

Trip Report on Witnessing RPT Underground Bonding

by Davis Earle
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I spent 3 days in Sudbury, Mar 4, 6 & 7, 1992

Item 1. The Fail Safe Meeting.

On the morning of the 4th I attended the Fail Safe Review for the RPT 4600' bonding at INCO Engineering. 10:30 to 1:00. It involved the screening of material and procedure for just the test run. The major hazard in the mine is a fire. No matter how small the mine must be evacuated which is very expensive. Materials in cage and drifts must be protected.

Tom examines the MDS and reviews the materials that can be used. The hoist man, if not satisfied, can refuse to take something down. He must refuse. Contractor must keep a copy of all MDS in his job box. Names of products must be submitted on HMCP-001 forms or already be on the existing list which contains 10,000 products. He looks at about 200 new products per year. It is cheaper for us if we can choose products already on the list. Not all of our materials had been cleared for UG but the INCO team doing that expected to be able to do it in time.

There was some discussion about fires, fumes etc. Ken Lanquille was quite cautious and insisted on double containers for chemicals, on a gas detector for MMA fumes and appropriate signs. I described our experiences at CRL with the MMA fumes. Bob Coultier was quite realistic and reasonable in his pronouncements. The other INCO people seem to be quite happy with the precautions being taken. The man in charge of signing the MDS for going UG was obviously quite experienced and familiar with the toxicity of substances. My impression was that Ken will be very cautious and require a high level of conservatism from SNO. The other safety people will not be unreasonable in their requirements on SNO. The Crieghton safety guy was there and the documentation expected of us and the locations for filing MDS was mentioned.

Item 2. Discussion with William about RPT handling in Santa Ana.

The orientation meeting for Kevin, William and I was cancelled because the mine was shut down. After lunch I spent 1/2 hour with William discussing the thermoforming, machining and sanding procedure done on our samples at RPT. In particular, the precautions taking re cleaning.

- a) The Polycast and Rohm acrylic was cut into 6" wide strips.
- b) Felt and rubber were laid out on a cart and the surfaces vacuum.
- c) The inside surface of the oven was tack wiped.
- d) The protective coating on the acrylic was removed (in some cases) and the acrylic was laid on the cart.
- e) Both surfaces were wiped clean with 20% alcohol solution while the acrylic was in the oven.
- f) After thermoforming a protective coating was put on the acrylic.
- g) After machining and sanding the acrylic when back into the oven for annealing. Go back to b) above.

Item 3. Orientation and visit to 6800'.

I came back Friday morning for the orientation course and we went down on the 8 am cage, Kevin, William, Larry and me. We visited the 6800' level and William inspected the cavity. After he had seen enough we went up to 4600'. INCO was in the process of placing a small charge in the second bench to check vibration levels. There were some comments about the significant delays during the last few months to do with corbeil installation and security. William's only comment to me was that installing the vessel would be more expensive then he had earlier thought. This probably had to do with the logistics of working UG - it may be more hostile then he had thought.

Item 4. First impressions on clean room.

We got to 4600' at about 11:30 and the two Dan's were finishing of the work bench in the clean room. William and Kevin did not like what they saw. Dan went into the clean room in his mine clothes (boots off), stuff was stored in the anteroom that would be better in the drift. There was rapid transfer of materials in and out of the three areas. RPT people talked about an air shower or a plastic current. Clean clothes before the clean room etc. They did not think that the bonding would be done in an adequately clean environment. Dan and RPT had a lengthy discussion and the pros and cons of the lab. Dan thought it better then the university physics department. Eventually I got into the discussion. Either we had to

work with what we had or send RPT back to Santa Ana until we got it better. As technical director of the contract I said we should proceed and do the best we could. Noting, of course, the RPT reservations. I should add, in spite of the RPT concerns which are valid, that Hallman et al have done an exceptional job in preparing this room for these tests. It does not have the shower facilities and air isolation we expect to have a 6800' but it is a much smaller volume. I should find out the air changes per minute from Doug.

