TO: Advisory Board on Radiation and Worker Health, Work Group on TBD-6000
FROM: Robert Anigstein and John Mauro, SC&A
SUBJECT: Review of NIOSH Response Paper No. 2
DATE: Friday, January 30, 2015

Review of "General Steel Industries Layout man Beta Skin Dose," Response Paper

On January 8, 2015, David Allen (NIOSH/DCAS) issued two "Response Papers" responding to our review of Revision 1 of Appendix BB to TBD-6000 (Anigstein and Mauro 2014b). The present memo is our reply to the second of these Response Papers (Allen 2015a). We first comment on the individual sections of the Response Paper in the order in which they are presented. The subsection headings in this section of our memo are taken from the Response Paper.

1 Comments on "General Steel Industries Layout man Beta Skin Dose," Response Paper

1.1 Background Summary

According to Allen (2015a):

> NIOSH and SC&A exchanged e-mails and files to understand SC&A's *revised position* on the agreed-upon parameter and exposure scenarios for beta dose calculations to the Layout man. . . . *SC&A appears to have modified the agreed-upon approach for beta-dose calculations, which caused a dose over-estimate.* (italics added)

Allen (2015a) is incorrect in stating that our memo of December 10, 2014 (Anigstein and Mauro 2014b), represents a revision of SC&A's position on ß skin doses to the layout man. The calculations of these doses closely paralleled the calculation of ß skin doses to the betatron operator from irradiated steel. Both sets of analyses assumed that the steel had been irradiated for 30 h. As stated by SC&A (2008, pp. 25–26) and reiterated in our memo of December 5, 2013:

> In calculating the concentrations of residual nuclides, we note that the same portion of a steel plate could be exposed to the betatron beam several times, both because of overlapping shots and because repeated radiographs were performed as flaws were repaired and checked. . . . The casting could be returned to the betatron room 5–10 times before leaving the plant. Given the possibility of four overlapping shots irradiating the same area and an average of 7½ examinations, we assumed that the HY-80 steel had been exposed for 30 h (4 × 7.5 × 1 h = 30 h). (Anigstein and Mauro 2013)

Furthermore, as stated in our later memo:

> We retained the exposure scenario described by SC&A (2008, p. 42): "To calculate the exposure of the layout man, we simplified the [photon exposure] scenario described in Section 2.2.4 and made the claimant-favorable assumption that he would be exposed to the steel 15 min after the last irradiation and would be in contact with the casting 90% of the time for 75 min." (Anigstein and Mauro 2014b)

Our only modification of these previously stated assumptions was to explicitly account for the remaining 10% of the shift by calculating the dose rate at a distance of 1 m and adding 10% of that rate to the total ß skin doses. This is again consistent with the betatron operator's ß skin dose calculations, in which the operator was assumed to be at a distance of 1 m during 50% of the time. Thus, the layout man's ß skin dose calculations are consistent with the corresponding calculations for the betatron operator that were agreed to by NIOSH, SC&A, and the Work Group on TBD-6000 during the December 19, 2013, meeting.

1.2 Agreed-Upon Scenario

Allen (2015a) outlined the scenario for calculating the layout man's exposure to photon radiation from irradiated steel, first described by SC&A (2008, Section 2.1.4). At that time, our intent was to describe and calculate a set of scenarios, based on available information, to present examples of calculations of doses from irradiated steel. The scenario outlined by Allen was based on a single interview of a former GSI [redacted]/betatron [redacted]. The day after the interview, and again the following day, the [redacted] sent emails to the senior author of this memo, explaining that the scenario that he had described was the exception rather than the rule. Additional information was provided in emails from a former betatron operator, cosigned by some of his former colleagues. This material, which is reproduced in the Attachment to the present memo, was transmitted by email to the then-Work Group on Procedures Review on May 28–29, 2008, with copies to NIOSH staff members.

These emails and memos indicate much more complex and nuanced scenarios. Since the exposures of the layout man to direct penetrating radiation from irradiated steel were trivial compared to direct exposure to the penumbra of the betatron x-ray beam and radiation scattered from the casting being radiographed in the New Betatron Building, we did not attempt to refine this calculation.

Unlike the case for γ rays, the β radiation from irradiated steel made a potentially significant contribution to the dose to the skin of the layout man. This is why the calculation of ß skin doses was based on a bounding scenario, since no one set of realistic scenarios could capture the complexity of the operation and calculate the skin doses in a claimant-favorable manner. In subsequent assessments, we took care to avoid changing the scenario first expounded in 2008.

Allen (2015a), however, has recommended an entirely new approach that has never been considered by the present work group or by SC&A. His scenarios presume detailed knowledge of the procedures involving the betatron radiography of steel castings and their subsequent examination and marking by the layout man. As can be seen from the correspondence included in the Attachment, the former GSI employees, meeting and sharing their collective memories, could not agree with certainty on a single representative scenario—it would be presumptuous for analysts working 50 years later to claim possession of such knowledge.

