

Civil Construction

Vacuum Load Static Analysis

February 6, 1996

LIGO

Laser Interferometer Gravitational-Wave Observatory

California Institute of Technology

The Ralph M. Parsons Company

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APPROVAL STATUS

YES

NO

NOT REQUIRED

M. D. C. [Signature]

Project Manager, Parsons

Technical Representative, Caltech

Parsons-LIGO

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VACUUM LOAD STATIC ANALYSES

A series of static analyses were carried out using different vacuum loading configurations. These configurations, provided by Caltech, represented forces caused by closing various valves and leaving certain tube sections at vacuum while others are at one atmosphere (as might be required in order to swap out a laser or beam splitter). The loading for each load case is listed below. Forces were caused by either a tube transition to a smaller diameter or a pipe end condition such as at a closed valve. All cases, except 6 and 7, were loaded symmetrically about the line connecting BSC2 and BSC4. A separate gravity load case for the vacuum equipment components (load case 8) was also included in the analyses. The finite element model of the LVEA foundation was based on the Hanford soil properties and a 30 inches thick foundation slab.

STATIC LOADS ON THE LVEA

Load Case	Condition	F _{H1}	F _{B3}	F _{B7x}	F _{B7y}	F _{A1}	F _{80k}	F _{G4}
1	All Evacuated	+42	-15	+34	+29	-34	0	0
2	Vertex @ 1 atm	0	0	+61	+27	-34	0	0
3	Diag. @ 1 atm (GV3 & 4 closed)	+42	-15	+34	+27	-39	0	-27
4	Manifold @ 1 atm (GV 1,2,3,4,&7 closed)	+42	-15	0	0	0	+27	+27
5	80k @ 1 atm (GV5,6,7,&8 closed)	+42	-15	+34	+27	-34	-27	0
6	80k @ 1 atm (GV7,&8 closed)	+42	-15	+34	+27	-34	-27	0
7	80k @ 1 atm (GV5,6 closed)	+42	-15	+34	+27	-34	0	0

The results from these load cases using the finite element method (FEM) were similar to results calculated by hand. The FEM moments on the surface of the concrete floor were very close to simply the force applied times the moment arm (usually 73"). The horizontal displacements of the floor were of the same order of magnitude with the resultant forces on the floor divided by the soil stiffness. This was because the concrete floor was very rigid in the horizontal direction in comparison to the underlying soil.

Displacements on the top of the concrete pad due to vacuum loads only were nearly 4 mills in the horizontal direction, while at the concrete centerline they were in the 2 mil range. Vertical displacements nearly reached 5 mills at both sections. Gravity load of the equipment, prior to operation, could cause nearly 45 mills deflection. Moments (combined x and y direction) at the top of the slab reached 408 foot kips occurring at BSR 6 and 7. This number is in general agreement with the simplification of multiplying the force by the moment arm (73" x 61k) giving 375 foot kips in the primary direction.

The mid-station foundation was analyzed for a static force of 27 kips acting along the tube, 73 inches above the concrete floor ($27k \times 73'' = 164 \text{ ft-k}$) The finite element model of the VEA foundation was based on the Hanford soil properties and a 30 inch thick foundation slab. Results using finite element analysis indicated that displacements were similar to the main LVEA slab at $2\frac{1}{2}$ mills in the horizontal direction at the top of the concrete slab but only 0.2 mills in the vertical direction. The moment at the top of the slab was nearly 167 foot- kips.

The tabulated numbers on the following pages are in units of inches and pounds.

Calculations based on these numbers indicated that the reinforced 30 inch slab should handle these deflections and moments without requiring excessive reinforcement.

CENTER OF CONCRETE

N O D E D I S P L A C E M E N T S / R O T A T I O N S

NODE NUMBER	LOAD CASE	X-TRANSLATION	Y-TRANSLATION	Z-TRANSLATION	X-ROTATION	Y-ROTATION	Z-ROTATION
134 LASER @ HAM1	1	0.86765E-03	-0.64103E-04	0.11539E-02	-0.38690E-06	-0.91864E-05	0.00000E+00
	2	0.31560E-03	0.89898E-04	-0.51620E-05	-0.10249E-06	-0.17672E-08	0.00000E+00
	3	0.10034E-02	-0.50219E-04	0.11512E-02	-0.40121E-06	-0.92197E-05	0.00000E+00
	4	0.14813E-02	0.99611E-04	0.11358E-02	-0.56181E-06	-0.92185E-05	0.00000E+00
	5	0.62494E-03	-0.12304E-03	0.11603E-02	-0.32273E-06	-0.91718E-05	0.00000E+00
	6	0.59724E-03	-0.66740E-04	0.11638E-02	-0.38386E-06	-0.91793E-05	0.00000E+00
	7	0.89535E-03	-0.12040E-03	0.11505E-02	-0.32577E-06	-0.91789E-05	0.00000E+00
	8	0.11750E-03	-0.13219E-03	-0.96668E-02	0.35306E-05	0.27232E-04	0.00000E+00
182 LASER @ HAM1	1	0.90512E-03	0.39404E-04	0.33534E-02	-0.20234E-05	-0.11066E-04	0.00000E+00
	2	0.32244E-03	0.14993E-03	-0.10957E-04	-0.16667E-06	0.10932E-06	0.00000E+00
	3	0.10442E-02	0.80374E-04	0.33643E-02	-0.20744E-05	-0.11168E-04	0.00000E+00
	4	0.15322E-02	0.31843E-03	0.33550E-02	-0.23177E-05	-0.11206E-04	0.00000E+00
	5	0.65697E-03	-0.65657E-04	0.33530E-02	-0.19095E-05	-0.11027E-04	0.00000E+00
	6	0.62883E-03	0.42732E-04	0.33575E-02	-0.20259E-05	-0.11032E-04	0.00000E+00
	7	0.93325E-03	-0.68985E-04	0.33489E-02	-0.19069E-05	-0.11061E-04	0.00000E+00
	8	0.10681E-03	-0.94099E-04	-0.12286E-01	0.51244E-05	0.18144E-06	0.00000E+00
230 HAM 1	1	0.11786E-02	0.15593E-03	0.83598E-04	-0.70552E-06	0.12564E-03	0.00000E+00
	2	0.33145E-03	0.21776E-03	-0.61368E-04	-0.14100E-06	0.38434E-06	0.00000E+00
	3	0.13225E-02	0.22975E-03	0.11905E-03	-0.86144E-06	0.12553E-03	0.00000E+00
	4	0.18237E-02	0.56601E-03	0.12392E-03	-0.11378E-05	0.12543E-03	0.00000E+00
	5	0.92316E-03	-0.21083E-05	0.76414E-04	-0.53973E-06	0.12565E-03	0.00000E+00
	6	0.89399E-03	0.16633E-03	0.81901E-04	-0.71567E-06	0.12565E-03	0.00000E+00
	7	0.12078E-02	-0.12502E-04	0.78111E-04	-0.52958E-06	0.12564E-03	0.00000E+00
	8	0.95929E-04	-0.46232E-04	-0.95588E-02	0.35739E-05	-0.27432E-04	0.00000E+00
374 HAM 2	1	0.51855E-03	0.37349E-03	-0.25261E-03	0.42858E-05	-0.30790E-05	0.00000E+00
	2	0.35715E-03	0.37801E-03	0.70555E-03	0.65633E-05	-0.58424E-05	0.00000E+00
	3	0.68207E-03	0.55494E-03	-0.40638E-03	0.19742E-05	-0.26585E-05	0.00000E+00
	4	0.12174E-02	0.11057E-02	-0.51209E-03	0.14616E-05	-0.14198E-07	0.00000E+00
	5	0.23993E-03	0.78520E-04	-0.26549E-03	0.44138E-05	-0.30922E-05	0.00000E+00
	6	0.20212E-03	0.40618E-03	-0.26259E-03	0.42939E-05	-0.30719E-05	0.00000E+00
	7	0.55636E-03	0.45836E-04	-0.25550E-03	0.44056E-05	-0.30993E-05	0.00000E+00
	8	0.75088E-04	0.92669E-04	-0.18534E-01	-0.13515E-04	0.97882E-04	0.00000E+00
496 HAM 3	1	0.45163E-03	0.38129E-03	-0.17593E-03	0.48966E-05	0.15877E-05	0.00000E+00
	2	0.36059E-03	0.38802E-03	0.15052E-02	0.98514E-05	-0.75697E-05	0.00000E+00
	3	0.62316E-03	0.58337E-03	-0.31925E-03	0.29999E-05	0.90840E-06	0.00000E+00
	4	0.11625E-02	0.11470E-02	-0.90031E-03	0.23712E-06	0.63769E-05	0.00000E+00
	5	0.16753E-03	0.70964E-04	-0.18506E-03	0.49583E-05	0.15354E-05	0.00000E+00
	6	0.12445E-03	0.41764E-03	-0.18417E-03	0.49128E-05	0.15470E-05	0.00000E+00
	7	0.49471E-03	0.34616E-04	-0.17682E-03	0.49421E-05	0.15761E-05	0.00000E+00
	8	0.64218E-04	0.11312E-03	-0.30470E-01	-0.26634E-04	0.10443E-03	0.00000E+00
774 HAM 6	1	-0.56173E-05	0.11729E-02	-0.85304E-04	-0.12959E-03	-0.85347E-07	0.00000E+00
	2	0.18430E-03	0.34646E-03	-0.39775E-04	-0.27614E-06	0.14279E-06	0.00000E+00
	3	0.67066E-04	0.13448E-02	-0.67092E-04	-0.12947E-03	-0.20959E-07	0.00000E+00

