Delivering Clean Components to the Cavity

R. G. Stokstad
Lawrence Berkeley Laboratory
Editor

January 17, 1992

Report SNO-STR-91-066

Table of Contents

I. Scope

This document concerns the cleanliness of the major components of the detector system from their fabrication and assembly above ground through delivery to the detector cavity. These components are to be installed during the clean phase of the detector construction period. The purpose here is to ensure that the surfaces of these components do not themselves introduce radioactive contamination in excess of the amount permissible at the time filling commences. This document provides an overview of everything necessary to achieve this. Thus, in addition to cleaning procedures and measurement of surface contamination, related aspects such as packaging, transportation, the Sudbury assembly facility, and interactions with fabricators and assemblers are also discussed.

The level of detail given here for a component will depend on the state of the design and R&D for that component. Thus the specification of procedures for the photomultiplier tubes and bases is practically complete, whereas those for the acrylic vessel or the photomultiplier support system are in outline form. This document provides a framework for filling in the remaining details, which in many cases can be done only after interacting with manufacturers and fabricators. Therefore, additional documentation can be expected at the stage of requests for quotations. Finally, the main concern here is the cleanliness of *surfaces* - the bulk radioactivity of materials and leaching have been considered in other SNO reports.

II. Introduction

There are two parts to achieving the low background radioactivity required for the successful operation of SNO. One part is the minimization of the radioactivity contained in the bulk material of the most critical regions of the detector - the acrylic vessel and the heavy water. The other part is the cleanliness of the surfaces of the acrylic vessel and, to varying extent, of all the components at the time the cavity is filled with water. Surface contamination is detrimental because some of it may remain on the surface and therefore not be removed by the water purification system. The portion that enters the water may be removed by the purification system at the rate of 1/e in 37 days, but this costs time that could be used for data collection.

To reduce radioactive contamination on surfaces, a five-element cleanliness program has been developed, the most recent description of which is found in SNO-STR-91-019 (ref. 1). The present document describes the second element of this program. The decision when to clean an object is based on the cost of cleaning it at that stage and keeping it clean thereafter versus the cost of cleaning at a later stage. Often, but not always, it is advantageous to keep things clean rather than to allow contamination to accumulate and then clean them later. The main reasons for delivering components to the cavity in a clean state are the relative ease of cleaning individual parts during an appropriate stage of their fabrication above-ground and the difficulty (often, impossibility) of cleaning components underground after they have been assembled into complex structures.

After deriving the cleanliness requirements and discussing methods for measuring surface contamination, the subsequent five sections of this report list the stages from source to cavity for each of the five major components of the detector, and outline cleaning procedures, tests for contamination, and packaging. These components (and the authors of the respective sections) are the acrylic vessel or AV (P. Doe and D. Earle), the light concentrators (N. Jelley), the photomultiplier tubes or PMT's (H. B. Mak), the photomultiplier support system or PSUP (R. Stokstad), and the signal cables (R. Van Berg). Following this are brief sections concerned with the Sudbury assembly facility, material transportation, installation equipment, and interactions with material suppliers and fabricators. Where no authorship is indicated, the section was written by the editor.

III. Cleanliness Requirements

A. Radioactivity.

The requirements for the cleanliness of components at the start of installation are derived ultimately from the requirements for background radioactivity set for operation of the detector[2]. These requirements vary with location in the cavity: 10^{-15} g/g Th for the heavy water, 5×10^{-14} g/g Th for the light water in between the AV and the PMT's, with less stringent requirements farther away from the AV. Based on these numbers, limits of 0.2 g of mine dust (containing 5 ppm of Th) on the inner surface of the AV and 50 g in the light water were obtained[2]. The value of 0.2 g per 440 m^2 of AV inner surface amounts to 0.05 $\mu g/cm^2$ and is a contamination level most likely too low to maintain during installation - it will need to be achieved by other means, e.g., through dust covers and/or a washing just before filling. Fortunately, the interior of the AV is amenable to washing.

An order-of-magnitude estimate of the permissible level of contamination for surfaces outside the AV can be made by dividing the 50 g of dust by the entire surface area of the cavity and detector components (with the exception of the interior of the AV). These areas are:

Component	Area (m^2)
Signal Cables in H_2O*	2500
PSUP panels	2500
Concentrators	2000
Cavity liner	2000
PMT mounts	1500
PMT's	1250
AV exterior	450
Steel Pipe	300
Total	12500 m^2

* for cables harnessed in bundles of 8 or 9.

The result, 0.4 $\mu g/cm^2$, is the average requirement to be met by the components at the time they are delivered to the cavity. Of course, the actual requirement is 2×10^{-12} g/cm^2 of Th, and more (or less) than 0.4 $\mu g/cm^2$ of any contaminating material is permissible if that material contains less (or more) than 5×10^{-6} g/g Th.

We might try at the outset to establish different contamination limits for different components based on their location inside or outside the PSUP water barrier, on the ease with which we might clean them *in situ*, and on their area. (If the total area is small, as with the steel PSUP struts, a larger contamination in $\mu g/cm^2$ can be tolerated because the contribution to the total amount of mine dust is small). On the other hand, surface contamination may migrate during the installation period when there is no barrier between the regions inside and outside the PSUP. The standards we set must also take into account our ability to measure surface contamination and its thorium content. These measurement techniques and their application in our circumstances are still under development. The cost of achieving a given level of cleanliness must also become a factor at some point. However, at the moment we have neither a strong justification nor the experience to go beyond applying a single, average standard to all components, indeed, to all surface areas in the cavity outside the AV, and to the cavity dome. As we acquire experience we can expect to modify and tailor standards to different areas.

B. Biology.

Biological growth on the surfaces of components submerged in water has caused problems for other neutrino detectors and is a serious concern for SNO. Choosing materials that discourage growth (either because of surface topology or chemical composition), depriving the bacteria of oxygen or other ambient ingredients needed for growth, and applying a biocide are measures available for treating this problem. How, when, and where to apply a biocide depends partly on the methods to be selected for the last cleaning of the detector system just before filling. Methods under consideration vary from wet (spray rinses) to dry (use of dust covers). In one possible scenario, the interior of the AV could be rinsed with a biocidal spray after the assembly is completed, the exterior could be wiped piecemeal with a biocidal solution as the sections are bonded together, and other component parts could be exposed to a biocide in a fabrication or assembly stage while above-ground, in conjunction with other cleaning procedures.

