Final Cleanliness Measures: A Conceptual Plan

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Abstract: A conceptual plan is described for the "last clean-up." It includes cleaning portions of the detector and cavity, and preventative measures (dust covers) for critical surfaces that cannot be cleaned. The cleanliness requirements for the different regions of the detector are given. Areas are noted where further R&D is needed.

Table of Contents

I. Scope and Introduction

This document presents a conceptual plan for the fourth element in the cleanliness program, the "clean-up before filling the cavity."[1] This part of the cleanliness program includes measures to remove dust that has accumulated on cavity and detector surfaces during the clean installation period and, in situations where such cleaning is not possible, to prevent the deposition of dust through the use of removable dust covers.

In addition to supplying clean, filtered air to the cavity during installation of the detector, a "last clean-up" was always envisioned to remove at least some of the dust that inevitably will settle on surfaces in the cavity.[2] How that clean-up would actually be done was not specified. This was appropriate because such a clean-up can only be planned after the configuration of the detector and the installation have been defined. We now know enough about the installation of the acrylic vessel (AV) and the photomultiplier support structure (PSUP) that we can plan, at least in concept, the final measures to insure cleanliness of the detector. These measures and the installation plan are intimately connected; as details of the installation plan are worked out, we expect them to affect the details of the cleanliness procedures.

II. The Three Regions

There are three separate volumes to be considered (see Fig. 1), each with its own cleanliness requirement (see Attachment 1).

Volume 1 is bounded by the interior surface of the AV. Cleanliness requirement at fill time: 0.05 microgram/cm^2 of mine dust. This gives a total amount of one microgram of Th on the interior of the AV, which is equal to the amount of thorium in 1000 tons of D_2O containing 10^{-15} g/g of Th.

Volume 2 is bounded by the exterior surface of the AV and the interior (front) surfaces of the photomultiplier tube (PMT) panels, tubes, and the PSUP water barrier. Cleanliness requirement at fill time: 17 g of mine dust over about 4000 m^2 = 0.4 micrograms/cm^2. This requirement is based on the amount of Th anticipated in the light water in volume 2.

Volume 3 is bounded by the cavity liner and by the exterior (back) surfaces of the PMT panels, tubes and bases, and the PSUP water barrier. It includes the signal cables, PSUP support cables, etc. Cleanliness requirement at fill time: in principle, 10 kg of dust spread over 8000 m^2 = 125 micrograms/cm^2. (This large level of dust represents what the water system should be capable of handling.) In practice, achieving an average dust level in the range of 0.4 micrograms/cm^2 throughout the cavity during the first 15 months of the installation period should result in a similar level in volume 3 after the PSUP water barrier is completed. Thus, albeit arbitrarily, we set an upper limit of 4 micrograms/cm^2 for the dust in volume 3.

The water barrier (Fig. 2) is made by a seal at the waist of the PMT tube to the interior of the hex cell holding the PMT. Adjacent PMT panels are sealed by flexible membranes attached to their perimeters. The tube bases and stainless steel components of the PSUP are in volume 3.

These levels of cleanliness can be verified with a tape lift test and x-ray fluorescence analysis.[3]

III. Time Scales

The time scale for the installation of the different components is important since the amount of dust that collects on a surface depends partly on the time the surface has been exposed. The installation schedule (as of Nov. '91) is summarized in Table 1. Briefly, for

Volume 1, the time from the start of AV assembly in the cavity to the finished vessel is about 8 months. From this point there is another 4 months until the conclusion of the PSUP panel installation.

Volume 2, the time from installation of the first PMT panel in the upper hemisphere to the last panel in the lower hemisphere is 14 months. The lower portion of the PSUP is installed over a period of about 4 months.

Volume 3, the cavity walls are exposed for about 18 months from the time they are cleaned before the cavity is sealed. The top part of the PSUP is exposed for 15 months, the lower part for up to 4 months.

IV. The Plan

A. Factors affecting the plan

The procedures for the last clean-up are influenced by a number of factors:

1. The spherical symmetry of the detector, which makes it difficult or impossible to gain physical access to most of the critical surfaces late in the installation period.

2. The shapes of the PSUP, panels, tubes, bases, cables, etc., which are sufficiently irregular to make impossible the removal of dust by wiping, even if there were easy access.

3. The need to protect the PMTs against light during the long installation period.

4. The complicated topography of the interior surface defined by the PMT/panel/water-barrier arrangement. This prevents rinsing volume 2. There are simply too many places where water would be held up or trapped, rendering a rinse a relocation rather than a removal of surface dust. Fortunately, it is not necessary to install a system for spraying the exterior of the AV to prevent crazing when the water level is lowered for exchange of D_2O and H_2O.[4]

5. The installation procedures for the PSUP and, especially, the AV. The difficulty of assembling these structures requires, in general, that the final cleanliness measures be designed to accommodate the installation procedure.

6. The existence of the water barrier between volume 2 and 3. This barrier relaxes the requirements for cleanliness in the latter region, once the barrier is complete.

The result of these factors is a plan combining physical cleaning, and protection by dust covers.

In the following, we discuss the procedures for each of the volumes in the cavity. Fig. 3 shows a sketch of a dust cover for a PMT panel, and Figs. 4a-f show how the installation and removal of light/dust covers would be incorporated in the installation sequence.

B. Volume 1

The installation procedure for the AV is complex, but in general the surfaces of the AV are cleaned after the bond joints have been finished and at the latest time at which there is still access to these surfaces. The procedure for finishing the bonded joints (grinding, polishing, etc.) and for cleaning the AV surfaces and the cavity thereafter are not under direct consideration here; they still need to be determined by the AV group.

Once the hemispheres of the AV are bonded together, volume 1 becomes isolated from volume 2. After all work inside the AV is concluded, a rinse of the interior surface can be made by lowering spray hoses through the chimney into the AV. The rinse water will need to be removed by means of a sump pump, also lowered from above. A biocide might be included in this rinse (see Section V).

C. Volume 2

The protection of the PMTs against light will be accomplished with opaque plastic "shower-cap" covers (see Fig. 3) installed on the front side of each panel at the time the panels are assembled on the surface. It should be possible to install and align the panels without removing the covers. The covers have strings attached for removing them at a later time. Fig. 4a shows (schematically) the light/dust covers in place on all panels at the completion of construction of the upper portion of the PSUP.

The covers remain on the panels during the construction of the AV. After the AV is completed, hanging in place, and has been cleaned, the shower-cap covers are removed from these panels. Fig. 4b shows the configuration of the components in the cavity at the time the shower-cap covers are to be removed. Note that there is access to the equatorial region of the AV by means of a scissors platform. This access enables the removal of shower caps that have slid down the exterior surface of the AV and come to rest in the ropes that support the AV. (The light/dust covers are made of a soft, flexible plastic sheet that will not damage the surface of the AV.)