	4	0.41066E-03	0.18849E-02	-0.64290E-04	-0.12940E-03	0.36629E-06	0.00000E+00
	5	-0.16218E-03	0.89120E-03	-0.87804E-04	-0.12962E-03	-0.24478E-06	0.00000E+00
	6	-0.18689E-03	0.11851E-02	-0.91926E-04	-0.12960E-03	-0.27419E-06	0.00000E+00
	7	0.19093E-04	0.87909E-03	-0.81182E-04	-0.12961E-03	-0.55938E-07	0.00000E+00
	8	-0.26743E-04	0.16454E-03	-0.55305E-02	0.27351E-05	-0.26799E-05	0.00000E+00
786	1	0.32743E-03	0.49431E-03	-0.16571E-03	0.21576E-05	-0.36197E-05	0.00000E+00
HAM 5	2	0.34065E-03	0.36877E-03	0.62184E-03	0.54249E-05	-0.56873E-05	0.00000E+00
	3	0.49598E-03	0.68435E-03	-0.26924E-03	0.16990E-05	-0.19652E-05	0.00000E+00
	4	0.10101E-02	0.12471E-02	-0.41165E-03	-0.78803E-06	-0.92410E-06	0.00000E+00
	5	0.52182E-04	0.19401E-03	-0.17728E-03	0.22080E-05	-0.37463E-05	0.00000E+00
	6	0.43891E-05	0.51998E-03	-0.17456E-03	0.21809E-05	-0.37269E-05	0.00000E+00
	7	0.37523E-03	0.16834E-03	-0.16843E-03	0.21846E-05	-0.36390E-05	0.00000E+00
	8	0.31880E-04	0.16035E-03	-0.16610E-01	-0.99314E-04	0.10683E-04	0.00000E+00
789	1	0.37563E-03	0.42531E-03	-0.17315E-03	-0.20365E-05	-0.44169E-05	0.00000E+00
HAM 4	2	0.36100E-03	0.37266E-03	0.14272E-02	0.79447E-05	-0.90006E-05	0.00000E+00
	3	0.55674E-03	0.62416E-03	-0.28186E-03	-0.15610E-05	-0.29617E-05	0.00000E+00
	4	0.10824E-02	0.11915E-02	-0.88738E-03	-0.69304E-05	0.96453E-07	0.00000E+00
	5	0.88481E-04	0.11903E-03	-0.17848E-03	-0.19813E-05	-0.45002E-05	0.00000E+00
	6	0.40597E-04	0.45741E-03	-0.17900E-03	-0.20135E-05	-0.44690E-05	0.00000E+00
	7	0.42352E-03	0.86929E-04	-0.17263E-03	-0.20043E-05	-0.44481E-05	0.00000E+00
	8	0.43117E-04	0.14967E-03	-0.29470E-01	-0.11450E-03	0.22928E-04	0.00000E+00
792	1	0.38598E-03	0.35476E-03	-0.42785E-03	0.76111E-06	-0.61884E-06	0.00000E+00
BSC 2	2	0.36533E-03	0.37573E-03	0.26746E-02	0.92419E-05	-0.87444E-05	0.00000E+00
	3	0.56857E-03	0.56743E-03	-0.38249E-03	0.21749E-05	-0.21971E-05	0.00000E+00
	4	0.11098E-02	0.11358E-02	-0.19346E-02	-0.52020E-05	0.52808E-05	0.00000E+00
	5	0.95123E-04	0.40810E-04	-0.43059E-03	0.75923E-06	-0.64942E-06	0.00000E+00
	6	0.42447E-04	0.39727E-03	-0.43101E-03	0.77163E-06	-0.64211E-06	0.00000E+00
	7	0.43865E-03	-0.17030E-05	-0.42743E-03	0.74871E-06	-0.62615E-06	0.00000E+00
	8	0.41956E-04	0.12274E-03	-0.43111E-01	-0.41763E-04	0.36973E-04	0.00000E+00
796	1	0.40403E-03	0.19335E-03	0.20904E-02	0.53958E-04	0.90774E-05	0.00000E+00
BSC 1	2	0.36207E-03	0.40819E-03	0.46763E-02	0.10872E-04	0.58111E-05	0.00000E+00
	3	0.55340E-03	0.43000E-03	0.22345E-02	0.53153E-04	-0.22940E-05	0.00000E+00
	4	0.11611E-02	0.96658E-03	-0.58229E-03	0.48353E-04	0.12298E-04	0.00000E+00
	5	0.11605E-03	-0.13101E-03	0.20827E-02	0.53925E-04	0.90700E-05	0.00000E+00
	6	0.53058E-04	0.25053E-03	0.20867E-02	0.53939E-04	0.90284E-05	0.00000E+00
	7	0.46702E-03	-0.18819E-03	0.20864E-02	0.53944E-04	0.91190E-05	0.00000E+00
	8	0.33701E-04	0.80574E-04	-0.39900E-01	0.57077E-04	0.29280E-04	0.00000E+00
801	1	0.59825E-03	0.47414E-03	0.10575E-02	-0.10829E-03	0.85495E-04	0.00000E+00
BSC 6	2	0.58354E-03	0.83313E-03	0.23417E-03	-0.19057E-03	0.83859E-04	0.00000E+00
	3	0.49418E-03	0.74030E-03	0.90522E-03	-0.10954E-03	-0.72759E-06	0.00000E+00
	4	0.14079E-02	0.10232E-02	0.10109E-02	-0.15187E-05	0.87191E-04	0.00000E+00
	5	0.31080E-03	0.13275E-03	0.10448E-02	-0.10831E-03	0.85429E-04	0.00000E+00
	6	0.24976E-03	0.54425E-03	0.10475E-02	-0.10833E-03	0.85368E-04	0.00000E+00
	7	0.65928E-03	0.62639E-04	0.10548E-02	-0.10827E-03	0.85557E-04	0.00000E+00
	8	0.27103E-04	0.47879E-04	-0.26299E-01	0.84063E-04	0.23640E-04	0.00000E+00
827	1	0.20039E-03	-0.90102E-03	0.13401E-03	0.10374E-03	-0.17151E-05	0.00000E+00
A2 LEFT ARM	2	0.28231E-03	-0.80104E-03	0.13948E-03	0.10370E-03	-0.16619E-05	0.00000E+00
	3	-0.10165E-03	-0.48446E-03	-0.19265E-05	0.10487E-03	-0.80378E-07	0.00000E+00

	4	0.43166E-03	0.12256E-02	0.22429E-02	0.48153E-05	0.23308E-05	0.00000E+00
	5	-0.72956E-04	-0.16435E-02	-0.20933E-02	0.98850E-04	-0.39585E-05	0.00000E+00
	6	0.11836E-03	-0.81001E-03	0.13016E-03	0.10374E-03	-0.17728E-05	0.00000E+00
	7	0.90786E-05	-0.17345E-02	-0.20895E-02	0.98850E-04	-0.39008E-05	0.00000E+00
	8	-0.34968E-04	0.15489E-04	-0.69948E-02	-0.15311E-04	-0.25691E-05	0.00000E+00
831	1	0.14812E-03	-0.69349E-03	0.26412E-02	-0.63289E-05	0.19246E-05	0.00000E+00
80K LEFT ARM	2	0.23086E-03	-0.59552E-03	0.26390E-02	-0.63968E-05	0.19482E-05	0.00000E+00
	3	-0.28027E-03	-0.27544E-03	0.26352E-02	-0.61412E-05	0.21032E-05	0.00000E+00
	4	0.40667E-03	0.15079E-02	-0.98708E-03	-0.98859E-04	-0.17455E-05	0.00000E+00
	5	-0.20249E-03	-0.17235E-02	0.36025E-02	0.92071E-04	0.36454E-05	0.00000E+00
	6	0.10797E-03	-0.60321E-03	0.26325E-02	-0.63938E-05	0.18670E-05	0.00000E+00
	7	-0.16234E-03	-0.18138E-02	0.36112E-02	0.92136E-04	0.37031E-05	0.00000E+00
	8	-0.54399E-04	0.99526E-05	-0.74692E-02	0.93409E-05	-0.44651E-05	0.00000E+00
1168	1	0.23882E-03	0.34234E-03	0.19922E-02	-0.85017E-05	-0.53614E-04	0.00000E+00
BSC 3	2	0.40537E-03	0.35049E-03	0.45302E-02	-0.46746E-05	-0.10600E-04	0.00000E+00
	3	0.43957E-03	0.53062E-03	0.21973E-02	0.24219E-05	-0.53301E-04	0.00000E+00
	4	0.95684E-03	0.11405E-02	-0.65873E-03	-0.11973E-04	-0.47766E-04	0.00000E+00
	5	-0.62522E-04	0.36130E-04	0.19912E-02	-0.85305E-05	-0.53611E-04	0.00000E+00
	6	-0.12671E-03	0.39445E-03	0.19898E-02	-0.85009E-05	-0.53609E-04	0.00000E+00
	7	0.30301E-03	-0.15978E-04	0.19935E-02	-0.85313E-05	-0.53615E-04	0.00000E+00
	8	0.87663E-05	0.12896E-03	-0.40234E-01	-0.35625E-04	-0.48075E-04	0.00000E+00
1493	1	0.50372E-03	0.53742E-03	0.81058E-03	-0.78665E-04	0.10358E-03	0.00000E+00
BSC 7	2	0.80406E-03	0.53831E-03	-0.83088E-04	-0.77102E-04	0.18230E-03	0.00000E+00
	3	0.73115E-03	0.48163E-03	0.93532E-03	0.13237E-05	0.10503E-03	0.00000E+00
	4	0.10182E-02	0.13356E-02	0.75296E-03	-0.80324E-04	0.12865E-05	0.00000E+00
	5	0.18486E-03	0.24892E-03	0.80704E-03	-0.78697E-04	0.10359E-03	0.00000E+00
	6	0.11023E-03	0.60102E-03	0.80750E-03	-0.78696E-04	0.10357E-03	0.00000E+00
	7	0.57836E-03	0.18531E-03	0.81012E-03	-0.78666E-04	0.10360E-03	0.00000E+00
	8	-0.15836E-04	0.13765E-03	-0.28341E-01	-0.30599E-04	-0.80277E-04	0.00000E+00
1502	1	0.19983E-03	0.16834E-03	-0.86624E-03	0.18231E-05	-0.16957E-05	0.00000E+00
BSC 4	2	0.23585E-03	0.21871E-03	-0.10457E-02	0.15071E-05	-0.10723E-05	0.00000E+00
	3	0.44891E-03	0.44581E-03	0.15554E-03	-0.28876E-05	0.28500E-05	0.00000E+00
	4	0.11508E-02	0.11173E-02	-0.96465E-03	0.32675E-05	-0.33631E-05	0.00000E+00
	5	-0.12926E-03	-0.16482E-03	-0.86996E-03	0.18990E-05	-0.17355E-05	0.00000E+00
	6	-0.17711E-03	0.21958E-03	-0.86633E-03	0.18584E-05	-0.16946E-05	0.00000E+00
	7	0.24768E-03	-0.21606E-03	-0.86987E-03	0.18637E-05	-0.17366E-05	0.00000E+00
	8	-0.22415E-04	0.80758E-04	-0.29268E-01	-0.14326E-05	0.70882E-05	0.00000E+00
1505	1	0.20512E-03	0.95028E-04	-0.67122E-03	0.12601E-05	-0.45968E-05	0.00000E+00
HAM 10	2	0.24783E-03	0.15582E-03	-0.87725E-03	0.14005E-05	-0.66304E-05	0.00000E+00
	3	0.44558E-03	0.42347E-03	-0.13956E-03	-0.14329E-05	-0.86137E-06	0.00000E+00
	4	0.11281E-02	0.11304E-02	-0.58459E-03	0.26059E-05	-0.25914E-05	0.00000E+00
	5	-0.11019E-03	-0.26034E-03	-0.66412E-03	0.13601E-05	-0.47035E-05	0.00000E+00
	6	-0.15127E-03	0.13898E-03	-0.66451E-03	0.13283E-05	-0.46404E-05	0.00000E+00
	7	0.24621E-03	-0.30429E-03	-0.67083E-03	0.12919E-05	-0.46599E-05	0.00000E+00
	8	-0.17330E-04	0.63073E-04	-0.23889E-01	0.62618E-04	0.18032E-04	0.00000E+00
1508	1	0.23850E-03	0.36771E-05	-0.62013E-03	-0.87269E-06	-0.35261E-05	0.00000E+00
HAM 11	2	0.29063E-03	0.73033E-04	-0.76469E-03	-0.70639E-07	-0.56437E-05	0.00000E+00
	3	0.43706E-03	0.39660E-03	-0.20090E-03	0.29107E-06	-0.15862E-05	0.00000E+00

