BSC

Design Calculation or Analysis Cover Sheet

Complete only applicable items.

1. QA: QA

2. Page 1

3. System	4. Document Identifier
Wet Handling Facility	050-SYC-WH00-00500-000-00A

5. Title
Wet Handling Facility Subgrade Structure and Foundation Design

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8. Notes/Comments
(None)

Attachments	Total Number of Pages
Attachment A – Wet Handling Facility Plans & Sections	17
Attachment B – SAP 2000 Model of WHF Foundation & Subgrade Structure	11
Attachment C – Vertical Deflection, Moment, Shear and Force Contours	135
Attachment D – SAP2000 Input & Output files (includes 1 CD)	1

RECORD OF REVISIONS

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DISCLAIMER

The calculations contained in this document were developed by Bechtel SAIC Company, LLC (BSC) and are intended solely for the use of BSC in its work for the Yucca Mountain Project.

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ACRONYMS / ABBREVIATIONS

AEF Annual Exceedance Frequency

ASCE American Society of Civil Engineers

BDBGM Beyond Design Base Ground Motion with Mean Annual Probability of Exceedance of 1E-4.

BSC Bechtel SAIC Company, LLC

D Dead load

DBGM-2 Design Base Ground Motion with Mean Annual Probability of Exceedance of 5E-4.

E Earthquake loads including hydrodynamic and lateral earth pressure increase

F Fluid load

FEM Finite Element Method

H Lateral earth pressure

ITS Important To Safety

L Live load

LBE 35', LBE110' Lower bound estimate for 35' and 110' deep alluvium, respectively

MAPE Mean Annual Probability of Exceedance

ME 35', ME 110' Median estimate for 35' and 110' deep alluvium, respectively

NRC U.S. Nuclear Regulatory Commission

R Seismic response of the structure inertia due to seismic accelerations.

SADA Seismic Analysis and Design Approach Document

SASSI System for Analysis of Soil Structure Interaction

SC Safety Category

SNF Spent Nuclear Fuel

SSI Soil Structure Interaction

UBE 35', UBE110' Upper bound estimate for 35' and 110' deep alluvium, respectively

WHF Wet Handling Facility

ZPA Zero Period Acceleration

1.0 PURPOSE

For the preliminary seismic analysis of the Wet Handling Facility (WHF), a multiple lumped mass stick model is utilized to represent the overall structure (above and below grade). Besides the dead load and live load, the subgrade portion of the structure, the pool, 114' x 116' x 52' (below grade), will be exposed to further more complicated loadings, such as, hydrostatic load, lateral earth pressure, surcharge pressure, hydrodynamic loads, dynamic lateral earth pressure, etc. Since the simplified overall stick model will not provide the related design data for the loads mentioned above, a separate finite element model is created to evaluate the grade foundation and the subgrade portion (pool) of the WHF structure.

The purpose of this calculation is to perform an evaluation of the grade foundation and the subgrade portion of the WHF for various loadings and to perform a preliminary foundation and subgrade concrete structure design in accordance with Project Design Criteria Document. The shear and flexural reinforcements for the foundation mat and subgrade concrete structure will be determined in this calculation. Building stability against overturning and sliding due to seismic loads will be evaluated in this calculation as well.

2.0 REFERENCES

2.1 PROCEDURES/DIRECTIVES

2.1.1 BSC (Bechtel SAIC Company) IT-PRO-0011, Rev. 5, *Software Management.* Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20070521.0001.

2.1.2 BSC (Bechtel SAIC Company) EG-PRO-3DP-G04B-00037, Rev. 08, *Calculations and Analyses.* Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070420.0002

2.1.3 ORD (Office of Repository Development) 2006. *Repository Project Management Automation Plan.* 000-PLN-MGR0-00200-000, Rev. 00E. Las Vegas, Nevada: U.S. Department of Energy, Office of Repository Development. ACC: ENG.20070326.0019.

2.2 DESIGN INPUTS

2.2.1 ASCE 4-98. 2000. *Seismic Analysis of Safety-Related Nuclear Structures and Commentary*. Reston, Virginia: American Society of Civil Engineers. TIC: 253158. [DIRS 159618]

2.2.2 MO0411SDSTMHIS.006. *Seismic Design Spectra and Time Histories for the Surface Facilities Area (Point D/E) at 5E-4 Annual Exceedance Frequency*. Submittal date: 11/16/2004. [DIRS 172426]

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2.2.6 BSC (Bechtel SAIC Company) *Supplemental Soils Report.* 100-S0C-CY00-00100-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070222.0001.

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2.2.12 ASCE/SEI 43-05. 2005. *Seismic Design Criteria for Structures, Systems, and Components in Nuclear facilities.* Reston, Virginia: American Society of Civil Engineers. TIC: 257275. [DIRS 173805]

2.2.13 ACI 349-01. 2001. *Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-01).* Farmington Hills, Michigan: American Concrete Institute. TIC: 252732. [DIRS 158833]

2.2.14 DOE (U.S. Department of Energy) 2005. *Software Validation Report for: SAP2000 Version 9.1.4.* Document ID: 11198-SVR-9.1.4-00-Win2000. Las Vegas, Nevada: U.S. Department of Energy, Office of Repository Development. ACC: MOL.20051012.0425. [DIRS 176790]

2.2.15 BSC (Bechtel SAIC Company) Wet Handling Facility Preliminary Layout Ground Floor Plan. 050-P0K-WH00-10301-000 Revision 00A September 2006.ACC: ENG.20060920.0004

2.2.16 BSC (Bechtel SAIC Company) Wet Handling Facility Preliminary Layout Ground Floor Plan. 050-P0K-WH00-10401-000 Revision 00A September 2006.ACC: ENG.20060920.0005

2.2.17 BSC (Bechtel SAIC Company) Wet Handlin g Facility Preliminary Layout Section A. 050-P0K-WH00-10501-000 Revision 00A September 2006.ACC: ENG.20060920.0006

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2.2.20 Regulatory Guide 1.61. 1973 . *Damping Values for Seismic Design of Nuclear Power Plants*. Washington, D. C.: U.S. Nuclear Regulatory Commission. ACC: MOL20050516.0262 [DIRS 149473]

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2.2.27 *SAP2000.* V.9.1.4, 2005. WINDOWS 2000. STN:11198-9.1.4-00. [DIRS 178238]

2.2.28 BSC (Bechtel SAIC Company) 2007 *IED Seismic Data.* 800-IED-MGR0-00701-000. REV.00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070216.0003

2.3 DESIGN CONSTRAINTS

None.

2.4 DESIGN OUTPUTS

Results of this calculation will be used in developing the Wet Handling Facility (WHF) Foundation and Subgrade concrete structure drawings for License Application. Document numbers have not been assigned to these drawings.

3.0 ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

3.1.1 The seismic loading (E) will govern the design over wind loading (W) including tornado (Wt), ash loads (A), etc.

Rationale: This is a Tier 1 calculation to obtain preliminary facility layout and reasonable design data. The more sophisticated FEM for whole structure for Tier 2 analysis will be used to supersede the results of the Tier 1 analysis. This assumption is being tracked in Calc Trac.

Where used: Section 6.3.

3.1.2 This calculation is based on WHF pl ans and sections shown in references 2.2.15, 2.2.16, 2.2.17, and 2.2.18, and sketches shown in Attachment A. Although they have been superseded by references 2.2.21, 2.2.22, 2.2.23, and 2.2.24, there are no significant changes to building dimensions or wall locations. The pool configuration and dimensions are taken from the later sketches in Ref. 2.2.21 to 2.2.24.

Rationale: The main difference between the two sets of drawings is the changing column lines and wall openings in the revised WHF floor plans and Attachment A is used to provide a general draft layout only. These changes or differences do not impact the mass properties, soil spring constants and the stick model results. A soil-structure interaction analysis using SASSI and detailed FEM using References 2.2.21, 2.2.22, 2.2.23, and 2.2.24 will supersede the results of this preliminary analysis. This assumption is being tracked in CalcTrac.

Where used: Section 6 and Attachment A.

3.1.3 The results of the soil spring constants (Ref. 2.2.10) and seismic accelerations/forces (Ref. 2.2.9) for the upper bound 35' alluvium will be used in this calculation

Rationale: As demonstrated in Ref. 2.2.9, the acceleration responses for the upper bound 35' alluvium is the most critical case; therefore, the results of the soil spring constants (Ref. 2.2.10) and seismic accelerations/forces (Ref. 2.2.9) for the upper bound 35' alluvium will be used in this calculation. This assumption will be verified with the Tier 2 'Soil Structure Interaction Analysis' using SASSI later. This assumption is being tracked in Calc Trac.

Where used: Section 6.2.5.1 & 6.4.2.

3.1.4 The membrane axial force acting at the wall is not included with the maximum/minimum flexural bending moments in the design of the reinforced concrete wall.

Rationale: The maximum/minimum flexural bending moments acting on the wall are usually not occurring at the same location as for the maximum/minimum membrane axial force. The reinforcement design is adequate for the Tier 1 preliminary reinforced concrete design. The more sophisticated FEM for whole structure for Tier 2 analysis and design will be used to supersede the results of the Tier 1 analysis and design. This assumption is being tracked in Calc Trac.

Where used: Section 6.6.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1 Stress Contour Plots generated by SAP2000 using nodal averaging will be used in the design of the required reinforcing steel.

Rationale: Reinforced concrete is a composite material comprised of concrete and reinforcing bars and behaves ductile within proper design limit. While peak element forces exceed the average values shown on the contour plots (Attachment C) as a result of the elastic property of the shell element, it is recognized that as concrete cracks and reinforcing bars yield, the peak resultants are redistributed over adjacent elements. Based on the nodal averaging, utilizing force resultants accounts for the redistribution and is appropriate for use in reinforcement concrete design.

Where used: Section 6.6.1.

4.0 METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation was prepared in accordance with procedure EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Ref. 2.1.2). Section 5.1.2 of the *Basis of Design for the TAD Canister-Based Repository Design Concept* (Ref. 2.2.7), classifies the WHF structure as ITS. Therefore, the approved version of this calculation is designated QA: QA.

4.2 USE OF SOFTWARE

The commercially available software Microsoft Excel 2003 and Microsoft Word 2003, which are the components of Microsoft Office 2003 Professional, are used in preparing this calculation. The use of Microsoft 2003 Professional in this calculation constitutes Level 2 software usage as defined in Section 4 and Attachment 12 of IT-PRO-0011, *Software Management* (Ref. 2.1.1). Microsoft 2003 Professional is listed in the current Controlled Software Report, as well as *The Repository Project Management Automation Plan* (Ref. 2.1.3). Microsoft Office was executed on a PC with X86 Architecture running the Microsoft Windows XP Professional Version 2002 Service Pack 2 operating system.

The Microsoft Word 2003 was utilized in general to prepare this calculation. The excel spreadsheet of the Microsoft Excel 2003 was utilized to provide input/output of the SAP2000 analysis and to calculate common formulas; such as, additions, multiplication, division, etc. The related formulas are listed and the calculated results were verified by checks using manual calculation.

The figures, sketches and graphical representations have been verified versus source data by visual inspection.

The calculation process and equations are documented in Section 6 of this calculation.

SAP 2000 V9.1.4, which is a commercially available Finite Element program for performing Static and Dynamic analysis, is classified as Level 1 software usage as defined in IT-PRO-0011, *Software Management* (Ref. 2.1.1). It was installed on stand-alone personal computer with the license key located on the networked client-server and operated on PC with Windows 2000 operating system. The SAP 2000 V9.1.4 is listed in the Qualified and Controlled Software Report and *The Repository Project Management Automation Plan* (Ref. 2.1.3) as qualified with Software Tracking Number: 11198-9.1.4-00 (Reference 2.2.27). The SAP2000 analyses performed in this calculation are fully within the range of the validation for SAP2000 (Ref. 2.2.14).

4.3 ANALYSIS/DESIGN METHOD

The "frozen" structural layout as of 9/25/06 of the Wet Handling Facility, 270' x 214', as shown in Attachment A, is based on the general layout obtained from Ref. 2.2.15 to 2.2.18. This "frozen" WHF layout, Attachment A, forms the basis for defining the structural configuration of the building, basemat, shear walls, diaphragms and known penetrations (block outs/openings).

A finite element model of the WHF foundation at grade and the subgrade concrete structure - the pool below ground, is developed and coupled with the Tier-1 ‘multiple stick' (Ref. 2.2.9) with shear walls on top of the grade basemat to attain the stiffening effects.

Dead, live, hydrostatic load, lateral earth pressure, surcharge pressure, hydrodynamic loads, dynamic lateral earth pressure and seismic loads were applied to the model and loading combinations were developed to maximize the soil pressures on the foundation. Combinations of the static and seismic loads were developed per Appendix A of SADA (Ref. 2.2.5).

The soil springs for the finite element model are calculated per Appendix C of SADA (Ref. 2.2.5). The Non-linear (compression only) springs are used to model the soil character underlying the foundation mat. Since a non-linear spring element is utilized to model the soil stiffness, a non-linear analysis is required for each loading combination. In each analysis case SAP2000 obtains a solution and then verifies that all of the spring elements are in compression. If tension exists in any spring element, SAP2000 will remove those springs and re-solves the problem. SAP2000 continues this iterative process until the solution converges and no tension exists in any spring elements.

From the non-linear analysis cases described above, SAP2000 is utilized to generate moment and shear contour plots which are used in designing the shear and flexural reinforcing in the foundation mat. In designing the flexural reinforcing a typical rebar pattern is selected and the corresponding moment capacity resulting from that reinforcing is computed. The contour plots will then be utilized to identify areas that may require additional reinforcing above the typical reinforcement pattern. In evaluating the shear reinforcing requirements in the foundation mat the shear capacity of the concrete (without any shear reinforcing considerations) is computed and the shear contour plots are utilized to determine areas of the foundation mat requiring transverse shear reinforcing. Transverse shear reinforcing will then be designed to provide the additional capacity required above the capacity provided by the concrete.

The overall stability of the WHF structure against sliding and overturning is evaluated. Because of the high seismic accelerations associated with the DBGM-2 ground motions, it is not practical to compute a static factor of safety against sliding for the WHF structure under DBGM-2 seismic input motions. Instead, this calculation will utilize energy balance methods discussed in ASCE 43-05 (Ref. 2.2.12) to compute the maximum predicted sliding displacement.

Non-ITS commodities (i.e. utility piping, electrical raceway, etc) connecting externally to the WHF will need to be designed to accommodate the sliding displacement with a safety factor. By providing flexibility in these connections the commodities will be able to accommodate the predicted sliding displacement with additional safety factor.

Details of the finite element analysis of the foundation mat and the stability calculations are discussed in Section 6.

In addition to the calculations that were performed with software (see section 4.2), calculations were performed manually throughout section 6.0.

5.0 LIST OF ATTACHMENTS

		Number of Pages
Attachment A	Wet Handling Facility Plans & Sections	17
Attachment B	SAP 2000 Model of WHF Foundation and Subgrade Structure	11
Attachment C	Vertical Deflection, Moment, Shear and Force Contours	135
Attachment D	SAP 2000 Input and Output files (1 CD included)	1

6.0 BODY OF CALCULATION

6.1 INPUTS

- Properties of concrete (Ref. 2.2.4, sect. 4.2.11.6.6) :

  γ_c = 150 pcf $E_c = 4.29 \times 10^3$ ksi (for f_c = 5 ksi) $\upsilon = 0.17$

- Properties of soil (Ref. 2.2.4, sect. 4.2.11.6.7 & Ref. 2.2.6, sect. 2.4) :

TABLE 1 Density, Friction and Lateral Soil Pressure Coefficients

Material	Density (pcf)	Friction Coeff	Soil Pressure Coeff		
			Ka (Active)	Ko (At-rest)	Kp (Passive)
Engineered Fill	127	0.90	0.2	0.33	5.0
Alluvium	114 – 117	0.81	0.23	0.37	4.4

TABLE 2 Static and Dynamic Soil Parameters

Material	Case	Elastic Modulus (ksi)	Coeff of Subgrade Reaction (kcf)	
			Vertical	Horizontal
Engineered Fill	Static	14 – 28	75 – 250	60 - 96
	Dynamic	30 – 170	150 – 500	120 – 192
Alluvium	Static	30 – 75	155 -520	104 – 120
	Dynamic	100 - 500	310 - 1040	208 - 240

- Response Spectra

  MO0411SDSTMHIS.006 (Ref. 2.2.2), *Seismic Design Spectra and Time Histories for the Surface Facilities Area (Point D/E) at 5E-4 Annual Exceedance Frequency* and MO0411WHBDE104.003 (Ref. 2.2.3), *Seismic Design Spectra and Time Histories for the Surface Facilities Area (Point D/E) at 10-4 Annual Exceedance Frequency.* Reference 2.2.4, section 6.1.10.1.1 cites these Data Tracking Numbers and Reference 2.2.28 authorizes the use of these data.Note that data for BDBGM case are included for information only. See following sheets for plots.

  The corresponding ZPA's (in g) are : for DBGM-2 a_h =0.58 a_v =0.52 and

  for BDBGM a'_h = 1.19 a'_v = 1.49

  The peak spectral accelerations (in g) are : for DBGM-2 : a_{ph} = 1.08 a_{pv} = 0.87 with 7% damping
  for BDBGM : a'_{ph} = 1.94 a'_{pv} = 2.13 with 10% damping

- Structure Damping Values

  For concrete structures 7% damping will be used from Ref. 2.2.5, section 7.2.4.2.

- Based on assumption 3.1.2, the WHF plans and sections shown in references 2.2.15, 2.2.16, 2.2.17, and 2.2.18, and sketches shown in Attachment A are used in this calculation. The pool configuration and dimensions are taken from the later sketches in Ref. 2.2.21 to 2.2.24.

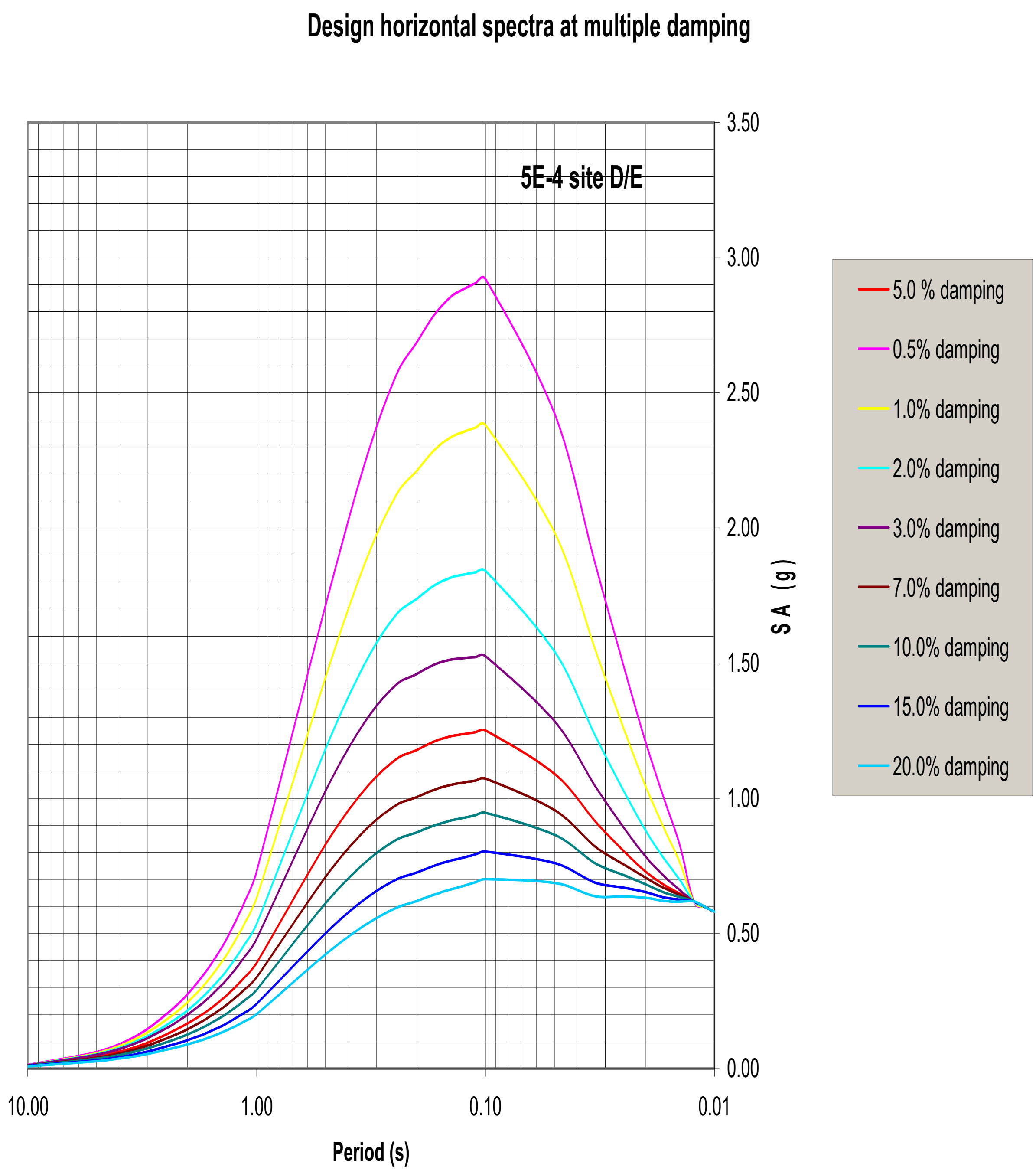


Figure1 <u>Horizontal Acceleration Response Spectra at 5E-4 AEF at point D/E (Ref. 2.2.2)</u>

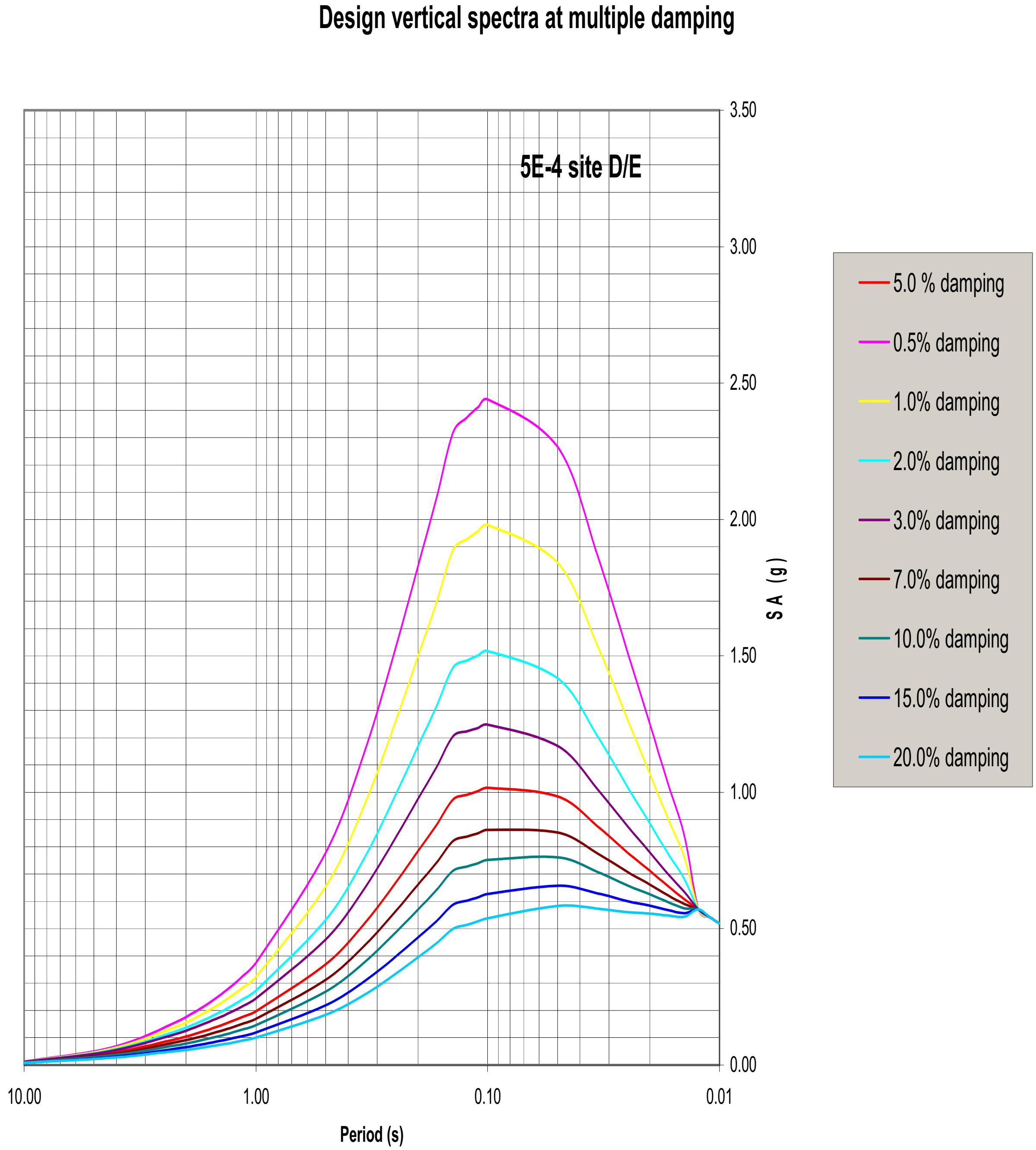


Figure 2 Vertical Acceleration Response Spectra at 5E-4 AEF at point D/E (Ref. 2.2.2)

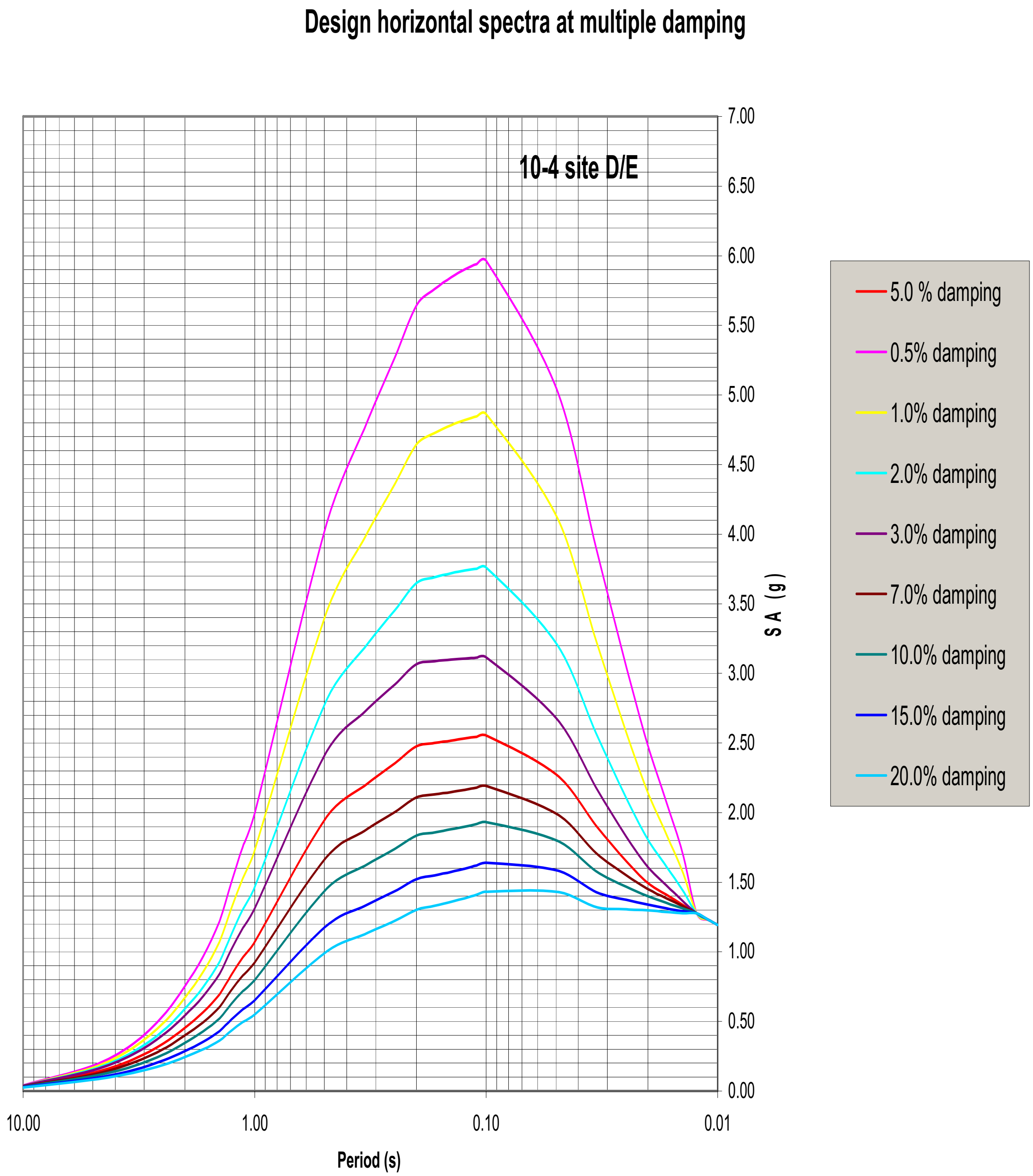


Figure 3 Horizontal Acceleration Response Spectra at 1E-4 AEF at point D/E (Ref. 2.2.3)

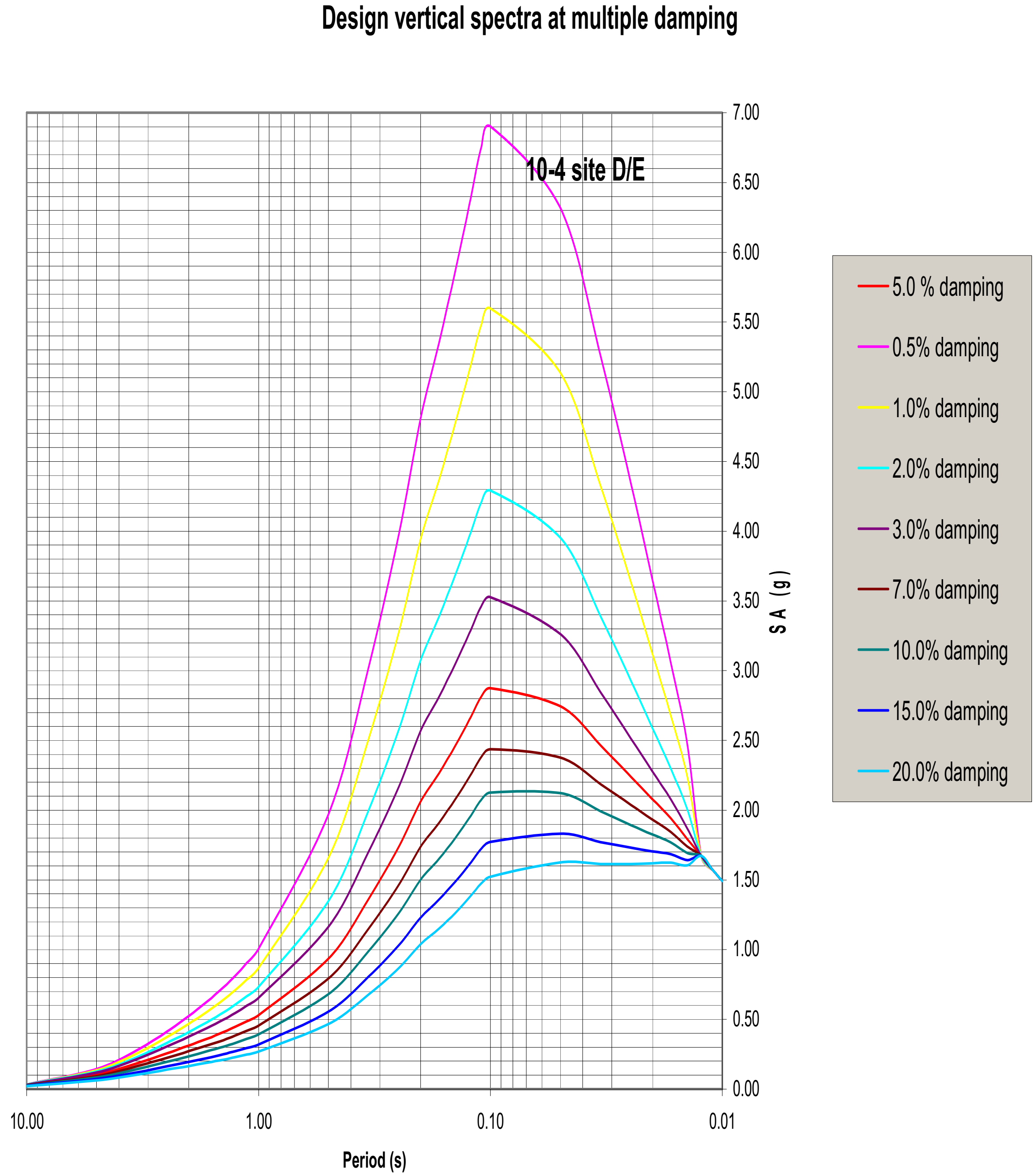


Figure 4 Vertical Acceleration Response Spectra at 1E-4 AEF at point D/E (Ref. 2.2.3)

6.2 LOADINGS

6.2.1 Dead Load

For elevations 32' and up to 100', the lumped dead load is calculated in Table 3 and to be input to SAP 2000 through its C.G. Dead loads plus ¼ live loads as calculated in Ref. 2.2.8 will be used for convenience because the ratio of the ¼ live loads to the dead loads plus ¼ live loads equals 1430/115913 = 1.23% (see Table 3), an insignificant effect in including the additional ¼ LL. The dead loads of the grade foundation and substructure, which are part of the finite element model, will be input to SAP 2000 directly. Note that dead loads include self-weight of the finite elements and other additional stationary weight on the structure which is listed in Table 3 (Ref. 2.2.8).

6.2.2 Live Load

As calculated in Ref. 2.2.8, a general live load of 100 psf will be used for the grade foundation and substructure. For elevations 32' and up to 100', the lumped live load is calculated in Table 3 and to be input to SAP 2000 through its C.G.

6.2.3 Hydrostatic Load

With 4' free board (Ref. 2.2.11, section 7.2), the fluid surface of the pool will be at elev. -4'. For pool base mat at elev. -52' (Ref. Attachment A), a linear varying hydrostatic pressure will impose at the concrete wall of the fuel pool, with a max pressure :

$$F_{max} = \gamma\ H = 0.0624 \text{ x } (52\text{-}4) = 2.995 \text{ ksf}$$

6.2.4 Earth Pressure

The pool portion of the Wet Handling Facility is below grade, top of pool base mat at elev. -52 ft. Its exterior walls will sustain various lateral earth pressure. The pool is integrated to the grade base mat and shear walls above; it will act as a restrained rigid retaining wall. The alluvium soil parameters will be used in design for conservatism.

6.2.4.1 Static Lateral Earth Pressure

Per Ref. 2.2.4, sect. 4.2.11.3.5, the at-rest lateral earth pressure shall be used for design. Consider alluvium for conservatism, γ = 117 pcf and Ko = 0.37, the linearly varying static lateral earth pressure has a max. :

$$P_{omax} = K_o\gamma H = 0.37 \text{ x } 0.117 \text{ x } (56'\text{-}6') = 2.165 \text{ ksf} \qquad \text{(Table 1)}$$

6.2.4.2 Surcharge Load

From Ref. 2.2.8 p. 26, the total weight of WHF including dead load and water is estimated to be 269692 kips. With net available grade supporting area, gross building area deduct pool area:

$$A = 270' \text{ x } 214' - 114' \text{ x } 116' = 44556 \text{ ft}^2.$$

The surcharge load and the corresponding lateral uniformly distributed pressure acting at the concrete wall of the fuel pool will be conservatively respectively, considered as:

$$q_s = 269692 / 44556 = 6.053 \text{ ksf} \qquad p_s = K_o\ q_s = 0.37 \text{ x } 6.053 = 2.240 \text{ ksf} \qquad \text{(Table 1)}$$

6.2.4.3 Compaction-induced Loads

From Ref. 2.2.6, figures 7-11 thru 7-15, an enveloping compaction-induced lateral earth pressure, shown in Fig. 5, will be used. Note that figure 7-14 is the governing case.

As indicated in Ref. 2.2.19, section 10.1, the combined static lateral earth pressure would be the greater of the compaction-induced loads plus the at-rest pressure or the surcharge plus the at-rest pressure.

TABLE 3 Dead Loads & Live Loads

Elev. ft (Joint)	Lumped DL+LL/4	(origin of x & y axes is at intersection of column lines A & 1, see Fig 7)				Lumped LL/4			Lumped LL			
	W_D kips	x ft	y ft	x*W	y*W	$W_{L/4}$ kips	W_L kips	x ft	y ft	$x*W_L$	$y*W_L$	Joints
100' (J6099)	7861.7	20.2	212.1	158806	1667467	69.5	278	26.5	207	7367	57546	J6098
80' (J5099)	48100.7	113.3	132.6	5449809	6378153	577.8	2311.2	105	133	242676	307390	
						-55.9	-223.6	26.5	207	-5925	-46285	
						Sub-sum	2087.6	113.4	125.1	236751	261104.4	J5098
40' (J4099)	44617	118.9	88.3	5304961	3939681	209	836	26.5	74	22154	61864	
						297	1188	183.5	106	217998	125928	
						158.6	634.4	105	30	66612	19032	
						Sub-sum	2658.4	115.4	77.8	306764	206824	J4098
32' (J3099)	15333.5	25.2	209.1	386404	3206235	173.9	695.6	26.5	207	18433	143989	J3098
0'	101438	104.2	130.5			1444.5	5778	105	133			
						115.5	462	97	28.5			
						-114.38	-457.52	105	115.5			
						Sub-sum	5782.5					
-52	52341.1	104.3	126.5			330.6	1322.4	105	127			
						29.25	117	105	146			
						Sub-sum	1439.4					
Σ	269692					3235	12941					
Σ(100 to 32)	115913	97.5	131.1	11299981	15191535	1430	5720	99.5	117.0	569315	669464	
Ref. 2.2.8, pp 23-24						Ref. 2.2.8, pp 10-16						

Additional dead load (DD) & LL added to Self-weight (DEAD) & LL

Elevation	slab ksf	DD ksf	LL ksf	Remarks
0'	0.225	0.11	0.10	Floor 20' lumped to 0' in B-C-1-2 area, Ref. 2.2.8, sh't 12
		0.291		Partition walls in B-C-1-2 area, 1632/104*54 = 0.291 ksf, Ref. 2.2.8, sh't 19
-52'		0.14		Ref. 2.2.8, sh't 10
		0.684		Four casks 2*800 kips/(2*18*65) = 0.684 ksf, in two 18' x 65' area

stiffen partial wall	THK (ft)	Modeled Hts(ft)	Tributary Hts (ft)	Density Factor	Remarks
CONC5K1**	4 or 2	6	20	3.33	As discussed in section 6.4.1, density factor is to adjust the
CONC5K2 **	4	6	16	2.67	tributary wall weight to floor 0', Ref. 2.2.8, sh't 19.
CONC5K3 **	4	6	40	6.67	** Different concrete property defined.

6.2.5 Seismic Loads

The DBGM-2 seismic event will be used for design. Data for BDBGM seismic event are provided for information only.

6.2.5.1 Structure Inertia Load

The overall seismic response of the WHF is represented by the floor level seismic loads calculated as accelerations multiplying the corresponding 'lumped mass' for elevation 32' and above and multiplying the corresponding element inertia mass, which includes dead load plus ¼ live load, for the grade foundation with partial shear walls and the substructure. Using SAP 2000 the structure inertia loads are analyzed in calculation *Tier 1 Seismic Analysis Using a Multiple Stick Model of the WHF* (Ref. 2.2.9) for DBGM-2 and BDBGM earthquake cases. As demonstrated in Ref. 2.2.9, the upper bound 35' and upper bound 110' soil cases were found to be the bounding seismic load conditions for EW and NS direction, respectively. Their acceleration responses are tabulated in Table 4. By comparison and on assumption 3.1.3, it shows that the upper bound 35' - D35U- is the most critical case . Therefore, the floor level accelerations from upper bound 35' case will be used to calculate seismic loads.

6.2.5.2 Dynamic Lateral Earth Pressure

The seismic lateral earth pressure increment is calculated per Ref. 2.2.1, sect. 3.5.3.2. For γ =0.117 kcf and coefficient c per Ref. 2.2.1, Figure. 3.5-1, $q_E = c\ \gamma\ a_h H = c*0.117*\ a_h H$
It is shown in Fig. 5, where the linearly distributed pressure is used instead.

The seismic accelerations to be used are ZPA : a_h =0.58 for DBGM-2 and a'_h = 1.19 for BDBGM

6.2.5.3 Dynamic Surcharge Load

Due to seismic effects, the vertical reaction at grade foundation, i.e. joint reactions at joint 2099, for D35U & B35U are 74748 & 204816 kips (Ref. 2.2.9, Attachments Q &K), respectively. By direct proportioning to those in section 6.2.4.2, the uniformly distributed lateral earth pressure for surcharge are then :

$$\Delta p_s = K_o\ q_s = 0.37 \times 74748/269692 \times 6.053 = 0.2772 \times 0.37 \times 6.053 = 0.621 \text{ ksf}$$

$$\Delta p'_s = K_o\ q_s = 0.37 \times 204816/269692 \times 6.053 = 0.7594 \times 0.37 \times 6.053 = 1.701 \text{ ksf}$$

6.2.5.4 Hydrodynamic Load

Hydrodynamic loads which were evaluated in calculation 050-SYC-WH00-00400-000-00A (Ref. 2.2.11, section 7) are shown in Figure 6 and will be used in this calculation.

6.2.6 Resistance to Lateral Loads

In case of seismic events, the resistance to the lateral movement of the Wet Handling Facility will be provided by the friction between the bases of the grade basemat and the pool basemat and the passive pressure developed on the below-grade pool walls.

The friction coefficient between foundation and sub-grade : α = 0.81 (from Table 1)

The passive earth pressure at the pool walls (see Table 1): $p_p = K_p \gamma H = 4.4 \times 0.117\ H = 0.515\ H$

TABLE 4 SEISMIC RESPONSES/JOINT ACCELERATIONS

Note that X-, Y-axes are interchanged from Ref. 2.2.9.

Seismic Case		D35Uy			D35Ux			D35Uz			Remarks
Response		UY	UX	UZ	UY	UX	UZ	UY	UX	UZ	
Joint	EL (ft)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	
6099	100	1.246	0.236	0.268	0.481	1.607	0.231	0.107	0.092	0.806	lumped mass
5099	80	0.979	0.046	0.014	0.118	0.976	0.036	0.042	0.047	0.706	lumped mass
4099	40	0.723	0.073	0.105	0.091	0.738	0.051	0.075	0.051	0.649	lumped mass
3099	32	0.689	0.082	0.192	0.250	0.684	0.161	0.108	0.068	0.677	lumped mass
2099	0	0.602	0.045	0.014	0.044	0.527	0.016	0.038	0.026	0.554	finite elements
1099	-52	0.538	0.052	0.013	0.043	0.527	0.014	0.025	0.022	0.411	finite elements

Ref. 2.2.9, Attachment G.

Seismic Case		D110Uy			D110Ux			D110Uz			Remarks
Response		UY	UX	UZ	UY	UX	UZ	UY	UX	UZ	
Joint	EL (ft)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	
6099	100	1.201	0.223	0.262	0.419	1.529	0.248	0.104	0.089	0.722	lumped mass
5099	80	0.968	0.040	0.013	0.104	0.973	0.036	0.033	0.040	0.645	lumped mass
4099	40	0.721	0.067	0.105	0.084	0.726	0.056	0.061	0.044	0.599	lumped mass
3099	32	0.688	0.073	0.195	0.227	0.671	0.179	0.088	0.079	0.623	lumped mass
2099	0	0.593	0.033	0.013	0.031	0.538	0.016	0.033	0.023	0.524	finite elements
1099	-52	0.518	0.037	0.013	0.032	0.490	0.015	0.018	0.018	0.409	finite elements

Ref. 2.2.9, Attachment J.

Seismic Case		B35Uy			B35Ux			B35Uz			Remarks
Response		UY	UX	UZ	UY	UX	UZ	UY	UX	UZ	
Joint	EL (ft)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	
6099	100	2.487	0.448	0.515	0.913	3.178	0.456	0.274	0.234	2.184	lumped mass
5099	80	1.986	0.088	0.027	0.223	1.986	0.070	0.108	0.120	1.926	lumped mass
4099	40	1.478	0.138	0.202	0.173	1.493	0.100	0.192	0.132	1.771	lumped mass
3099	32	1.406	0.154	0.372	0.474	1.374	0.320	0.276	0.174	1.843	lumped mass
2099	0	1.184	0.084	0.027	0.083	1.042	0.031	0.098	0.068	1.512	finite elements
1099	-52	1.026	0.097	0.024	0.079	0.999	0.027	0.063	0.056	1.129	finite elements

Ref. 2.2.9, Attachment K.

Note that the lumped weights are: 7861.7, 48100.7, 44617 & 15333.5 kips at El. 100', 80', 40' & 32', respectively, see Table 3.

Figure 5 Lateral Earth Pressure

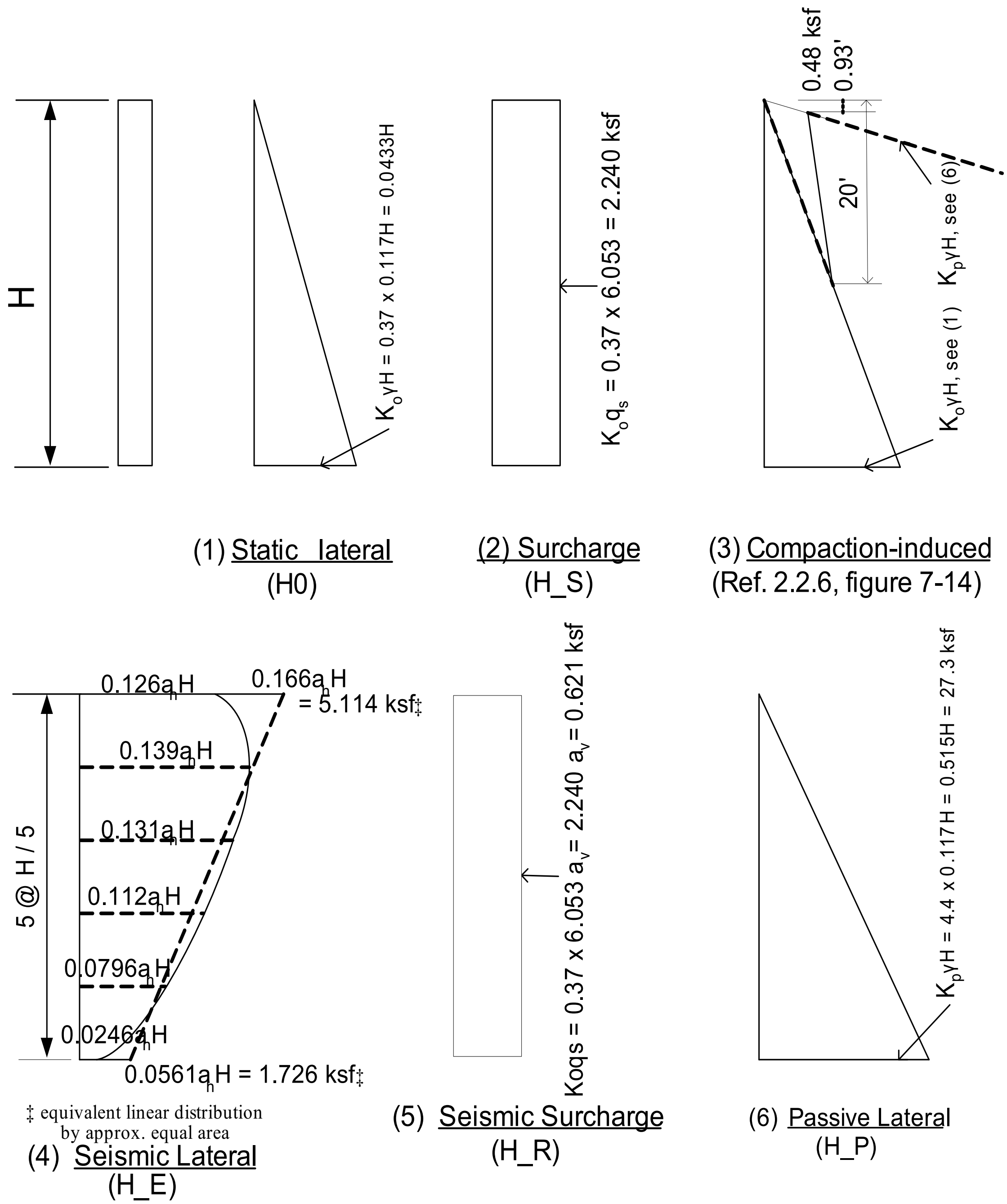
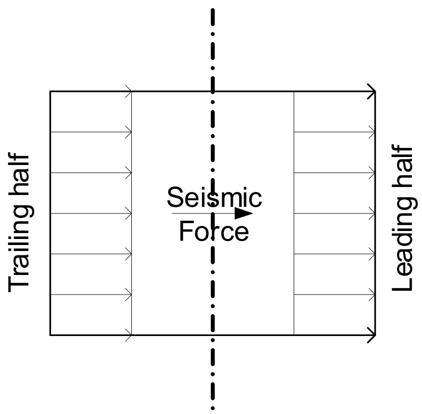
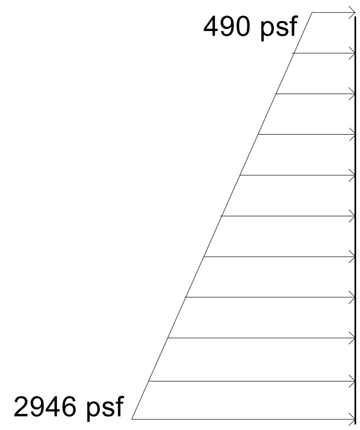


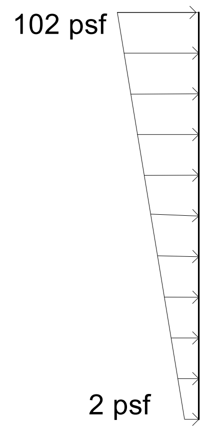
Figure 6 Hydrodynamic Pressure



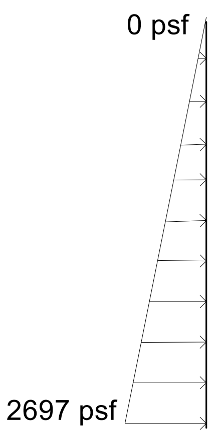
(1) Hydrodynamic pressure direction



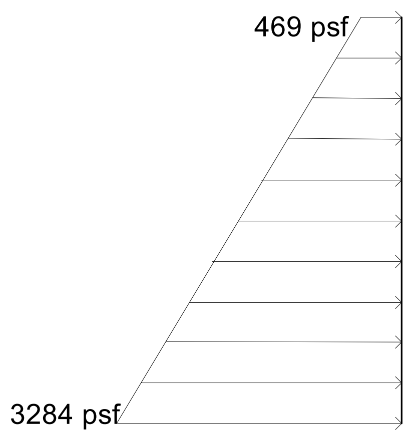
(2) Impulsive Pressure p_i (FI_NS)



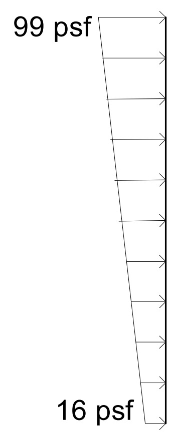
(3) Convective Pressure p_c (FC_NS)



(4) Vertical Hydrodynamic Pressure p_v (F_V)



(5) Impulsive Pressure p_i (FI_EW)



(6) Convective Pressure p_c (FC_EW)

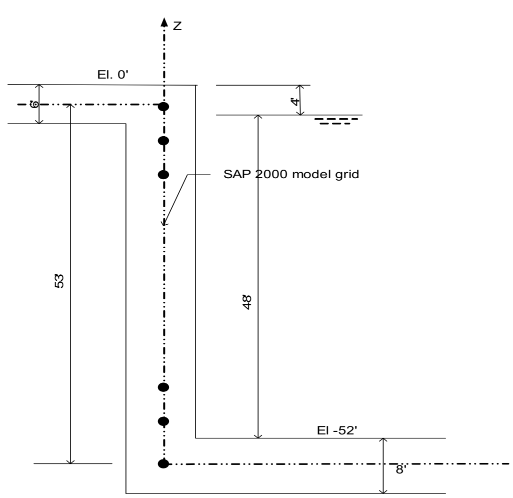
Note that except for loading (4), pressure on the leading half of the pool will be additive to the hydrostatic pressure, and deductive on the trailing half for loadings (2), (3), (5) and (6).

Loadings included in the SAP2000 analysis are those discussed in section 6.2. Some of those are linearly distributed loadings which are further tabulated in Table 5 by using MS Excel spreadsheet to facilitate the input to SAP2000 :

TABLE 5 Linearly Distributed Loadings

Elev	Z-coor	Depth	Seismic Lat	Hydro	Hydro-dynamic Pressure				
			Earth Press	Stat Press	Vert	NS (ksf)		EW (ksf)	
ft	ft	ft	ksf	ksf	ksf	Impluse	Convect	Impluse	Convect
-3	53	0	5.114	0.000	0.000	0.49	0.102	0.469	0.099
-7	49	4	4.859	0.250	0.225	0.695	0.094	0.704	0.092
-11	45	8	4.603	0.499	0.449	0.899	0.085	0.938	0.085
-15	41	12	4.347	0.749	0.674	1.104	0.077	1.173	0.078
-19	37	16	4.092	0.999	0.899	1.309	0.069	1.407	0.071
-23	33	20	3.836	1.249	1.124	1.513	0.060	1.642	0.064
-27	29	24	3.580	1.498	1.348	1.718	0.052	1.877	0.058
-31	25	28	3.324	1.748	1.573	1.923	0.044	2.111	0.051
-35	21	32	3.069	1.998	1.798	2.127	0.035	2.346	0.044
-39	17	36	2.813	2.247	2.023	2.332	0.027	2.580	0.037
-43	13	40	2.557	2.497	2.247	2.537	0.019	2.815	0.030
-47	9	44	2.302	2.747	2.472	2.741	0.010	3.049	0.023
-51	5	48	2.046	2.997	2.697	2.946	0.002	3.284	0.016
-56	0	53	1.726						
Remarks			(1)	(1)	(1)	(1)	(1)	(1)	(1)
SAP2000 notation			P0	FST	FDY	FINS	FCNS	FIEW	FCEW

(1) Linear distributed pressure applied.
Note that to facilitate input the loads of the earth pressure and hydro pressure, static & dynamic, to the SAP2000 model, it is adequate to input the earth pressure as between Z = 0' to 53' and the hydro pressures as between Z = 5' to 53' as demonstrated in picture below.



Grade Foundation & Pool Cross-section

6.3 LOADING COMBINATIONS

The loadings described in section 6.2 belong to the following category and listed below :

D Dead loads include self-weight of elements (DEAD) and lumped dead load plus ¼ LL and superimposed dead loads (DD).

L Live load (LL).

F Fluid load includes the hydrostatic pressures applied vertically and laterally (F0).

H Lateral earth pressure includes static lateral earth pressure due to soil (H0) and surcharge (H_S).

E Seismic loads comprise of :

(a) Inertia forces from the accelerations on mass of D plus ¼ L due to earthquakes (DBGM & BDBGM). The corresponding weights are represented in joint lumped load cases W6099X, W6099Y, W6099Z, W5099X, …, W3099X, W3099Y, W3099Z; element load cases W0X, W0Y & W0Z for elements at El. 0'; element load cases W_52X, W_52Y & W_52Z for elements at El. -52' and element load cases WSWX, WSWY & WSWZ for subgrade walls and intermediate floor.

(b) Hydrodynamic forces which compose of vertical and lateral hydrodynamic pressures (F_V), impulsive pressure (FI_EW & FI_NS), and convective pressure (FC_EW & FC_NS).

(c) Seismic lateral earth pressures compose of those due to soil action (H_EN, H_ES, H_EE, & H_EW, corresponding to north, south, east & west direction, respectively) and surcharge (H_R). In addition, while the overall seismic lateral force exceeds the at-rest seismic lateral earth pressure and displace the structure excessively, the passive lateral earth pressure may be motivated instead (H_PN, H_PS, H_PE & H_PW, corresponding to north, south, east & west direction, respectively).

Note that for each seismic loading (E) there are three independent orthogonal components in directions N-S, E-W & vertical and the direction can be opposite.

The reinforced concrete structure shall be evaluated for load combinations indicated in Ref. 2.2.4, sections 4.2.11.4.4 & 4.2.11.4.5. A, L_r, S_n, R_o, W, W_t, T_o, T_a, & Y_m are not applicable per assumption 3.1.1, the load combinations become as follow:

1. U = 1.4 D + 1.7 L + 1.4 F + 1.7 H

2. U = 1.4 D + 1.7 L + 1.7 H

3. U = 1.05 D + 1.3 L + 1.05 F + 1.3 H

4. U = 1.05 D + 1.3 L + 1.3 H

5. U = D + L + F + H

6. U = D + L + H

7. U = D + L + F + H + E

8. U = D + L + H + E

9. U = 0.9 D + F + H + E

10. U = 0.9 D + H + E

The fluid loadings (F) occur only when pool is filled with water. While the pool is empty, there will be no SNF and the facility will not be in a critical design condition. Therefore, loading combinations 2, 4, 6, 8 and 10 won't be considered.

Loading combinations 1, 3, and 5 can be analyzed with SAP2000 Linear Static Analysis. Loading combinations 7 & 9 will be analyzed with SAP2000 Nonlinear Static Analysis since foundation uplift may occur.

To obtain the design responses from the spatial components, N-S, E-W & Vertical, as discussed above, SADA Appendix A (Ref. 2.2.5) gives the governing 24 seismic loading combinations using the 'Component Factor Method (1.0/0.4/0.4)', Ref. 2.2.1, section 3.2.7.1.2, as listed below :

R = 1.0EX + 0.4EY + 0.4EZ ;	R = 0.4EX + 1.0EY + 0.4EZ;	R = 0.4EX + 0.4EY + 1.0EZ
R = 1.0EX + 0.4EY - 0.4EZ ;	R = 0.4EX + 1.0EY - 0.4EZ;	R = 0.4EX - 0.4EY + 1.0EZ
R = 1.0EX - 0.4EY + 0.4EZ ;	R = -0.4EX + 1.0EY + 0.4EZ;	R = -0.4EX + 0.4EY + 1.0EZ
R = 1.0EX - 0.4EY - 0.4EZ ;	R = -0.4EX + 1.0EY - 0.4EZ;	R = -0.4EX - 0.4EY + 1.0EZ
R = -1.0EX + 0.4EY + 0.4EZ ;	R = 0.4EX - 1.0EY + 0.4EZ;	R = 0.4EX + 0.4EY - 1.0EZ
R = -1.0EX + 0.4EY - 0.4EZ ;	R = 0.4EX - 1.0EY - 0.4EZ;	R = 0.4EX - 0.4EY - 1.0EZ
R = -1.0EX - 0.4EY + 0.4EZ ;	R = -0.4EX - 1.0EY + 0.4EZ;	R = -0.4EX + 0.4EY - 1.0EZ
R = -1.0EX - 0.4EY - 0.4EZ ;	R = -0.4EX - 1.0EY - 0.4EZ;	R = -0.4EX - 0.4EY - 1.0EZ

Where R represents the part of inertia forces of the seismic loads, **E,** (a). EX, EY & EZ represent seismic events in X (N-S), Y (E-W) & Z (Vertical) directions, respectively. Note the global coordinate system used in SASP2000 model is X to the south, Y to the east and Z upward.

From SADA Appendix A, section A3.4 (Ref. 2.2.5), the other parts of the seismic loads (**E**), (b) & (c), i.e. seismic lateral earth pressures (H_R, H_EN, H_ES, H_EE, & H_EW, H_PN, H_PS, H_PE & H_PW) and the hydrodynamic pressures (F_V, FI_EW & FI_NS, & FC_EW & FC_NS), by analogy, will only occur concurrently and accompanying with the 1.0E_ case only.

As examples of the SAP2000 input of the loading combination, their expanded expression are shown below :

1. **U = 1.4 D + 1.7 L + 1.4 F + 1.7 H**

   = 1.4 (DEAD+DD) + 1.7 (LL) + 1.4 (F0) + 1.7 (H0 + H_S)

7. **U = D + L + F + H + E**

   = (DEAD+DD) + (LL) + (F0) + (H0 + H_S) + E

   = (DEAD+DD) + (LL) + (F0) + (H0 + H_S) + (R = 1.0EX+0.4EY+0.4EZ)

   -1.0(FI_NS+FC_NS) – 0.4(F_V) – 0.4(H_R) + 1.0(H_ES)

   Where R = (1.0EX+0.4EY+0.4EZ), etc. represents inertia forces of the structure lumped mass and elements described in next page.

Note that the complete listing of the loading combinations can be displayed from the SAP2000 model (Attachment D, file: WHF_FDNnSUBh.SDB)

Based on Table 4 and the seismic loadings combinations listed in last page, the corresponding seismic accelerations are combined for the governing DBGM 35' Alluvium upper bound (D35U) case and tabulated below :

These accelerations are applied to their respective joint lumped weight assigned in load cases W6099X, W6099Y, W6099Z, …, W3099X, W3099Y & W3099Z; (for joint 2099) to El. 0' elements assigned in load cases W0X, W0Y & W0Z; (for joint 1099) to El. -52' elements assigned in load cases W_52X, W_52Y & W_52Z; and for subgrade walls and intermittent floors assigned in load cases WSWX, WSWY & WSWZ which the average values from joints 2099 and 1099 will used.

