Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Project Internal Reference:

Project: SCDMS

Title: The lead, Inserts, Pull-out Strength and the Applicable Tighten Torque.

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Key Words: Corroding lead, Fastening insert, Shear engagement area, Pull-out strength, minimum shear strength, parent material, torque, Tighten, Load.

Abstract Summary:

The corroding lead needs special attention to the process of installation, fabrication and handling because of her unique mechanical properties (extra soft, very low elastic modulus, tensile & shear strength). Alcoa inserts are designed to provide high resistance to torque-out and pull-out loads. The amount of the fastener tightening torque is calculated based on the combined working condition of the bolt and her parent corroding lead material.

Applicable Codes:

"Fastener Standards", 6th edition, Industrial Fasteners Institute
"Metals Handbook" 9th edition, Vol. 2, American Society for Metals.
"Manual of Steel Construction, ASD", AISC, 9th edition
"Inserts and Studs", Alcoa Fastening Systems

The principle and the application of the Inserts:

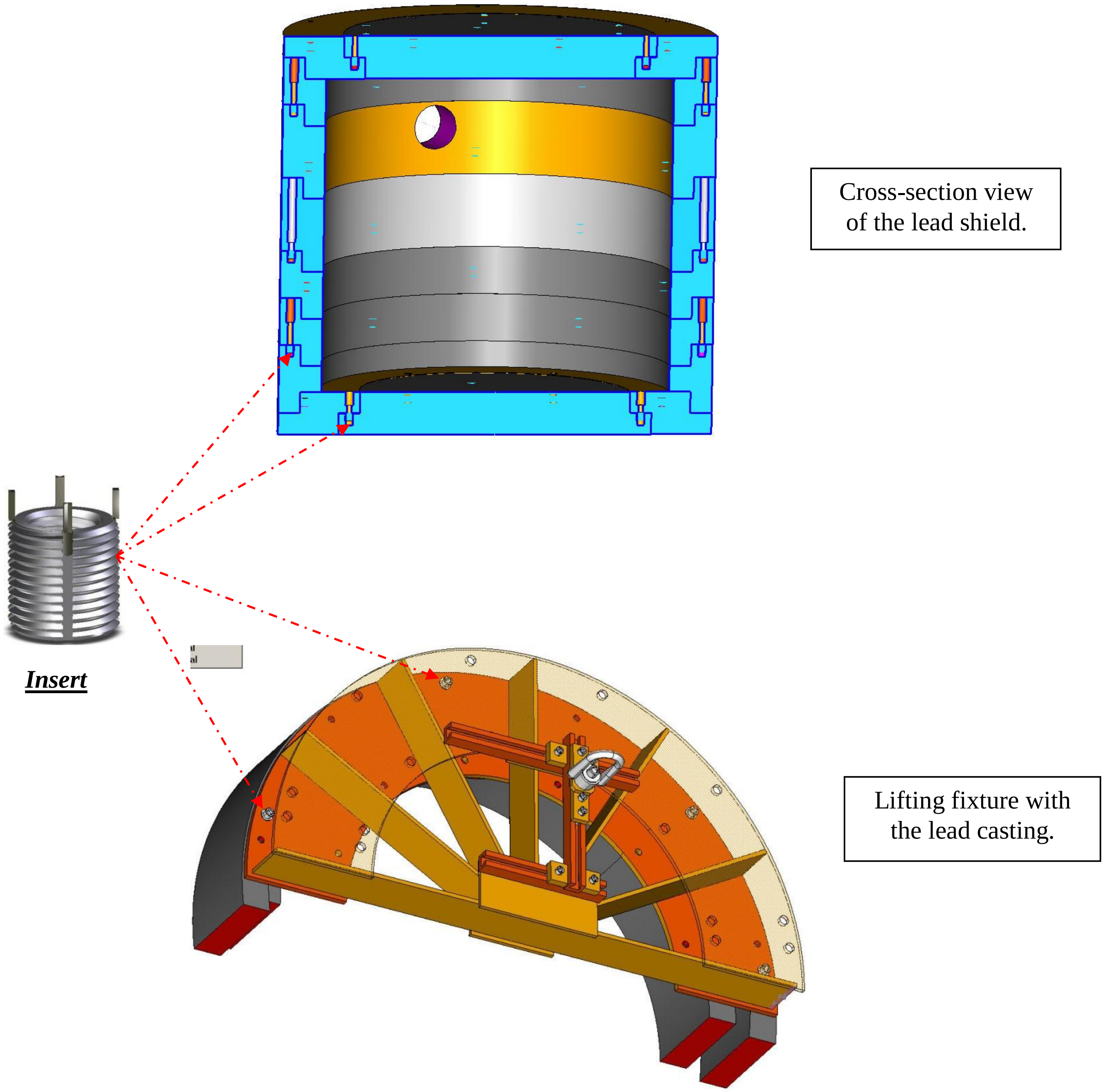

Figure 1, The applications of the Inserts.