	4	0.10376E-02	0.11494E-02	-0.32427E-03	0.17133E-05	-0.13568E-05	0.00000E+00
	5	-0.39298E-04	-0.37714E-03	-0.60103E-03	-0.76819E-06	-0.36839E-05	0.00000E+00
	6	-0.84390E-04	0.38945E-04	-0.60458E-03	-0.80143E-06	-0.36432E-05	0.00000E+00
	7	0.28360E-03	-0.41241E-03	-0.61658E-03	-0.83945E-06	-0.35668E-05	0.00000E+00
	8	-0.12125E-05	0.50491E-04	-0.15721E-01	0.72673E-04	0.16871E-04	0.00000E+00
1520	1	0.27272E-03	-0.79393E-03	-0.95731E-04	0.13181E-03	-0.15692E-05	0.00000E+00
HAM 12	2	0.35315E-03	-0.70570E-03	-0.75209E-04	0.13165E-03	-0.15280E-05	0.00000E+00
	3	0.22112E-03	0.26777E-03	-0.94700E-04	-0.10357E-05	-0.15035E-05	0.00000E+00
	4	0.56449E-03	0.12081E-02	-0.72875E-04	0.49055E-06	0.86167E-06	0.00000E+00
	5	0.95525E-04	-0.12730E-02	-0.55861E-04	0.13136E-03	-0.22355E-05	0.00000E+00
	6	0.10159E-03	-0.78549E-03	-0.77276E-04	0.13178E-03	-0.17128E-05	0.00000E+00
	7	0.26665E-03	-0.12815E-02	-0.74316E-04	0.13139E-03	-0.20919E-05	0.00000E+00
	8	0.22243E-05	0.43181E-04	-0.60324E-02	-0.16022E-05	0.83348E-05	0.00000E+00
1673	1	0.12395E-03	0.18333E-03	-0.66218E-03	0.47653E-05	-0.15886E-05	0.00000E+00
HAM 9	2	0.16871E-03	0.22627E-03	-0.89405E-03	0.71066E-05	-0.16452E-05	0.00000E+00
	3	0.42560E-03	0.44631E-03	-0.13794E-03	0.88129E-06	0.14182E-05	0.00000E+00
	4	0.11545E-02	0.10822E-02	-0.56393E-03	0.24742E-05	-0.28132E-05	0.00000E+00
	5	-0.22499E-03	-0.12808E-03	-0.65999E-03	0.49042E-05	-0.16518E-05	0.00000E+00
	6	-0.26601E-03	0.23347E-03	-0.66391E-03	0.48169E-05	-0.15783E-05	0.00000E+00
	7	0.16497E-03	-0.17821E-03	-0.65826E-03	0.48526E-05	-0.16621E-05	0.00000E+00
	8	-0.42390E-04	0.98230E-04	-0.24096E-01	-0.13115E-04	-0.64961E-04	0.00000E+00
1758	1	0.32331E-04	0.22662E-03	-0.53523E-03	0.37848E-05	-0.42047E-07	0.00000E+00
HAM 8	2	0.83322E-04	0.26648E-03	-0.70385E-03	0.61273E-05	-0.92509E-06	0.00000E+00
	3	0.39873E-03	0.44117E-03	-0.19491E-03	0.16179E-05	-0.32994E-06	0.00000E+00
	4	0.11661E-02	0.98151E-03	-0.28302E-03	0.11808E-05	-0.18067E-05	0.00000E+00
	5	-0.33956E-03	-0.40041E-04	-0.52350E-03	0.39682E-05	-0.14742E-06	0.00000E+00
	6	-0.37207E-03	0.28609E-03	-0.53655E-03	0.38057E-05	-0.77125E-07	0.00000E+00
	7	0.64844E-04	-0.99516E-04	-0.52218E-03	0.39473E-05	-0.11234E-06	0.00000E+00
	8	-0.57846E-04	0.12596E-03	-0.15370E-01	-0.12536E-04	-0.78302E-04	0.00000E+00
2013	1	-0.76651E-03	0.28863E-03	-0.12363E-04	0.23916E-05	-0.13275E-03	0.00000E+00
HAM 7	2	-0.70583E-03	0.33506E-03	0.89980E-05	0.23632E-05	-0.13260E-03	0.00000E+00
	3	0.27290E-03	0.22780E-03	-0.14832E-03	0.18728E-05	0.10716E-05	0.00000E+00
	4	0.12036E-02	0.51933E-03	-0.31869E-04	-0.12479E-05	-0.69880E-06	0.00000E+00
	5	-0.12269E-02	0.12903E-03	-0.13158E-04	0.33712E-05	-0.13207E-03	0.00000E+00
	6	-0.12336E-02	0.29956E-03	-0.28926E-04	0.32051E-05	-0.13209E-03	0.00000E+00
	7	-0.75988E-03	0.11810E-03	0.34045E-05	0.25578E-05	-0.13272E-03	0.00000E+00
	8	-0.74122E-04	0.21593E-03	-0.81051E-02	-0.10782E-04	0.25042E-04	0.00000E+00
2098	1	-0.49826E-03	0.27233E-03	0.28415E-02	0.68081E-05	0.11164E-04	0.00000E+00
LASER @ HAM 7	2	-0.43710E-03	0.31987E-03	0.28413E-02	0.67529E-05	0.11222E-04	0.00000E+00
	3	0.23940E-03	0.64801E-04	-0.20344E-03	0.21219E-05	-0.10534E-05	0.00000E+00
	4	0.11991E-02	0.42504E-03	0.19744E-03	-0.24733E-05	-0.11317E-05	0.00000E+00
	5	-0.97505E-03	0.84571E-04	0.26289E-02	0.90753E-05	0.12190E-04	0.00000E+00
	6	-0.97952E-03	0.20184E-03	0.26175E-02	0.89614E-05	0.12170E-04	0.00000E+00
	7	-0.49379E-03	0.15506E-03	0.28529E-02	0.69220E-05	0.11185E-04	0.00000E+00
	8	-0.85488E-04	0.24166E-03	-0.10768E-01	-0.11505E-04	0.20006E-05	0.00000E+00
2183	1	-0.47874E-03	0.22363E-03	0.99850E-03	-0.44620E-06	0.65139E-05	0.00000E+00
LASER @ HAM 7	2	-0.41776E-03	0.27170E-03	0.99363E-03	-0.49414E-06	0.65169E-05	0.00000E+00
	3	0.21889E-03	-0.12718E-03	0.14259E-03	-0.16171E-05	-0.16115E-05	0.00000E+00

	4	0.11898E-02	0.39497E-03	0.23684E-03	-0.13286E-05	0.10685E-05	0.00000E+00
	5	-0.96213E-03	-0.38340E-04	0.76617E-03	0.80023E-06	0.53803E-05	0.00000E+00
	6	-0.96594E-03	0.31974E-04	0.75878E-03	0.72636E-06	0.53584E-05	0.00000E+00
	7	-0.47494E-03	0.15332E-03	0.10059E-02	-0.37233E-06	0.65357E-05	0.00000E+00
	8	-0.97903E-04	0.26274E-03	-0.88798E-02	-0.78158E-05	-0.22640E-04	0.00000E+00
2140	1	-0.82698E-03	0.23505E-03	0.25595E-03	0.19123E-05	-0.10313E-03	0.00000E+00
A1	2	-0.75952E-03	0.28269E-03	0.26049E-03	0.18837E-05	-0.10307E-03	0.00000E+00
	3	-0.44789E-03	-0.59552E-04	0.64092E-04	-0.77773E-07	-0.10427E-03	0.00000E+00
	4	0.12325E-02	0.41729E-03	0.22497E-02	-0.20301E-05	-0.25896E-05	0.00000E+00
	5	-0.15411E-02	-0.11764E-04	-0.19848E-02	0.38790E-05	-0.10044E-03	0.00000E+00
	6	-0.16332E-02	0.77523E-04	-0.19793E-02	0.38228E-05	-0.10045E-03	0.00000E+00
	7	-0.73484E-03	0.14576E-03	0.25045E-03	0.19685E-05	-0.10312E-03	0.00000E+00
	8	-0.42698E-04	0.25362E-03	-0.55894E-02	-0.89265E-05	-0.10082E-05	0.00000E+00
2208	1	-0.63863E-03	0.20074E-03	0.30946E-02	-0.22188E-05	0.41291E-05	0.00000E+00
80K RIGHT ARM	2	-0.57232E-03	0.24910E-03	0.30924E-02	-0.22227E-05	0.41671E-05	0.00000E+00
	3	-0.25600E-03	-0.21195E-03	0.30606E-02	-0.27772E-05	0.34891E-05	0.00000E+00
	4	0.14808E-02	0.39814E-03	-0.10017E-02	0.23204E-05	0.94488E-04	0.00000E+00
	5	-0.16057E-02	-0.10965E-03	0.40730E-02	-0.44840E-05	-0.90009E-04	0.00000E+00
	6	-0.16973E-02	-0.58632E-04	0.40825E-02	-0.45451E-05	-0.90058E-04	0.00000E+00
	7	-0.54703E-03	0.14972E-03	0.30851E-02	-0.21577E-05	0.41790E-05	0.00000E+00
	8	-0.48788E-04	0.27211E-03	-0.29255E-02	-0.64707E-05	-0.21074E-04	0.00000E+00

