STAR Note # 393

STUDY OF THE EMC MODULE STRAPS STRESS USING STRAIN GAGES

WSU-EMC, Jose Riso, 4/1/1999

The straps are the component of the EMC module that link the back and front plates in position and are subject to stress in tension produced by the full load applied between the plates. They required particular attention in their design as well as in tests performed to insure their quality and strength.
The main factor affecting the design has been the lack of space. The restriction in phi is imposed by the need to keep the gap between modules within the maximum value established not to compromise the physics of the calorimeter and in eta to avoid interference with the space required for optical connectors and fiber routing. Tolerances and construction techniques have been developed to satisfy safety, as well as dimension and budget requirements.
The safety factor (SF) for the straps has been set at about 4 for the normal preloading condition but suffering variations due to the module angular position in the barrel and accumulation of clearances of the same sign. Human safety is not at risk since in addition to the straps the back and front plates are also linked with two bulkheads at the ends, this bulkheads are capable of sustain the total load by themselves with a SF of 10 and the covers with a SF of 2.5.
A small EMC module prototype has been adapted to perform stress tests on the straps under different loading conditions. The module consists of: back plate, compression plate, front plate, shower maximum detector, twenty layers of 1% Sb Antimonial lead plates 5mm thick, 21 layers of scintillator tiles 5 mm thick, 8 straps, 8 sets of Belleville washers/adjusting screws and the eta=0 bulkhead.
The strain gages have been arranged in a Poisson full Whetstone bridge configuration in order to cancel output readings due to temperature variations and bending of the straps under different load conditions. Several tests have been performed and the results are fully reported in this document.

Strain gage used:

MEASUREMENTS GROUP, INC.
Gage: CEA-09-125UN-120
Resistance in ohms at 24 degree ‘C’: 120.0 +/- 0.3%
Gage factor at 24 degree ‘C’: 2.070 +/- 0.5%

Tests performed:

1) EMC module resting on the front plate (6 O’clock), load applied through load cells.
2) EMC module resting on the front plate (6 O’clock), load applied through load cells. A shim 0.004” thick has been placed between the pocket and the strap to verify redistribution of stress if the strap-pocket tolerance is shorter by that amount.
3) EMC module resting on the front plate (6 O’clock), load applied through load cells. A shim 0.008” thick has been placed between the pocket and the strap to verify redistribution of stress if the strap-pocket tolerance is shorter by that amount.
4) EMC module resting on the front plate (6 O’clock), load applied through load cells, the strap # 5 has been removed to study redistribution of the stress.
5) EMC module hanging from the back plate (12 O’clock), load applied through load cells.
6) EMC module rotated to 9 O’clock, straps 1-3-5-7 up, load applied through load cells.
7) EMC module resting on its front plate, load transferred to the Belleville washers.
8) EMC module hanging from the back plate (12 O’clock) load applied through Belleville washers.
9) EMC module resting on the back plate (6 O’clock)
10) EMC module rotated to 9 O’clock, straps 1-3-5-7 up, load applied through Belleville washers.

- For all the above cases the back to front plate load has been 4760 lbs to produce an average stress in tension to the straps equivalent to a full size module.
- All the tests have been repeated and the bridge 0 balance has been readjusted during no load periods.

Straps stress tests results

	TEST 1			TEST 2		
Strain gauge #	σ (psi)	ε (in/in)	Elong.(inch)	σ (psi)	ε (in/in)	Elong.(inch)
1	4407	0.000157	0.0019	4333	0.000155	0.0019
2	4565	0.000163	0.0020	4488	0.000160	0.0019
3	7983	0.000285	0.0034	7839	0.000280	0.0034
4	7824	0.000279	0.0034	8074	0.000288	0.0035
5	7720	0.000276	0.0033	10606	0.000379	0.0045
6	7623	0.000272	0.0033	7943	0.000284	0.0034
7	6106	0.000218	0.0026	5552	0.000198	0.0024
8	7301	0.000261	0.0031	6983	0.000249	0.0030

	TEST 3			TEST 4		
Strain gauge #	σ (psi)	ε (in/in)	Elong.(inch)	σ (psi)	ε (in/in)	Elong.(inch)
1	5103	0.000182	0.0022	4240	0.000151	0.0018
2	6379	0.000228	0.0027	4177	0.000149	0.0018
3	7589	0.000271	0.0033	12301	0.000439	0.0053
4	9270	0.000331	0.0040	7995	0.000286	0.0034
5	12470	0.000445	0.0053			
6	8037	0.000287	0.0034	8520	0.000304	0.0037
7	4542	0.000162	0.0019	9131	0.000326	0.0039
8	7438	0.000266	0.0032	7177	0.000256	0.0031