As shown in Table 1, the new NIOSH approach leads to annual doses that are less than one-third of those in the revised Appendix BB (Allen 2014).

Table 1. Annual Doses to Skin of Layout Man from Beta Rays Emitted by Irradiated Steel

Skin on:	Dose (rad/y)		
	SC&A[a]	NIOSH	
		2014[b]	2015[c]
Hands and feet	1.89	0.807	0.264
Rest of body	1.14	0.463	0.147

[a] Anigstein and Mauro (2014b)

[b] Allen (2014)

[c] Allen (2015a)

1.3 Fraction of Short/Long Shot

Allen (2015a) stated:

> In the original SC&A report (SCA 2008), referenced and quoted in its January 12, 2014, memo ([Anigstein and Mauro 2014a]), the scenario used was that of a single large-casting created 100% short shots and the interrupting casting created by 100% long shots. Then, in its latest calculations, SC&A provided a *mixture* of short and long shots for the interrupting casting and eliminated the single large casting scenario.

As he did earlier in the Response Paper, Allen (2015a) disregarded the stated difference in our calculations of photon and ß skin doses from irradiated steel, and claimed we have changed our methodology, which is not the case. The reason we chose to use a more precise exposure scenario for the photon dose assessment is that MCNPX reports delayed gammas, and the resulting doses, as a function of time following instantaneous irradiation. We subjected these results to a double integration, first calculating the cumulative dose as a function of the duration of the irradiation of the metal, including interruptions between successive radiographic exposures, and then calculating the dose or exposure of the operator over a given time following the last irradiation. Such a method did not appear to be practical for the ß dose calculations, since these had to be performed in two separate steps. We first had to compute the specific activity of each radionuclide produced by the photoactivation of the steel. We next performed six separate MCNPX simulations of the dose rates from a unit activity of each nuclide. We then combined the results of both sets of analyses to integrate the ß skin dose over the duration of the exposure of the worker in question, accounting for the radioactive decay of each radionuclide.

At that time, it appeared to be cumbersome to separately account for the buildup and decay of each of the six radionuclides addressed by our analyses due to intermittent irradiations and worker exposures. Our intent was to produce a bounding, claimant-favorable analysis that would be unlikely to understate the actual doses.

Allen (2015a) further states:

> The Layout man would be marking the locations for a shot or for a defect found in a shot. The time necessary to do this work would be unaffected by how long the x-ray exposure occurred for that shot. That means it would take just as long to mark a location for a short shot as it would to mark a location for a long shot. The appropriate ratio should be 10% long shots and 90% short shots.

As described in the emails and memos reproduced in the Attachment, the job of the layout man supporting the betatron operation was to examine the film from previous radiographic exposures of the same casting, identify defects, and mark their locations. These defects would then be repaired by grinders, chippers, and welders. After the repairs, the casting would be sent back to the betatron to confirm that the defects were removed. Furthermore, the same casting was often subjected to both short and long shots. Thus the concept that different-length shots represented different castings is an oversimplification. The castings, or portions of the castings, subject to long shots were much thicker, given that they were exposed for 1 h vs. 3 min for the short shots, and at a distance of 6 ft vs. 9 ft. They were thus far more likely to have casting defects, which would take much more time to locate and mark. Although we cannot quantify with certainty the relative amount of time the layout man would spend on each type of casting, a 64:36 ratio is much more likely than 9:1.

1.4 New SC&A Scenario

According to Allen (2015a): "In December 2014, memorandum, SC&A revised its position that the beta-dose calculations used will vary significantly from a gamma-dose approach." As discussed in Section 1.1 of this memo, we have explicitly *not* changed the fundamental assumptions used to calculate the ß skin doses to the layout man. These doses, expressed as mrad/shift, were first presented by SC&A (2008, Table 18). Our most recent calculation of the ß doses utilized MCNPX analyses of the buildup of radionuclides in irradiated steel that were repeated in 2013, using the latest publicly released version of the code and some improved MCNPX modeling parameters. We also modeled the short and long shots in greater detail, explicitly accounting for different source-to-target distances. We likewise repeated the MCNPX simulations of skin dose rates from each of the six ß-emitting radionuclides in 2013 and 2014 to obtain more accurate results, including the dose rates at 1 m, which had implicitly been set to zero in earlier analyses. (This had been done to avoid lengthy calculations with our then-limited computer resources.) Since these calculated dose rates constitute a small fraction of the total skin doses, adding this component is a refinement to our calculation, not a change in our position. All these refinements improved the accuracy of our analyses, but do not constitute changes to the underlying scenario.