TOP OF CONCRETE
 NODE DISPLACEMENTS / ROTATIONS

NODE NUMBER	LOAD CASE	X-TRANSLATION	Y-TRANSLATION	Z-TRANSLATION	X-ROTATION	Y-ROTATION	Z-ROTATION
4672 80K RIGHT ARM	1	-0.57669E-03	0.23402E-03	0.30946E-02	-0.22188E-05	0.41291E-05	0.00000E+00
	2	-0.50982E-03	0.28244E-03	0.30924E-02	-0.22227E-05	0.41671E-05	0.00000E+00
	3	-0.20366E-03	-0.17029E-03	0.30606E-02	-0.27772E-05	0.34891E-05	0.00000E+00
	4	0.29186E-02	0.36333E-03	-0.10017E-02	0.23204E-05	0.97141E-04	0.00000E+00
	5	-0.29763E-02	-0.42388E-04	0.40730E-02	-0.44840E-05	-0.92662E-04	0.00000E+00
	6	-0.30686E-02	0.95443E-05	0.40825E-02	-0.45451E-05	-0.92712E-04	0.00000E+00
	7	-0.48435E-03	0.18209E-03	0.30851E-02	-0.21577E-05	0.41790E-05	0.00000E+00
	8	-0.36490E-03	0.36917E-03	-0.29255E-02	-0.64707E-05	-0.21074E-04	0.00000E+00
4671 A1	1	-0.23997E-02	0.20636E-03	0.25595E-03	0.19123E-05	-0.10647E-03	0.00000E+00
	2	-0.23313E-02	0.25444E-03	0.26049E-03	0.18837E-05	-0.10641E-03	0.00000E+00
	3	-0.20378E-02	-0.58385E-04	0.64092E-04	-0.77773E-07	-0.10761E-03	0.00000E+00
	4	0.11936E-02	0.44774E-03	0.22497E-02	-0.20301E-05	-0.25896E-05	0.00000E+00
	5	-0.30736E-02	-0.69950E-04	-0.19848E-02	0.38790E-05	-0.10378E-03	0.00000E+00
	6	-0.31658E-02	0.20181E-04	-0.19793E-02	0.38228E-05	-0.10379E-03	0.00000E+00
	7	-0.23075E-02	0.11623E-03	0.25045E-03	0.19685E-05	-0.10646E-03	0.00000E+00
	8	-0.57820E-04	0.38752E-03	-0.55894E-02	-0.89265E-05	-0.10082E-05	0.00000E+00
4670 HAM 7	1	-0.27896E-02	0.25276E-03	-0.12363E-04	0.23916E-05	-0.13687E-03	0.00000E+00
	2	-0.27268E-02	0.29961E-03	0.89980E-05	0.23632E-05	-0.13673E-03	0.00000E+00
	3	0.28897E-03	0.19970E-03	-0.14832E-03	0.18728E-05	0.10716E-05	0.00000E+00
	4	0.11931E-02	0.53805E-03	-0.31869E-04	-0.12479E-05	-0.69880E-06	0.00000E+00
	5	-0.32398E-02	0.78465E-04	-0.13158E-04	0.33712E-05	-0.13619E-03	0.00000E+00
	6	-0.32468E-02	0.25149E-03	-0.28926E-04	0.32051E-05	-0.13621E-03	0.00000E+00
	7	-0.27826E-02	0.79737E-04	0.34045E-05	0.25578E-05	-0.13685E-03	0.00000E+00
	8	0.30151E-03	0.37767E-03	-0.81051E-02	-0.10782E-04	0.25042E-04	0.00000E+00
4669 HAM 12	1	0.24918E-03	-0.28030E-02	-0.95731E-04	0.13594E-03	-0.15692E-05	0.00000E+00
	2	0.33023E-03	-0.27123E-02	-0.75209E-04	0.13577E-03	-0.15280E-05	0.00000E+00
	3	0.19857E-03	0.28331E-03	-0.94700E-04	-0.10357E-05	-0.15035E-05	0.00000E+00
	4	0.57742E-03	0.12008E-02	-0.72875E-04	0.49055E-06	0.86167E-06	0.00000E+00
	5	0.61992E-04	-0.32753E-02	-0.55861E-04	0.13549E-03	-0.22355E-05	0.00000E+00
	6	0.75899E-04	-0.27941E-02	-0.77276E-04	0.13591E-03	-0.17128E-05	0.00000E+00
	7	0.23528E-03	-0.32842E-02	-0.74316E-04	0.13551E-03	-0.20919E-05	0.00000E+00
	8	0.12725E-03	0.67214E-04	-0.60324E-02	-0.16022E-05	0.83348E-05	0.00000E+00
4668 BSC 7	1	0.20832E-02	0.17379E-02	0.81058E-03	-0.81318E-04	0.10692E-03	0.00000E+00
	2	0.35849E-02	0.17154E-02	-0.83088E-04	-0.79756E-04	0.18829E-03	0.00000E+00
	3	0.23325E-02	0.46177E-03	0.93532E-03	0.13237E-05	0.10837E-03	0.00000E+00
	4	0.10375E-02	0.25609E-02	0.75296E-03	-0.82977E-04	0.12865E-05	0.00000E+00
	5	0.17646E-02	0.14499E-02	0.80704E-03	-0.81350E-04	0.10693E-03	0.00000E+00
	6	0.16896E-02	0.18020E-02	0.80750E-03	-0.81349E-04	0.10691E-03	0.00000E+00
	7	0.21582E-02	0.13858E-02	0.81012E-03	-0.81319E-04	0.10694E-03	0.00000E+00
	8	-0.12200E-02	0.59663E-03	-0.28341E-01	-0.30599E-04	-0.80277E-04	0.00000E+00
4667 BSC 3	1	-0.57678E-03	0.46986E-03	0.19922E-02	-0.85017E-05	-0.55088E-04	0.00000E+00
	2	0.24637E-03	0.42061E-03	0.45302E-02	-0.46746E-05	-0.10600E-04	0.00000E+00
	3	-0.37134E-03	0.49429E-03	0.21973E-02	0.24219E-05	-0.54775E-04	0.00000E+00
	4	0.22895E-03	0.13201E-02	-0.65873E-03	-0.11973E-04	-0.49240E-04	0.00000E+00
	5	-0.87808E-03	0.16409E-03	0.19912E-02	-0.85305E-05	-0.55085E-04	0.00000E+00
	6	-0.94224E-03	0.52196E-03	0.19898E-02	-0.85009E-05	-0.55083E-04	0.00000E+00
	7	-0.51262E-03	0.11199E-03	0.19935E-02	-0.85313E-05	-0.55089E-04	0.00000E+00
	8	-0.71236E-03	0.66333E-03	-0.40234E-01	-0.35625E-04	-0.48075E-04	0.00000E+00

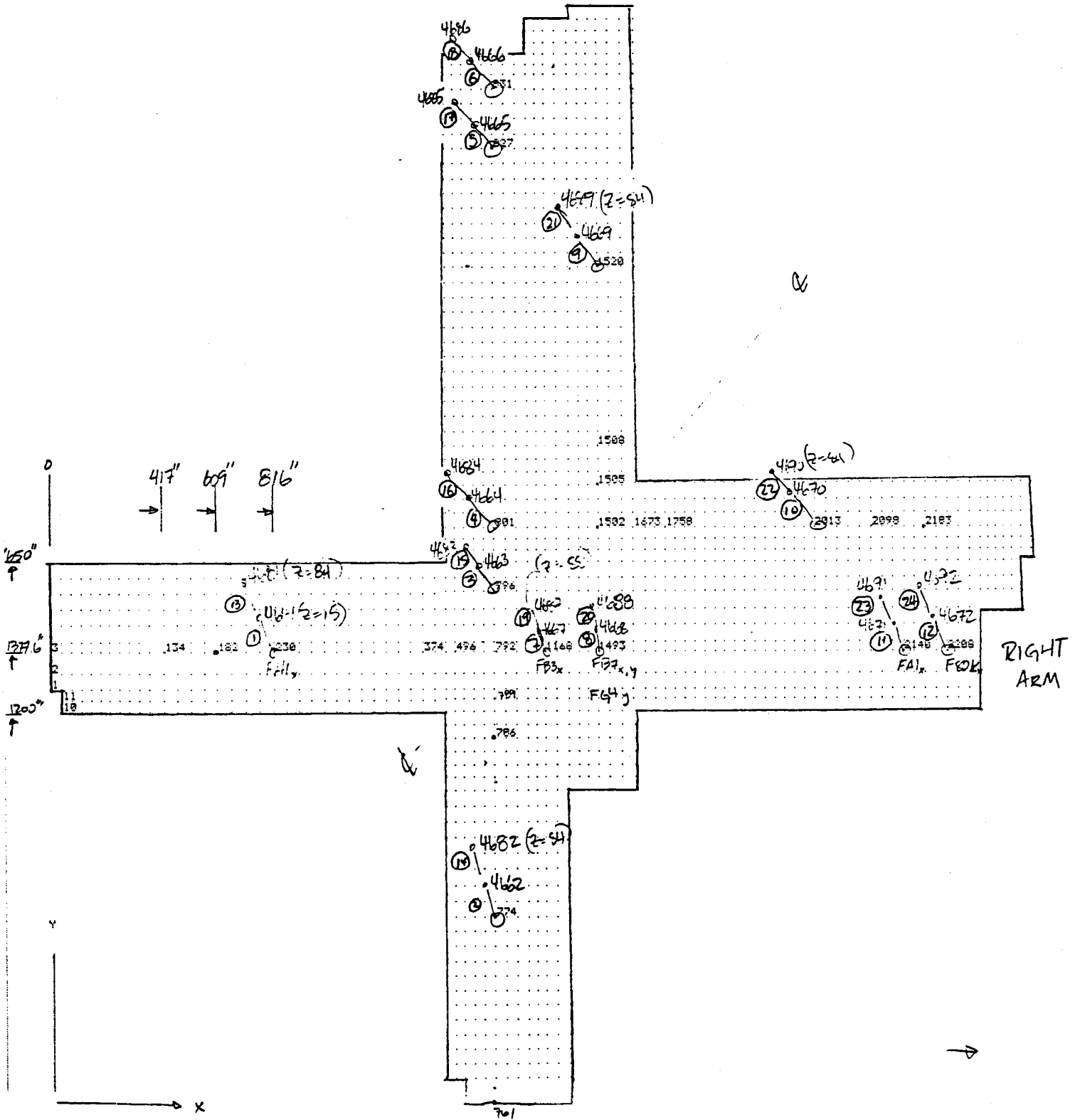
4666	1	0.17699E-03	-0.59855E-03	0.26412E-02	-0.63289E-05	0.19246E-05	0.00000E+00
80K LEFT ARM	2	0.26008E-03	-0.49956E-03	0.26390E-02	-0.63968E-05	0.19482E-05	0.00000E+00
	3	-0.24872E-03	-0.18333E-03	0.26352E-02	-0.61412E-05	0.21032E-05	0.00000E+00
	4	0.38049E-03	0.30113E-02	-0.98708E-03	-0.10151E-03	-0.17455E-05	0.00000E+00
	5	-0.14781E-03	-0.31251E-02	0.36025E-02	0.94724E-04	0.36454E-05	0.00000E+00
	6	0.13597E-03	-0.50730E-03	0.26325E-02	-0.63938E-05	0.18670E-05	0.00000E+00
	7	-0.10679E-03	-0.32164E-02	0.36112E-02	0.94789E-04	0.37031E-05	0.00000E+00
	8	-0.12138E-03	-0.13016E-03	-0.74692E-02	0.93409E-05	-0.44651E-05	0.00000E+00
4665	1	0.17467E-03	-0.24829E-02	0.13401E-03	0.10708E-03	-0.17151E-05	0.00000E+00
A2	2	0.25738E-03	-0.23823E-02	0.13948E-03	0.10704E-03	-0.16619E-05	0.00000E+00
	3	-0.10285E-03	-0.20833E-02	-0.19265E-05	0.10821E-03	-0.80378E-07	0.00000E+00
	4	0.46662E-03	0.11534E-02	0.22429E-02	0.48153E-05	0.23308E-05	0.00000E+00
	5	-0.13233E-03	-0.31521E-02	-0.20933E-02	0.10219E-03	-0.39585E-05	0.00000E+00
	6	0.91767E-04	-0.23919E-02	0.13016E-03	0.10708E-03	-0.17728E-05	0.00000E+00
	7	-0.49433E-04	-0.32431E-02	-0.20895E-02	0.10219E-03	-0.39008E-05	0.00000E+00
	8	-0.73504E-04	0.24515E-03	-0.69948E-02	-0.15311E-04	-0.25691E-05	0.00000E+00
4664	1	0.19012E-02	0.21244E-02	0.10575E-02	-0.11163E-03	0.88149E-04	0.00000E+00
BSC 6	2	0.18619E-02	0.37380E-02	0.23417E-03	-0.19656E-03	0.86512E-04	0.00000E+00
	3	0.48326E-03	0.24093E-02	0.90522E-03	-0.11289E-03	-0.72759E-06	0.00000E+00
	4	0.27363E-02	0.10460E-02	0.10109E-02	-0.15187E-05	0.89844E-04	0.00000E+00
	5	0.16127E-02	0.17833E-02	0.10448E-02	-0.11165E-03	0.88082E-04	0.00000E+00
	6	0.15508E-02	0.21951E-02	0.10475E-02	-0.11167E-03	0.88021E-04	0.00000E+00
	7	0.19631E-02	0.17126E-02	0.10548E-02	-0.11162E-03	0.88210E-04	0.00000E+00
	8	0.38170E-03	-0.12131E-02	-0.26299E-01	0.84063E-04	0.23640E-04	0.00000E+00
4663	1	0.54019E-03	-0.62742E-03	0.20904E-02	0.55432E-04	0.90774E-05	0.00000E+00
BSC 1	2	0.44923E-03	0.24512E-03	0.46763E-02	0.10872E-04	0.58111E-05	0.00000E+00
	3	0.51899E-03	-0.37870E-03	0.22345E-02	0.54627E-04	-0.22940E-05	0.00000E+00
	4	0.13456E-02	0.22989E-03	-0.58229E-03	0.49827E-04	0.12298E-04	0.00000E+00
	5	0.25210E-03	-0.95128E-03	0.20827E-02	0.55399E-04	0.90700E-05	0.00000E+00
	6	0.18848E-03	-0.56996E-03	0.20867E-02	0.55413E-04	0.90284E-05	0.00000E+00
	7	0.60381E-03	-0.10087E-02	0.20864E-02	0.55418E-04	0.91190E-05	0.00000E+00
	8	0.47291E-03	-0.77558E-03	-0.39900E-01	0.57077E-04	0.29280E-04	0.00000E+00
4662	1	-0.68975E-05	0.31488E-02	-0.85304E-04	-0.13372E-03	-0.85347E-07	0.00000E+00
HAM 6	2	0.18644E-03	0.35060E-03	-0.39775E-04	-0.27614E-06	0.14279E-06	0.00000E+00
	3	0.66752E-04	0.33188E-02	-0.67092E-04	-0.13360E-03	-0.20959E-07	0.00000E+00
	4	0.41616E-03	0.38578E-02	-0.64290E-04	-0.13353E-03	0.36629E-06	0.00000E+00
	5	-0.16585E-03	0.28674E-02	-0.87804E-04	-0.13375E-03	-0.24478E-06	0.00000E+00
	6	-0.19100E-03	0.31610E-02	-0.91926E-04	-0.13373E-03	-0.27419E-06	0.00000E+00
	7	0.18254E-04	0.28552E-02	-0.81182E-04	-0.13374E-03	-0.55938E-07	0.00000E+00
	8	-0.66941E-04	0.12351E-03	-0.55305E-02	0.27351E-05	-0.26799E-05	0.00000E+00
4661	1	0.30951E-02	0.16652E-03	0.83598E-04	-0.70552E-06	0.12977E-03	0.00000E+00
HAM 1	2	0.33722E-03	0.21987E-03	-0.61368E-04	-0.14100E-06	0.38434E-06	0.00000E+00
	3	0.32374E-02	0.24267E-03	0.11905E-03	-0.86144E-06	0.12966E-03	0.00000E+00
	4	0.37370E-02	0.58308E-03	0.12392E-03	-0.11378E-05	0.12955E-03	0.00000E+00
	5	0.28399E-02	0.59876E-05	0.76414E-04	-0.53973E-06	0.12978E-03	0.00000E+00
	6	0.28106E-02	0.17706E-03	0.81901E-04	-0.71567E-06	0.12977E-03	0.00000E+00
	7	0.31244E-02	-0.45581E-05	0.78111E-04	-0.52958E-06	0.12977E-03	0.00000E+00
	8	-0.31555E-03	-0.99841E-04	-0.95588E-02	0.35739E-05	-0.27432E-04	0.00000E+00