	TEST 5			TEST 6		
Strain gauge #	σ (psi)	ε (in/in)	Elong.(inch)	σ (psi)	ε (in/in)	Elong.(inch)
1	4549	0.000162	0.0019	4436	0.000158	0.0019
2	4456	0.000159	0.0019	4262	0.000152	0.0018
3	8382	0.000299	0.0036	8716	0.000311	0.0037
4	8261	0.000295	0.0035	7525	0.000269	0.0032
5	7780	0.000278	0.0033	8242	0.000294	0.0035
6	6721	0.000240	0.0029	6602	0.000236	0.0028
7	6048	0.000216	0.0026	5987	0.000214	0.0026
8	7422	0.000265	0.0032	6436	0.000230	0.0028

	TEST 7			TEST 8		
Strain gauge #	σ (psi)	ε (in/in)	Elong.(inch)	σ (psi)	ε (in/in)	Elong.(inch)
1	4114	0.000147	0.0018	3853	0.000138	0.0017
2	5339	0.000191	0.0023	4714	0.000168	0.0020
3	8660	0.000309	0.0037	9503	0.000339	0.0041
4	8788	0.000314	0.0038	9386	0.000335	0.0040
5	8466	0.000302	0.0036	7890	0.000282	0.0034
6	8721	0.000311	0.0037	6332	0.000226	0.0027
7	7507	0.000268	0.0032	7752	0.000277	0.0033
8	8118	0.000290	0.0035	8594	0.000307	0.0037

	TEST 9			TEST 10		
Strain gauge #	σ (psi)	ε (in/in)	Elong.(inch)	σ (psi)	ε (in/in)	Elong.(inch)
1	3253	0.000116	0.0014	4220	0.000151	0.0018
2	4052	0.000145	0.0017	4468	0.000160	0.0019
3	8394	0.000300	0.0036	9237	0.000330	0.0040
4	8566	0.000306	0.0037	8070	0.000288	0.0035
5	7970	0.000285	0.0034	8127	0.000290	0.0035
6	6684	0.000239	0.0029	5922	0.000212	0.0025
7	6557	0.000234	0.0028	7637	0.000273	0.0033
8	8256	0.000295	0.0035	7836	0.000280	0.0034

Relevant dimensions*:

Straps length:

Strap #	
1	11.133”
2	11.132”
3	11.132”
4	11.133”
5	11.133”
6	11.133”
7	11.133”
8	11.132”

Distance back to front plate taken between strap pocket; a shim 0.008” thick has been added to the pocket of the strap # 5 (module preloaded).

Strap #	
1	11.136”
2	11.135”
3	11.134”
4	11.138”
5	11.131”
6	11.136”
7	11.136”
8	11.136”

Distance pocket to pocket with the front and back plate pressed together:

Pocket #	
1	1.181”
2	1.176”
3	1.181”
4	1.176”
5	1.181”
6	1.177”
7	1.181”
8	1.179”

- The dimensions are the average of a set of 4 measurements taken for each point.
- For the tests the components has been randomly selected.

Conclusions

The results of the tests shows that under the worst conditions the SafetyFactor doesn’t decrease below 2.4, the deflection of the aluminum plates plus elasticity of the stack help to keep the stress on straps exposed to addition of clearances within reasonable stress limits. Human safety or adjacent equipment is not at risk for the reasons explained in the introduction.
The implementation of full size operational modules with strain gages on the straps is not practical for several reasons:

- **The module covers make contact with the strain gages cemented to the external face of the strap.**
- **The routing of 120 wires out of the sealed module.**

- **The need of readjust the balance of the Wheatstone bridge under no load condition in order to obtain accurate strain values.**
- **The installation of the strain gages on each strap requires 120 hours of one skilled technician per module.**

<u>Procedures for the installation of strain gauges on the straps:</u>
Surface preparation for bonding the strain gages to SST 316

