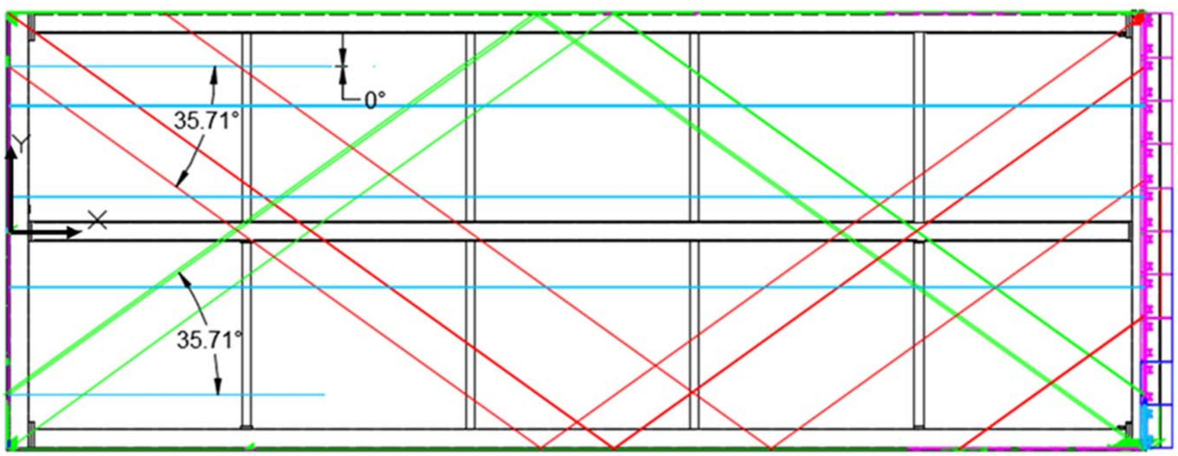
Considerations on the APA frame

- The effect on wire tension due to APA frame distortions during transport and handling.
- Strength of nut plate threads
- Stress in the APA frame due to higher g-loads
- Installing the conduits

Effect on wire tension during transport and handling

- Each APA is wrapped with 23.4km of 152 micron wire.
- It is important to not to break wires during transportation and handling.
- Note: Some wires are sloped down at 35.71, some up and some are horizontal.



Approach

- The APA is supported in it's shipping frame on isolators, but will still be subjected to forces that distort the APA and stretch some of its wires.
- Frame displacement data was extracted from the 3 transportation cases that will have the largest effect on wire tension.
  - Quasi-static sea transport (analyzed by Jake Nesbit)
  - Road transportation with vibration (analyzed by Ang Lee)
  - Road transportation with shock (analyzed by Ang Lee)
- The effects on wires for both "in-plane" and "out-of-plane" distortions were considered.

Frame distortion

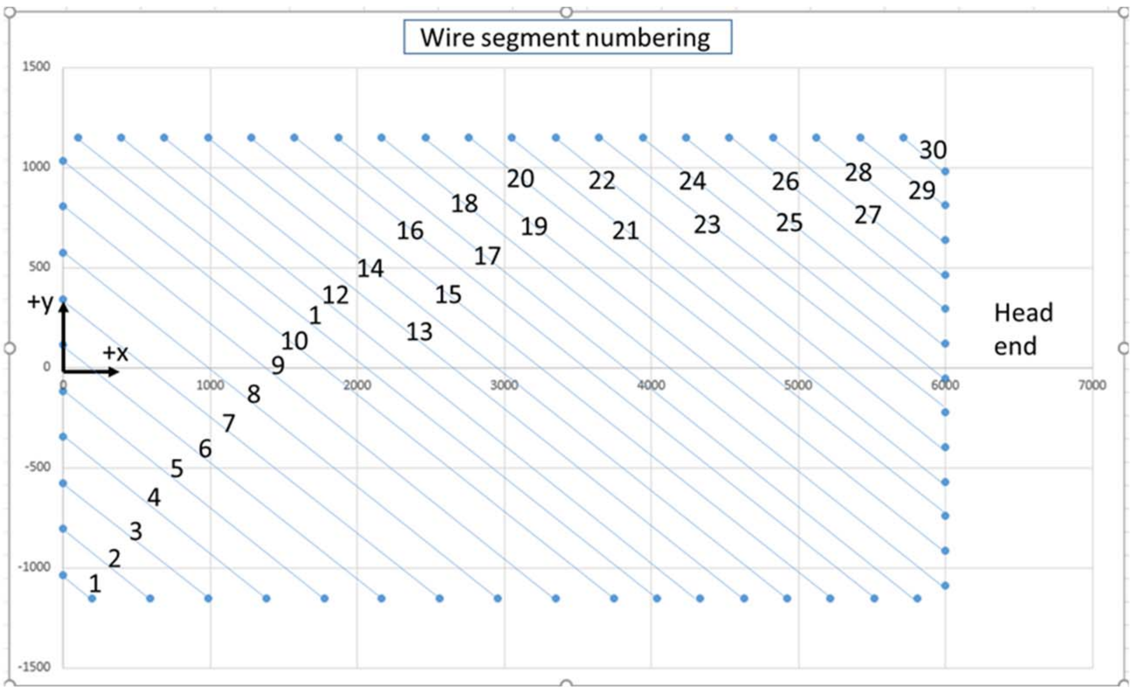
Displacements as defined by the difference between the maximum and minimum displacements (See image on page 2 for coordinate system.)