POSITION OF VACUUM FORCES ON MOMENT ARMS

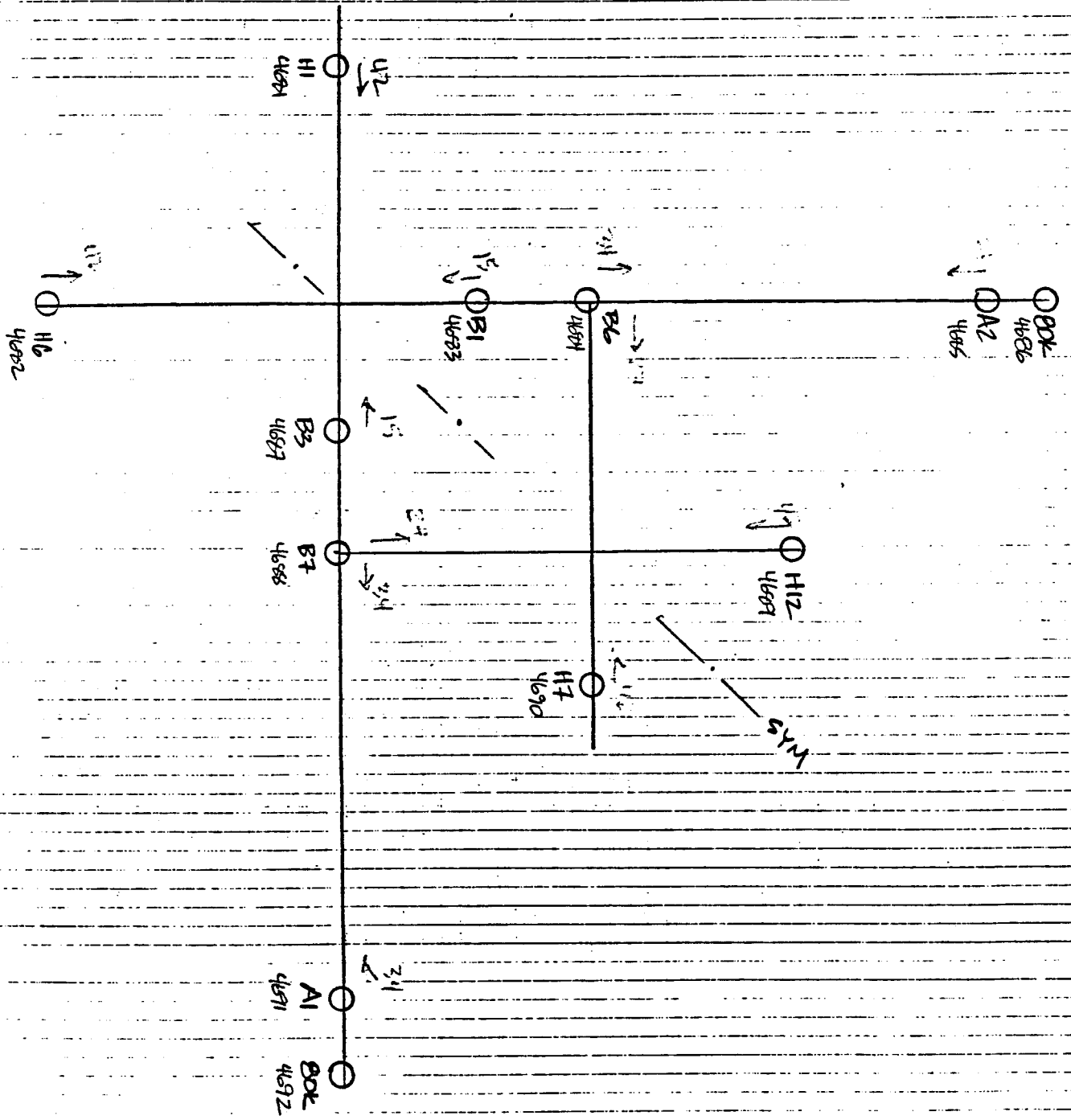
LVEA-ST1

Z = STE of moment arm (pipe ϕ) U.O.N.