TABLE 6 DESIGN ACCELERATIONS

Note that X-, Y-axes are interchanged from Ref. 2.2.9.

Seismic Case		1.0EX+0.4EY+0.4EZ (NS101/201)			0.4EX+1.0EY+0.4EZ (NS105/205)			0.4EX+0.4EY+1.0EZ (NS109/209)		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)
6099	100	1.738	1.022	0.661	0.916	1.481	0.683	0.829	0.797	1.006
5099	80	1.013	0.526	0.324	0.455	1.043	0.310	0.456	0.481	0.726
4099	40	0.788	0.410	0.353	0.389	0.790	0.385	0.376	0.401	0.712
3099	32	0.744	0.568	0.509	0.382	0.832	0.527	0.374	0.483	0.818
2099	0	0.555	0.301	0.243	0.266	0.635	0.242	0.255	0.297	0.566
1099	-52	0.557	0.268	0.184	0.272	0.565	0.183	0.254	0.257	0.422

Seismic Case		1.0EX+0.4EY-0.4EZ (NS102/202)			0.4EX+1.0EY-0.4EZ (NS106/206)			0.4EX-0.4EY+1.0EZ (NS110/210)		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)
6099	100	1.665	0.937	0.016	0.842	1.396	0.038	0.640	-0.199	0.791
5099	80	0.976	0.492	-0.241	0.418	1.009	-0.255	0.419	-0.303	0.715
4099	40	0.747	0.350	-0.167	0.348	0.730	-0.135	0.317	-0.178	0.628
3099	32	0.689	0.482	-0.033	0.328	0.746	-0.014	0.309	-0.068	0.665
2099	0	0.534	0.270	-0.200	0.246	0.605	-0.201	0.219	-0.185	0.554
1099	-52	0.539	0.248	-0.146	0.254	0.545	-0.146	0.212	-0.173	0.412

Seismic Case		1.0EX-0.4EY+0.4EZ (NS103/203)			-0.4EX+1.0EY+0.4EZ (NS107/207)			-0.4EX+0.4EY+1.0EZ (LNS111/211)		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)
6099	100	1.549	0.025	0.447	-0.370	1.096	0.498	-0.457	0.413	0.821
5099	80	0.976	-0.257	0.313	-0.325	0.949	0.282	-0.325	0.387	0.698
4099	40	0.729	-0.168	0.269	-0.202	0.717	0.344	-0.215	0.328	0.671
3099	32	0.678	0.017	0.355	-0.165	0.632	0.398	-0.173	0.283	0.689
2099	0	0.519	-0.181	0.232	-0.155	0.600	0.229	-0.166	0.261	0.553
1099	-52	0.515	-0.163	0.174	-0.150	0.531	0.171	-0.168	0.223	0.411

Seismic Case		1.0EX-0.4EY-0.4EZ (NS104/204)			-0.4EX+1.0EY-0.4EZ (NS108/208)			-0.4EX-0.4EY+1.0EZ (NS112/212)		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)
6099	100	1.476	-0.060	-0.198	-0.443	1.011	-0.147	-0.646	-0.584	0.607
5099	80	0.939	-0.291	-0.252	-0.363	0.915	-0.283	-0.362	-0.397	0.687
4099	40	0.689	-0.228	-0.250	-0.243	0.657	-0.176	-0.273	-0.251	0.587
3099	32	0.624	-0.069	-0.186	-0.219	0.546	-0.144	-0.238	-0.268	0.536
2099	0	0.498	-0.212	-0.211	-0.176	0.569	-0.214	-0.203	-0.221	0.542
1099	-52	0.497	-0.183	-0.156	-0.167	0.511	-0.158	-0.210	-0.207	0.401

TABLE 6 DESIGN ACCELERATIONS (cont'd)

Note that X-, Y-coordinates are interchanged from Ref. 2.2.9.

Seismic Case		-1.0EX+0.4EY+0.4EZ (NS113/213)			0.4EX-1.0EY+0.4EZ (NS117/217)			0.4EX+0.4EY-1.0EZ (NS121/221)		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)
6099	100	-1.476	0.060	0.198	0.443	-1.011	0.147	0.646	0.584	-0.607
5099	80	-0.939	0.291	0.252	0.363	-0.915	0.283	0.362	0.397	-0.687
4099	40	-0.689	0.228	0.250	0.243	-0.657	0.176	0.273	0.251	-0.587
3099	32	-0.624	0.069	0.186	0.219	-0.546	0.144	0.238	0.268	-0.536
2099	0	-0.498	0.212	0.211	0.176	-0.569	0.214	0.203	0.221	-0.542
1099	-52	-0.497	0.183	0.156	0.167	-0.511	0.158	0.210	0.207	-0.401

Seismic Case		-1.0EX+0.4EY-0.4EZ (NS114/214)			0.4EX-1.0EY-0.4EZ (NS118/218)			0.4EX-0.4EY-1.0EZ (NS122/222)		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)
6099	100	-1.549	-0.025	-0.447	0.370	-1.096	-0.498	0.457	-0.413	-0.821
5099	80	-0.976	0.257	-0.313	0.325	-0.949	-0.282	0.325	-0.387	-0.698
4099	40	-0.729	0.168	-0.269	0.202	-0.717	-0.344	0.215	-0.328	-0.671
3099	32	-0.678	-0.017	-0.355	0.165	-0.632	-0.398	0.173	-0.283	-0.689
2099	0	-0.519	0.181	-0.232	0.155	-0.600	-0.229	0.166	-0.261	-0.553
1099	-52	-0.515	0.163	-0.174	0.150	-0.531	-0.171	0.168	-0.223	-0.411

Seismic Case		-1.0EX-0.4EY+0.4EZ (NS115/215)			-0.4EX-1.0EY+0.4EZ (NS119/219)			-0.4EX+0.4EY-1.0EZ (NS123/223)		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)
6099	100	-1.665	-0.937	-0.016	-0.842	-1.396	-0.038	-0.640	0.199	-0.791
5099	80	-0.976	-0.492	0.241	-0.418	-1.009	0.255	-0.419	0.303	-0.715
4099	40	-0.747	-0.350	0.167	-0.348	-0.730	0.135	-0.317	0.178	-0.628
3099	32	-0.689	-0.482	0.033	-0.328	-0.746	0.014	-0.309	0.068	-0.665
2099	0	-0.534	-0.270	0.200	-0.246	-0.605	0.201	-0.219	0.185	-0.554
1099	-52	-0.539	-0.248	0.146	-0.254	-0.545	0.146	-0.212	0.173	-0.412

Seismic Case		-1.0EX-0.4EY-0.4EZ (NS116/216)			-0.4EX-1.0EY-0.4EZ (NS120/220)			-0.4EX-0.4EY-1.0EZ (NS124/224)		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)
6099	100	-1.738	-1.022	-0.661	-0.916	-1.481	-0.683	-0.829	-0.797	-1.006
5099	80	-1.013	-0.526	-0.324	-0.455	-1.043	-0.310	-0.456	-0.481	-0.726
4099	40	-0.788	-0.410	-0.353	-0.389	-0.790	-0.385	-0.376	-0.401	-0.712
3099	32	-0.744	-0.568	-0.509	-0.382	-0.832	-0.527	-0.374	-0.483	-0.818
2099	0	-0.555	-0.301	-0.243	-0.266	-0.635	-0.242	-0.255	-0.297	-0.566
1099	-52	-0.557	-0.268	-0.184	-0.272	-0.565	-0.183	-0.254	-0.257	-0.422

By multiplying the lumped mass on each floor (see Table 3) with the accelerations in the Table 6, the corresponding seismic forces for each floor, El. 100' to -52', for the seismic loading combinations are tabulated as below :

** see discussion on Resistance to Lateral Loads in sheet 29.

TABLE 7 SEISMIC FORCES

Note that X-, Y-coordinates are interchanged from Ref. 2.2.9.

Seismic Case		1.0EX+0.4EY+0.4EZ			0.4EX+1.0EY+0.4EZ			0.4EX+0.4EY+1.0EZ		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)
6099	100	13664.4	8035.6	5193.6	7199.5	11643.5	5365.7	6516.9	6269.6	7905.5
5099	80	48736.6	25297.0	15568.8	21905.1	50156.5	14929.0	21913.4	23118.2	34924.8
4099	40	35151.1	18299.5	15749.0	17341.5	35225.8	17170.7	16758.4	17874.8	31759.5
3099	32	11402.8	8713.7	7803.8	5861.8	12758.4	8084.6	5733.9	7407.1	12549.4
2099	0	56334.8	30495.8	24643.3	27027.4	64461.0	24525.0	25864.2	30114.5	57365.8
1099	-52	29144.5	14013.8	9609.4	14240.5	29580.6	9561.8	13289.7	13461.6	22089.2
Sum		194434.2	104855.4	78568.0	93575.8	203825.7	79636.8	90076.4	98245.8	166594.2
SRSS		220905.6		H_P **	224279.7		H_P **	133289.1		**

Seismic Case		1.0EX+0.4EY-0.4EZ			0.4EX+1.0EY-0.4EZ			0.4EX-0.4EY+1.0EZ		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)
6099	100	13088.1	7364.6	124.0	6623.2	10972.6	296.1	5030.3	-1566.6	6222.3
5099	80	46942.4	23679.1	-11613.2	20111.0	48538.6	-12253.0	20130.3	-14550.7	34404.0
4099	40	33325.4	15622.1	-7432.8	15515.8	32548.3	-6011.0	14155.2	-7937.3	28029.4
3099	32	10572.0	7394.3	-502.8	5030.9	11439.1	-222.0	4732.6	-1047.3	10196.0
2099	0	54212.5	27401.2	-20278.7	24905.2	61366.5	-20397.0	22191.0	-18775.3	56231.4
1099	-52	28217.5	12970.5	-7617.5	13313.4	28537.2	-7665.1	11094.9	-9073.7	21565.4
Sum		186357.9	94431.9	-47320.9	85499.6	193402.3	-46252.0	77334.2	-52950.9	156648.5
SRSS		208917.8		H_P **	211458.3		H_P **	93725.1		**

Seismic Case		1.0EX-0.4EY+0.4EZ			-0.4EX+1.0EY+0.4EZ			-0.4EX+0.4EY+1.0EZ		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)
6099	100	12177.9	199.4	3510.4	-2906.9	8617.9	3911.9	-3589.5	3243.9	6451.7
5099	80	46953.4	-12371.9	15048.0	-15653.2	45633.6	13555.0	-15644.9	18595.3	33550.9
4099	40	32547.9	-7512.6	12018.9	-9007.8	31982.0	15336.3	-9590.9	14631.0	29925.0
3099	32	10401.5	259.3	5450.3	-2527.7	9697.0	6105.5	-2655.5	4345.6	10570.4
2099	0	52661.6	-18394.0	23509.0	-15722.2	60858.1	23232.9	-16885.4	26511.7	56073.7
1099	-52	26949.7	-8521.5	9085.6	-7826.4	27801.0	8974.6	-8777.2	11682.0	21501.9
Sum		181692.0	-46341.4	68622.3	-53644.1	184589.5	71116.2	-57143.5	79009.5	158073.6
SRSS		187508.7		H_P **	192226.4		H_P **	97508.4		**

Seismic Case		1.0EX-0.4EY-0.4EZ			-0.4EX+1.0EY-0.4EZ			-0.4EX-0.4EY+1.0EZ		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)
6099	100	11601.6	-471.5	-1559.2	-3483.2	7946.9	-1157.7	-5076.1	-4592.2	4768.5
5099	80	45159.3	-13989.7	-12134.0	-17447.3	44015.7	-13627.0	-17428.1	-19073.6	33030.1
4099	40	30722.2	-10190.1	-11162.9	-10833.5	29304.5	-7845.5	-12194.1	-11181.1	26194.9
3099	32	9570.7	-1060.1	-2856.2	-3358.5	8377.6	-2201.0	-3656.8	-4108.8	8216.9
2099	0	50539.3	-21488.6	-21413.1	-17844.5	57763.6	-21689.1	-20558.6	-22378.2	54939.3
1099	-52	26022.7	-9564.8	-8141.3	-8753.4	26757.6	-8252.3	-10972.0	-10853.3	20978.1
Sum		173615.7	-56764.8	-57266.5	-61720.4	174166.1	-54772.6	-69885.7	-72187.2	148127.9
SRSS		182660.0		H_E **	184778.9		H_P **	100473.9		**

** see sheet 29 for discussion.

TABLE 7 SEISMIC FORCES (cont'd)

Note that X-, Y-coordinates are interchanged from Ref. 2.2.9.

Seismic Case		-1.0EX+0.4EY+0.4EZ			0.4EX-1.0EY+0.4EZ			0.4EX+0.4EY-1.0EZ		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)
6099	100	-11601.6	471.5	1559.2	3483.2	-7946.9	1157.7	5076.1	4592.2	-4768.5
5099	80	-45159.3	13989.7	12134.0	17447.3	-44015.7	13627.0	17428.1	19073.6	-33030.1
4099	40	-30722.2	10190.1	11162.9	10833.5	-29304.5	7845.5	12194.1	11181.1	-26194.9
3099	32	-9570.7	1060.1	2856.2	3358.5	-8377.6	2201.0	3656.8	4108.8	-8216.9
2099	0	-50539.3	21488.6	21413.1	17844.5	-57763.6	21689.1	20558.6	22378.2	-54939.3
1099	-52	-26022.7	9564.8	8141.3	8753.4	-26757.6	8252.3	10972.0	10853.3	-20978.1
Sum		-173615.7	56764.8	57266.5	61720.4	-174166.1	54772.6	69885.7	72187.2	-148127.9
SRSS		182660.0		H_P **	184778.9		H_P **	100473.9		**

Seismic Case		-1.0EX+0.4EY-0.4EZ			0.4EX-1.0EY-0.4EZ			0.4EX-0.4EY-1.0EZ		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)
6099	100	-12177.9	-199.4	-3510.4	2906.9	-8617.9	-3911.9	3589.5	-3243.9	-6451.7
5099	80	-46953.4	12371.9	-15048.0	15653.2	-45633.6	-13555.0	15644.9	-18595.3	-33550.9
4099	40	-32547.9	7512.6	-12018.9	9007.8	-31982.0	-15336.3	9590.9	-14631.0	-29925.0
3099	32	-10401.5	-259.3	-5450.3	2527.7	-9697.0	-6105.5	2655.5	-4345.6	-10570.4
2099	0	-52661.6	18394.0	-23509.0	15722.2	-60858.1	-23232.9	16885.4	-26511.7	-56073.7
1099	-52	-26949.7	8521.5	-9085.6	7826.4	-27801.0	-8974.6	8777.2	-11682.0	-21501.9
Sum		-181692.0	46341.4	-68622.3	53644.1	-184589.5	-71116.2	57143.5	-79009.5	-158073.6
SRSS		187508.7		H_E **	192226.4		H_P **	97508.4		**

Seismic Case		-1.0EX-0.4EY+0.4EZ			-0.4EX-1.0EY+0.4EZ			-0.4EX+0.4EY-1.0EZ		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)
6099	100	-13088.1	-7364.6	-124.0	-6623.2	-10972.6	-296.1	-5030.3	1566.6	-6222.3
5099	80	-46942.4	-23679.1	11613.2	-20111.0	-48538.6	12253.0	-20130.3	14550.7	-34404.0
4099	40	-33325.4	-15622.1	7432.8	-15515.8	-32548.3	6011.0	-14155.2	7937.3	-28029.4
3099	32	-10572.0	-7394.3	502.8	-5030.9	-11439.1	222.0	-4732.6	1047.3	-10196.0
2099	0	-54212.5	-27401.2	20278.7	-24905.2	-61366.5	20397.0	-22191.0	18775.3	-56231.4
1099	-52	-28217.5	-12970.5	7617.5	-13313.4	-28537.2	7665.1	-11094.9	9073.7	-21565.4
Sum		-186357.9	-94431.9	47320.9	-85499.6	-193402.3	46252.0	-77334.2	52950.9	-156648.5
SRSS		208917.8		H_P **	211458.3		H_P **	93725.1		**

Seismic Case		-1.0EX-0.4EY-0.4EZ			-0.4EX-1.0EY-0.4EZ			-0.4EX-0.4EY-1.0EZ		
Response		UX	UY	UZ	UX	UY	UZ	UX	UY	UZ
Joint	EL (ft)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)	(kips)
6099	100	-13664.4	-8035.6	-5193.6	-7199.5	-11643.5	-5365.7	-6516.9	-6269.6	-7905.5
5099	80	-48736.6	-25297.0	-15568.8	-21905.1	-50156.5	-14929.0	-21913.4	-23118.2	-34924.8
4099	40	-35151.1	-18299.5	-15749.0	-17341.5	-35225.8	-17170.7	-16758.4	-17874.8	-31759.5
3099	32	-11402.8	-8713.7	-7803.8	-5861.8	-12758.4	-8084.6	-5733.9	-7407.1	-12549.4
2099	0	-56334.8	-30495.8	-24643.3	-27027.4	-64461.0	-24525.0	-25864.2	-30114.5	-57365.8
1099	-52	-29144.5	-14013.8	-9609.4	-14240.5	-29580.6	-9561.8	-13289.7	-13461.6	-22089.2
Sum		-194434.2	-104855.4	-78568.0	-93575.8	-203825.7	-79636.8	-90076.4	-98245.8	-166594.2
SRSS		220905.6		H_P **	224279.7		H_P **	133289.1		**

All loadings discussed in section 6.2 are included in SAP2000 '*load cases*'. In section 6.3 LOADING COMBINATIONS, loading combination equations 1, 3, and 5 which represent the static cases are defined as '*analysis load cases*' LS101, LS102 and LS103, respectively. The 24 seismic loading combinations corresponding to loading combination equation 7 and the another 24 seismic loading combinations corresponding to loading combination equation 9, which SAP2000 nonlinear static analysis is required, are defined as '*analysis load cases*' NS101 through NS124 and NS201 through NS224, respectively.

To facilitate the evaluation and design, the *'enveloping'* feature of SAP2000 is used to obtain the maximum and minimum values by defining loading combination 'ENVLS1' to envelope *analysis load cases* LS101, LS102 and LS103 and loading combination 'ENVNS1' to envelope *analysis load cases* NS101 through NS124 and NS201 through NS224.

<u>Resistance to Lateral Loads</u>

Resistance to lateral loads can be activated in several ways as described in section 6.2.6 :

(a) Friction between basemat and subgrade: friction coefficient $\alpha = 0.81$, use 0.5 for conservative &

total weight W = 269692 kips $R_f = 0.5 \times 269692 = 134846$ kips

(b) Seismic lateral earth pressure : from Figure 5, (4) & H = -6-(-60) = 54', $a_h = 0.58$

$$p = (0.0561+0.166)a_hH^2 / 2 = 0.1111 \times 0.58 \times 54^2 = 187.8 \text{ klf}$$

for north & south retaining walls, 114' long, $R_f = 187.8 \times 114 = 21411$ kips

for east or west retaining walls, 116' long, $R_f = 187.8 \times 116 = 21787$ kips

(c) Passive lateral earth pressure : from Figure 5, (6) & H = -6-(-60) = 54',

$$p = 0.515H^2 / 2 = 0.515 \times 54^2 / 2 = 750.87 \text{ klf}$$

for north & south retaining walls, 114' long, $R_f = 750.87 \times 114 = 85599$ kips

for east or west retaining walls, 116' long, $R_f = 750.87 \times 116 = 87101$ kips

When the SRSS of the lateral seismic forces listed in Table 7 is less than the sum of the net friction force (= friction force in (a) +/- friction force due to vertical seismic force listed in Table 7) and the seismic lateral earth pressure (b), the lateral seismic force for this seismic event will be resisted as such. The load cases for seismic lateral earth pressure, H_EN, H_ES, H_EE & H_EW, will then be used in the seismic loading combinations.

When the SRSS of the lateral seismic forces listed in Table 7 is larger than the sum of the net friction force (= friction force in (a) +/- friction force due to vertical seismic force listed in Table 7) and the seismic lateral earth pressure (b), the lateral seismic force for this seismic event will be resisted by the friction force and the passive lateral earth pressure. The load cases for passive lateral earth pressure, H_PN, H_PS, H_PE & H_PW, will then be used in the seismic loading combinations.

Based on the discussion above, the load case, either H_E or H_P, to be used in the seismic loading combinations is indicated as such in Table 7. For seismic combinations with 1.0EZ, friction force only is able to provide appropriate lateral load resistance; therefore, neither H_E nor H_P needs to be used in the seismic loading combinations.

6.4 SAP 2000 FINITE ELEMENT MODEL

6.4.1 Finite Element Model

The finite element model of the WHF grade foundation and subgrade concrete structure is created using SAP2000. The foundation and concrete structure are enclosed by concrete shear walls; therefore, locations of center lines of structure elements will be used in the modeling. Since the spans between shear walls are larger on the grade basemat than those on the pool basemat, finer element meshes are used for the latter in order to obtain accurate results for design.

The foundation at grade, which supports the shear walls, is 266’ by 210’ (between center lines of exterior shear walls) and is rigidly connected to the pool pit at the middle. The pool is 114’ x 116’ x 52’, which is the underground portion of the WHF, composed of walls, slabs, and basemat with center to center dimensions 106’ x 108’ x 53’ (see Attachment A).

In addition to the “Global Coordinate System and Origin”, other coordinate systems ‘GRD1’ & ‘GRD2’ are utilized for convenience of modeling (see Fig 7). The thick shell elements are used to model the basemats and the shear walls with thickness 4 ft and over.

Since this model is utilized in designing the foundation mat and the effects of the shear walls on top of grade basemat are to stiffen the foundation mat in this model, partial shear walls of 6 ft high (same as basemat thickness) are used to model the shear walls on the grade basemat. These partial walls will serve to stiffen the foundation mat sustaining the soil pressures and are used to connect the multiple stick representing floor 32’ and above (Ref. 2.2.9). The SAP 2000 rigid constraint definition – ‘Rigid Body Constraint’ - is then used to couple the partial stiffening shear walls to the ‘multiple stick’ model (Ref. 2.2.9). The resulting model yields an accurate representation of the foundation mat with the stiffening effects of the shear walls included in the model. Attachment B shows the isometric view of the WHF foundation mat with the subgrade structure. The finite element mesh of the foundation mat and substructure is also shown in Attachment B.

To consider the stiffness properties of the soil underlying the foundation mat, a series of non-linear (compression only) springs are computed. The soil spring stiffness is computed using the 35 ft. upper bound soil springs computed in the WHF soil spring calculation (Ref. 2.2.10). In this calculation a series of global springs, 3 translational and 3 rotational, are computed. This calculation uses these global springs to compute “local” springs to be placed under each node in the foundation mat mesh. The method of determining these “local” springs is discussed in the Seismic Analysis and Design Approach Document (Ref. 2.2.5). Details of the soil spring calculation are given in section 6.4.2.

In the SAP 2000 model, the 2 joint link elements - Nonlinear Link (Ref. 2.2.14) - were used to represent the vertical compression only springs. The gap element option in the SAP 2000 link definition was used such that the link had stiffness in compression as defined above and had zero stiffness when the gap element is open, i.e. in tension. To create the 2 joints used to define the link element, the nodes used to define the foundation finite element mesh were copied down an arbitrary distance of 2 ft. The joint identifications at these locations were assigned joint numbers Gm, …, Gn to match with the joint numbers on the foundation mesh, Bm,…,Bn. Such that Gm and Bm have the same X and Y coordinate and thus are located along the same vertical line. Link elements would then connect Gm-Bm, ……,Gn-Bn.

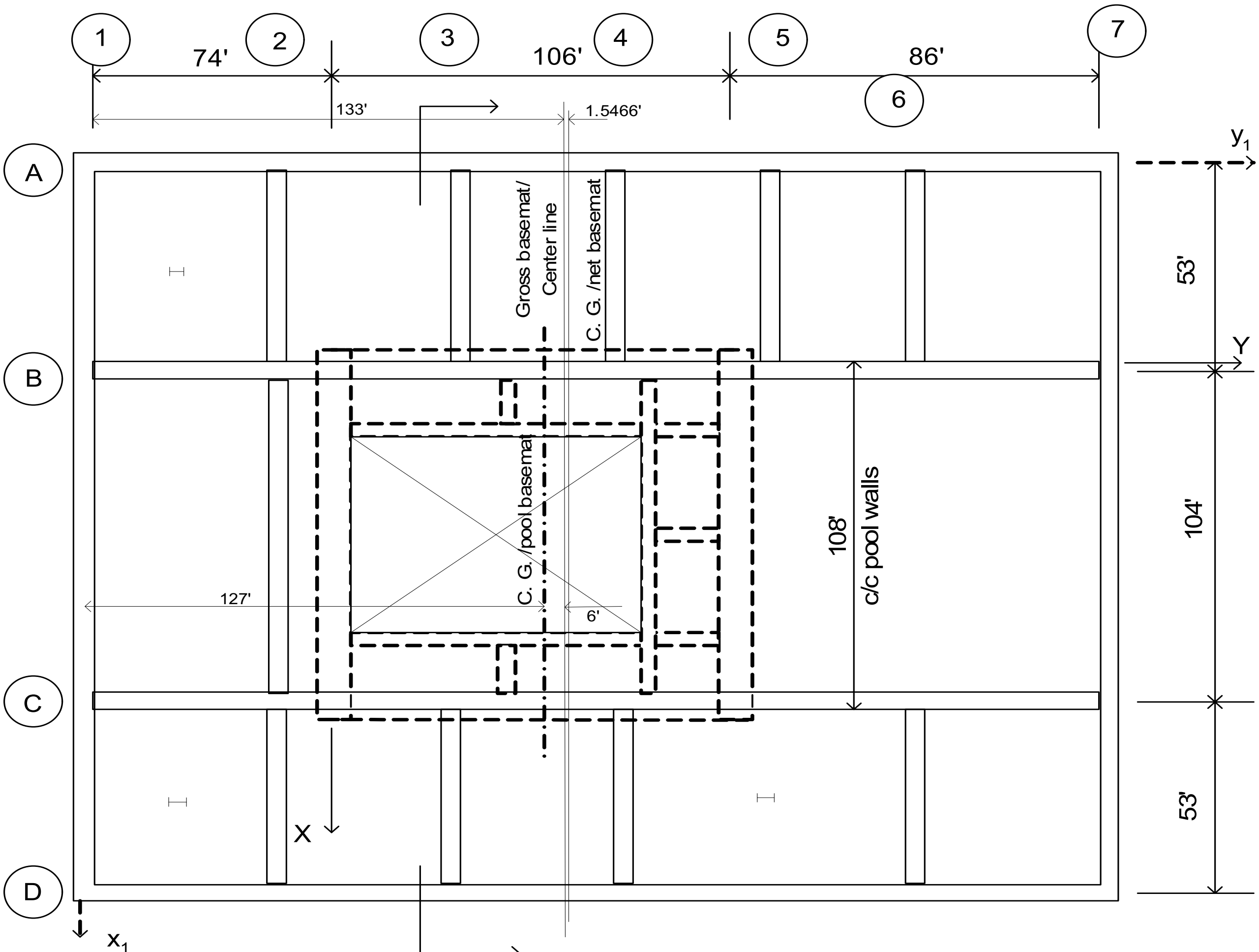
Horizontal springs are used to model friction under the foundation mat as the part of the lateral resistance of the soil. The horizontal soil springs are located at the foundation mesh nodes, Bm, …, Bn. These springs are linear springs since friction occurs in any direction. Those nodes with the soil springs are shown in figures 8 & 9. As the total seismic lateral force acting at the WHF exceeds the friction, the lateral earth pressure (be it seismic or passive) will be activated as lateral resisting force.

In the *WHF Mass Properties* (Ref. 2.2.8) the masses of the grade foundation, the lower half of the wall on the grade foundation, and the substructure were lumped at their respective centers of gravity. In this analysis the foundation mat and the substructure are included in the finite element model and thus their masses are included in the model through the density assigned to the concrete shell elements. The density assigned to the partial shear walls needs to be factored to obtain the correct wall weights. Thus the normal concrete density of 150 pcf is multiplied by a factor, such as 20’/6’ or 3.333, resulting in a value of 150*3.333 = 500 pcf used to define the wall element concrete density (see Table 3 for detail). The dead loads and live loads on elevation 32’ and above will be applied through their corresponding centers of gravity (Table 3).

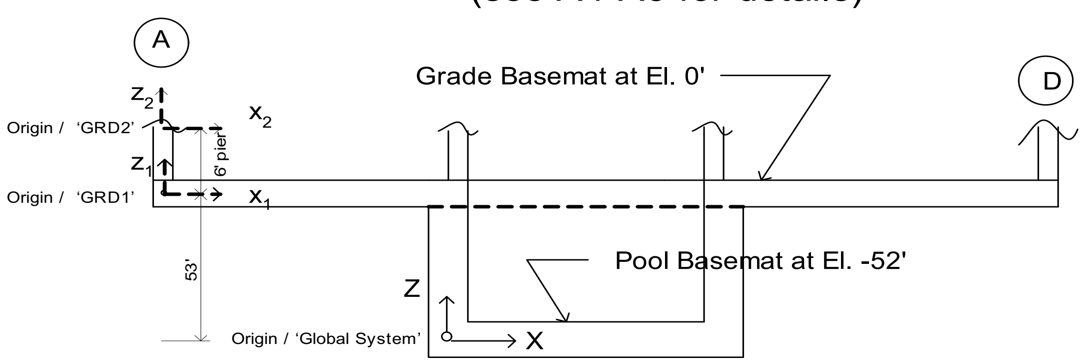
The loadings imposed on the WHF, which are discussed in section 6.2, will be then applied to the SAP 2000 model. SAP 2000 model files, input and output are included in attachment D.

Figure 7 WHF Foundation Layout

(see assumption 3.1.6)



Plan at El. 0'
(see A4-A5 for details)



Cross-section
(see A5 for details)

6.4.2 Boundary Conditions

As stated in section 6.4.1, the boundary conditions for the foundation mats were modeled using non-linear compression only springs based on the 5E-4 upper bound 35' alluvium case, (Ref. 2.2.10) for the vertical springs, and linear springs in the horizontal directions. The soil springs used in the seismic analysis (Ref. 2.2.9) were global springs, meaning that only two (0' & -52') support points were used in the seismic analysis model. The foundation finite element model will have a support point located at each node of the foundation mat mesh. Therefore, the global spring must be converted into individual springs applied to each node of the foundation finite element mesh. The spring constants for pool basemat from calculation 050-CYC-CY00-00100-000-00A (Ref. 2.2.10), sheet 38, will be used. According to assumption 3.1.3, the foundation moduli/springs corresponding to the soil springs of the 'upper bound estimate, 35' alluvium of 5E-4 annual exceedance frequency' are calculated below. Note that the x- and y- axes are rotated between Ref. 2.2.10 and this calculation.

The SADA (Ref. 2.2.5) Appendix C recommends equations for calculating horizontal and vertical soil springs per unit area from global spring values:

$k_h = K_h / A = k_x$ or k_y and $k_v = K_v / A$ or $k_v = K_\psi / I_A$

where k_h and k_v are the horizontal and vertical spring per unit area, respectively. K_h, K_v and K_ψ are the global horizontal (K_X / K_Y), vertical (K_Z) springs and rotational spring ($K\varphi$), respectively. A and I_A are the area and moment of inertia of the basemat area about the centroid.

(A) Pool Basemat

The equivalent foundation springs from Ref. 2.2.10, are :

$K_{z1} = 3.020 \times 10^7$ klf ; $K_{x1} = 2.480 \times 10^7$ klf ; $K_{y1} = 2.505 \times 10^7$ klf

$K_{\psi z1} = 1.289 \times 10^{11}$ k-ft/rad ; $K_{\psi x1} = 9.391 \times 10^{10}$ k-ft/rad; $K_{\psi y1} = 9.743 \times 10^{10}$ k-ft/rad

With pool basemat (model) dimensions 106'x108', $A = 106 \times 108 = 11448$ ft^2

$I_x = 108 \times 106^3 / 12 = 10719144$ ft^4 and $I_y = 106 \times 108^3 / 12 = 11127456$ ft^4

The corresponding foundation moduli are :

Horizontal:

$k_{x1} = 2.480 \times 10^7 / 11448 = 2166$ kcf ,

$k_{y1} = 2.505 \times 10^7 / 11448 = 2188$ kcf

$k_{h1} = 1.289 \times 10^{11} / (10719144+11127456) = 5900$ kcf

Vertical:

$k_{z1} = 3.020 \times 10^7 / 11448 = 2638$ kcf

$k_{z1} = 9.391 \times 10^{10} / 10719144 = 8761$ kcf

$k_{z1} = 9.743 \times 10^{10} / 11127456 = 8756$ kcf

For a given load condition the stiffer spring will yield lower bending moment and shear forces in the basemat; therefore, use $k_{x1} = 2166$ kcf, $k_{y1} = 2188$ kcf and $k_{z1} = 2638$ kcf, which will give more conservative (upper bound) design forces for the basemat design.

Figure 8 shows the nodes on the pool basemat where their tributary spring restraints and foundation moduli will be located. For horizontal springs, k_{x1} and k_{y1} are input to SAP 2000 as foundation moduli. For vertical compression springs, k_{z1} has to be input as individual spring restraint by its tributary area. The calculation is shown in Attachment D, PMAT_jt_masslnk.xls, which is originally generated by SAP2000 automatically to lump the basemat mass to the nodes involved from their tributary areas and is conveniently utilized here.

(B) Grade Basemat

Similarly, the spring constants for grade basemat from calculation 050-CYC-CY00-00100-000-00A (Ref. 2.2.10), sheet 38, will be used. The corresponding foundation moduli/springs corresponding to the soil springs of the 'upper bound estimate, 35' alluvium of 5E-4 annual exceedance frequency' are calculated below. Note that the x- and y- axes are rotated between Ref. 2.2.10 and this calculation.

From Ref. 2.2.10, the equivalent foundation springs are :

$K_{z1} = 2.037 \times 10^7$ klf ; $K_{x1} = 1.705 \times 10^7$ klf ; $K_{y1} = 1.624 \times 10^7$ klf

$K_{\psi z1} = 6.633 \times 10^{11}$ k-ft/rad ; $K_{\psi x1} = 6.138 \times 10^{11}$ k-ft/rad; $K_{\psi y1} = 4.255 \times 10^{11}$ k-ft/rad

With grade basemat (model) dimensions 266'x210' and pool pit sizes 106'x108' (see Figure 7), the geometric properties:

$A_{net} = 266\text{x}210 - 106\text{x}108 = 55860 - 11448 = 44412 \text{ ft}^2$; $e = 11448\text{x}6 / 44412 = 1.5466$ ft

$I_x = 210\text{x}266^3/12 + 55860\text{x}1.5466^2 - 108\text{x}106^3/12 - 11448\text{x}(6+1.5466)^2 = 3.1813\text{x}10^8 \text{ ft}^4$

$I_y = 266\text{x}210^3/12 - 106\text{x}108^3/12 = 1.9416\text{x}10^8 \text{ ft}^4$

the corresponding foundation moduli are :

Horizontal:

$k_{x1} = 1.705 \times 10^7 / 44412 = 383.9$ kcf ,

$k_{y1} = 1.624 \times 10^7 / 44412 = 365.7$ kcf

$k_{h1} = 6.633 \times 10^{11}/(3.1813\text{x}10^8 + 1.9416\text{x}10^8) = 1295$ kcf

Vertical:

$k_{z1} = 2.037 \times 10^7 / 44412 = 458.7$ kcf

$k_{z1} = 6.138 \times 10^{11}/3.1813\text{x}10^8 = 1929$ kcf

$k_{z1} = 4.255 \times 10^{11}/1.9416\text{x}10^8 = 2191$ kcf

For a given load condition the stiffer spring will yield lower bending moment and shear forces in the basemat; therefore, use $k_{x1} = 383.9$ kcf, $k_{y1} = 365.7$ kcf and $k_{z1} = 458.7$ kcf, which will give more conservative (upper bound) design forces for the basemat design.

Similarly, Figure 9 shows the nodes on the grade basemat to share their tributary spring restraints and foundation moduli. For horizontal springs, k_{x1} and k_{y1} are input to SAP 2000 as foundation moduli. For vertical compression springs, k_{z1} has to be input as individual spring restraint by its tributary area. The calculation is shown in Attachment D, GMAT_jt_masslnk.xls.

(C) Shear Walls on Grade Basemat

As discussed in section 6.4.1, the effects of the shear walls on top of grade basemat are to stiffen the foundation mat in this model. A 6 ft tall shell element will be used to model the inter-weave shear walls attached to the grade basemat. Using SAP2000, the multiple stick model from Ref. 2.2.9 will then be constrained to the top of these 6 ft shell elements.

Figure 8 POOL BASEMAT NODES

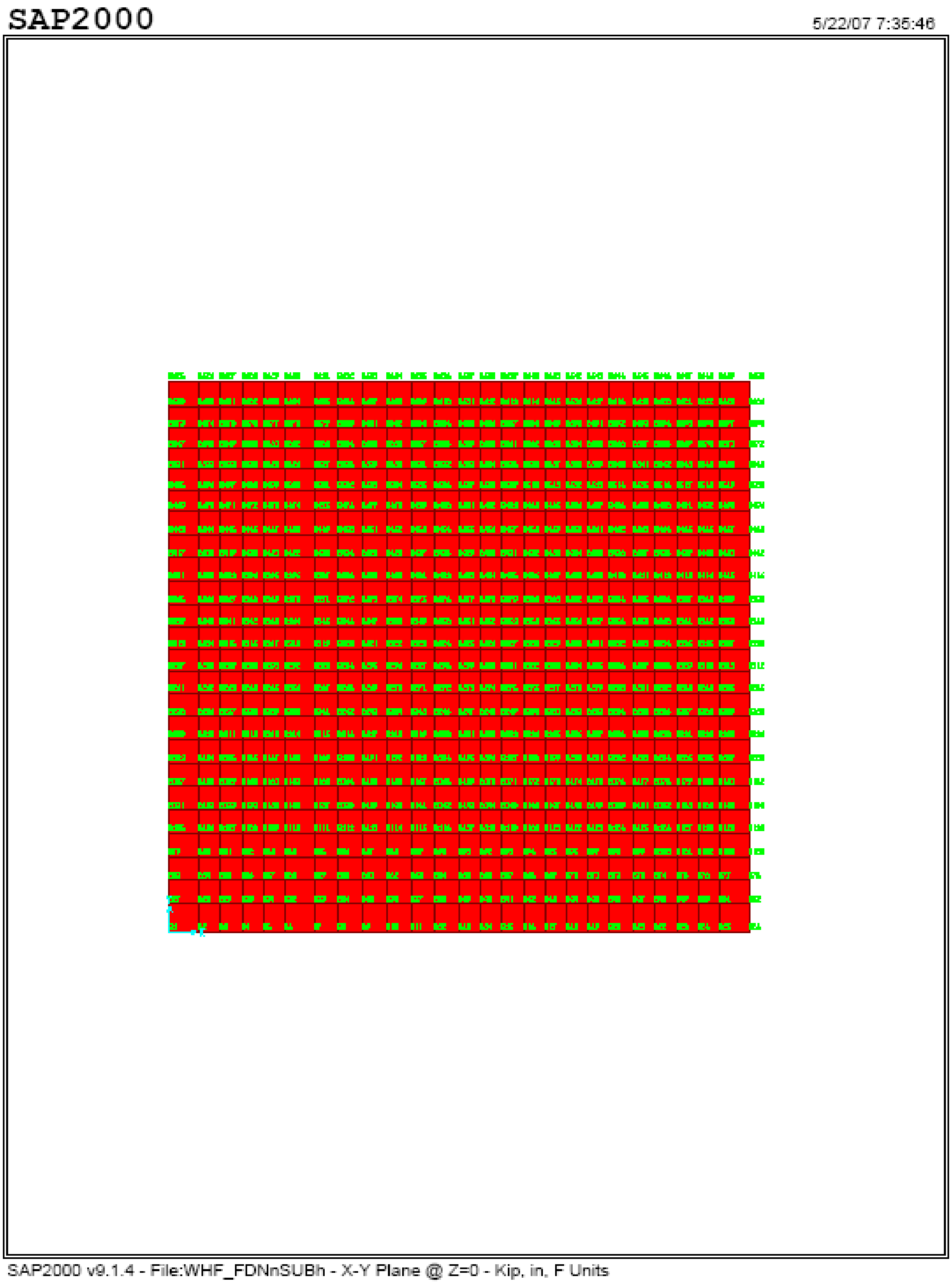
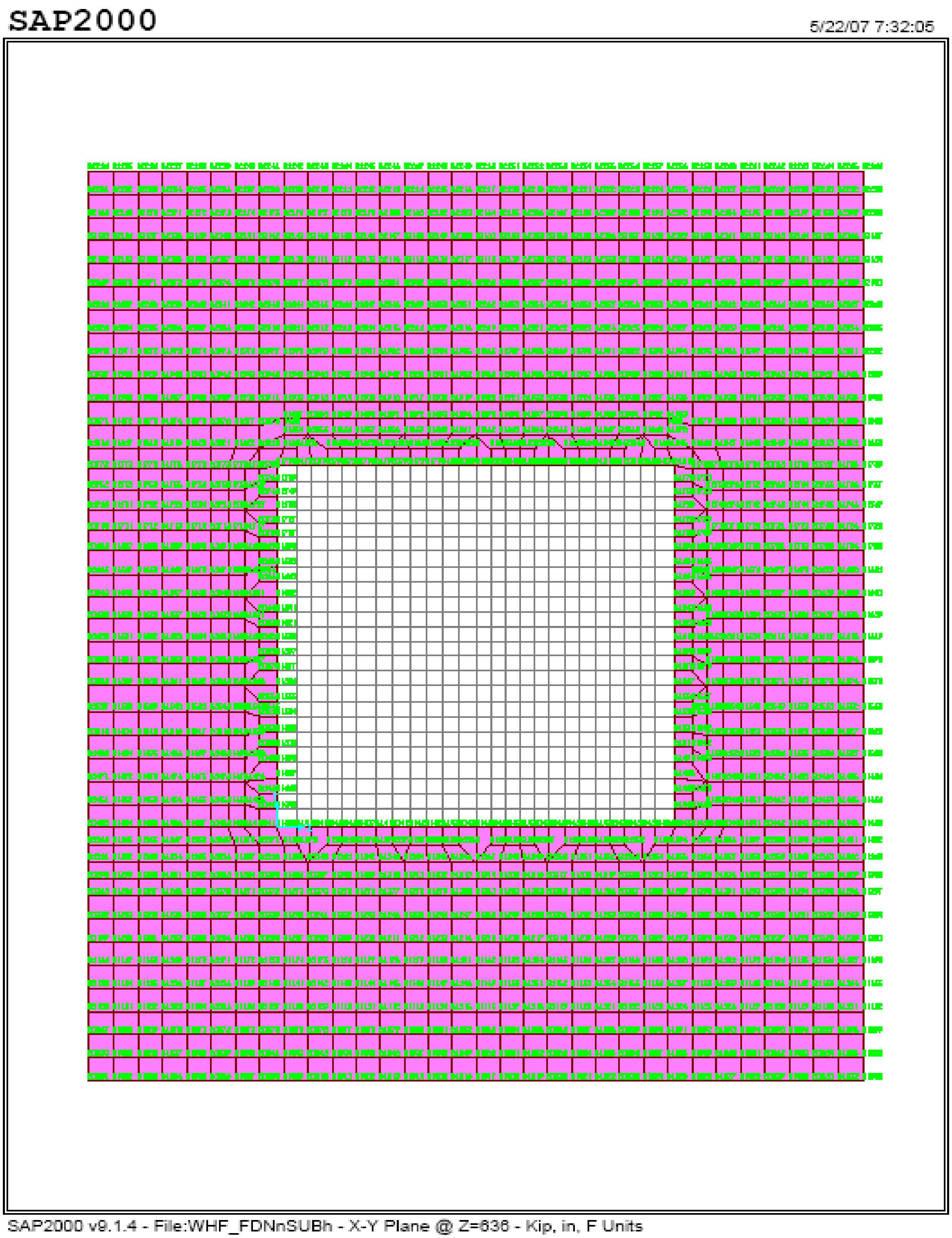


Figure 9 GRADE BASEMAT NODES



6.5 SAP 2000 ANALYSIS RESULTS

6.5.1 Base Reactions

The base reactions (refer to Attachment D, WHF_FDN&SUB_BSREAC.xls) of all loading combinations are listed below:

TABLE 8 : Base Reactions								
OutputCase	CaseType	StepType	GlobalFX	GlobalFY	GlobalFZ	GlobalMX	GlobalMY	GlobalMZ
Text	Text	Text	Kip	Kip	Kip	Kip-ft	Kip-ft	Kip-ft
LS101	Combination		3	0	394589	20956752	-19915921	-124
LS102	Combination		3	0	296256	15732474	-14953158	-93
LS103	Combination		2	0	279156	14841308	-14086654	-88
NS101	NonStatic	Last Step	-75867	-76721	123341	14135032	-19435650	1484317
NS102	NonStatic	Last Step	-77097	-68936	211630	18314715	-23158943	1691768
NS103	NonStatic	Last Step	-74204	29325	132289	4282083	-18939195	6140543
NS104	NonStatic	Last Step	-137549	55108	220531	7912163	-23821679	10731259
NS105	NonStatic	Last Step	-67521	-85571	122221	19578328	-13186497	585981
NS106	NonStatic	Last Step	-61370	-77778	210457	23754866	-16722411	521861
NS107	NonStatic	Last Step	38773	-69738	129555	18434747	-2534517	-5133168
NS108	NonStatic	Last Step	44919	-61941	217787	22610877	-6070207	-5196740
NS109	NonStatic	Last Step	-65349	-70699	62712	10148351	-10021405	745897
NS110	NonStatic	Last Step	-56308	35355	71610	291967	-9337659	5130901
NS111	NonStatic	Last Step	40942	-54863	70045	9004436	630685	-4972878
NS112	NonStatic	Last Step	49983	51191	78943	-851949	1314438	-587875
NS113	NonStatic	Last Step	68061	-37138	141722	11278399	4928245	-6077908
NS114	NonStatic	Last Step	126072	-29347	229965	15455211	2202638	-8890624
NS115	NonStatic	Last Step	77102	68914	150624	1422579	5611803	-1693113
NS116	NonStatic	Last Step	83243	76700	238912	5602262	2072682	-1756540
NS117	NonStatic	Last Step	-44914	61920	144467	-2873583	-11476933	5195394
NS118	NonStatic	Last Step	-38768	69717	232698	1302547	-15012623	5131822
NS119	NonStatic	Last Step	61375	77757	151796	-4017572	-824729	-523207
NS120	NonStatic	Last Step	67526	85549	240033	158965	-4360643	-587327
NS121	NonStatic	Last Step	-49978	-51213	283311	20589243	-18861578	586529
NS122	NonStatic	Last Step	-40937	54842	292209	10732858	-18177825	4971533
NS123	NonStatic	Last Step	56312	-35377	290644	19445327	-8209481	-5132247
NS124	NonStatic	Last Step	65354	70678	299541	9588943	-7525735	-747243
NS201	NonStatic	Last Step	-75867	-76721	99770	12906388	-18290452	1484317
NS202	NonStatic	Last Step	-77097	-68936	188058	17086071	-22013745	1691768
NS203	NonStatic	Last Step	-74204	29325	108718	3053439	-17793997	6140543
NS204	NonStatic	Last Step	-119920	37119	196958	7229878	-22140893	8825482
NS205	NonStatic	Last Step	-67521	-85571	98649	18349684	-12041298	585981
NS206	NonStatic	Last Step	-61370	-77778	186886	22526222	-15577213	521861
NS207	NonStatic	Last Step	38773	-69738	105984	17206103	-1389319	-5133168
NS208	NonStatic	Last Step	44919	-61941	194215	21382233	-4925009	-5196740
NS209	NonStatic	Last Step	-65349	-70699	39141	8919707	-8876207	745897
NS210	NonStatic	Last Step	-56308	35355	48039	-936677	-8192461	5130901
NS211	NonStatic	Last Step	40942	-54863	46474	7775791	1775883	-4972878
NS212	NonStatic	Last Step	49983	51191	55371	-2080593	2459636	-587875
NS213	NonStatic	Last Step	68061	-37138	118151	10049755	6073443	-6077908
NS214	NonStatic	Last Step	126073	-29346	206392	14226484	3348078	-8890574
NS215	NonStatic	Last Step	77102	68914	127053	193935	6757001	-1693113
NS216	NonStatic	Last Step	83243	76700	215341	4373618	3217880	-1756540
NS217	NonStatic	Last Step	-44914	61920	120896	-4102227	-10331735	5195394
NS218	NonStatic	Last Step	-38768	69717	209127	73903	-13867425	5131822
NS219	NonStatic	Last Step	61375	130566	128225	-6071066	320469	2328509
NS220	NonStatic	Last Step	67526	85549	216462	-1069679	-3215445	-587327
NS221	NonStatic	Last Step	-49978	-51213	259740	19360599	-17716379	586529
NS222	NonStatic	Last Step	-40937	54842	268637	9504214	-17032627	4971533
NS223	NonStatic	Last Step	56312	-35377	267072	18216683	-7064283	-5132247
NS224	NonStatic	Last Step	65354	70678	275970	8360298	-6380537	-747243
ENVLS1	Combination	Max	3	0	394589	20956752	-14086654	-88
ENVLS1	Combination	Min	2	0	279156	14841308	-19915921	-124
ENVNS1	Combination	Max	126073	130566	299541	23754866	6757001	10731259
ENVNS1	Combination	Min	-137549	-85571	39141	-6071066	-23821679	-8890624

6.5.2 Contour Plots of Vertical Deflection, Moment, Shear and Force.

Based on the WHF Foundation and Subgrade Structure model discussed in section 6.4, with loadings described in sections 6.2 & 6.3, contour plots of vertical deflection, element's moment, shear and force are output from the SAP2000 analysis, which is included in Attachment C to facilitate evaluation and design.

6.5.3 Maximum Bearing Pressure on Foundation Mat.

The bearing pressure on the mat is determined by multiplying the maximum vertical deflections of joints connecting the link elements by the equivalent subgrade moduli. The max bearing pressure is a localized stress concentration based on linear elastic characteristics. A reasonable area weighted average pressure is also calculated and indicated :

For grade basemat : k_{z1} = 458.7 kcf (sheet 33)

P_{max} = 0.0113x458.7 = 5.18 ksf, at north-east corner, JT #B2234, load case LS103, i.e. D+L+F+H (sheet C4)

P_{avg} = 0.00778x458.7 = 3.57 ksf (see Attachment D, Grade Basemat Deflections, row 63309)

P_{max} = 0.0324x458.7 = 14.9 ksf, at north-west corner, JT #B1001, enveloped seismic load case ENVNS1 (sheet C5),

which is load case NS116 (sheet C6). The corresponding area weighted average

P_{avg} = 0.0102x458.7 = 4.68 ksf (see Attachment D, Grade Basemat Deflections, row 63309)

For pool basemat : k_{z1} = 2638 kcf (sheet 32)

P_{max} = 0.007x2638 = 18.5 ksf, at north-west corner, JT #B1, load case LS103, i.e. D+L+F+H (sheet C7)

P_{avg} = 0.00425x2638= 11.2 ksf (see Attachment D, Pool Basemat Deflections, row 32509)

P_{max} = 0.0159x2638 = 41.9 ksf, at north-west corner, JT #B1, enveloped seismic load case ENVNS1 (sheet C8),

which is load case NS124 (sheet C9). The corresponding area weighted average

P_{avg} = 0.0068x2638 = 17.9 ksf (see Attachment D, Pool Basemat Deflections, row 32509)

From the *Supplemental Soils Report* (Ref. 2.2.6), Figure B6-2, the allowable bearing capacity of the large foundation mats is 50 ksf > 41.9 ksf > 14.9 ksf; therefore, the maximum bearing pressure on the grade basemat and pool basemat are less than the allowable.

6.6 CONCRETE REINFORCEMENT DESIGN

6.6.1 Bending Moments, Shear, and Membrane Forces in Foundation Mat

Stress contour plots for the grade & pool basemats, pool shelf, retaining walls, pool walls and pool separation walls are included in Attachment C. The contour plots represent the bending moments M11 & M22, twisting moment M12, shear forces V13 & V23, axial forces F11 & F22 and in-plane force F12. For further information on the definitions of M11, M22, M12, V13, V23, F11, F22 and F12 refer to Figure 10 and Figure 11.

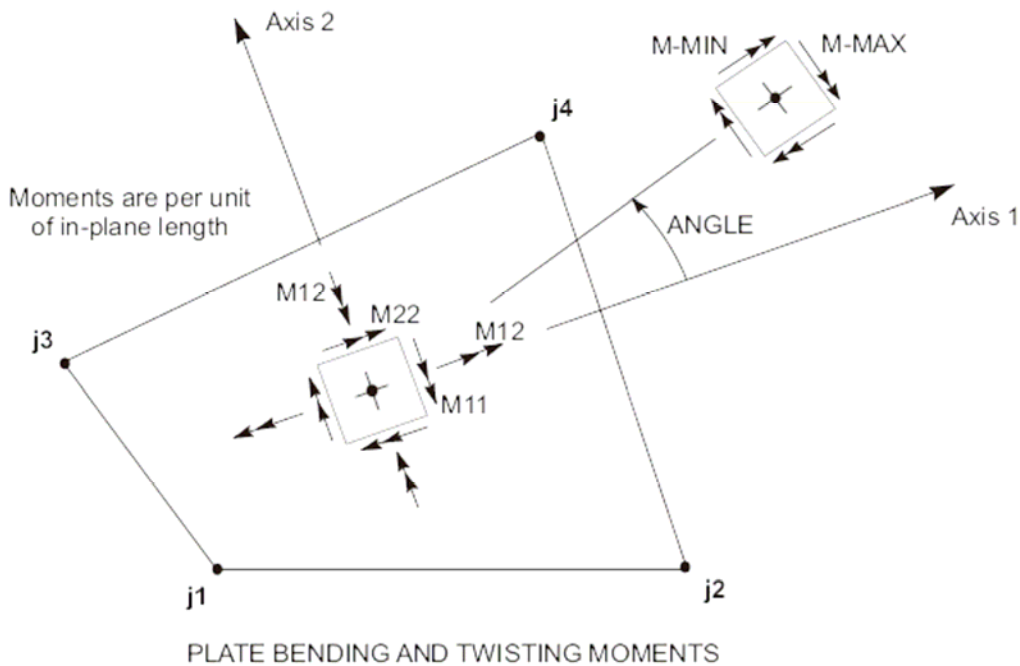


Figure 10 Shell Element Bending and Twisting Moments (Ref. 2.2.27)

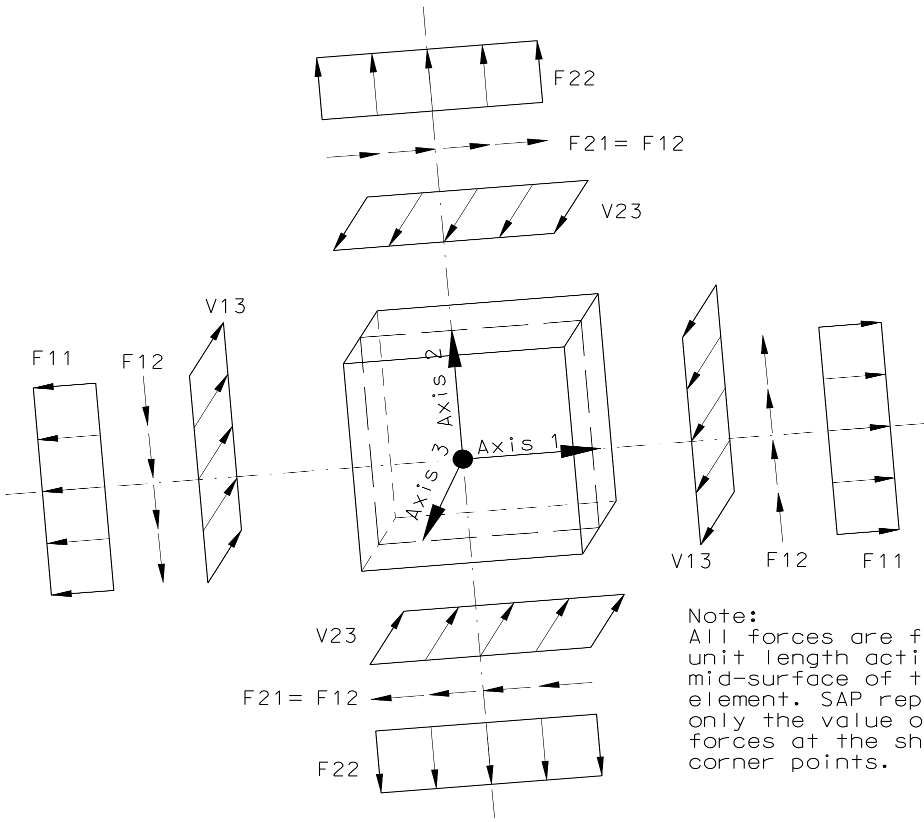


Figure 11 Shell Element Membrane and Shear Forces (Ref. 2.2.27)

SAP 2000 stress averaging at joints is used to develop the contour plots. SAP2000 computes the resultant force/ moment values at a joint by merging the element resultants tributary to that joint. The maximum moment and shear values are derived graphically by visual inspection of the force contours (Assumption 3.2.1 & Attachment C). Maximum and minimum moment and shear values are documented in Tables 10 and 11, respectively.

Since the South Retaining wall is identical to North Retaining wall and South Pool wall is identical to North Pool wall, evaluation and design will be made for North Retaining wall and North Pool wall in the following sections.

The project design criteria document (Reference 2.2.4, section 4.2.11.6.2) specifies a concrete compressive strength f'_c of 4,000 psi or 5,000 psi for Important to Safety (ITS) structures. A concrete strength of 5,000 psi will be used for this calculation.

Determine the effective structural depth "d" by using one layer #18 each-way at top and bottom of basemat:
For depth of basemat = 72" concrete cover = 3" #18 rebar outside diameter d_b =2.5"

d = 72" -3" (cover) – 1.5 d_b = 72-3-1.5*2.5 = 72- 6.4 = 65.25"

Calculate the moment capacity by using one layer #18 @ 12" on-center, A_s = 4.0 in^2/ft:

$$\phi M_n = \phi A_s f_y (d - \frac{a}{2}) \geq M_u$$ ACI 349-01, Chapter 10 (Reference 2.2.13)

where f_y = 60 ksi, ϕ =0.9 for flexural, & b = 12" $a = \frac{A_s f_y}{0.85 f'_c b} = \frac{4\ in^2 (60\ ksi)}{0.85\ (5\ ksi)(12")} = 4.7\ in$

$$\phi M_n = \frac{0.9\ (4\ in^2)(60\ ksi)(65.25" - \frac{4.7"}{2})}{12\ in/ft} = 1132\quad ft - k/ft$$

Determine the shear capacity of concrete requirement per ACI 349-01, Chapter 11 (Reference 2.2.13, Eq-11-3). ϕ =0.85 for shear

$$\phi V_c = \phi 2 \sqrt{f'_c}\ bd = \frac{0.85\ (2)\ \sqrt{5000\ psi}\ (12\ in/ft)(65.25\ in)}{1000\ lb/kip} = 94.1\ k/ft$$

Determine the shear capacity of #5 ties at 12" on center each way: s = 12 inches A_v = 0.31 in^2/ft

$\phi V_S = \phi A_v {*} f_y d / s$ (Ref. 2.2.13, Eq-11-15)

ϕV_S = 0.85 *0.31*60*65.25 /12 =85.97k/ft

Shear Capacity of concrete + ties ϕ Vn= 94.1 +85.97 = 180 kips / ft

Similarly, calculations are made for other concrete members with their reinforcements, i.e. 8 ft pool foundation, 4 ft Pool shelf, 8 ft exterior retaining walls, 4 ft pool walls and 2 ft pool separation wall, and listed in Table 9.

Moment and shear capacity was compared to demand from the contour plots for M11, M22, V13 and V23. At the same location of M11 and M22, the twisting moment M12 was added to demand values for M11 and M22 to determine demand. The following Tables 10 & 11 summarize the maximum demand for moments and shears in comparison to the capacity Table 9. Moment values are based on values at the face of the intersecting members and shear is based on values "d" from face of the intersecting members (Ref.2.2.13, Section 11.1.3.1).

Note that the membrane axial force acting at the wall is not included with the maximum/minimum flexural bending moments in the design of the reinforced concrete wall because that the maximum/minimum flexural bending moments acting at wall are usually not occurring at the same location as for the maximum/minimum membrane axial force by assumption 3.1.4.

From the contour plots, the maximum shear V13, does not occur in the same location as maximum V23. Therefore, additional shear reinforcement for V23 is not required beyond what is provided for maximum V13 or V23 and conversely.

For the foundation plan, wall elevation and section showing flexural and shear reinforcement, see Figures 12 thru 16.