	ux	uy	uz
Case 1	1.30	3.48	5.27
Case 2	0.70	6.47	1.92
Case 3	0.31	2.70	0.99

“In-plane” effects

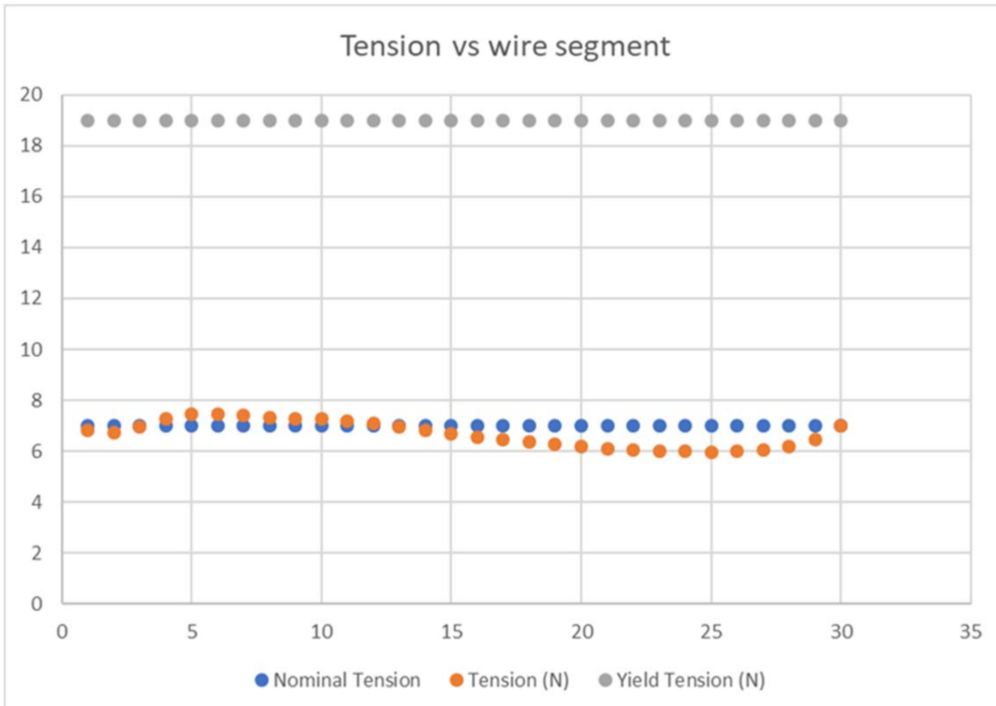
- 30 wire segments were checked on the wires sloped at -35.71 degrees
- Determined the change in length in the x-y plane between two nodes on each end of the wire.
- Wires sloped at +35.71 will see similar strains
- Wires with no slope will not see as much stress.