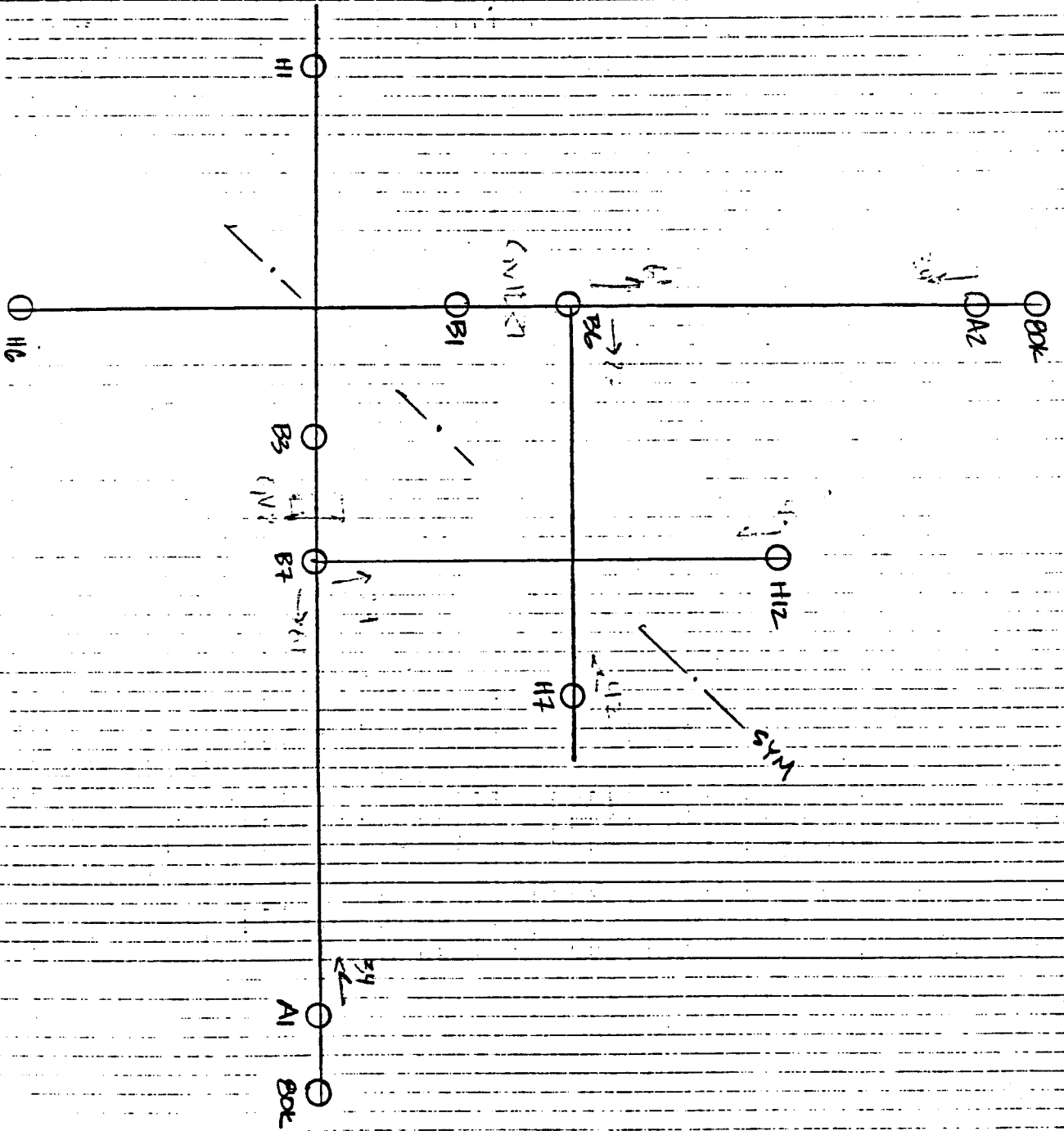
LEFT ARM



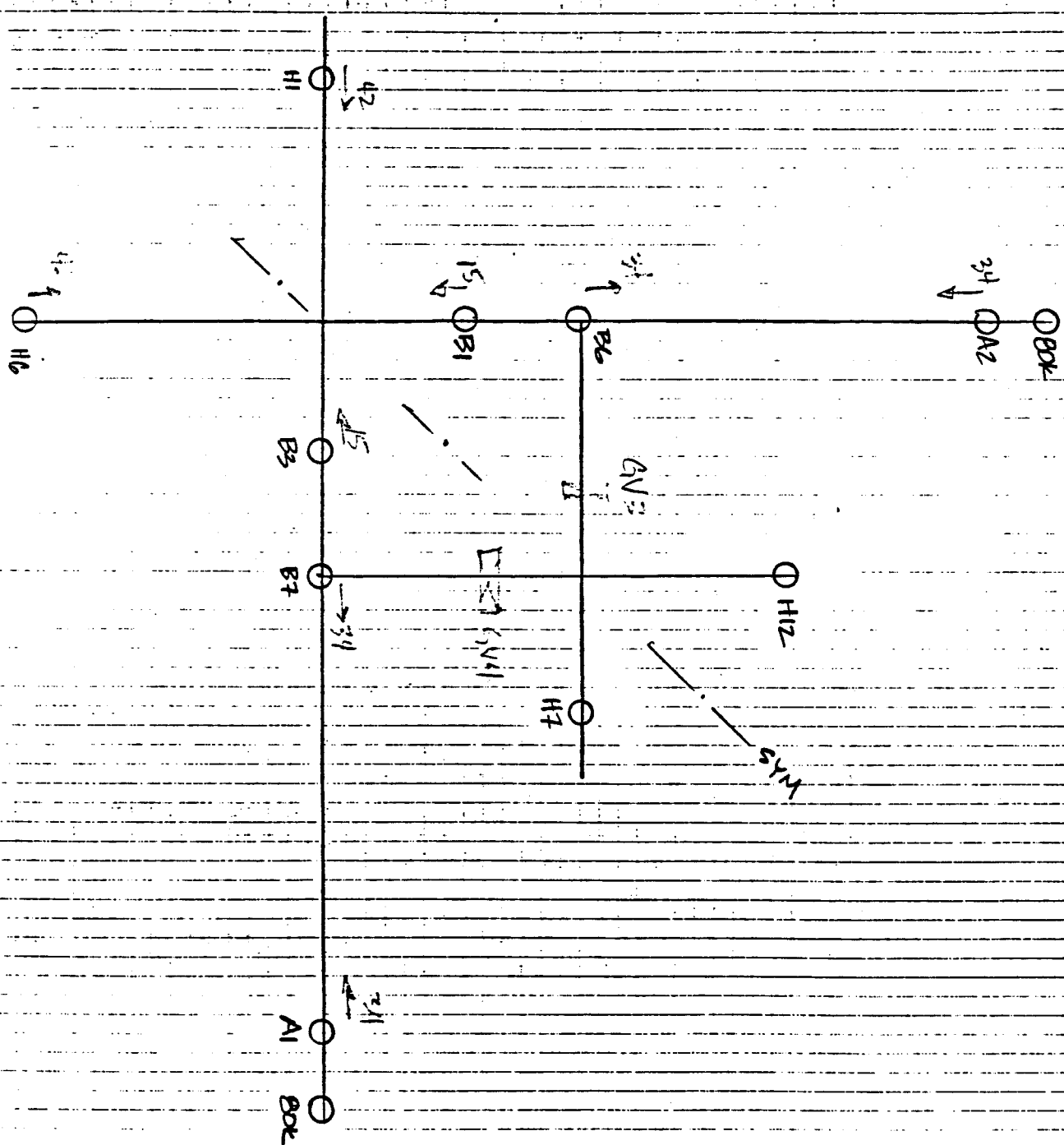
Rev	Date	By	Ck	Title
				LIGO LVEA VACUUM LOAD CASE 1 ALLEVACUATED



Rev	Date	By	Ck	Title
				LIGO LVEA
				VACUUM LOAD CASE Z
				VALVES 1 & 2 CLOSED VERTEX @ 1 ATM



Rev	Date	By	Ck	Title
				LIGO LVEA
				VACUUM LOAD CASE 3
				GV3&4 CLOSED DIAG @ 1 ATM