At the time sections V. through IX. were written, application of a biocide above-ground was not under consideration, and hence this possibility is not discussed there. There are still significant questions to be answered through further R&D (which biocide, how best to apply it, its effect on surface properties, permanence of protection, consequences of the biocide remaining on the surface and getting into the water, etc.) before procedures can be established. In the meantime, we draw attention here to this problem and recognize the need to consider it as an aspect of delivering clean components.

IV. Measuring Surface Contamination

This section deals with the question "How clean is clean?" and with one of the more difficult and controversial aspects of contamination control - the verification of surface cleanliness. The ability to measure and monitor the cleanliness of surfaces, however, is central to the whole cleanliness program. In order to deliver clean components to the cavity, some measurements will have to be made "in the field", i.e., at the locations where the components are fabricated, assembled, or tested. This in turn requires that the tests, or at least some of them, be simple and easy to use.

A. Desiderata for surface contamination tests.

In general, one would like a test or combination of tests to be

1. sensitive ($0.4x10^{-6}$ g/cm^2 of mine dust or $2x10^{-12}$ g/cm^2 Th),
2. semi-quantitative or quantitative,
3. analytic,
4. fast,
5. simple and, if possible,
6. inexpensive.

B. Classes of tests.

Visual inspection is of course the first test. A surface that is obviously dirty to the naked eye need not be subjected to more sensitive tests. And even if of the amount of radioactivity contained in the gross contamination were small, the surface should be cleaned for the sake of the water purification system. Some surfaces that look clean at first sight reveal dust particles when viewed in strong oblique light. Some forms of contamination show up well in ultraviolet light. A hand lens or small field microscope can provide additional sensitivity. Hydrophobic contamination can be detected by observing the behavior of the water on the surface during the last rinse - the water break test. This and other more sensitive wetting tests (atomizer, contact angle, and ring test) can be used on components where there is a potential for contamination with oily materials, and where wetting agents that would invalidate the test are known to be absent. There are also chemical tests that are specific to certain elements or compounds.

Visual tests by their nature have the advantage of being *in situ* - one observes the contamination present on the surface. Determining the sensitivity of visual tests can be difficult, however, since they are inherently qualitative and their sensitivity will vary with the type of surface under scrutiny.

Another class of tests involves observing contamination by removing it from the surface. The removal can be effected by washing, wiping, or applying an adhesive tape. In the case of washing, the solvent or rinse is filtered and the particles that are caught in the filter are counted. Both a rinse test and a wipe test increase sensitivity by concentrating the contamination into a smaller area for observation. The tape lift test does not concentrate (unless multiple applications are performed with the same piece of tape) but rather provides a one-to-one mapping of the contamination on the surface. Its rationale is that the contamination on the sticky tape is easier to analyze because the tape is transparent, or very thin, and because it can be removed to the laboratory. A characteristic of these tests is that they measure only what was removed from the surface, and thus depend on the efficiency of the removal method.

In some cases the American Society for Testing and Materials (ASTM) has specified procedures for tests[3] that can be applied as described or used as a starting point for further development. Examples are the atomizer, water break, and tape lift tests. General procedures for the optical counting of particles on surfaces have also been established.

C. Analytical methods.

There are a variety of analytical methods that can be applied to determine the amount and nature of contamination on a surface. Observation with a microscope can distinguish some types of contamination and, in the case of dust, can be used to characterize the distribution of particle number versus size. A number of quite sensitive, quantitative, and analytical techniques are available. Neutron activation analysis, PIXE, x-ray fluorescence, and mass spectrometry are some examples. (Although the semiconductor industry has developed laser scanning devices that locate, size, and count individual particles of dust on a silicon wafer, such devices are expensive ($200K) and impractical for the large areas and types of surfaces we encounter.)

Methods normally applied for direct measurement of thorium in bulk samples (mass spectrometry, neutron activation analysis, direct counting) can also be used for measurement of surface contamination if the surface-to-volume ratio of the sample can be made large enough, and if the amount of contaminant in the bulk can be measured separately. For comparison, 0.15 $\mu g/cm^2$ of mine dust (5 ppm Th) on the surface of a slab of acrylic 1 cm thick corresponds to 0.6 pg/g of Th.

D. Research and development.

The challenge is to choose and develop the optimum tests for each of the detector components. At LBL an optical microscope and an X-ray fluorescence spectrometer[4] are being used to develop tape lift and wipe tests for use on ABS plastic, stainless steel, glass, and acrylic. The goal is to determine the sensitivity of these tests and to see how quantitative they can be made. The procedure is to start with a clean surface, then contaminate it with mine dust, measure the amount of contamination, and then evaluate the effectiveness of a test for measuring that contamination. As a part of this, samples of the above materials will be prepared with known amounts of dust for use as calibrations in semi-quantitative comparisons in the field. (The level of sensitivity is highest for glass, and it appears that amounts of dust as small as a microgram per cm^2 can be observed visually under the right circumstances.) Similarly, examples of wipe tests made on surfaces with different amounts of mine dust can provide a crude calibration for field tests.

This developmental work indicates that a tape lift test in conjunction with an X-ray fluorescence analysis presently affords a sensitivity of 0.15 $\mu g/cm^2$ (three sigma level). The method is based on the measurement of Fe and the known fraction of iron in norite (about 6%). The amount of Th per unit area can then be obtained from the known level of Th in mine dust, which is about 5 ppm. (The sensitivity is limited mainly by the amount of Fe already present in the tape, and the counting time.) To the extent that there is a correlation between the amounts of elements such as Fe, Ti, Ni, Co, Sr, etc. and the amount of Th in other common contaminant materials, this method can have a wider application. Attempts to establish such a correlation for the (bulk) contaminating materials in acrylic have met with mixed results - data from CRL suggest[5] such a correlation while those from Guelph do not[6].

It might be possible to measure the thorium content in materials by using proton induced x-ray emission (PIXE). At Queen's university they plan to try this method on the contaminants present on the surfaces of the PMT's. If successful, this method might also provide a way of establishing a correlation between Th and other more prevalent elements, such as iron, that could be useful for surface contamination analysis.

V. Acrylic Vessel

P. Doe and D. Earle

The AV will be made of approximately 160 individual panels to be bonded together in the cavity and will be suspended by Kevlar ropes from the cavity deck.

The stages leading to the installation of the AV are:

a) Casting of flat sections by the manufacturer.

b) Fabrication of spherical sections by thermoforming.

c) Machining of the edges of the sections, followed by sanding and annealing to relieve local stress.

d) Trial assembly.

e) Surface cleaning.

f) Packing and shipping to Creighton.

g) Transportation to the cavity.