1.5 Impossible Scenario

We acknowledge that the 30-h continuous irradiation discussed in Section 1.1 of this memo represents a bounding scenario. However, the scenario proposed by Allen (2015a) is likewise unrealistic: "A scenario that would result in the highest yet physically possible dose is one in which [two] castings are alternated repeatedly." The same casting would not have been shuttled back and forth between the betatron and the layout man: The layout man marked the castings for repair, not to re-expose the same casting. Furthermore, this scenario assumes that the casting was removed from the betatron building following each exposure. The point of our scenario was to account for successive, overlapping shots of the same portion of the casting. The casting would stay in the betatron building until all the shots have been completed. Also overlooked by Allen (2015a) is the fact that two betatrons could have been operating simultaneously during the period of intense activity described in the Attachment. It is not impossible for the same layout man to have been working on castings radiographed by the two machines.

1.6 Results of the Proposed Approach

We have confirmed that the mathematical model presented by Allen (2015a, Appendix) correctly embodies the scenarios described by the author, and that the results presented by Allen (2015a, Tables 1 and 2) are the output of that model. However, we observed that the derivation of the equations used in the model would benefit from a clearer explanation. We present our comments in the Appendix to this memo.

We note the misalignment of the columns in Allen (2015a, Table 1): the column headed "mrad/casting" should be under the top-level heading "Interrupting Castings" rather than under "Single Casting," as reported by Allen (2015b).

2 Summary and Conclusions

We find that the scenarios intended to represent the exposures of the skin of the layout man to β radiation proposed by Allen (2015a) do not represent the operations at GSI.

- The assumption that the same casting would be repeatedly exposed to betatron radiation until the activity concentrations of each of the six β-emitting radionuclides used in the skin dose calculations reached equilibrium is unrealistic.

- The assumption that the amount of time spent on long- and short-shot castings is proportional to the number of long and short shots is not based on any available information. The heavy castings requiring long shots may have required more time to locate and mark casting defects.

- Actual castings required both long and short shots, as well exposures of intermediate durations.

- Given the variability and uncertainty about the layout man's exposures to β rays from irradiated steel, the simple bounding scenario previously proposed by SC&A and agreed upon by NIOSH and the Work Group on TBD-6000 provides a claimant-favorable assessment that leads to plausible doses to the skin.

Appendix

Comments on Allen (2015a, Appendix)

Equations 1 and 2, presented by Allen (2015a, Appendix) and reproduced below in a slightly altered form, correctly describe the continuous buildup and decay of radionuclides created during the betatron radiography of steel castings.

$$\frac{dC}{dt} = P - \lambda C \qquad \textbf{(1)}$$

C = the number of atoms of a particular nuclide

P = the production rate of that nuclide (atoms/s)

λ = the decay constant for that nuclide (s^{-1})

The solution to Equation 1 is correctly expressed as

$$C = \frac{P}{\lambda}\left(1 - e^{-\lambda t}\right) \qquad \textbf{(2)}$$

Allen (2015a) then presented Equations 3 and 4 to define a new quantity, P_{eff}, to describe the buildup and decay due to intermittent irradiations:

$$C_1 = \frac{P}{\lambda}\left(1 - e^{-\lambda t_1}\right) = \frac{P_{eff}}{\lambda}\left(1 - e^{-\lambda t_c}\right) \qquad \textbf{(3)}$$

P_{eff} = the effective production rate

t_1 = the shot[1] time (amount of time the actual x-ray beam is turned on)

t_c = cycle time (amount of time from the end of one shot to the end of the next shot)

Solving Equation 3 for P_{eff} yields

$$P_{eff} = P\left(\frac{1 - e^{-\lambda t_1}}{1 - e^{-\lambda t_c}}\right) \qquad \textbf{(4)}$$

Allen (2015a) proposed substituting P_{eff} for P in Equation 2 to evaluate the peak concentration at the end of an integral number of cyles, which would yield

[1] The term "shot," in the parlance of GSI radiographers, is synonymous with "irradiation" in the present discussion.

$$C = \frac{P}{\lambda}\left(\frac{1 - e^{-\lambda t_1}}{1 - e^{-\lambda t_c}}\right)\left(1 - e^{-\lambda t}\right) \quad \textbf{(5)}$$

In order to determine the validity of Equation 5, we performed a detailed derivation of the interrupted buildup, which corresponds to Allen's (2015a) single casting scenario.

We first used Equation 2 to express the incremental buildup of a radionuclide during a continuous irradiation of duration t_1, but added a factor to account for its decay during a subsequent period, $t - t_1$, following the initial exposure:

$$\delta_1 C(t) = \frac{P}{\lambda}\left(1 - e^{-\lambda t_1}\right) e^{-\lambda(t - t_1)} \quad (t \geq t_1)\ \textbf{(6)}$$

$\delta_1 C(t)$ = incremental activity concentration of radionuclide at time t following a single irradiation beginning at $t = 0$, and a subsequent period of decay