Appropriate lighting, e.g., low-level incandescent light should be used when the PMTs are exposed to light during the time between removal of the shower caps and the installation of the equatorial light/dust barrier.

The PMT's and the outer surface of the AV will both be protected from light and dust for the next stage of the installation by means of a equatorial diaphragm of plastic sheet that is fastened to the PSUP stiffening ring and that stretches across the bottom of the AV, as shown in Fig. 4c. The chimney of the AV is also covered with opaque plastic sheet to prevent light and dust entering from above. The upper halves of volumes 1 and 2 are now sealed against light and dust. Testing of uncovered PMTs with a light source could now begin. The lower half of the PSUP is then constructed (Fig. 4d), and the PMT panels with their light/dust covers are installed in the lower hemisphere of the PSUP.

As late as possible, but before the last few panels are installed in the PSUP, the opaque equatorial diaphragm is removed and pulled out through the last open section in the PSUP (Fig. 4e). The lower hemisphere shower-cap dust covers are removed after this (Fig. 4f). The remaining PMT panels are put in place, the water barrier completed, and volume 2 is thereby sealed.

D. Volume 3

The lower walls and bottom of the cavity should receive a thorough final cleaning, since this is where most of the dust or residue from earlier activities will have collected. There is also good physical access to this region.

The upper surfaces in this volume, i.e., the upper part of the cavity liner and the PSUP exterior, should need neither wiping down nor covering, since the permitted dust load is an order of magnitude more than in volume 2. However, it will be possible to monitor the dust deposition and install covers on the upper part of the PSUP if that should prove necessary.

V. Biocides

Since a rinse of the interior of the AV is planned for dust removal, incorporating a biocide in the rinse should be straight forward. An inorganic biocide, 0.1% NaOCl, has been shown to be suitable for application to acrylic.[5] In contrast to the organic biocides, there is no danger of this substance, when present in small quantities, promoting biological growth by serving as a source of food.

Volumes 2 and 3 cannot be rinsed with an inorganic biocide because these compounds have been shown to be harmful to the surfaces of the reflectors. (Even a rinse of volume 3 would inevitably result in rinse water contacting the reflector surfaces.) These volumes cannot be rinsed with an organic biocide for the same reason that they cannot be rinsed to remove dust, viz., water will be trapped or held-up in the complicated surface of the PSUP. This will prevent the complete removal of the organic biocide after its application. As noted above, a residual organic biocide would very likely stimulate growth Some of the problems with the use of biocides are discussed in Attachment 2.

Similar arguments indicate the inadvisability of applying a biocide to the detector components before they are delivered to the cavity.

VI. Further R&D

R&D on several questions is needed to support the implementation of the plan.

1. The optimum material for the dust covers, with regard to fabrication, opacity, and dust retention.

2. The effectiveness of dust covers. We need to know how much dust might re-enter the air when the covers are removed.

3. The optimum design of covers for subsequent removal. Working with prototypes is necessary to demonstrate the removal of covers without their becoming stuck or tangled.

4. The effectiveness of a rinse in removing dust and other contamination from the interior of the AV. R&D into appropriate surfactants and rinsing procedures is needed.

The dust covers make up a large area of thin plastic sheet in the cavity. INCO approval will be needed.

VII. Summary

The above plan for the final cleanliness measures involves different procedures for each of the three volumes. It reflects the different cleanliness requirements for each volume as well as what is possible given the topography of the detector and the installation plan.

The plan is conceptual. Detailed procedures and equipment need to be designed to accomplish the plan. Thus, subsequent documents describing the cleaning of the AV and the implementation of dust covers are anticipated. As the plans for installation of the detector become more detailed, particularly for the assembly and bonding of the AV, modifications of these cleanliness measures may be expected. However, the concept presented here is not likely to require major revision.

References

1. E.D. Hallman and R.G. Stokstad, "Establishing a Cleanliness Program and Specifications for the Sudbury Neutrino Observatory," SNO-STR-91-009, October, 1992.

2. H.C. Evans and H.W. Lee, "Cleanliness Considerations for Construction of the SNO Detector," SNO-STR-88-73, June, 1988.

3. R.G. Stokstad, Ed. "Delivering Clean Components to the Cavity," SNO-STR-91-066, January, 1992, Section IV.

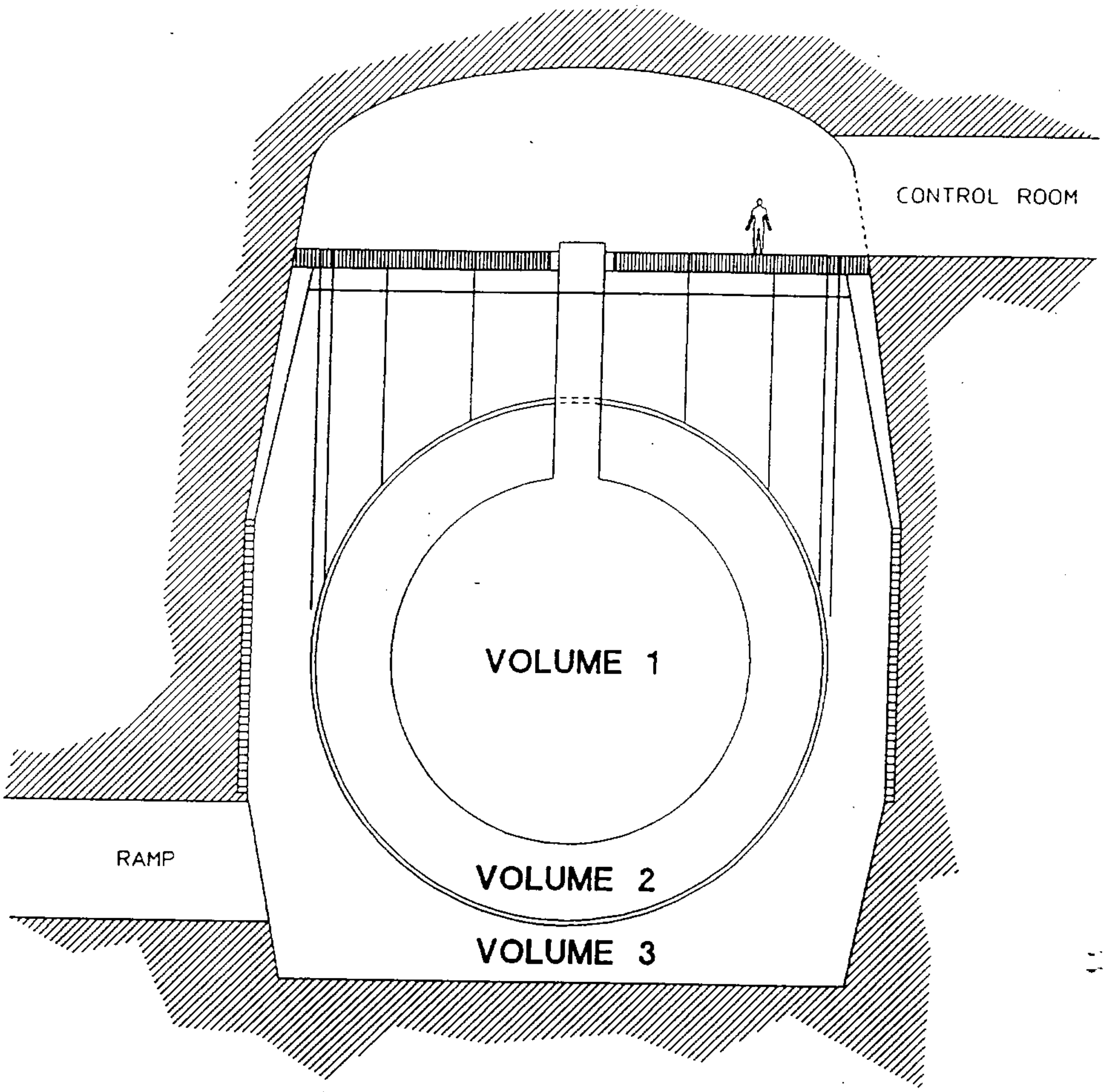
4. P. Doe, "Stress in acrylic due to water absorption and desorption," SNO-STR-92-13, March 1992