Foot end



Head end

Results: Case 1 “in-plane”



Max Tension increases from 7 to 7.5N

Results – Case 1 “out-of-plane”

APA will bow out ~5mm > ~radius of curvature > 900m

The APA will bow and the bending stresses and strains at the midplane of the APA will be zero. The wires are offest from this nuetral axis and will be stretched. This strain can be conservatively approximated as the ratio of the offset from the neutral plane to the wires.

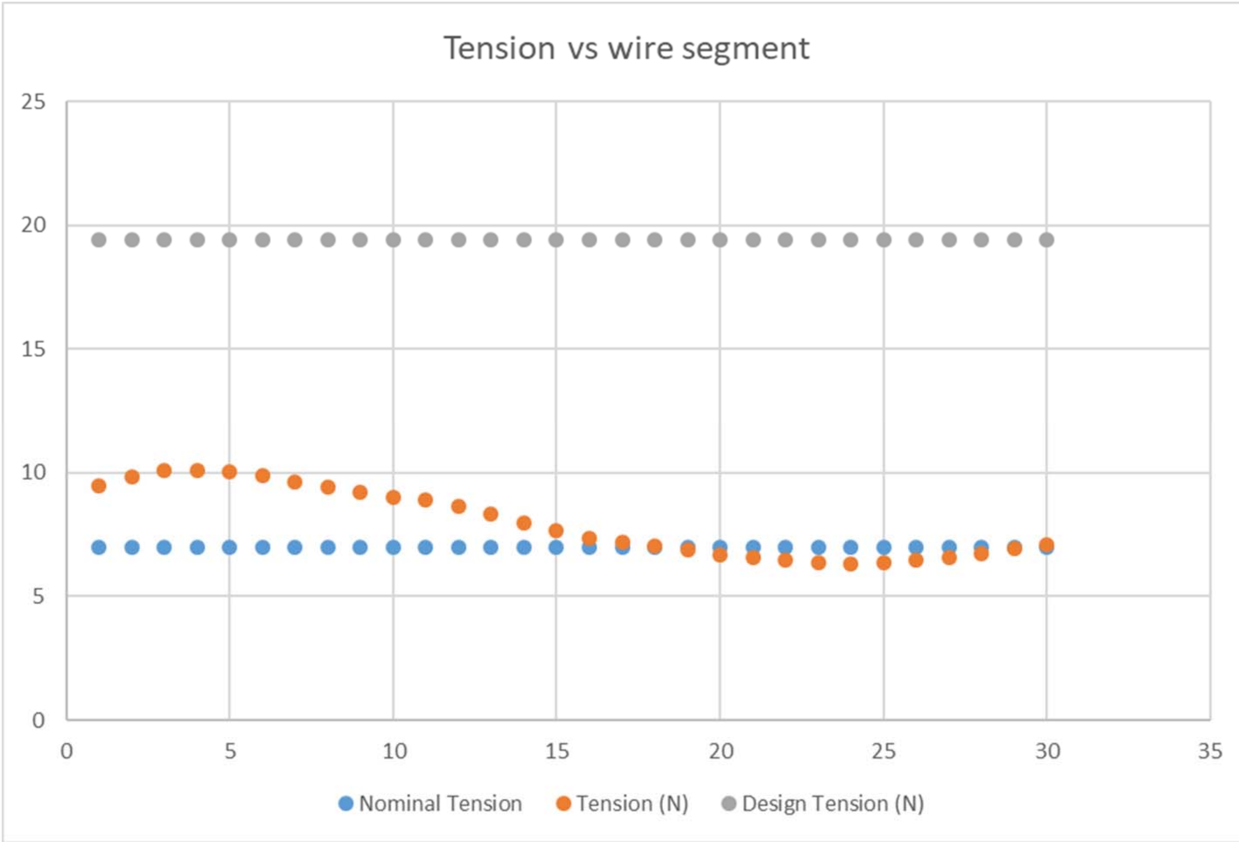
$v := 65 \cdot mm$ Offset from the neutral plane of the APA to the wires

$\varepsilon := \frac{v}{r} = 7.222 \cdot 10^{-5}$ Additional wire strain seen by wires aligned to the APA long axis. Strain will be less for angled wires.

$T := \varepsilon \cdot A \cdot E = 0.168\ N$ Conservative estimate of additional Tension due to "bowing".