TABLE 9 REINFORCED CONCRETE MEMBER CAPACITIES

Memb	Thickness	Rebar		Effective		ΦMn	ΦVc	ΦVs	ΦVn	Remarks
	t (in)	Flexural	Shear	d (in)	a (in)	k-ft/ft	k/ft	k/ft	k/ft	
Fdn	72	#18 @ 12"	#5 @12"	65.25	4.71	1132	94.1	86.0	180.1	
Fdn	96	#18 @ 12"	--	89.25	4.71	1564	128.7		128.7	
				88	6.54	2120	126.9		126.9	*** add bottom face E-W inner layer #11@12"
Pool shelf, 24		#11 @ 12"	--	19.5	1.84	130	28.1		28.1	
Ext. Wall	west, 96"	#18 @ 12"	#5 @12"	89.25	4.71	1564	128.7	117.6	246.3	
				88	6.54	2120	126.9	115.9	242.9	*** add inside face vert inner layer #11@12"
	east, 96"	#18 @ 12"	--	89.25	4.71	1564	128.7		128.7	
	north, 96"	#18 @ 12"	#5 @12"	89.25	4.71	1564	128.7	117.6	246.3	Use same for S. Exterior wall
Pool Wall	north, 48"	#14 @ 12"	#5 @12"	43.5	2.65	427	62.7	57.3	120.1	Use same for S. Pool wall
	east, 48"	#11 @ 12"	--	43.5	1.84	299	62.7		62.7	Use same for other subgrade interior walls, UNO
	N. sep., 24"	#11 @ 12"	--	19.5	1.84	130	28.1		28.1	Use same for Pool W. separation wall

Note that for 48" thick concrete member, effective d = 48-4.5 (nominal) = 43.5" & As = 2.25 in^2 for #14@12" and As = 1.56 in^2 for #11@12".
for 24" thick, d = 24 - 4.5 = 19.5" & As = 1.56 in^2 for #11@12"
*** #11 @12" will be added as inner layer. The corresponding d = 96 - 3 -1.5(2.5) - 1.25 = 88.0" & As = 5.56 in^2.

TABLE 10 MOMENT D/C RATIOS

Memb	Thickness	Enveloped Moment (k-ft/ft)				Sum		Sum		Capacity	D/C	Remarks /Reference
	t (in)	M11	M12	M22	M12	Mu=M11+M12		Mu=M22+M12		ΦMn		
Fdn	72	577 / -790	30.9 / 20	849 / -923	24.5 / 42.7	608	-810	874	-966	1132	0.85	C10-C15
Fdn	96	1003 / -641	59 / 61.4	/ -445	/ 7.4	1062	-702	--	-452	1564	0.68	C20-C25
				1394 /	67 /			1461		2120	0.69	
Pool shelf, 24		85.5 /-45.6	3.1 / 3.7	116 / -78.2	2.1 / 1.4	89	-49	118	-80	130	0.90	C30-C35
Ext. Wall	west, 96"	885 / -1054	27/ 9.3	890 /	33.2 /	912	-1063	923	--	1564	0.68	C40-C45
				/ -1670	/ 8.5				-1678	2120	0.79	
	east, 96"	517 / -905	18.3 / 34.4	521 / -879	90 / 55.8	535	-939	611	-935	1564	0.60	C56-C61
	north, 96"	678 /-1029	65 / 58.6	819 / -1182	57.7 / 23.8	743	-1088	877	-1206	1564	0.77	C72-C77
Pool Wall	north, 48"	333 / -159	3.7 / 45	158 / -81	10.3 / 12	337	-204	168	-93	427	0.79	C88-C93
	east, 48"	165 / -89	13.9 / 3.3	106 / -44	6.9 / 19.6	179	-92	113	-64	299	0.60	C104-C109
	N. sep., 24"	43.5 / -43.4	13 / 13	34.7 / -36.5	13 / 13	57	-56	48	-50	130	0.44	C120-C125

Note that value of M12 can be either plus or minus.

TABLE 11 SHEAR D/C RATIOS

Memb	Thickness	Enveloped Shear (k/ft)		Capacity	D/C	Remarks / Reference
	t (in)	V13	V23	ΦVn		
Fdn	72	126 / -126	114 / -148	180.1	0.82	C16-C19
	96	99.3 / -92.4	103 / -81	126.9	0.81	C26-C29
Pool shelf, 24		24.1 / -23.1	35 / -24.7	28.1	1.24	C36-C39, slab change to 48" later
Ext. Wall	west, 96"	137 / -133	190 / -142	242.9	0.78	C46-C49
	east, 96"	104 / -101	107 / -93	128.7	0.83	C62-C65
	north, 96"	128 / -126	151 / -126	246.3	0.61	C78-C81
Pool Wall	north, 48"	64.6 / -62.6	29.4 / -34	120.1	0.54	C94-C97
	east, 48"	39.8 /-35.5	33.6 / -33.4	62.7	0.63	C110-C113
	N. sep., 24"	12 / -12	12.1 / -13.6	28.1	0.48	C126-C129

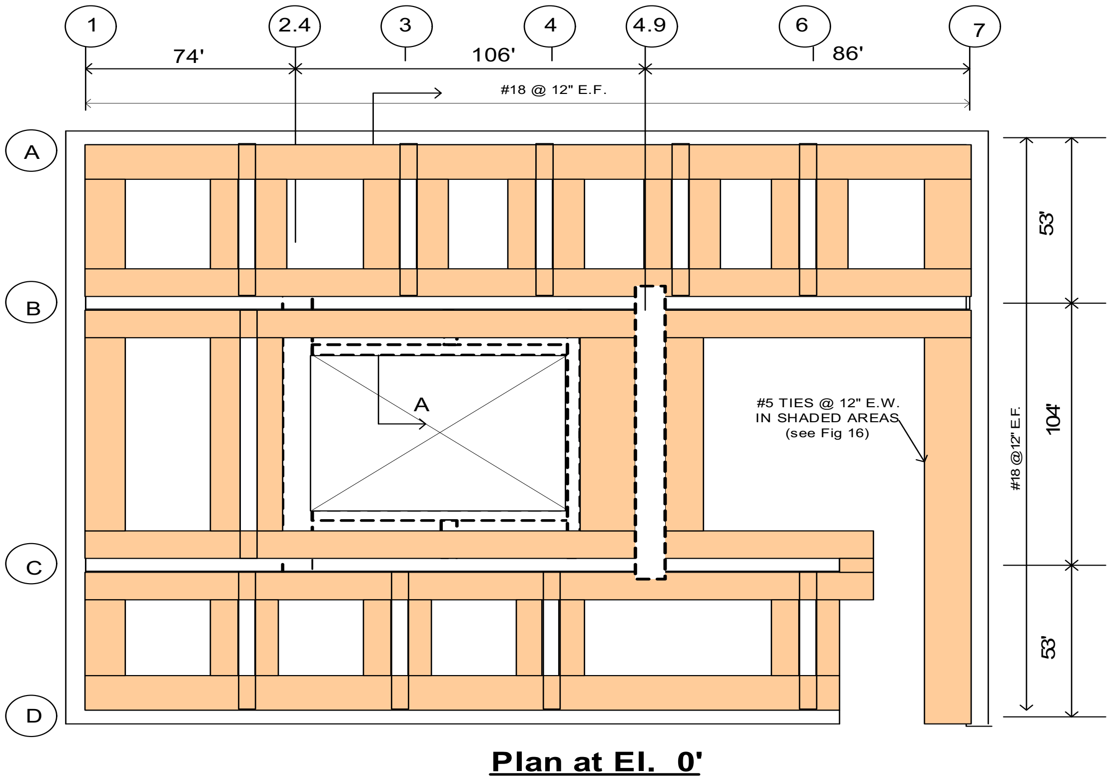


Figure 12 Grade Basemat Reinforcement (6' thick concrete)

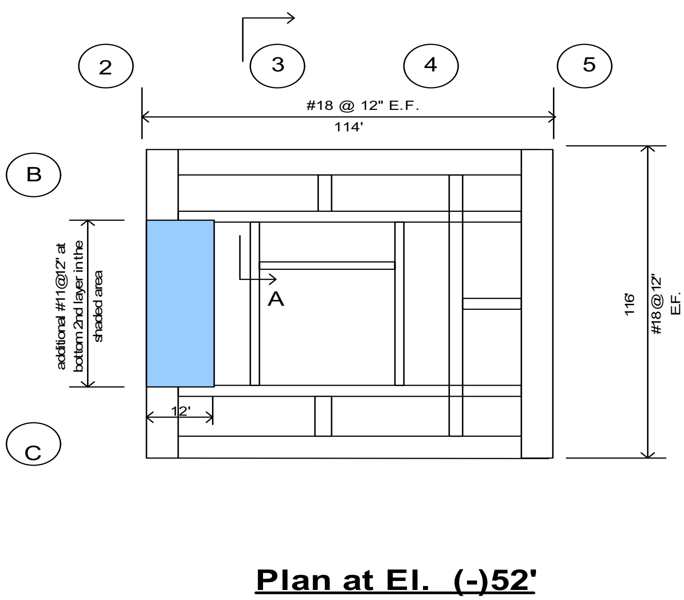


Figure 13 Pool Basemat Reinforcement (8' thick concrete)

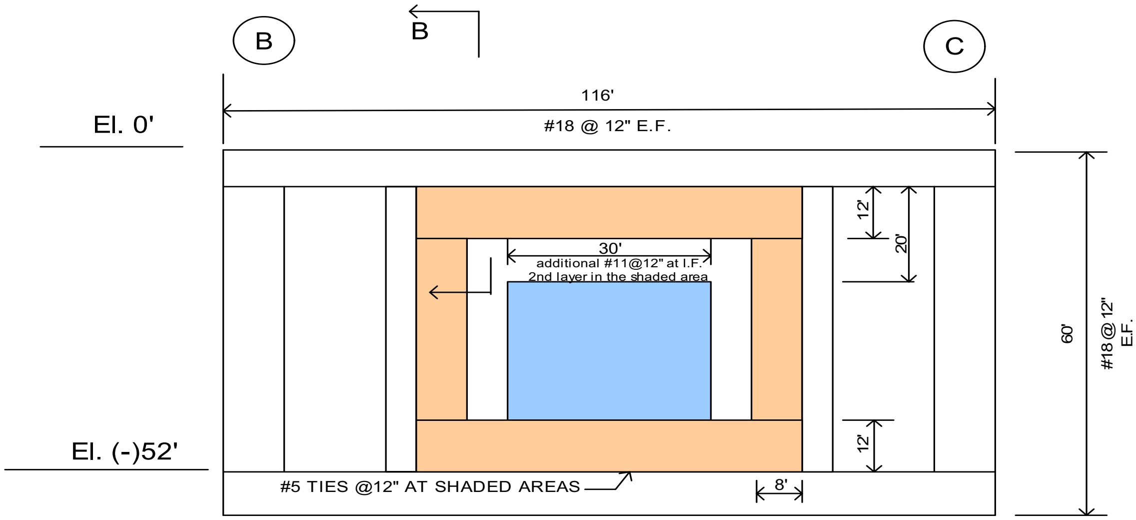


Fig 14 West Retaining Wall Elev.
(8' thick concrete)

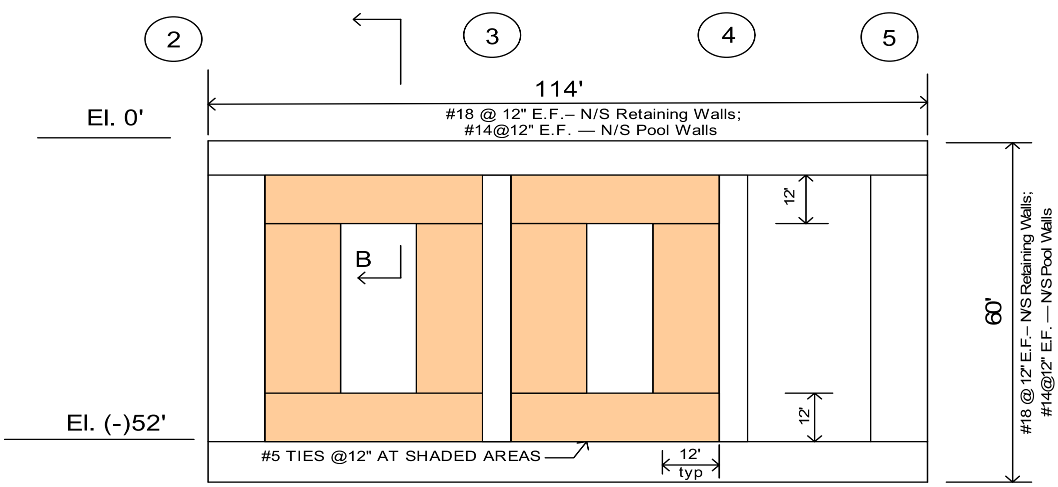


Fig 15 Wall Elev.
North/South Retaining Wall (8' thick)
North/South Pool Wall (4' thick)

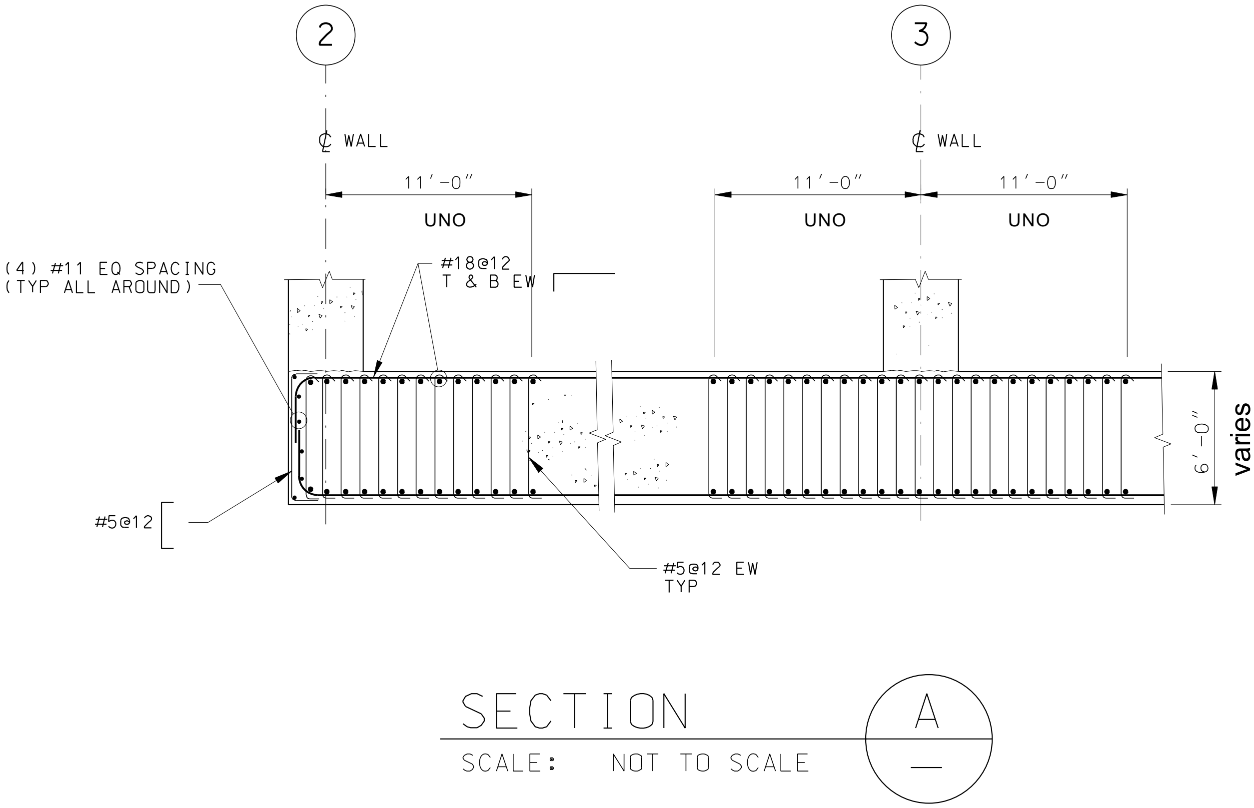


Figure 16 Concrete Cross Section

6.7 STRUCTURAL STABILITY EVALUATION

This section evaluates the stability of the structure for sliding and overturning under the design basis ground motions. *Seismic Analysis and Design Approach Document* (Section 11.1 of Ref. 2.2.5) is used for the evaluation of sliding and overturning stability. Sliding displacement is calculated by using the approximate method suggested in Appendix A of the ASCE /SEI 43-*05 Seismic Design Criteria for Structures, Systems and Components in Nuclear Facilities* (Ref.2.2.12).

6.7.1 CHECK SLIDING STABILITY

6.7.1.1 Static Check

The static resistance to sliding V_R, is a function of the soil cohesion c, the resistance due to passive soil pressure P_P *L and the available friction force Nμ. Therefore $V_R = c + N\mu + P_P *L$.

Using c = 0 (for granular soils) minimizes the sliding resistance and results in an upper bound value for the computed soil displacement.
N = Normal compressive force (sum of vertical reactions on gap elements) from SAP2000 model for any combination listed in section 6.3.

μ = Friction coefficient for alluvium = 0.81 (Reference 2.2.5, Table 6-2) Use 0.5 for conservatism.

L = width of grade basemat = 214' (Least dimension of the building for max sliding effect) & for pool width L' = 116'

P_P = passive soil pressure on the grade basemat & subgrade structure (pool) = $K_P \rho H^2 /2$ (Ref.2.2.25, Eq.11-5)

K_P = Coefficient of passive resistance = 4.4 (alluvium, Reference 2.2.5, Table 6-2)

ρ = Moist Density =114 pcf (alluvium, Reference 2.2.5, Table 6-2)

H = Thickness of grade basemat = 6' H' = 60-6 = 54' for subgrade structure, pool

$P_P = 4.4*114*6^2 /2000 = 9.029$ kips/ft $P_P' = 4.4*114*(6+60)*54 /2000 = 893.85$ kips/ft (trapezoid pressure)

P_P *L = 214*9.029 = 1932 kips P_P' *L' = 116*893.85 = 103687 kips

The total weight of the WHF = 269692 kips = W (Ref.2.2.8)

V_R (Total) = 269692*0.5 + 1932 + 103687 = 240465 kips

Equivalent coefficient of friction = V_R /W = 240645 /269692 = 0.892

Check static factor of safety against sliding for load combinations NS104 for max. lateral forces & NS209 for min. Vertical loads as shown in Table 8:

D+L+F+H+1.0EX-0.4EY-0.4EZ (NS104) & 0.9D+F+H+0.4EX+0.4EY+1.0EZ (NS209)

These cases will envelope the most critical loading combinations. From analysis output the base reactions for both cases are summarized as follows. (see Table 8) :

NS104	Σ FZ = 220531 kips	NS209	Σ FZ = 39141 kips
	Σ FX = 137549 kips		Σ FX = 65349 kips
	Σ FY = 55108 kips		Σ FY = 70699 kips

Resultant lateral force on foundation = $(FX^2 + FY^2)^{1/2} = \Sigma F$

ΣF = 148178 kips ΣF = 96275 kips

V_R = 0.892*220531 = 196714 kips V_R = 0.892*39141 =34914 kips

Factor of safety against sliding = Resistance / lateral force = $V_R / \Sigma F = FS_s$

FS_s = 196714 /148178 = 1.33 > 1.1 O.K. FS_s = 34914 /96275 = 0.363 < 1.1

Section 11.1.1 of Ref. 2.2.5 recommends a minimum factor of safety of 1.1. Therefore calculate predicted magnitude of building displacement using ASCE /SEI 43-05 (Ref. 2.2.12)

6.7.1.2 Sliding displacement

Equivalent Coefficient of sliding friction μ = 0.892

Peak vertical ground acceleration (Ref 2.2.2) A_V = 0.52g

Effective coefficient of friction $\mu_e = \mu\ (1\text{-}0.4\ A_V /g) = 0.706$ (Ref.2.2.12, Eq. A-1)

Sliding coefficient $C_S = 2\ \mu_e\ g = 1.413g$ (Ref.2.2.12, Eq. A-2)

Best estimate of sliding distance, $d_s = C_S / (2\ \pi\ f_{es})^2$ (Ref.2.2.12, Eq. A-3)

f_{es} = the lowest natural frequency at which the horizontal 10% damped vector spectral acceleration SA_{VH} equals $C_{S,}$

$SA_{VH} = [SA_{H1}^2 + 0.16\ SA_{H2}^2]^{1/2}$ (Ref.2.2.12, Eq. A-4)

SA_{H1} and SA_{H2} are the 10% damped spectral accelerations for each of the two orthogonal horizontal components. Since $SA_{H1} = SA_{H2}$, $SA_{VH} = 1.08\ SA_{H1} = C_S$ SA_{H1} = 1.413g / 1.08 = 1.308g

Horizontal spectral accelerations for 10% damped condition are well below 1.308g for all frequency ranges. Therefore it can be concluded that the building will not slide when subjected to the 10% damped spectral accelerations.

However an estimate of upper bound displacement value can be made by substituting the natural frequency (first mode frequency) for f_{es}. The lowest natural frequency, f_{es}, is taken as the frequency at peak spectral acceleration for 10% damping for the displacement calculation. From Ref. 2.2.5, Table 6.5, it is the period T = 0.1 sec; therefore, f_{es} = 1/T = 10 hz.

$d_s = C_S / (2\ \pi\ f_{es})^2 = 1.413g / (2\ \pi\ 10)^2$ = 0.0115 ft = 0.138” say 0.2 inches.

Considering a factor of safety of 2 (Reference 2.2.5, section 11.1) any connection that enters the structure should have a flexibility of at least 2 d_s or 0.4 inches.

6.7.2 CHECK OVERTURNING STABILITY

6.7.2.1 Static Check – Overturning

Since the building plan dimension in the north /south direction 214' is appreciably less than east /west dimension 270', overturning in the X direction will be the critical condition. The two cases to be considered are: full seismic load in the X direction coupled with 40% seismic load in the upward (+Z) direction and full seismic load in the upward (+Z) direction with 40% seismic load in the X direction. The governing load cases are shown below.

Load combination NS201, 0.9D+F+H+1.0EX+0.4EY+0.4EZ will have the maximum overturning loads in the weak direction with associated restoring forces.

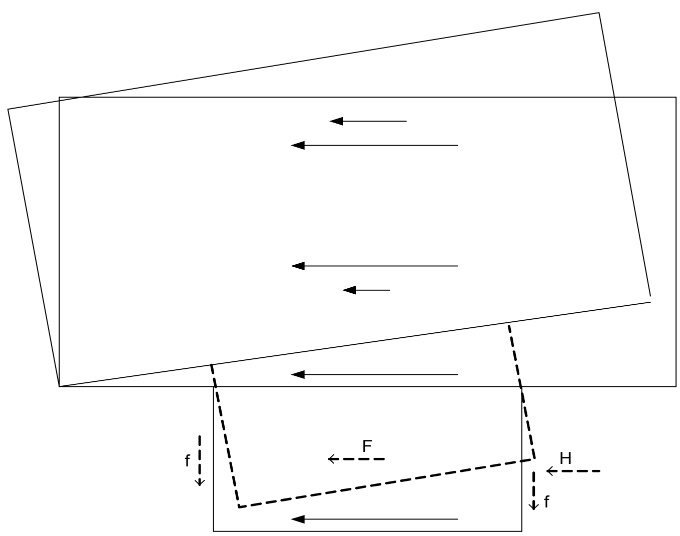
Load combination NS209, 0.9D+F+H+0.4EX+0.4EY+1.0EZ, will have the least restoring force with associated overturning loads.

As the building overturns, it will topple against the grade edge as shown in figure below. The acting forces below the grade level will become the resisting forces. The fluid load F composes of impulsive and convective forces as shown in Figure 6 can be calculated :

$$M_{RF} = 2((0.49+0.102)*48'/2*(52-6-2*48'/3)+(2.946+0.002)*48'/2*(52-6-48'/3))98' = 455009 \text{ k-ft}$$

Due to the embedment of the subgrade structure, the lateral earth pressure H and soil skin friction f will help in resisting the overturning effects. However those resisting forces will not be accounted for conservatism.

Table 3 shows Summary of Mass and Center of Mass and Table 7 shows the applied joint loads for these two cases. From these loads the Overturning and restoring moments are calculated for Load cases NS201 and NS209 as follows.



OVERTURNING & RESISTING MOMENTS

Load case NS201

JT	Elev. ft	Moment arm, h (ft)	Fx kips	M_{OT} k-ft	Moment arm, d (ft)	W kips	Ez kips	Fz = 0.9W-Ez kips	M_R k-ft
J6099	100	106	13664.4	1448426	22.1	7861.7	5193.6	1882	41591
J5099	80	86	48736.6	4191348	113	48100.7	15568.8	27722	3132567
J4099	40	46	35151.1	1616951	121.1	44617	15749	24406	2955603
J3099	32	38	11402.8	433306	27.2	15333.5	7803.8	5996	163101
J2099	0	6	56334.8	338009	106.2	101438	24643.3	66651	7078326
J1099	-52	-46	29144.5	-1340647	105.2	52341.1	9609.4	37498	3944746
			Σ	6687393				Σ	17315933

Load case NS209

JT	Elev. ft	Moment arm, h (ft)	Fx kips	M_{OT} k-ft	Moment arm, d (ft)	W kips	Ez kips	Fz = 0.9W-Ez kips	M_R k-ft
J6099	100	106	6516.9	690791	22.1	7861.7	7905.5	-830	-18342
J5099	80	86	21913.4	1884552	113	48100.7	34924.8	8366	945339
J4099	40	46	16758.4	770886	121.1	44617	31759.5	8396	1016731
J3099	32	38	5733.9	217888	27.2	15333.5	12549.4	1251	34020
J2099	0	6	25864.2	155185	106.2	101438	57365.8	33928	3603196
J1099	-52	-46	13289.7	-611326	105.2	52341.1	22089.2	25018	2631872
			Σ	3107977				Σ	8212816

The factor of safety against overturning FS_R = Restoring moment / Overturning moment.

For load case NS201 FS_R =17315933+455009/ 6687393 = 2.66 > 1.1 O.K.
For load case NS209 FS_R = 8212816+455009/ 3107977= 2.79 > 1.1 O.K.

It shows that the WHF structure has adequate safety margin against overturning.

7.0 RESULTS AND CONCLUSIONS

7.1 RESULTS

The primary results of this calculation are:

- Design Forces and Moments:

  The contour plots shown in Attachment C represent the shear forces and bending moments that will occur in the WHF grade basemat and subgrade structure under the design loading combinations. The contours were used to obtain the design forces for designing the preliminary flexural and shear reinforcement for the WHF basemats and subgrade structure walls.

- Foundation Mat Flexural Reinforcement:

  The basemats were designed for the maximum bending moments, M_u , of 966 and 1461 k-ft/ft for grade and pool basemats, respectively. The preliminary reinforcement selected was #18 bars at 12 inch spacing on center, each way, top and bottom. This reinforcement yields the design moment capacities, ϕM_n , are 1132 and 1564 k-ft/ft for grade and pool basemat, respectively. However, an additional inner layer of #11@ 12" is provided locally to reinforce the pool with a total design moment capacity, ϕM_n , 2120 k-ft/ft. Therefore, the flexural demand/capacity ratio = M_u / ϕM_n = 0.85 and 0.68 for the grade and pool basemat, respectively

- Basemat Shear Reinforcement:

  The max shear V_u for the pool basemat is 103 k/ft, which is less than the concrete capacity, $\phi V_{c,}$ of 126.9 k/ft; therefore, no shear reinforcement is required. For the grade basemat the max shear V_u is 148 k/ft, which exceeds the concrete capacity, $\phi V_{c,}$ of 94.1 k/ft, which indicates that shear reinforcement is required in some areas of the mat. The preliminary shear reinforcement selected was #5 bars at 12 inch spacing on center, which provides 0.31 in^2/ft. The total shear capacity including steel capacity is 180.1 k/ft. Therefore, the shear demand/capacity ratio = 103/126.9 = 0.81 and 148/180 = 0.82 for the pool and grade basemat, respectively.

  The grade basemat reinforcement is designed for uniform thickness of 6 feet. Where thickness is reduced due to rail or other pockets the slab will be designed to account for local variations during final design.

- Retaining Walls:

  The retaining walls were designed for the maximum bending moments, M_u , of 1206, 939 and 1678 k-ft/ft for north /south, east and west walls, respectively. The preliminary reinforcement selected was #18 bars at 12 inch spacing on center, each way, both faces. This reinforcement yields the design moment capacity, ϕM_n , is 1564 k-ft/ft. However, an additional inner layer of #11@ 12" is provided locally to reinforce the west retaining wall with a total design moment capacity, ϕM_n , 2120 k-ft/ft. Therefore, the flexural demand/capacity ratio = M_u / ϕM_n = 0.77, 0.60 and 0.79 for the north /south, east and west walls, respectively.

  For east retaining wall, the max shear V_u is 107 k/ft, which is less than the concrete capacity, $\phi V_{c,}$ of 128.7 k/ft; therefore, no shear reinforcement is required. The max shear V_u are 151 and 190 k/ft for the north/south and west retaining walls, respectively. Both exceed the concrete capacity, $\phi V_{c,}$ of 128.7 k/ft, which indicates that shear reinforcement is required in some areas of the wall. The preliminary shear reinforcement selected was #5 bars at 12 inch spacing on center, which provides 0.31 in^2/ft. The total shear capacity including steel capacity are 246.3 and 242.9 kips/ft for north and west retaining walls, respectively. Therefore, the shear demand/capacity ratio = 107/128.7 = 0.83, 151/246.3 = 0.61 and 190/242.9= 0.78 for the east, north and west retaining walls, respectively.

- Pool Walls:

  The pool walls were designed for the maximum bending moments, M_u, of 337 and 179 k-ft/ft for north /south and east walls, respectively. The preliminary reinforcement selected was #14 bars @ 12" and #11 @ 12", each way, both faces for north/south and east walls, respectively. This reinforcement yields the design moment capacities, ϕM_n, 427 and 299 k-ft/ft respectively. Therefore, the flexural demand/capacity ratio = M_u / ϕM_n = 0.79 and 0.60 for the north /south and east walls, respectively.

  For east pool wall, the max shear V_u is 39.8 k/ft, which is less than the concrete capacity, $\phi V_{c,}$ of 62.7 k/ft; therefore, no shear reinforcement is required. The max shear V_u is 64.6 for the north/south pool walls, exceeding the concrete capacity, $\phi V_{c,}$ of 62.7 k/ft, which indicates that shear reinforcement is required in some areas of the wall. The preliminary shear reinforcement selected was #5 bars at 12 inch spacing on center, which provides 0.31 in^2/ft. The total shear capacity including steel capacity is 120 kips/ft for north/south walls. Therefore, the shear demand/capacity ratio = 39.8/62.7 = 0.63 and 64.6/120 = 0.54 for the east and north/south walls, respectively.

- Pool Shelf Slab and Separation Walls:

  The maximum bending moment, M_u, are 118 and 57 k-ft/ft for the Pool Shelf Slab and Separation Wall, respectively. The preliminary reinforcement selected was #11 bars @ 12 inch each way, both faces. This reinforcement yields the design moment capacity, ϕM_n, 130 k-ft/ft. Therefore, the flexural demand/capacity ratio = M_u / ϕM_n = 0.91 and 0.44 for the Pool Shelf Slab and Separation Wall, respectively.

  The max shears V_u are 35 and 13.6 k/ft for pool shelf slab and north separation wall, respectively. The 13.6 k/ft is less than the corresponding concrete capacity, $\phi V_{c,}$ 28.1k/ft; therefore, no shear reinforcement is required. The 35 k/ft for the pool shelf slab which will be increased to 48" thick with shear capacity of 62.7 k/ft. Therefore, the shear demand/capacity ratio = 35/62.7 = 0.56 and 13.6/28.1 = 0.48 for the Pool Shelf Slab and Separation Wall, respectively.

- Soil Bearing Pressures:

  Under static condition, the max soil bearing pressures are 5.18 and 18.5 ksf for grade and pool basemat, respectively. Under seismic condition, the max soil bearing pressures are 14.9 and 41.9 ksf for grade and pool basemat, respectively . These are less than the 50 ksf allowable bearing pressure for the mat foundation from Ref.2.2.6, Figure B6-2.

- Foundation Overturning Stability Check:

  The structure has a static factor of safety against overturning of about 2.7 which indicates that the structure is stable against overturning.

- Foundation Sliding Stability Check:

  A static margin of safety against sliding could not be demonstrated for the WHF, which means that the structure might slide when subjected to the 2000 year return period earthquake. The sliding stability was then evaluated based on the reserve energy method described in Appendix A.1 of the ASCE /SEI 43-05 (Ref.2.2.12), to determine the distance d_s that the structure will slide. Although the reserve energy method did not indicate that the WHF would slide under DBGM-2 seismic loads the sliding distance was conservatively calculated to be 0.2 inches.

7.2 CONCLUSIONS

Results from this calculation demonstrate that a reasonable design is achieved for the imposed design loads for the grade and pool basemats and the subgrade walls. The maximum shear forces and moments occur at the edge, central, and corner areas of the structure, as expected. The maximum shear forces occur at the face of supports (walls or basemats), as expected. The preliminary flexural and shear reinforcement is indicative of the basemats and walls thickness and provides a reasonable design.

The structure is stable against overturning.

Based on the reserve energy method described in Appendix A.1 of Reference 2.2.12, the structure may slide when subjected to the maximum 2000 year return period earthquake. A safety factor of two will be applied to the computed sliding displacement d_s of 0.2 inches. Therefore, 0.4 inches ($2d_s$) will be used when evaluating the flexibility of any commodities or utilities entering the structure, or clearance of any adjacent structures such as the Entrance Vestibule. This methodology ensures that no unacceptable interaction will occur between the structure and any ITS commodities entering the structure, or any adjacent structure, under seismic loading conditions.

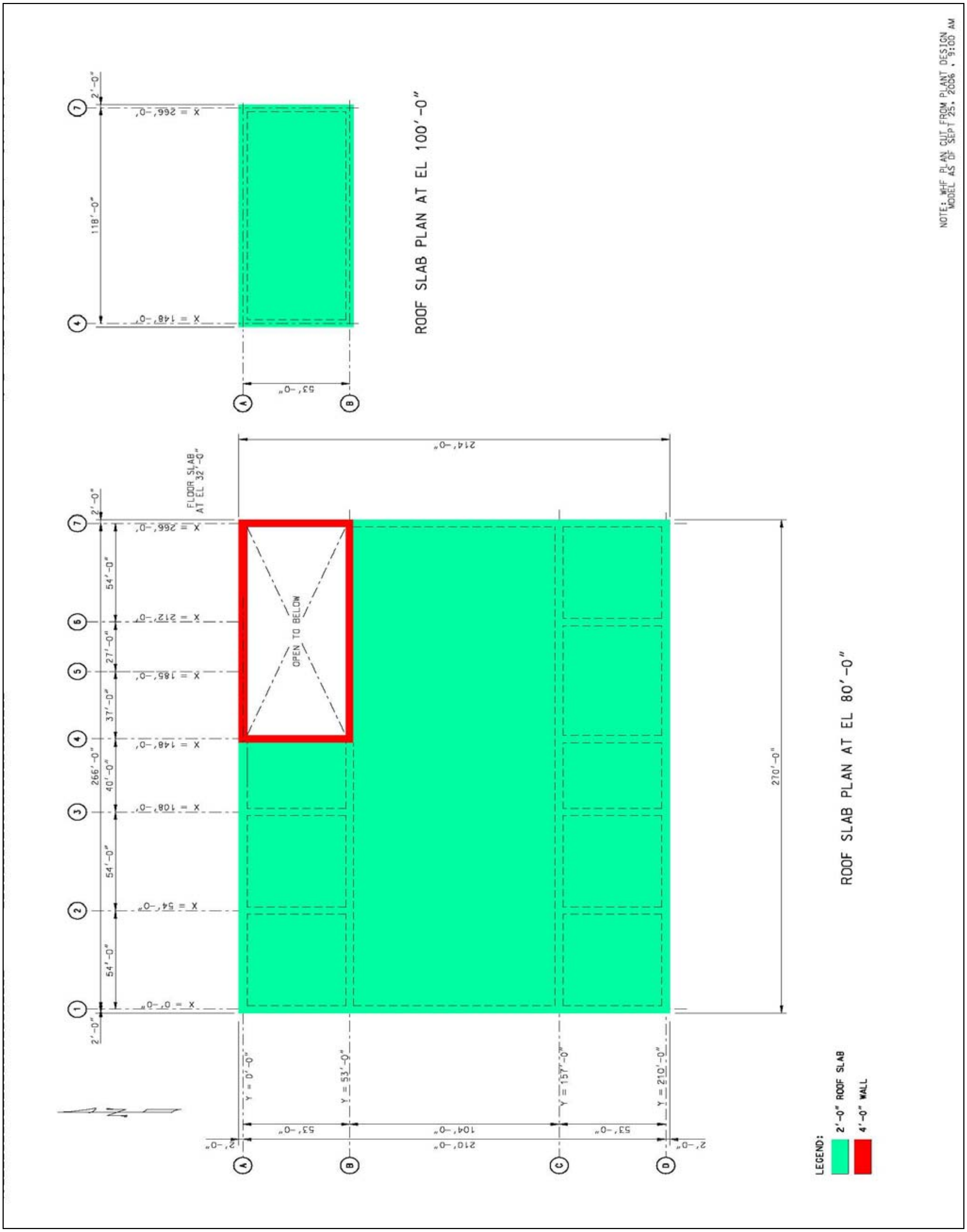
These calculation outputs are reasonable compared to the inputs and are suitable for their intended use.

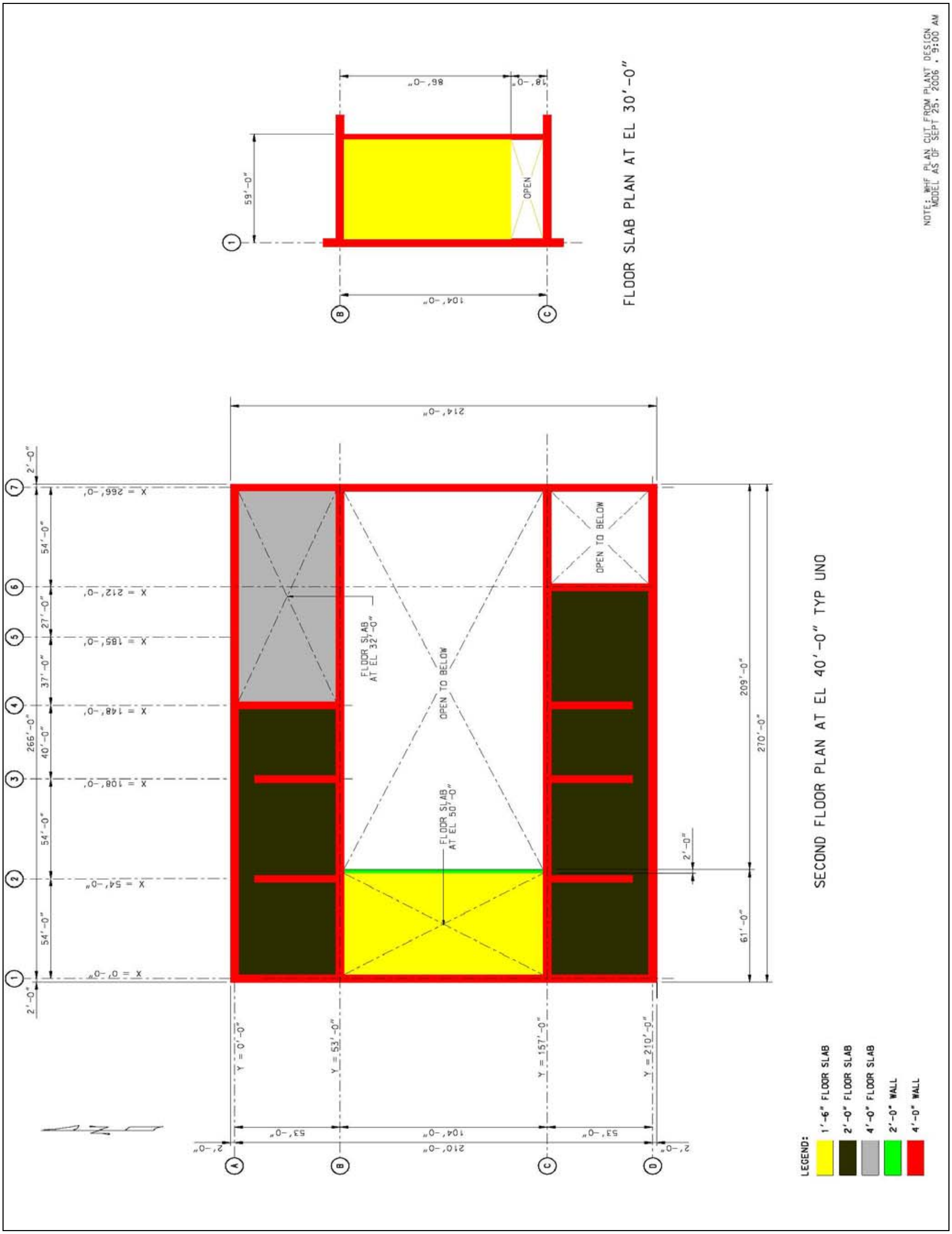
ATTACHMENT A

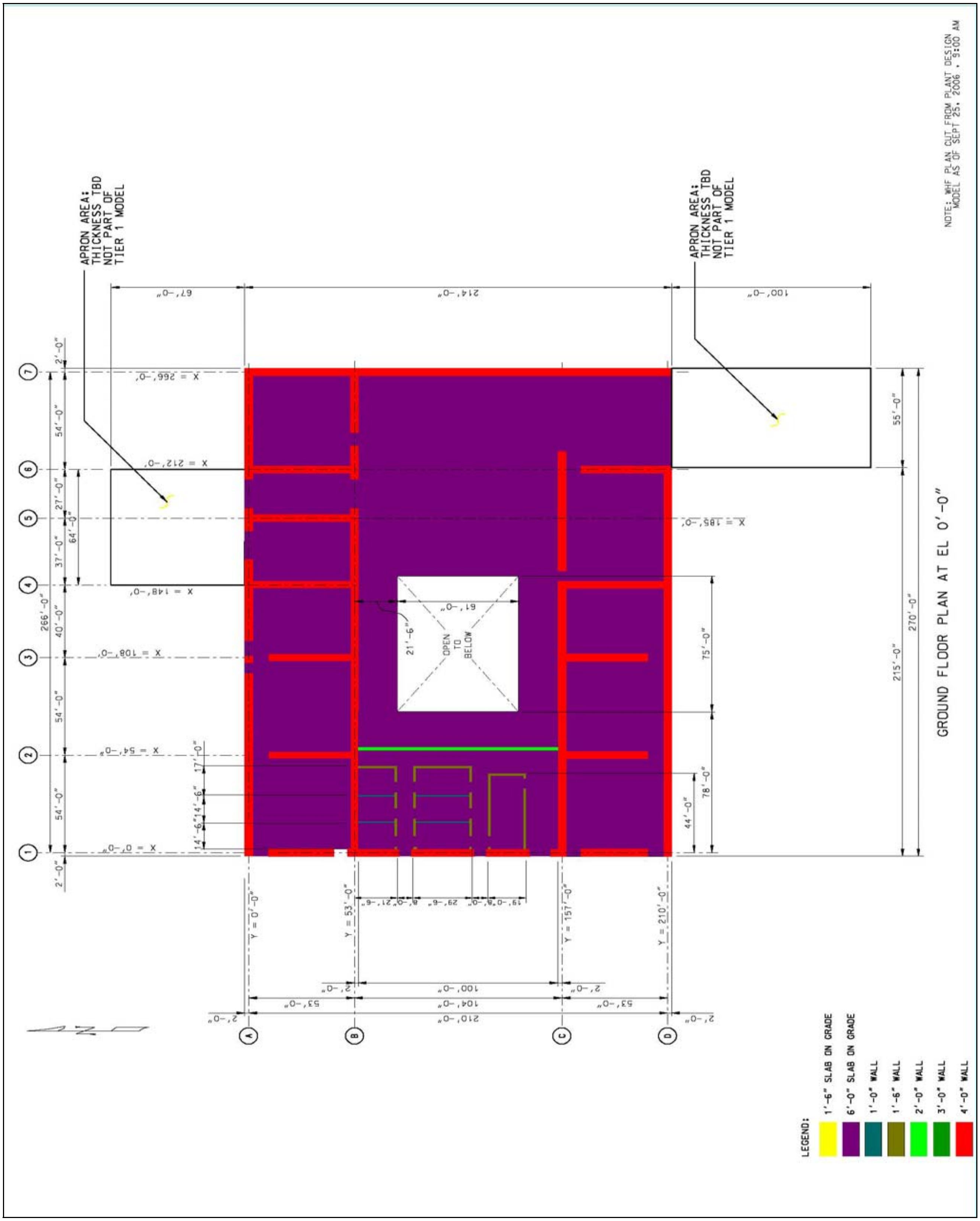
WET HANDLING FACILITY

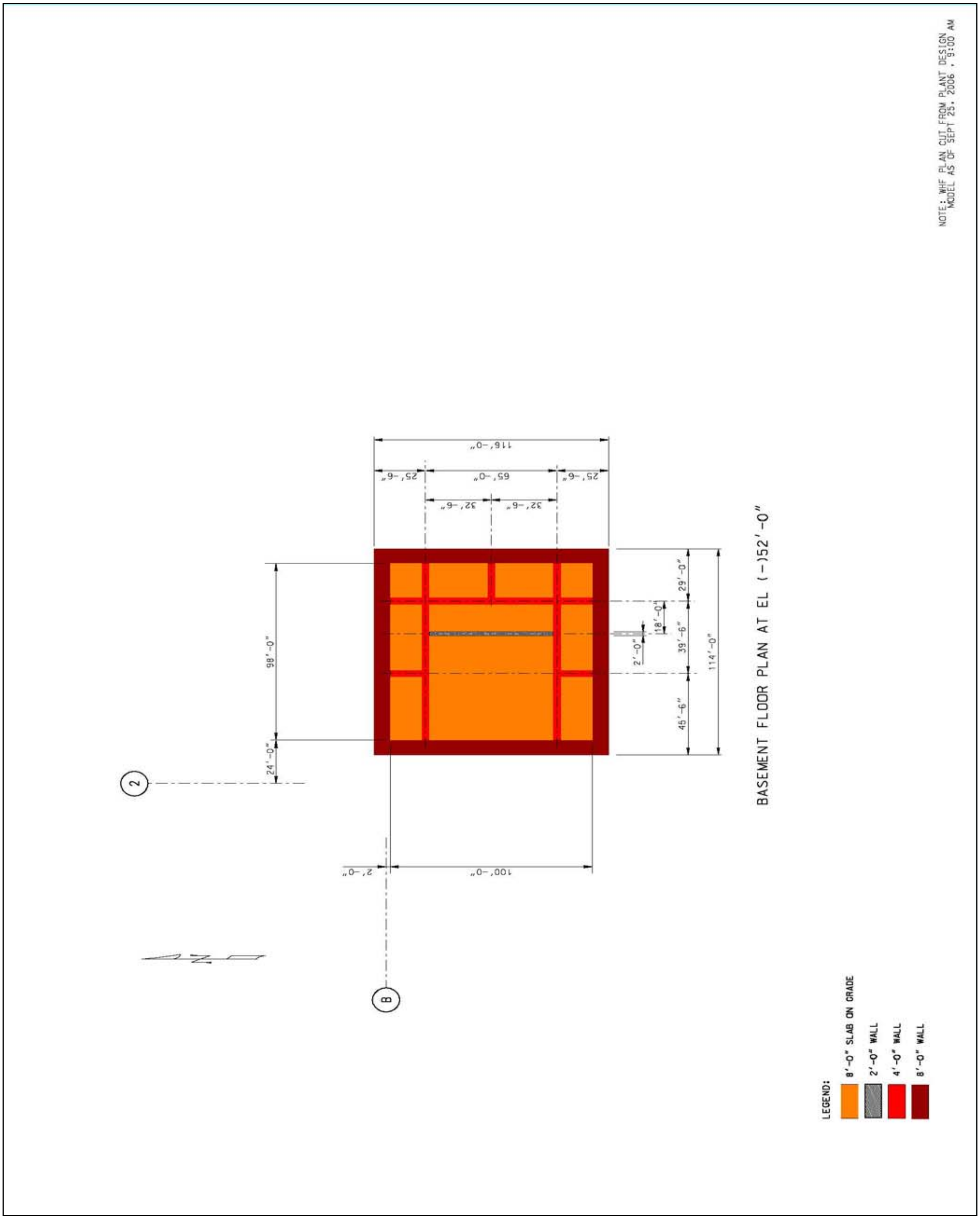
PLANS & SECTIONS

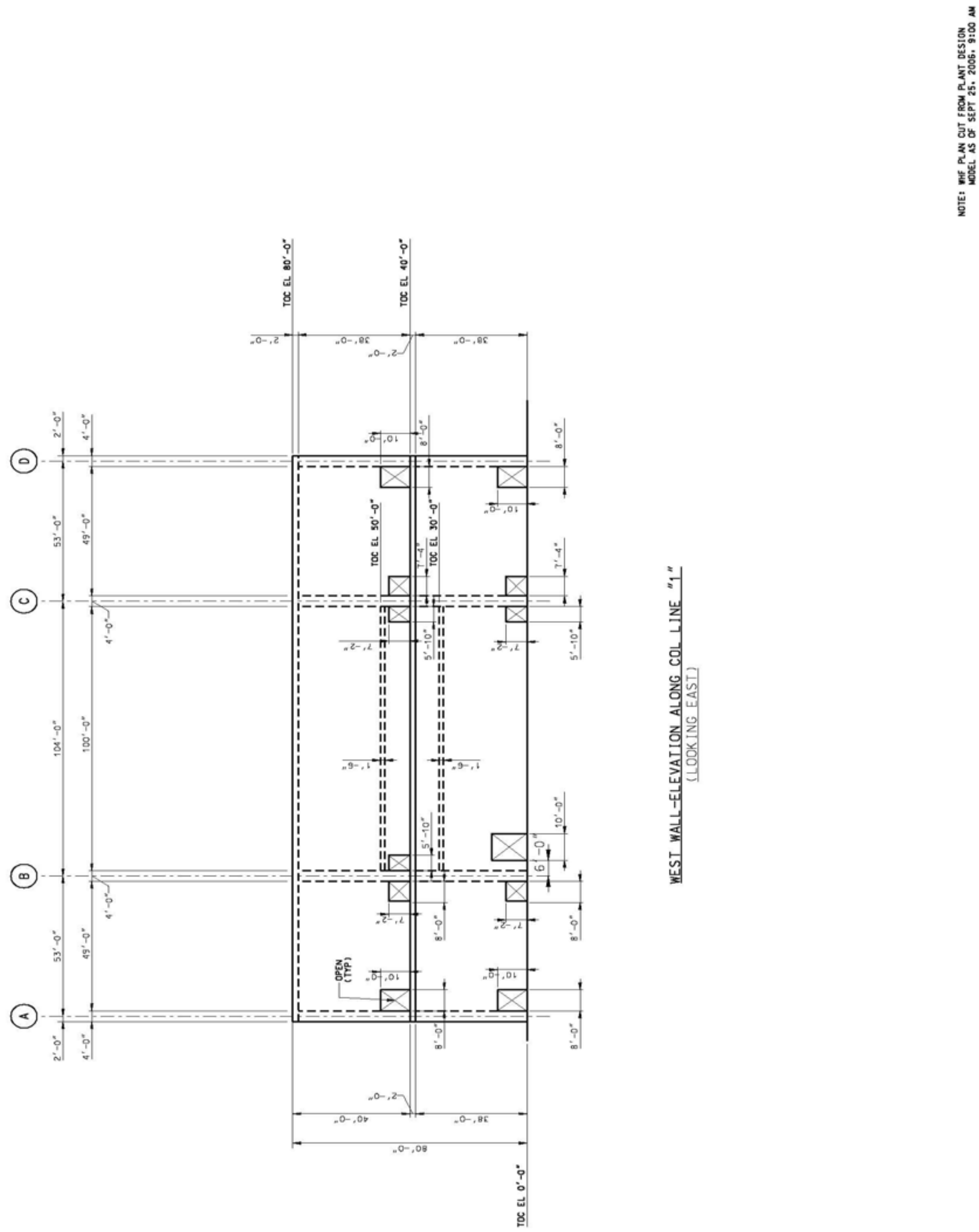
(With assumption 3.1.2, Attachment A is based on the WHF plans and sections shown in references 2.2.15, 2.2.16, 2.2.17, and 2.2.18, and the pool configuration and dimensions referred to the later sketches in Ref. 2.2.21 to 2.2.24).