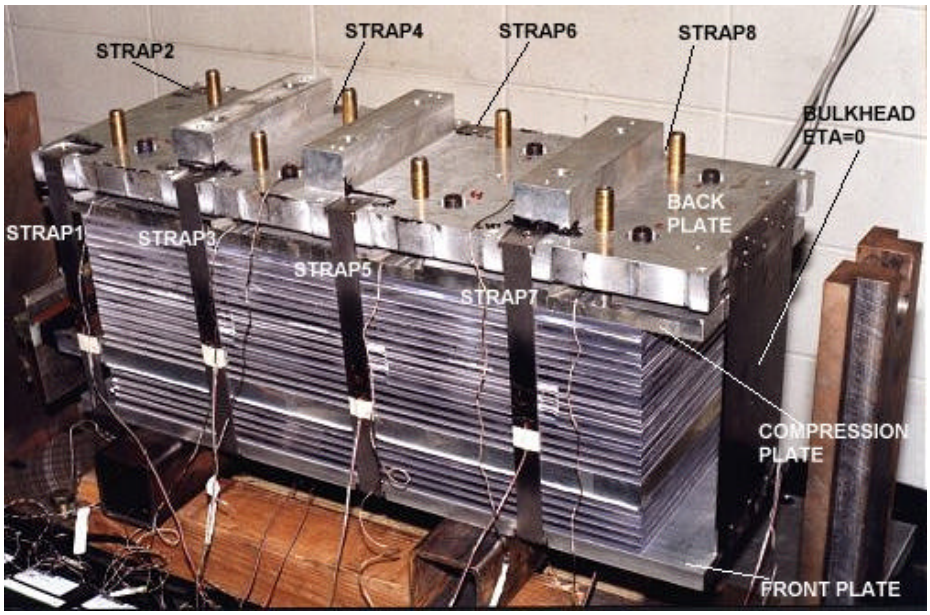
Side "A" of the strap:
Degreaser.
Grit-blast.
220-grit abrasive paper.
320-grit abrasive paper.
Gage location layout.
Conditioner.
Neutralizer.
Layout of the gage.
Adhesive and catalyst application.

Side "B" of the strap:
Same steps as side "A".
Solder correspondent wires to configure the bridge.
Solder bridge excitation and output wires.
Apply protective coating and test.

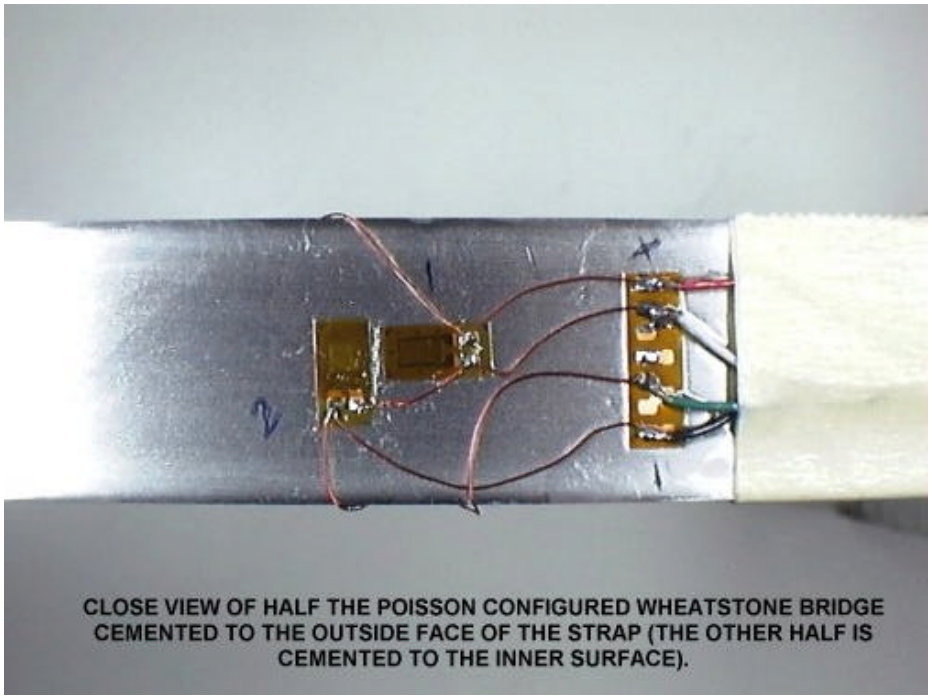
The time required for the proper installation, test and calibration of the set of strain gages per strap is about 4 Hs for a skilled technician.

The operation of cementing the gages is not 100% successful, it depend of many factors, mechanical, chemical and environmental. Our experience has been 25% failure of the bond, in these cases the gages are usually damaged and the process has to be started from the step one.

