With hole; small leak
4-2 (D3-a)	34-02	Short quartz; leak tight, failed high voltage test
4-3 (D3-b)	46-01	With hole; big leak
4-4 (D4)	64-07	With hole; broken quartz
5-1 (D2)	39-12	With hole; small leak
5-2 (D3-a)	36-10	Short quartz; leak tight, failed high voltage test
5-3 (D3-b)	63-10	With hole; big leak
5-4 (D4)	63-13	With hole; broken quartz
6-1 (D2)	20-13	With hole; failed high voltage test
6-2 (D3-a)	18-01	No hole; failed high voltage test
6-3 (D3-b)	72-13	With hole; big leak
6-4 (D4)	21-02	No hole; broken quartz
7-1 (D2)	67-06	With hole; small leak
7-2 (D3-a)	9-10	No hole; big leak
7-3 (D3-b)	57-01	With hole; big leak
7-4 (D4)	44-15	With hole; broken quartz

Table 6: Endcap Assignments

References

[1] S.R. Elliott and R.G.H. Robertson, "What can be learned by placing one NCD in the D2O?", Internal NCD Report (1996)

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[3] A. Hime *et al.*, "Gas Handling and Diagnostic Procedures for Neutral-Current Detectors in SNO", Internal NCD Document (1998)

[4] R.G.H. Robertson, "Leakchecking of Blind Welds", Internal NCD Document (1998)

[5] Peter Thornewell, "Detectors for the Sudbury Neutrino Observatory", D.Phil. Thesis, Oxford University (1998)

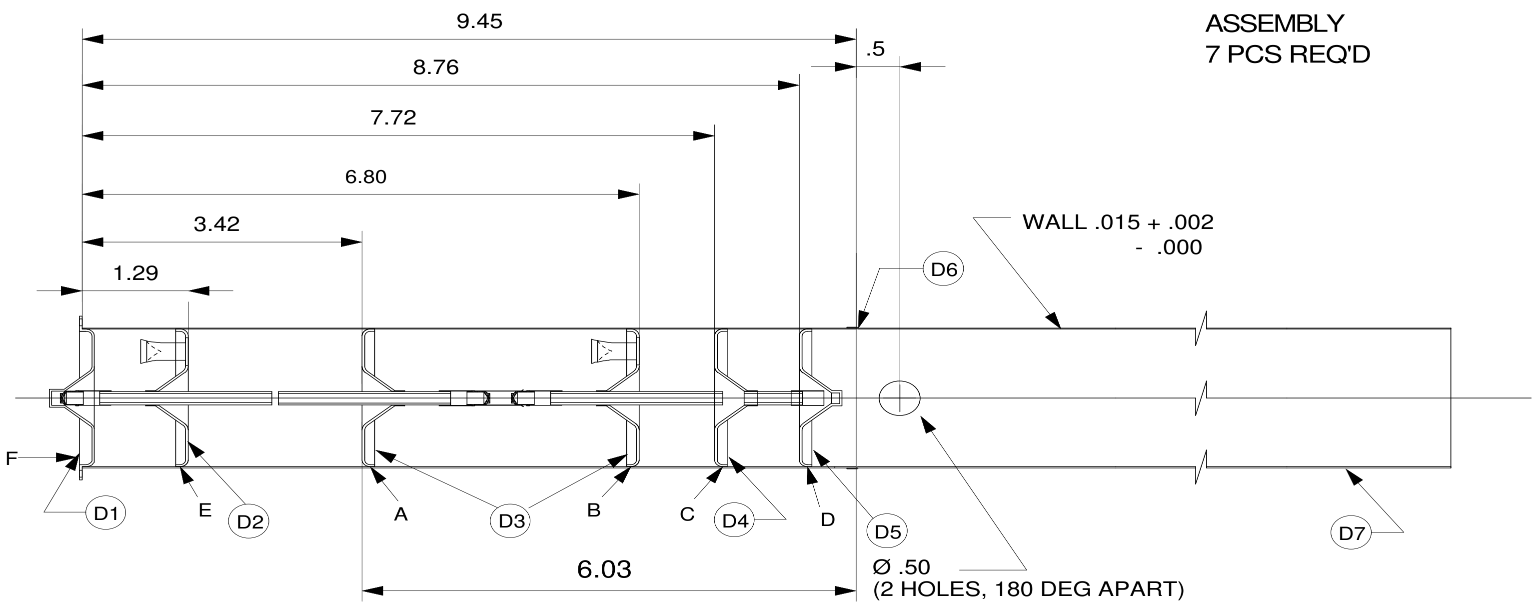
[6] S.R. Elliott, private communication, April 1999

[7] Geoff Miller, private communication, November 1998

[8] K.M. Heeger *et al.*, "MC Studies and Data Analysis of the NCD Construction Hardware In-Situ Monitoring Experiment", SNO-STR-99-005 (1999)