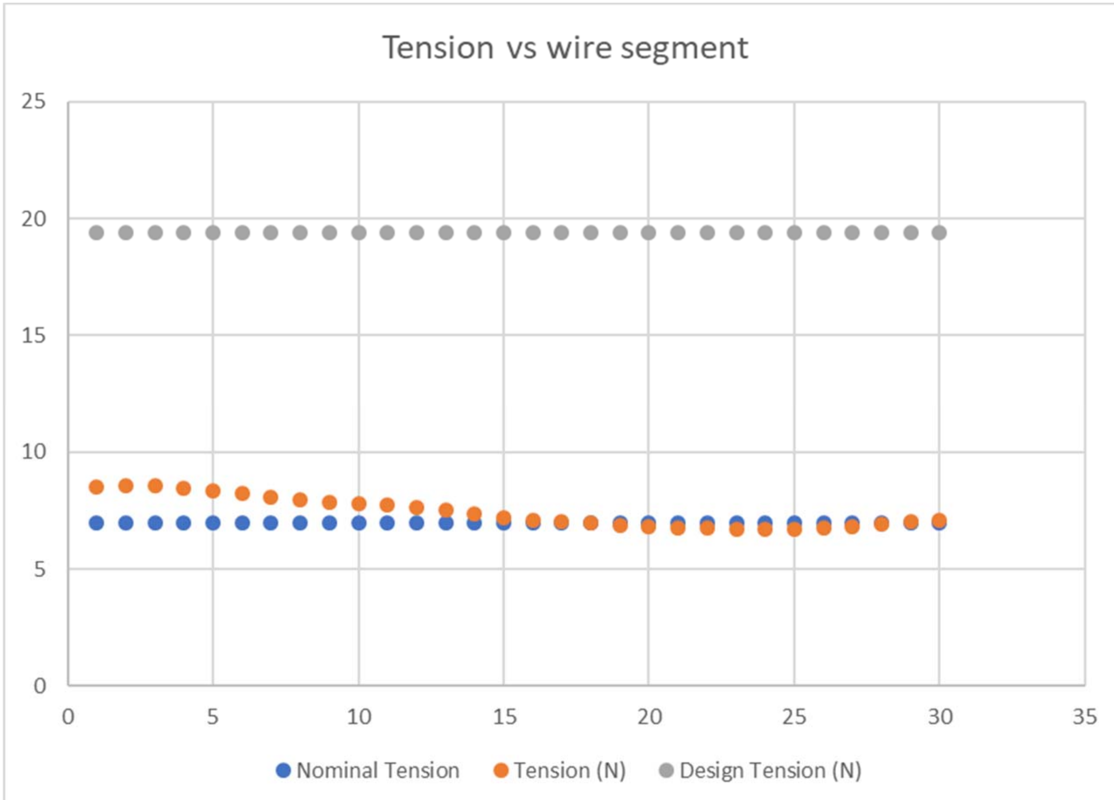
Tension < 7.5N+.17N < 7.67N

Results case 2 " in plane"



Tension increases from 7 to 10.1N.
Note: Transverse deflection is less than 2mm and can be ignored

Results case 3 “ in plane”