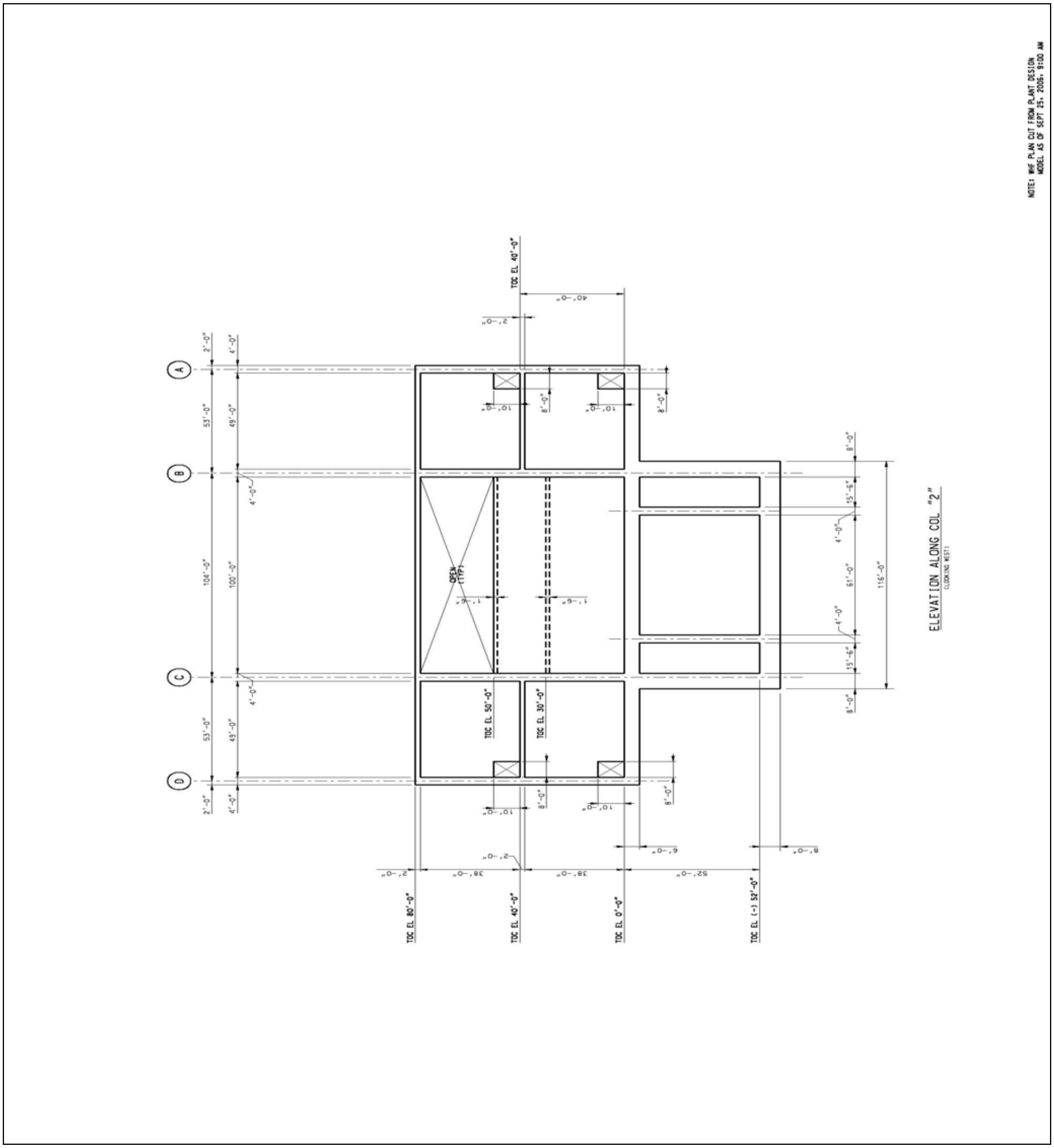

ROOF SLAB PLAN AT EL 100'-0"
ROOF SLAB PLAN AT EL 80'-0"
FLOOR SLAB AT EL 32'-0"
OPEN TO BELOW
NOTE: WHF PLAN CUT FROM PLANT DESIGN MODEL AS OF SEPT 25, 2006, 9:00 AM
LEGEND:
2'-0" ROOF SLAB
4'-0" WALL

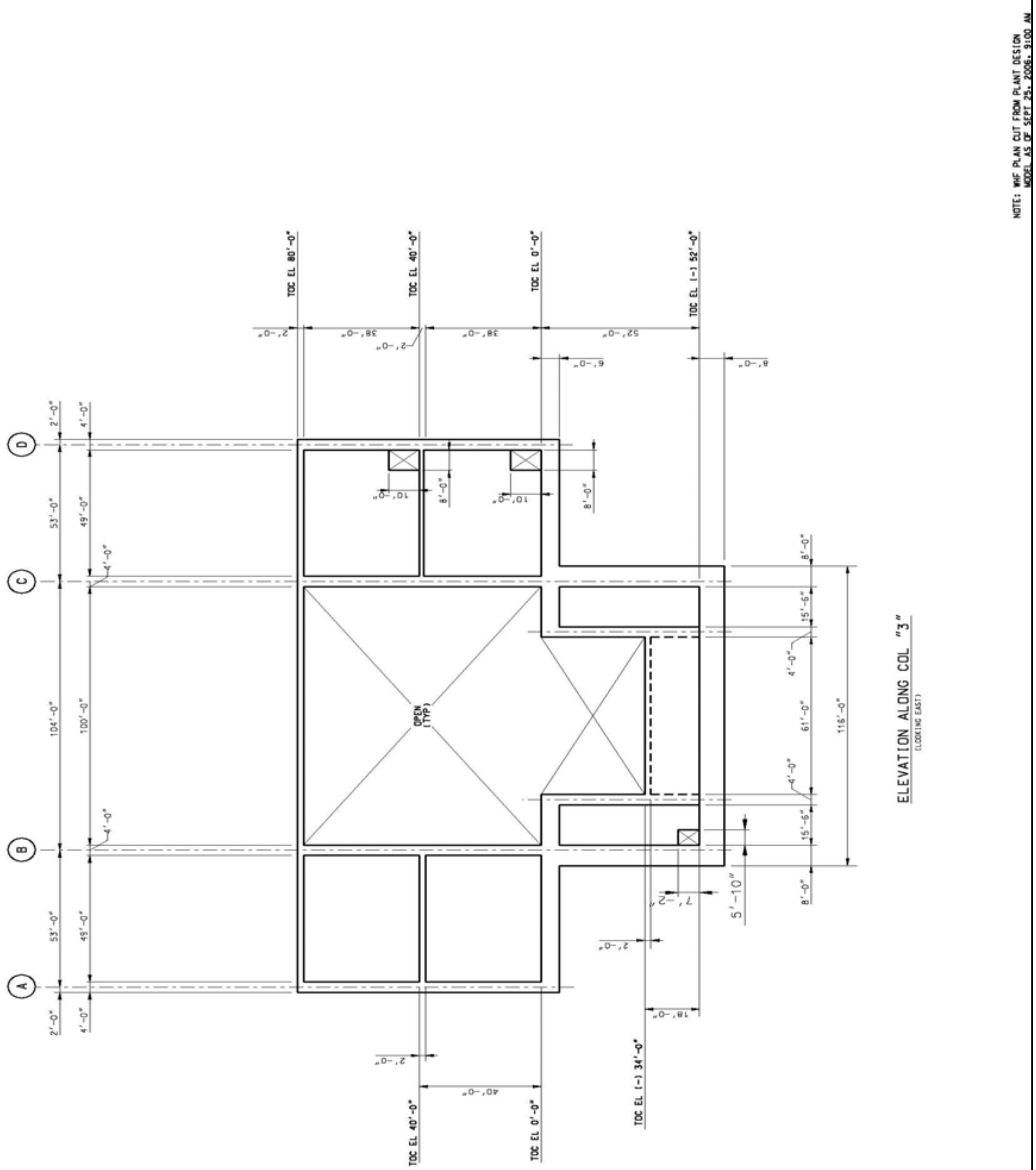

FLOOR SLAB PLAN AT EL 30'-0"
SECOND FLOOR PLAN AT EL 40'-0" TYP UNO
OPEN
OPEN TO BELOW
FLOOR SLAB AT EL 32'-0"
FLOOR SLAB AT EL 50'-0"
NOTE: WHF PLAN CUT FROM PLANT DESIGN MODEL AS OF SEPT 25, 2006 , 9:00 AM
LEGEND:
1'-6" FLOOR SLAB
2'-0" FLOOR SLAB
4'-0" FLOOR SLAB
2'-0" WALL
4'-0" WALL

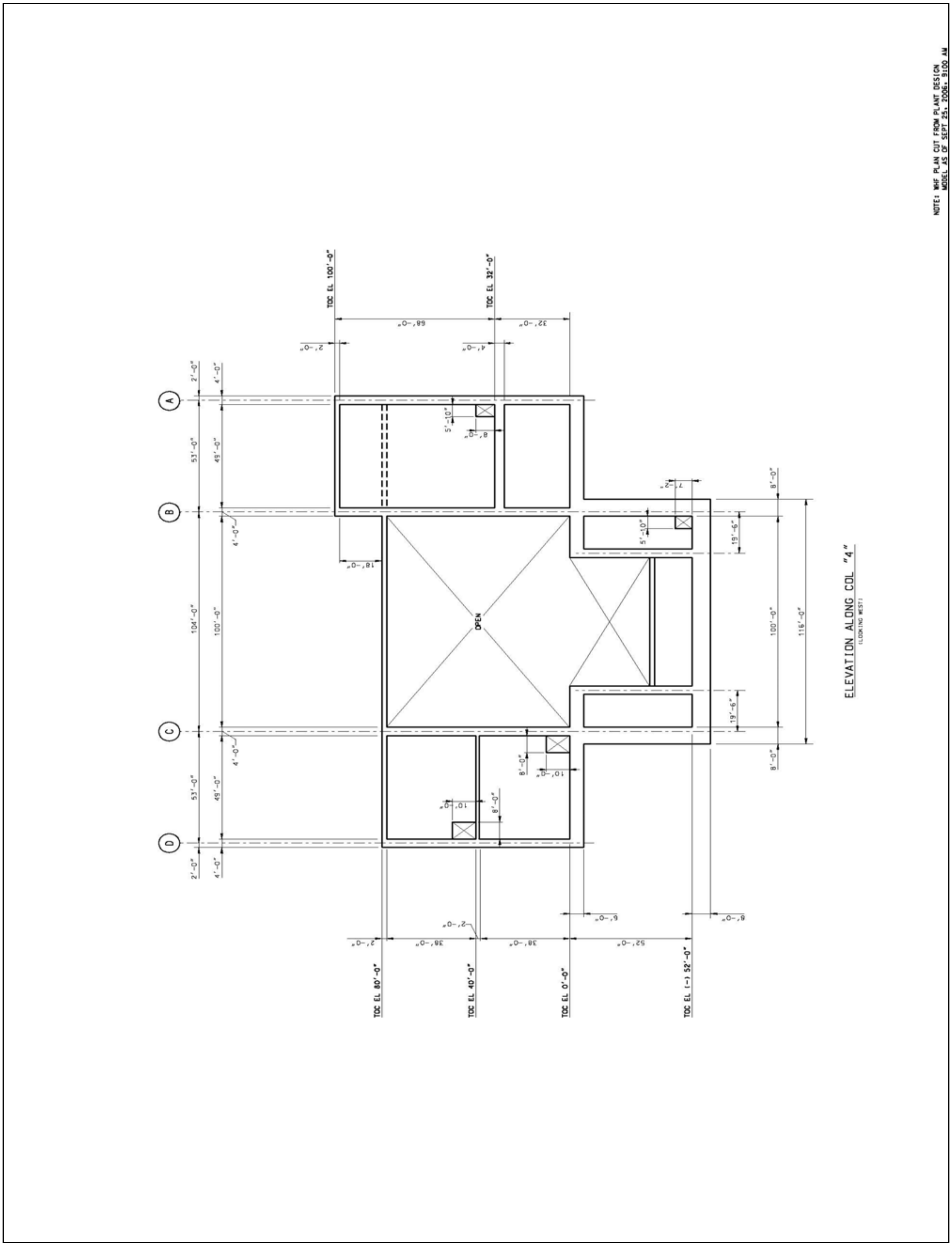

GROUND FLOOR PLAN AT EL 0'-0"
NOTE: WHF PLAN CUT FROM PLANT DESIGN MODEL AS OF SEPT 25, 2006, 9:00 AM
APRON AREA: THICKNESS TBD NOT PART OF TIER 1 MODEL
APRON AREA: THICKNESS TBD NOT PART OF TIER 1 MODEL
OPEN TO BELOW
LEGEND:
1'-6" SLAB ON GRADE
6'-0" SLAB ON GRADE
1'-0" WALL
1'-6" WALL
2'-0" WALL
3'-0" WALL
4'-0" WALL
X = 0'-0"
X = 54'-0"
X = 108'-0"
X = 148'-0"
X = 185'-0"
X = 212'-0"
X = 266'-0"
Y = 0'-0"
Y = 53'-0"
Y = 157'-0"
Y = 210'-0"
266'-0"
270'-0"
215'-0"
214'-0"
210'-0"
104'-0"
100'-0"
67'-0"
61'-0"
21'-6"

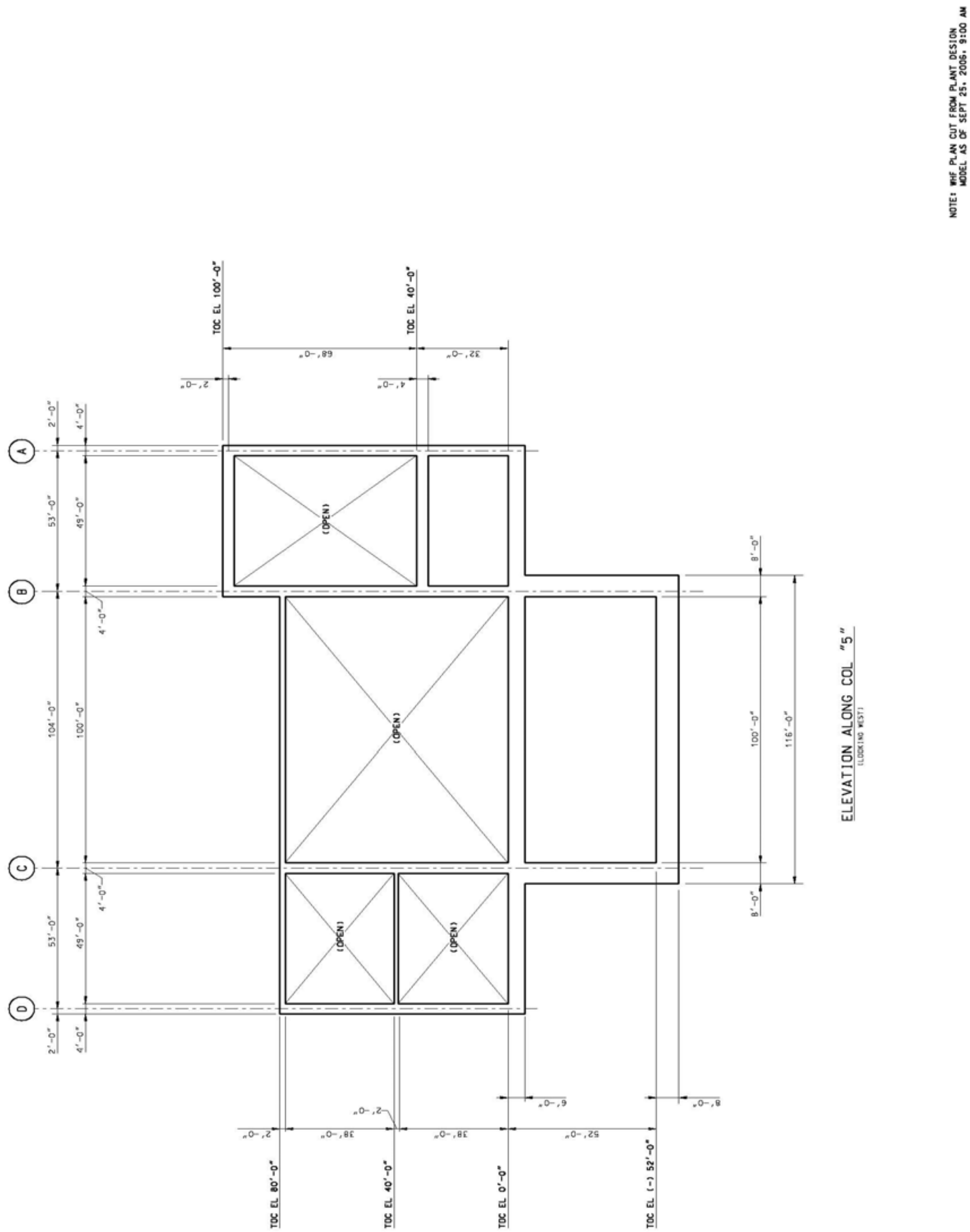

NOTE: WHF PLAN CUT FROM PLANT DESIGN
MODEL AS OF SEPT 25, 2006, 9:00 AM
BASEMENT FLOOR PLAN AT EL (-)52'-0"
116'-0"
25'-6"
65'-0"
25'-6"
32'-6"
32'-6"
98'-0"
24'-0"
29'-0"
18'-0"
2'-0"
39'-6"
45'-6"
114'-0"
2'-0"
100'-0"
2
B
N
LEGEND:
8'-0" SLAB ON GRADE
2'-0" WALL
4'-0" WALL
8'-0" WALL

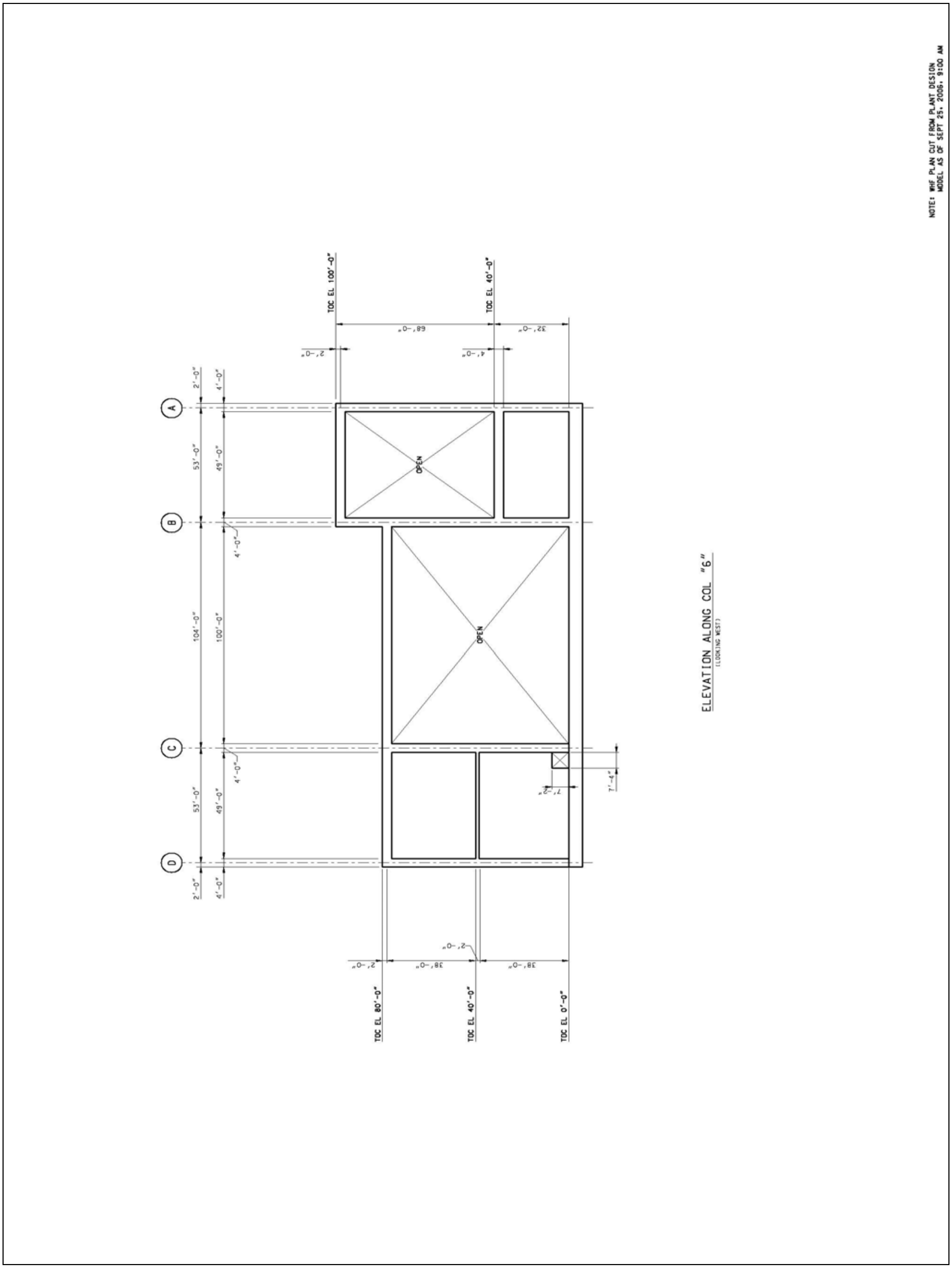

NOTE: WHF PLAN CUT FROM PLANT DESIGN MODEL AS OF SEPT 25, 2006, 9:00 AM
WEST WALL-ELEVATION ALONG COL LINE "1"
(LOOKING EAST)
TOC EL 80'-0"
TOC EL 40'-0"
TOC EL 50'-0"
TOC EL 30'-0"
TOC EL 0'-0"
OPEN (TYP)
A
B
C
D
53'-0"
104'-0"
49'-0"
100'-0"
2'-0"
4'-0"
38'-0"
40'-0"
80'-0"


ELEVATION ALONG COL "2"
TOC EL 80'-0"
TOC EL 40'-0"
TOC EL 0'-0"
TOC EL (-) 52'-0"
TOC EL 50'-0"
TOC EL 30'-0"
OPEN (TYP)
A
B
C
D

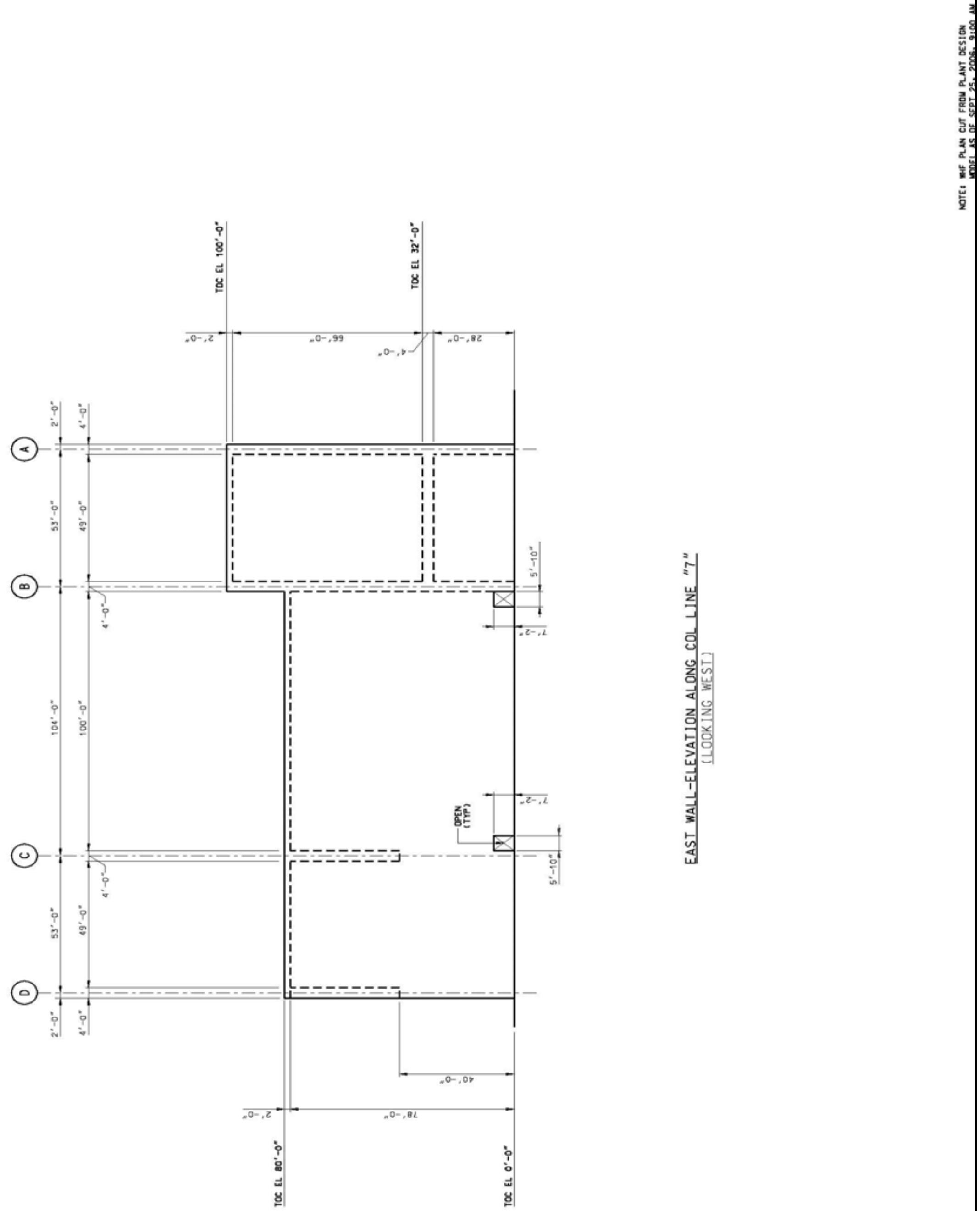

NOTE: WHF PLAN CUT FROM PLANT DESIGN
MODEL AS OF SEPT 25, 2006, 9:00 AM
TOC EL 80'-0"
TOC EL 40'-0"
TOC EL 0'-0"
TOC EL (-) 52'-0"
TOC EL (-) 34'-0"
OPEN
(TYP)
ELEVATION ALONG COL "3"
(LOOKING EAST)

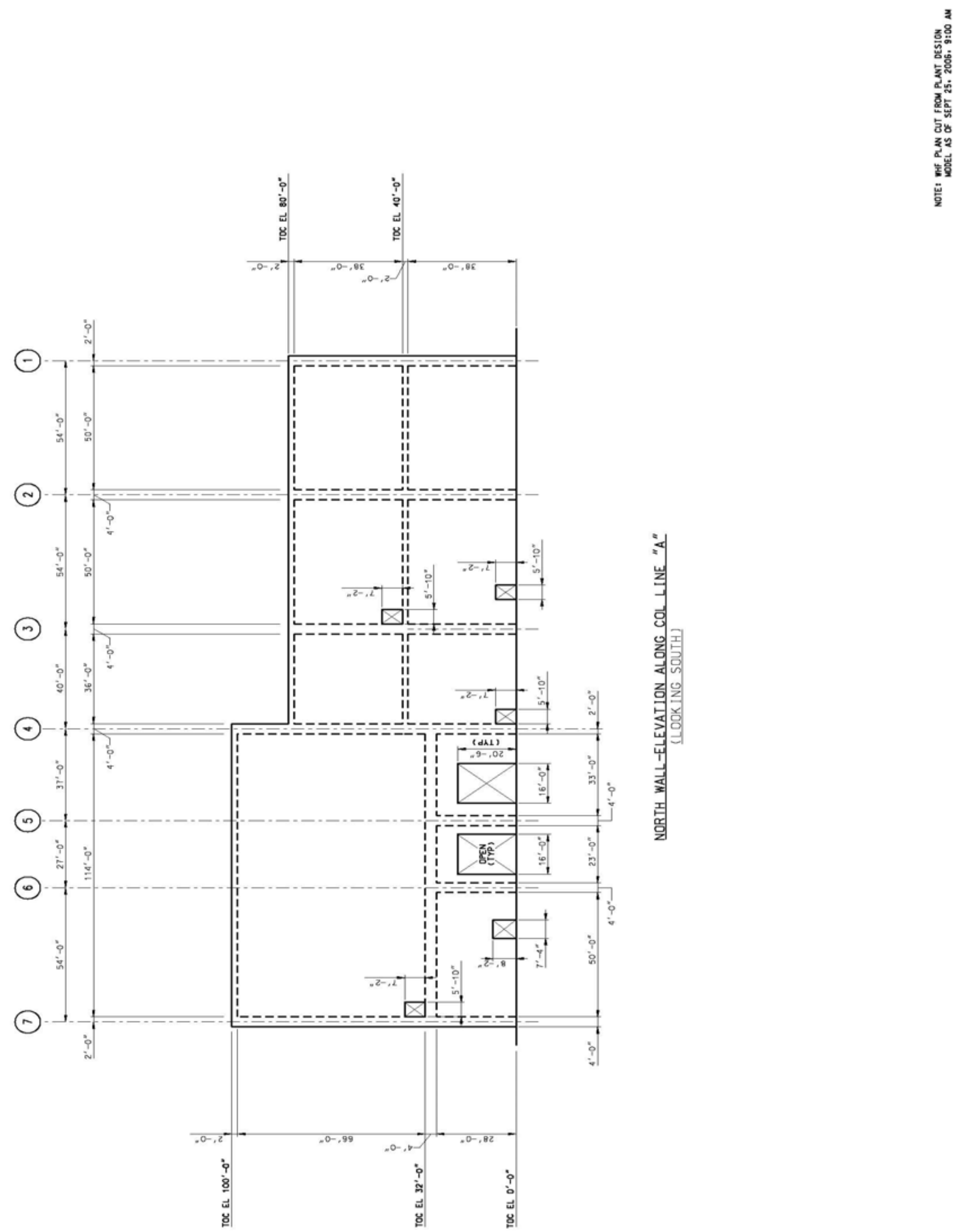

NOTE: WHF PLAN CUT FROM PLANT DESIGN
MODEL AS OF SEPT 25, 2006, 9:00 AM
ELEVATION ALONG COL "4"
(LOOKING WEST)
TOC EL 100'-0"
TOC EL 32'-0"
TOC EL 80'-0"
TOC EL 40'-0"
TOC EL 0'-0"
TOC EL (-) 52'-0"
OPEN
A
B
C
D
53'-0"
104'-0"
100'-0"
116'-0"
49'-0"
19'-6"
68'-0"
32'-0"
38'-0"
52'-0"

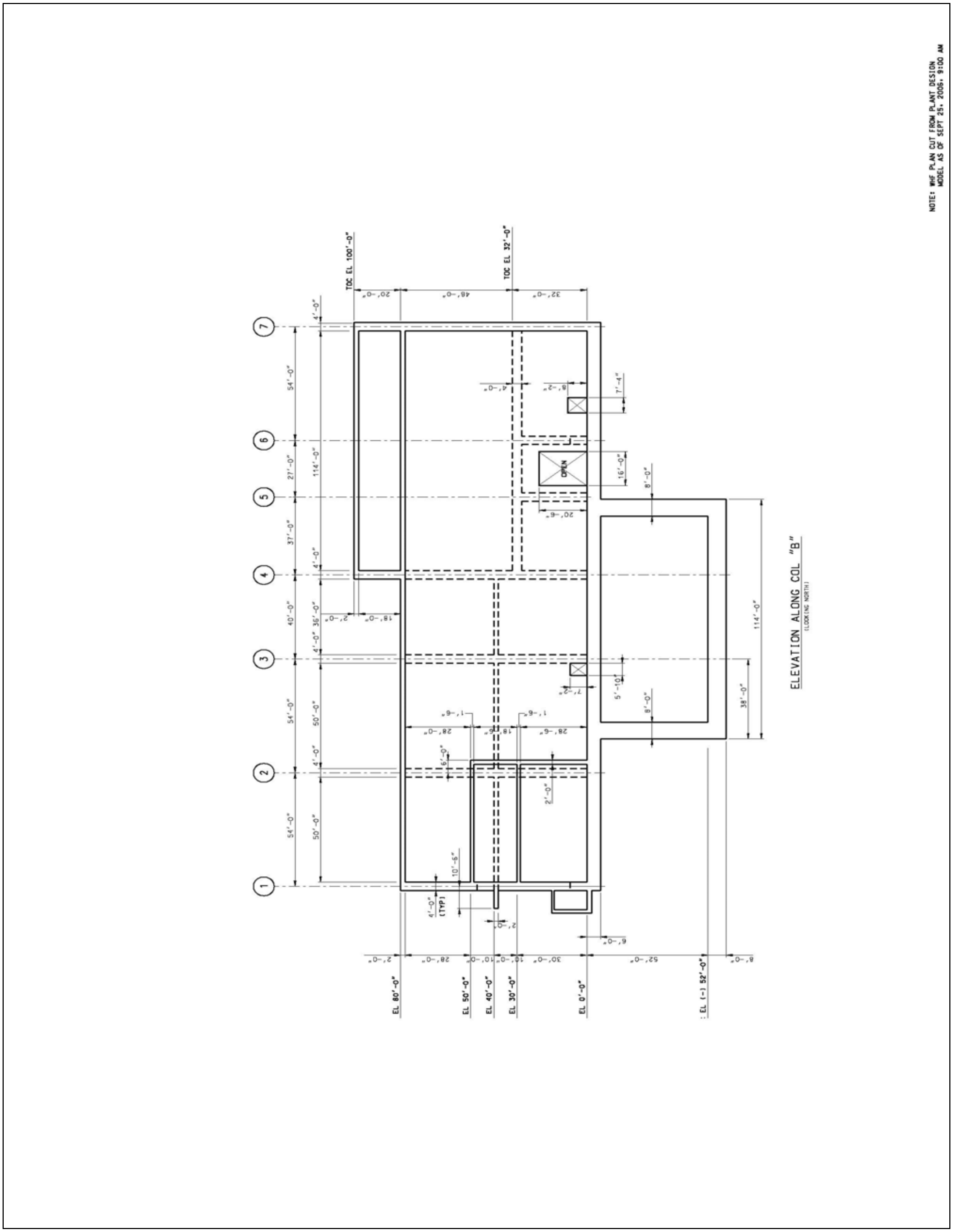

NOTE: WHF PLAN CUT FROM PLANT DESIGN
MODEL AS OF SEPT 25, 2006, 9:00 AM
ELEVATION ALONG COL "5"
(LOOKING WEST)
TOC EL 100'-0"
TOC EL 40'-0"
TOC EL 80'-0"
TOC EL 40'-0"
TOC EL 0'-0"
TOC EL (-) 52'-0"
(OPEN)
(OPEN)
(OPEN)
(OPEN)
A
B
C
D
2'-0"
4'-0"
53'-0"
49'-0"
104'-0"
100'-0"
116'-0"
8'-0"
68'-0"
32'-0"
38'-0"
52'-0"
6'-0"

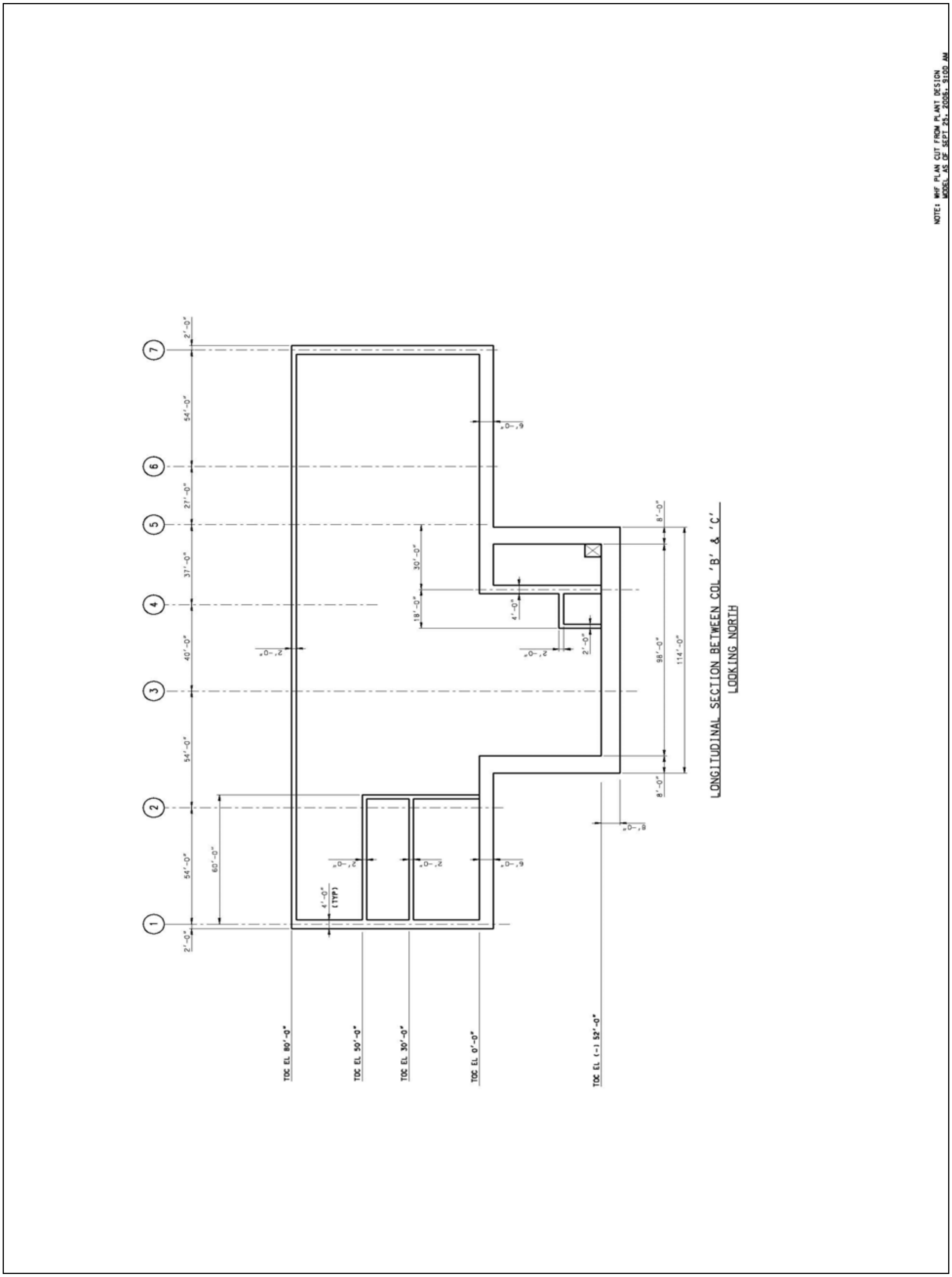

NOTE: WHF PLAN CUT FROM PLANT DESIGN MODEL AS OF SEPT 25, 2006, 9:00 AM
ELEVATION ALONG COL "6"
(LOOKING WEST)
TOC EL 100'-0"
TOC EL 40'-0"
TOC EL 80'-0"
TOC EL 40'-0"
TOC EL 0'-0"
OPEN
OPEN
A
B
C
D
53'-0"
104'-0"
53'-0"
49'-0"
100'-0"
49'-0"
68'-0"
32'-0"
38'-0"
38'-0"
7'-4"

 May 2007

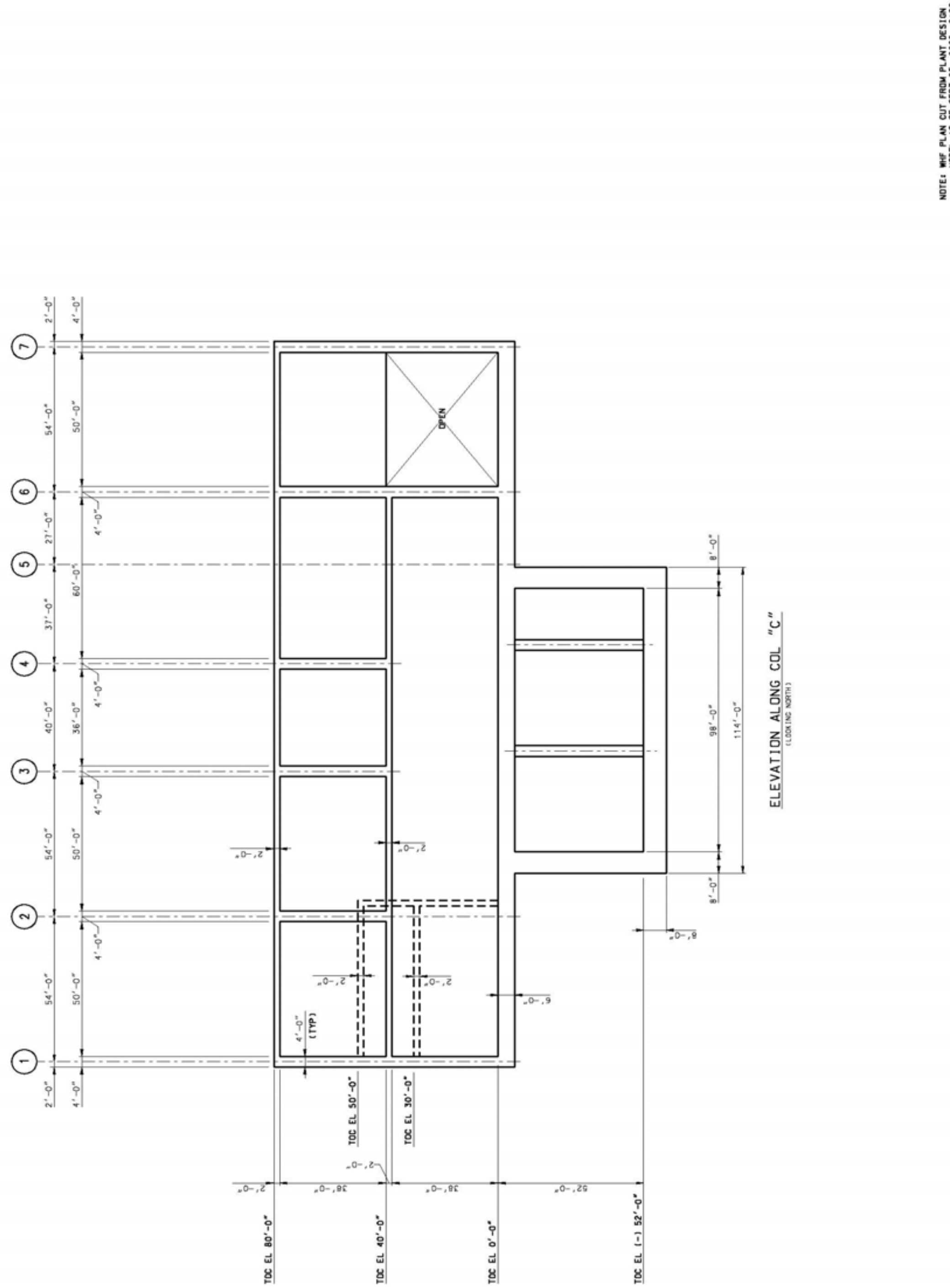

EAST WALL-ELEVATION ALONG COL LINE "7"
(LOOKING WEST)
TOC EL 100'-0"
TOC EL 32'-0"
TOC EL 80'-0"
TOC EL 0'-0"
OPEN (TYP)

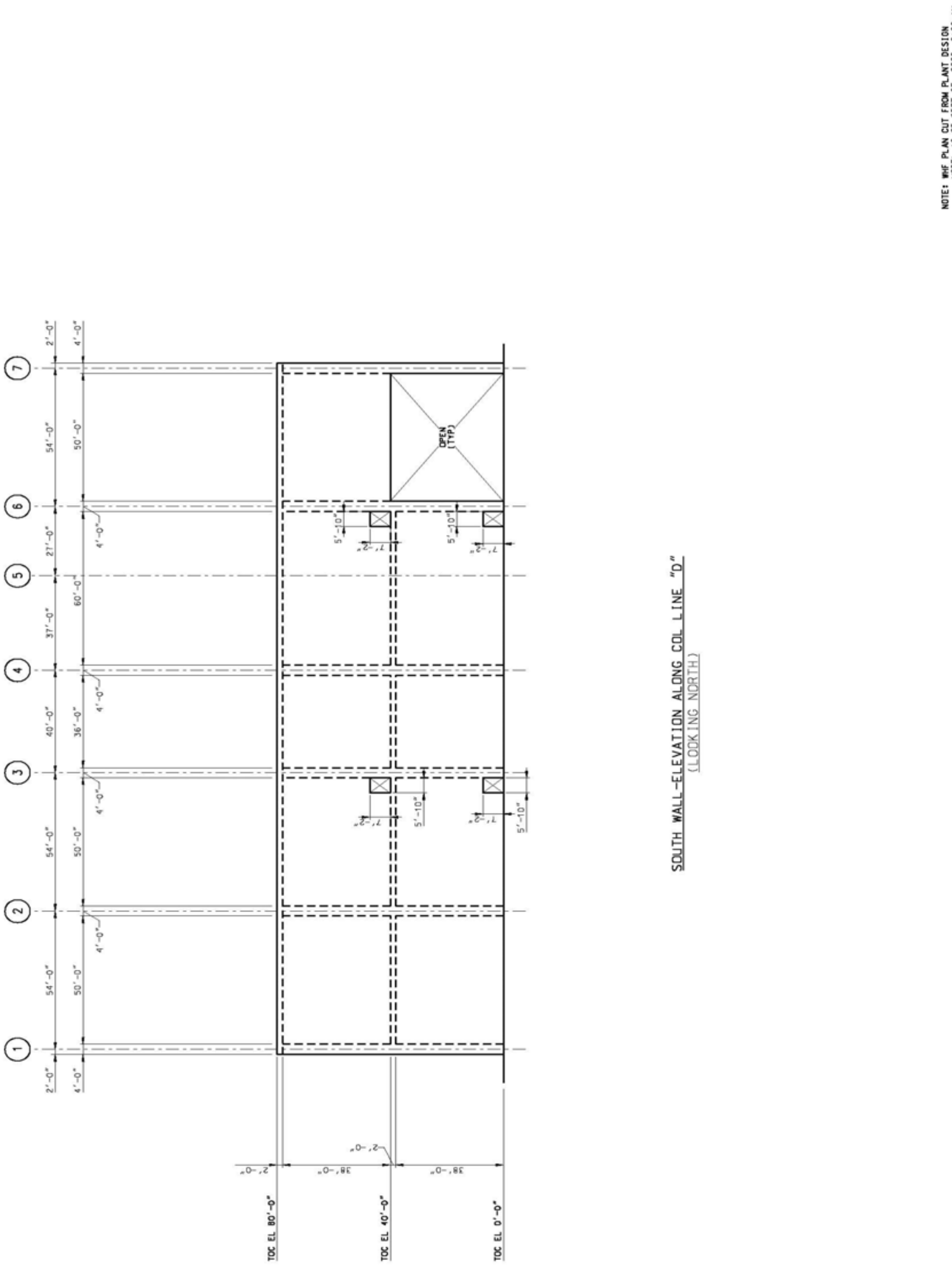

NOTE: WHF PLAN CUT FROM PLANT DESIGN MODEL AS OF SEPT 25, 2006, 9:00 AM
NORTH WALL-ELEVATION ALONG COL LINE "A"
(LOOKING SOUTH)
TOC EL 80'-0"
TOC EL 40'-0"
TOC EL 100'-0"
TOC EL 32'-0"
TOC EL 0'-0"
OPEN (TYP)


NOTE: WHF PLAN CUT FROM PLANT DESIGN MODEL AS OF SEPT 25, 2006, 9:00 AM
ELEVATION ALONG COL "B"
(LOOKING NORTH)
TOC EL 100'-0"
TOC EL 32'-0"
EL 80'-0"
EL 50'-0"
EL 40'-0"
EL 30'-0"
EL 0'-0"
EL (-) 52'-0"
OPEN



LONGITUDINAL SECTION BETWEEN COL 'B' & 'C'
LOOKING NORTH


NOTE: WHF PLAN CUT FROM PLANT DESIGN
MODEL AS OF SEPT 25, 2006, 9:00 AM
ELEVATION ALONG COL "C"
(LOOKING NORTH)
OPEN
TOC EL 80'-0"
TOC EL 40'-0"
TOC EL 0'-0"
TOC EL (-) 52'-0"
TOC EL 50'-0"
TOC EL 30'-0"
98'-0"
114'-0"

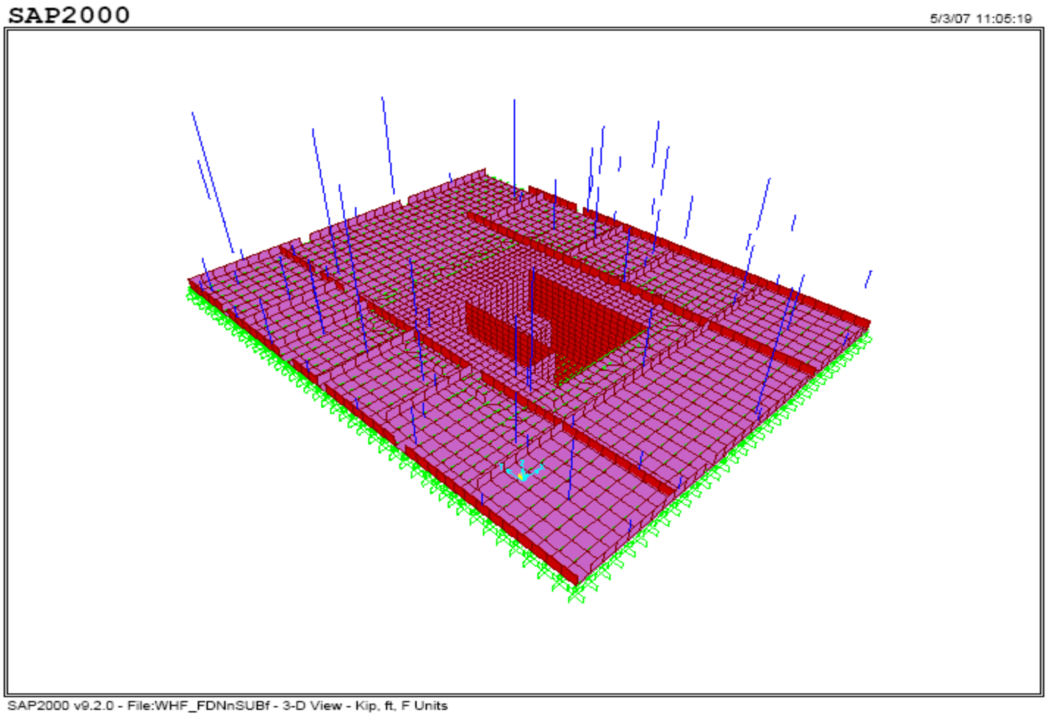

NOTE: WHF PLAN CUT FROM PLANT DESIGN MODEL AS OF SEPT 25, 2006, 9:00 AM
SOUTH WALL-ELEVATION ALONG COL LINE "D"
(LOOKING NORTH)
OPEN (TYP)
TOC EL 80'-0"
TOC EL 40'-0"
TOC EL 0'-0"

ATTACHMENT B

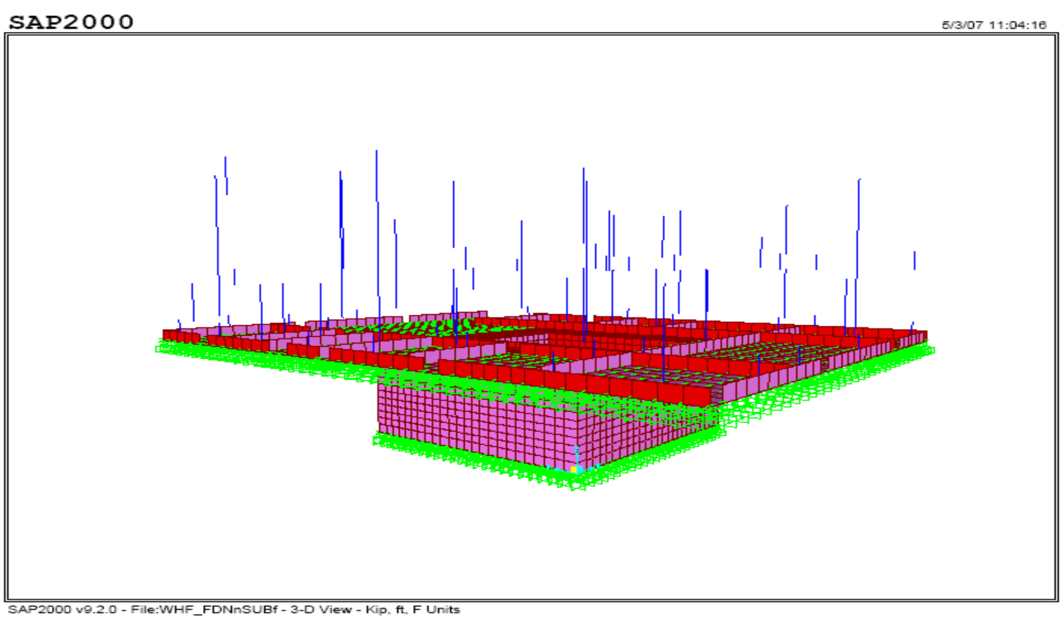
SAP 2000 MODEL

OF

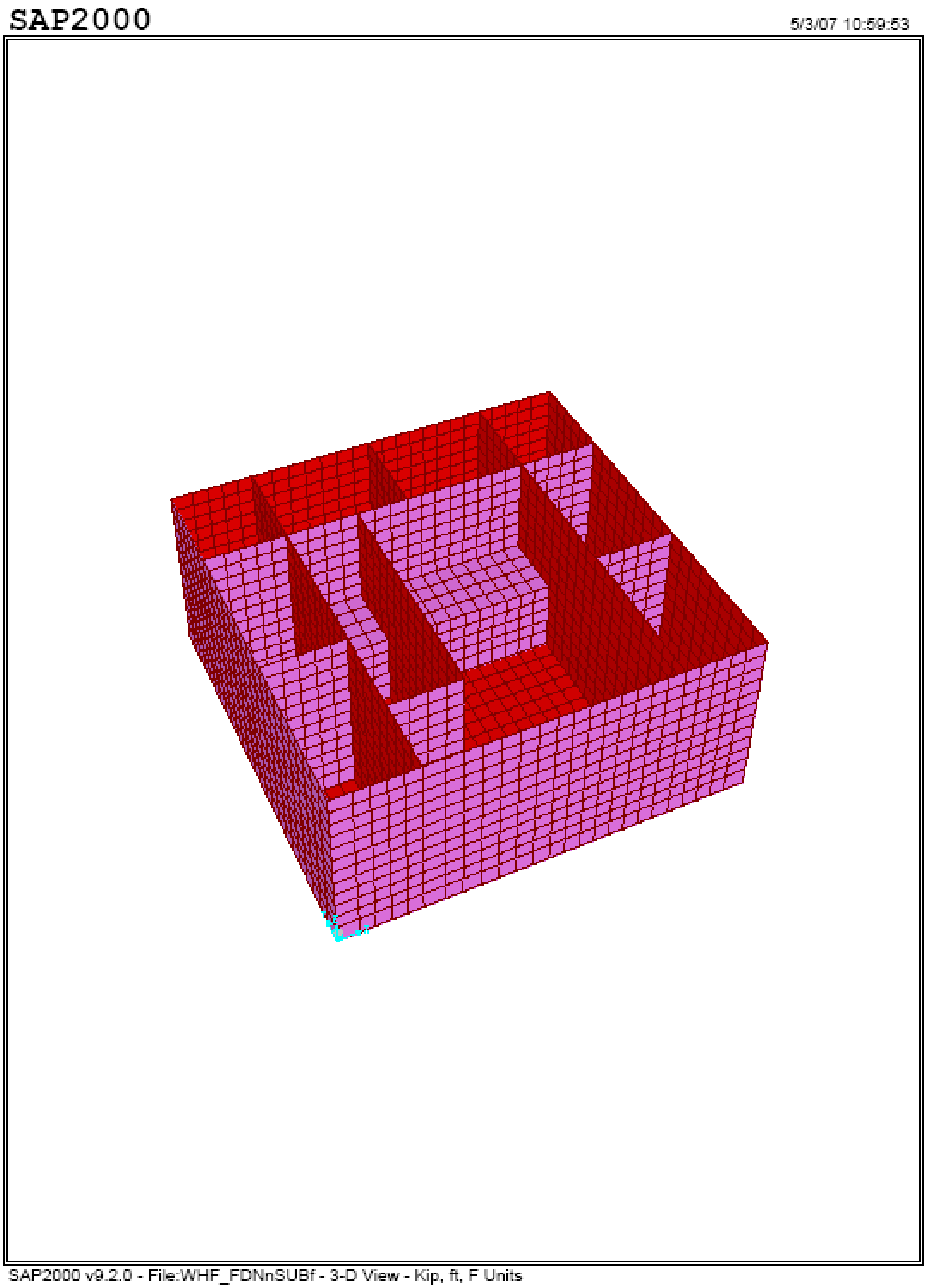
WHF FOUNDATION & SUBGRADE STRUCTURE



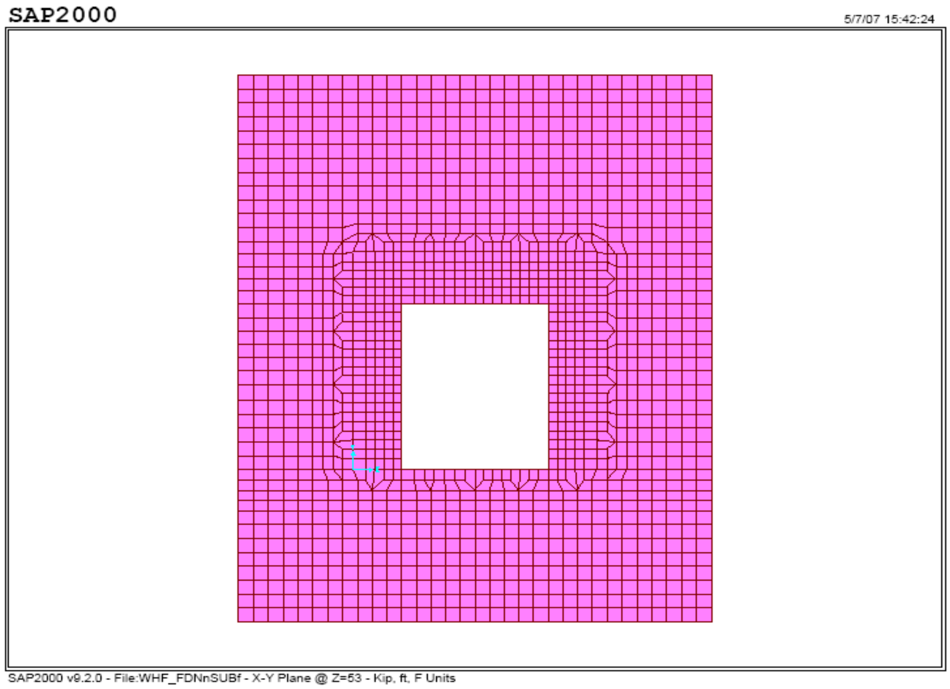
WHF ISO-VIEW 1



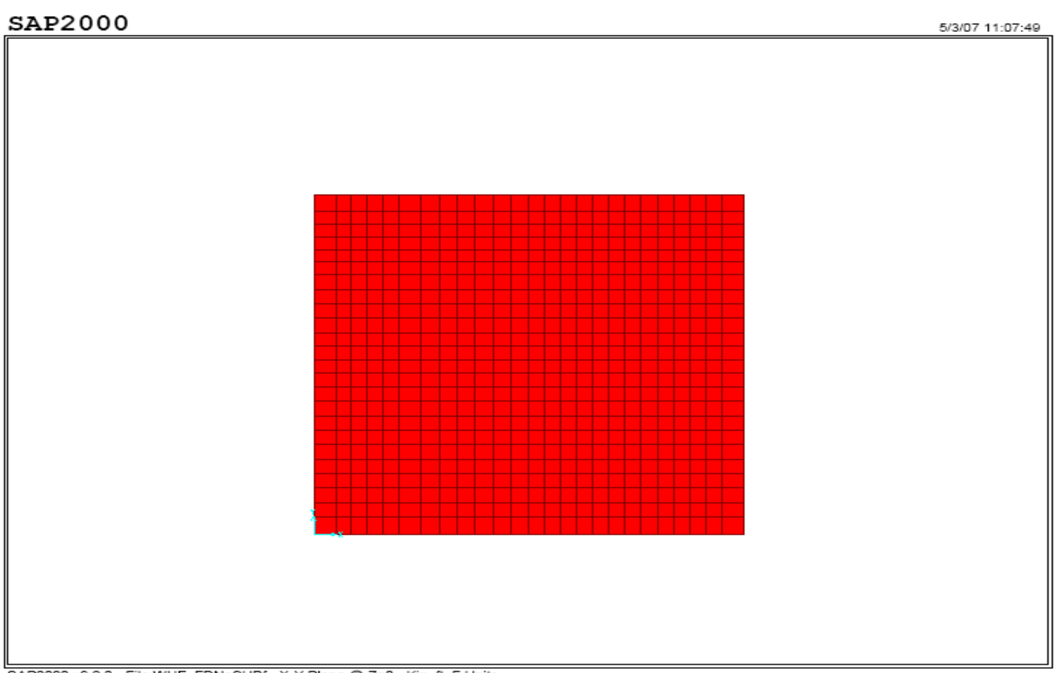
WHF ISO-VIEW 2


SAP2000
5/3/07 10:59:53
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - 3-D View - Kip, ft, F Units