[9] A.W.P. Poon, "External Backgrounds in the NCD CHIME Experiment", January 5,1999, $URL : http//snohp1.lbl.gov/\ snoman/reports/chime_bkg/chim_bgd.html$

[10] M. Smith *et al.*, "Quantifying the Aluminum Contamination of Nickel Tubes to be Used In NCD Construction", Internal NCD Document (1997)



D1: D5787102 ENDCAP FOR ANCHOR END, WELD TO TUBE
D2: D5807101 ENDCAP ASSEMBLY (COUNTER) WITH SLEEVE, SEALED COPPER ENDPLUG, AND PINCH-OFF TUBE (D5816101), WELD TO TUBE. SEAL ON COPPER ENDPLUG VACUUM LEAK TIGHT < X10-9 ATM CC/SEC HE
D3: See D5808101 FOR INTER-COUNTER JOINT. NOTE: NO ANODE WIRE.
D4: ENDCAP WITH BROKEN QUARTZ TUBE
D5: REMOVE OUTER RING FROM D1 TO FIT INSIDE TUBE
D6: LAP JOINT
D7: 34.65" CVD NI TUBE

NOTES:
1. ALL WELDS TO BE DONE IN HE ENVIRONMENT
2. WELDS AT D1 and D5: VAC. TIGHT < X10-9 ATM CC/SEC HE

Figure 1: SNO NCD CHIME - Technical Drawing of a Counter

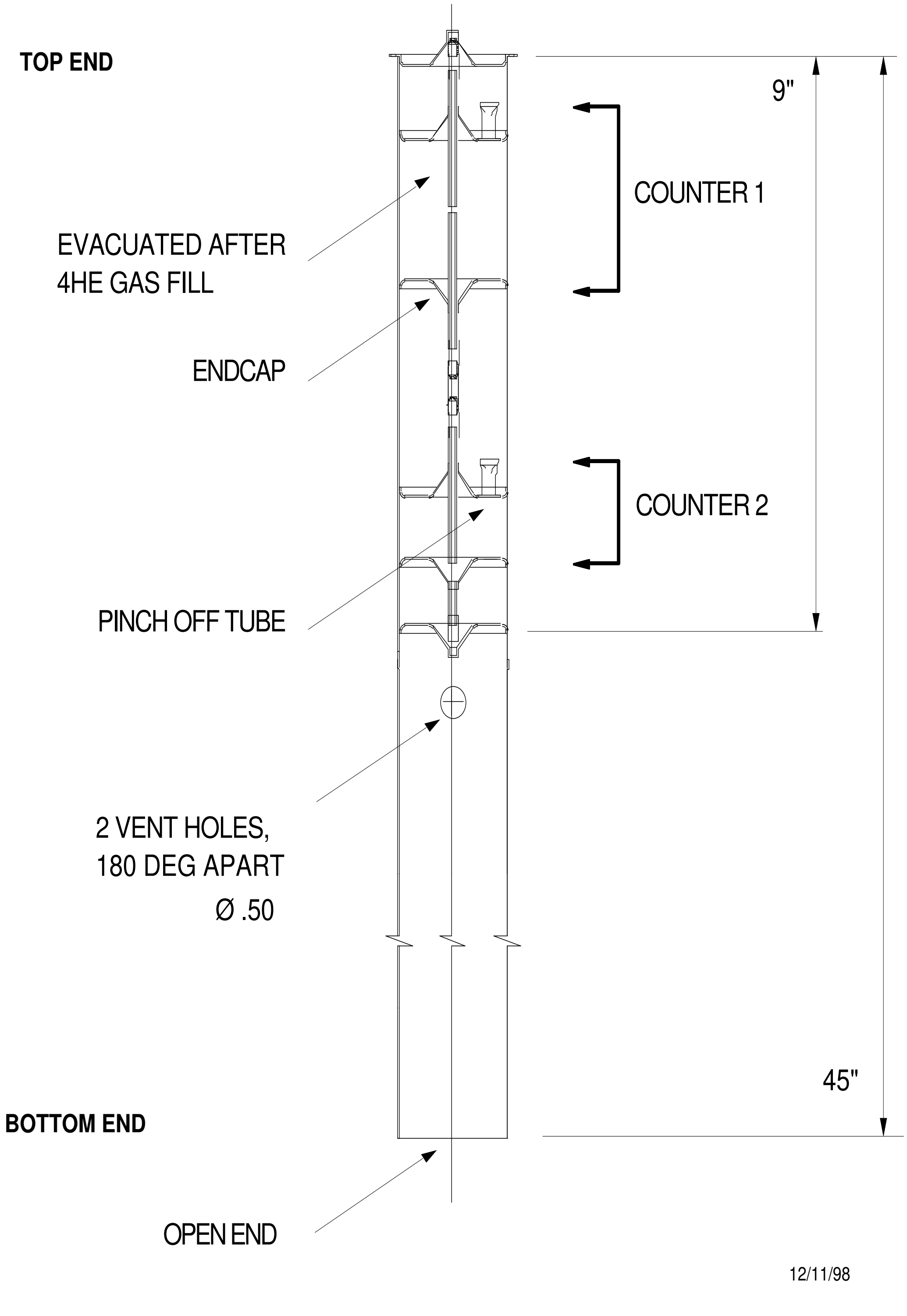


Figure 2: SNO NCD CHIME - Schematic of a Counter

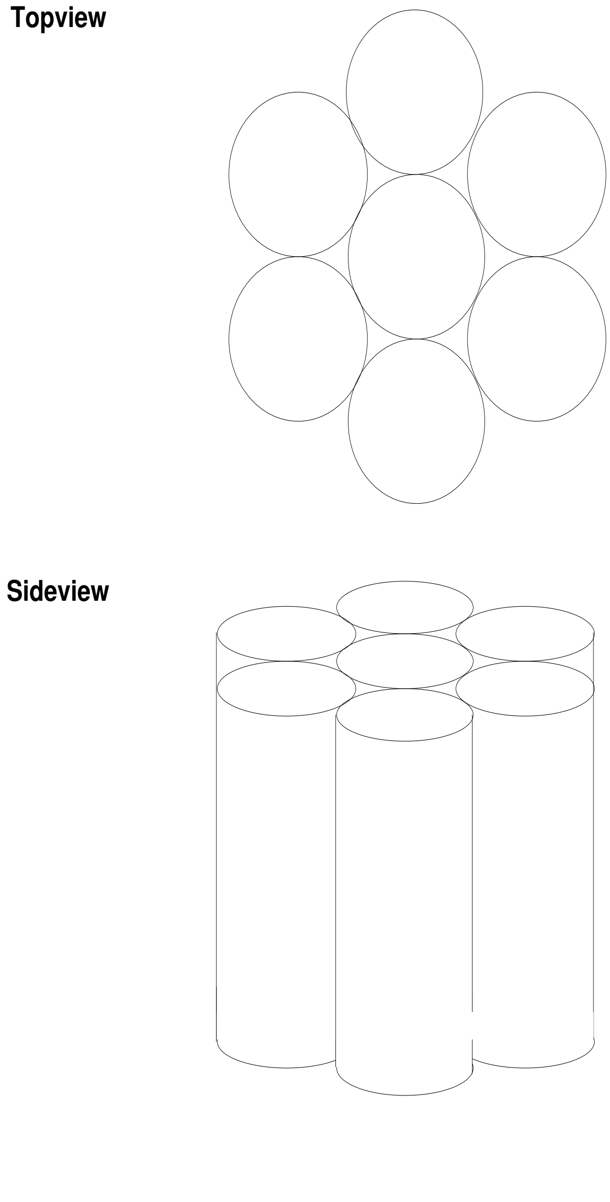


Figure 3: SNO NCD CHIME - Schematic of Closed Packed Configuration

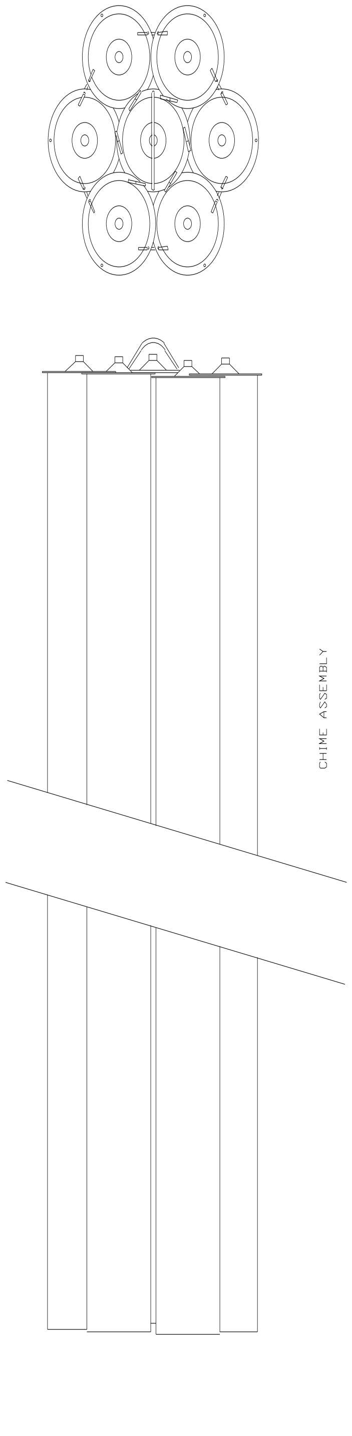


Figure 4: SNO NCD CHIME - Assembled Configuration