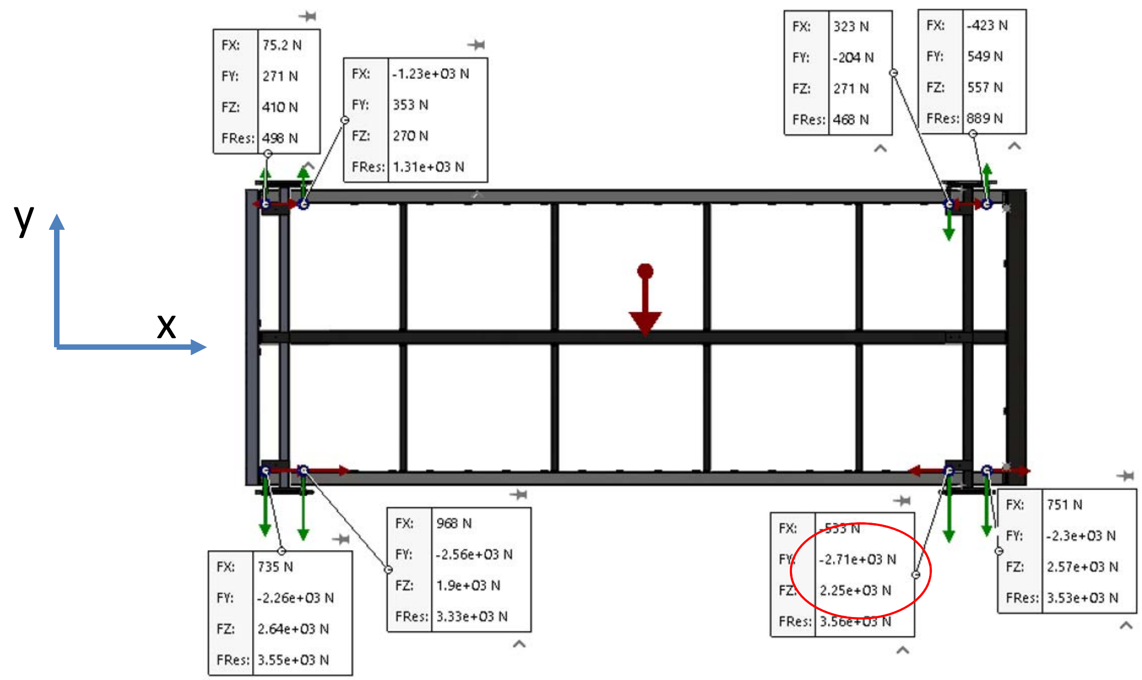


Tension increases from 7 to 8.59N.
Note: Transverse deflection is less than 1mm and can be ignored.

Strength of M20 connections - inputs

Inputs Mass of APA with protection, contingency and a 1.4 load factor is 868kg
loads –determined by FEA

Pin to Nut Plate Forces



Maximum FY on pins. See note.

Slide courtesy of Jake Nesbit

Note: Polarity shown represents forces acting on the pins. The forces of the pin acting on the nut plate are equal and opposite.

Results

Analysis of M20 nut plate connection to transport frame

1 Introduction

This document presents an initial check of the structural analysis the APA m20 nut plates on the side tubes of the APA.

2 Design

M20 nut plate is welded to the inner tube wall of the APA. A fixture controls the alignment to the holes in the tube

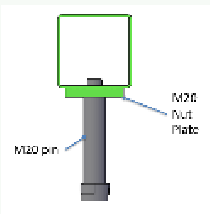


Figure 1 M20 nut plate

3 APA Mass and factored load

$mAPA\_lf := 620 \cdot kg \cdot 1.4 = 868\ kg$ — Mass of APA factored with Protection and Contingency

$F := 2710 \cdot N$ — The load from FEA

4 Strength of M20 connection:

The inputs for this analysis are as follows:

$Fb := F = (2.71 \cdot 10^{3})\ N$ — Tensile force per bolt

$Fbs := \left((553 \cdot N)^{2} + (2250 \cdot N)^{2}\right)^{.5} = (2.317 \cdot 10^{3})\ N$ — Shear force per bolt

For M20 screws (per J3.6 page 16.1-131 of 14th ed.)

$Fu := 500 \cdot MPa$ — Ultimate tensile stress of 304 SS

$Fnt := .75 \cdot Fu = 375\ MPa$ — Nominal tensile stress, per table J3.2

$Fnv := .45 \cdot Fu = 225\ MPa$ — Nominal shear stress, per table J3.2

$Ab := \left(\frac{\pi}{4}\right) \cdot (20 \cdot mm)^{2} = 314.159\ mm^{2}$ — Nominal unthreaded body area of bolt

$Rnt := Fnt \cdot Ab = (1.178 \cdot 10^{5})\ N$ — Nominal tensile strength

$Rnv := Fnv \cdot Ab = (7.069 \cdot 10^{4})\ N$ — Nominal shear strength

$Rdt := .75 \cdot Rnt = (8.836 \cdot 10^{4})\ N$ — Design tensile strength for $\phi := .75$

$Rdv1 := .75 \cdot Rnv = (5.301 \cdot 10^{4})\ N$ — Design shear strength for $\phi := .75$