Let us assume that the kth irradiation begins at time kt_c and ends at time $kt_c + t_1$. The incremental activity concentration at time t due to such an irradiation, which is subject to radioactive decay over the period $t - t_1 - k\,t_c$, is expressed as

$$\begin{aligned}\delta_k C(t) &= \frac{P}{\lambda}\left(1 - e^{-\lambda t_1}\right) e^{-\lambda(t - t_1 - kt_c)} \\ &= \frac{P}{\lambda}\left(1 - e^{-\lambda t_1}\right) e^{-\lambda(t - t_1)} e^{\lambda k t_c}\end{aligned} \quad (t \geq t_1 + t_c)$$

According to this scheme, the irradiation that begins at $t = 0$ has the sequence number $k = 0$. If there are n irradiations, the final one would be designated by $k = n - 1$. The total activity concentration after n irradiations, at time $t = (n - 1)\,t_c + t_1$, is expressed as

$$\begin{aligned}C_n(t) &= \sum_{k=0}^{n-1} \delta_k C(t) \\ &= \frac{P}{\lambda}\left(1 - e^{-\lambda t_1}\right) e^{-\lambda(n-1)t_c} \sum_{k=0}^{n-1}\left(e^{\lambda t_c}\right)^k\end{aligned} \quad \textbf{(7)}$$

The last term in the bottom equation is the sum of a power series, which has the form

$$\sum_{k=0}^{n-1} r^k = \frac{r^n - 1}{r - 1} \quad \textbf{(8)}$$

Substituting $e^{\lambda t_c}$ for r in Equation 8 and using the resulting expression to evaluate the summation in Equation 7 we obtain

$$C_n(t) = \frac{P}{\lambda}\left(1 - e^{-\lambda t_1}\right)\left(\frac{1 - e^{-\lambda n t_c}}{1 - e^{-\lambda t_c}}\right) \qquad \textbf{(9)}$$

(Several intermediate steps were omitted in the interest of brevity).

We note that in Allen's (2015a) derivation, the first irradiation begins at $t_c - t_1$. Let us replace t with t' in Equation 5 and note that $t' = t + t_c - t_1$. After n irradiations, $t' = nt_c$. If we make this substitution in Equation 5 and rearrange terms, it becomes identical to Equation 9.

Equation 5 in the present memo should not be confused with the Equation 5 used by Allen to model the "interrupting casting" scenario. In that scenario, the casting is intermittently irradiated over a 24-h period, allowed to decay for 24 h, and is then again irradiated, the cycle being repeated until the activities of all radionuclides reach equilibrium. Allen's Equation 5 can be derived from our Equation 9 by carrying out a second summation, analogous to that shown above.

The calculations used to evaluate the β skin doses do correctly express the model described by Allen (2015a). However, the discussion by Allen (2015a, Appendix) relies on intuitive arguments and illustrations—the present discussion represents a more rigorous mathematical derivation.

References

Allen, D. 2014. "Site Profiles for Atomic Weapons Employers that Worked Uranium Metals: Appendix BB – General Steel Industries," Battelle-TBD-6000, Appendix BB, Revision No. 1. http://www.cdc.gov/niosh/ocas/pdfs/tbd/b-6000-apbb-r1.pdf

Allen, D. 2015a. "General Steel Industries Layout man Beta Skin Dose," Response Paper. http://www.cdc.gov/niosh/ocas/pdfs/dps/dc-gsilaybeta-010815.pdf

Allen, D. 2015b. "RE: Request for Calculations" January 20, 2015, personal e-mail to Robert Anigstein (SC&A), CC: Ted Katz and Jim Neton (NIOSH), Paul Ziemer (ABRWH), and John Stiver and John Mauro (SC&A).

Anigstein, R., and J. Mauro. 2013. "Review of Skin Dose Calculations for General Steel Industries." Memo to Advisory Board on Radiation and Worker Health Work Group on TBD-6000. http://www.cdc.gov/niosh/ocas/pdfs/abrwh/scarpts/sca-gsiskindose-120513.pdf

Anigstein, R., and J. Mauro. 2014a. "Update of Doses from External Exposure at General Steel Industries." Memo to Advisory Board on Radiation and Worker Health Work Group on TBD-6000." http://www.cdc.gov/niosh/ocas/pdfs/abrwh/scarpts/sca-gsiexdose-011214.pdf

Anigstein, R., and J. Mauro. 2014b. "Review of 'Site Profiles for Atomic Weapons Employers that Worked Uranium Metals Appendix BB – General Steel Industries,' Revision 1." http://www.cdc.gov/niosh/ocas/pdfs/abrwh/scarpts/sca-gsiapbbr1-121014.pdf

S. Cohen & Associates (SC&A). 2008. "Review of 'Site Profiles for Atomic Weapons Employers That Worked Uranium and Thorium Metals - Appendix BB: General Steel Industries,' Battelle-TBD-6000, Appendix BB, Rev. 0." http://www.cdc.gov/niosh/ocas/pdfs/abrwh/scarpts/sca-gsisp-r1.pdf

ATTACHMENT

This attachment contains email messages and memos regarding betatron operations and procedures from former GSI employees. This material is reproduced exactly as received, unformatted and unedited, except for some elimination of extraneous line breaks and vertical spaces.