SOME PICTURES TAKEN DURING THE STRAPS STRAIN TESTS

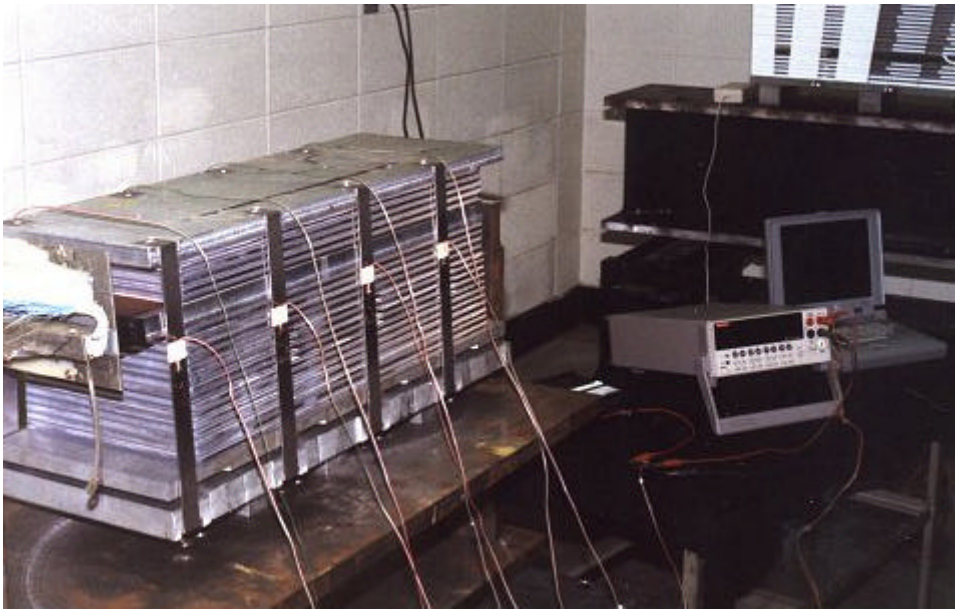


PICTURE SHOWING THE POSITION OF STRAPS IN THE MODULE

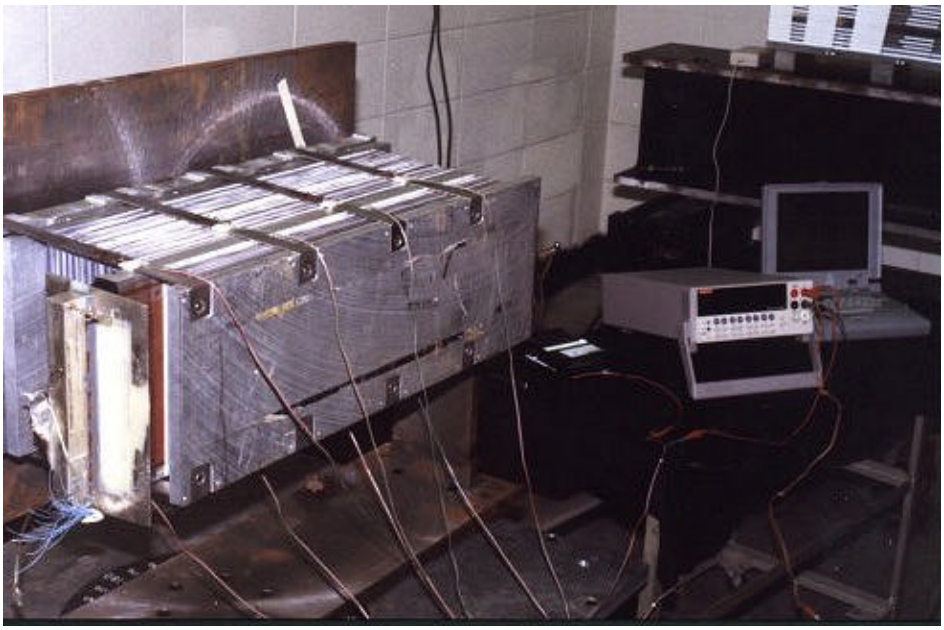


CLOSE VIEW OF HALF THE POISSON CONFIGURED WHEATSTONE BRIDGE CEMENTED TO THE OUTSIDE FACE OF THE STRAP (THE OTHER HALF IS CEMENTED TO THE INNER SURFACE).

STRAPS STRESS TEST AT 12 O'CLOCK POSITION



STRAPS STRESS TEST AT 6 O'CLOCK POSITION



STRAPS STRESS TEST AT 9 O’CLOCK POSITION