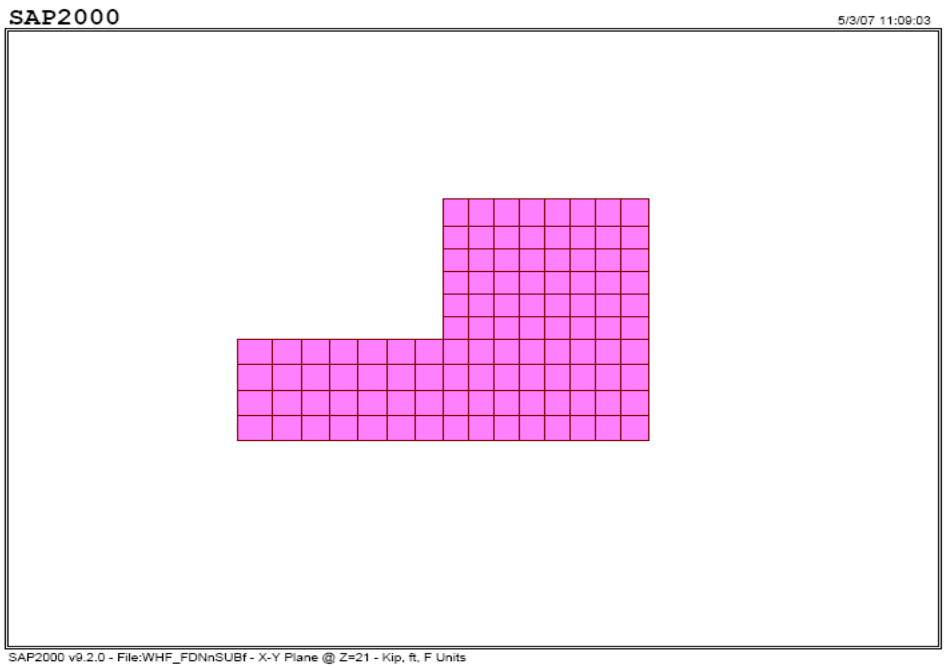
POOL ISO



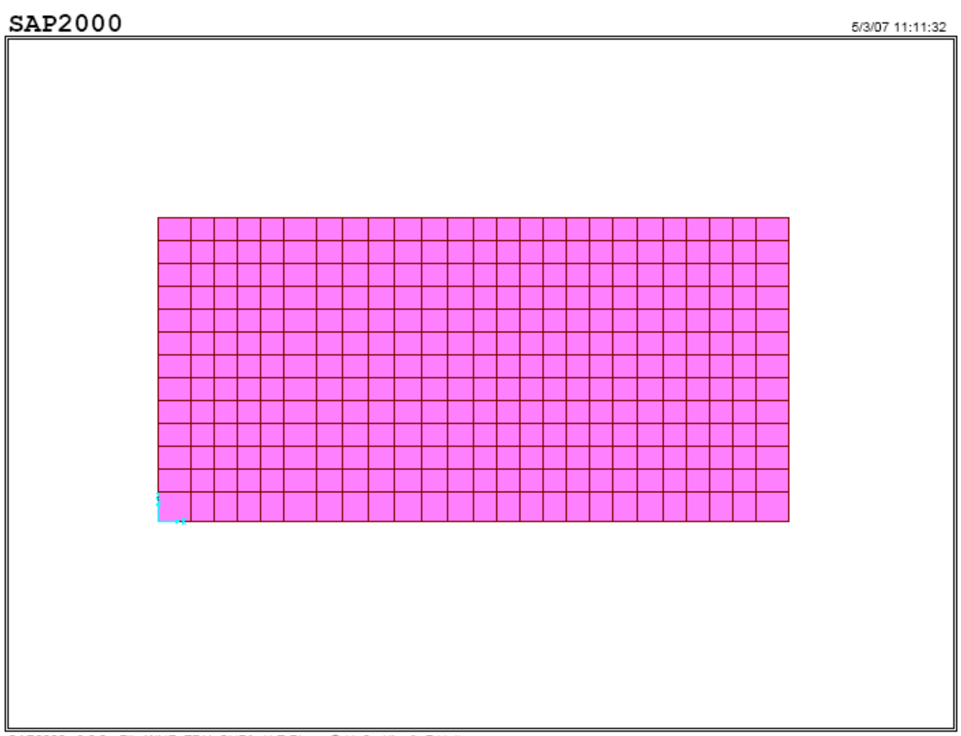
GRADE BASEMAT



POOL BASEMAT

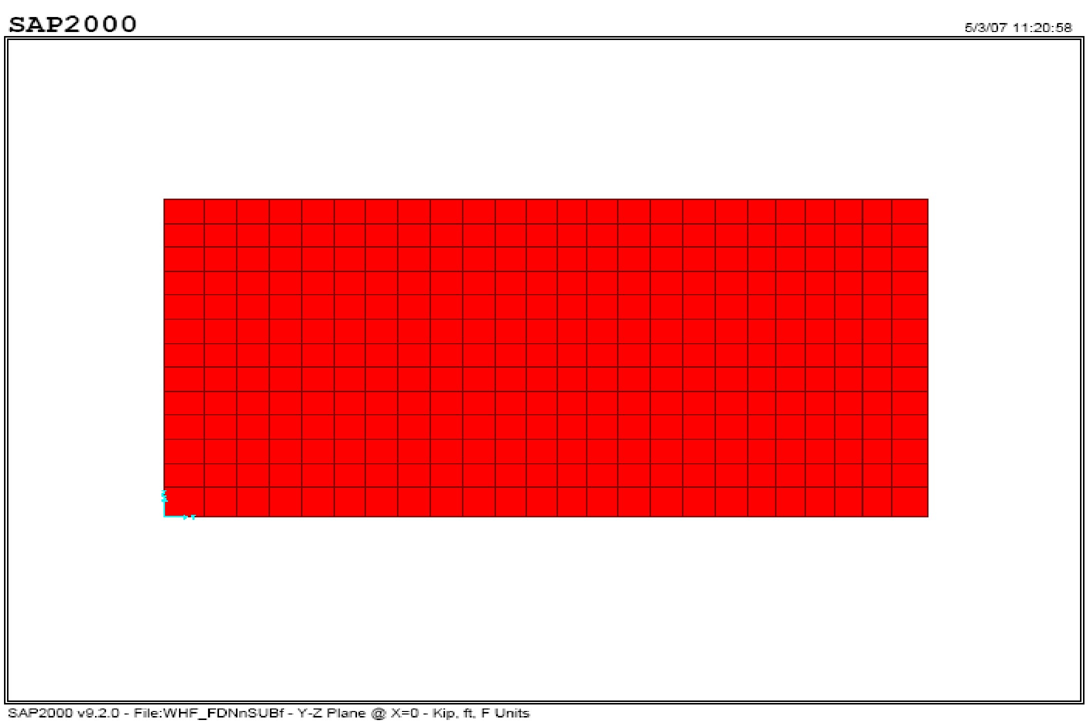


POOL SHELF

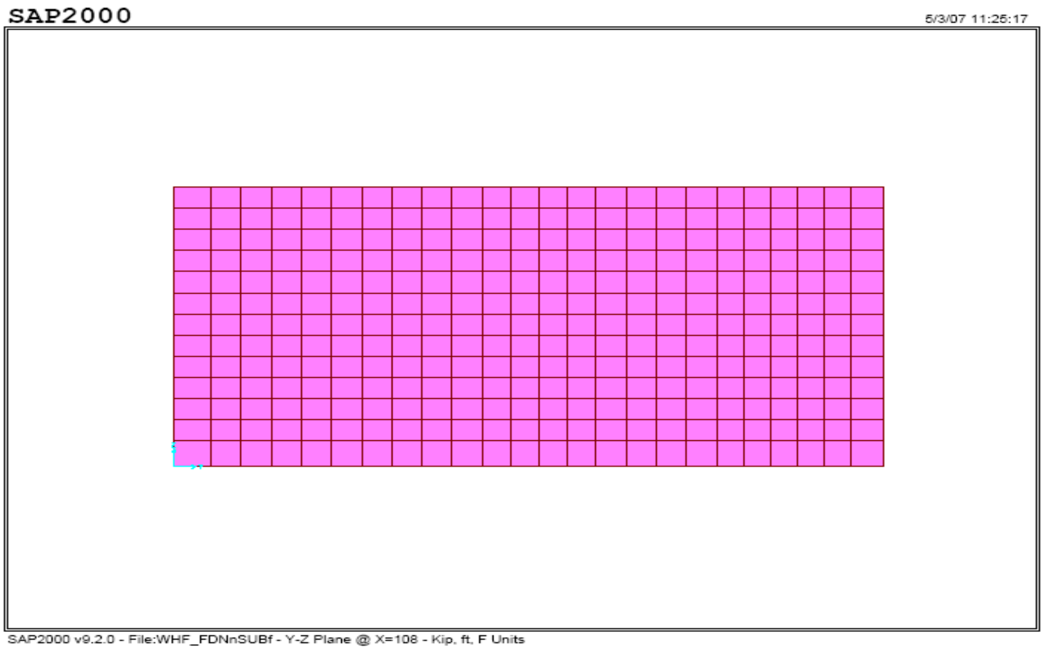


WEST WALL

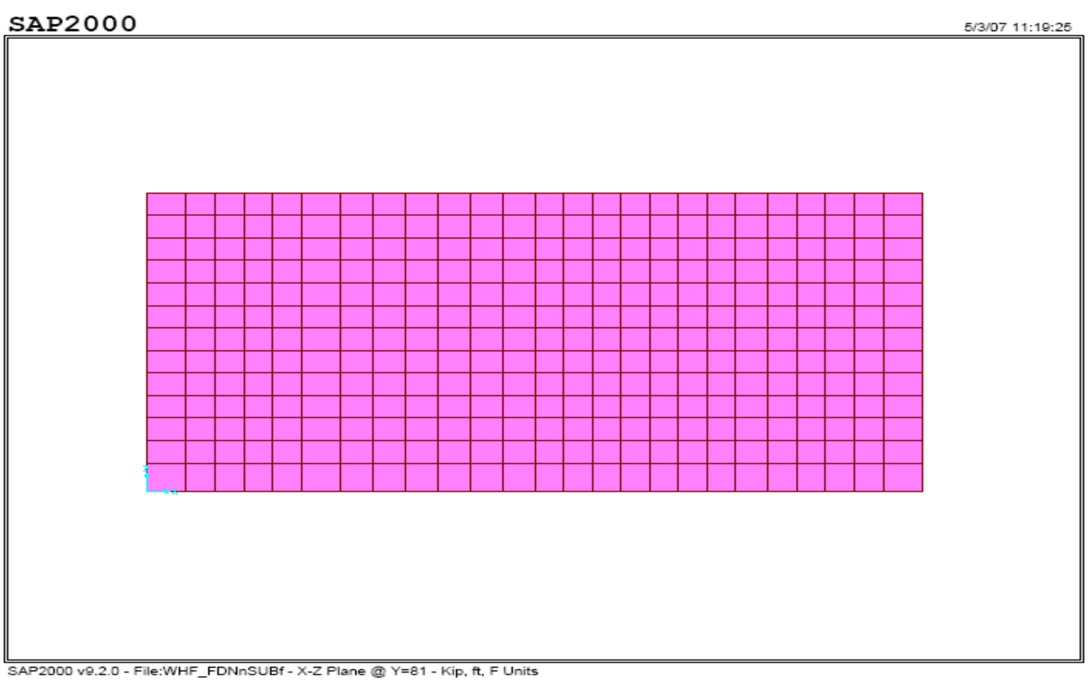
EAST WALL



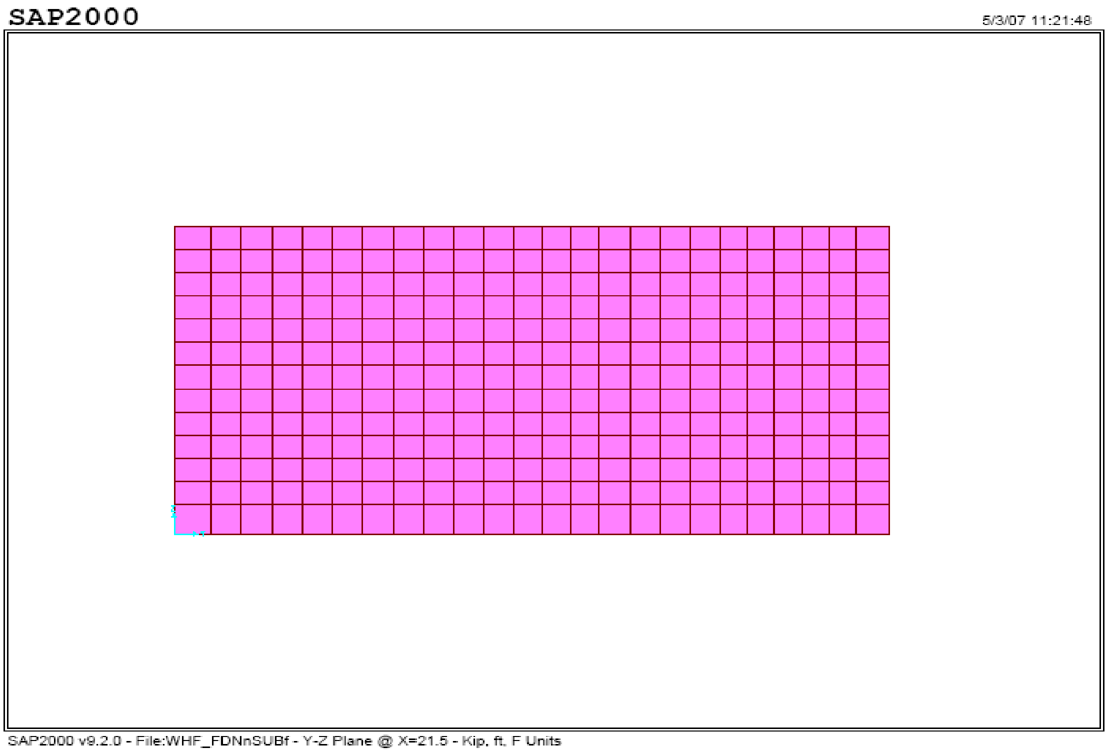
NORTH WALL



SOUTH WALL

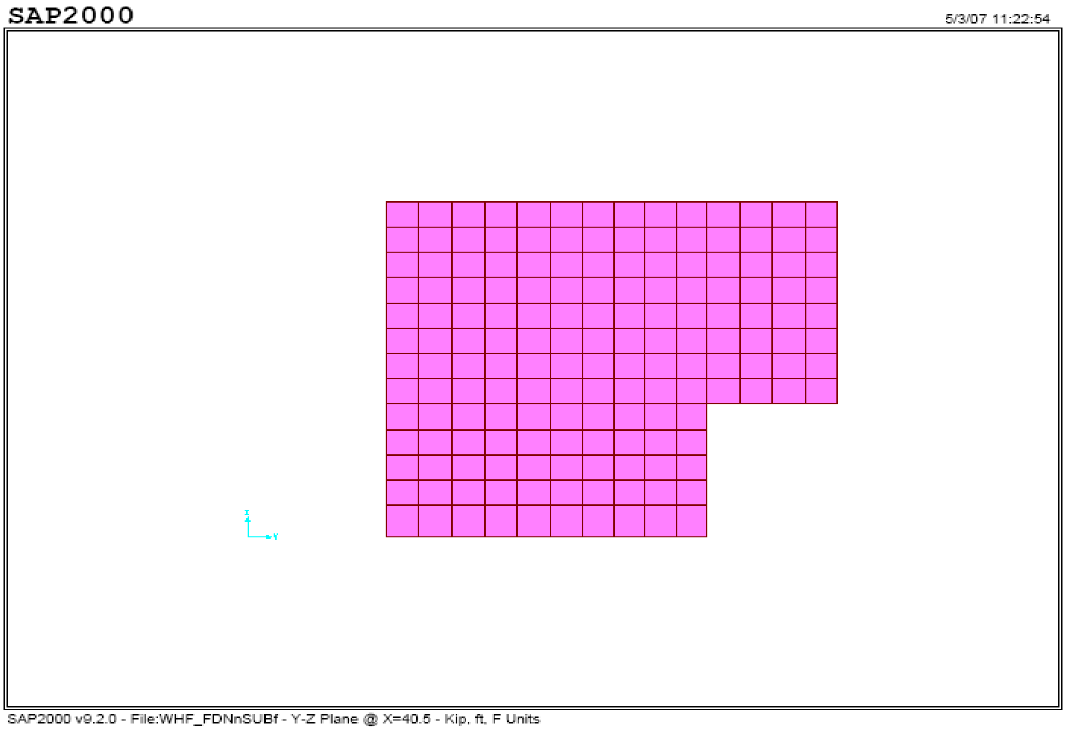


POOL EAST WALL

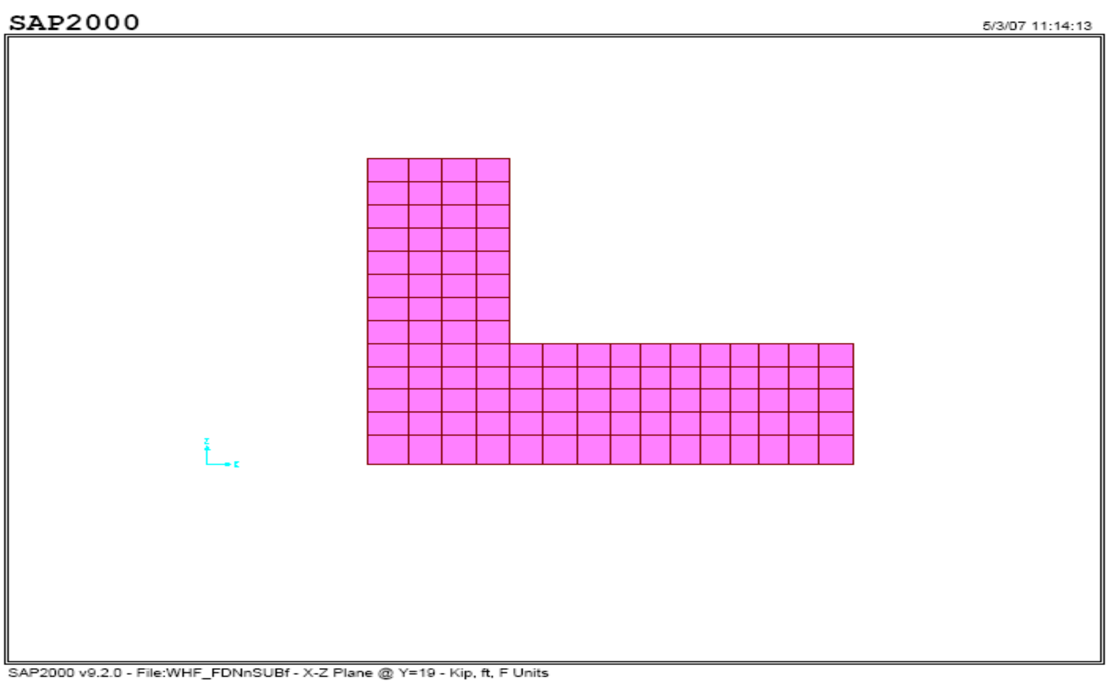


POOL NORTH WALL

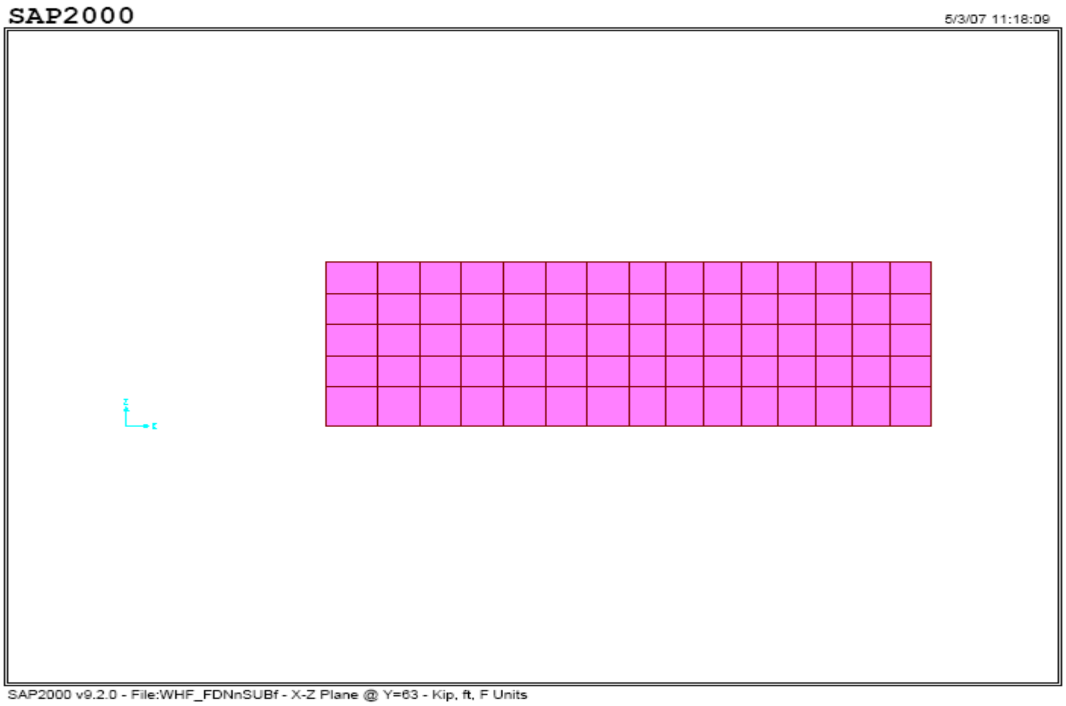
POOL SOUTH WALL



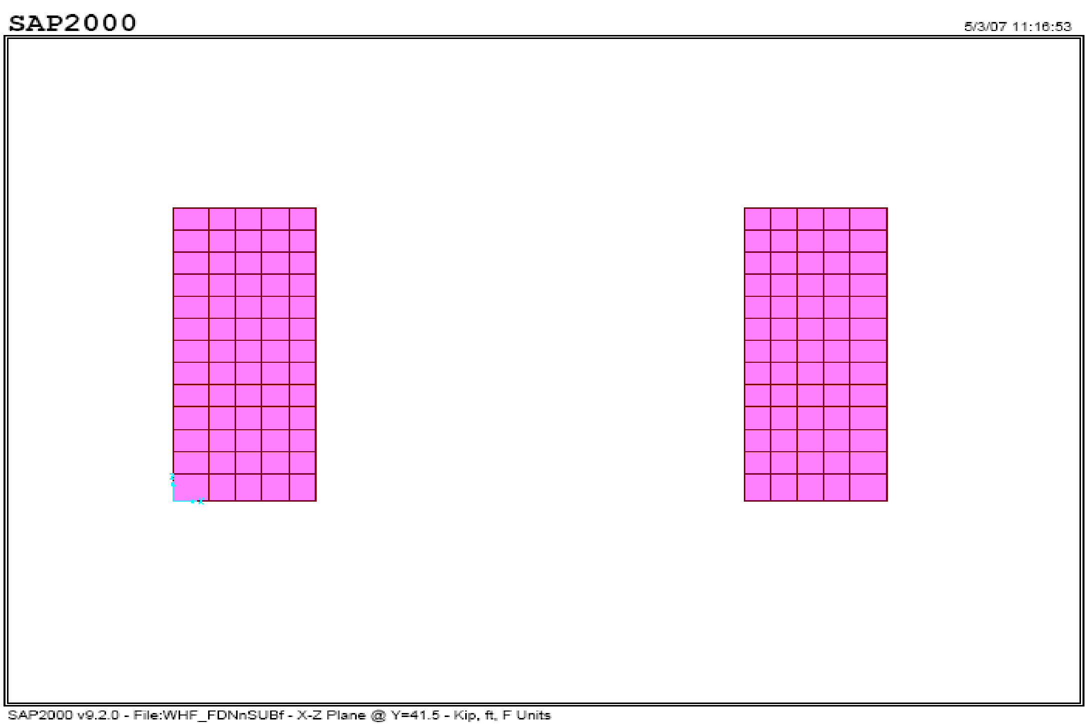
POOL NORTH SEPARATION WALL



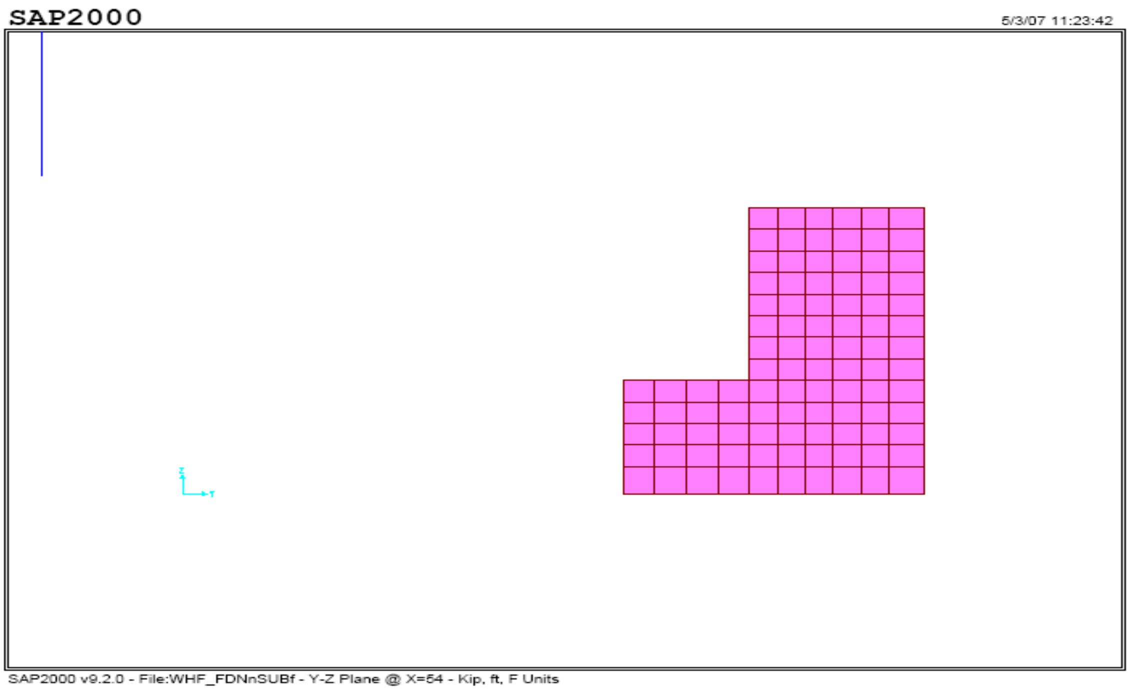
POOL WEST SEPARATION WALL



POOL SHELF WALL



SUBGRADE INTERIOR WALLS 1



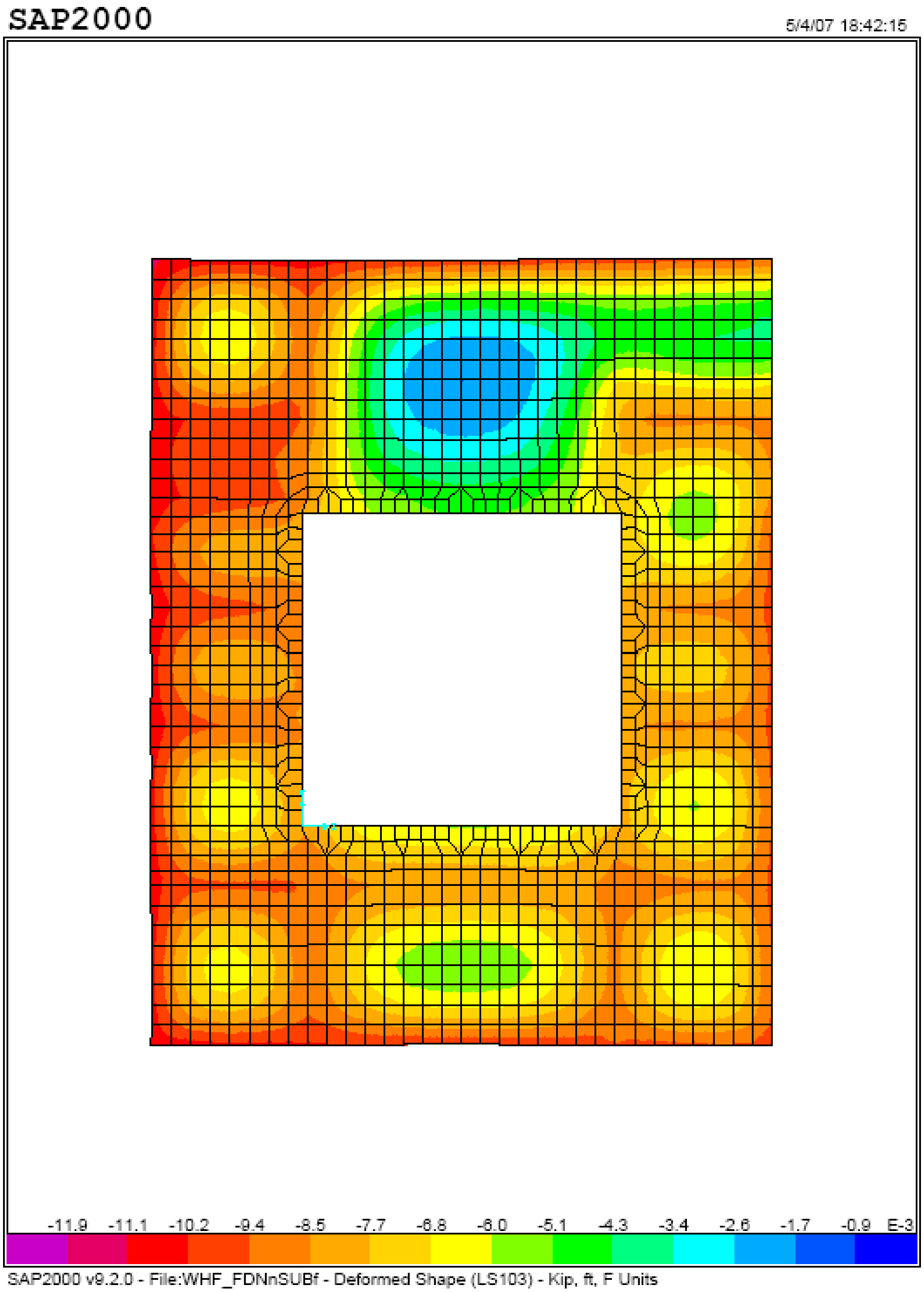
SUBGRADE INTERIOR WALL 2

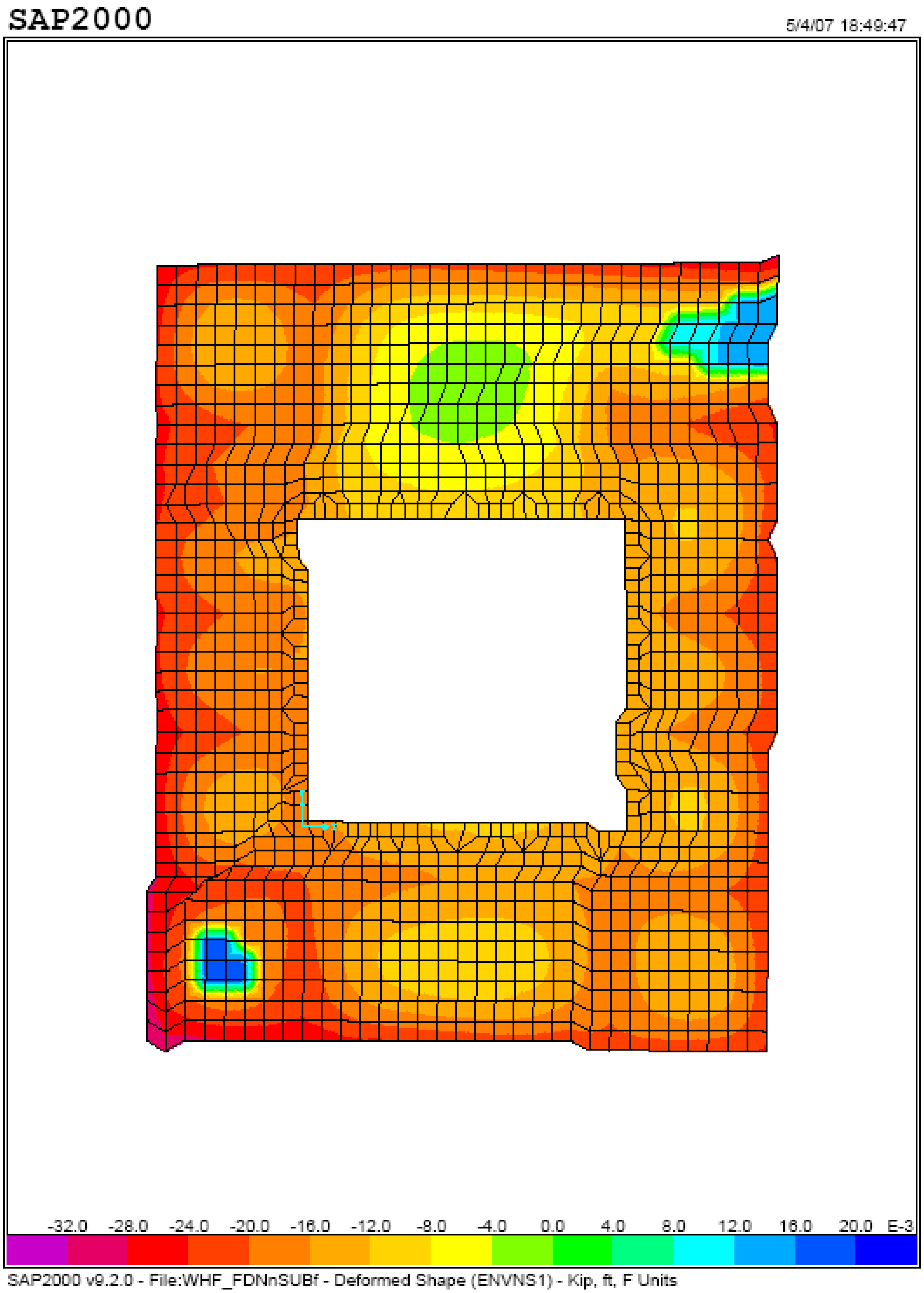
ATTACHMENT C

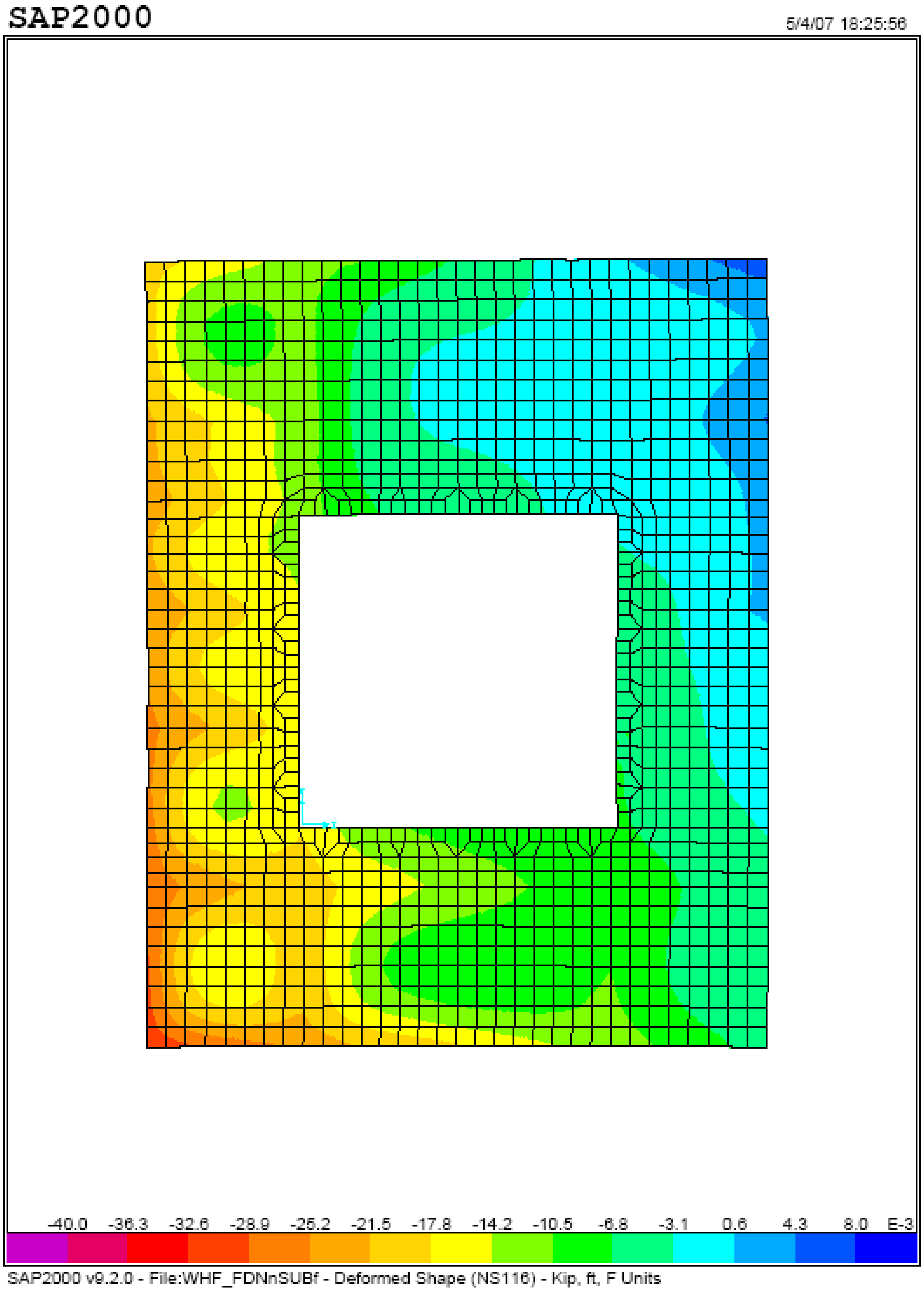
VERTICAL DEFLECTION

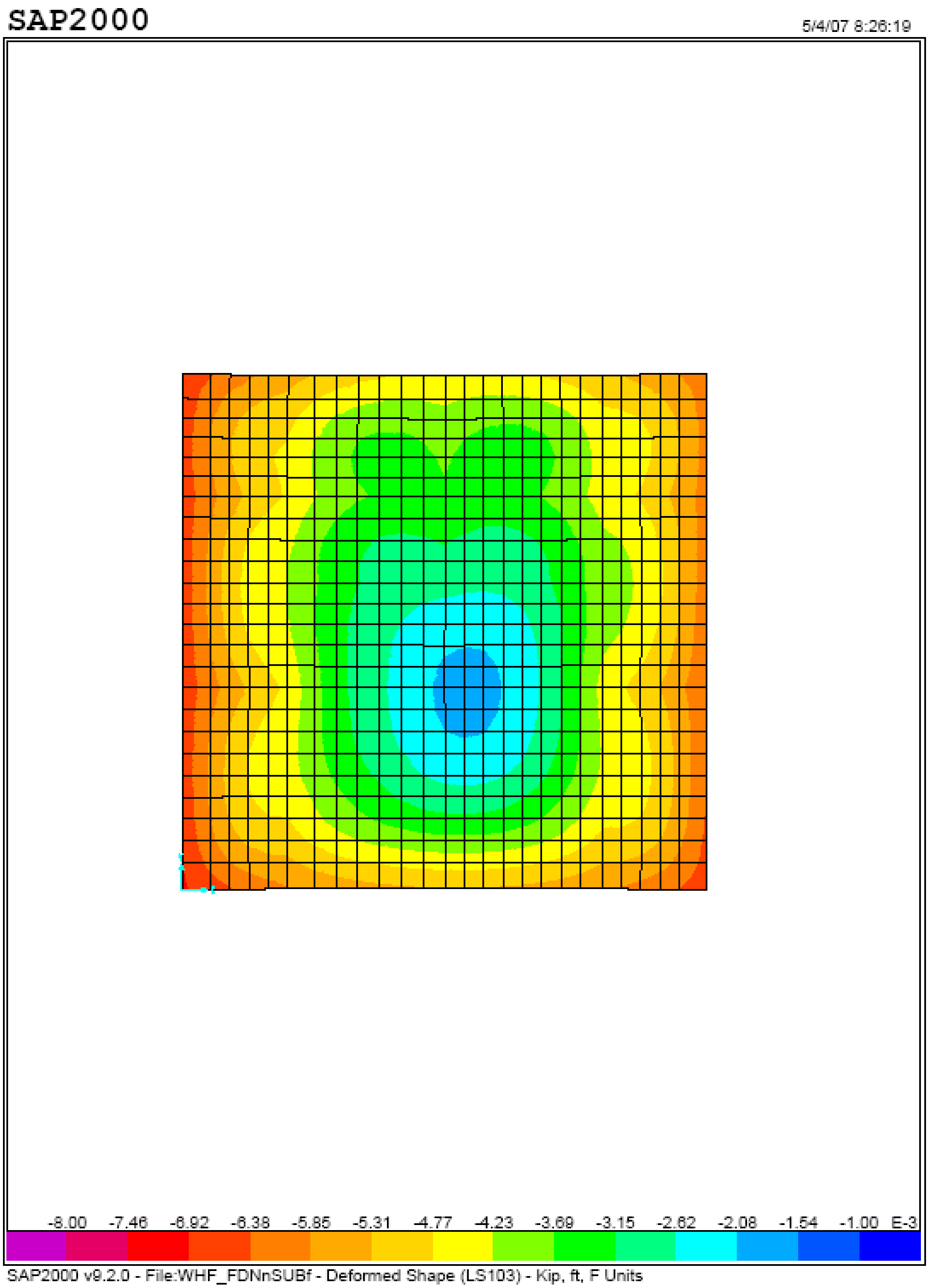
MOMENT, SHEAR AND FORCE CONTOURS

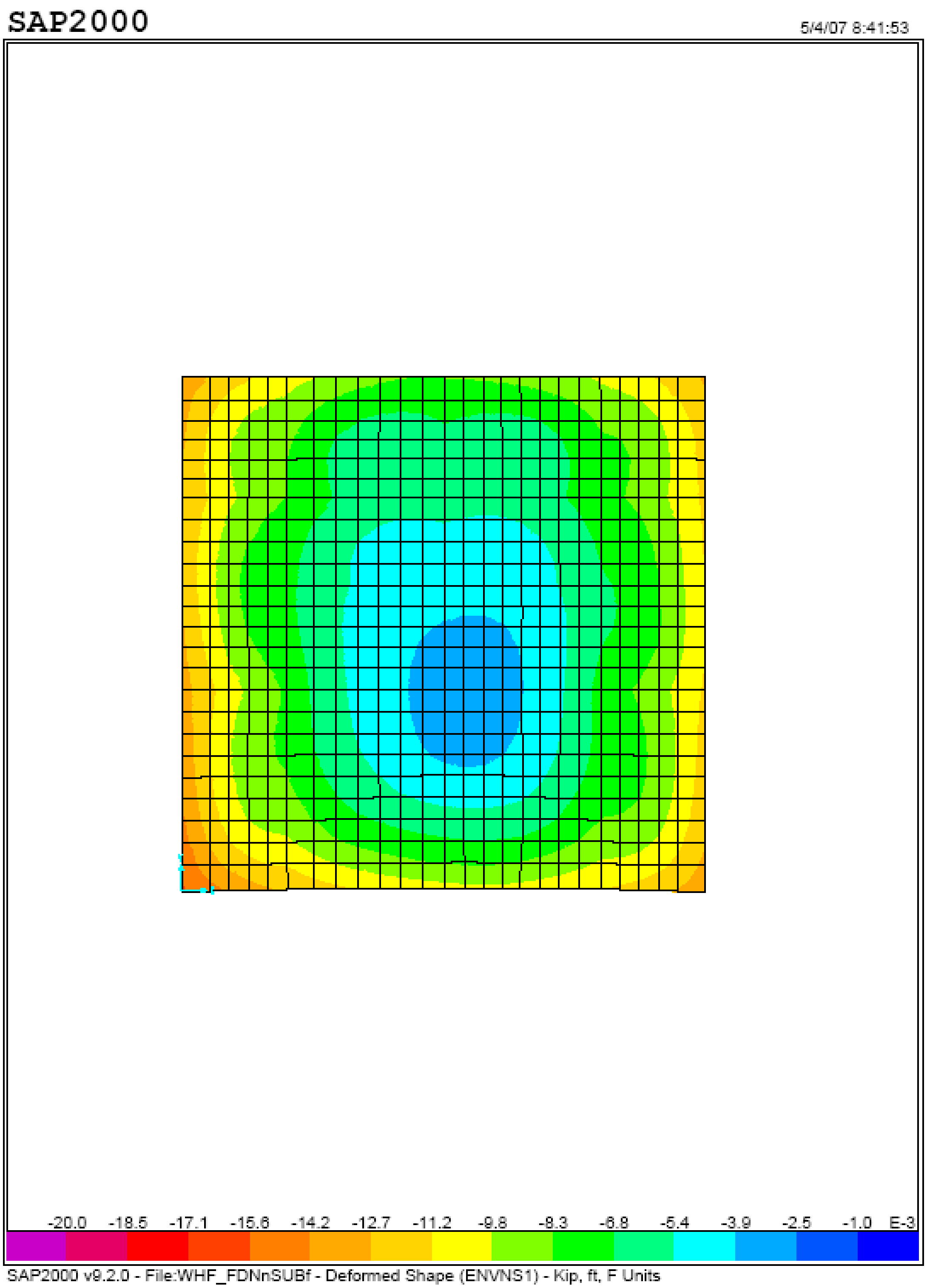
Based on the WHF Foundation and Subgrade Structure model discussed in section 6.4, with loadings described in sections 6.2 & 6.3, the contour plots of vertical deflection, element's moment, shear and force are output from the SAP2000 analysis to facilitate evaluation and design:


SAP2000
5/4/07 18:42:15
-11.9 -11.1 -10.2 -9.4 -8.5 -7.7 -6.8 -6.0 -5.1 -4.3 -3.4 -2.6 -1.7 -0.9 E-3
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Deformed Shape (LS103) - Kip, ft, F Units

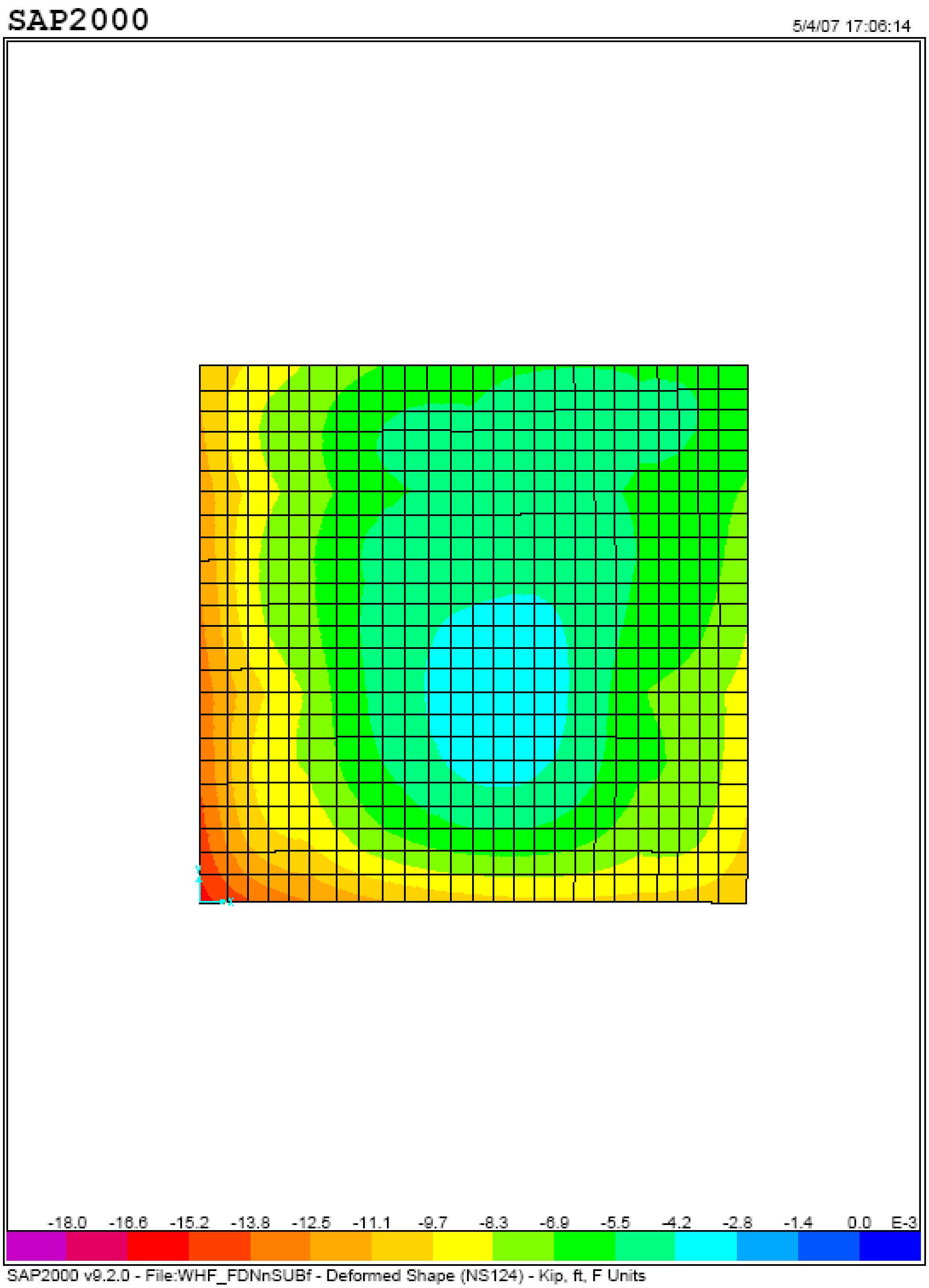

SAP2000
5/4/07 18:49:47
-32.0 -28.0 -24.0 -20.0 -16.0 -12.0 -8.0 -4.0 0.0 4.0 8.0 12.0 16.0 20.0 E-3
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Deformed Shape (ENVNS1) - Kip, ft, F Units

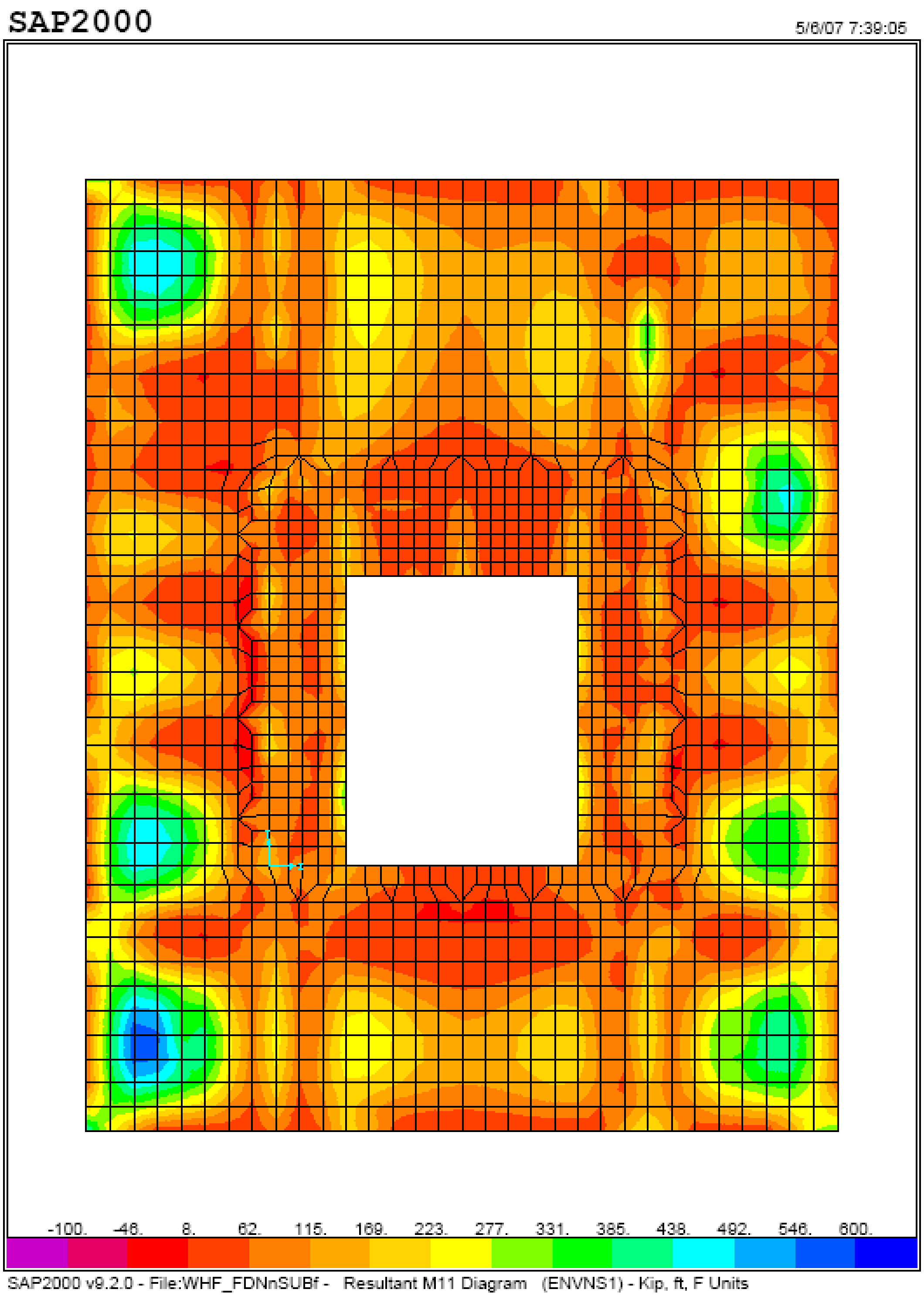

SAP2000
5/4/07 18:25:56
-40.0 -36.3 -32.6 -28.9 -25.2 -21.5 -17.8 -14.2 -10.5 -6.8 -3.1 0.6 4.3 8.0 E-3
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Deformed Shape (NS116) - Kip, ft, F Units

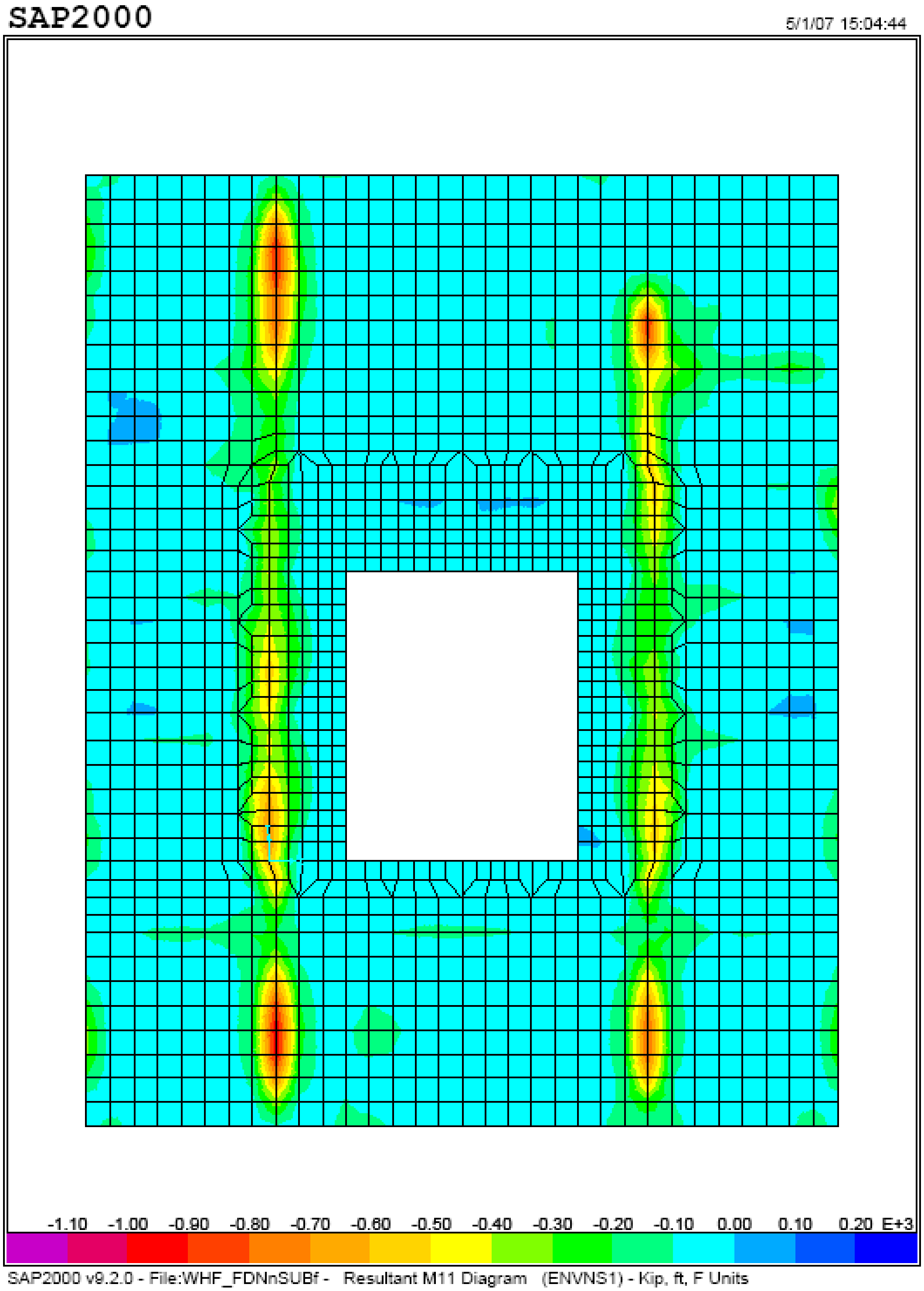

SAP2000
5/4/07 8:26:19
-8.00 -7.46 -6.92 -6.38 -5.85 -5.31 -4.77 -4.23 -3.69 -3.15 -2.62 -2.08 -1.54 -1.00 E-3
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Deformed Shape (LS103) - Kip, ft, F Units

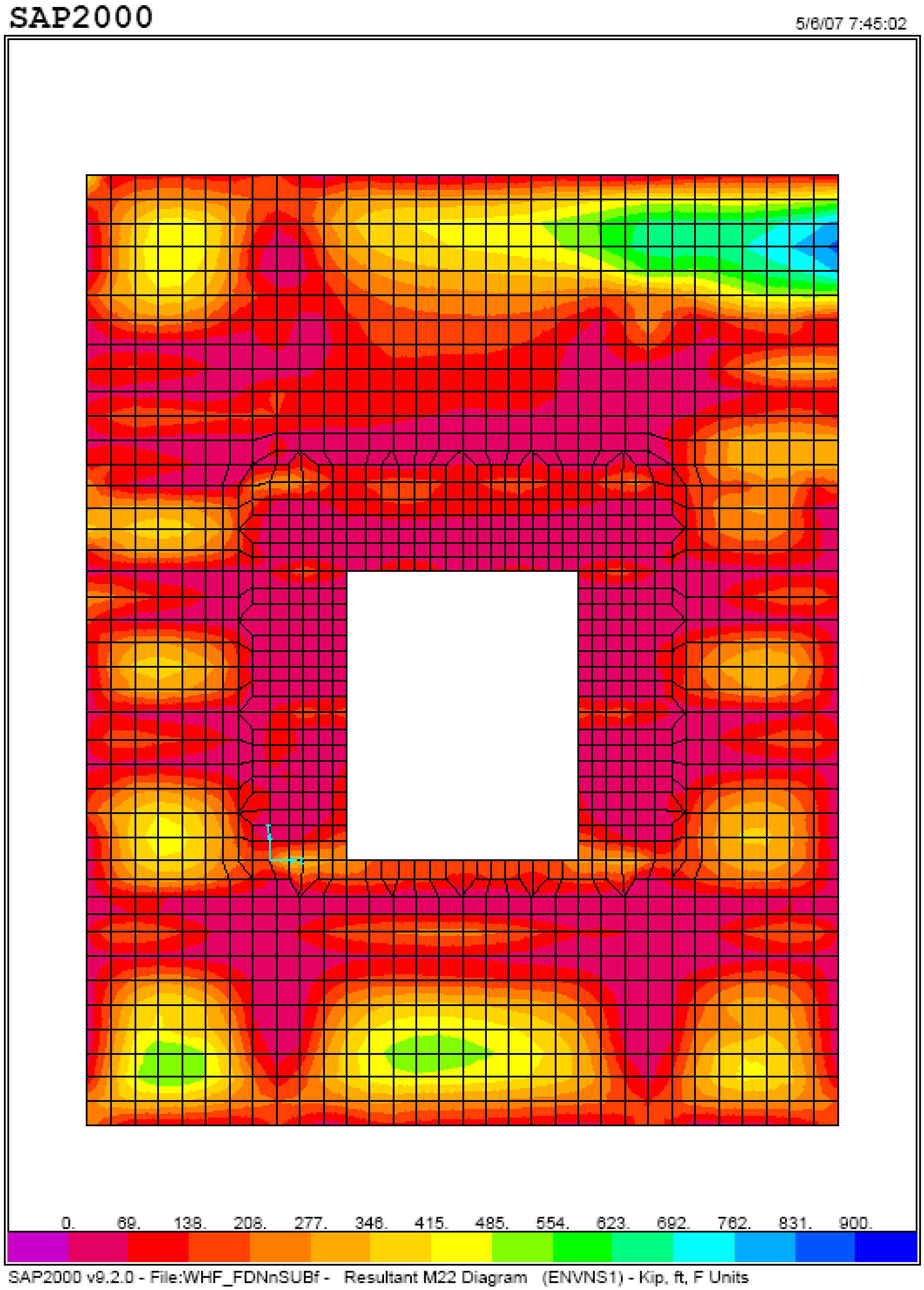


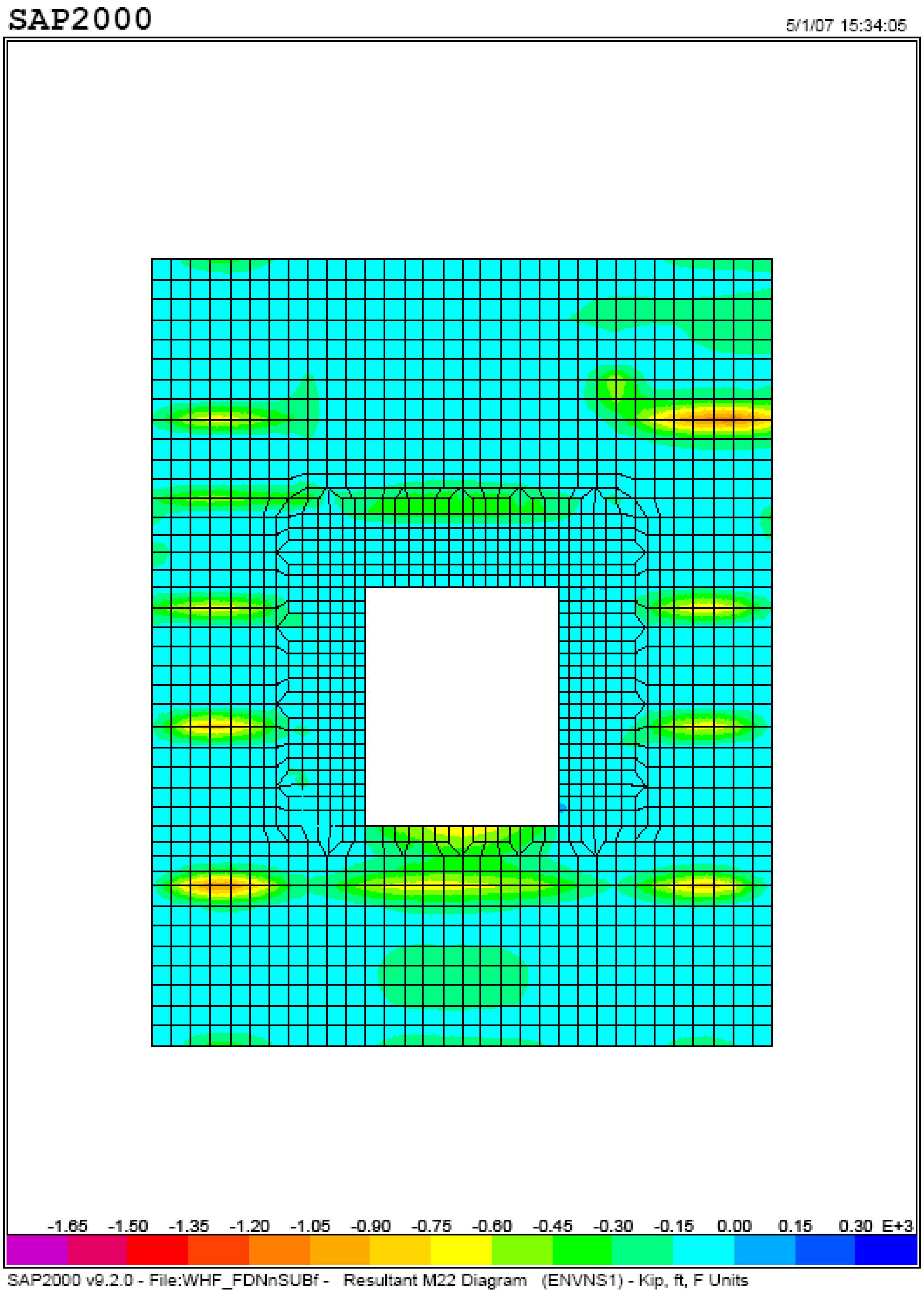
SAP2000
5/4/07 8:41:53
-20.0 -18.5 -17.1 -15.6 -14.2 -12.7 -11.2 -9.8 -8.3 -6.8 -5.4 -3.9 -2.5 -1.0 E-3
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Deformed Shape (ENVNS1) - Kip, ft, F Units

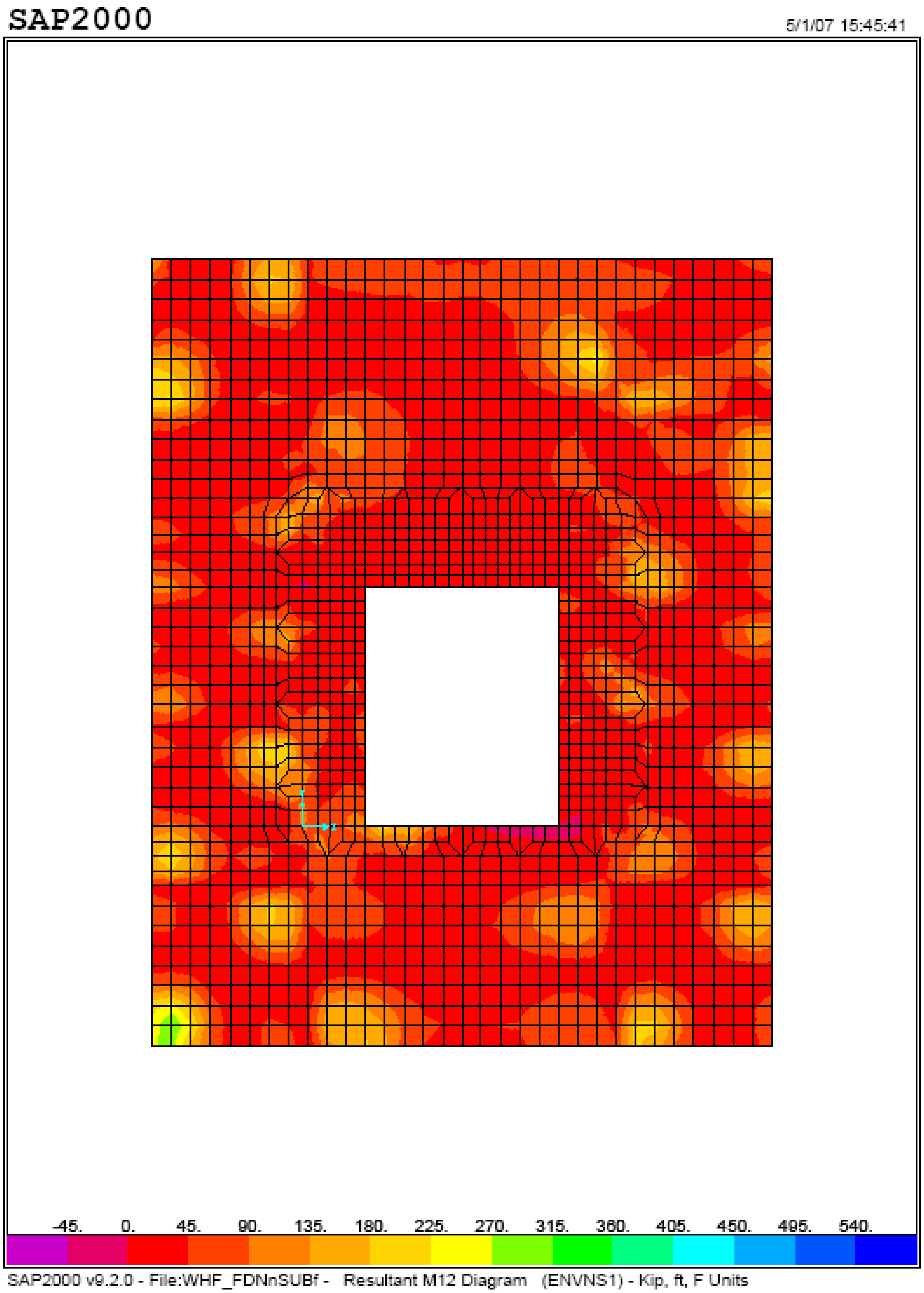

SAP2000
5/4/07 17:06:14
-18.0 -16.6 -15.2 -13.8 -12.5 -11.1 -9.7 -8.3 -6.9 -5.5 -4.2 -2.8 -1.4 0.0 E-3
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Deformed Shape (NS124) - Kip, ft, F Units