Subj:	**large casting processing at GSI**
Date:	12/19/2007 10:29:58 AM Eastern Standard Time
From: [redacted]*)* *To:* [redacted]	

Dr. Bob, I misled both of us last evening 12-18-07 by starting with a "green casting" just finishing up being radiographed in the new betatron. Of course that could happen; but will try to explain the normal approach as I remember.

The beginning of the month about ten of the people responsible for processing the castings chose the castings that might be shipped that month. Special emphasis was placed by everyone on these (perhaps) eight castings. These would have a small number of exposures not yet "cleared." These could come from and return to the new betatron more than once in a shift depending on the size of the weld. This would allow many more workers to be processing a casting recently radiographed in the last eight hours. These would include the betatron operators loading the casting on the transfer car, chainmen removing the casting to the floor, marking by layout men or (see note below) then removing the defect by burners, chipping & grinding the defect area to prepare for welding. welding, then grinding the weld and returning to the new betatron.

note - the repair could now be clear - Grinders would go over the casting or magnaflux (two) operators would check for surface cracks. This depends on which grinders or magnaflux crews were "open" Cracks if any should be minimal.

Please call [redacted] when you wish, as except for shower and lunch will be here. Normally go to lunch late if I go.

Please remember this part of my life was a minimum of 42 years ago and my memory is not as perfect.

Thank you for what you do - [redacted] 11-19-07

Subj:	**Re: Very important Procedure Information**
Date:	12/20/2007 3:00:50 PM Eastern Standard Time
From: [redacted]) *To:* [redacted]	

[redacted] your e-mail to Dr. Bob and John Mauro is excellent. Seems that each time we discuss among ourselves new information is revealed. You must remember that this all happened over 40 years ago and is quite complex. I would be willing to travel to N.Y. to discuss further; but might be best for Dr. Bob to come here.

[redacted]> wrote:
Bob / John

I had a chance to meet with [redacted] and [redacted] last night . We grabbed a Holiday hamburger!

They were both concerned that you may have only been given "a part of" the very complex casting movement process from the Betatron Buillding to the Plant floor.

The fact that a casting would be partially inspected with the Betatron, and re-inspected with the Betatron on an average of about 10 times per [redacted] and [redacted] is very important I would think, in any modeling. Re-inspections on welded/ repaired sections is part of this process as well. (special welding material being checked over and over as well).

I know they both would like to discuss this with you.

[redacted] said that a "GREEN" casting was one that came in for the first time, with plans to inspect it 100%. (large steam chest as an example with 350 shots needed).

If they were allowed to work on it "non-disturbed " that would be the exception to the rule. There was always some "priority or RUSH"! Hot casting !!!!!

[redacted]'s management perspective came into view : Bonuses were paid...... "based on what went out the door, because they could be billed !"

[redacted] said he mentioned a 8 hr. timeline for some workers to start on the GREEN castings. "This appears to be RARE "! Because of the Production factors.

Please allow him to explain this in detail.

[redacted] and [redacted] told me that the aprox. 10 return trips were far more common and that people (grinders, burners chippers inspectors, timekeepers chainmen labors, R.R. etc. etc.) handled and worked on these types of freshly betatron tested castings much more often. Please confirm with them, but they said this happened "in a matter of 15 or so minutes"! There was no need for massive layout and heavy markup.... that had already been done on the GREEN PROCESS. (they could make you a list of the types of workers).

Please keep in mind that no layout etc. took place in the betatron cell room.... they wanted that free and ready for the next shot !

These "HOT...URGENT-RUSH" castings meant production and money for GSI ! (Bonuses were paid...... "based on what went out the door, because they could be billed !")

This much more common procedure, and faster interaction with the castings, should be considered in any models, should it not?

Please discuss with the men, I was trying to follow the conversation as best I could. They really are interested and concerned that you get the exact and total picture of the time and motion part of the GSI Betatron / casting process .

Thanks again,
[redacted]

Begin forwarded message:

> From: [redacted]
> Date: December 19, 2007 3:35:50 PM CST
> To: [redacted]
> Cc: [redacted]
> <[redacted]
> Subject: Procedure
>
> Bob:
>
> [redacted] and [redacted] are finalizing a GSI Betatron and Casting activity "written and verbal flowchart for you.
>
> [redacted] is very concerned that he may have given you come > incomplete information last night.
>
> [redacted] has taken the time to contact [redacted] and some of the other key Betatron workers to verify the correct procedures.
>
> This is the information that he just sent me as well.
>
> Thanks,
> [redacted]
>
> [redacted] is having some computer problems and having an issue sending
> it to you directly.