For female M20 threads

$D := 20 \cdot mm$ — Nominal diameter of screw

$p := 2.5 \cdot mm$ — Pitch of screw

$Le := 12.7 \cdot mm$ — Length of thread in tube wall

$dp := (D - 0.64952 \cdot p) = 18.376\ mm$ — Pitch diameter per ISO 898 Part 1

$Ass := 0.5 \cdot \pi \cdot dp \cdot Le = 366.589\ mm^{2}$ — Shear area of threads per ISO 898 Part 1

$Fu := 500 \cdot MPa$ — Ultimate tensile stress of 304 SS

$Fnv := .6 \cdot Fu = 300\ MPa$ — Nominal shear stress of 304 SS 0.6 = Ratio of shear/tensile strength in table J3.2)

$Rnv := Fnv \cdot Ab = (9.425 \cdot 10^{4})\ N$ — Nominal design strength of female threads

$Rdv2 := .75 \cdot Rnv = (7.069 \cdot 10^{4})\ N$ — Design shear strength of female threads

$Rdmin := min(Rdt, Rdv2) = (7.069 \cdot 10^{4})\ N$

$Fb = (2.71 \cdot 10^{3})\ N$ <Rdmin=(70.69*10^3) N ✓ — Verification of tensile strength

Fbs=(2.317*10^3) N<Rdv1=(53.01*10^3) N ✓ — Calulation of shear force from FEA
Verification of bolt shear strength

Note: Per User note on page 16.3-134 it is not necessary to check combined stresses because required stress is less than 30% of available stress.

High G load analysis on APA frame - inputs

Three load cases were analyzed with extra g-load on the APA frame

- Case 8 - The APA and transport box lying flat. This case represented possible orientation in the South Dakota warehouse and this orientation is no longer foreseen. (g-load applied perpendicular to the plane of the APA)
- Case 9 - The APA and transport box in landscape mode. This is the typical orientation during transportation. (g-load aligned to minor axis of the APA)
- Case 13 - The APA vertical with the head end down. This is orientation the upside down APA will see when transported down the shaft. (g-load aligned to major axis of the APA)
- Load factor of 1.4 applied to loads on the APA frame
- Proper resistance factors applied to material and connections