PARSONS

Calculation Sheet

Job Number

402117-22101

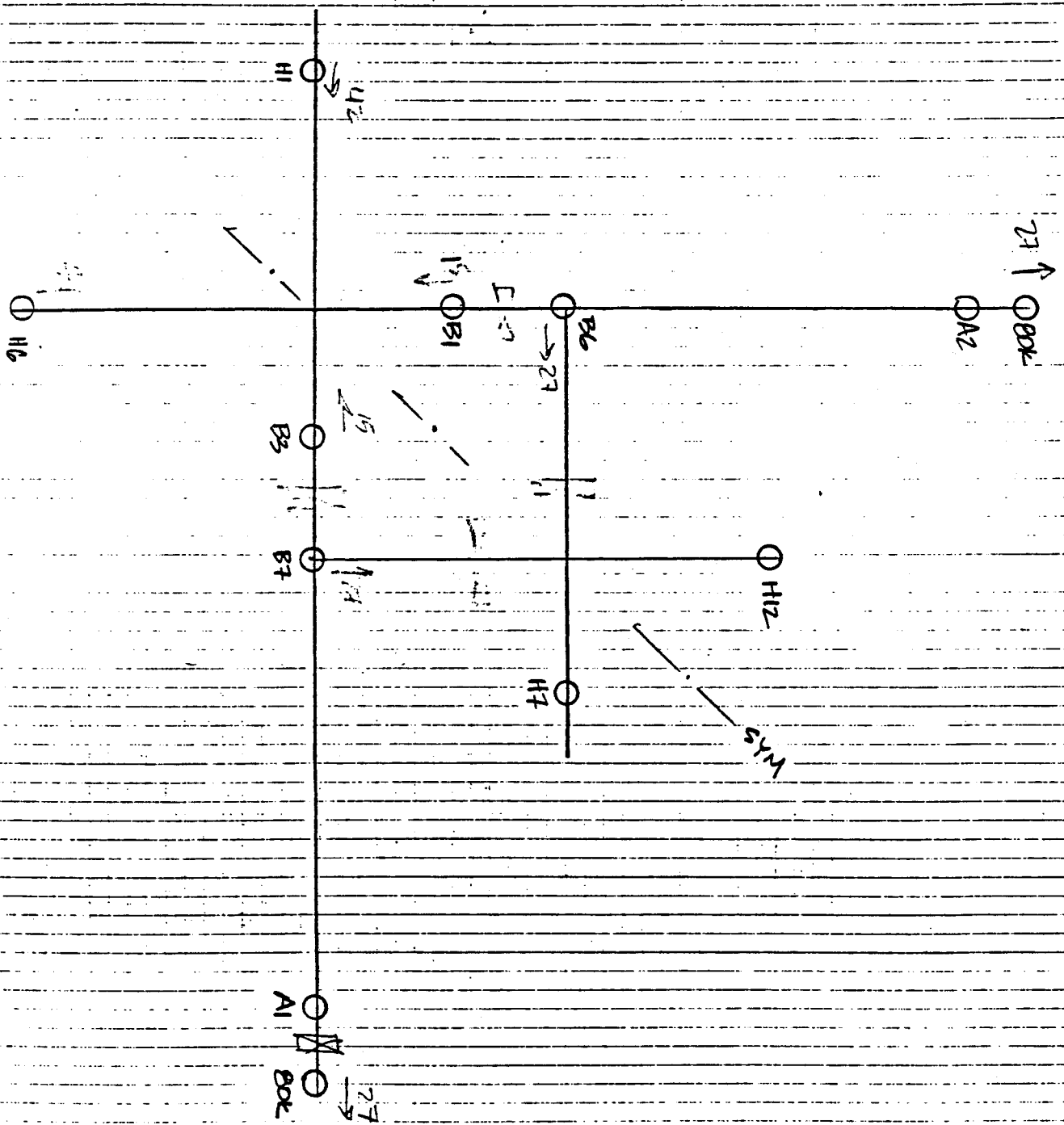
Cost Center

Page Number

Sheet of

Rev	Date	By	Ck

Title LIGO LVEA
 VACUUM LOAD CASE 4
 CLOSE GV 1,2,3,4, & 7; MANIFOLD @ 1 ATM





PARSONS

Calculation Sheet

Job Number

402117-22101

Cost Center

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Sheet of

Rev

Date

By

Ck

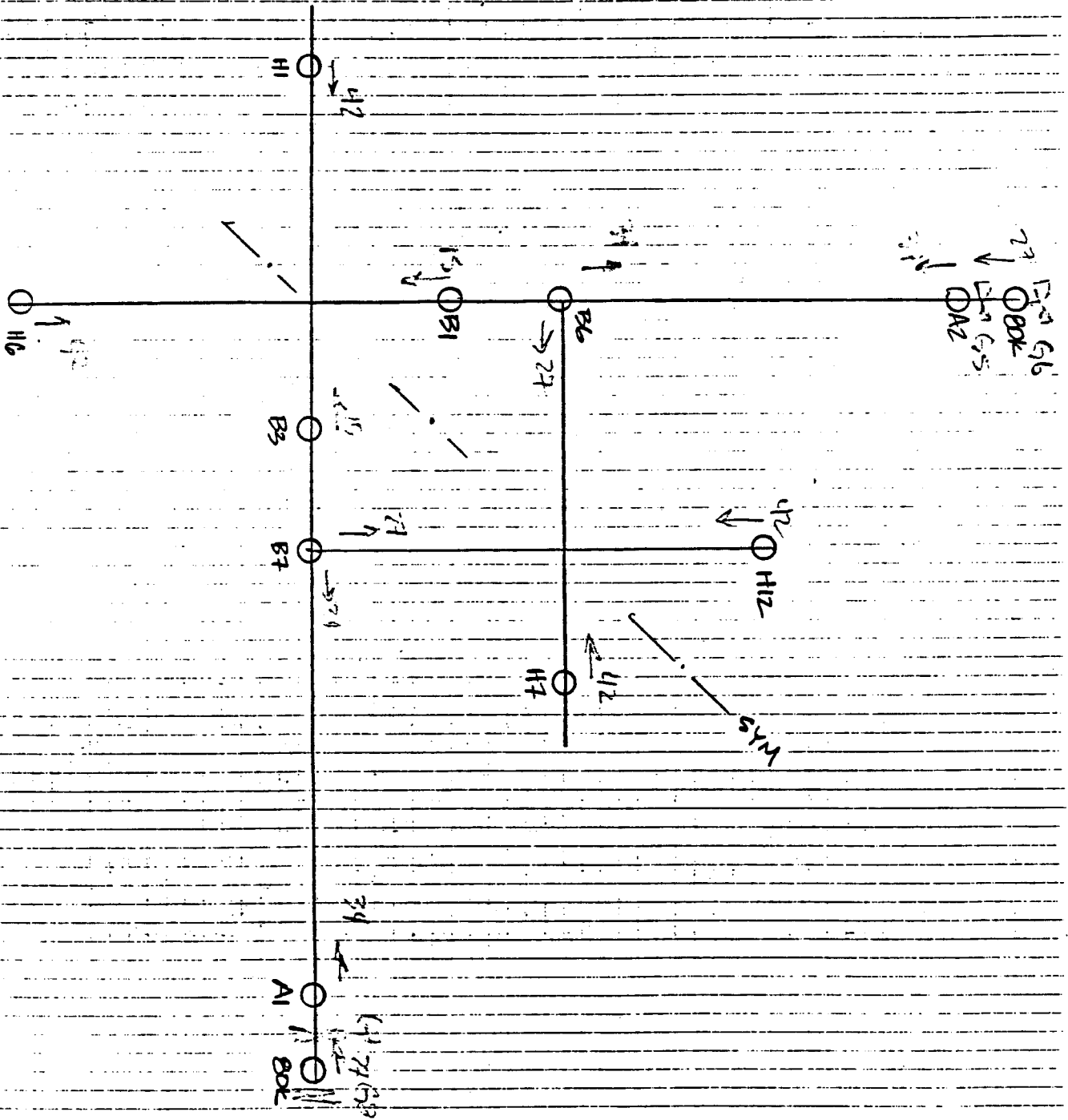
Title

LIGO LVEA

VACUUM LOAD CASE 5

GV7#8 CLOSED BOK @ IATM

GV5#6 CLOSED





PARSONS

Calculation Sheet

Job Number

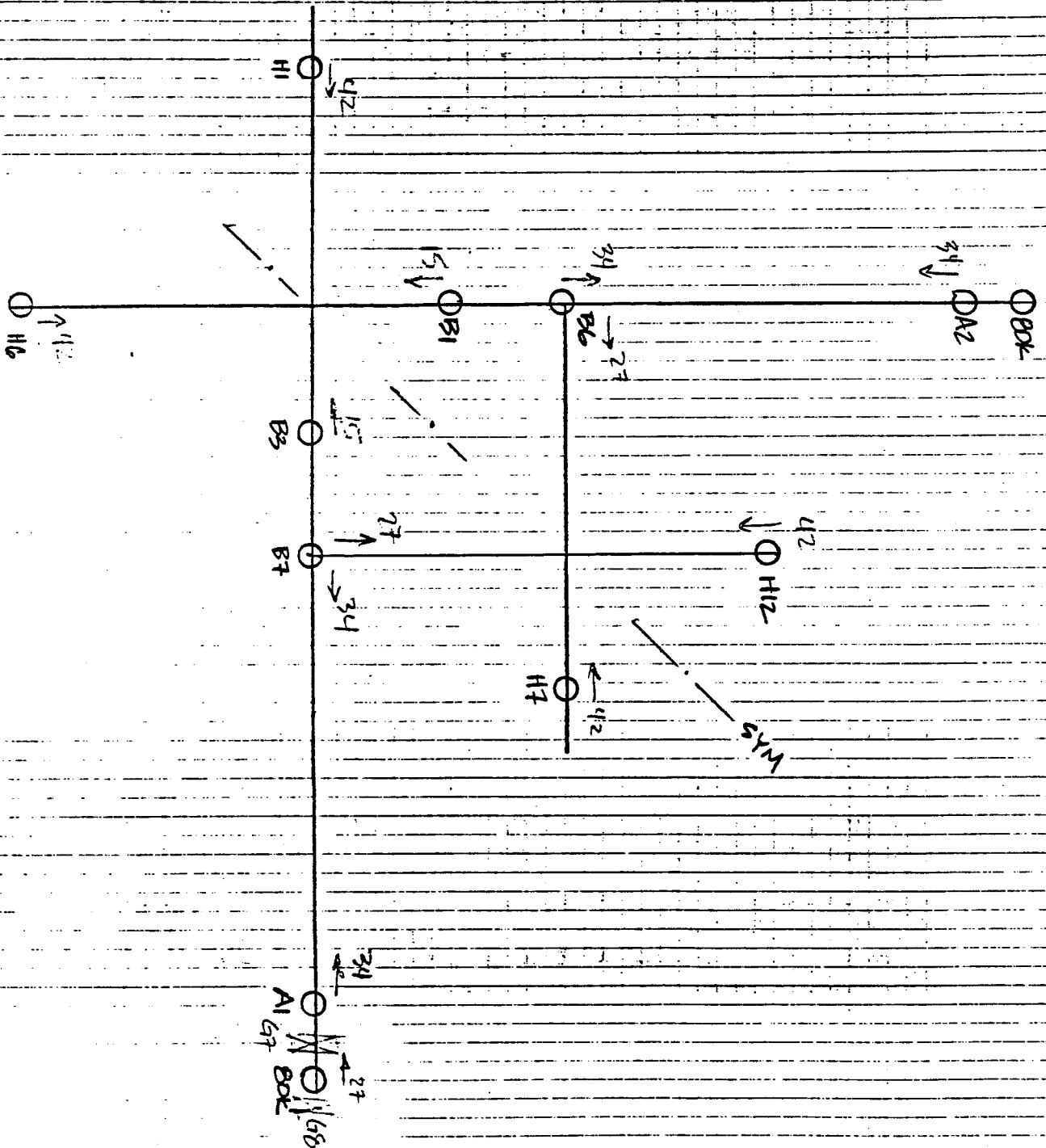
402117-22101

Cost Center

Page Number

Sheet

Rev	Date	By	Ck	Title
				LIGO LVEA
				VACUUM LOAD CASE 6
				GV 7 & 8 CLOSED 80K @ 1 ATM





PARSONS

Calculation Sheet

Job Number

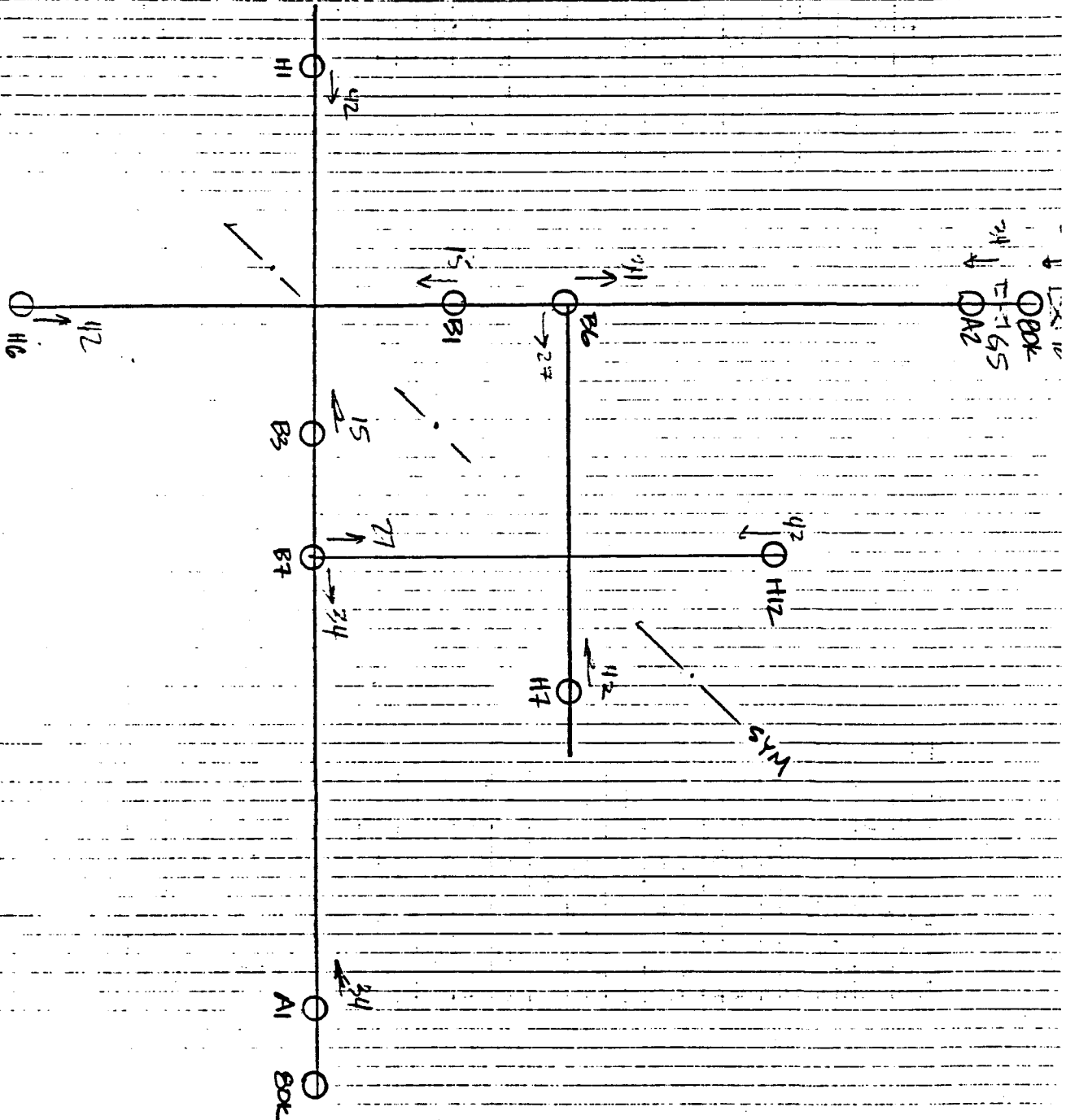
402117-22101

Cost Center

Page Number

Sheet c

Rev	Date	By	Ck	Title
				L1G0 LVEA
				VACUUM LOAD CASE 7
				GV 5&6 CLOSED 80K@1ATM