BETATRON WORKING PROCEDURES[2]

In most cases in large casting work, betatron shots were laid out to be covered by a 14" x 17" metal cassette. Layout of a casting of normal curvature would normally be 11" x 13" of X's. On a 11" x 13" layout width wise there would be a 1 1/2" overlap.Vertically there would be a 2" top and bottom overlap.

In a casting of a radical curvature where large blowout on film was to be expected, 10" x12" layout was used. On a 10" width layout there would be a 2" side by side overllalp and vertically a 2 1/2" overlap from top to bottom.In the center of each shot was a number and underneath the number a vertical arrow would be pointing toward the number. On the side of the number would be placed a pentrometer or penny indicating the thickness of the metal.

On the inside of the casting where the film placement took place, two lead arrows were placed horizontally facing each other.

The lead arrows were for the purpose of placement of film in tracing defects on castings. Film placement of a l4" x 17" cassette was held in place by powerful magnets along with a l4" x 17" solid piece of 3/8" thick lead sheet for a scatter shield behind the cassette. All lead X"s, numbers, arrows and pentrometers were held in place by double faced magnetic tape.

On the outside of the casting X"s and numbers were metal stamped into the casting for future re-xray of casting.

I would have to confirm that in 100% of xrayed castings, overlapping of shots would dictate reactivation of frame or border area of shot.

In the case where defects were found in castings,casting would be sent to chipper and burning floor for removal of defects.

On return of casting to Betatron for xray work the same shots with defects would have to be reshot for film proof of defect removals. This process would repeat itself along with magniflux testing of ID and OD of casting until alldefects are removed.

As in the case of first time xraying of casting, the operator would shoot one shot at a time moving along side of casting. Neighboring shots on the top, bottom and sides would receive multiple doses and activate neighboring shot overlap. To my knowledge these layout procedures and elimination procedures were standerd operating procedure on atomic submarine work,Westinghouse GE and all industrial work and tank, hulls, and turrets.

These are commonly used operating procedures for complete removal of defects to be done efficiently.

In these procedures,casting,open cavity work of course took place from burning, chipping, grinding and removal of defects. All films were read and checked by film readers of company status. All defects were proven removed by film inspection or magniflux inspection. In the xraying process lead X's, arrows, numbers and pentrometers were constantly rehandled and reused as needed.

In my opinion as open cavity removal of defects took place by burning, chipping and grinding.Profuse hot sparks and molten metal flew everywhere. This airborne molten metal and hot sparks would burn your arms, neck and scalp as magniflux crews worked along with chippers, burners and grinders. I feel it would be impossible for inhalation of this material not to take place under these conditions. Only someone experienced in working in this capacity could verify the accuracy of these statements.

[2] "Betatron," attachment to [redacted], "Fwd: betatron work proceedues " October 20, 2007, personal e-mail to Robert Anigstein (SC&A), CC: [redacted]

[redacted]
Telephone [redacted]
Operator 24 and 25 Mev Betatrons
Magniflux operator
General Steel Industries – [redacted]

11/26/07

SHOOTING PROCEEDURES OF STEAM CHEST[3]

FOR SOME REASON THERE IS A MISUNDERSTANDING OF THE TIME WE OPERATORS SPENT IN THE SHOOTING ROOM. FOR SOME REASON IT IS THOUGHT THAT MORE OF OUR WORKING TIME WAS SPENT IN THE CONTROL ROOM. IN REALITY, THERE WAS,ON A LARGE STEAM CHEST, ABOUT 300 TO 400 SHOTS---WITH ABOUT 10% OF THE TOTAL SHOTS CONSIDERED AS LONG SHOTS!

SET UP TIME TOOK AROUND 15 MINUTES OR UNDER, WITH A TOTAL OF ABOUT 32-40 NORMAL SHOTS BEING FIRED IN AN EIGHT HOUR PERIOD. A 3 INCH THICK SHOT WAS ABOUT 40-60 ROENGTENS, AT 9 FEET WITH DOUBLE A FILM, TAKING ABOUT 30 SECONDS FOR THE SHOT TO RUN. A SIDE WALL OF A STEAM CHEST WAS ABOUT 4 TO 4 AND ONE HALF INCHES THICK. A FOUR INCH SHOT MIGHT BE 200 ROENGTENS, AT 9 FEET, DOUBLE A FILM, WITH A RUNNING TIME AROUND ONE AND ONE HALF MINUTE.