Item 5. Bonding of test samples.

a) Thursday's work as told to me by Doug.

At Laurentian, the acrylic samples were unpacked from the RPT shipping crates. Some places on the sheets were cleaned with kimwipes dampened with inhibited monomer. The protective covering was removed. They were cleaned with spar cleaner soapy solution and a sponge. They were rinsed in tap water. Air dried for an hour or so. Visually inspected for dust. Double bagged in heavy polyethelene.

b) Friday at 4600'.

Particle counter readings in units of 1000 particles/0.1 ft³

In drift
size

0.3	574	562	550	546	510	501	484
0.5			93	93			
1.0					10.6	10.5	
3.0	1.5	1.4					
5.0							0.49

In ante room
size

0.3	130	146	149	147	112
0.5	13	14	14	15	
1.0					2.6
3.0					
5.0					

In clean room

size	A	A	A	A	B	B	C	C	C
0.3	15	13	12	11	15	12	31	25	24
0.5	1.9	1.6			1.6				
1.0			0.35	0.24		0.21	1.1	0.55	0.6

In clean room									
size	D	D	A	A	C	C	C	C	C
0.3	20	11	7.6	8.2	17	16	15	18	13
0.5									
1.0	0.65	0.6	0.2	0.47	0.8				
3.0									
5.0						0.2	0.11	0.37	0.08

In clean room									
size	B	B	B	B	B	A	A	A	A
0.3	3.6	3.4	3.3	2.1	2.4	8.7	4.1	3.9	4.9
0.5									
1.0		0.11	0.09	0.07	0.08	0.4	0.2	0.16	0.3
5.0	0.02								

In clean room		
size	C	C
0.3	10	6.7
0.5		
1.0	0.3	0.2
3.0		
5.0		

A to D are various locations in the clean room. (There is a sketch in my note book) A is on the table near the wall with the filter unit. B is on the bench under the extra laminar flow hood. C is out in the middle of the room and D is near C. The readings seem to indicate fluctuations of up to a factor of 10 with the cleanest spot being on the bench under the laminar flow hood where the hort. bond was made and the dirtiest spot in the middle of the room where the vert. bond was made. The room could be rated at about Class 20,000 i.e. number of particles below 0.5 microns per cu ft. The room is about 10 times better than the ante room and about 50 times better than the drift. Many more measurements were taken on Sat.

Kevin and William spent Friday afternoon preparing the acrylic samples for cleaning, damning etc. We three stripped to our underwear and changed into whites with caps, no gloves. We went into the clean room where the materials to be used were unpacked and laid out on the table. The acrylic was removed from the double bags, one bag in the ante room, the other in the clean room. The hort. acrylic pieces were placed on the bench under the laminar flow and the vert. pieces were mounted on a simple jig, which had to be assembled, to hold them vertically. There

was some trouble with this jig. It was rather unsteady since the floor was not flat, the pieces would not stand unless taped together and the 1/8" bond gap while OK at the bottom was closed at the top. An acrylic spacer had to be used to keep the top gap at 1/8". An extension to take surplus bonding syrup was placed on the top of the vert. pieces. Both joints were now ready for finally cleaning and dam application.

We choose to leave the vert. gap open to the room environment overnight but the hort. gap was taped over with masking tape. The time from opening the packed acrylic to taping the hort. gap shut was about 1 hour. This entire operation took Kevin and William about 2 hours. We noted that the bottom of the booties got dirty from the clean room floor.

The time sequence is as follows:

2:00 pm acrylic out of wrapping
2:20 opened vert. acrylic panels/ hort. acrylic in place
2:52 finished with vert. acrylic
3:15 taped gap in hort. acrylic
3:33 locked outside door

c) Sat.