Procedures for each stage:

Note: the procedures described below are not final but rather represent our current expectation of how things will be done. Final procedures will depend on the results of pilot production runs and further tests for radioactivity at various stages to ascertain where contamination might be introduced. Discussions must be held with the fabricator and machine shop personnel before instituting some of the measures suggested here (e.g., installation of air filters on molds and ovens). The choice of the particular cleaning procedure following the trial assembly will also determine the level of cleanliness required up to that point.

a) Examine release agents used on walls of molds for radioactivity and flow filtered air into the mold before and during the casting procedure. After casting, inspect the sections and take samples to analyze for bulk radioactivity. Cover the acrylic sections with protective paper or plastic sheet and plastic bag. Crate for shipping to the fabricator.

b) Uncrate the section and store it. When ready for forming, remove protective coating, measure and inspect section for damage. Thermoform the section, which rests horizontally on a female mold covered with rubber or felt, with the upper surface covered and the edges clamped to the molding tool. (Gravity does the forming.) Care must be taken that dust does not come in contact with the surface of the acrylic while it is hot and in a plastic state. Cleaning of the oven and the use of filtered air during thermoforming are recommended. After cooling, trim the section to rough dimensions, remove any residue (left by the mold surface during thermoforming) with alcohol and water, and apply temporary protection (paper or plastic). Crate the thermoformed section for shipment to the machining facility.

c) Remove sections from shipping crates, remove temporary protection from those areas to be machined and from those areas needed for holding the section with suction cups or other clamping devices. Machine sections on a five dimension computer controlled milling machine. Care must be taken that the machining procedure does not leave foreign matter in the acrylic surface. Inspect sections, repack, and return to fabricator.

d) Begin trial assembly of some fraction of the vessel in the fabricator's facility. This step will help train assembly personnel and debug the assembly procedure and equipment.

e) Remove any protective films placed on the acrylic during the trial assembly. Clean the surfaces of the sections by manual washing and wiping or using an ultrasonic bath. Inspect surfaces for damage and the edges for residue from sanding. Establish cleanliness using visual inspection of surface with intense oblique and transmitted light and possibly by additional methods (tape lift test and x-ray fluorescence, or other tests yet to be developed). Clean the jigs and fixtures used in the trial assembly.

f) Double-bag the acrylic sections and Kevlar rope. The outer bag must be robust and waterproof. Bag the cleaned jigs, fixtures and tools. Place sections in foam cradle and enclose section in shipping box.

g) After arrival at SNO surface building in Creighton, remove sections from shipping box and place individual section on a frame or cradle. If cost effective, return shipping box to fabricator. Transfer cradle onto rail undercarriage and transport by rail to shaft cage and then to car wash.

Outstanding questions:

The following questions should be resolved by making test runs with acrylic sheets at the fabrication and machine shops:

What is the best type of protective film (paper or plastic) for the sections? How clean does autoclave need to be? Should we recycle special shipping crates or use throw-away ones? What is the best way to clean the rope?

VI. Concentrators — N. Jelley

The production of the concentrators breaks down into six stages:

a) Acquiring anodized aluminium sheet, which is selected for low radioactivity.

b) Coating of anodized sheet on both sides by OCLI, Santa Rosa, California.

c) Cutting of coated anodized aluminium (CAA) sheets into petals.

d) Removing plastic protective film and cleaning petals prior to coating their edges.

e) Manufacturing the ABS retaining dishes and the PMT Baffles, and solvent-welding them together.

Procedures for each stage:

a,b) The CAA sheets provided by OCLI are protected on one side by a thin low-tack plastic film. Samples of such sheet have been tested for radioactivity and this has indicated that by selection of the anodized aluminium sheet we can obtain CAA of sufficiently low radioactivity. It is very unlikely that the variation in activity between samples that has been seen is caused by the coating process but it will be prudent to sample the activity of the CAA sheets. As these CAA sheets are machined there is no need to require special packaging prior to shipping to the UK other than that necessary to avoid any damage.

c) Only a cutting fluid of very low radioactivity, compatible with the plastic protective film and which can be easily removed, is to be used for the CNC milling of the CAA sheets into petals.

d) Protective film to be removed and the petals to be ultrasonically cleaned in acetone (10 min) and IPA (10 min). A vapor degreasing plant may also be suitable. Petals to be handled with gloves from this point on. After evaporation of the edge coating, the petals are to be bagged and then shipped with suitable protective packaging to the retaining dish manufacturer and assembler.

e) The PMT baffle and retaining dish each to be bagged immediately after being produced. Petals to be mounted in retaining dishes in a clean room (class to be specified but preliminary estimates indicate that dust contamination during assembly can be simply kept insignificant). Test surface cleanliness of baffle, dish and sample petals with:

visual inspection
wipe tests
solvent ring test (if appropriate)
atomizer test (if appropriate)

Joining of PMT baffle and dish and the assembly of petals in dishes carried out using gloves. Unit bagged and put in box ready for shipping to the Sudbury assembly facility.

VII. Photomultiplier Tubes H. B. Mak

The PMT's are shipped from Japan to Queen's U. where waterproof bases will be mounted and acceptance tests performed. The sequence at Queen's is as follows:

a) Unpack and inspect.

b) Mount resistor board and polypropylene housing, apply heat shrink.

c) Acceptance test.

d) Apply conformal coating to electrical components inside polypropylene housing. Application and setting of conformal coating chemical.

e) Fill space inside polypropylene housing with silica gel.

f) Complete waterproofing of PMT-base system by application of heat shrink and adhesive.

g) Water leak check.

h) Final electrical test of PMT and measurement of "after-pulsing".

i) Packaging for transportation to the Sudbury assembly facility.

The critical handling stages in which to avoid Th and U contamination are:

i. application of heat shrink in stage b.
ii. application of conformal coating chemical in stage d.
iii. filling and setting of silica gel in stage e.
iv. application of heat shrink and adhesive in stage f.
v. absorption of Th and U compounds in stage g.

Procedures for cleaning followed in above stages:

1. On unpacking, each PMT will be inspected for damage and dirt. The PMT's come packed in a plastic bag inside a cardboard box. There is a piece of foam molded to the shape of the PMT to protect the PMT in each box. After unpacking, the following procedures need to be performed in an environment sufficiently dust-free to maintain cleanliness.

2. Clean PMT neck, inside surface of heat shrink, and polypropylene housing with Kimwipe and appropriate solution before application of heat shrink.

3. Wipe PMT using Kimwipe and commercial window cleaner before acceptance test to remove marks and dust that may affect photon detection.