5. J. Stachiw, "Compatibility of Biocides with Non-Cross Linked Acrylic," March 16, 1992.

Table 1

Installation Schedule
(read from schedule with plot date: 13 Nov. '91)

Date	Activity	[months to start of fill]
April 20, 1993	Cavity clean-up finished Start PSUP installation	[17.5]
June 10	Start upper PMT panels PMT panels have dust/light covers on them	[15.7]
Sept 15	Finish installing upper PMT panels Start upper hemisphere of AV	[12.5]
Feb. 25	Start lower hemisphere of AV	[7.2]
	Hoist lower shell, bond, and clean surfaces	
May 1	AV installation complete remove dust covers from PMT panels install equatorial diaphragm light/dust cover cover chimney	[5]
	Start lower hemisphere of PSUP PMT panels have dust/light covers on them	
Aug 15	PSUP finished	[1.5]
Sept. 1	Remove dust covers, clean cavity 1. equatorial diaphragm dust cover, then 2. PMT panel covers install few remaining lower PMT panels complete water barrier biocidal rinse of interior of AV (if not done earlier) clean lower walls and floor of cavity liner	[1]
Oct. 1	Begin H_2O fill	[0]



The three volumes.

Fig. 1

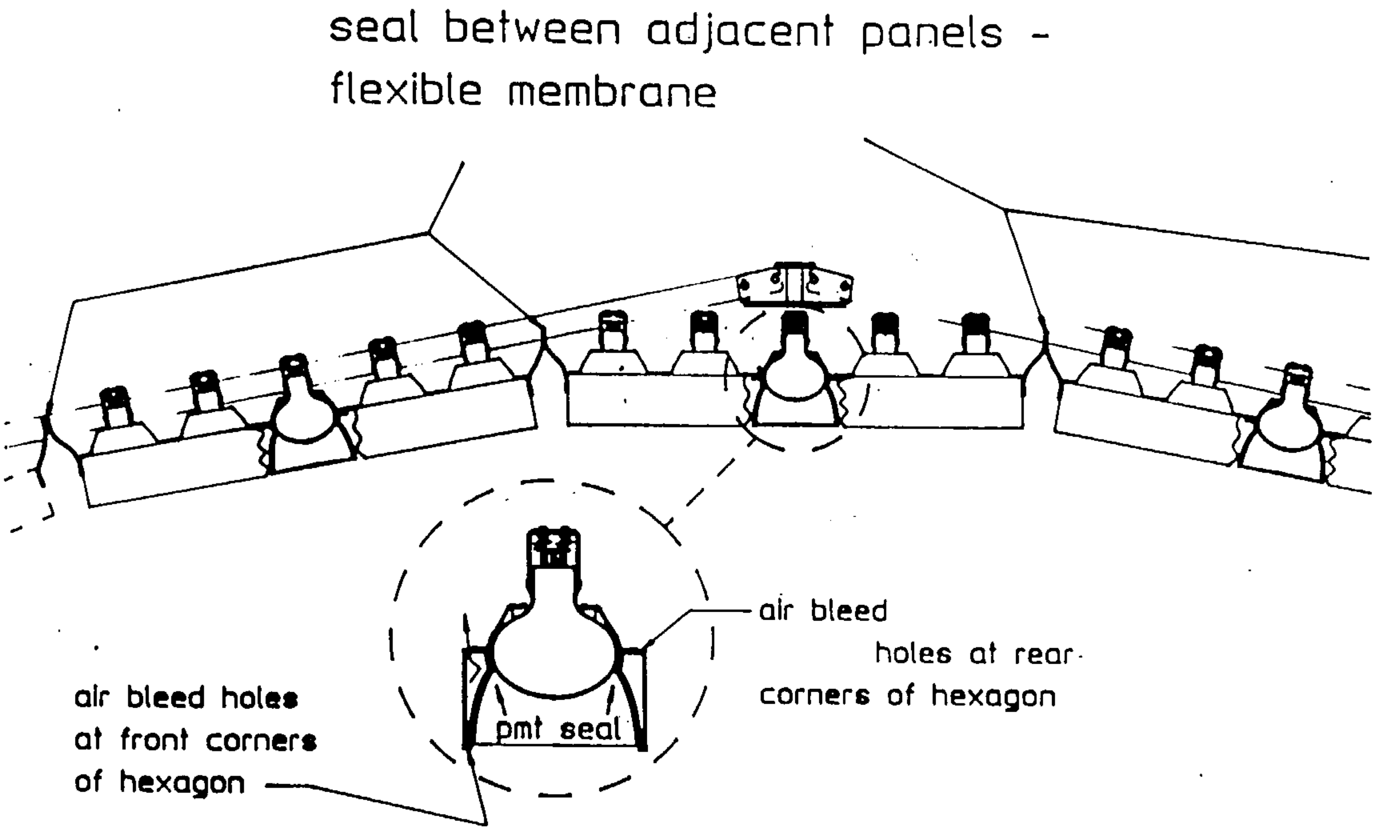
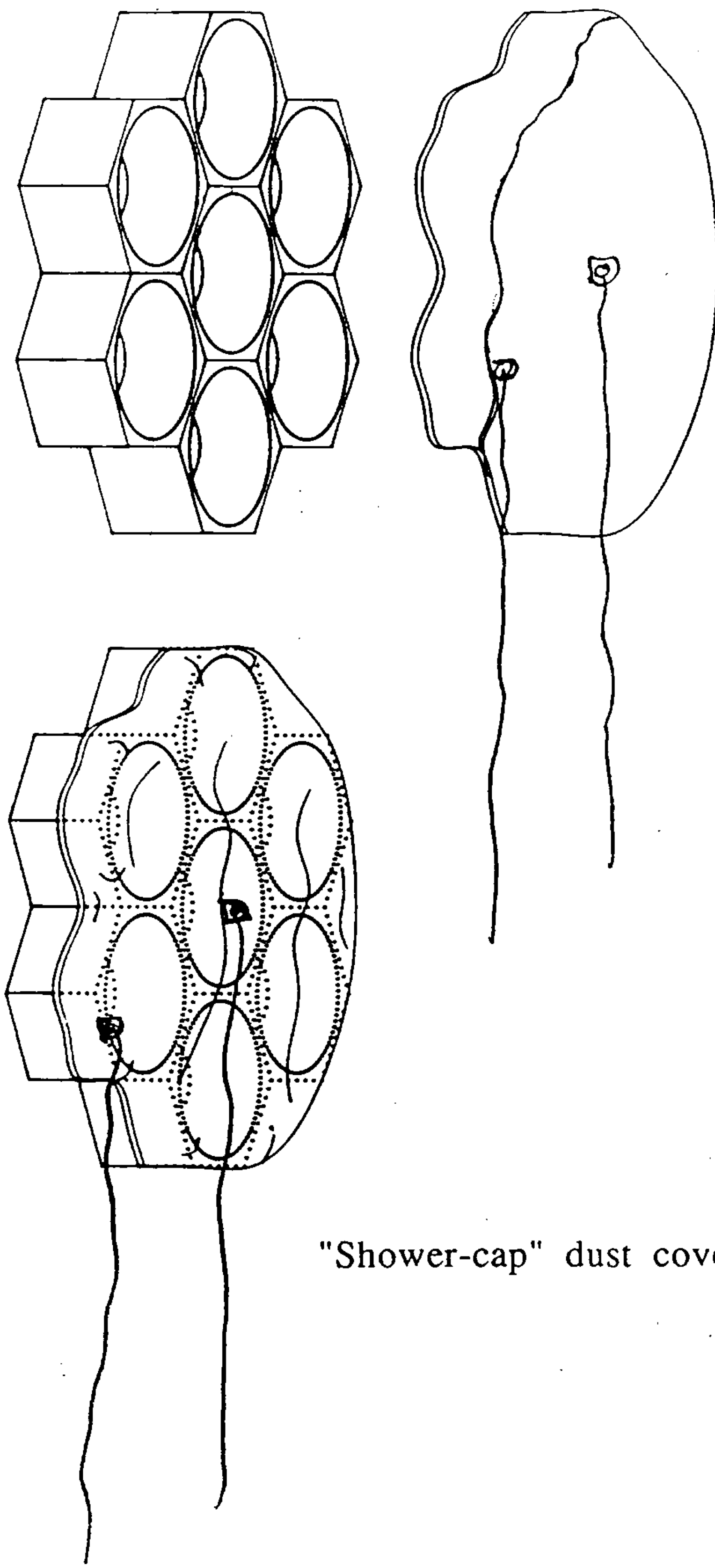