Kevin installed the dams on both gaps. I have extensive notes for this day and many (55) particle counter readings taken on Friday and Saturday. On Friday the clean room was about class 20000 but on Saturday it was more like 6000. Readings fluctuated by about a factor of 5.

8:37 am Finished cleaning the floor with tack rags
8:40 Started cleaning the vert. bond faces with 20% isopropyl, followed by inhibited monomer with kimwipes. Took 5 mins to do both surfaces.
8:51 Started to seal the gap with tape. A problem keeping the correct gap at the top of the vert. pieces. Put in an acrylic spacer. Could be done better with a double clamp. 1" wide tape accurately placed over the 1/8" gap.
8:55 Gap closure complete with 1" wide Al tape. The vert. gap was open to the clean room for 19 hrs. before cleaning. Now placing masking tape on either side of the gap in preparation for priming the acrylic surface for the silicone 795.
9:03 Took 1 min to clean the test sample.
9:08 Cleaned mechanical dam to be used on top of vert. pieces.
9:21 Top of vert. gap sealed with top dam in place. Started cleaning area to which dam sticks with full strength alcohol followed immediately by clean dry kimwipe. Alcohol

not allowed to dry on the surface.

9:27 Finished cleaning the vert. pieces. Now ready for primer.
Go to the hort. pieces.

9:28 Removed overnight tape from hort. gap.

9:30 Sealed gap on test piece. Surfaces were exposed to the room
for 27 mins.

9:31 Started alcohol wipe on hort. gap surfaces. Train went by.
Humidity 62%. Temp. 70 degs F. No increase in dust levels.

9:36 Started monomer wipe on hort. piece.

9:41 Started taping gap. The lab book has drawings of the dam
material and how it is attached to the acrylic.

9:44 Top gap sealed. Now putting masking tap on outside of dam
area.

9:52 Finished top surface which becomes bottom surface when the
acrylic is turned over. Gap sealed.

10:11 Kevin comments that he can see the dust settling out on the
vert. acrylic but not on the hort. pieces which are under the
laminar flow hood.

10:24 Gap on hort. pieces now closed with upper dam in place. Now
adding braces. The upper dam on the hort. bond is different
from the lower and both vert. dams. See lab book for a
drawing.

10:27 Top dam is ready.

10:31 Started preparing and cleaning dam gasket. Wiped with
alcohol and then covered grooves with Al tape to protect until
ready to glue to the acrylic.

10:37 Finished cleaning one piece of gasket material.

10:51 Started cleaning 2nd 6' long gasket.

11:00 Finished. Waiting delivery of primer from the surface.

12:26 Back inside clean room. After lunch. Primer just arrived.

12:34 Started cleaning surfaces for applying primer to vert. acrylic.
Alcohol used to clean surfaces whereas 20% alcohol for
bonded surfaces. Again alcohol is wiped off before it dries.

12:43 Primer is applied to vert. acrylic in much the same way as
the alcohol. Primer is also wiped onto dam material and hort.
acrylic.

12:48 Doug placed sticky tape around clean room to collect dust.

12:56 Letting primer dry on the acrylic. Forms a milky film like car
wax which can be inspected to see if coverage is complete
before it is wiped off, as with car wax.

13:07 Removed milky film from the acrylic surface and the Al tape.

13:10 Started applying Si 795 to the vert. acrylic on the surfaces
between the three strips of masking tape. This is a black
sticky caulking compound.

13:25 Removing masking tape from vert. gap. Exposing the gap to

room air.

13:33 Exposed test piece gap to room air as well.

13:36 Started applying 795 to hort. pieces. Leaving the vert. stuff to dry for approximately an hour with the gap exposed.

13:43 Hort. gap exposed to air.

13:46 Applying narrow masking tape to vert. gap to seal it.

13:48 Closing hort. gap as well.

13:53 Applying 795 to the dam material. Here a very thick layer is applied. Used an acrylic spaced to make sure it was thick.

14:06 Finished 795 on one dam. Sealed gap in the small test piece.