4. Inspection of surfaces inside housing for dust and blow out surfaces if needed with clean nitrogen from commercial nitrogen tank before applying conformal coating chemical. The PMT and base will be stored on a shelf to allow the coating to set. The PMT will be covered by a plastic bag.

5. Fill polypropylene housing with silica gel and let set in clean environment inside plastic bag.

6. Clean polypropylene housing, plug, and inside surface of heat shrink using Kimwipe and suitable solution before applying heat shrink and adhesive.

7. Use distilled water for leak check. Change water as required.

8. After water test, wipe PMT glass and waterproof base with Kimwipe and suitable solution to remove dust and marks. Visually inspect glass and waterproof base under strong oblique light, and blow away loose pieces of material with clean nitrogen gas if necessary.

9. Place PMT in plastic bag and tie bag to prevent dust from reaching PMT.

10. Place PMT in box for shipment to Sudbury assembly facility.

We will study the Th and U concentrations in dust at assembly rooms using proton induced X-ray emission in the near future to quantify the maximum amount of dust that can be allowed to settle on a PMT.

VIII. Photomultiplier Support System — R. Stokstad

The PSUP consists of a geodesic structure made of stainless steel (struts, nodes, suspension cables and mounts, and hardware for mounting panels), PMT holders of ABS plastic (panels made up of hexagonal unit cells, each holding one PMT and reflector), and a water barrier (to be specified).

The stages for the geodesic structure are:

a) Steel pipe and sheet delivered by supplier.

b) Struts and nodes fabricated.

c) Trial assembly.

d) Disassembly and cleaning.

e) Packaging for shipment to SNO surface building at Creighton.

f) Transportation to cavity.

Procedures for the above stages:

a) The material from the supplier should be free of oil, soil, grit, and scale. Scale will be removed by mechanical action and pickling in acid. The ASTM provides standard procedures for cleaning stainless steel parts[7].

b) The fabricator (of struts, nodes, etc.) will maintain the above level of cleanliness and, in addition, clean and descale all welds.

c) The pre-assembly will be done under normal industrial conditions (i.e., good housekeeping), but without special precautions for cleanliness.

d) When the completed structure is disassembled, any modified parts will undergo the same cleaning procedures as during fabrication. The individual components will then be washed in a hot detergent solution and have a final rinse in de-ionized water. Drying and the inner level of packaging of the components will take place in an enclosure that has a synthetic floor covering (e.g., epoxy paint, linoleum, or such) and filtered air. The parts must appear free of dust when viewed under oblique light. A white cloth used to wipe a surface must remain clean to the naked eye. These cleanliness tests will be supplemented with less frequent tape lift tests and X-ray fluorescence analysis as needed.

e) Samples of the commercial grade plastic packaging material that comes in contact with the steel surfaces will be checked for the presence of surface contamination containing minerals. Protocols for sample inspections of the stainless steel surfaces at the time of packaging will be developed. Individually wrapped stainless steel parts will be packaged in subgroups that will fit inside the surface-to-underground containers, and then be crated for shipment to the Creighton surface building.

f) The crating will be removed at Creighton and the subgroups of parts placed in waterproof containers for rail transportation underground. After passing through the car wash, the containers will be opened in the SNO laboratory area and the subgroup wrapping removed. The innermost plastic wrap is removed at the time a part is needed for installation.

The stages for the PMT panels are as follows:

a) Injection molding of individual hexagonal unit cells.

b) Assembly of cells into panels.

c) Shipment of panels to the Sudbury assembly facility.

d) Loading of the panels with concentrators and PMT's.

e) Packaging of the loaded panels and transportation to the cavity.

Procedures for the above stages:

a) Verify that the mold and release agent do not introduce U or Th. The unit hexagonal cells and parts for holding the PMT tube and for mounting the panels will be placed in plastic bags as soon as possible after removal from the injection mold. Precautions at this stage will be taken such that dust or other contamination is below the level detectable in oblique light and detectable with a wipe test and visual observation of the wipe. (These cleanliness tests will be supplemented with less frequent tape lift tests and X-ray fluorescence analysis as needed.) All the bagged hexagonal cells and plastic mounting parts will be transported to an assembler.

b) Assembly will occur under conditions that maintain the cleanliness of the plastic at the level when bagged at the molder. (Should remedial cleaning be needed before assembly, this will be done with a mild detergent solution and a final rinse with deionized water). These conditions will include assembly in an enclosure with filtered air and a synthetic floor. The same type of wipe test will be applied. Upon completion of assembly, each panel will be placed in a plastic bag that is large enough to contain the same panel when the are PMT's mounted in it.

c) The panels are then crated for protection and transported to the Sudbury assembly facility.

d) These (empty) panels, the PMT tubes and the reflectors will be assembled into loaded panels in a clean area (an enclosure with filtered air, etc.) under procedures designed to maintain the existing level of cleanliness of the parts.

e) Upon completion, the loaded panel will be covered with the same plastic bag in which it arrived, and then loaded into a metal frame with wheels or casters. This frame along with others will be placed in a waterproof container for transportation to Creighton and loaded onto a railway undercarriage for transportation underground. After passing through the car wash and being removed from the container, the metal frame holding a panel will be moved to a location where the panel can be removed, unbagged, and then lifted into place on the geodesic dome.

Samples of the commercial grade plastic packaging material used for bagging the plastic parts will be checked for the presence of surface contamination containing minerals.

IX. Signal Cables R. Van Berg

Since a very large surface area of PMT cables will be below the cavity deck and since cleaning this surface area after installation would be very difficult (if not impossible), it is necessary to keep the cables clean throughout the manufacturing, assembly, storage, and delivery steps. With additions and corrections, the following outline will form the basis for RFQ's to cable suppliers and assemblers as well as for procedures directly under SNO control.

The stages for the signal cables are as follows:

a) Manufacture of cable.

b) Assembly and packaging of cables and connectors.

c) Storage.

d) Shipment to the cavity.

Procedures for the above stages:

a) The Cable - the final jacket extrusion process should be inherently clean although we should have an actual inspection before purchase. The cable from the extruder is generally rolled directly onto shipping reels and then cut off as the full length is reached (probably 5000' or so in our "large order" case). As soon as a reel is full, it should be encased in plastic film (or equivalent) to prevent dust from settling on the outer cable turns. "Double bagging" or some form of additional outer wrapping is advisable so that any dust accumulated during shipping and storage may be easily removed without undue contamination of the assembler's work area.