Fig. 2

The water seal for the PSUP and PMT's.



"Shower-cap" dust covers for PMT panels.

Fig. 3

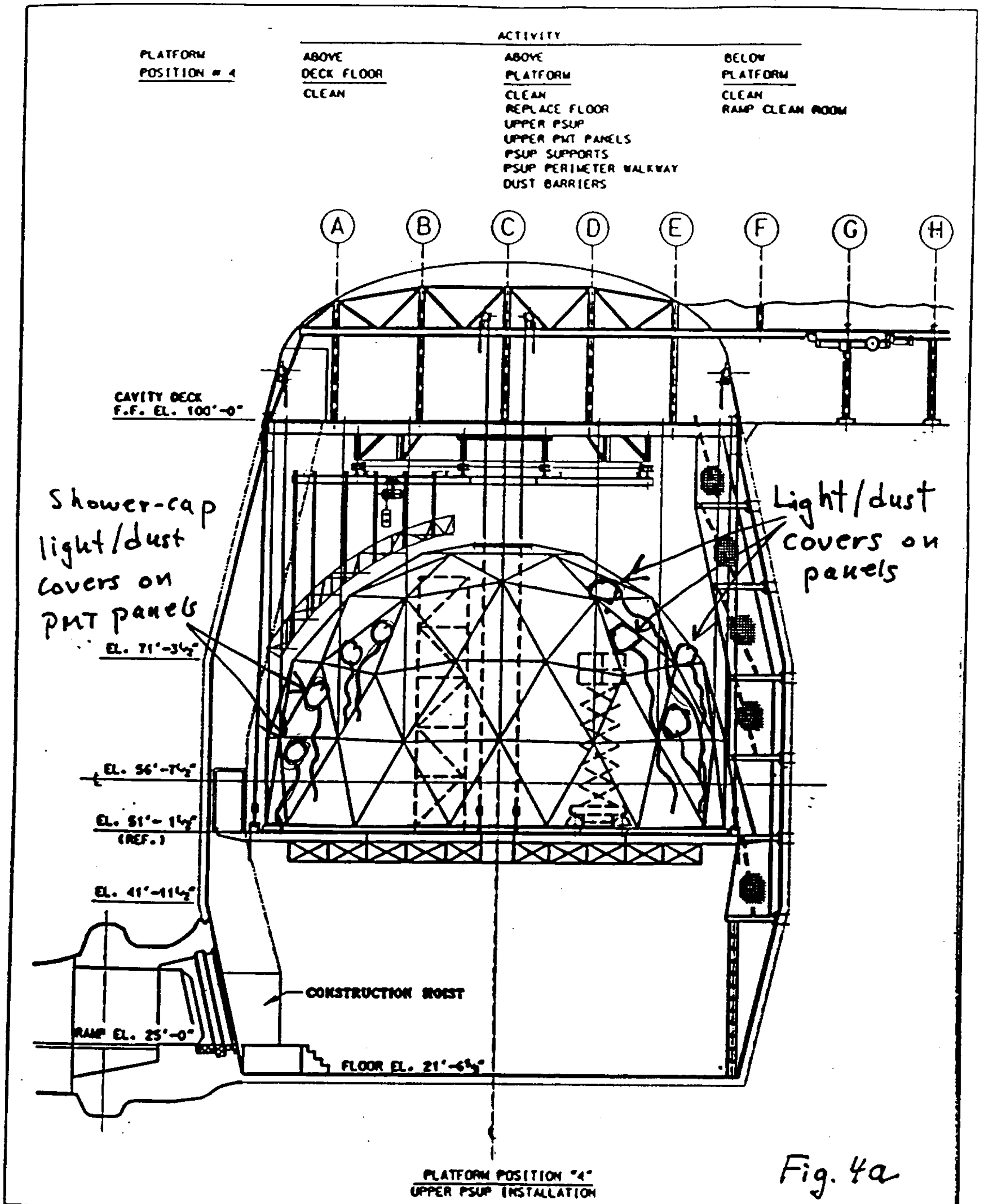
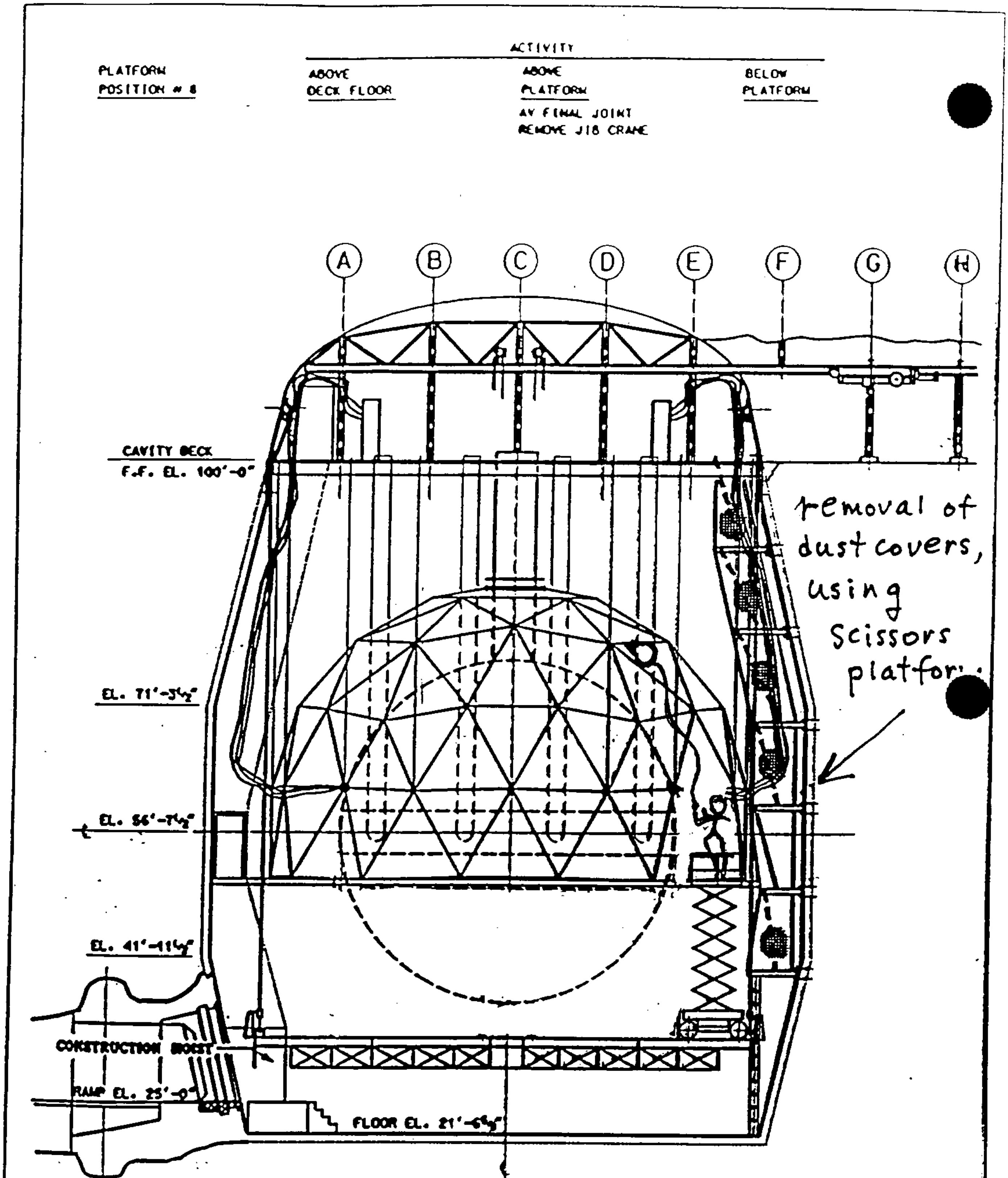

ACTIVITY
PLATFORM POSITION # 4
ABOVE DECK FLOOR
CLEAN
ABOVE PLATFORM
CLEAN
REPLACE FLOOR
UPPER PSUP
UPPER PMT PANELS
PSUP SUPPORTS
PSUP PERIMETER WALKWAY
DUST BARRIERS
BELOW PLATFORM
CLEAN
RAMP CLEAN ROOM
A
B
C
D
E
F
G
H
CAVITY DECK F.F. EL. 100'-0"
Shower-cap light/dust covers on PMT panels
Light/dust covers on panels
EL. 71'-3½"
EL. 56'-7½"
EL. 51'-1½" (REF.)
EL. 41'-11½"
CONSTRUCTION HOIST
RAMP EL. 25'-0"
FLOOR EL. 21'-6½"
PLATFORM POSITION "4"
UPPER PSUP INSTALLATION