We conservatively assume that the lead material for the SCDMS shield is pure lead with at least of 99.94% purity, such lead also called as corroding lead.

It is found that the material properties are as following:

F_t = 1.8 ksi,   the tensile strength.
F_y = 0.8 ksi, the yield strength
F_v = 1.82 ksi, the shear strength
E = 2 x 10^3 ksi, the modulus of elasticity.
ρ = 0.4097 lbs/in^3, mass density.
(See "Properties of Leads and Lead Alloys", p500, Metals Handbook, 9^{th} edition.)

Figure 1 of page 2 showing the applications of the inserts:

- Increasing or maximize the compressive force for the lead shield casting assembly.
- Increasing the shear engagement area to maximize the resistant against the pull-out strength during lifting and handling for the lead castings.

It is found out from the above lead material property information that the tensile, shear and yield strength are very low compare with the other metals. In order to provide enough resistance to torque-out and pull-out loads for the lead castings, it is applying the insert technology to fulfill such requirements.

The pull-out strength/each insert:

$P_{pull\text{-}out1}$ = Min. shear engagement area x Min. shear strength of the parent material
= 2.5505 in^2 x 1.82 ksi
= 4.642 kip

(Per Keenserts Inserts & Studs, "Alcoa Fastening Systems", assume using Insert #KNHXHL1210J, which has internal thread of ¾ -10, external Thread of 1-1/4 – 12, engage length = 1.25", shear engagement area = 2.5505 in^2, section 3 of Tridair Product, page 15).

$P_{pull\text{-}out2}$ = Min. shear engagement area x Min. shear strength of the parent material
$= \pi L_e D_{s\ min}\ n\ [\frac{1}{2n} + 0.57735\ (D_{s\ min} - E_{n\ max})]\ F_v$
= π 1.25 in x 1.2368 in x 12 [1/24 +0.57735 (1.2368 – 1.2039)] 1.82 ksi
= 58.2828 in^2 (0.0417 + 0.019) x 1.82 ksi
= 6.438 kip

Where:

L_e: length of the thread engagement

n: Threads per inch

$D_{s\ min}$: Minimum major diameter of the external thread

$E_{n\ max}$: Maximum pitch diameter of internal thread

(Per page A-9, section of Basic Elements of Screw Thread Design, "Fastener Standards", 6th edition, Industrial Fasteners Institute)

Since:

$P_{pull\text{-}out1} = 4.642$ kip < $P_{pull\text{-}out2} = 6.438$ kip

So:

$P_{pull\text{-}out}$ = 4.642 kip

per each Alcoa insert with part number of KNHXHL1210J at the parent material of the pure lead castings with purity of 99.94% or higher.

The maximum lead casting part mass weight is about 3,500 lbs, there are at least four (4) connect bolts (with insert) for each casting part, so the insert device should have enough force to resist the pull-out force produced from the mass weight of the lifting object- lead castings.

Tightening torque:

The bolts for install the lead shield and lead casting lifting fixture must generate the appropriate torque for the tensional clamp load (P_{clamp}).

$$P_{clamp} \leq P_{pull\text{-}out\ yield} = 4.642 \div \left(\frac{1.82}{0.8}\right) \text{ ksi} = 2.04 \text{ kip}$$

Where : $P_{pull\text{-}out\ yield}$ is the pull-out force within the elastic limit of the parent material (corroding lead) by applying the Alcoa insert with part number of KNHXHL1210J .

$$T = KD_n\, P_{clamp}$$
$$= 0.2 \times 1.25 \text{ in} \times 2.04 \text{ kip}$$
$$= 510 \text{ in- lbs} = 43 \text{ ft-lbs}.$$

Where:

T: Tightening torque (assembly torque).

K: Torque coefficient.

D_n: Nominal bolt diameter.

P_{clamp}: Bolt clamp force based on the yield strength of the lower strength of the material (fastener or the parent material).

(Per section of Torquing and preload consideration, “Fastening & Joining”, 2rd edition, by Robert Parmley).

Usually, the torque value is only for initial assembly of the fastener, continue using of the same bolt and nut (insert) assembly tends to alter and change the torque coefficient gradually.

Also, the mechanical relationship between the corroding lead and the subject insert needs more study and discussion, to this end, the best way is to set up simulating shop test. The data from the simulating test will help to better understand the relationship between the applying bolts (brass) and nut (insert), preload and tightening torque, and other related issues.

Eventually, the data from the simulating test will become part of this note, and the note probably also will be revised per the new test data.