The Connectors - again, the basic pieces are naturally "clean" at the end of manufacturing. Individual parts are plastic bagged (kitted for assembly - all plug parts in one bag, all jack parts in another - with dessicants) and then larger quantities are bagged together. The dry-end connectors are less critical, but should probably follow similar procedures.

b) General Technique - usually a cable harness is laid out on a long bench, connectors are attached, the bundle is tied and then the entire harness is packaged. In our case it would probably be advantageous to attempt a somewhat different procedure. It may be possible to put multiple cable reels (8 or 9) in a tented area, apply either the wet- or dry-end connectors and labels, pull out the required slack, begin coiling the finished end while tieing the bundle along its length, then cut off at finished length and attach the other connectors and labels. The outer diameter of the coil should be less than 42" so that three piles of coils will fit into the rail car container for transportation to the cavity. The connectors at the ends of the cables should be held in place by some protective box located in the middle plane of the coil so that the connectors will not be damaged. Each coiled bundle of 8 cables (or 9 for "spared" bundles) would then have a bag or wrapping that would not be opened until installation time. Coils could then be stacked in groups (perhaps with another bag around the group), which will then be crated for shipment to Creighton. The crates should prevent gross contamination from contacting the bagged cables inside.

c) The crates may have to be stored for weeks or months before shipment to Creighton. The only requirement for this storage is that it be dry.

d) The stacked coils will be removed from the crate at the Creighton surface facility and transferred to waterproof rail-car containers. There will be a total of about 1200 coils, each weighing about 40 lbs., which means the transfer of the individual coils does not require a hoist. The coils are stacked in three piles on a clean dolly that can be rolled into the container. After the container passes through the car wash, the dolly can then be removed and stored where the coils can then be taken as needed for installation. Assuming the dolly can handle 1600 lbs., there will be 40 coils per dolly and a total of 30 rail car shipments will be required.

X. The Sudbury Assembly Facility

The PMT's and concentrators will be loaded into the hexagonal cells of the PSUP panels in Sudbury. The Sudbury assembly facility[8] will provide storage for the components as they arrive and a clean area in which the actual assembly or loading of the panels takes place. A loaded panel will be bagged in the clean area and placed in a metal frame with wheels. Four panels in their frames will then be placed in a waterproof container for transportation to the SNO surface building at Creighton, where the containers will be loaded onto rail carriages.

The clean assembly area in this facility will likely consist of a temporary indoor structure with transparent plastic walls and ceiling, and a ventilation system supplying filtered air. There will be anterooms in which personnel can don cover garments, stored components can be unpacked, and in which assembled panels can be transferred to their waterproof container. These rooms can be ventilated with filtered air exhausted from the clean assembly area.

Provision is envisioned for cleaning tools and equipment used in assembly and for loading and unloading containers from a truck.

A more detailed specification of the characteristics of the Sudbury assembly facility will have to await a number of logistical decisions on storage space, required production rate, and number of shifts to be worked. Obviously, the particulars will be quite dependent on the buildings available for rent at that time.

XI. Material Transport to the Cavity

Given the extremely dusty and dirty conditions in the drift from the elevator shaft to the car wash, the greatest source of contamination for the laboratory is likely to be the introduction of mine dust with the transportation of components, equipment, and movement of personnel. Thus, components should be protected from mine dust and the outermost level of packaging must be removed or the shipping container cleaned before the cargo enters the clean area. Otherwise, some of the contamination on the exterior of the container could eventually migrate to sensitive areas of the laboratory. Adequate care, therefore, has to be given to the cleaning of the outer surfaces of packaging material and the equipment used to transport components.

A. General considerations for the design of transportation and packaging.

The surfaces to be washed should be topologically simple. Nooks and crannies provide places from which dust, mud, and dirt will be hard to remove completely. "Small" amounts (small compared to the total quantity of dirt on a container) that nevertheless dislodge would be enormous amounts on the scale of our cleanliness requirements.

The surface area to be cleaned should be minimized. Smaller packages should be combined and transported in a single container.

The wash water has to reach the entire surface to be cleaned. Any outer structures or frames used to hold and transport a waterproof package (e.g., an acrylic panel) must either be removed from the package before washing or, if not removed, be as open as possible so that the wash water can reach everywhere.

We should not attempt to wash the rail carriages. They are complicated surfaces and they acquire the maximum amount of dirt due to their proximity to the dust and mud on the floor of the drift. The requirement that the bottom of a container be washed means it must be separated from the rail carriage. Given the need to lift the container from the undercarriage at some point, this is better done just before entering the car wash. In this way the rail carriage is left outside the car wash and the amount of dirt passing the first door is significantly reduced.

The type of watertight containers being designed for the transport of the PMT panels could also be used for the transport of many other items such as cable, mechanical, and electrical equipment. Then these items, which should satisfy the cleanliness requirements and be bagged before being loaded into the container on the surface, need not be individually equipped with waterproof wrapping and individually washed. A standard dolly that can be rolled into a container will facilitate the transportation of a variety of items.

If, because of their size, the acrylic panels are not transportable in the above containers, the panels, suitably bagged and protected from abrasion, will likely have to be held in a frame that places the panel at an angle to the vertical. This frame, which would also be separated from the rail undercarriage before entering the car wash, should be designed in such a way that it, as well as the waterproof packaging of the acrylic panel, is accessed completely by the wash water. In this case, the frame could stay with the panel through the car wash and into the clean area.

Approximately 250 tank cars of D_2O, each weighing four tons, will have to be transported from the surface to the car wash. Rather than washing these tanks and having to manipulate them inside the car wash and clean area, it would be highly preferable to transfer the D_2O by means of a pipeline system. The tank cars then need not enter the car wash at all. This has significant advantages for both material transport and cleanliness.

B. Criteria for the design of a container for the PSUP components.

The containers for transporting the PSUP components from the Sudbury assembly facility or the SNO surface building to the cavity should:

1. have a waterproof and smooth (as possible) outer surface,

2. fit, if possible, in the upper cage as well as in the lower cage,

3. be able to hold four panels,

4. be long enough so that PSUP struts can fit inside,

5. have a flat bottom so that the panels, mounted in their rectangular transportation frames, will be able to roll in and roll out of the container,

6. be removable from the rail car undercarriage before entering the car wash, and

7. fit onto a dolly so that it can be easily moved in the Sudbury assembly facility, Creighton surface building and rail-car loading facility, and in the clean area underground (the corridor junction).