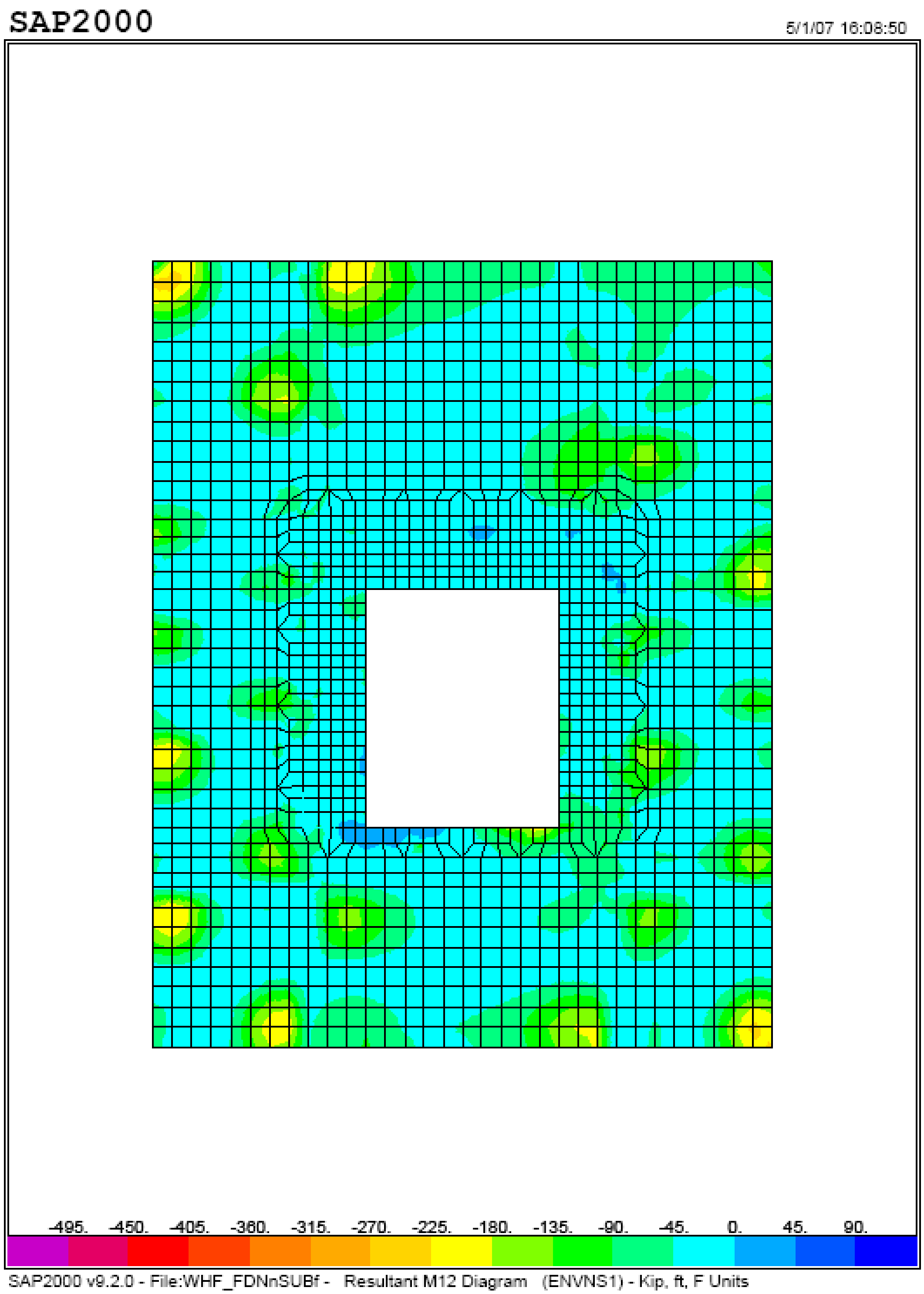

SAP2000
5/6/07 7:39:05
-100. -46. 8. 62. 115. 169. 223. 277. 331. 385. 438. 492. 546. 600.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M11 Diagram (ENVNS1) - Kip, ft, F Units

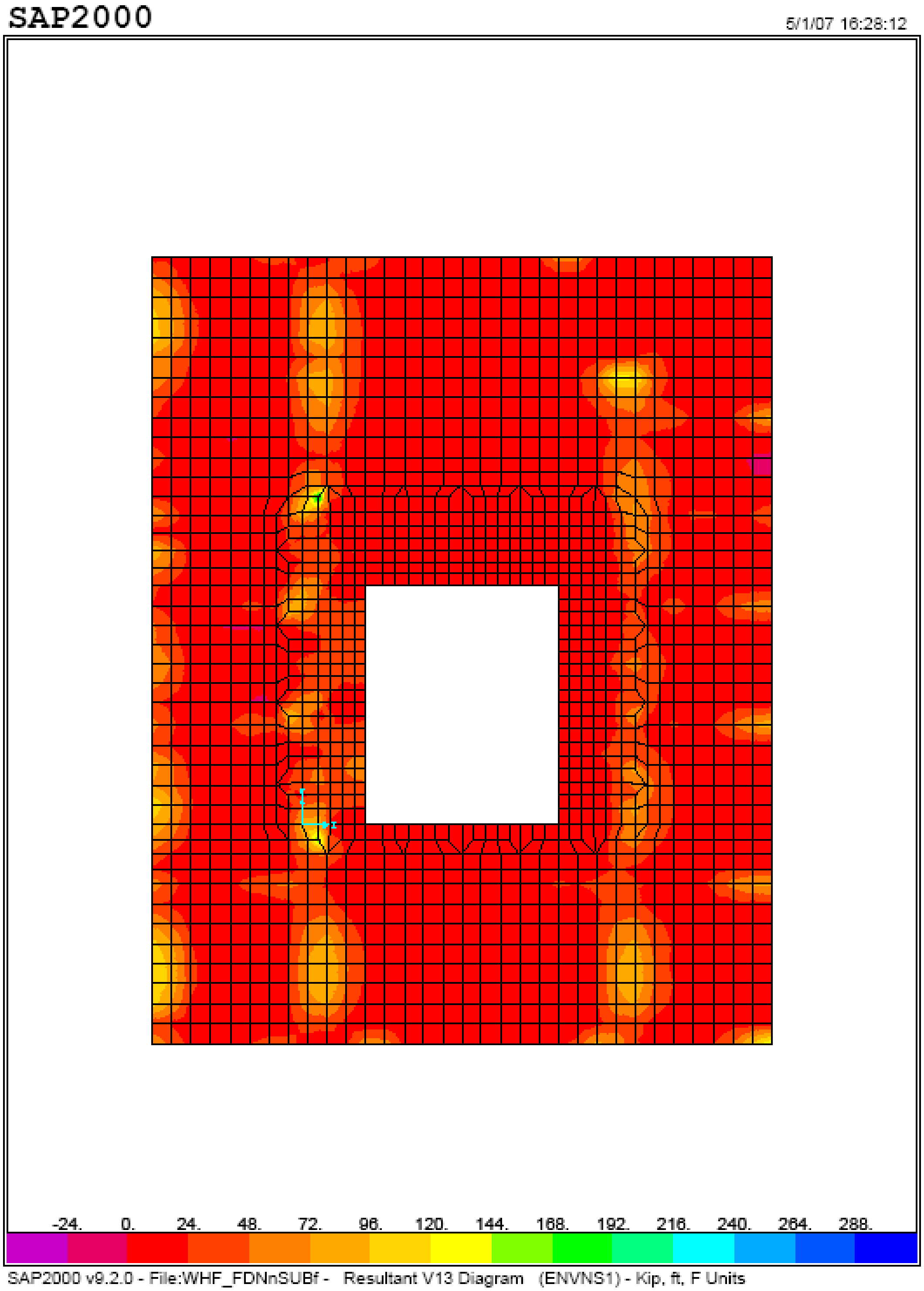

SAP2000
5/1/07 15:04:44
-1.10 -1.00 -0.90 -0.80 -0.70 -0.60 -0.50 -0.40 -0.30 -0.20 -0.10 0.00 0.10 0.20 E+3
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M11 Diagram (ENVNS1) - Kip, ft, F Units

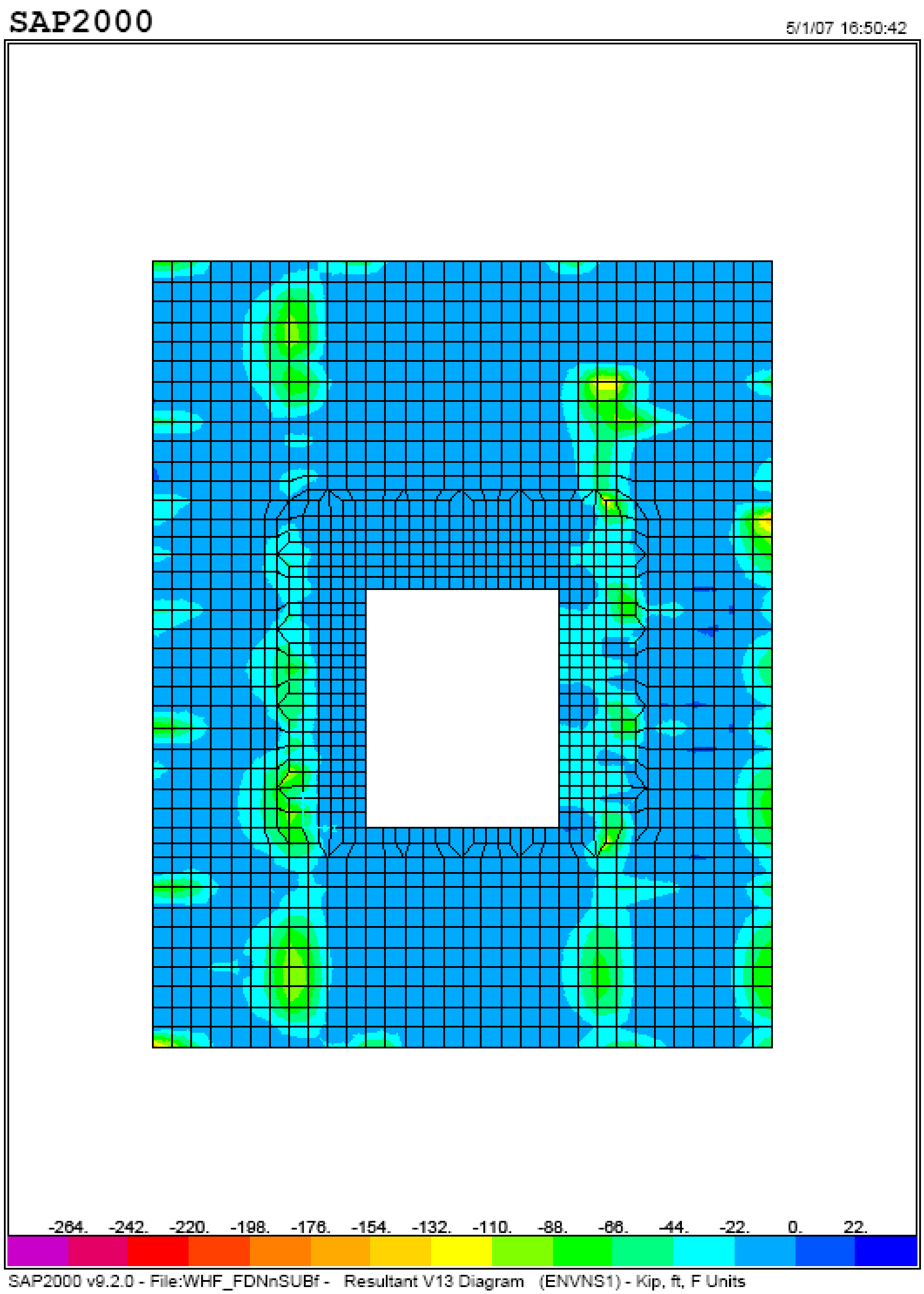

SAP2000
5/6/07 7:45:02
0. 69. 138. 208. 277. 346. 415. 485. 554. 623. 692. 762. 831. 900.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M22 Diagram (ENVNS1) - Kip, ft, F Units

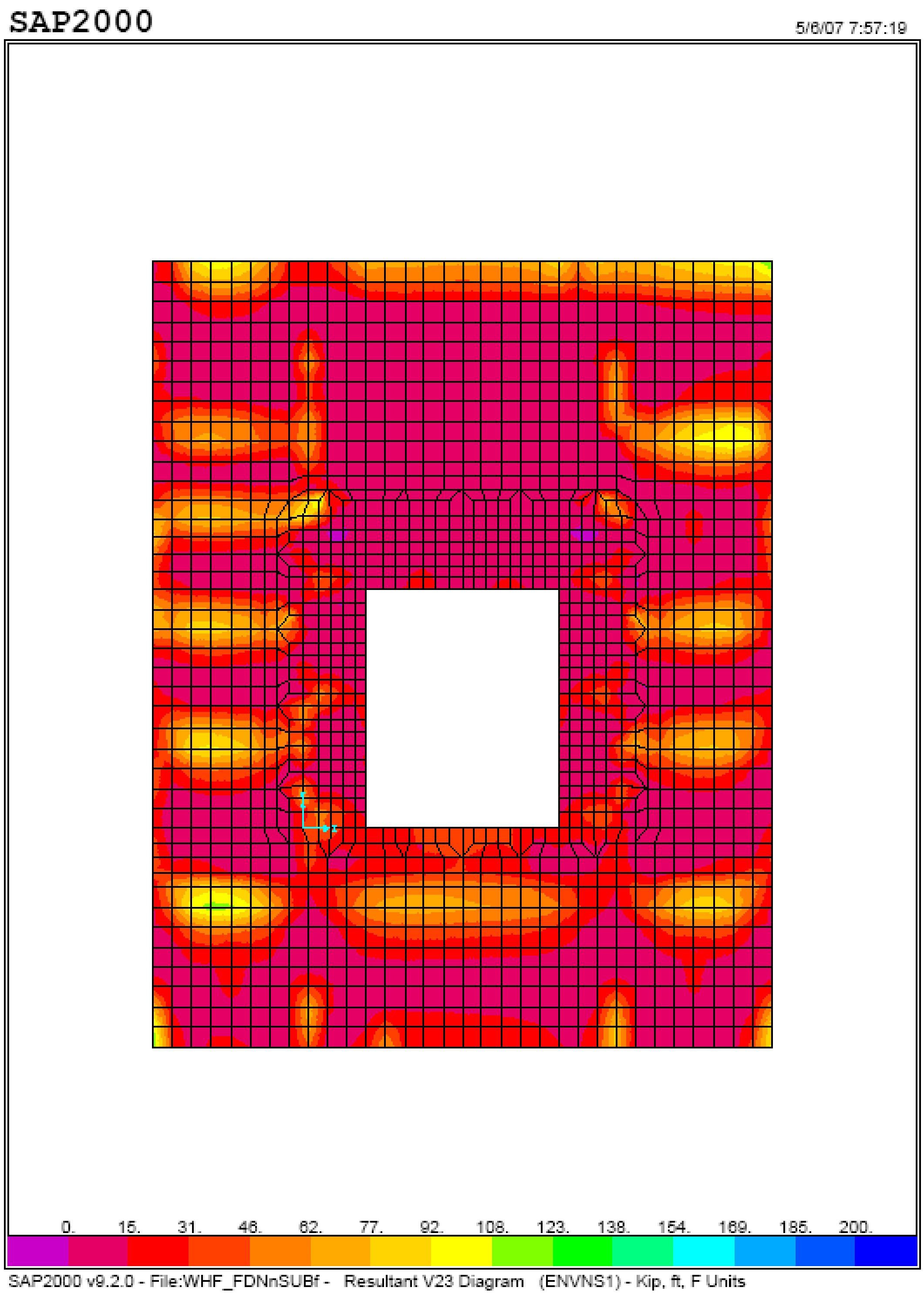

SAP2000
5/1/07 15:34:05
-1.65 -1.50 -1.35 -1.20 -1.05 -0.90 -0.75 -0.60 -0.45 -0.30 -0.15 0.00 0.15 0.30 E+3
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M22 Diagram (ENVNS1) - Kip, ft, F Units

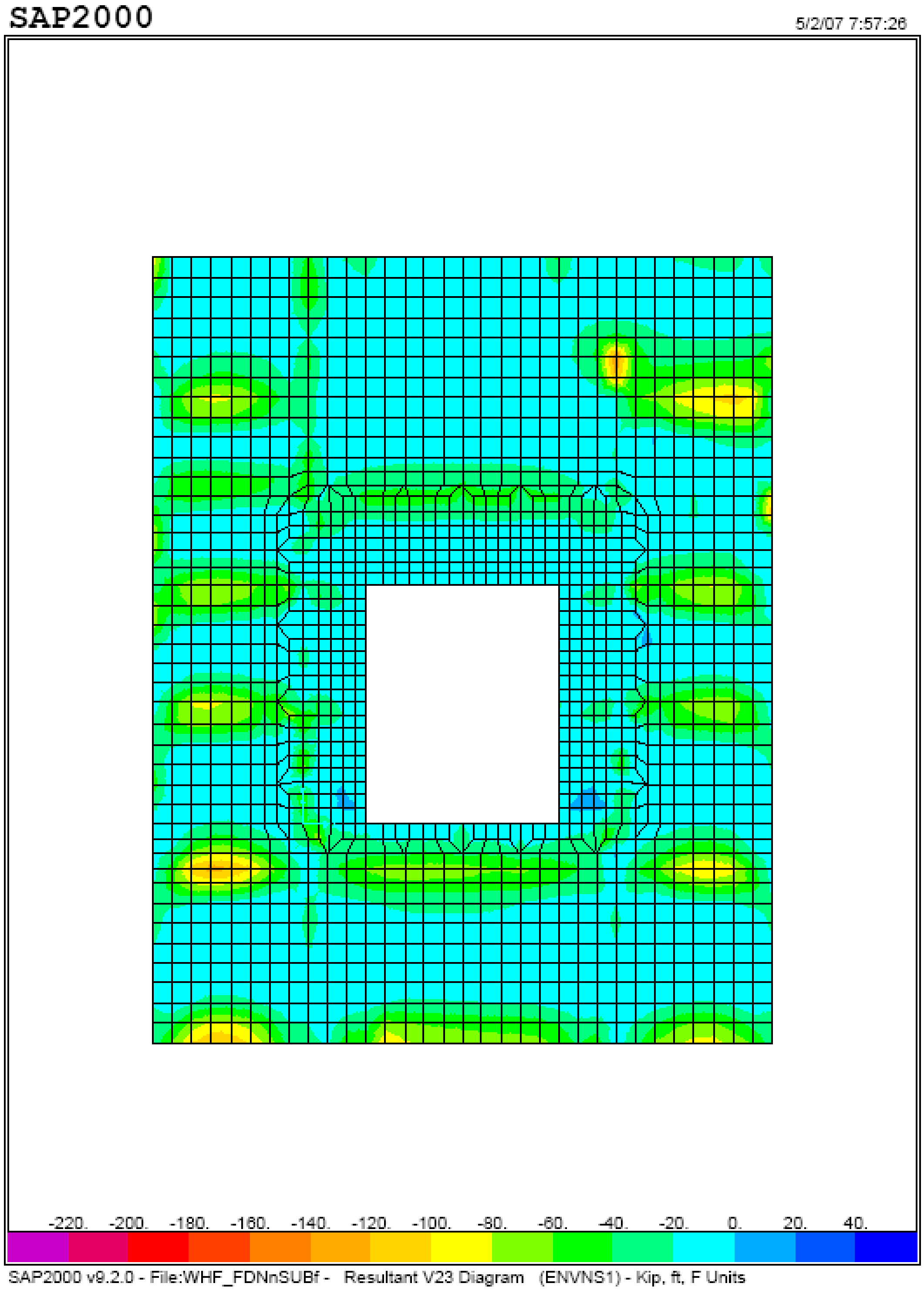

SAP2000
5/1/07 15:45:41
-45. 0. 45. 90. 135. 180. 225. 270. 315. 360. 405. 450. 495. 540.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M12 Diagram (ENVNS1) - Kip, ft, F Units

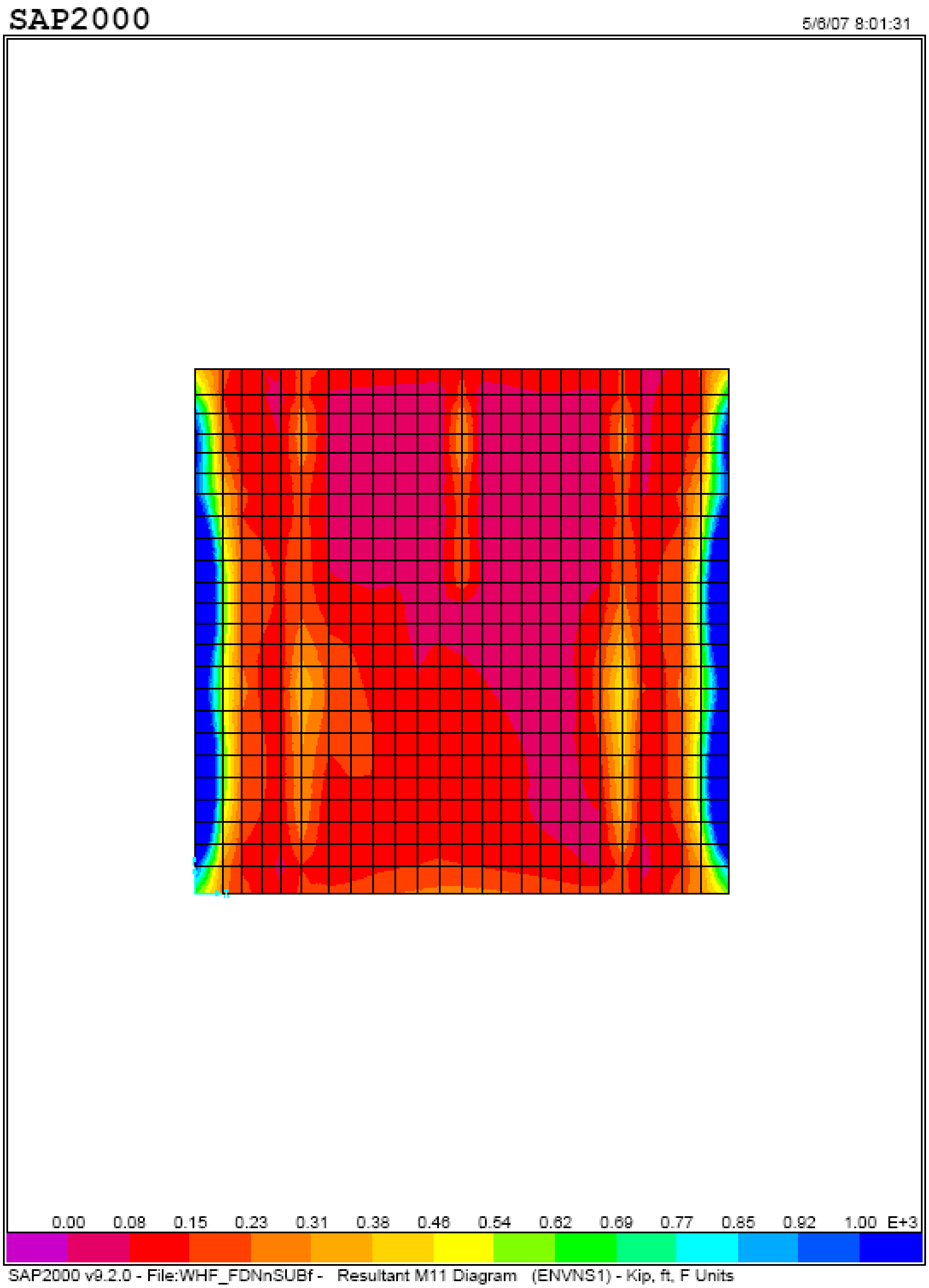

SAP2000
5/1/07 16:08:50
-495. -450. -405. -360. -315. -270. -225. -180. -135. -90. -45. 0. 45. 90.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M12 Diagram (ENVNS1) - Kip, ft, F Units


SAP2000
5/1/07 16:28:12
-24. 0. 24. 48. 72. 96. 120. 144. 168. 192. 216. 240. 264. 288.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant V13 Diagram (ENVNS1) - Kip, ft, F Units


SAP2000
5/1/07 16:50:42
-264. -242. -220. -198. -176. -154. -132. -110. -88. -66. -44. -22. 0. 22.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant V13 Diagram (ENVNS1) - Kip, ft, F Units


SAP2000
5/6/07 7:57:19
0. 15. 31. 46. 62. 77. 92. 108. 123. 138. 154. 169. 185. 200.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant V23 Diagram (ENVNS1) - Kip, ft, F Units


SAP2000
5/2/07 7:57:26
-220. -200. -180. -160. -140. -120. -100. -80. -60. -40. -20. 0. 20. 40.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant V23 Diagram (ENVNS1) - Kip, ft, F Units


SAP2000
5/6/07 8:01:31
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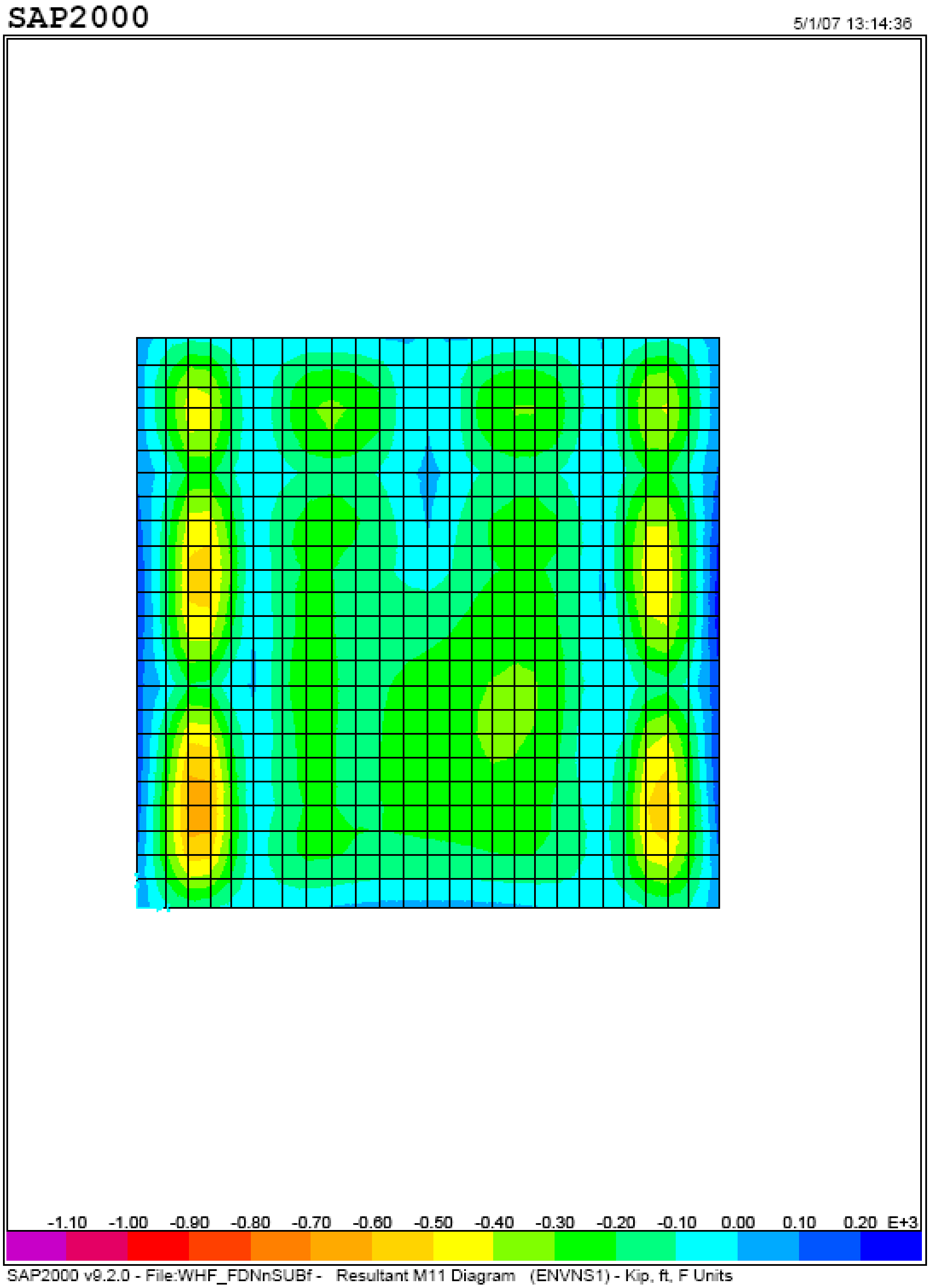
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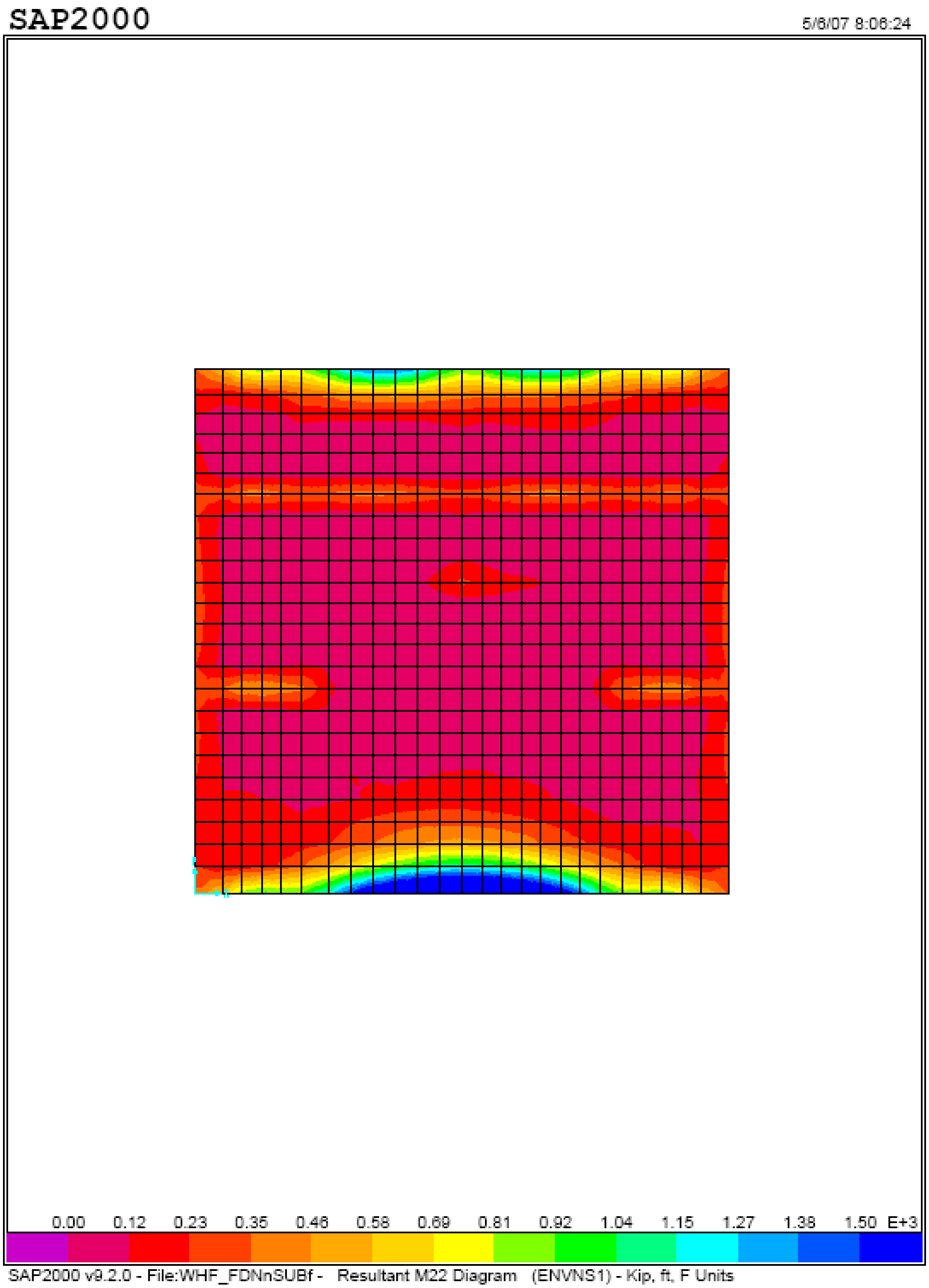
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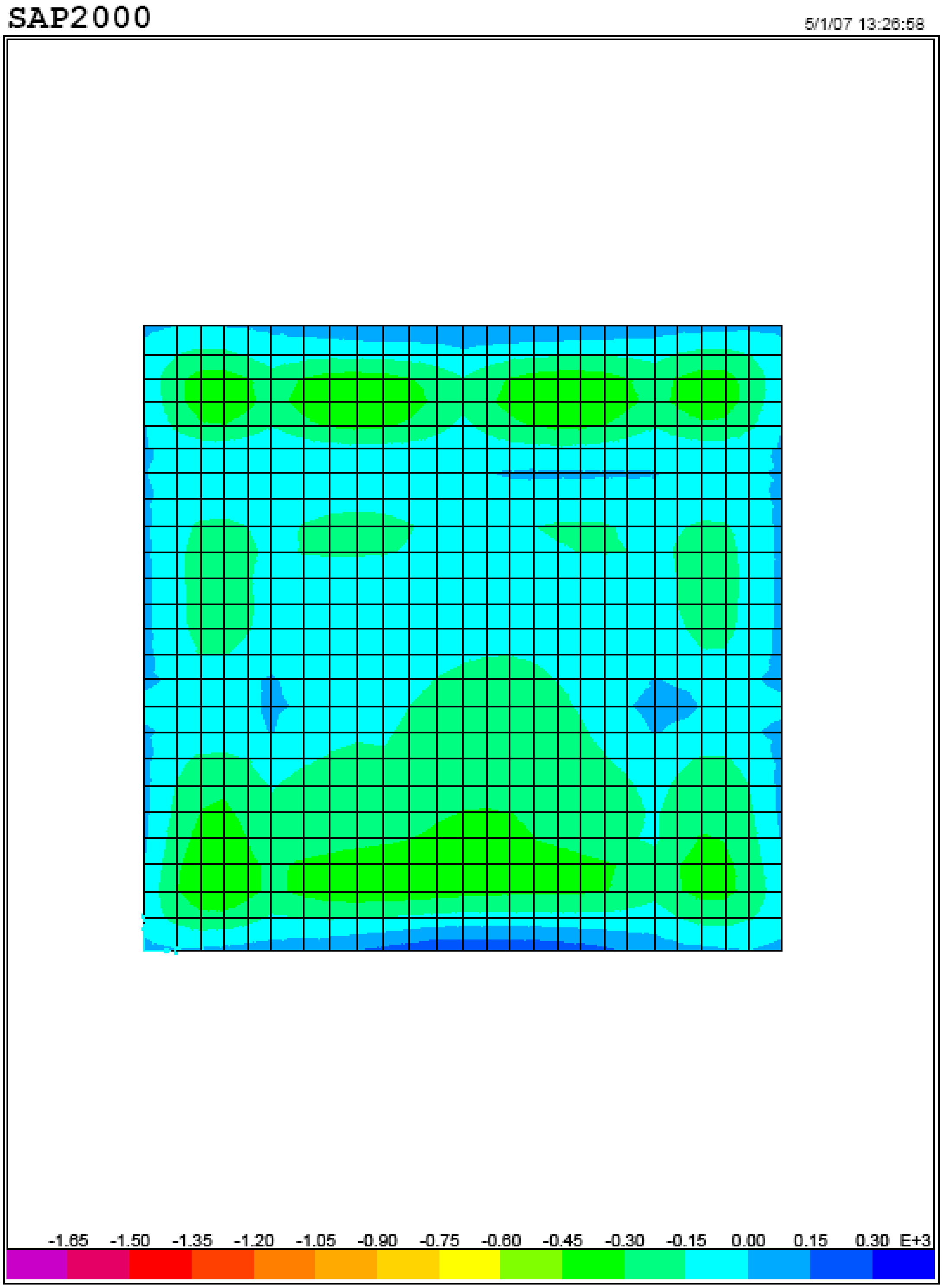
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M22 Diagram (ENVNS1) - Kip, ft, F Units



