Module Strap Tests and How they Effect the 25 cm Stack Construction

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06 September 1994

MASTER

*Work supported by the U.S. Department of Energy, Division of High Energy Physics, Contract W-31-109-ENG-38.

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Purpose

We were asked at the previous Atlas collaboration meeting to confirm our proposal that the Argonne design option could maintain the tie straps in a pre-stressed condition after welding. This was deemed necessary to maintain compression loading of the steel plate stack. The compression load requirement was set at a load equivalent to that necessary to maintain continuity of the stack using friction. We will attempt to prove that through the strap testing and the ultimate construction of the 25 cm prototype stack that we have in fact met these requirements.

Strap Tests

A series of strap tests were performed using the fixture shown in Fig. 1. The tests will be described in detail at a later date, but the preliminary results are shown here.

Four actual tests were performed with fully instrumented straps. The actual tests are described below.

1. The first test was conducted with no preload on the strap other than that necessary to maintain straightness. In this first test the strap merely assumed the load applied by the spring washers.
2. In this test a preload was applied to the strap, and a different load was applied to the spring washers. The final load was then measured and was close to the applied spring load.
3. This test used the same strap preload and a different spring load was applied. As expected the resultant final load approximated the spring load.

At this point, it was realized that regardless of the strap preload the resultant load would be the spring load when the system reached equilibrium. This is attributable to the final ΔL of the system as explained by the equation shown in Fig. 2.

4. In this test the spring load was applied, and the prestress load on the strap was kept at the same value. The difference in this test however was that the

system was compressed against a solid block which simulates the plate stack when it is compressed to solid.

The table below gives the loads applied and the final resultant strap loads.

Test	Strap Preload	Spring Load	Final Strap Load
1	247 lbs. (112 kg)	713 lbs. (324 kg)	889 lbs. (404 kg)
2	3075 lbs. (1397 kg)	713 lbs. (324 kg)	1011 lbs. (459.5 kg)
3	3055 lbs. (1389 kg)	1188 lbs. (540 kg)	1454 lbs. (661 kg)
4	3012 lbs. (1369 kg)*	882 lbs. (401 kg)	1540 lbs. (700 kg)**

* Strap stress = 24,096 psi (170 Mpa)

** Strap stress = 12,320 psi (87.8 Mpa) (Conversion 1 Mpa = 141.9 psi)

The only test that we consider relevant is test # 4 since tests 1-3 always assumed the spring load after welding. The slight variations in final load can be attributed to measurement error and some minor effect due to thermal expansion. Test # 4 clearly indicates that 50% of the strap preload was retained. **The strap stress in test # 4 @ 1540 lbs was 12320 psi.**

Friction Loads

The CERN group requested that we consider a design in which the compressive load on the stack is enough to support the weight of the stack through friction. The friction load required to support the load of the stack was recalculated based on a 1 meter module length. Assuming the weight of the 1 meter module is 6042 lbs. (2746 kg), and a coefficient of friction of .2, the required normal force necessary to maintain that shear load if the module is supported at both ends is 30,210 lbs. (13732 kg). Since there are two shear planes this load becomes 15,105 lbs (6866 kg). This load is carried by 44 straps therefore the single strap load is 343lbs. (156 kg). **The stress on the strap as a result of this load is 2744 psi.**

25 cm Stack Construction

A 25 cm stack of plates was fabricated at Argonne as a demonstration model of the fabrication and assembly technique we propose to use. This stack

was completed on August 30, 1994 and shipped to CERN on August 31, 1994. Careful attention was paid to measuring and understanding this model during its construction. It is our intention to formally present these results at a later date but the preliminary results are presented here. The stack is shown in Fig.3. All of the master plates were punched in a similar manner to that proposed for the final construction. The spacer plates were not punched however, but were stack machined as a group. This technique is shown in Fig. 4. This technique proved to be a very successful and economic method. It will be considered for further construction, since fine blanking tooling is expensive.

The spacer plates were then welded to the masters and stacked. The stack was compressed in a hydraulic press between two specially constructed platens as shown in Fig. 5. The straps were then preloaded, using the same tool as was used for the strap tests, and welded to the outer plate of the stack. The dimensions of the stack were taken before and after welding and the results are presented here.

Location	Loose Stack Height	Platen Installed	Compressed
A	9.792 in.	9.795 in.	9.739 in.
B	9.818 in.	9.805 in.	9.741 in.
C	9.836 in.	9.816 in.	9.750 in.
D	9.806 in.	9.809 in.	9.740 in.

The mean value of the compressed measurements is 9.742 in.

As the compression load was applied periodic measurements were taken with the following results.

Compression Load	Change in Stack Height
11,928 lbs. (5422 kg.)	.0389 in. (.988 mm)
19,880 lbs. (9036 kg.)	.0445 in. (1.130 mm)
29,820 lbs. (13555 kg.)	.0504 in. (1.28 mm)
35,784 lbs. (16265 kg.)	.0532 in. (1.351 mm)

The plot is shown in Fig. 6.

Within the measurement error, we can assume that at the final load, the stack was compressed to solid. The tie down bolts were then tightened and the stack was removed from the press.

The straps were then each preloaded to 24,000 psi and welded. After welding, and releasing the compression load, a final set of measurements was taken as shown in Fig. 7.

Figure 7

The table below lists the final measurements of the stack.

Location	Stack Height
AB 1	9.768 in.
AB 2	9.752 in.
AB 3	9.755 in.
AB 4	9.742 in.
AB 5	9.746 in.
AB 6	9.750 in.
AB 7	9.799 in.
CD 1	9.762 in.
CD 2	9.752 in.
CD 3	9.752 in.
CD 4	9.743 in.
CD 5	9.749 in.
CD 6	9.755 in.
CD 7	9.780 in.

Prior to making these measurements, it was observed that the stack had some flare at the ends since the ends were not fixed. This produced a curve to the stack at the ends. For this reason the corner measurements were not used.

The mean value of the measurements used is 9.749 in.

This indicates an expansion in the stack of .007 in. Referring back to the strap tests, this would indicate that the spring load of the stack exceeded the preload on the strap by a value equal to the increased length. However, if the measurements taken at the center of the stack are assumed ignoring the curvature of the stack, the value is 9.742 in. This indicates no expansion of the stack and therefore the prestress in the strap is preserved.

Conclusions

The results of these exercises are open to some interpretation and further tests should be done, however, it is clear that a preload is retained in the strap that is well above the load necessary to maintain the required friction load in the stack. The amount of preload is a direct result of the spring constant in the stack as was observed in the strap tests.

To summarize, the required strap stress is 2744 psi (19.3 Mpa). The retained prestress is 12,320 psi, (86.8 Mpa) assuming a 50% loss during welding. The final strap stress is at least that value or higher, since the spring load of the stack exceeds that value if the height expansion is accepted.

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TENSIONING FIXTURE

Figure 1

Initial Conditions

*After Welding
& Release*

Force Balance:

$$F_0^{Spring} + k_1 \Delta l - [F_0^{Strap} - k_2 \Delta l] = 0$$

Solving for Δl and substituting into F :

$$F = F_0^{Strap} - \frac{k_1 (F_0^{Strap} - F_0^{Spring})}{k_1 (1 + k_2 / k_1)}$$

Weak Spring : $F \sim F_0^{Spring}$

Strong Spring : $F \sim F_0^{Strap}$

Figure 2

Figure 4

Figure 5

Figure 6