Fig. 4a



PLATFORM POSITION "8"
AV LOWER HALF INSTALLATION

Fig. 4b

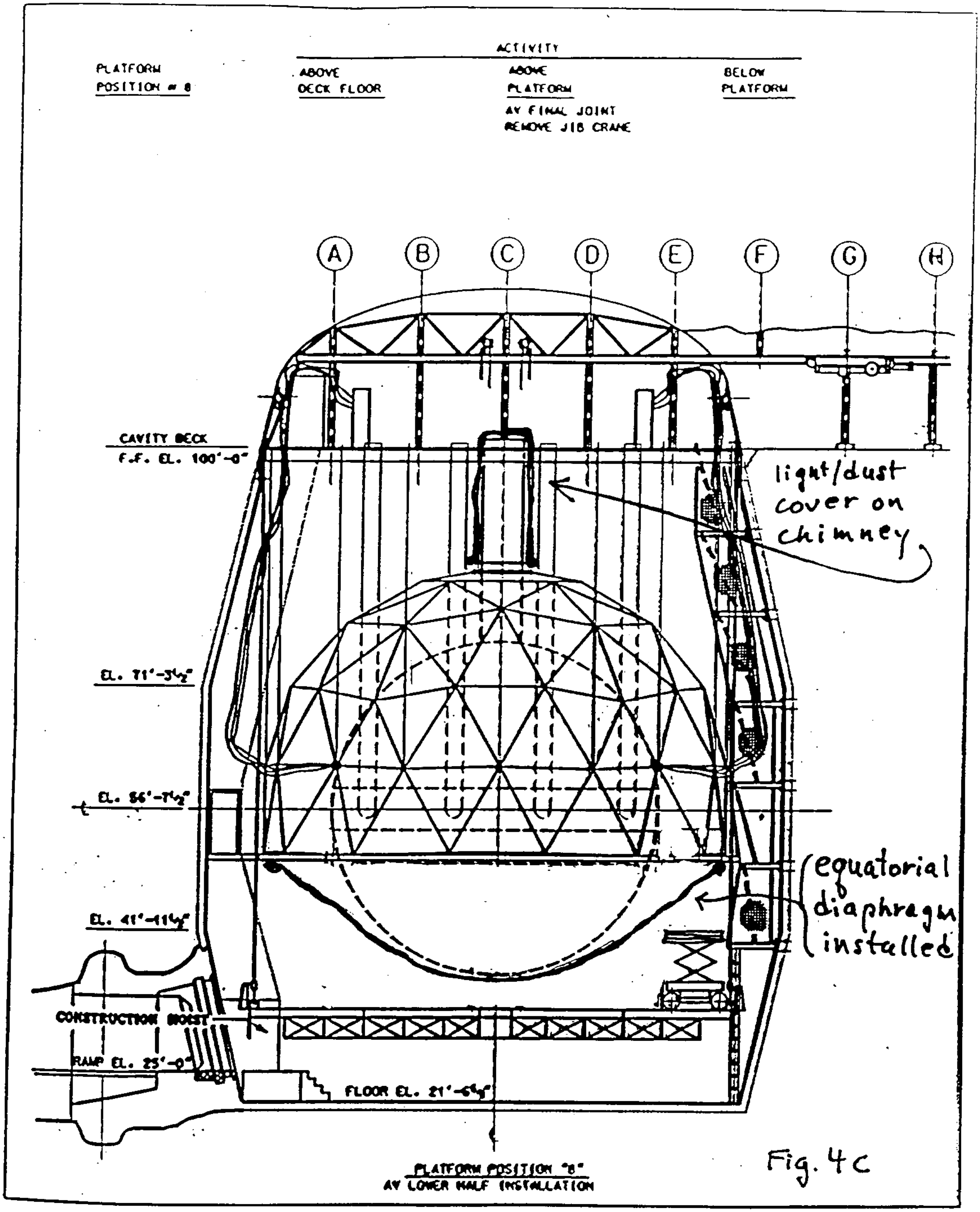

ACTIVITY
PLATFORM POSITION # 8
ABOVE DECK FLOOR
ABOVE PLATFORM
AV FINAL JOINT
REMOVE JIB CRANE
BELOW PLATFORM
A
B
C
D
E
F
G
H
CAVITY DECK
F.F. EL. 100'-0"