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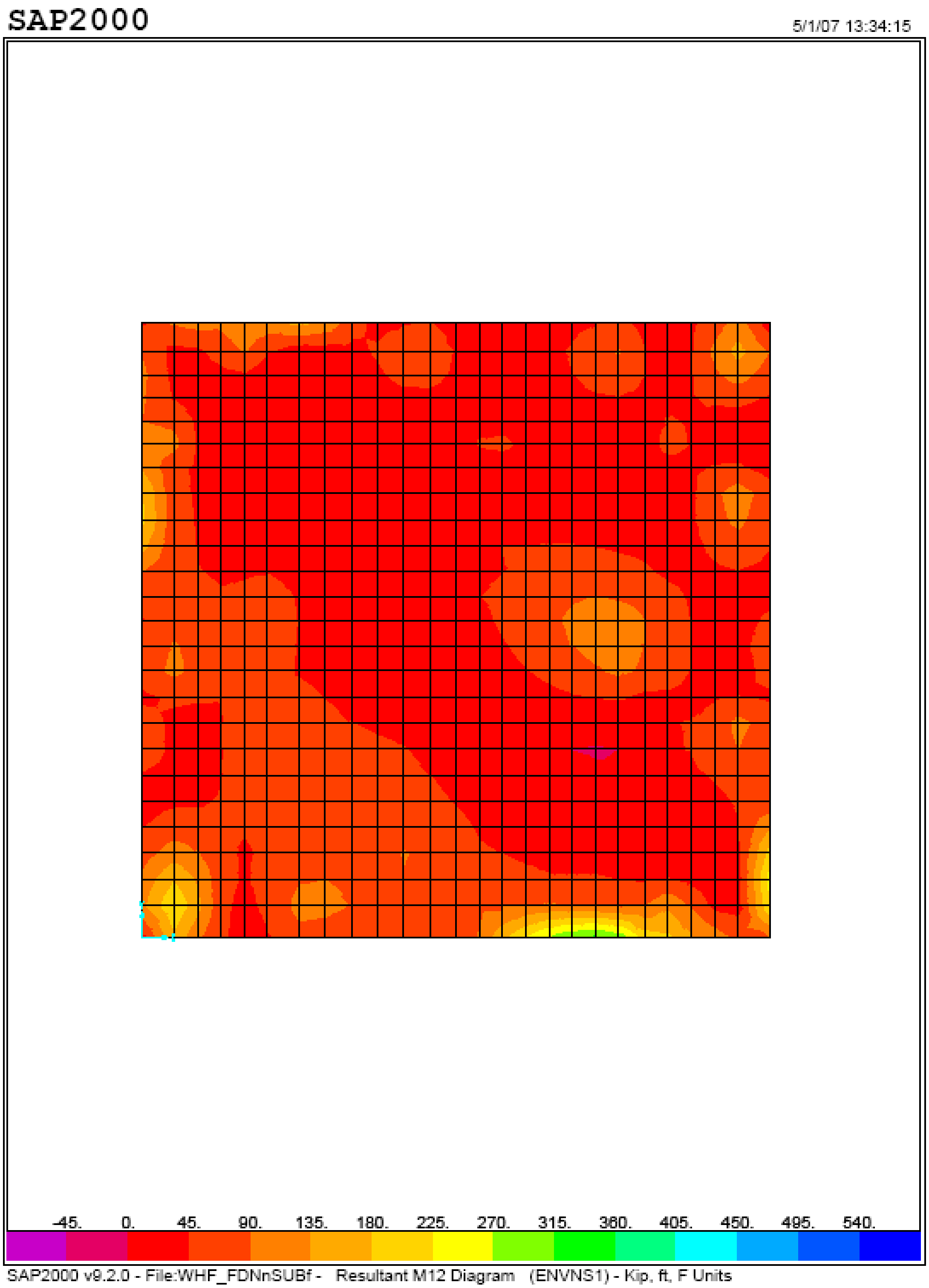
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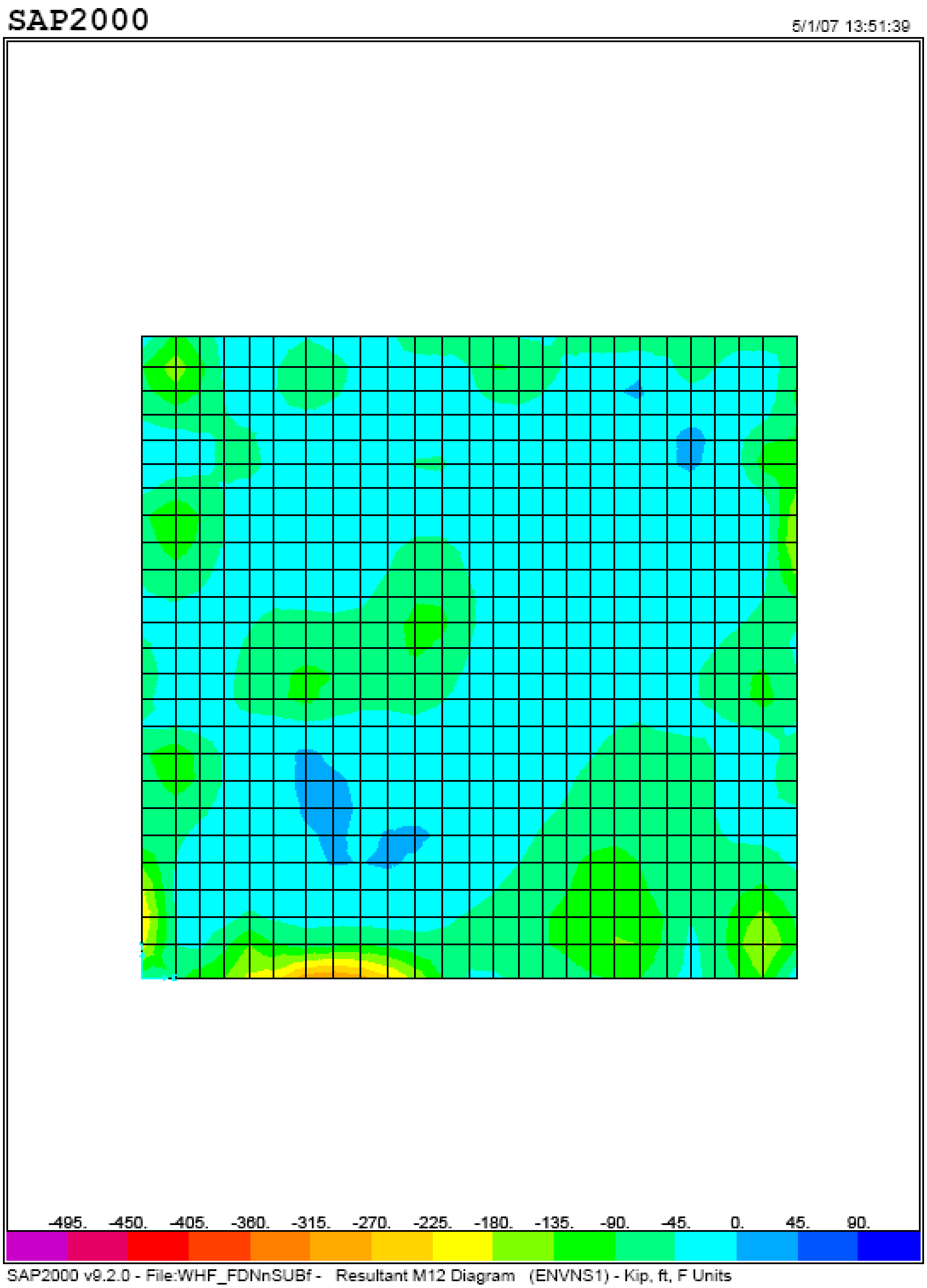
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M12 Diagram (ENVNS1) - Kip, ft, F Units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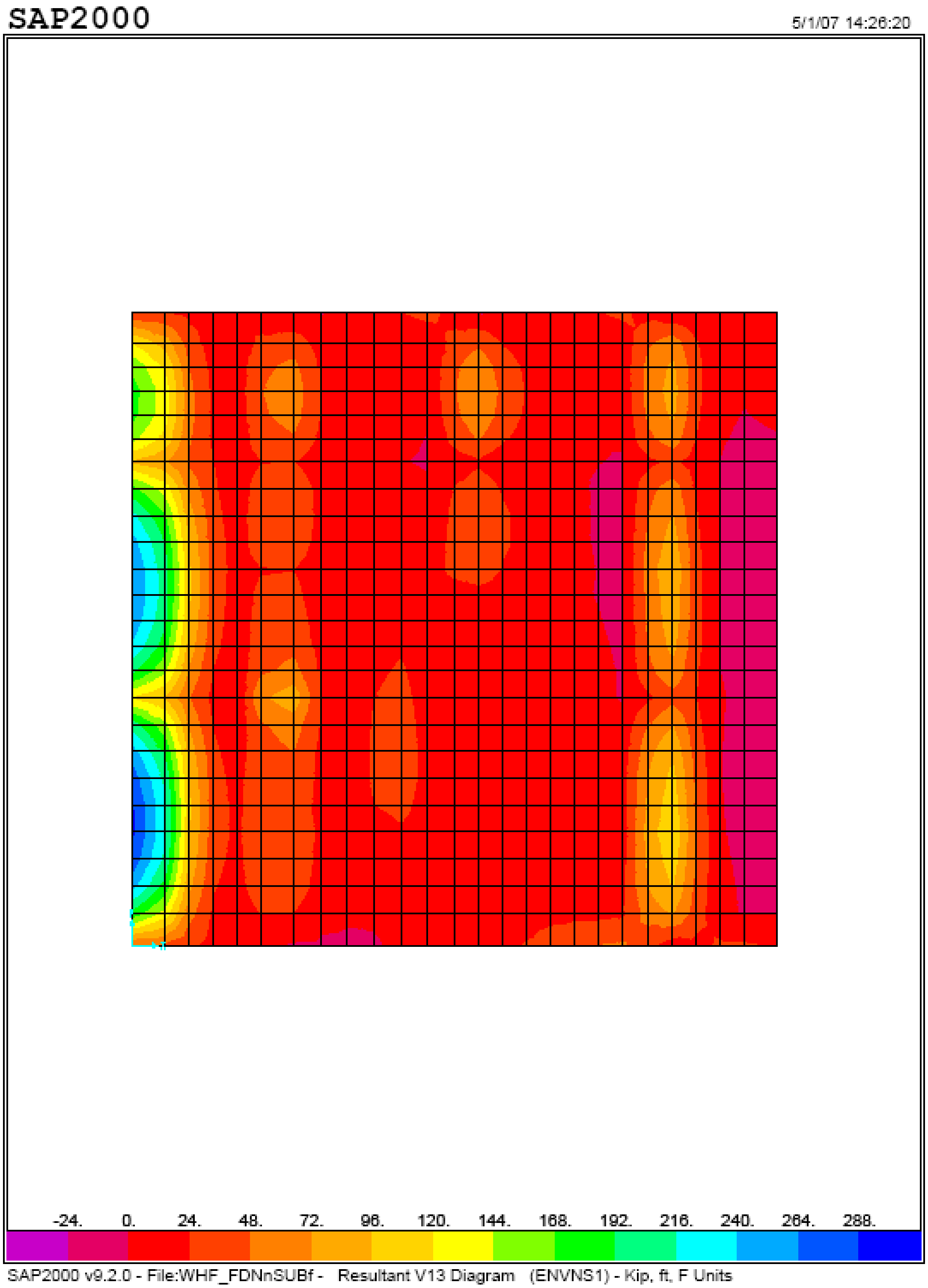
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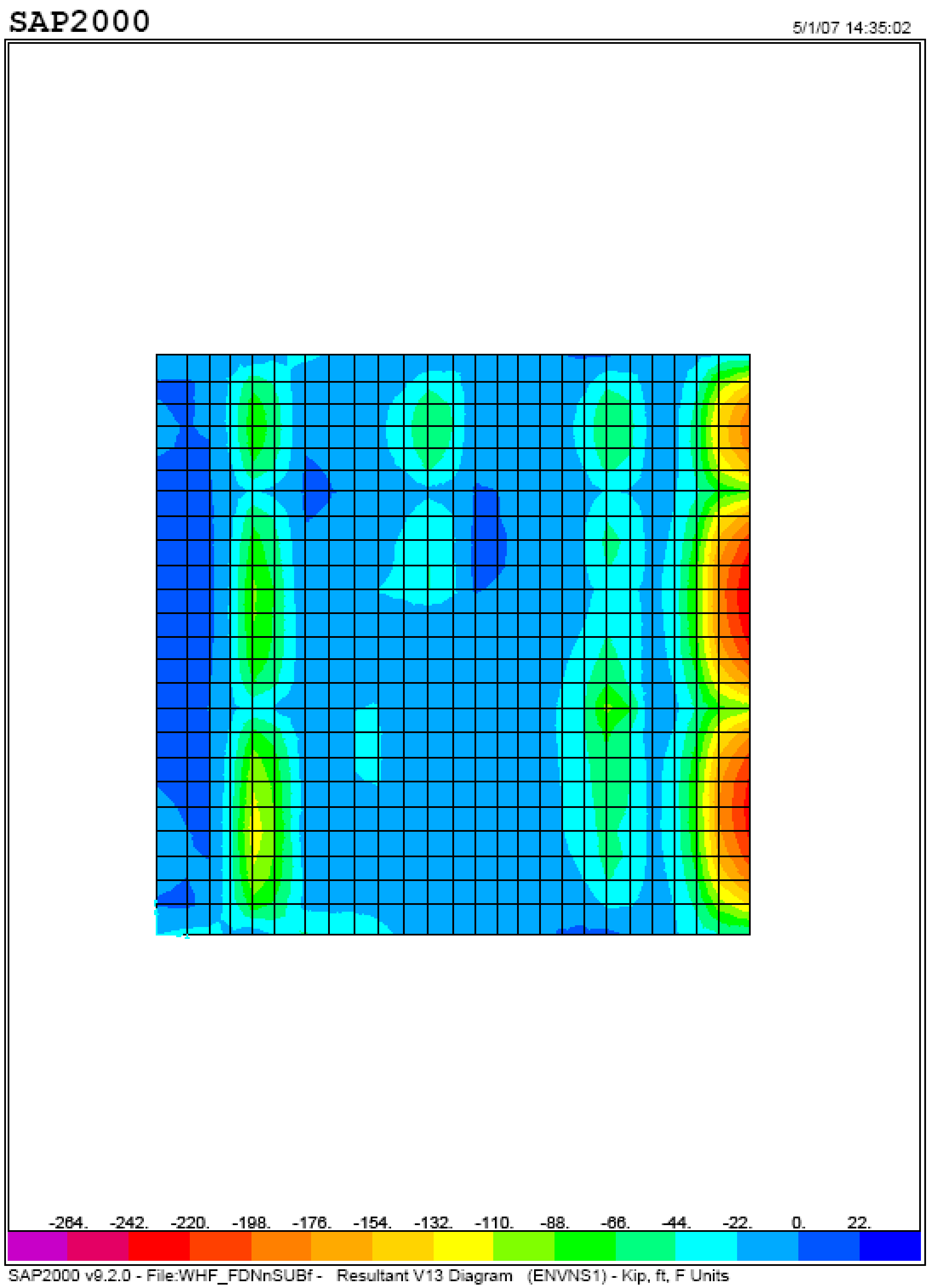
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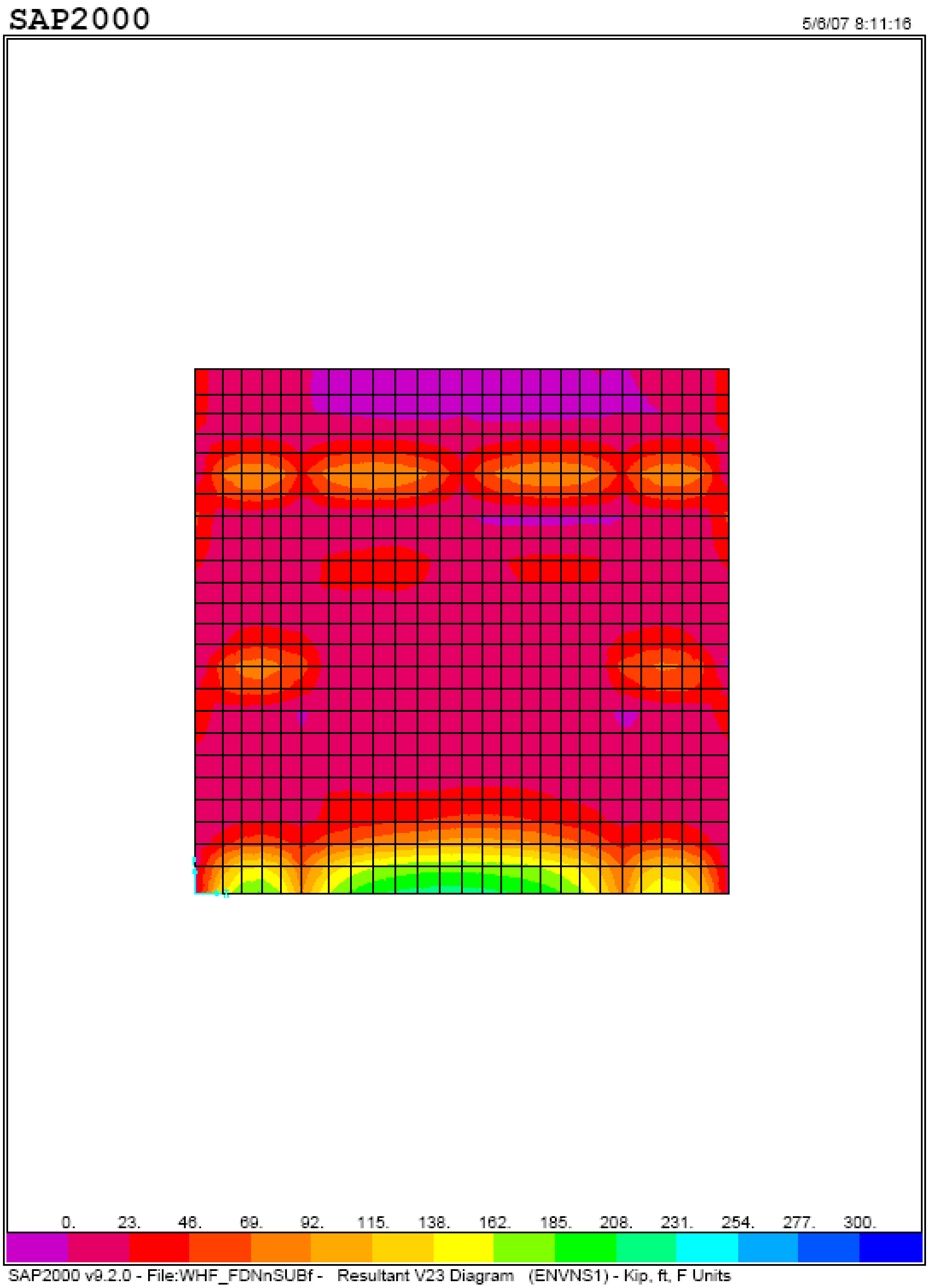
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23.
46.
69.
92.
115.
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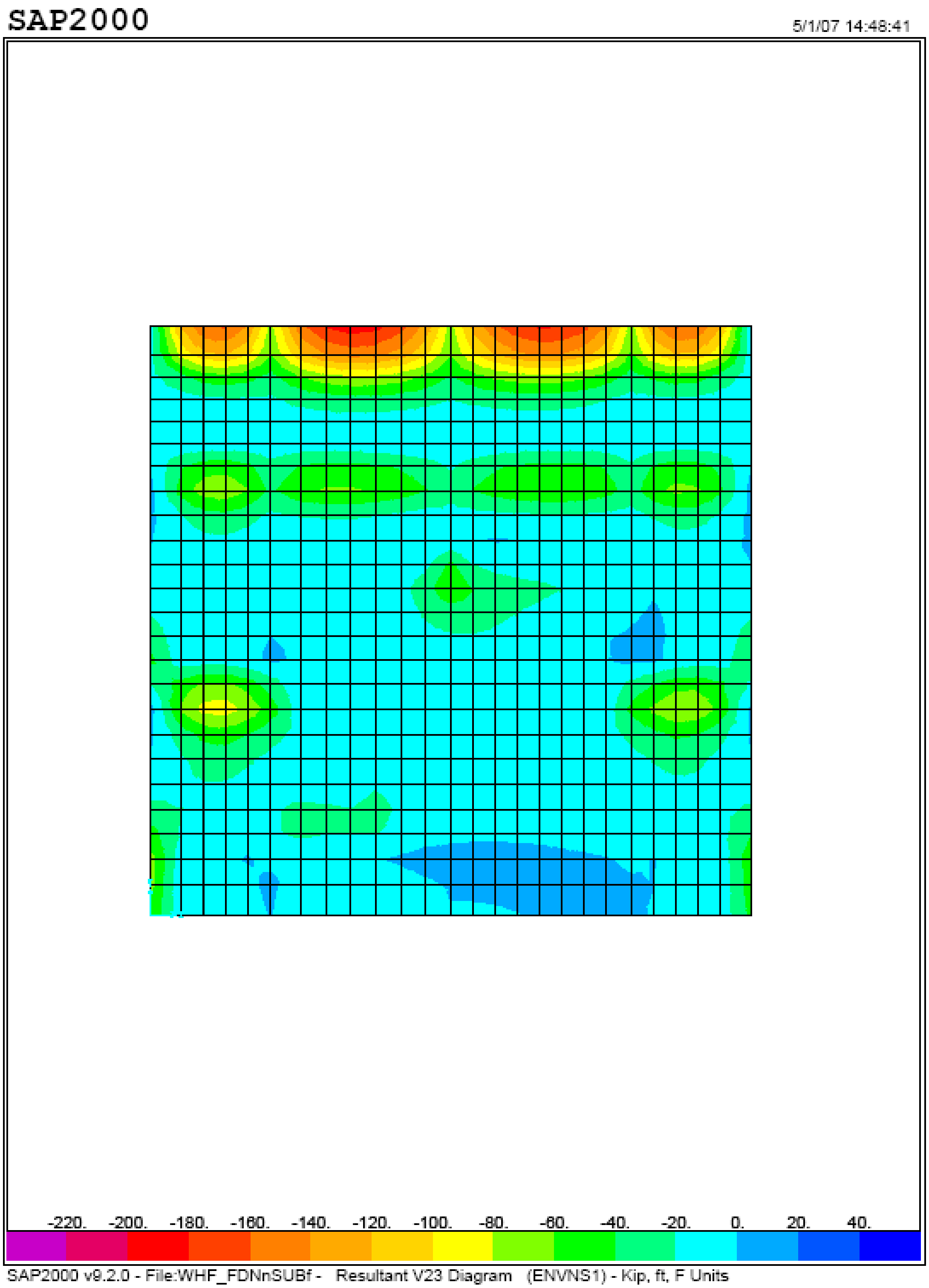
162.
185.
208.
231.
254.
277.
300.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant V23 Diagram (ENVNS1) - Kip, ft, F Units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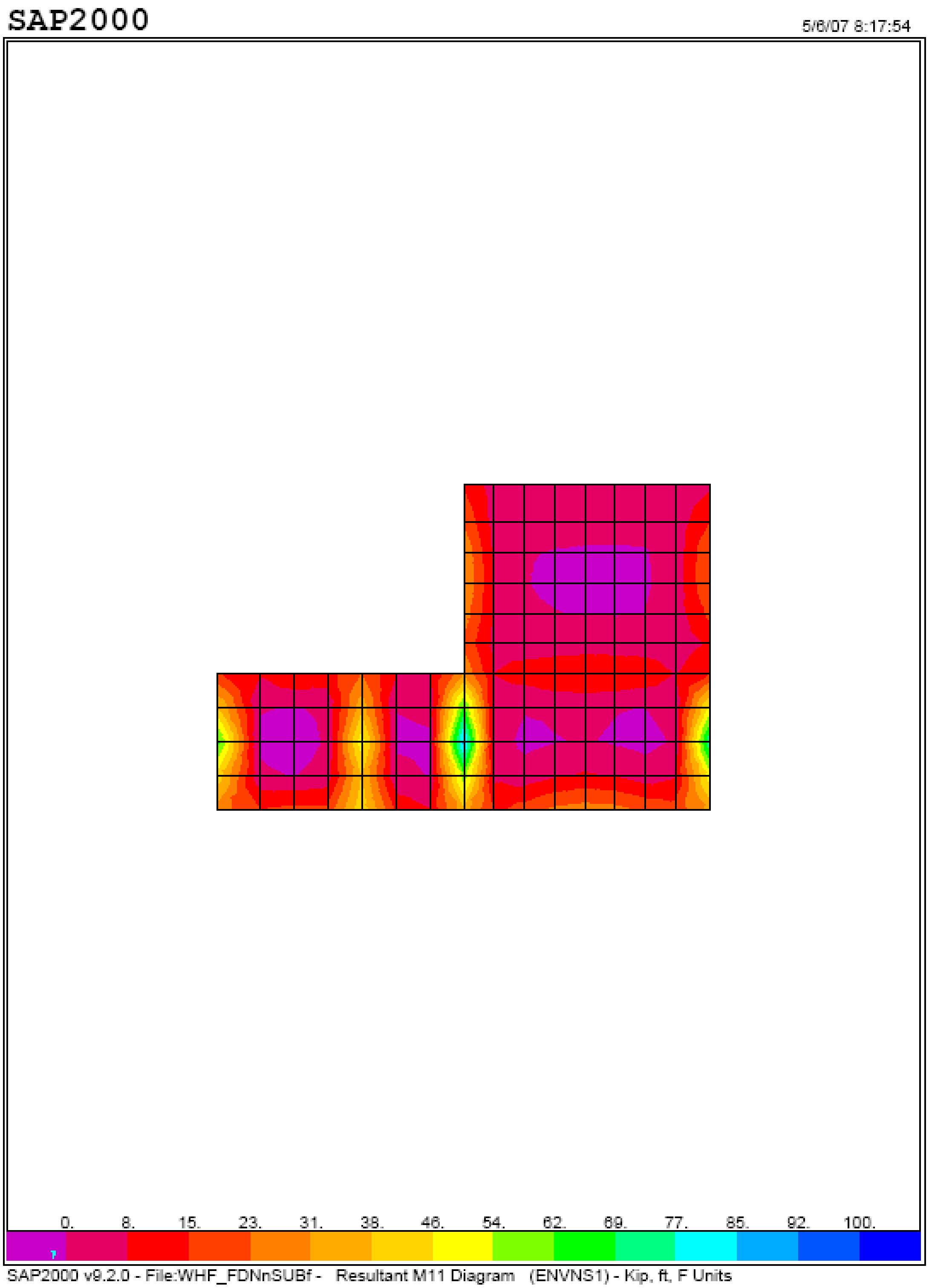
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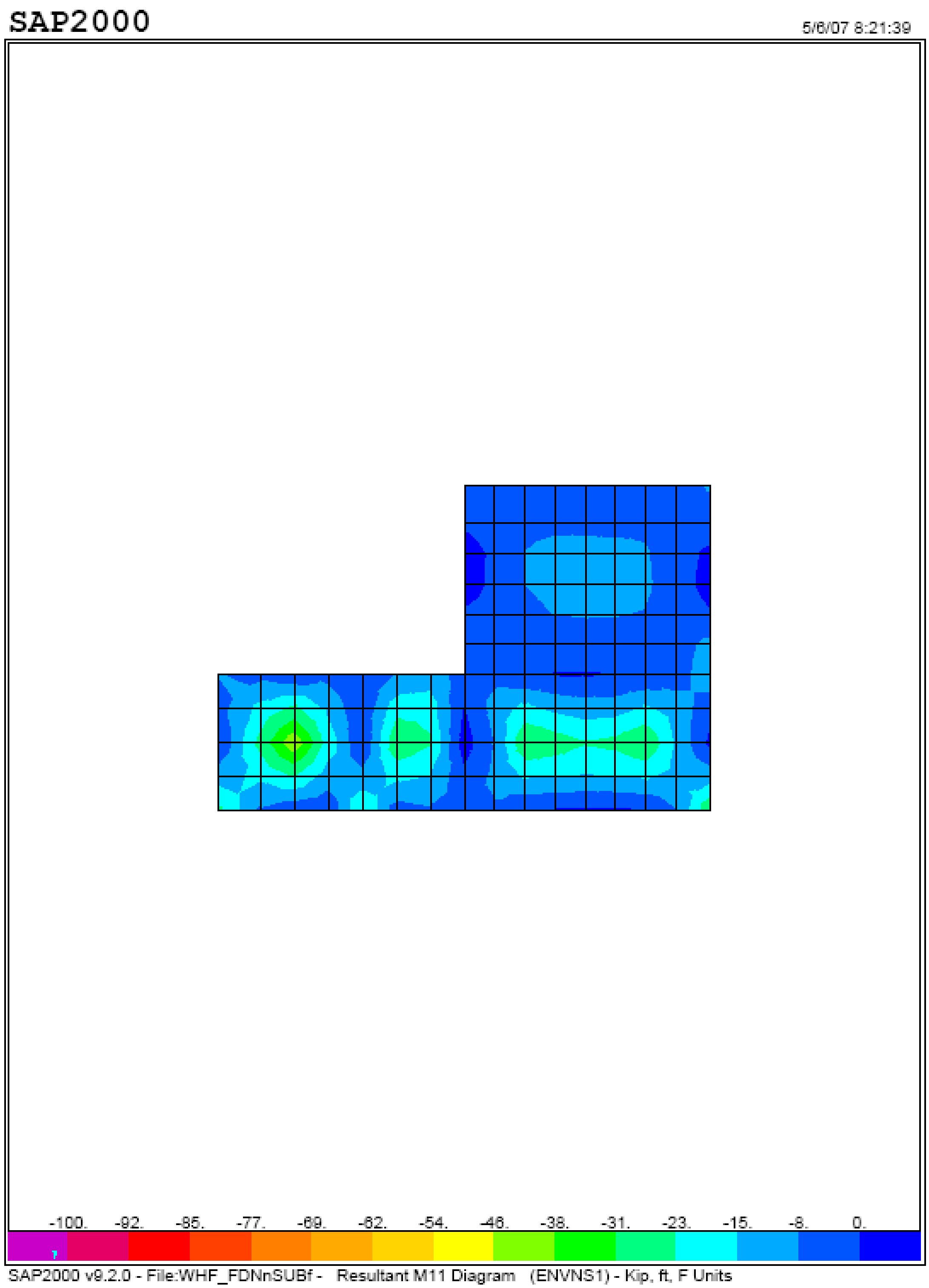
5/6/07 8:17:54
0.
8.
15.
23.
31.
38.
46.
54.
62.
69.
77.
85.
92.
100.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M11 Diagram (ENVNS1) - Kip, ft, F Units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-85.
-77.
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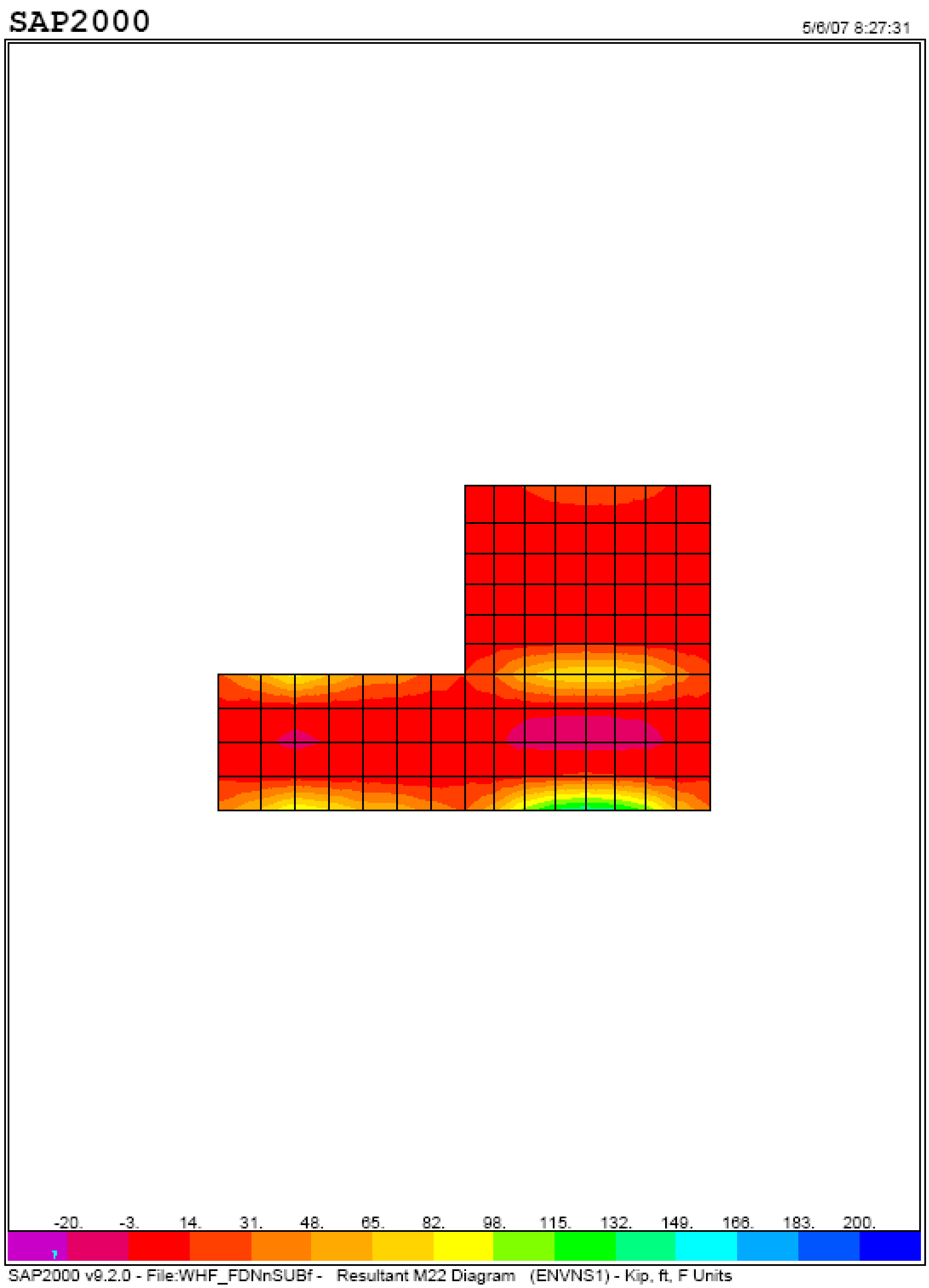
-62.
-54.
-46.
-38.
-31.
-23.
-15.
-8.
0.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M11 Diagram (ENVNS1) - Kip, ft, F Units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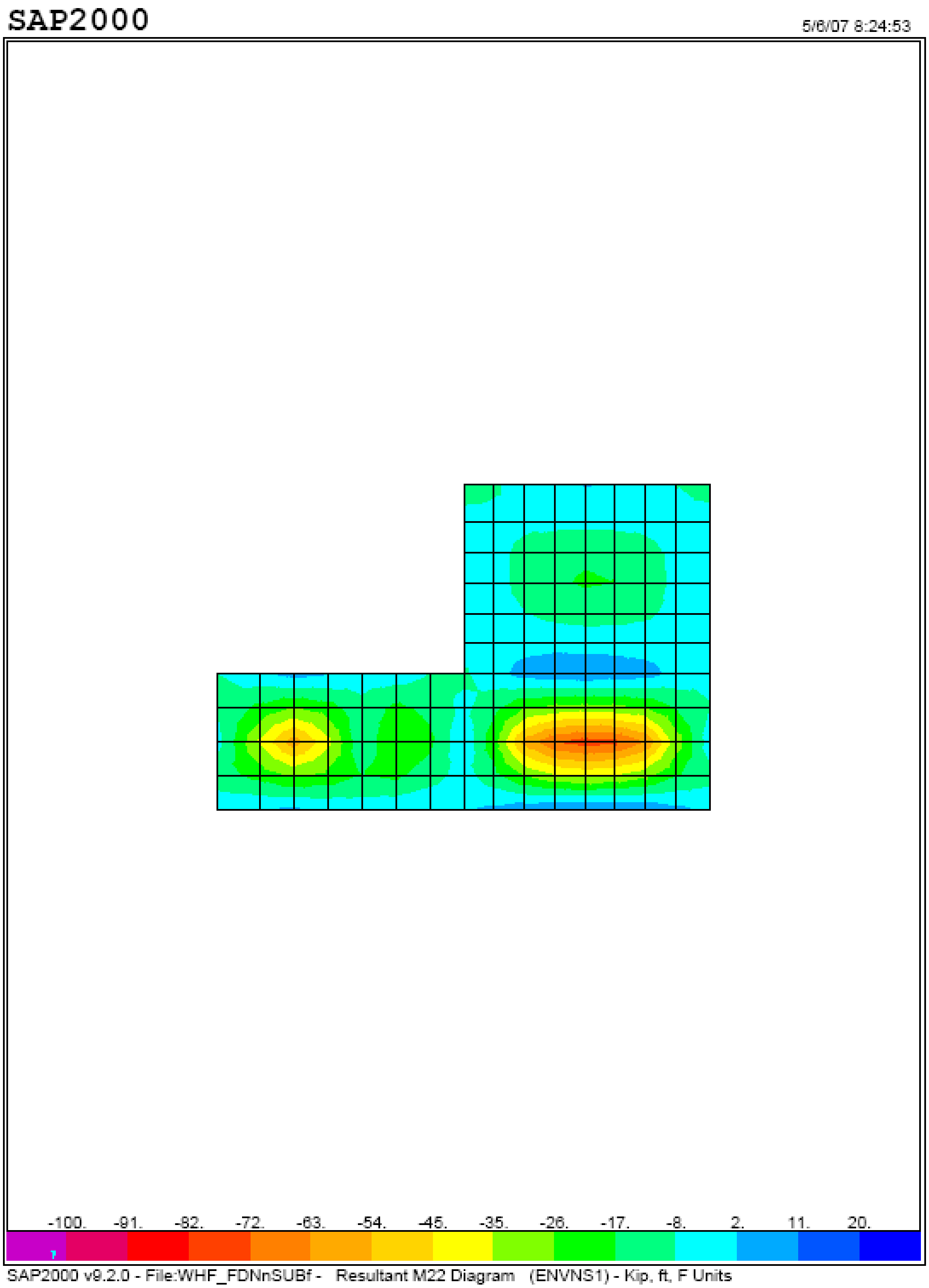
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M22 Diagram (ENVNS1) - Kip, ft, F Units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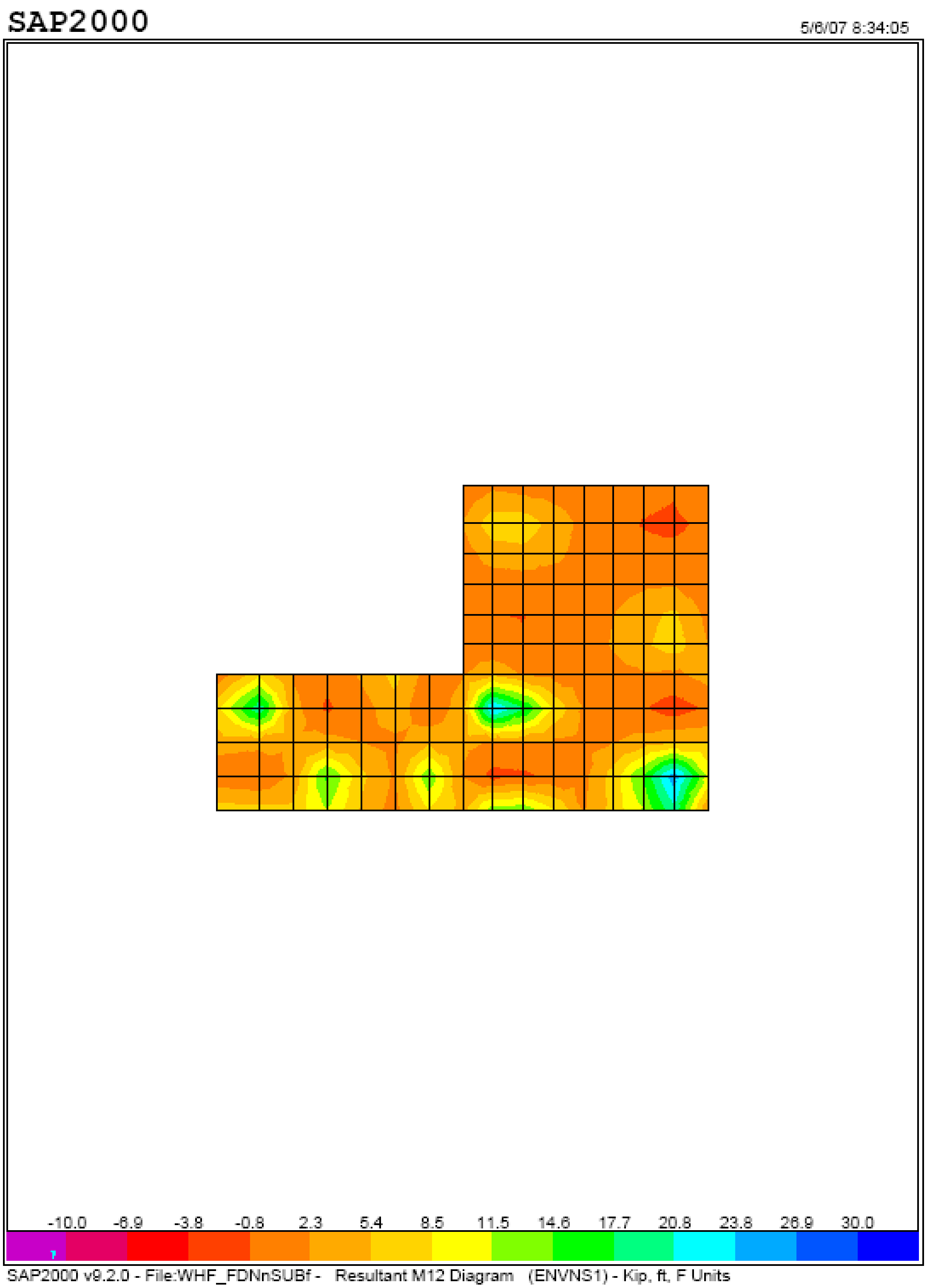
-91.
-82.
-72.
-63.
-54.
-45.
-35.
-26.
-17.
-8.
2.
11.
20.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M22 Diagram (ENVNS1) - Kip, ft, F Units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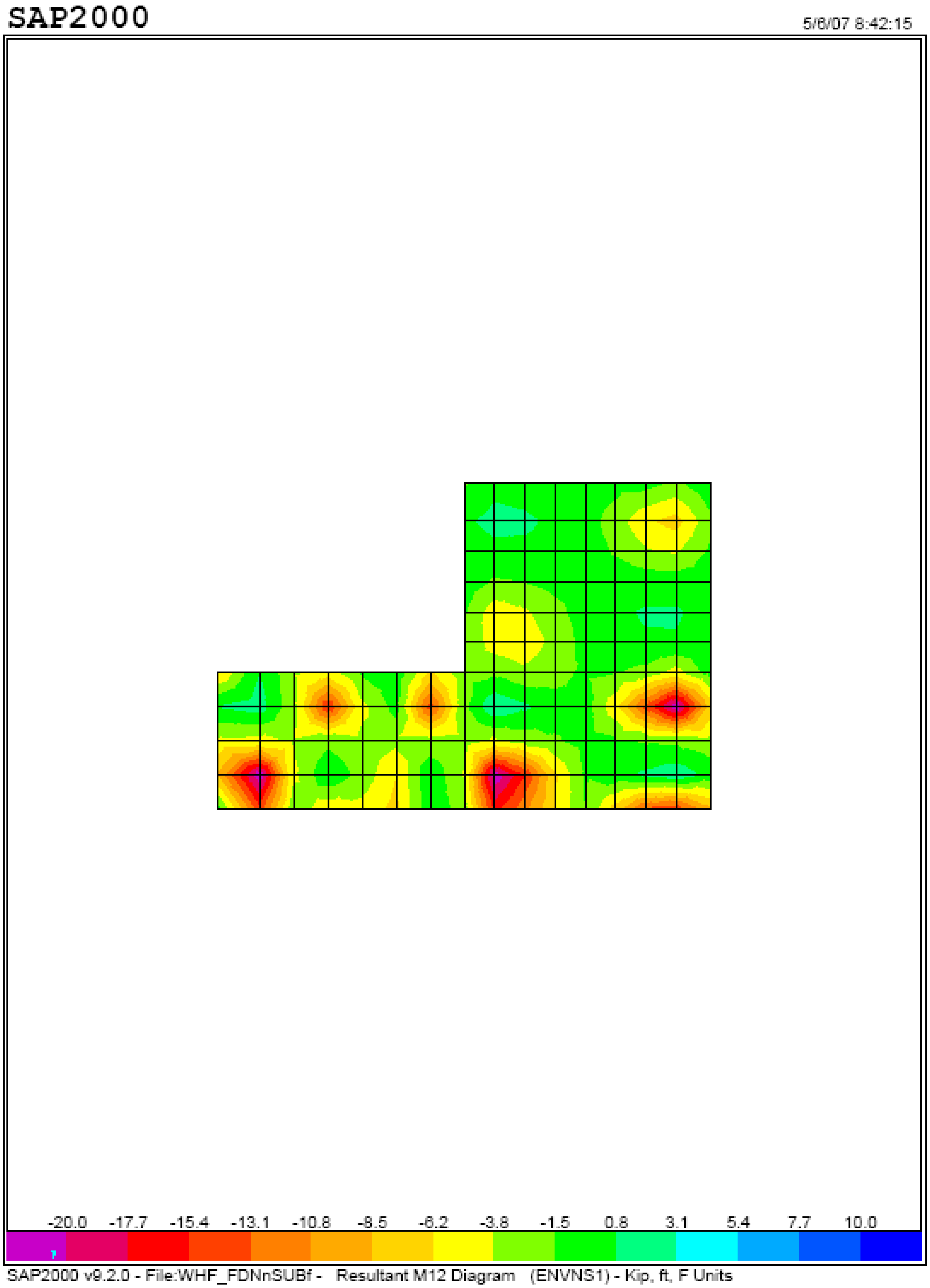
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M12 Diagram (ENVNS1) - Kip, ft, F Units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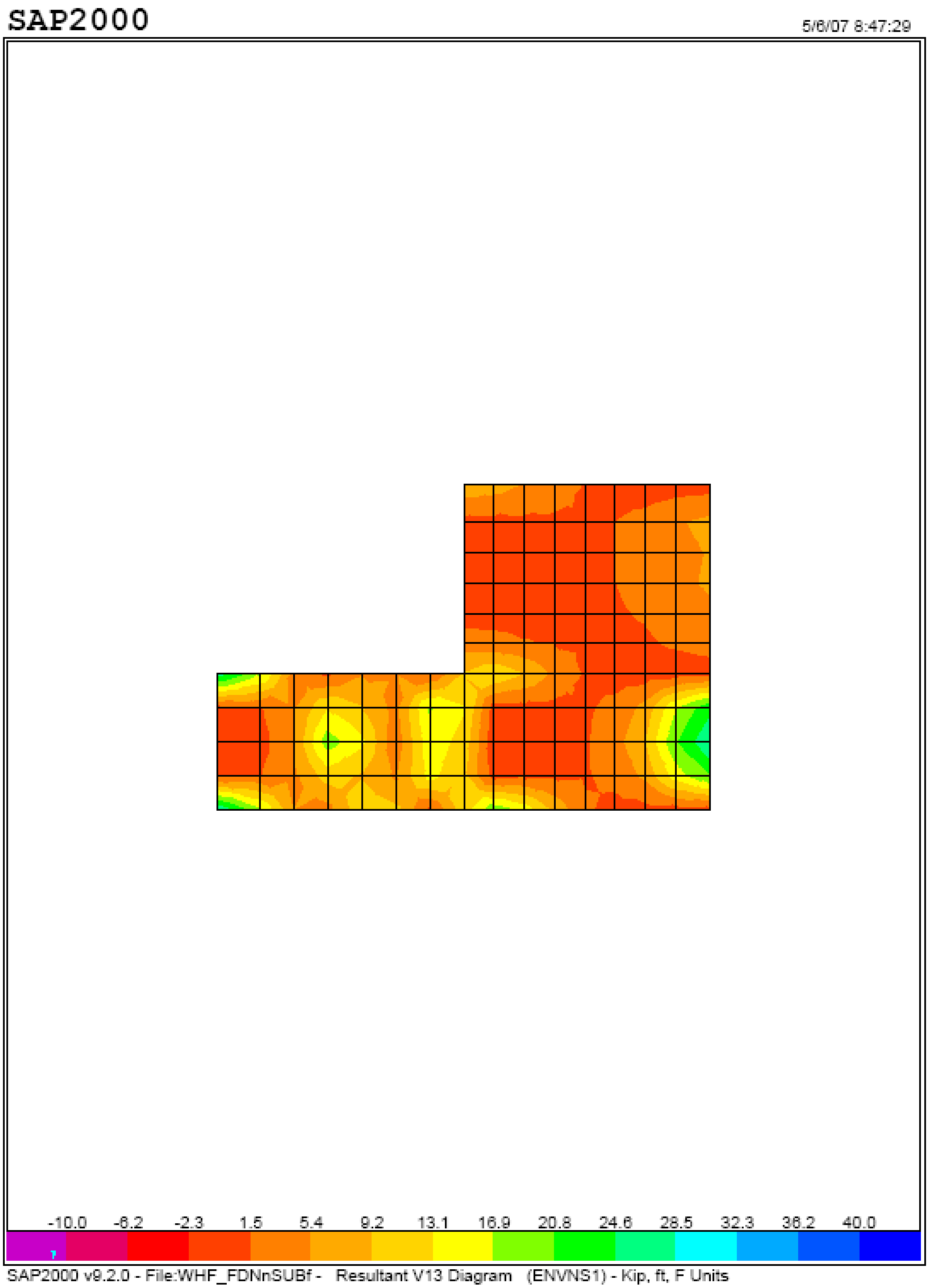
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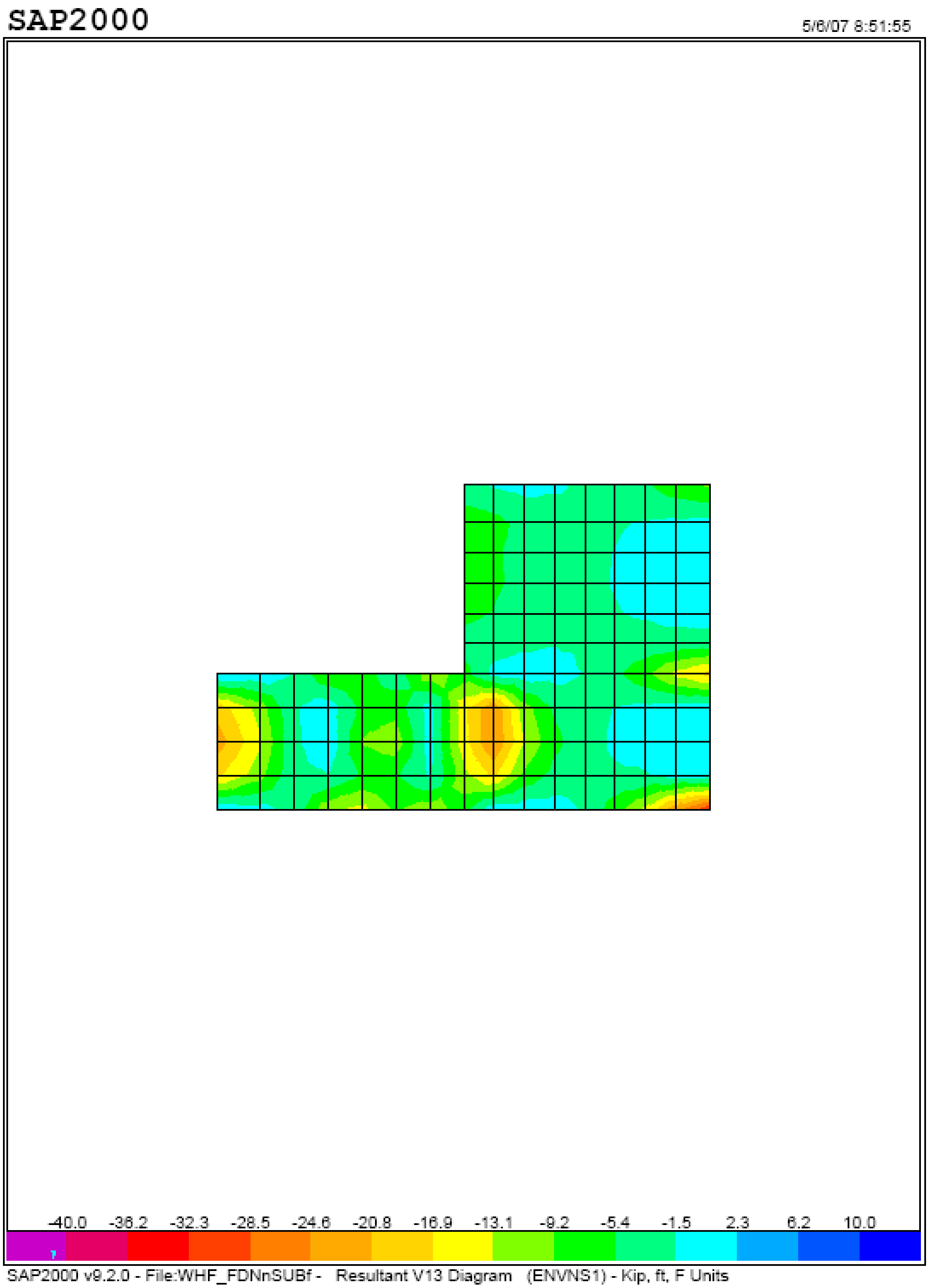
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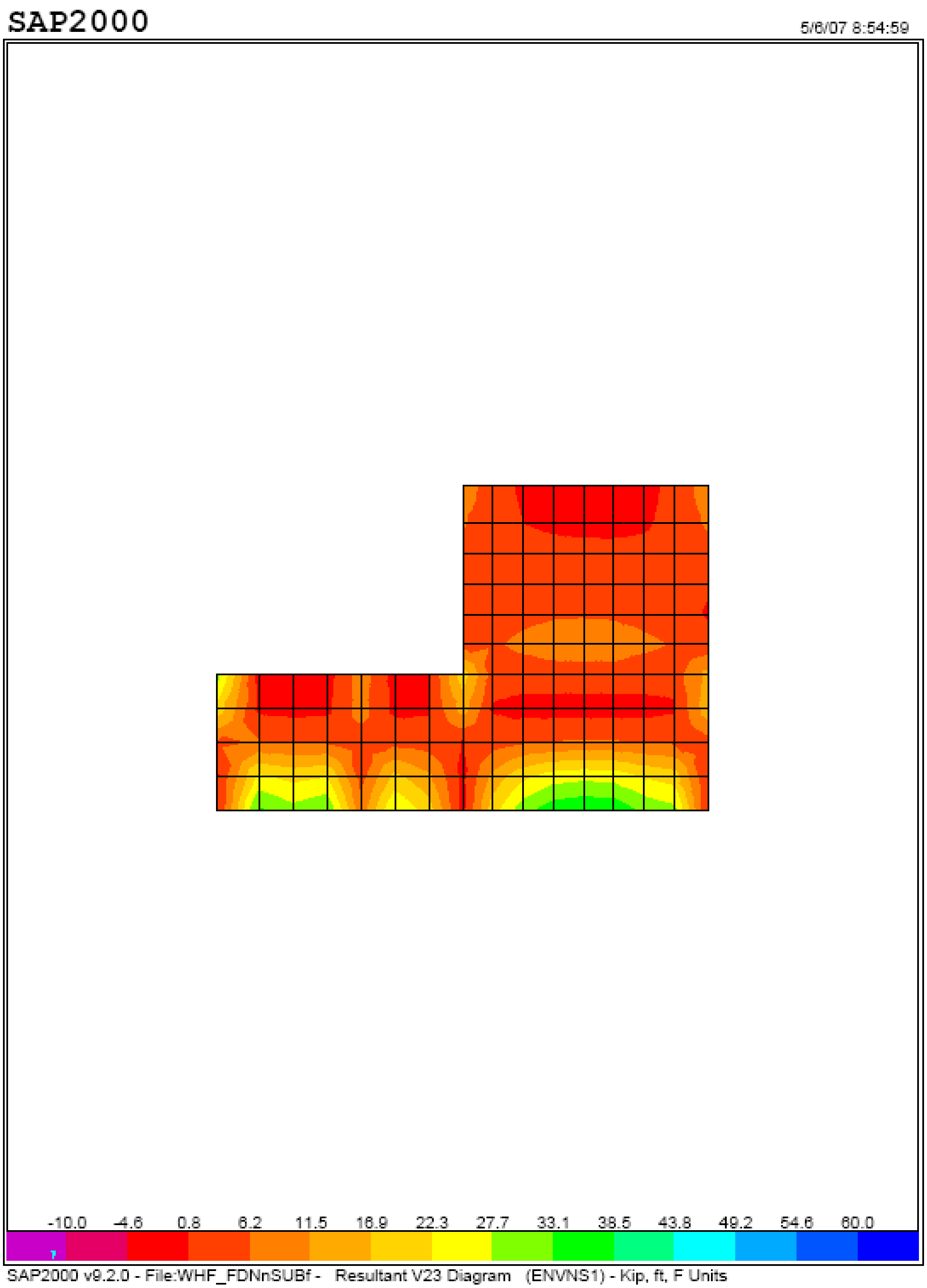
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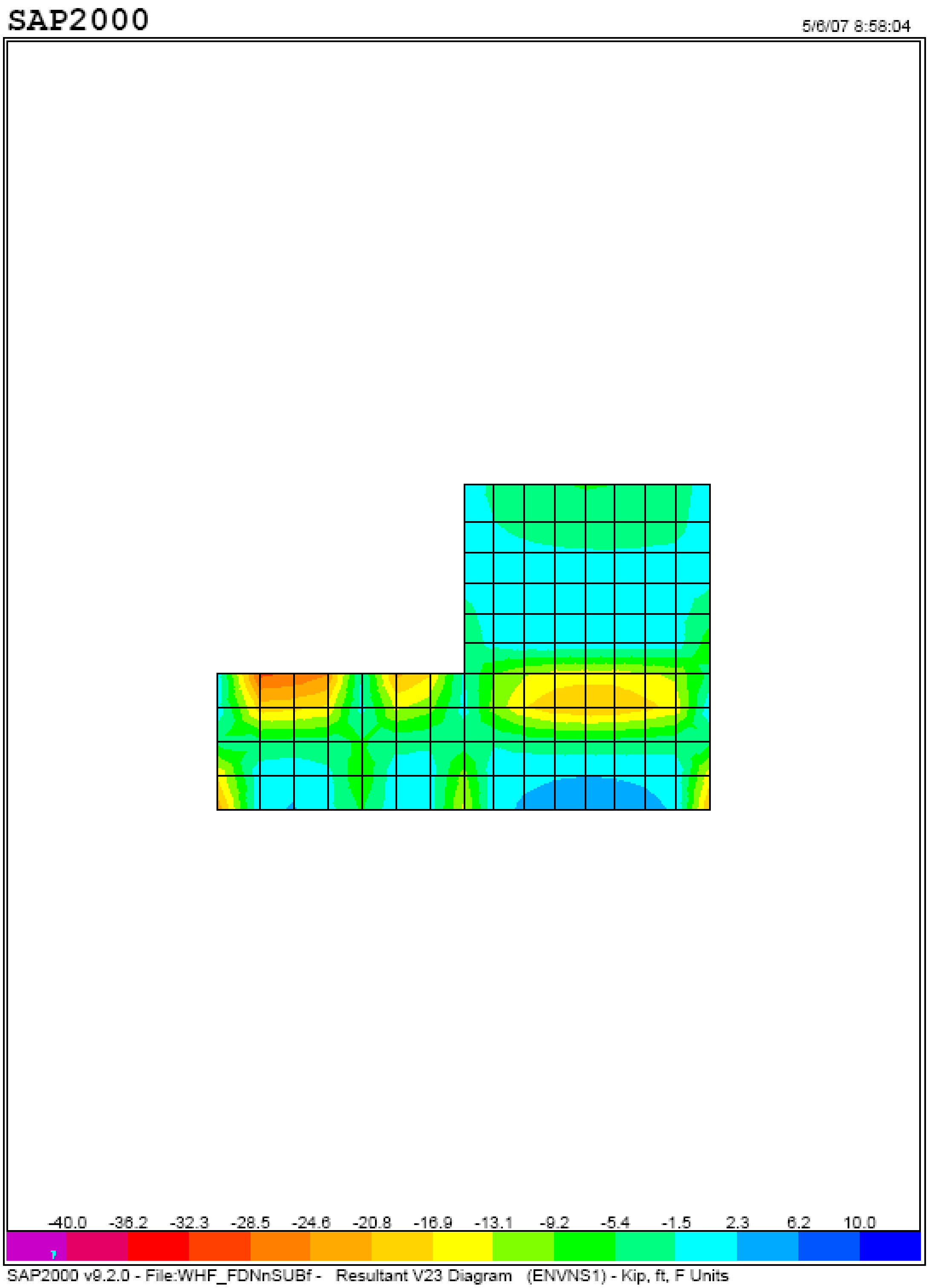