C. The car wash.

Mine dust will be present on the surfaces of whatever packaging materials or containers are used to cover equipment and components on their trip from the surface to the cavity. Even though these containers or packaging materials are removed from the corridor junction after unloading or unwrapping, contamination introduced by them into this area could eventually spread to other more critical areas of the detector site. Hence the need for the car wash.

C.1. Washing and drying the containers.

The installation of the PSUP will require the washing of something like 250 to 300 containers. There are over 160 acrylic panels to be transported through the car wash. Therefore, a system making use of a fixed sprinkler array and a blow-dry manifold should be considered. The sprinkler system should handle both a detergent wash and a clean water rinse. Mechanical scrubbing (included in nearly every automobile car wash) will also be necessary. The blow-dry system makes use of high velocity streams of air to remove droplets of water from the container or the waterproof package that has just been washed. The air in the car wash, which has been exhausted from the corridor junction, should be clean enough for this purpose. Consultation with companies that build automobile car washes might answer some of the design questions.

The alternative to the above system is manual washing using water guns, brushes, and swabs, some of which equipment should also be available from the car wash industry. Combinations of manual techniques and more automated methods can also be imagined. The choice of what to use will have to be based on an analysis considering the capital and operating costs of the different possibilities. Whatever the choice, the containers and outer packaging will have to withstand the washing and drying procedures. A thin plastic baggie may not survive.

C.2. Bringing containers through the car wash.

An overhead monorail with a hoist would be an ideal way to lift a container from its rail undercarriage outside the car wash, and transport it (suspended) through the washing and drying areas. The container would then be set down in the corridor junction on a dolly, moved to a nearby convenient location and unloaded. A similar procedure would be followed for a frame holding an acrylic panel.

If for some reason it should not be possible to do this with a monorail, there is an alternative method involving raised rails. The container or frame is pulled onto and along an inclined rail and is thereby raised and separated from its undercarriage. The container is then pulled forward and through the car wash by a winch.

C.3. Monitoring the effectiveness of the washing.

Levels of contamination on the surface can be high enough to be unacceptable and still be invisible to a casual inspection by eye. Thus, if a quick visual inspection shows evidence of residual dust or dirt when the container leaves the wash/dry area and is about to move into the clean area, a rewash will be necessary before the container is opened or goes farther. If no dirt is visible, more sensitive wipe tests (with a visual inspection of the wipe) are then to be employed. A program of checking with the most sensitive test (a tape lift test with X-ray fluorescence analysis) will determine whether the quick tests applied after each wash are adequate and how often spot-checks with more sensitive methods will be necessary. The X-ray apparatus should be capable of providing results from a test within ten to fifteen minutes.

XII. Installation Equipment

A considerable amount of equipment will be involved in the installation process and much of it will be first brought into the cavity after the clean phase of construction begins. Even though this equipment will be removed from the cavity later, it should satisfy the same cleanliness standards as the components if it is not to serve as a source of contamination for the components that remain.

Examples of this equipment are scaffolding for assembling the PSUP and AV, rigging equipment, jigs, carts, electrical tools, hand tools, and various supplies including cans of chemicals. Some of this equipment may have to be made for, or adapted to, clean room use, i.e., have drip pans where fluid lubrication is essential, chain holders on hoists to prevent introduction of spalled metal, brushless motors, etc.

Large-sized equipment such as scaffolding may need, depending on its history, a cleaning treatment similar to that of the stainless steel: immersion in a hot detergent solution and a rinse in de-ionized or filtered water. It may be preferable to have the supplier of the scaffolding arrange for this and bag the parts at the washing site. Depending on cost and the overall quantity of equipment that will have to be cleaned, however, it may be advantageous to have washing facilities (for example, three 14' long tubs - one detergent and two rinse) located at Creighton or Sudbury.

Many electrical tools will not be immersible and therefore will have to be cleaned using appropriate detergents or solvents, brushes and wipes, and then bagged. Indeed, bagging should be a necessary sign of an object's cleanliness, and unbagged tools should not be permitted to enter the cavity.

New solvent cans or other small containers of materials should undergo visual inspection for cleanliness and be bagged or labeled before being placed in one of the large waterproof containers for transportation underground.

XIII. Interactions with Suppliers and Fabricators

The requirements for cleanliness of components may not fit the normal course of operations for a supplier or fabricator, just as with the requirements for bulk radioactivity. In the case of the acrylic vessel, significant effort has gone into contractual specification of acceptable bulk radioactivity and into procedures for verifying that the material meets these specifications. This was also true for the photomultiplier tubes. The situation for surface contamination is similar. If there is inadequate specification of cleanliness requirements in a contract and insufficient understanding on the part of the fabricator, remedial cleaning may be required after delivery. On the other hand, requirements that are unnecessarily stringent or very difficult to verify may increase the cost without a corresponding benefit.

It appears that the best course of action involves an interaction between potential suppliers or fabricators in which we ascertain the levels of cleanliness currently possible, and estimate what would be needed to ensure an acceptable product. In some cases the latter may be very simple - merely bagging something as it comes off the press. In other cases, it may be advisable for the fabricator to add a filter to a ventilation system or to build a temporary enclosure and supply filtered air to reduce airborne dust, or such. In this process, a first step is an inspection of the facility where the work will be performed. Tests for surface contamination on products currently coming from that facility (or on pilot products made for SNO) may be helpful in deciding what additional measures a contractor should take. The tests for cleanliness that we would use (or have a fabricator use) should be demonstrated and shown to be practical and appropriate. Out of these discussions with the supplier or fabricator should come the specifications to be included in a contract.

References

1. "Establishing a Cleanliness Program and Specifications for the Sudbury Neutrino Observatory", E.D. Hallman and R.G. Stokstad, SNO-STR-91-009, September, 1991.

2. "Leaching, Cleaning, and Water Specifications", D. Sinclair, SNO-STR-90-165, December, 1990.

3. Standard Method for Measuring and Counting Particulate Contamination on Surfaces, ASTM F24-65 (Reapproved 1983).

   Standard Practice for Sampling for Surface Particulate Contamination by Tape Lift, ASTM E1216-87.

   Standard Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters, ASTM F312-69 (Reapproved 1980).

   Standard Test Method for Hydrophobic Surface Films by the Atomizer Test, ASTM F21-65 (Reapproved 1989)

   Standard Test Method for Hydrophobic Surface Films by the Water-Break Test, ASTM F22-65 (Reapproved 1983)

4. Trace Element Determination with Semiconductor Detector X-Ray Spectrometers, R.D. Giauque, F.S. Goulding, J.M. Jaklevic and R.H. Pehl, Analytical Chemistry, 45, (1973) 671.