light/dust cover on chimney
EL. 71'-3½"
EL. 56'-7½"
equatorial diaphragm installed
EL. 41'-11½"
CONSTRUCTION HOIST
RAMP EL. 25'-0"
FLOOR EL. 21'-6½"
PLATFORM POSITION "8"
AV LOWER HALF INSTALLATION

Fig. 4c

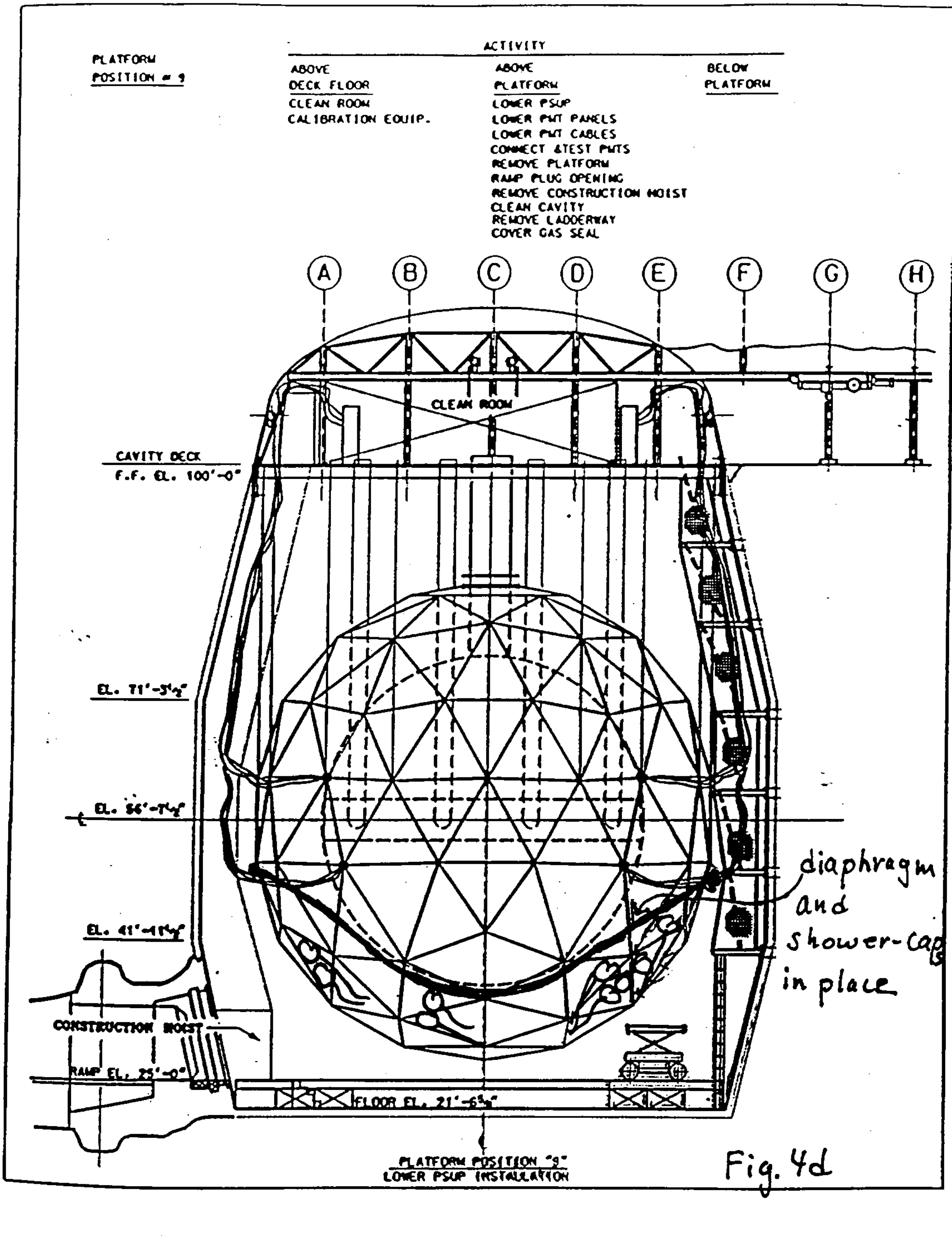
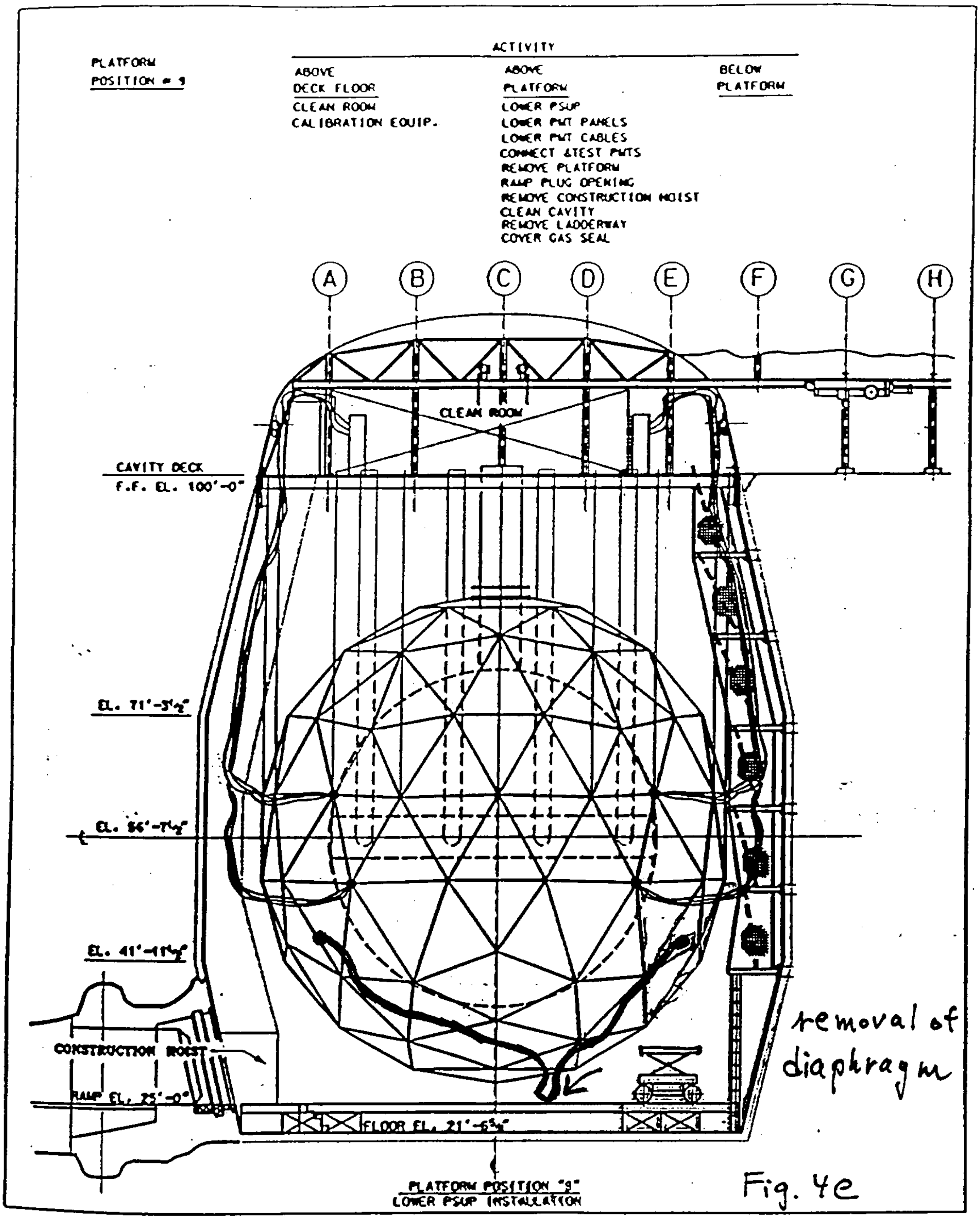