14:12 Dam applied to the bottom of vert. gap, 2 1/2" piece.

14:18 Dam applied to one vert. side.

14:25 Finished the first 6' dam.

14:33 Started on 2nd vert. dam. Clean with alcohol. Apply primer.

14:52 Applying 795 to dam for the 2nd vert. side. There was a delay because Kevin had to go back to the 1st vert. dam and apply a 795 bead along the outside of the dam. The concave shape of this bead is critical.

15:01 2nd vert. dam in place. Now being rolled hard to remove an bubbles in the 795. This was done very carefully.

15:12 Hort. dam in place but still needs bead.

15:23 End pieces for hort. dam are rigid and so a bit of a problem.

15:33 Dam on hort. piece being rolled.

15:42 Caulking edges of the 2nd vert. dam. Hort. dam still to go. Pressure on us to finish to catch the 4 pm cage. Not good. Earle and Hallman leave clean room so as not to disturb Kevin.

d) Wed afternoon spoke with Kevin.

On Monday he and Dan when down for the whole day. They had the syrup poured by 11 am. The MMA smell was less then on Sat during the cleaning phase. The vert. bond was filled by injecting the syrup with a syringe at a point just above the bottom dam. The entire vertical gap was filled this way. The hort. gap was filled by exposing about 1/3 of the gap at one end and pouring in the syrup, allowing it to flow along the gap. This filled up the 2" gap but not the reservoir at the top, which was filled by removing the tape and pouring in some syrup.

The heat tapes were put on and set to 120 degs. The first 24 hrs is the most critical time normally somebody checks the temperature every hour during this time but we are relying on the controls. There was no chart recorder, as at RPT, and no feed back control. Kevin watched the temperature for an hour or so before taking the 4 pm cage.

On Tuesday, Kevin went down at noon. Temperatures still at 120 but bubbles in lower part of vert bond indicated an exothermic reaction possibly due to a temperature excursion of the heat tapes ?? The hort bond was cured so that its temperature could be raised to 155 degs. The vert bond is being cured by moving the heating tape up the gap and noting how things are going by checking the cure line. It was proceeding faster than experience would suggest. Kevin came up on the 4 pm cage.

On Wednesday, he went down at 8 and came up at noon. The hort bond temperature was increased to 185 and the vert tapes were moved again, temp still at 120.

Tomorrow he expects the vert cure line to be at the top at which point he can increase the temp to 155 and may not need to go to 185 for this bond.

Item 6. Impressions:

1) I am concerned about the number of man hours of work we will be able to get each day. The transit time from collar to cavity including showers and changing will be even worse then it was getting to the 4600' lab because the distance is greater and a shower is required. The INCO requirement to limit out work day should really be modified.

2) The requirement to catch the 4 pm cage is an important factor. Not only does it shorten the work day but more important is its effect on the work done from 2 pm on. Workers will not start anything they are not sure they can finish, they will continually be looking at their watches, they will attempt to rush and be careless at the end of their shift when they are most tired and team work will be severely compromised by conflicting wishes of the group. There will be many occasions when this situation can not be allowed to occur. Either the construction schedule must be lengthen or the 4 pm deadline must be modified.

3) While the making of these bonds underground was a useful exercise in preparation for vessel fabrication there were things not tested.

a) The orientation of the horizontal bond was typical of a bond near the chimney not of one near the equator.

b) The pieces bonded were light in weight and easily moved around. They were set up on their jigs, briefly separated for cleaning and then returned to the bonding position before a protective tape was placed over them. In the actually cavity the surfaces can not be cleaned once the panel is in place. Will the actually panels be exposed for only an hour

after cleaning? I think not. Deionizing clean air may be a solution but it has to be tested.

c) During the application of the dam there was easy access to all four edges of the gap and the acrylic was easily rotated, move etc as required. This will not be so when we have 6 by 6 panels, some edges of which will have been bonded into place. The logistics of the vessel fabrication will be very different.