5. CRL Acrylic Radioactivity work: September, 1990 - January, 1991; D. Earle, et al., February 18, 1991.

Correlation between trace element concentrations and Th levels in Polycast materials, E. Bonvin, Februrary 18, 1991.

6. P. Jagam, reported at the Vancouver collaboration meeting.

7. Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems, ASTM A380-88. Includes a description of the solvent ring test.

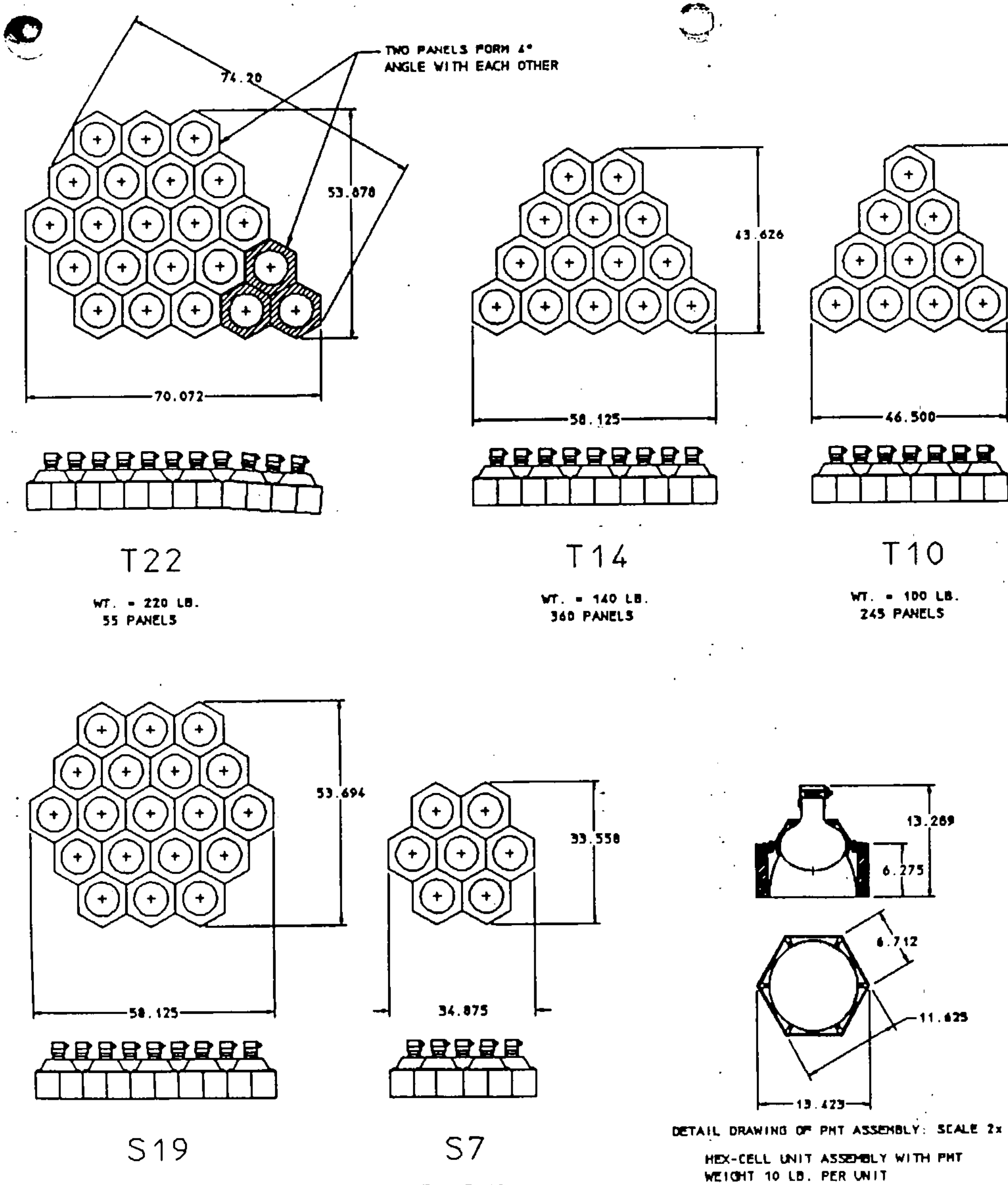
8. The Sudbury Assembly Facility, E.D. Hallman, in progress.

Material transportation and cleaning - surface to cavity

R. Stokstad

(Prepared for a meeting at Rexdale on 9/9/91)