PLATFORM POSITION # 9
ACTIVITY
ABOVE DECK FLOOR
CLEAN ROOM
CALIBRATION EQUIP.
ABOVE PLATFORM
LOWER PSUP
LOWER PMT PANELS
LOWER PMT CABLES
CONNECT &TEST PMTS
REMOVE PLATFORM
RAMP PLUG OPENING
REMOVE CONSTRUCTION HOIST
CLEAN CAVITY
REMOVE LADDERWAY
COVER GAS SEAL
BELOW PLATFORM
A
B
C
D
E
F
G
H
CLEAN ROOM
CAVITY DECK
F.F. EL. 100'-0"
CONSTRUCTION HOIST
RAMP EL. 25'-0"
diaphragm and shower-cap in place
PLATFORM POSITION "9"
LOWER PSUP INSTALLATION

Fig. 4d



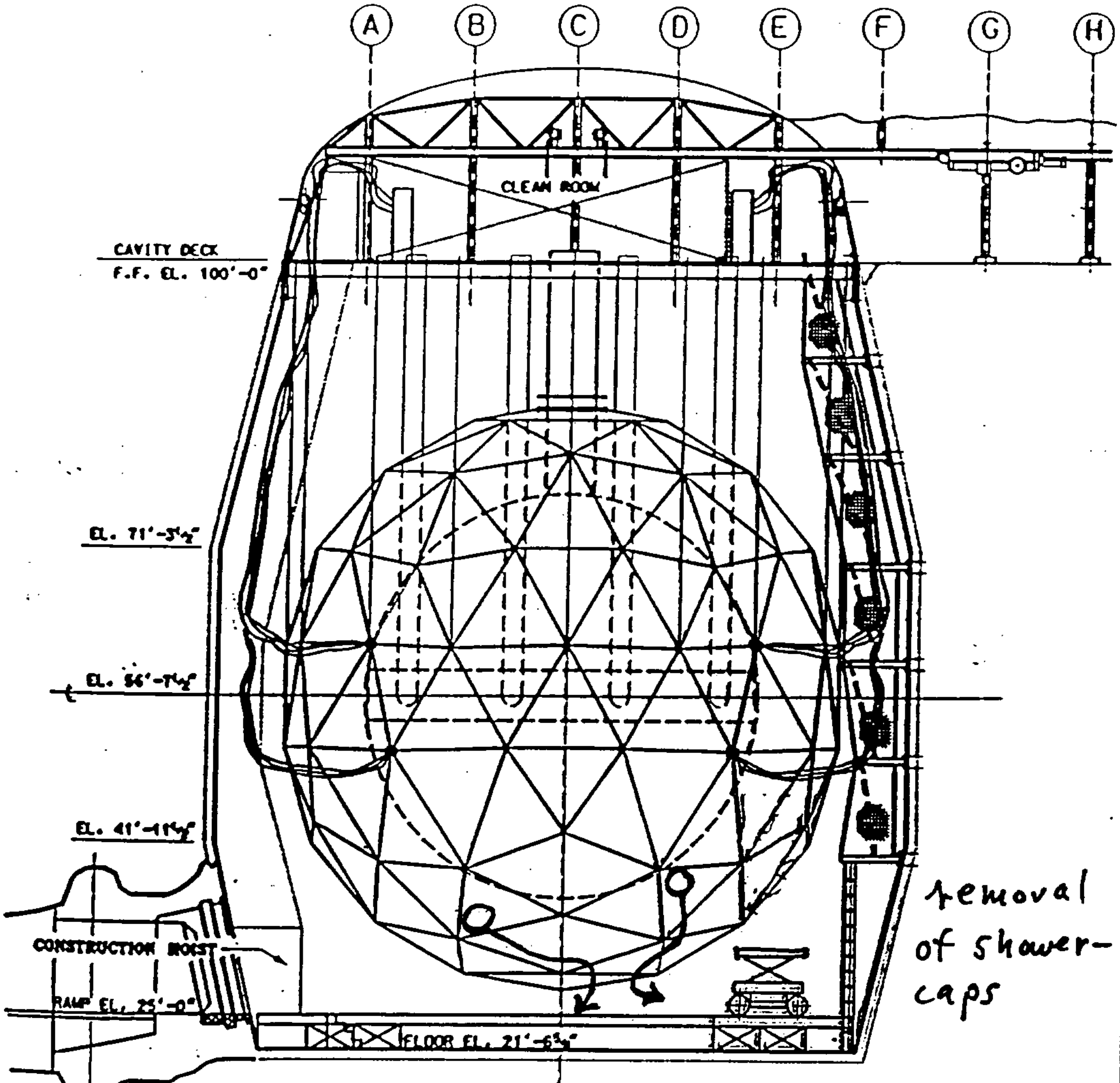
PLATFORM POSITION # 9
ACTIVITY
ABOVE DECK FLOOR
CLEAN ROOM
CALIBRATION EQUIP.
ABOVE PLATFORM
LOWER PSUP
LOWER PMT PANELS
LOWER PMT CABLES
CONNECT &TEST PMTS
REMOVE PLATFORM
RAMP PLUG OPENING
REMOVE CONSTRUCTION HOIST
CLEAN CAVITY
REMOVE LADDERWAY
COVER GAS SEAL
BELOW PLATFORM
A
B
C
D
E
F
G
H
CLEAN ROOM
CAVITY DECK
F.F. EL. 100'-0"
EL. 71'-3½"
EL. 56'-7½"
EL. 41'-11½"
CONSTRUCTION HOIST
RAMP EL. 25'-0"
FLOOR EL. 21'-6¾"
removal of diaphragm
PLATFORM POSITION "9"
LOWER PSUP INSTALLATION