THERE WAS OF COURSE THREE OR FOUR THICK RIBS IN THE STEAM CHEST AROUND 9 TO 10 INCHES THICK. THIS LONG SHOT WAS FIRED AT 6 FEET, ABOUT , 4500 TO 5000 ROENGTENS , DOUBLE A FILM AND SLOWER FILM TO PICK UP THINNER THICKNESS OFF THE SIDE OF THE RIB.. RUNNING TIME ABOUT 32 MINUTES AT 160 R PER MINUTE. WHEN WE STARTED SHOOTING A STEAM CHEST WE STARTED AT THE BOTTOM ROW---SAY, LEFT TO RIGHT. OPERATOR WOULD SET UP THE OUTSIDE WITH PLACING LEAD X'S, NUMBERS, AND ARROW, PLUS PENTROMETER ON THE SHOT. LETS SAY THE THICKNESS WAS 4 AND ONE HALF INCHS THICK. THE 4.5 PENTROMETER WOULD BE PLACED ON THE SIDE OF THE SHOT NUMBER. **ALL SHOTS 3 TO 5.5 INCHES THICK WAS SHOT AT 9 FEET, DOUBLE A FILM—ALL SHOTS 6 TO 18 INCHES THICK SHOT AT 6 FEET DOUBLE A FILM. THE DIFFERENCE BEING, IN MOVING THE MACHINE FROM 9 FEET TO 6 FEET, WE INCREASE INTENSITY FOR THE THICKER METAL AND SHORTEN ROENTGEN RUNNING TIME PER THE THICK METAL.**

IF IN EFFECT 32-SHOTS, OF SHORT DURATION(0-3 MINUTES) ARE FIRED IN AN EIGHT HOUR SHIFT, APPROXIMATLEY 4 MINUTES PER SHOT IS SPENT IN THE CONTROL ROOM. THIS TOTALS 2 HOURS AND 8 MINUTES IN THE CONTROL ROOM LEAVING SET UP TIME AT APPROXIMATELY 5 HOURS AND 52 MINUTES WITH SET UP TIME AT 11 MINUTES PER SHOT.

THE OPERATOR, WHILE SETTING UP THE OUTSIDE OF THE SHOT----THE ASSISTANT IS PLACING TWO HORIZONTAL LEAD ARROWS ON THE INSIDE OF THE SHOT, PLACING THE BOTTOM MAGNET, PLACING THE 14 X 17 CASSETTE ON THE MAGNET, FOLLOWED BY PLACING A LEAD SCATTER SHIELD ON THE BACK OF THE CASSETTE, AND THEN PIN-IN THE CASSETTE WITH THE TOP MAGNET. THE ASSISSTANT THEN, TAKES AN ANGLE READING OF THE FILM BY A BUBBLE PROTRACTER AND TELLS THE OPERATOR THE ANGLE TO PLACE ON THE BETATRON CAMERA. THE ASSISTANT THEN GOES TO THE OUTSIDE OF THE SHOT—HOLDS THE DISTANCE STRING AT 9 FEET AND HELPS THE OPERATOR ADJUST CAMERA ALIGNMENT AND DISTANCE.

IT IS TO BE REMEMBERED THAT THE X'S AND NUMBERS OF THE SHOTS ARE METAL STAMPED INTO THE CASTING METAL FOR FUTURE REFERENCE AND POSITION. THE AIMING LIGHT OF THE BETATRON IS PLACED 6 INCHES TO RIGHT OF THE NUMBER-CENTERING THE BETATRON CONE ON THE SHOT.

[3] "STEAMCHESTS.doc," attachment to [redacted], "Emailing: STEAM CHESTS" November 26, 2007, personal e-mail to Robert Anigstein (SC&A).

MY PURPOSE IN WRITING THIS IS TO CLARIFY THAT MOST SHOTS ARE OF NORMAL DURATION AND VERY QUICK RUNNING TIME ON THE BETATRON AND THAT MOST OF OUR TIME IS SPENT NOT IN THE CONTROL ROOM---BUT THE SHOOTING ROOM! WE HAD THREE EIGHT HOUR SHIFTS, WITH A 20 MINUTE PAID LUNCH---WHICH MEANT---WE ATE ON THE RUN! LONG SHOTS WERE OF COURSE DESIRABLE---BUT AGAIN MADE UP GENERALLY 10 % OF THE TOTAL SHOTS ON MOST CASTINGS

[redacted]
BETATRON OPERATOR
MAGNAFLUX OPERATOR-

[redacted]
BETATRON OPERATOR

[redacted]-FILM READER

[redacted]
BETATRON OPERATOR -LAYOUT

12/15/07

Overlap[4]

[redacted]—Reply to your e-mail on overlap-----

I contacted Mr. [redacted], [redacted] of the GSI betatrons, on the subject of overlap of film. Mr. [redacted] and I agreed in this---Using 14 X 17 cassettes--If we were shooting a steam chest, with a 11 X 13 layout of x's, the end rows (around the end) and bottom rows of shots would be radiated a total of four times. The shot itself would be ONE, accompanied by three overlaps. For instance the end shot would be the shot itself- the top and bottom overlap shot—and one side overlap totaling four radiations of the end shot. The same would apply to the bottom row of shots- The exception would be the bottom row end shots(first shot on corner bottom row) that would have the main shot –ONE--- one side overlap shot---and one top overlap shot totaling THREE radiations of that zone.