PARSONS

Calculation Sheet

Job Number

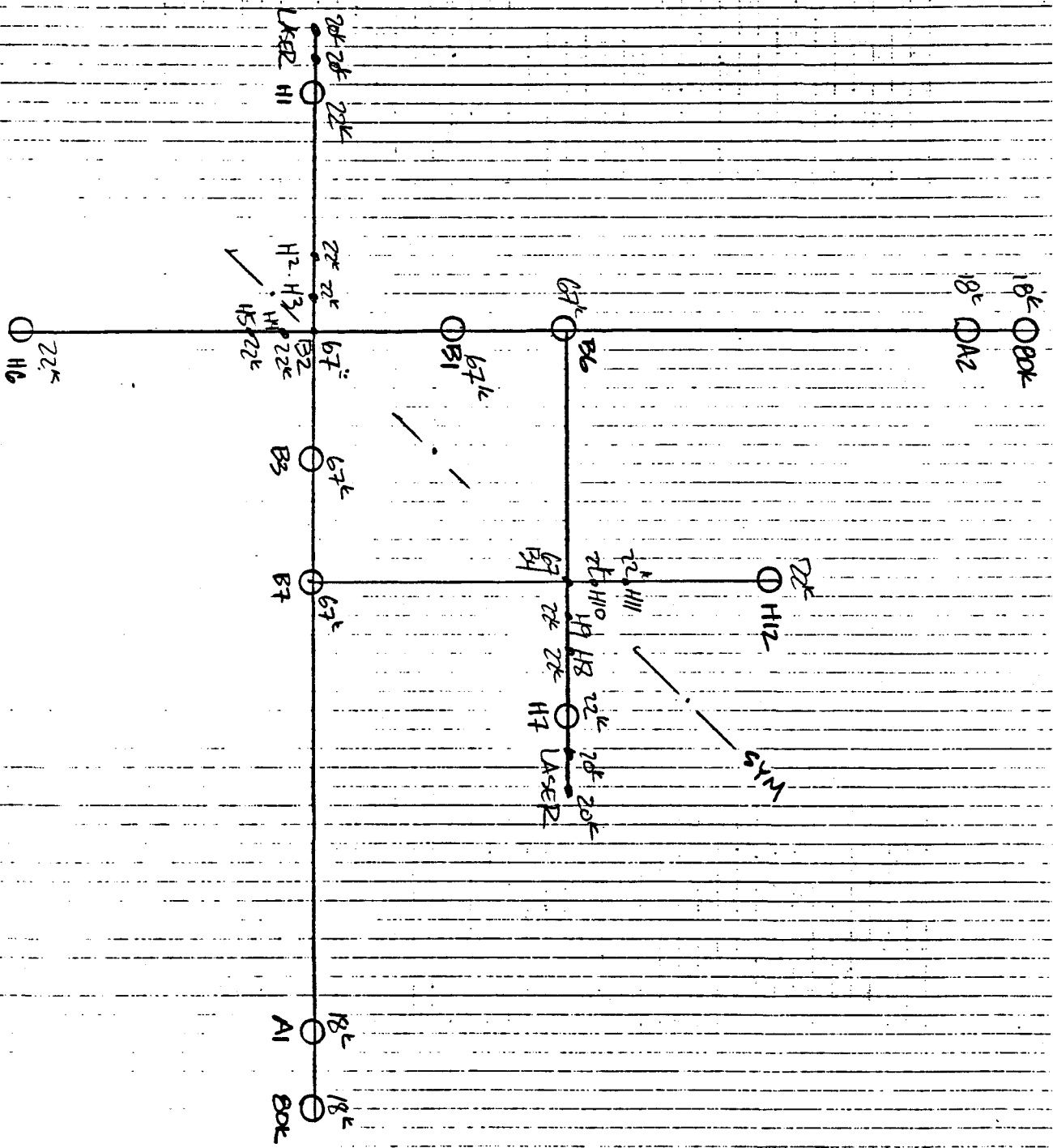
402117-22101

Cost Center

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Sheet

Rev	Date	By	Ck	Title
				L1G0 LVEA
				VACUUM LOAD CASE 8
				EQUIPMENT DEAD LOADS





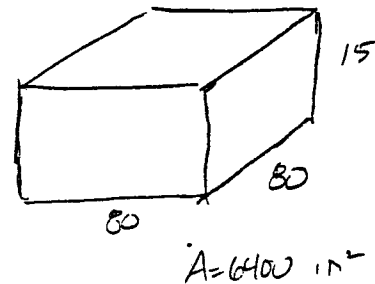
Rev	Date	By	Ck	Title
	12/22/95	CEN		UGO
				ELEMENT PROPERTIES
				30" CONCRETE FLOOR & BEAM SUPPORT OF STEEL

Concrete 80"x80" x 15" Beam element

$$I = \frac{BH^3}{12} = \frac{80^4}{12} = 3,413,333 \text{ in}^4$$

$$E_c I = (3.6 \times 10^6)(3.4 \times 10^6) = 1.2 \times 10^{13}$$

$$J = \left(\frac{1}{3} - .21\right) \left(1 - \frac{1}{12}\right) 80^4 = 4,505,600$$



STEEL 2 meter ϕ 1/2" wall 2 meters = 78.7"

$$A = \frac{\pi}{4} (78.7^2 - 77.7^2) = 122.8 \text{ in}^2$$

$$I = \pi r^3 t = \pi \left(\frac{78.7}{2}\right)^3 \frac{1}{2} = 95,856 \text{ in}^4$$

$$J = 19,712$$

$$E_s I = 29,000 \times 95,856 = 2.7 \times 10^{12}$$

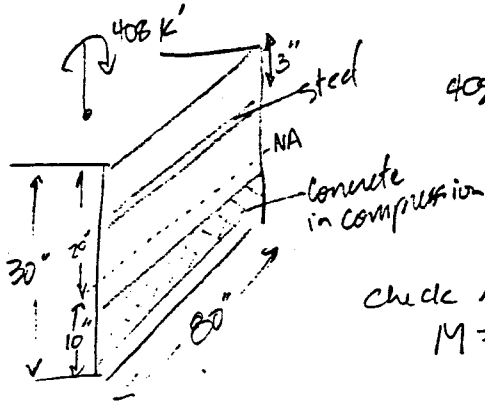
15" of Concrete
 73" of Steel
 ΣI

Combined:

$$I = \frac{15}{88} 1.2 \times 10^{13} + \frac{73}{88} 2.7 \times 10^{12} = 4.3 \times 10^{12}$$

Calculation Sheet

Rev	Date	By	Ck	Title
				LIGO
				SLAB CHECK WITH STATK MOMENTS



$408 \text{ ftKips} = 4.9 \times 10^6 \text{ in-lbs}$

$\sigma_s = 30 \text{ ksi}$

check area of steel:

$M = \sigma_s A_s 17" = 4.9 \text{ EG}$

$A_s = \frac{4.9 \text{ EG}}{(17)(30000)} = 9.6 \text{ in}^2 \text{ or } 1.4 \text{ in}^2 \text{ per ft}$
 OK ✓

check area of concrete

$F_c = \frac{4.9 \times 10^6 \text{ in-lbs}}{20 \text{ in}} = 2.45 \text{ ES lbs}$

USE $f'_c = 3000 \text{ psi}$

$F_c = f'_c \cdot A_c = 2.45 \text{ ES}$

$A_c = 82 \text{ in}^2$

1 inch wide compression strip
 OK ✓



PARSONS

Calculation Sheet

Job Number

40217-2101

Cost Center

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Rev	Date	By	Ck	Title
	12/22/95	CEW		LIGO EQP WEIGHT (lbs)

NOTE

134	}	20000.1	lbs	LASER
182				
230	}	22001.6		HAM 1-5
324				
496				
724				
706				
709				
787				
792	}	67001.8		BEAM SPLITTER
796				
801				
827	}	17998.5		BOK PUMP
831				
1168	}	67001.8		BEAM SPLITTER
1493				
1502				
1505	}	22001.6		HAM 7-10
1508				
1520				
1673				
1758				
2013				
2098	}	20000.1		LASER
2183				
2140	}	17998.5		BOK PUMP
2208				



Rev	Date	By	Ck	Title
	1/2/95	CEW		L160 SOIL DEFLECTION

Mid-Station
Soil deflection calculation (Horizontal)

$$F = K_H \delta$$

$$\delta = \frac{F}{K_H} = \frac{27,000 \text{ lbs}}{26,995,468 \text{ lbs/in}} = .001 \text{ in} = 1 \text{ mill}$$

LVEA

$$\delta = \frac{61,000}{90.375 \times 10^6} = 0.7 \text{ mil}$$

MID STATION

MID-ST1

STRESS Page 83

LOAD CASE 1 = 27K ON TUBE

LOAD CASE 2 = EQUIPMENT LOAD

.....BEAM FORCES AND MOMENTS

i = CENER OF CONCRETE j = TOP OF CONCRETE

BEAM	LOAD	AXIAL	SHEAR	SHEAR	TORSION	BENDING	BENDING	
NO.	NO.	R1	R2	R3	M1	M2	M3	
i	1	1	7.815E-11	1.650E-10	-2.700E+04	0.000E+00	2.376E+06	3.348E-09
j			-7.815E-11	-1.650E-10	2.700E+04	0.000E+00	-1.971E+06	1.574E-09
	1	2	6.700E+04	-4.668E-09	-9.441E-10	0.000E+00	4.232E-09	-3.287E-08
			-6.700E+04	4.668E-09	9.441E-10	0.000E+00	8.464E-09	-4.338E-08

N O D E D I S P L A C E M E N T S / R O T A T I O N S

NODE	LOAD	X-	Y-	Z-	X-	Y-	Z-
NUMBER	CASE	TRANSLATION	TRANSLATION	TRANSLATION	ROTATION	ROTATION	ROTATION
TOP OF CONCRETE							
477	1	-0.24396E-02	0.39412E-04	0.17019E-03	0.33329E-06	-0.77196E-04	0.00000E+00
	2	0.11666E-03	0.19350E-03	-0.10775E-01	-0.34625E-05	0.41873E-05	0.00000E+00
CENTER OF CONCRETE							
150	1	-0.13009E-02	0.44412E-04	0.17019E-03	0.33329E-06	-0.74543E-04	0.00000E+00
	2	0.53852E-04	0.14156E-03	-0.10731E-01	-0.34625E-05	0.41873E-05	0.00000E+00