Fig. 4e

PLATFORM POSITION # 9

ACTIVITY

ABOVE DECK FLOOR	ABOVE PLATFORM	BELOW PLATFORM
CLEAN ROOM	LOWER PSUP	
CALIBRATION EQUIP.	LOWER PMT PANELS	
	LOWER PMT CABLES	
	CONNECT &TEST PMTS	
	REMOVE PLATFORM	
	RAMP PLUG OPENING	
	REMOVE CONSTRUCTION HOIST	
	CLEAN CAVITY	
	REMOVE LADDERWAY	
	COVER GAS SEAL	



removal of shower-caps

PLATFORM POSITION "9"
LOWER PSUP INSTALLATION

Fig 4f

ATTACHMENT 1

From: ST%"SINCLAIR@physics.carleton.ca" 18-DEC-1991
To: STOKSTAD
Subj: actions

I have reviewed the actions against me from your notes of a meeting of 12/13/91.

1) Review dust loading between AV and PSUP.

There are two ways to get a limit here.

i) Assume all Rn escapes from dust and that the 212Pb sticks to the AV. This effectively adds all of the activity to the AV load. The total AV load is about 30 tonnes @ 1 ppt, 3E-5 g Th or 6 g mine dust. This is a very conservative estimate. It would be more realistic to expect the Pb to come out on all surfaces equally or to stay in the water.

ii) Assume all Rn escapes from the dust and stays in the water. Try to maintain water at 5E-14 g/g Th. Total water is about 1.7 kT, so total Th is 8.5E-5 g or 17 g dust. Again this may be conservative because MC calculations show that we could live with 5E-13 g/g. This conclusion might change if the acrylic really comes in at < 1ppt.

Thus I feel that the 17 g limit could be relaxed by a factor of 2 but Iwould not like to see it much higher.

2) Dust load outside the PSUP

In the outer water there are about 5 kT of water or 5E9 g. Thus if all Rn gets into the water the load would be 1E-11 g/g. However, the probability of the short lived Rn getting into the clean area is very small as the daughter products will be effectively removed by the ion exchange beds. The risk is then that the outer water and the inner water mixes through the PSUP. The flow calculations predict a flow which is every where outwards at a total flow of 150 l/min. If we assume that this would allow an inward flow of 15 l/min of unsupported activity of half life 10 hour, then the total addition to the load on the inner water is 10e-13 g/g. This is very crude but perhaps suggests that 10 kg is an upper bound which we would like to avoid. It all depends on how tight the PSUP is.

The IX units in the water system are rated at 43.2 kGrain each and we have 12 units arranged as two sets of 6 in parallel. If we want to avoid saturating the first 6 then our capacity is 6 x 43.2 * 64.8 gm or 17 kg. This is not a hard number as the units can be regenerated but it indicated that the 10 kg total dirt load could be handled.

Second Thoughts on Biocidal Washing

Chris Waltham, Salvador Gil and Louis McGarry
Physics Department, UBC
February 22, 1992

Evaluation of Biocides

After an initial evaluation of biocides, John Smit and Bill Ramey have made the following observations:

1. At 200ppm Adesol 20 and Amberquat kill 3-4 logs of attached bacteria (i.e. the biological activity as expressed in uptake of radiolabelled nutrients goes down by 3-4 orders of magnitude).

2. At 0.01-10ppm these biocides *stimulate growth*. These are both quaternary ammoniums and can provide organic carbon and nitrogen in media where these are normally limited. The molecules are charged and may well adhere to plastic surfaces and be resistant to removal.

3. Cidex (a glutaraldehyde formulation) stimulated growth even more than the quats. This may, however, have been due to nitrites in the mixture.

Implications

1. The extremely low levels of organic biocides which can stimulate growth make adequate rinsing extremely difficult.

2. A bleach treatment of Volume 1 at 100ppm would be much more effective and safe from a biological point of view. We have sent samples to Jerry Stachiw to test for crazing effects.

3. Bleach does not seem to acceptable anywhere near the concentrators.

4. It is possible that we will have to rely on degassing the water and providing a cover gas during the fill.

Cover gases under consideration are:

(a) Argon

(b) Nitrogen

(c) Carbon Dioxide

(d) Sterile Air

(a)-(c) are either totally or mostly useless to the nutrient-limited life we are worried about.

As with the biocides it is transitions which are hazardous. Getting to an anoxic state might create problems as low oxygen levels (0.1% - 5%, Ramey guesses) can stimulate otherwise dormant microaerophils (I hate biology). This is worrisome in the case of (b) (at least) because a reasonably sized nitrogen plant would take many months to achieve 1% oxygen levels. Sterile air, easily achievable by micron-sized HEPA filters, could prove a safer option during the filling stage.

Salvador Gil is preparing a stätement on cover gas work at UBC for the March Water Meeting.