+Cleaning



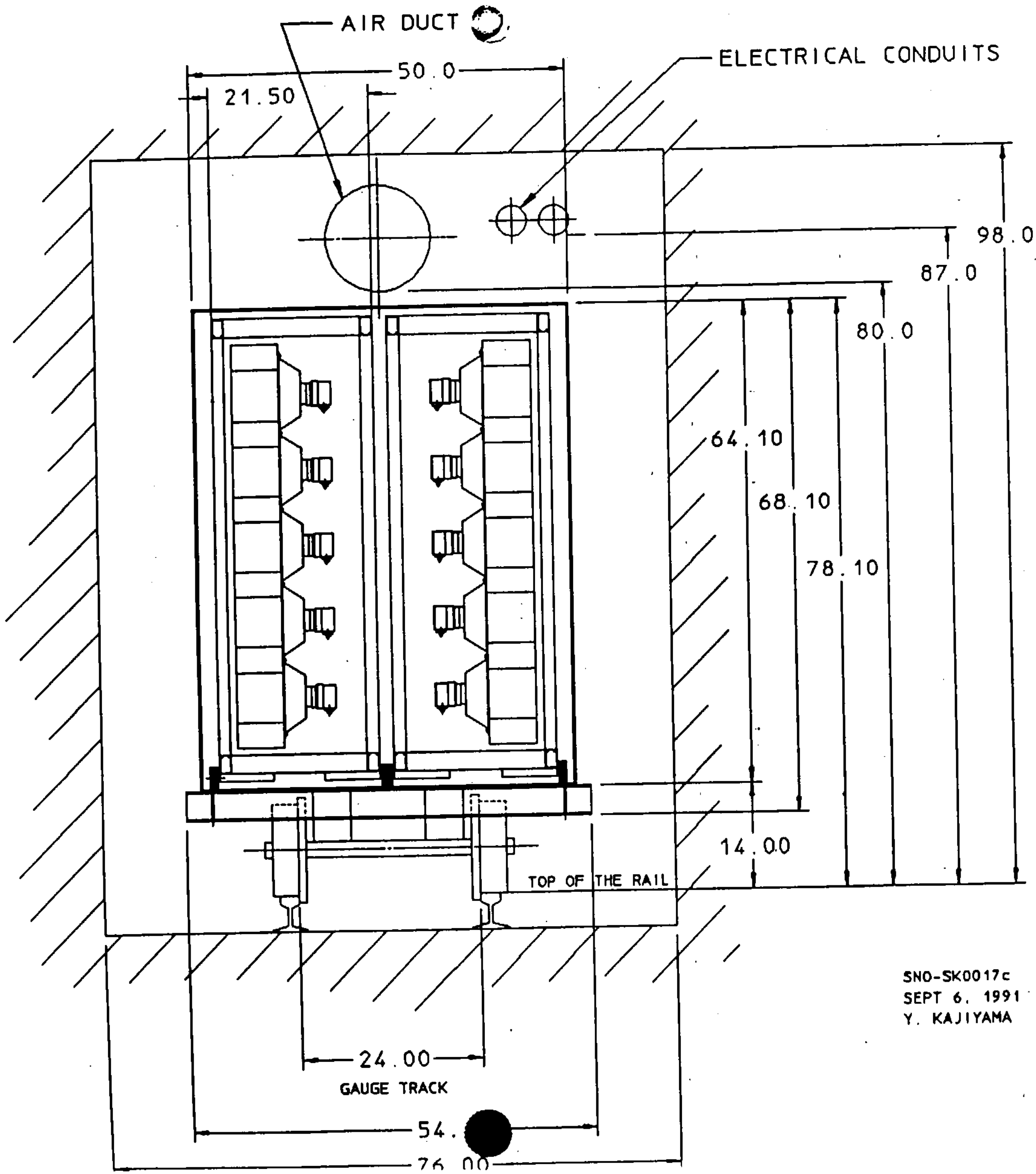
NOMENCLATURE

T22 - Triangle's Snowflake panel with 22 hex-cells
T14 - Triangle panel with 14 hex-cells
T10 - Triangle Panel with 10 hex-cells
S19 - Snowflake panel with 19 hex-cells
S7 - Snowflake panel with 7 hex-cells

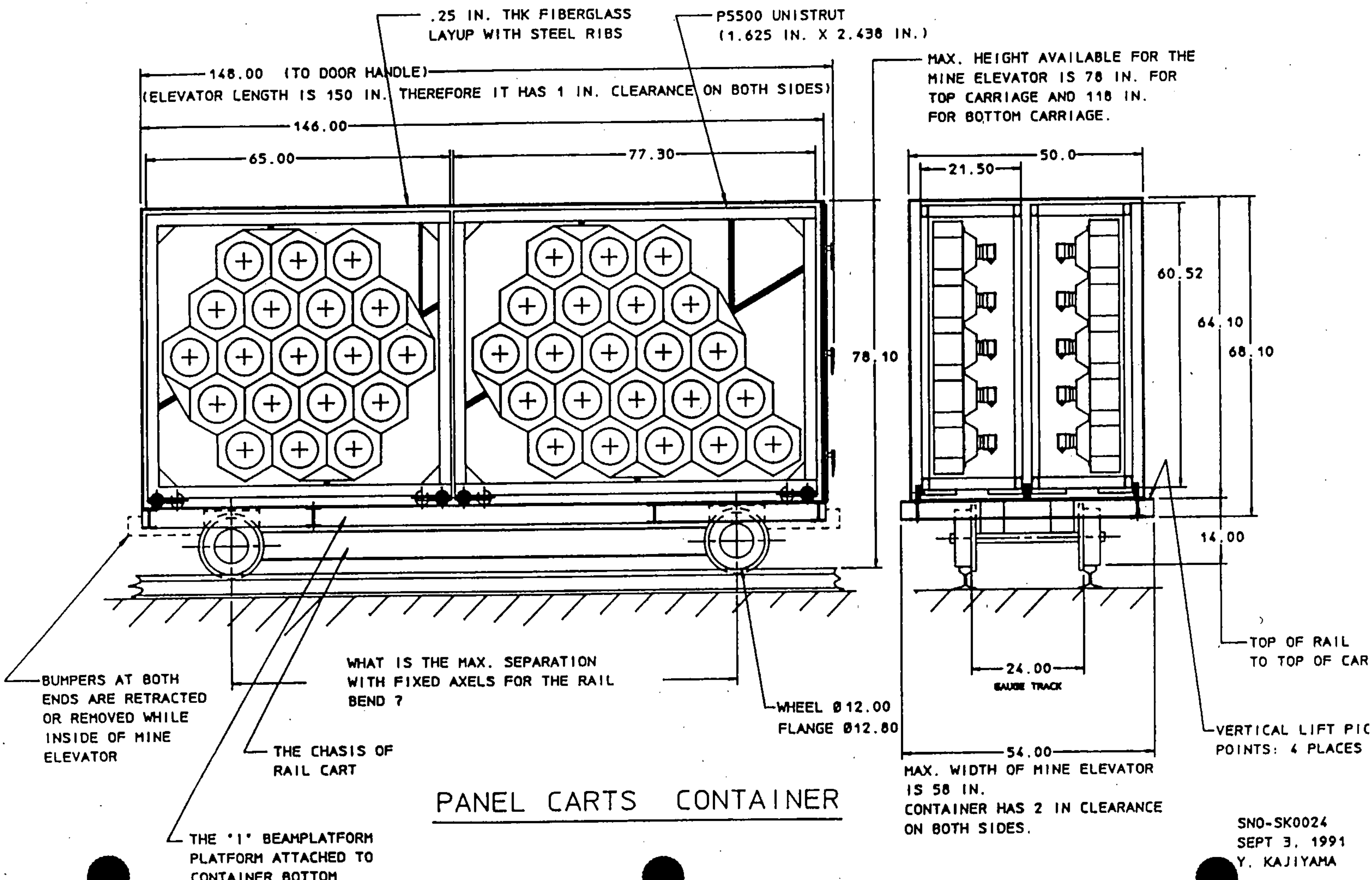
Corrected 9/16/91

S. 8a
SEP 991
Y. K YAMA

5 DIFFERENT TYPES OF PANELS FOR SNO PSUP



SNO-SK0017c
SEPT 6, 1991
Y. KAJIYAMA



PANEL CARTS CONTAINER

SNO-SK0024
SEPT 3, 1991
Y. KAJIYAMA

667-0665

gov.
stokstad@lli.bit net

... 2

YAMAHA

M.E. (914) 945-1037