In the case of all the rest of the shots—The main shot itself be fired—accompanied by the top and bottom overlap shots –accompanied by the each side overlap shots—Totaling 5 radiations of the same shot zones that were radiated// (the main shot covering all four x's is ONE—the top two x's is TWO—The bottom two x's is THREE –the left side x's are Four---and the right sidetwo x's are Five)-- One main shot , covering all four x'sand Four overlap shots—TOTALING FIVE RADIATIONS OF THE SHOT ZONE In most instances, each X is shot a total of four times, the main shot. Top or bottom shot, side shot, and diagonal shot of the X.

The interesting observation is if we were shooting at 9 feet distance, the sides, top, and bottom radiation flare out would be wider at surface causing more radiated surface (beam not limited to a 14 x 17 size.).

If we were shooting a NUCLEAR CHANNEL HEAD—(looks like an upside down bowl) there is no end of the casting because it is completely circular..

This shooting procedure is common throughout industry and applied to all our shooting.

[redacted]

OPERATOR 24 & 25 MEV BETATRONS
NAVY QUALIFED IN MAGNAFLUX
[redacted]

[redacted] OF GSI BETATRONS
[redacted]

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[4] "Overlap," attachment to [redacted], "Fwd: Emailing: overlap of shots" December 18, 2007, personal e-mail to Robert Anigstein (SC&A), CC: [redacted].

12/19/07

Casting Processing at GSI[5]

DR. BOB-

As the casting leaves the Betatrons, the Betatron operators load up the casting on the rail or transfer car. THE casting leaves the BETATRON as **quickly** as shooting is completed and **layout markup is done, on the floor of either 9 or 8 building, not in the betatron building.**.***The casting heads quickly for set up***.The chainmen take the transfer car outside the new betatron to either 9 or 8 Building. The chainmen hook up the casting to the crane and the casting is set up on the floor of either 9 or 8 building.Repair work of GE—Westinghouse and Navy castings was done in 9 building. Layout and markup of the same type of castings, was done in 8 building. Repair of tanks, turrets, underframes, rotoblasting and heat treating was done in 10 building. Film readers are reading and marking film. **Immediatley, upon set up of the casting**,layout men from the betatron department mark up defects on the casting. The defects are traced on the outside of the casting by laying the film over the 4 x's—shot number—and vertical arrow pointing to the number. The defect on the inside is traced on the casting by placing the film over the two horizontal arrows and marking the film on the inside of the casting. INSPECTORS are generally present for the location of defects, size, etc, etc. AS quick as the <u>outside</u> of a casting is marked up, grinder workers may be placed, on the casting,to smooth defect areas for sonics crews as the layout team mark up the <u>INSIDE</u> of the casting. AS grinders finish all defect areas being ground smooth, sonic crews locate defect placement laying nearest to inside or outside surface. AS defects are located by sonic crews, burners, chippers, grinders may be used for defect removal. Of course if burning is done, preheat of the casting may be done by gas torch as the same done along with welding. Timekeepers are checking with repair crews as to time needed for repair.**The closer the shipping time of the casting, the more attention is given to timely work done to the casting and quick handling**.

Of course the fewer defects left on a casting, this casting may a lot of times be labled "HOT" and the aim of course is to ship out as soon as possible. A GREEN casting ,of course, will have more defects, but in all cases, these same people are in play for the necessary removal of defects.

As MR. [redacted] points out—"THE same casting might be back and forth to the betatron a number of times, depending on when it must be shipped" **By back and forth to the betatron, I mean that the casting has to be re-radiographed a number of times to prove removal of defects**.This is always done in a timely manner and as quickly as possible.THE inspectors, grinders burners, welders, chippers, chainmen, cranemen, magnaflux crews and betatron crews, timekeepers, all performing their tasks as needed! Also magnaflux crews will be checking the surface of the defects along with welding passes laid in the defects, as the defects are brought to surface. **Secondary follow up repairs required this whole process to be repeated with the exception of layout.**

Generally magnaflux crews work with grinders, chippers, and burners in removal of defects, while inspectors will check for size and location of defects, or any defects that may have occurred by faulty process. The least amount of defect left on the casting the quicker handling of casting by all workmen. I hope this clarifies the complex procedures and we are always willing to discuss.**Our concern is to provide enough detail for a much clearer explanation.**

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[5] "Casting," attachment to [redacted], "Procedure " December 19, 2007, personal e-mail to Robert Anigstein (SC&A), CC: [redacted]

THESE THOUGHTS AND EXPERIENCES WERE COMPILED BY-----------
[redacted]—operator 24 & 25 MEV betatrons—Qualified by NAVY in MAGNAFLUX—[redacted]
MR. [redacted]- BETATRONS and NDT—GSI [redacted]
[redacted] –BETATRONS---FILM READER—[redacted]
[redacted] BETATRONS—FILM READER—[redacted]
[redacted] operator 24 & 25 MEV Betatrons- LAYOUT__NAVY IN MAGNAFLUX—[redacted]
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