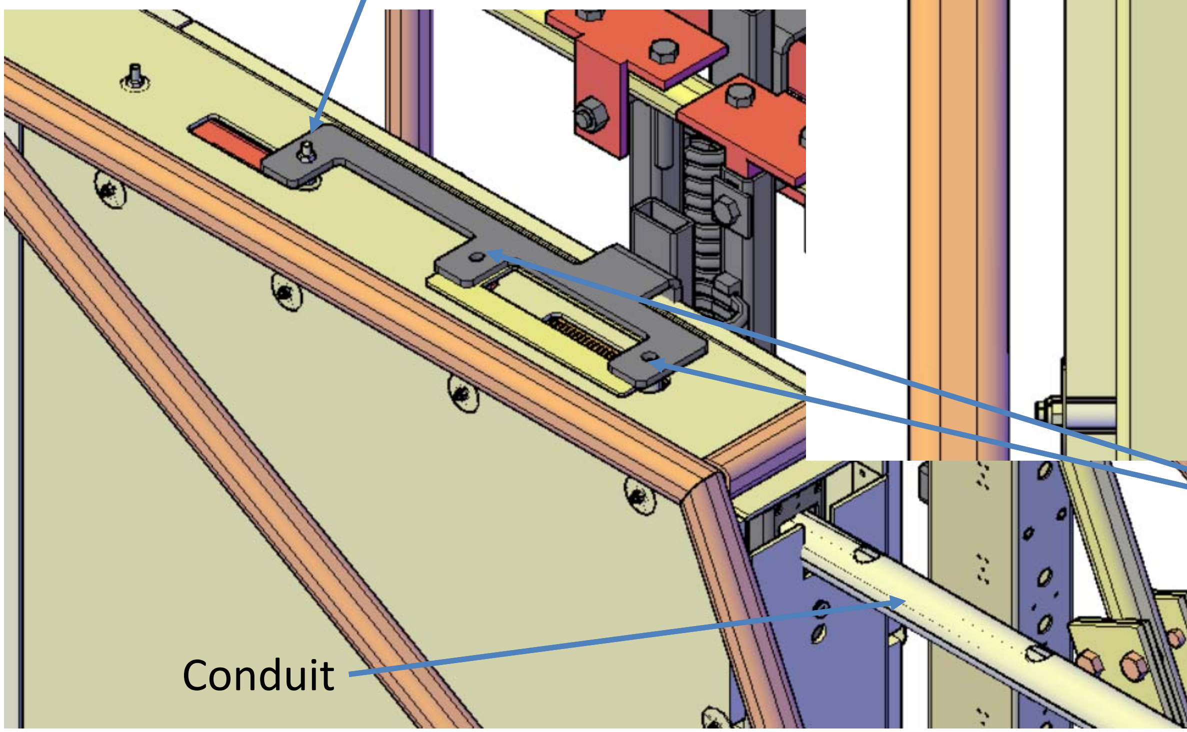
High G load analysis on APA frame

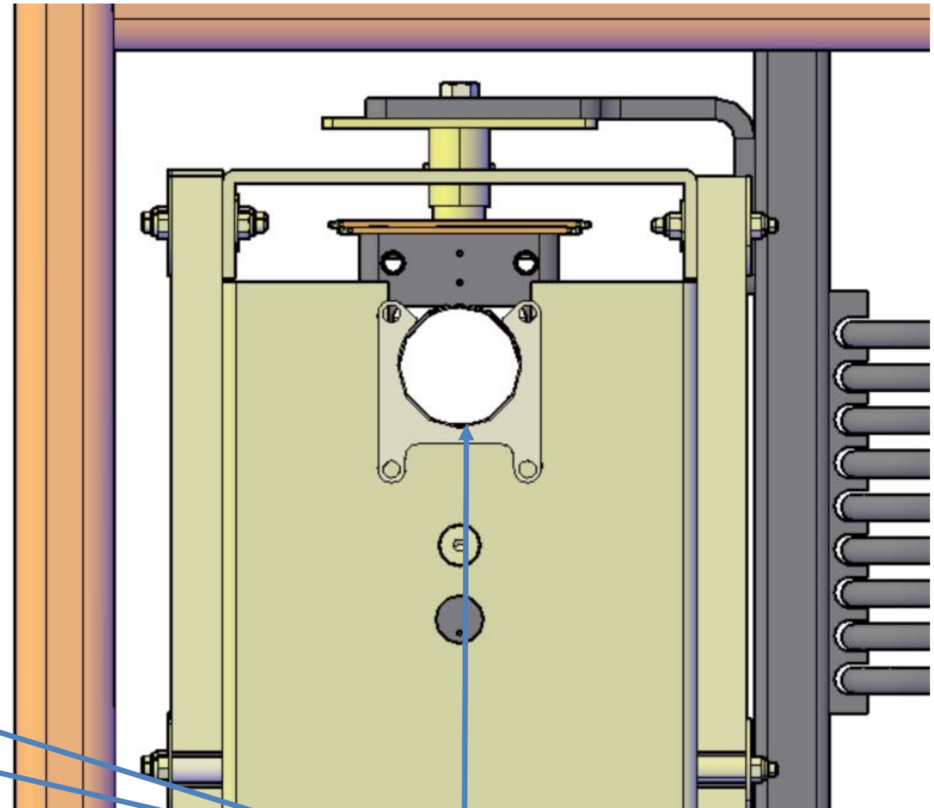
- G-load increased until a limiting factor was reached
  - Limiting factor > Weld strength by AISC code
  - Case 8 > 4g
  - Case 9 > 4g
  - Case 13 > 6g
- Max g-load from vibration or shock that can transferred to the APA. (Analysis was done in the vertical direction for the various orientations. The vertical direction is typically the direction of maximum g-loads.)
- Ang Lee's analysis dynamic analysis estimates g-loads much lower than 4 g's.

Conduit installation – New images will be provided with a step by step

Tapered nose guides conduit – not shown

An extension is mounted to the APA support bracket to pick up rivnut location. Conceptual





Large M20 bolts are removed one edge at time to clear passageway