d) The bonds took one day to prepare, at least one day for the dams to harden and then the vert bond took several days to cure and several more days at higher temperatures to complete. So we can assume that each bond will take up to 7 days to finish. A lot of that time is curing time when something else can be done but this something else can not disturb the curing bond. We will have to be realistic as to how many bonds can be in the works at any one time.

e) The strength and cleanliness of a bond is very operator dependent. It can not be assumed that anyone can be trained to do an adequate job. It requires a patience, meticulous, Type B mentality. How many Kevins do we need in the cavity?

f) During acrylic vessel fabrication there should not be other construction in the cavity. Distractions should be keep to a minimum.

g) A method of annealing the bonds should be researched and developed.

Item 7. Visual inspection of bonds.

The two underground bonds and one made earlier in Santa Ana were shipped to CRL where they were visually inspected.

Santa Ana bond.

a) Measurements around the outside of this piece indicate it to be uniformly 2 1/4" thick +/- 1/16. This appears to be 1/4" thinner than the original Polycast material. It would seem that RPT machined off 3/16" or so of this material after bonding to give it a good appearance.

b) The surface finish is very good. It looks like the virgin material but I suspect it is not. There is no evidence of polishing or sanding but I think it has because of the thickness measurement.

c) The bond gap varies from 1/4 " at one end to 5/16" at the other end and is 1/8" at places in the middle. This gap seems large.

d) There are disc spacers at each end. These are 1/2" diameter and 1/8" thick.

- e) The entire bond is uniformly cloudy with white specks throughout. The density of the specks vary by a factor of 10.
- f) Two smudges. Maybe not fingerprints since they appear to be 3D but that may just be due to refraction.

4600' hort. bond.

- a) The entire surface of the material has been sanded with a circular disc which has left many scratch marks. The entire surface has a poor visual appearance or is hazy, different from the Santa Ana bond, due to the sanding.
- b) One surface has a wave in it which is about 3 mm deep due to routing. Dimension checks around the outside confirm this. At one end the material is 2 1/2" at the sides but 2 3/8" in the middle where the bond is. The other end is better, sides 2 1/2" to middle 2 7/16"
- c) The bond width varies from 3/8" to 1/8"
- d) The bond is not so clean as the virgin material but better then the Santa Ana bond. A few white specks. These appear to be in the syrup not on the sides of the virgin material.

4600' vert. bond.

- a) The entire surface is the same as the hort. bond.
- b) Also has a wave but only 1 mm deep. Dimensions around the outside are also better. At one end from 2 7/16" to 2 5/16". The other end is 2 7/16" at side and middle.
- c) The bond width varies from 3/16" to 3/8"
- d) The bottom foot of material has many bubbles as Kevin said. This section is mechanically unacceptable.
- e) There are also about 12 other bubbles at various locations through out the bond. Not related to the concentrated problem near the bottom.
- f) There is a 3" long smudge like those seen in the hort. bond.
- g) There were 4 red specks in addition to the white ones.

While the material may look bad it may be fine for SNO. If the radioactivity is low, if the optical properties in water are good and if the strength of the bond is good then we don't have a problem.

I am concerned about the misalignment of pieces..

Two - 1' sections from each bond were saved for mechanical, optical and visual checks and the remainder was vaporize for Th/U checks.

Item 8. Conclusions:

The appearance of the various materials differ significantly from one sample to the next. The virgin material is within the QC guidelines stated by the manufactures for their material in the number and size of bubbles and inclusions. The RPT bonded joints are relatively clean with most of the dust on the sanded surfaces that were bonded together. Since the radioactivity tests all showed low values for Th/U one can assume that visual variations do not contribute significantly to radioactivity. The optical properties are also similar between samples. The sheets purchased by SNO should be visually inspected but if they pass the manufactures QC they should be good enough for SNO.

Doug Hallman has also issued a report on the underground bonding operation.