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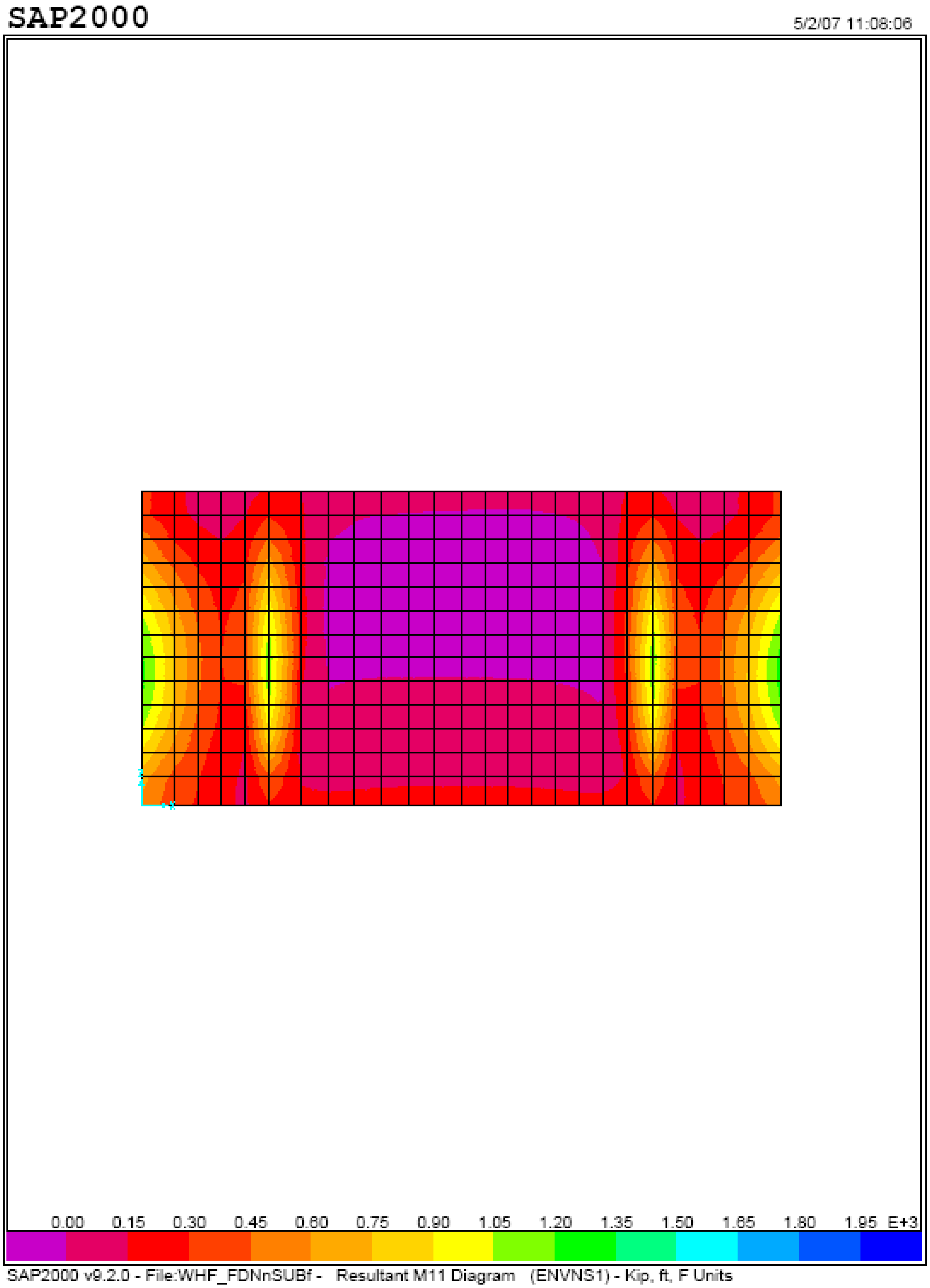
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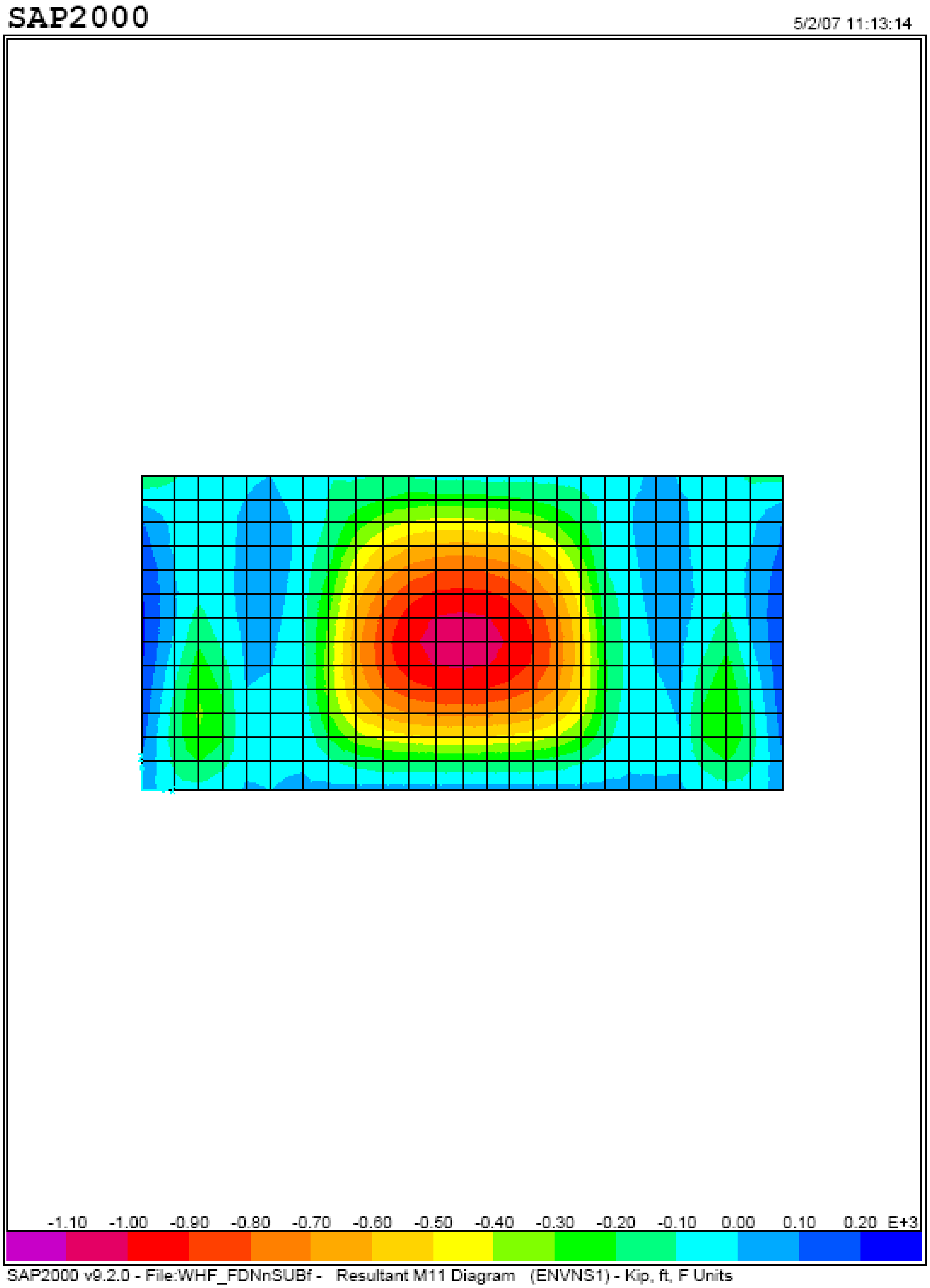
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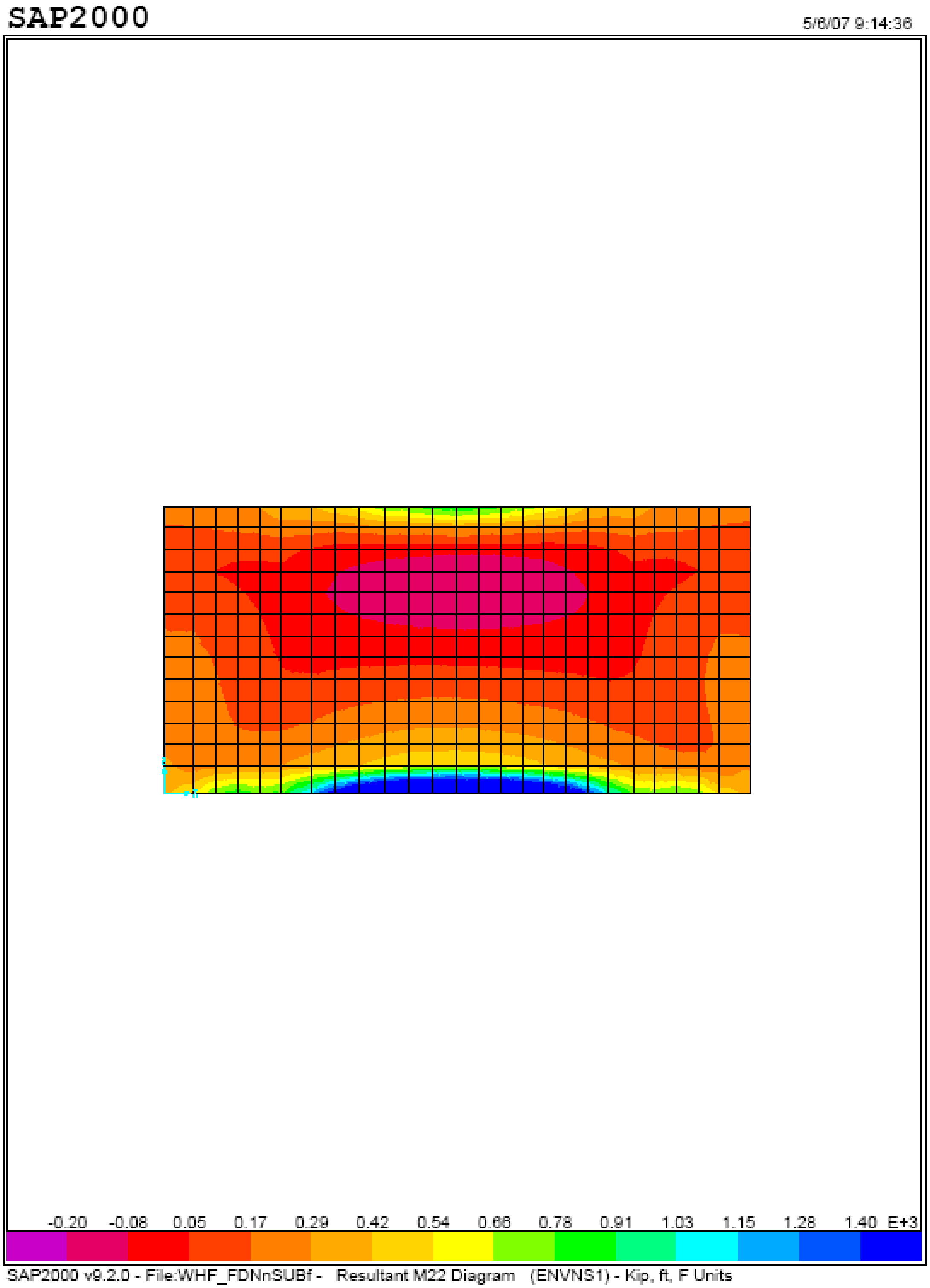
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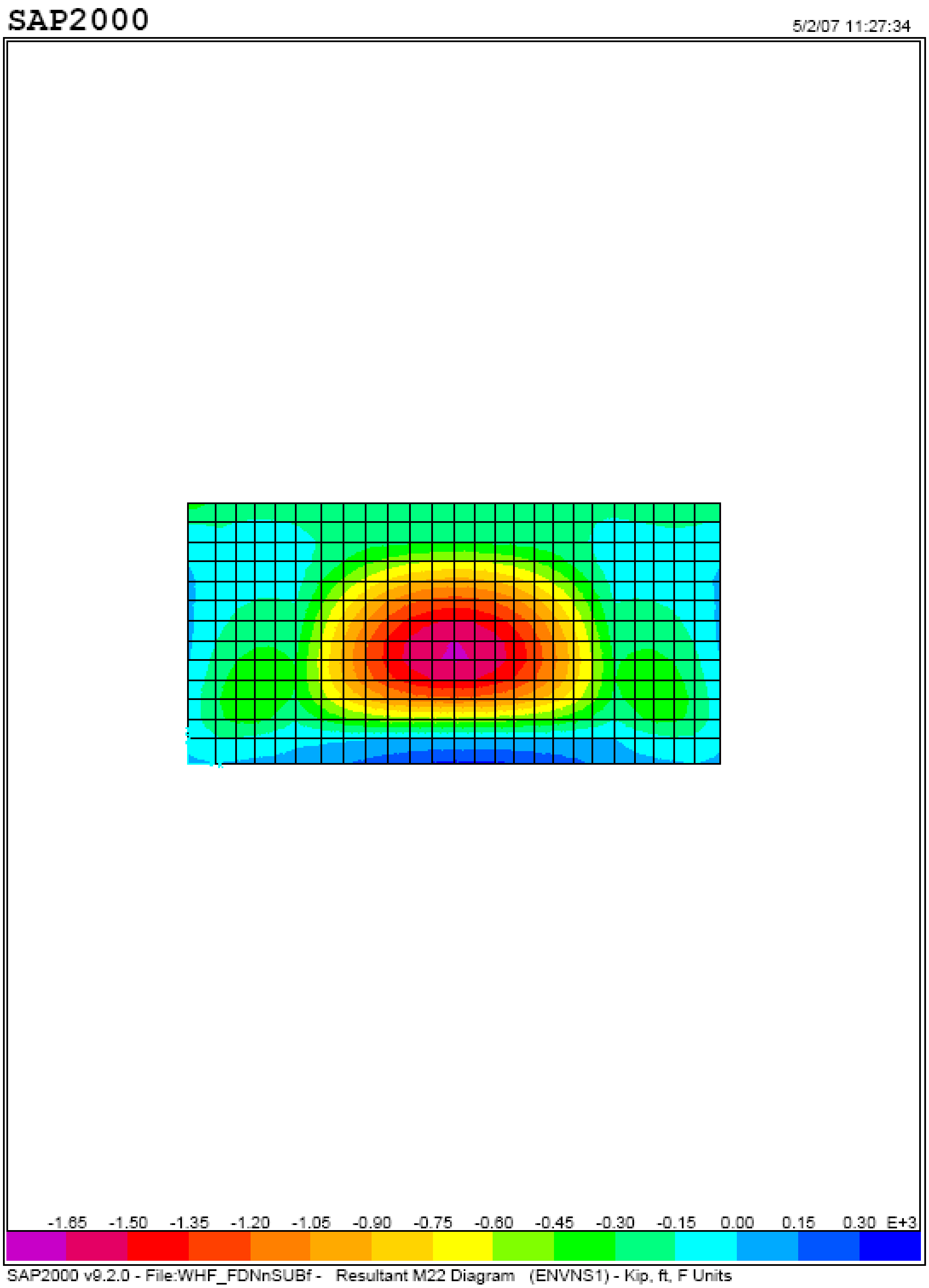
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M22 Diagram (ENVNS1) - Kip, ft, F Units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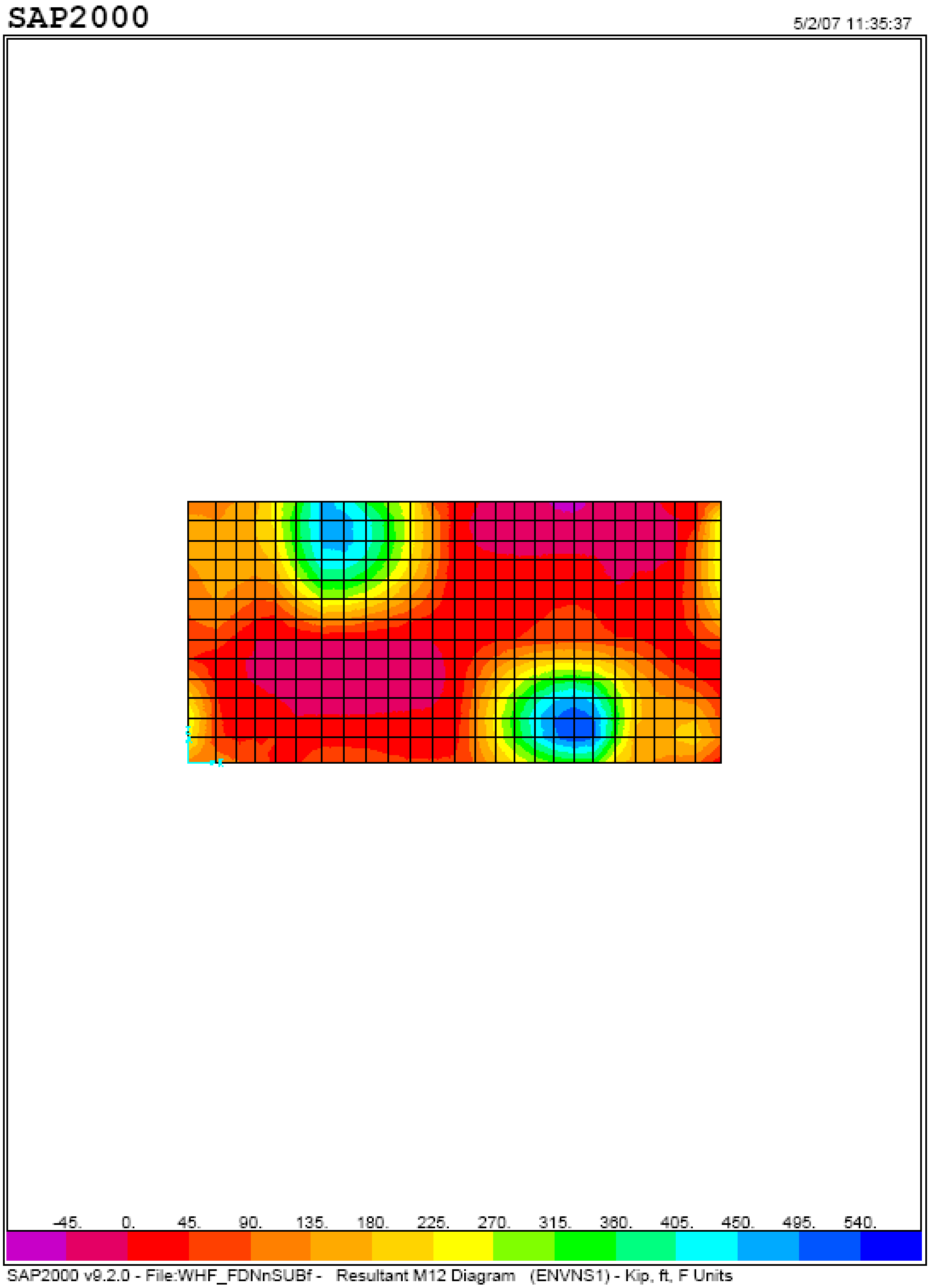
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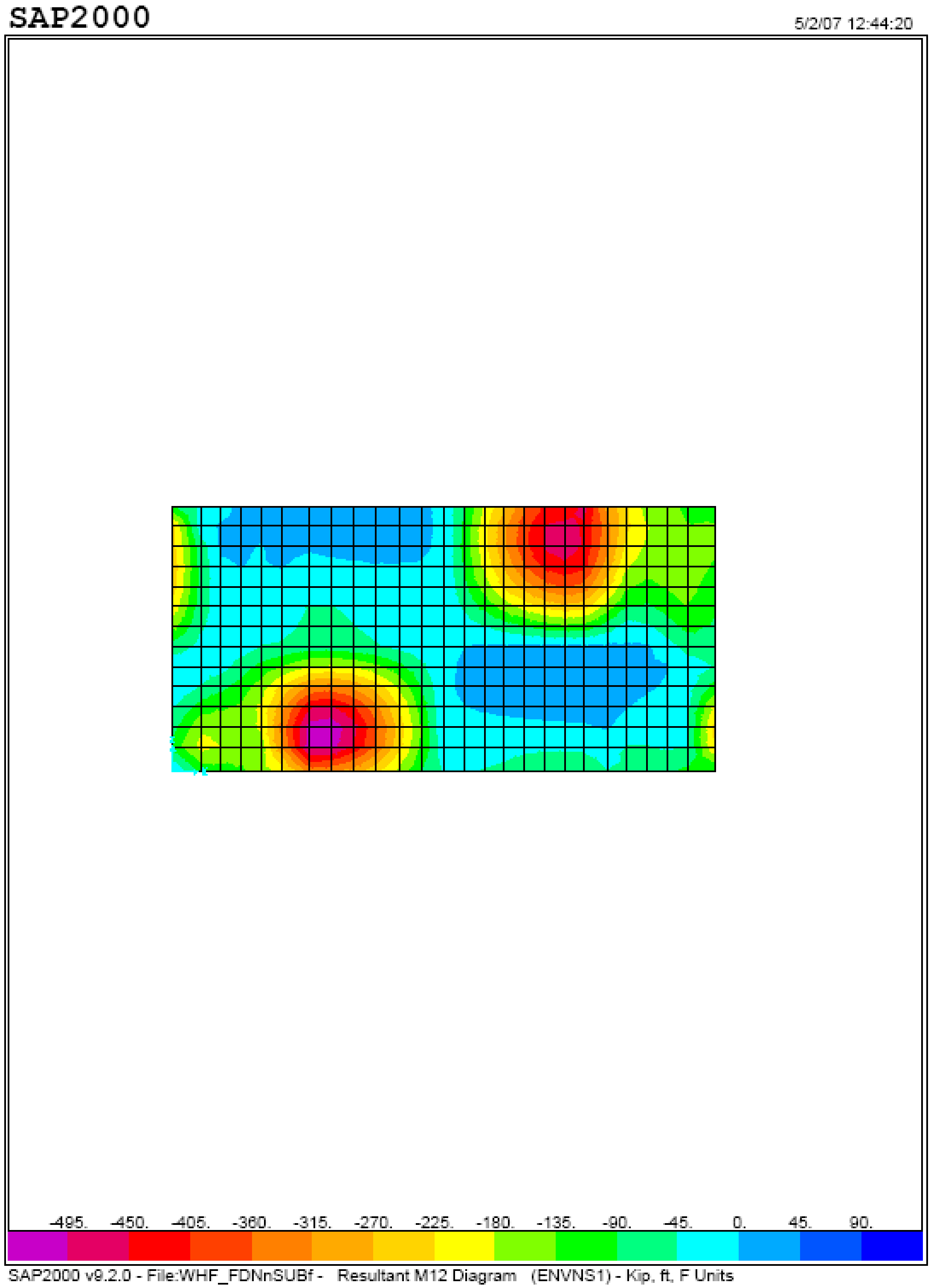
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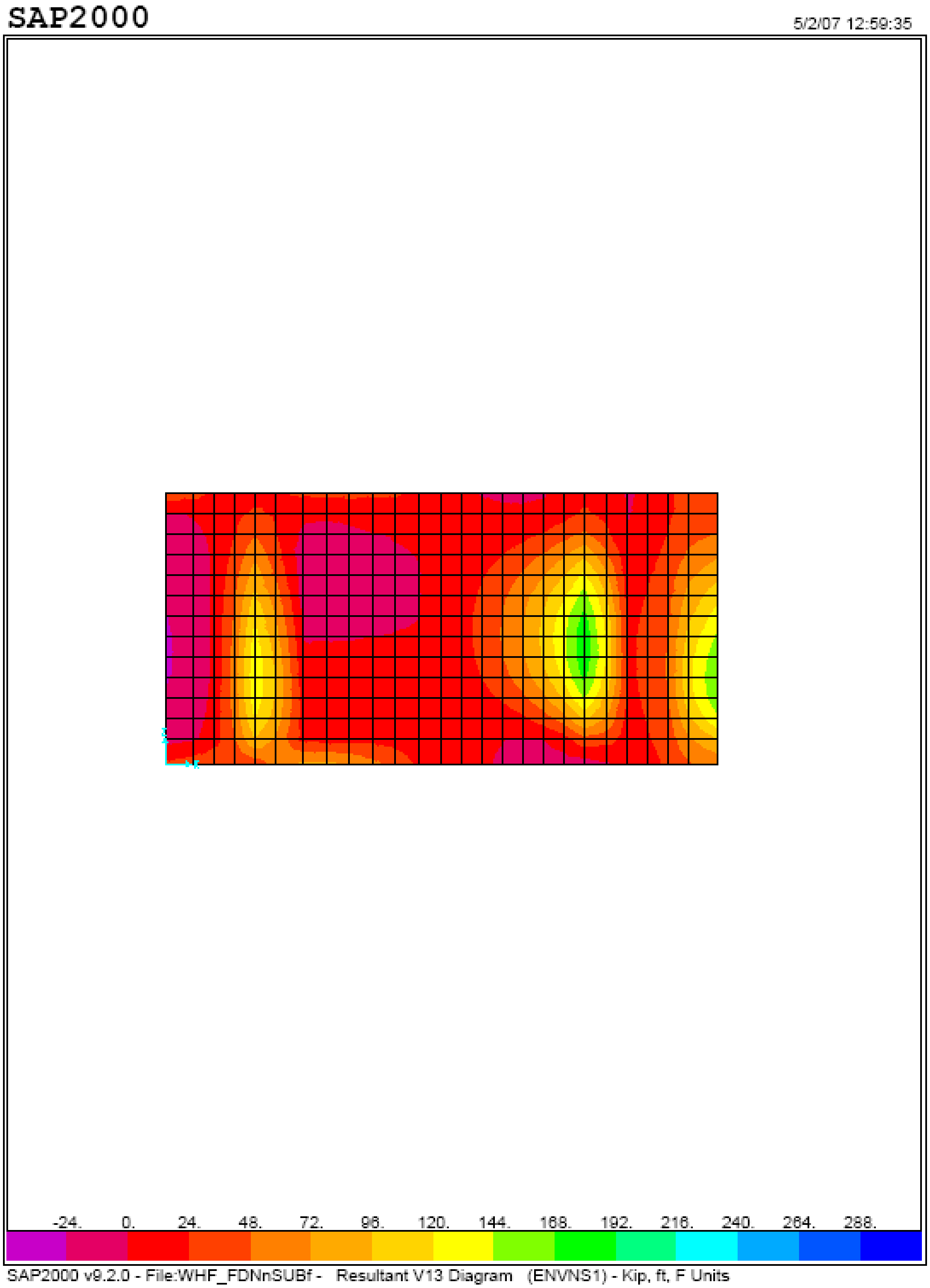
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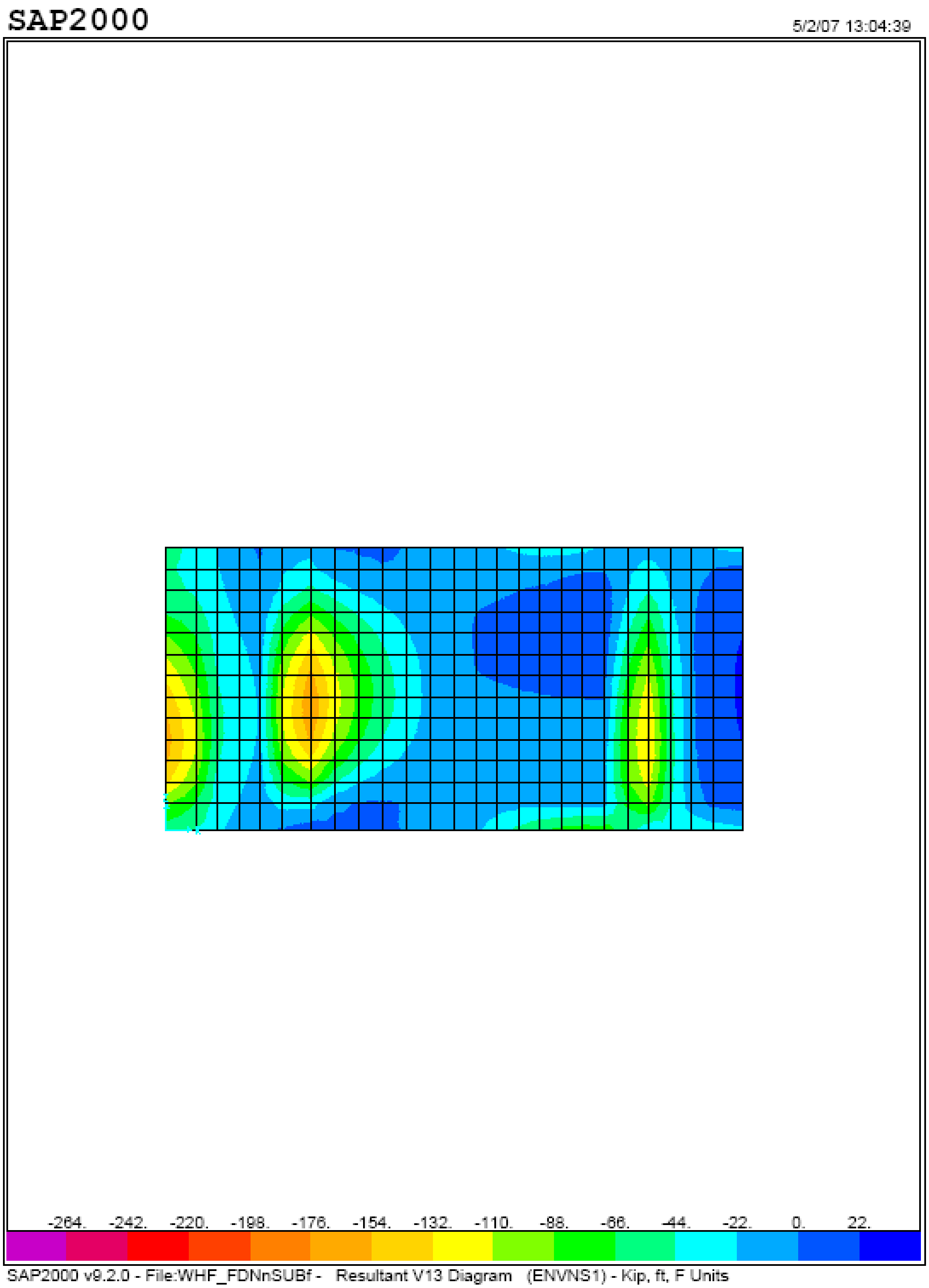
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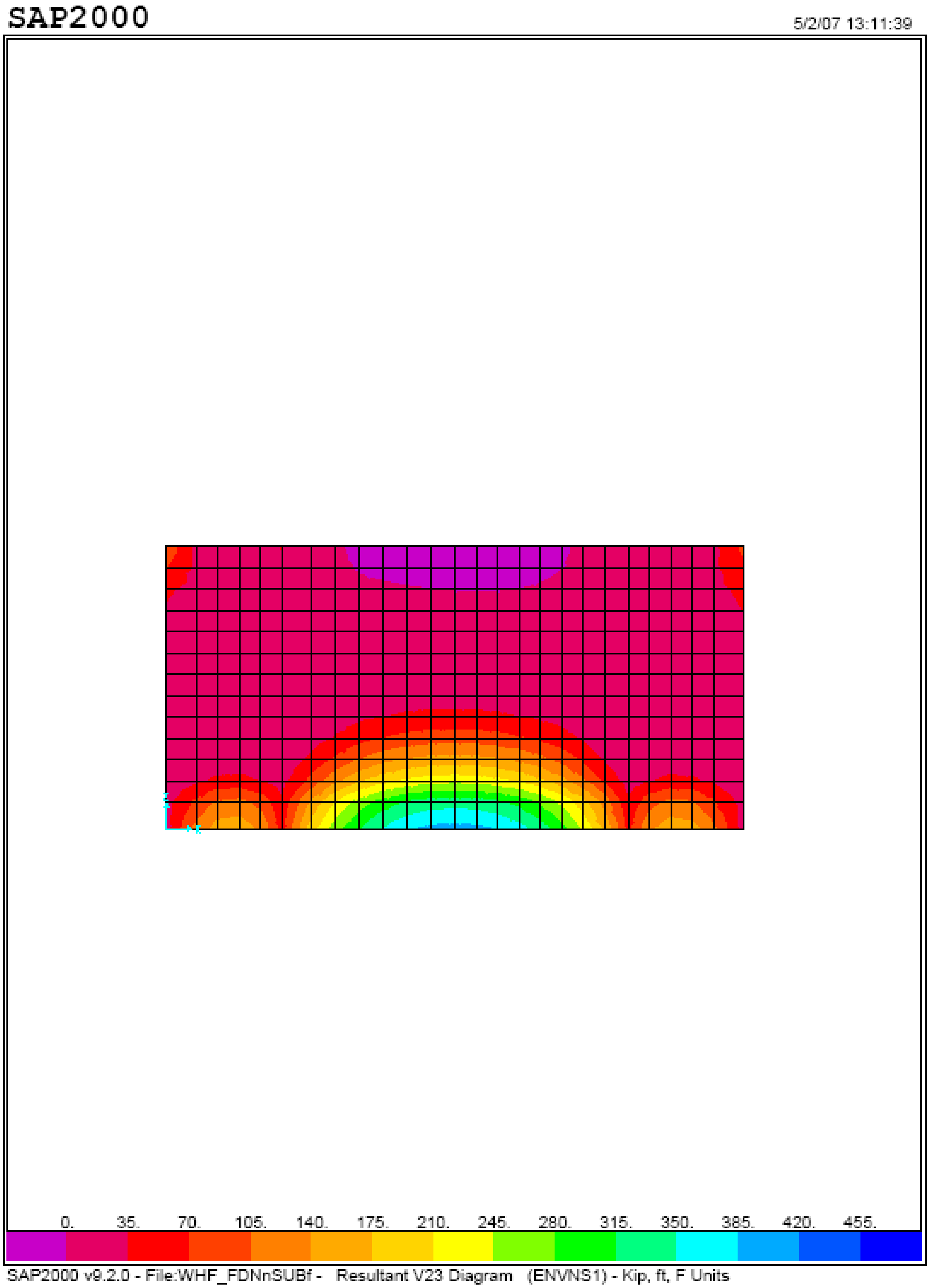
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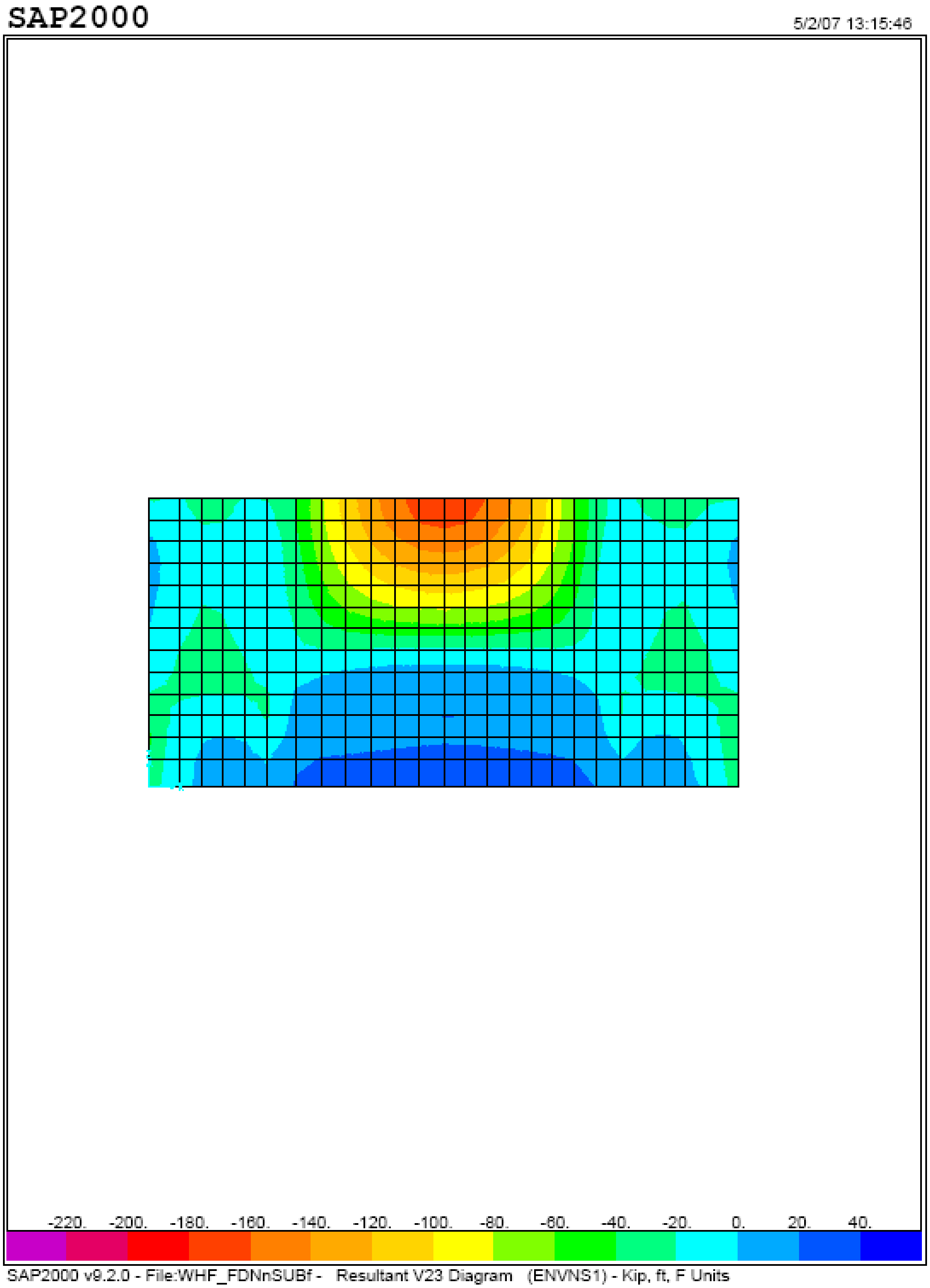
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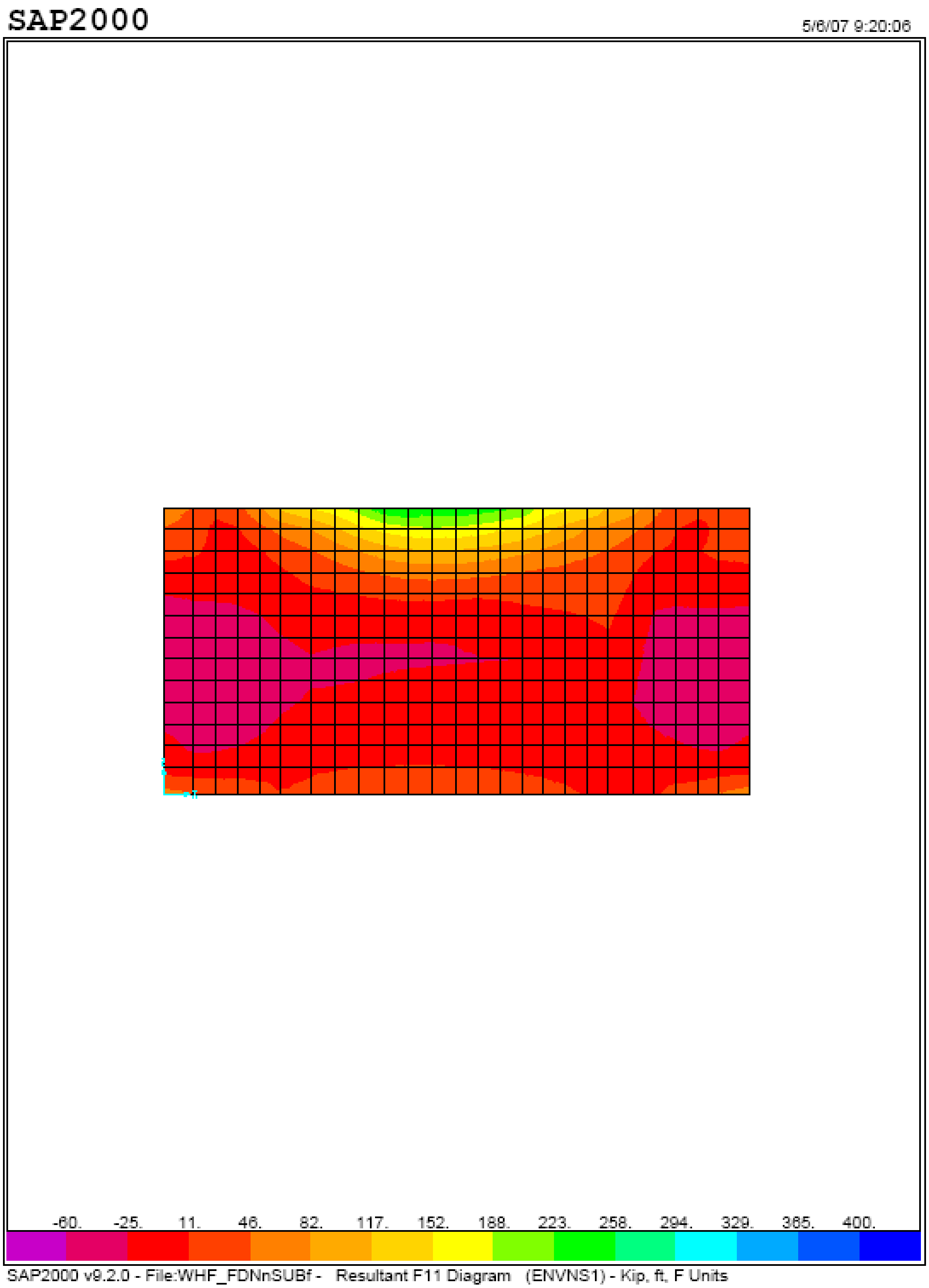
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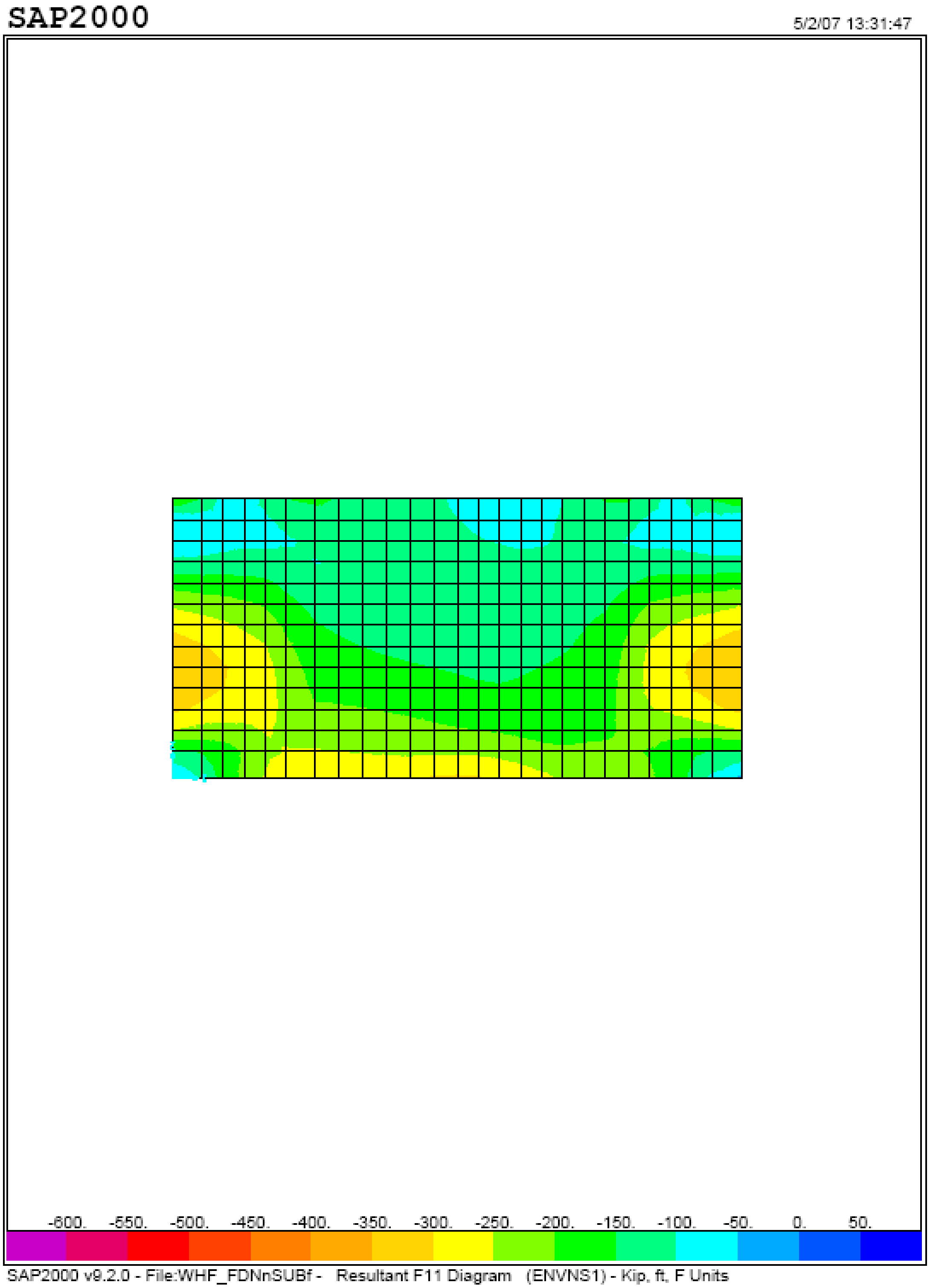
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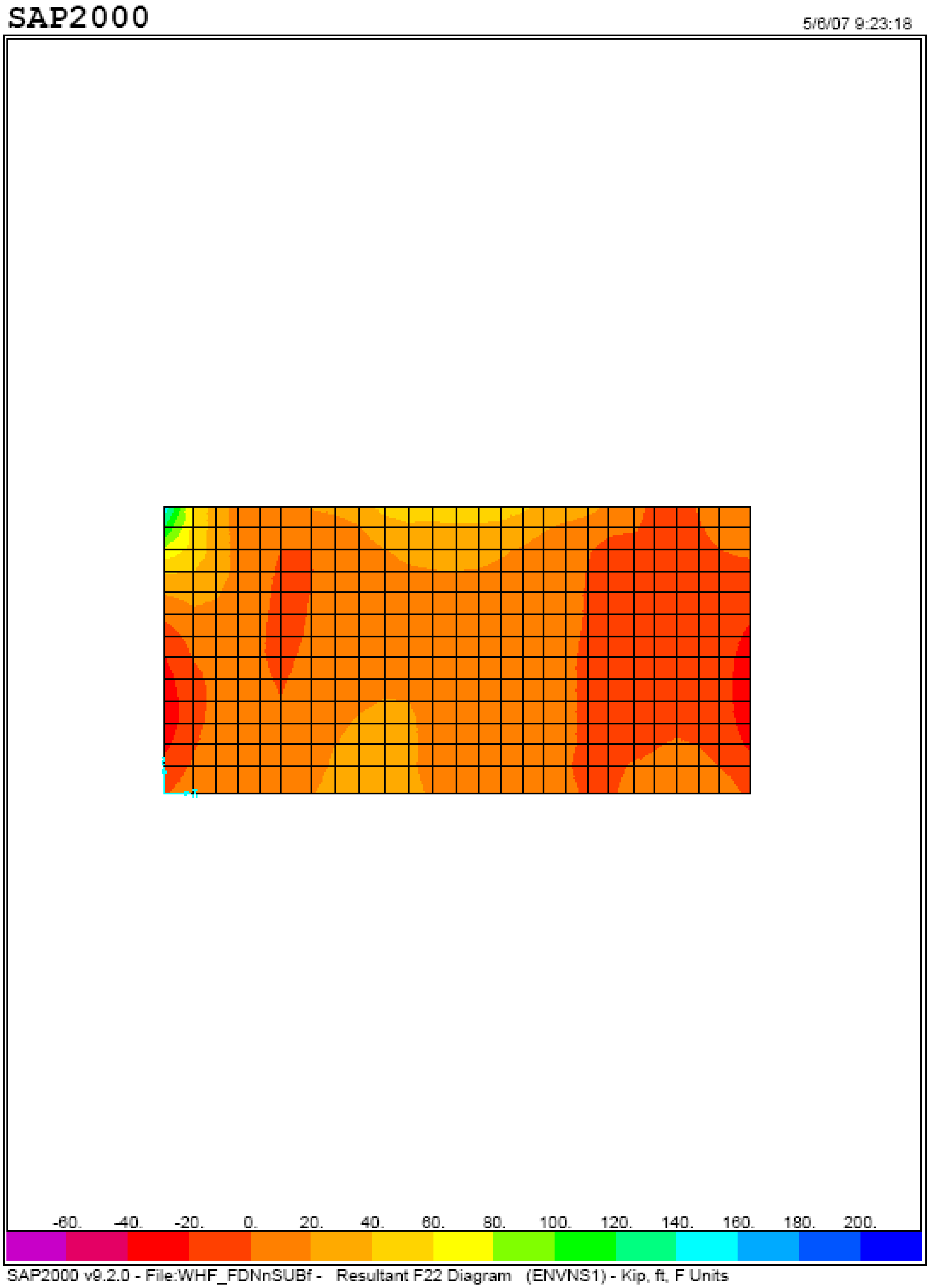
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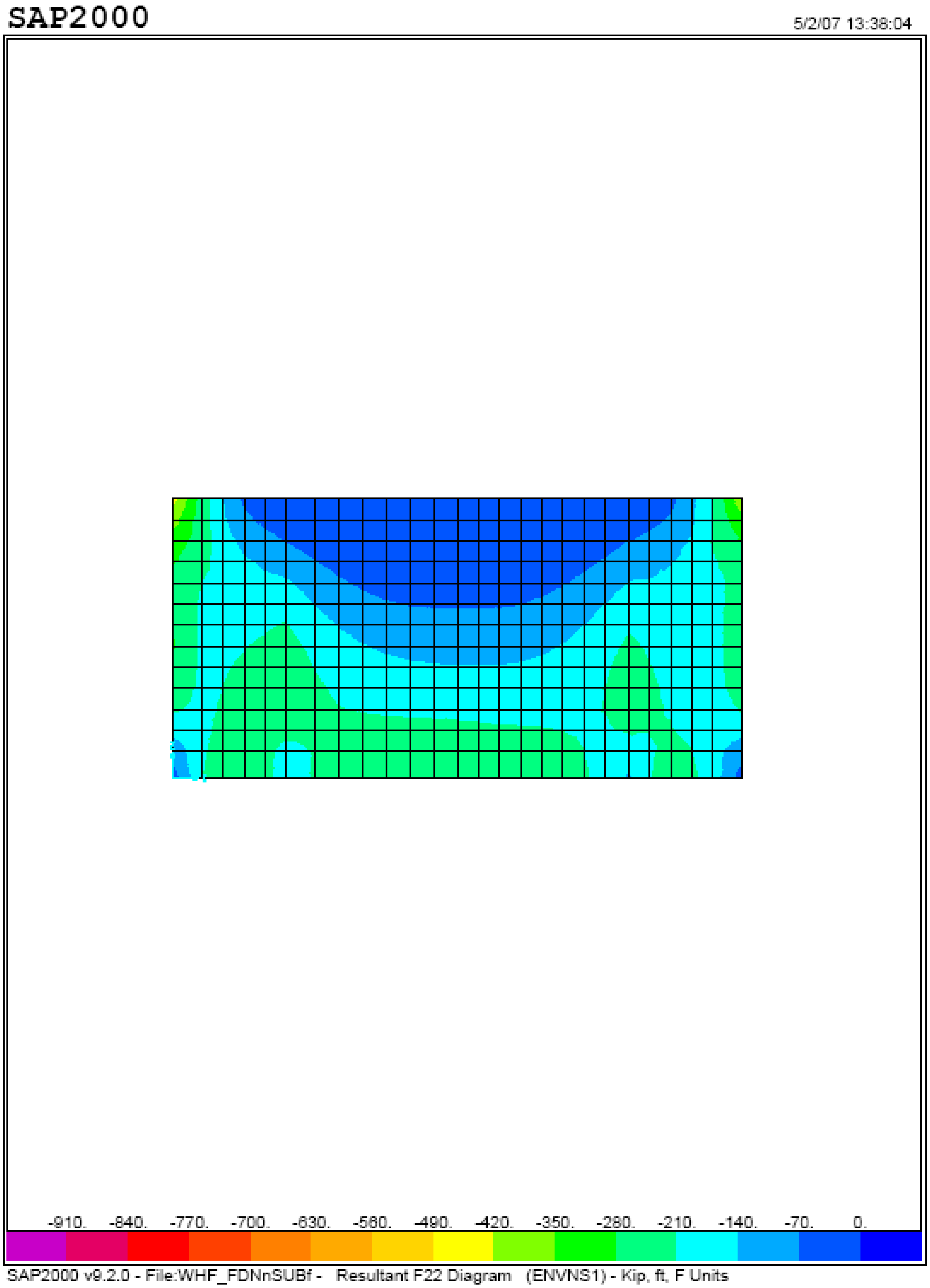
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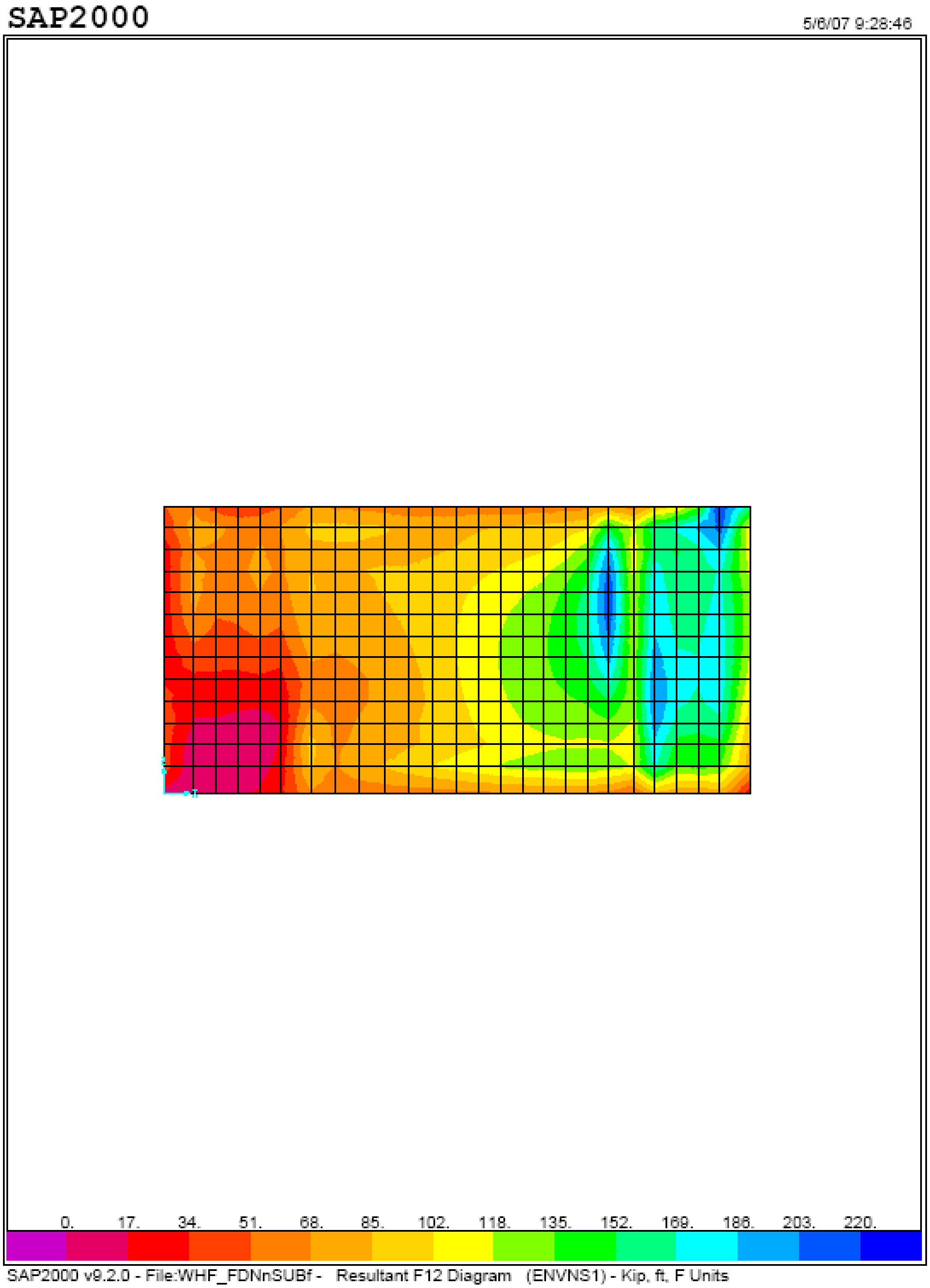
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118.
135.
152.
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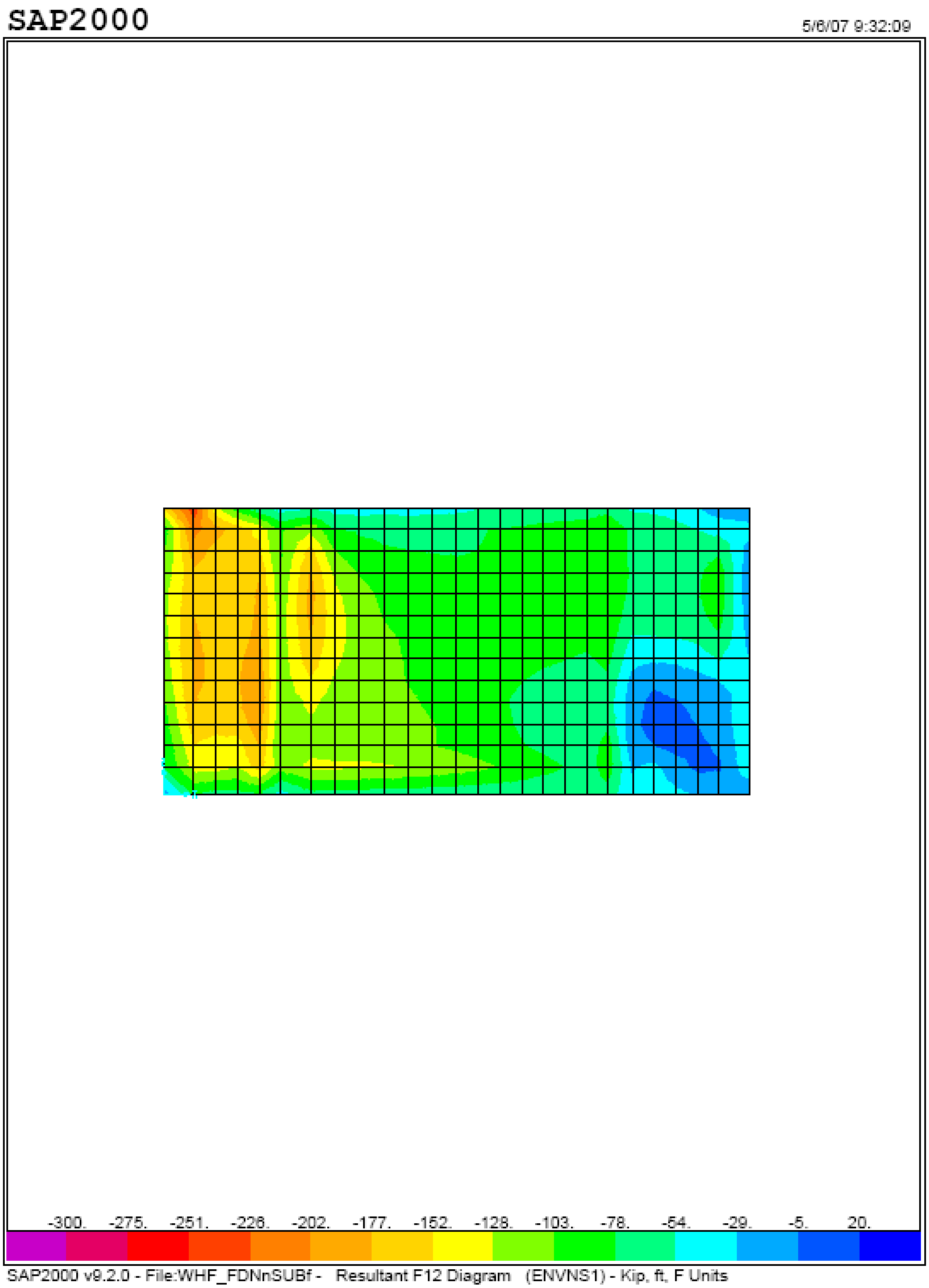
203.
220.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant F12 Diagram (ENVNS1) - Kip, ft, F Units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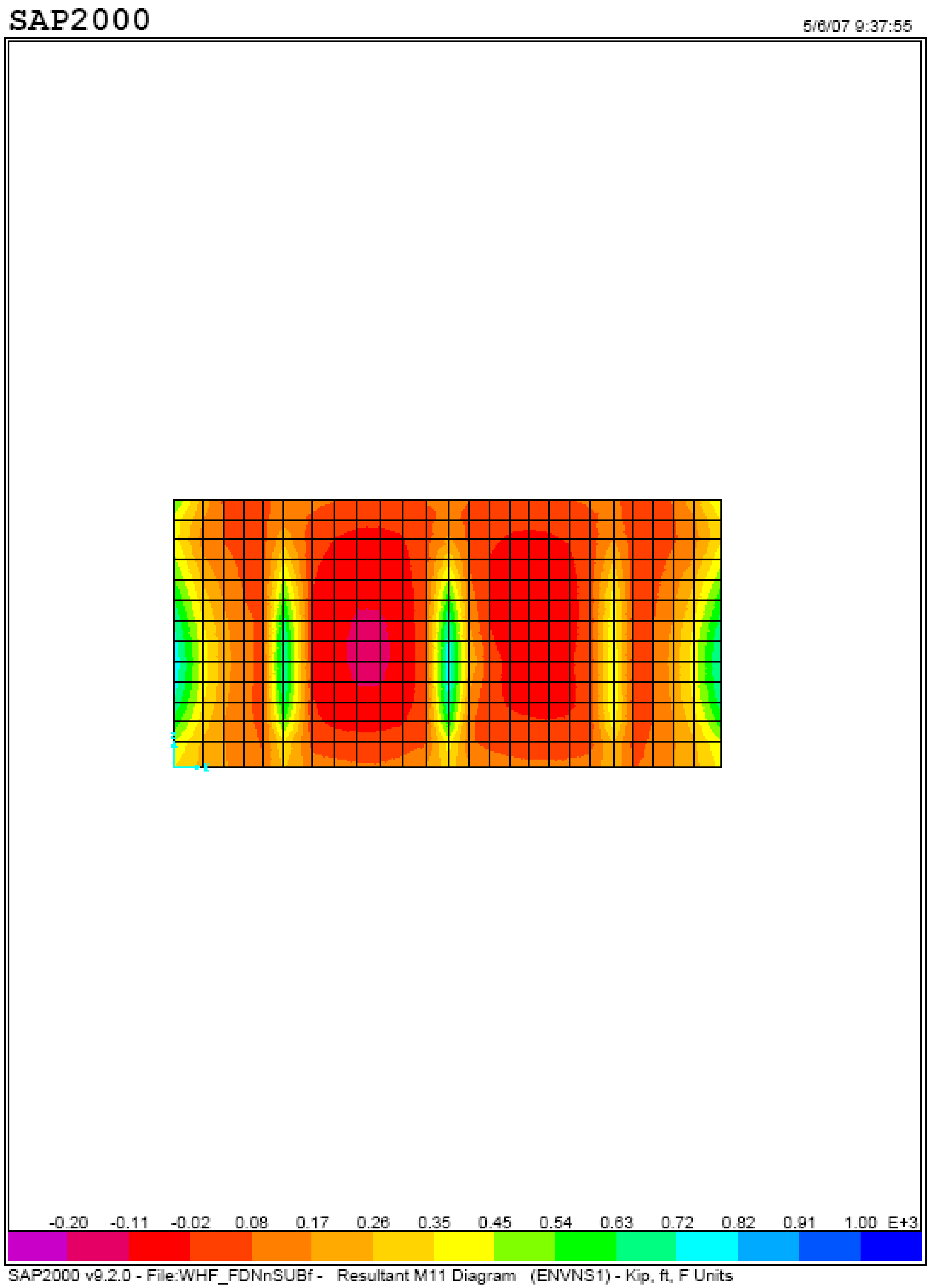
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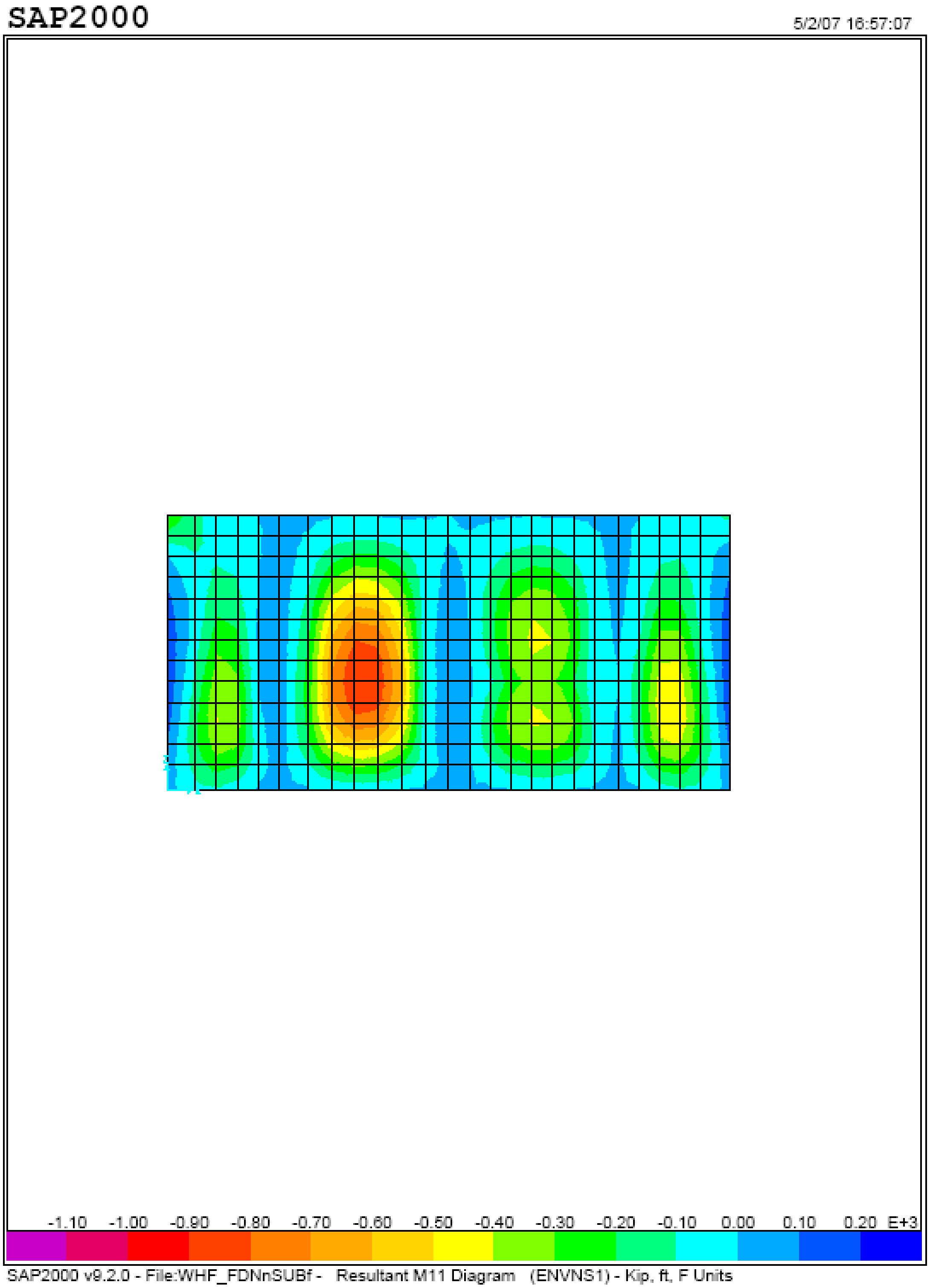
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant M11 Diagram (ENVNS1) - Kip, ft, F Units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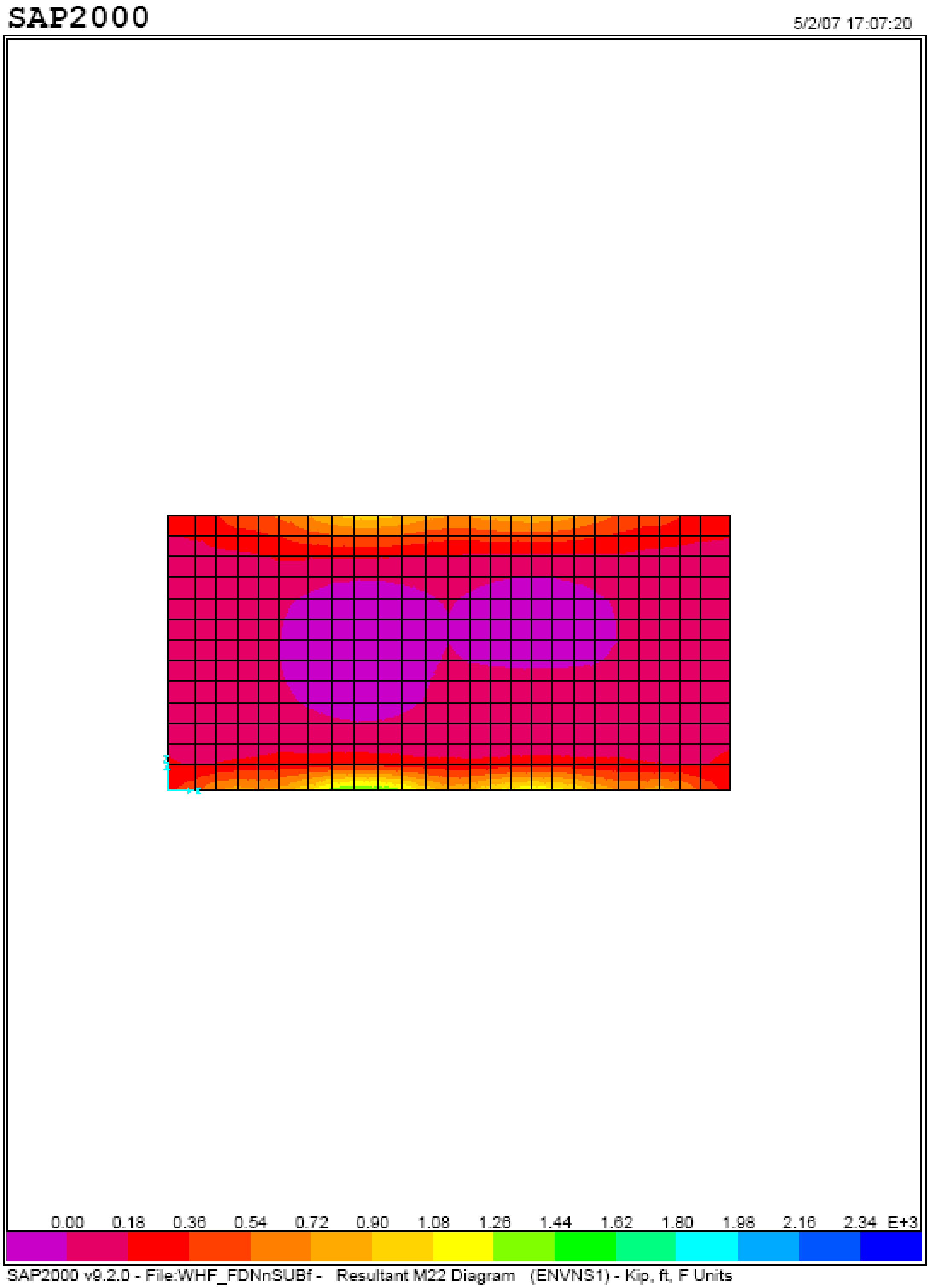
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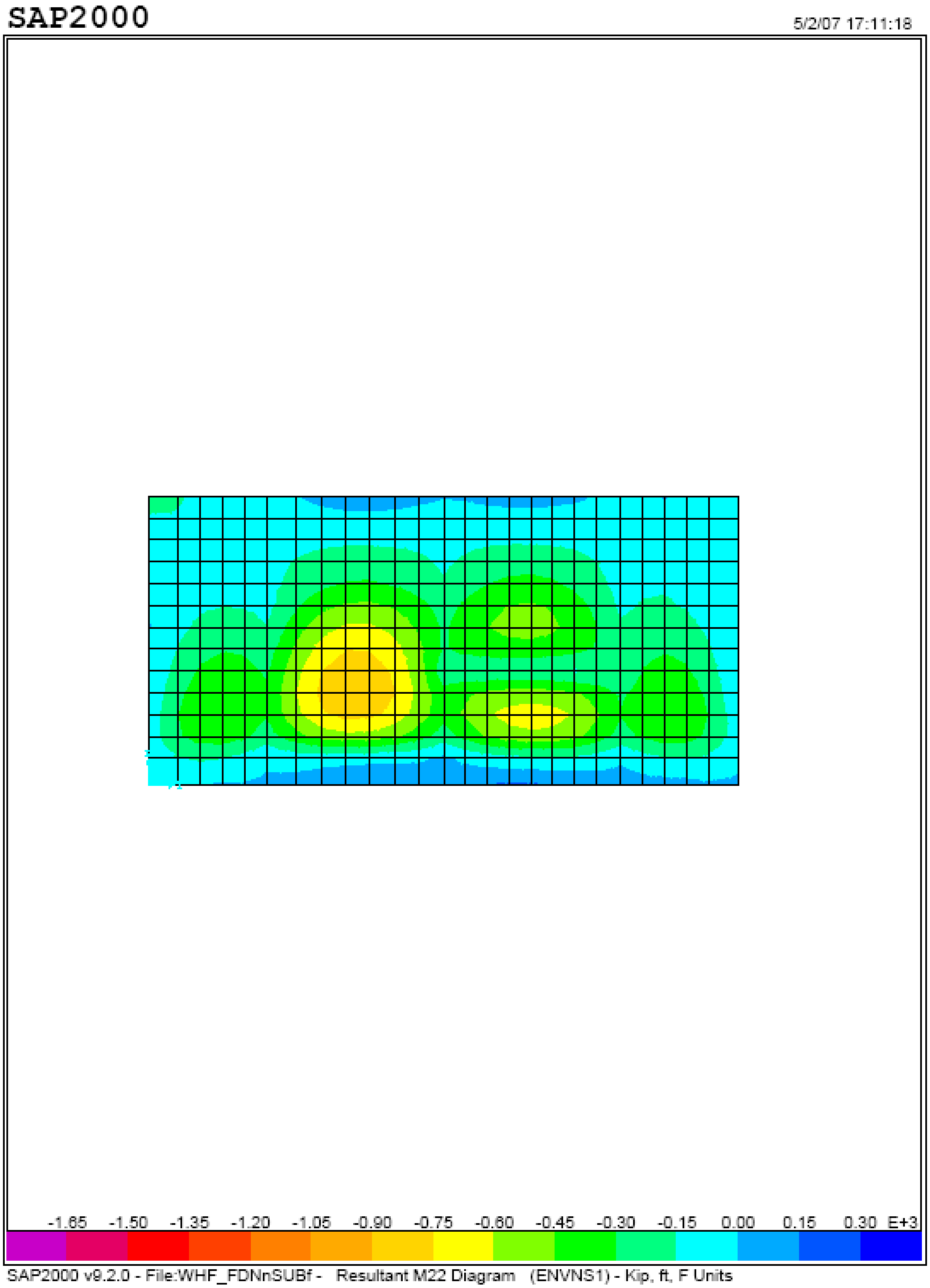
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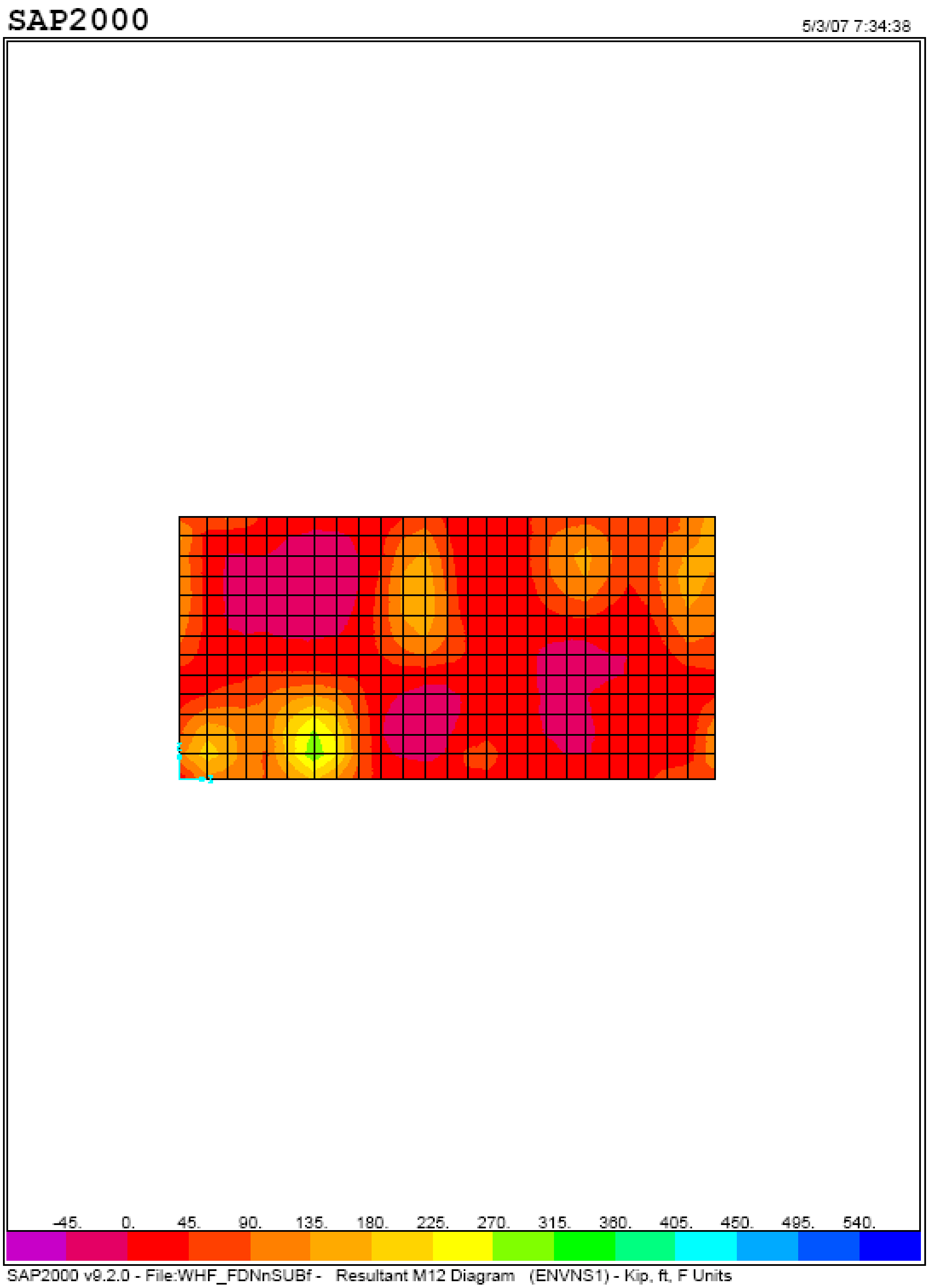
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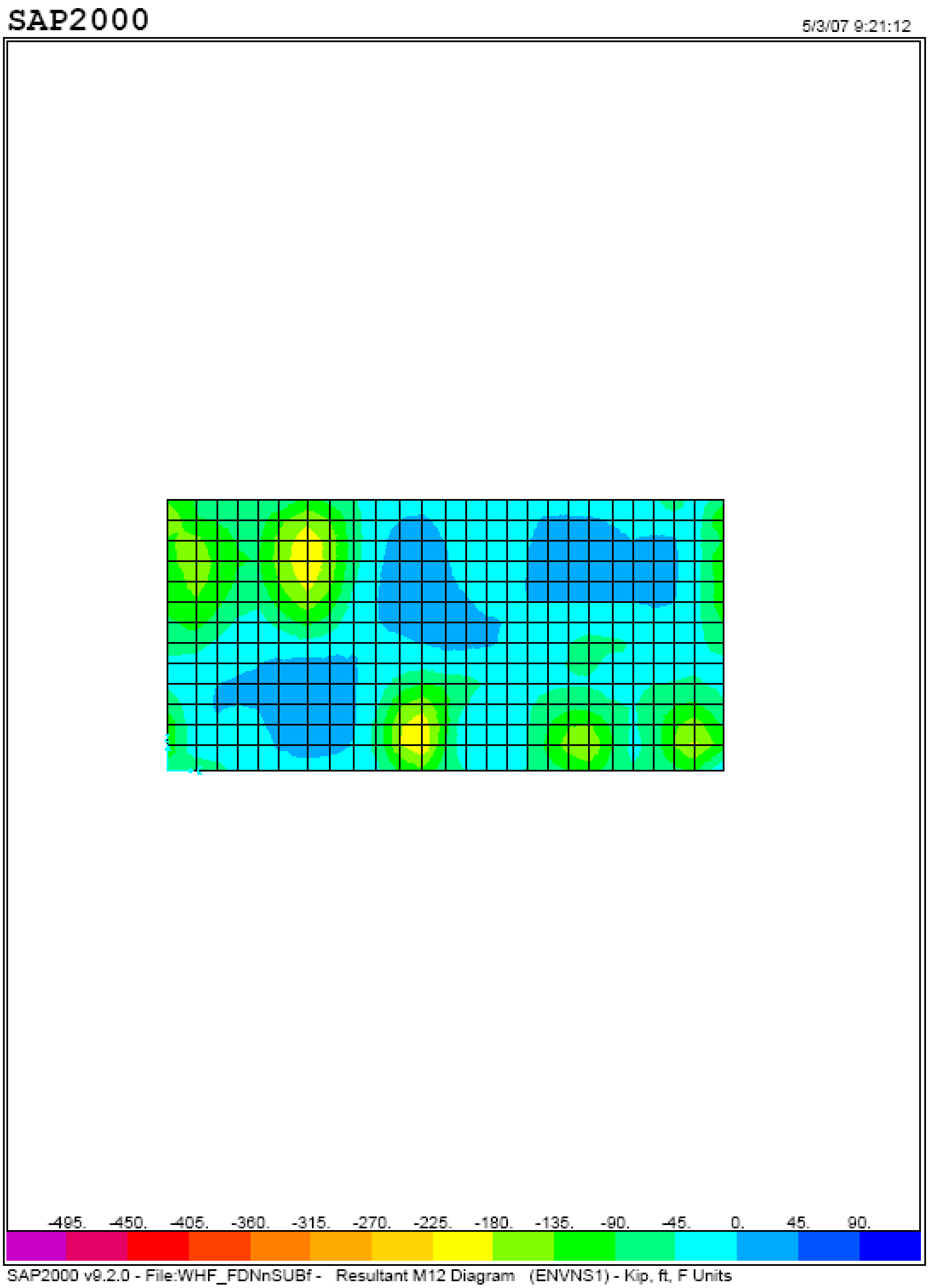
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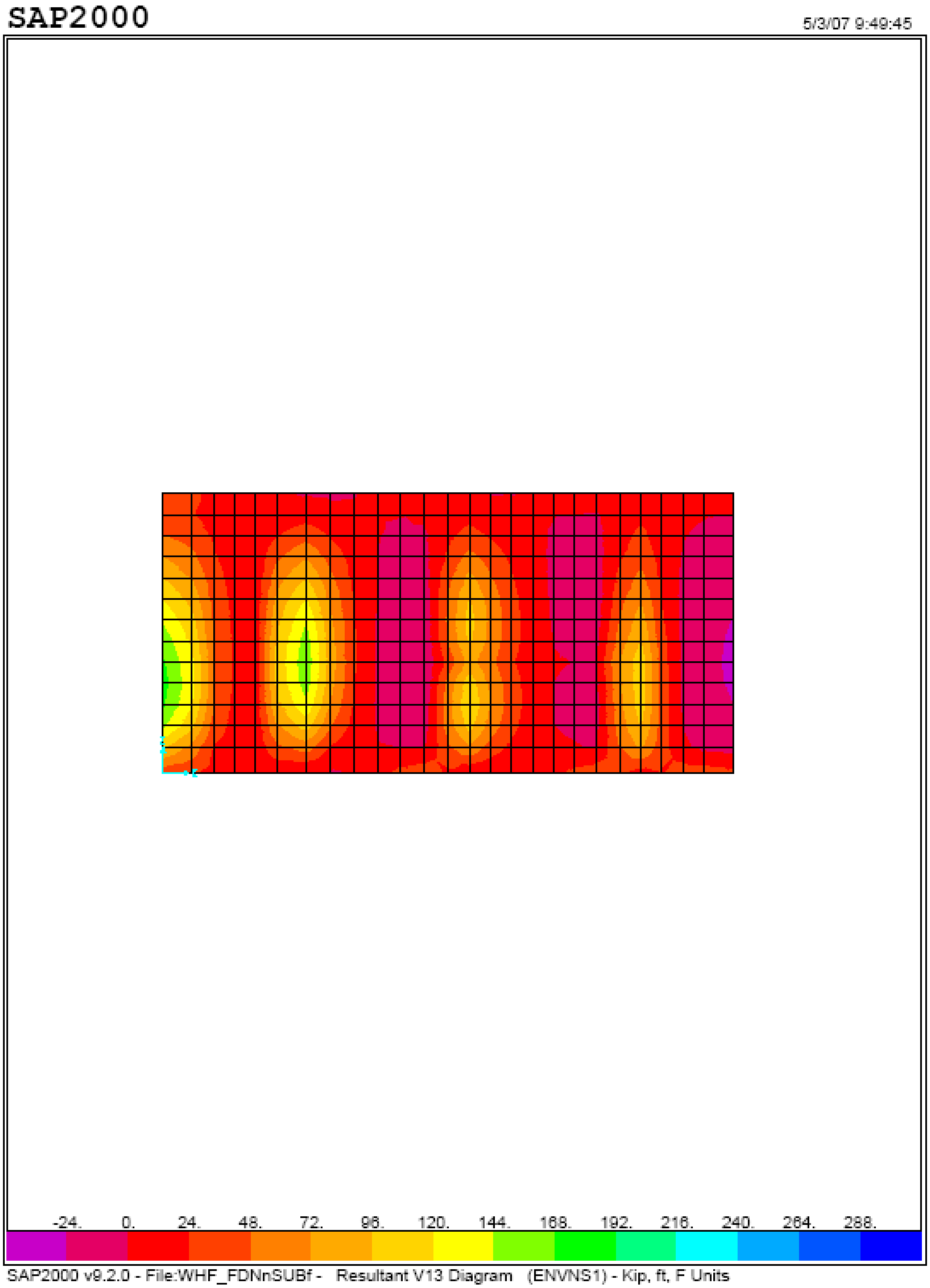
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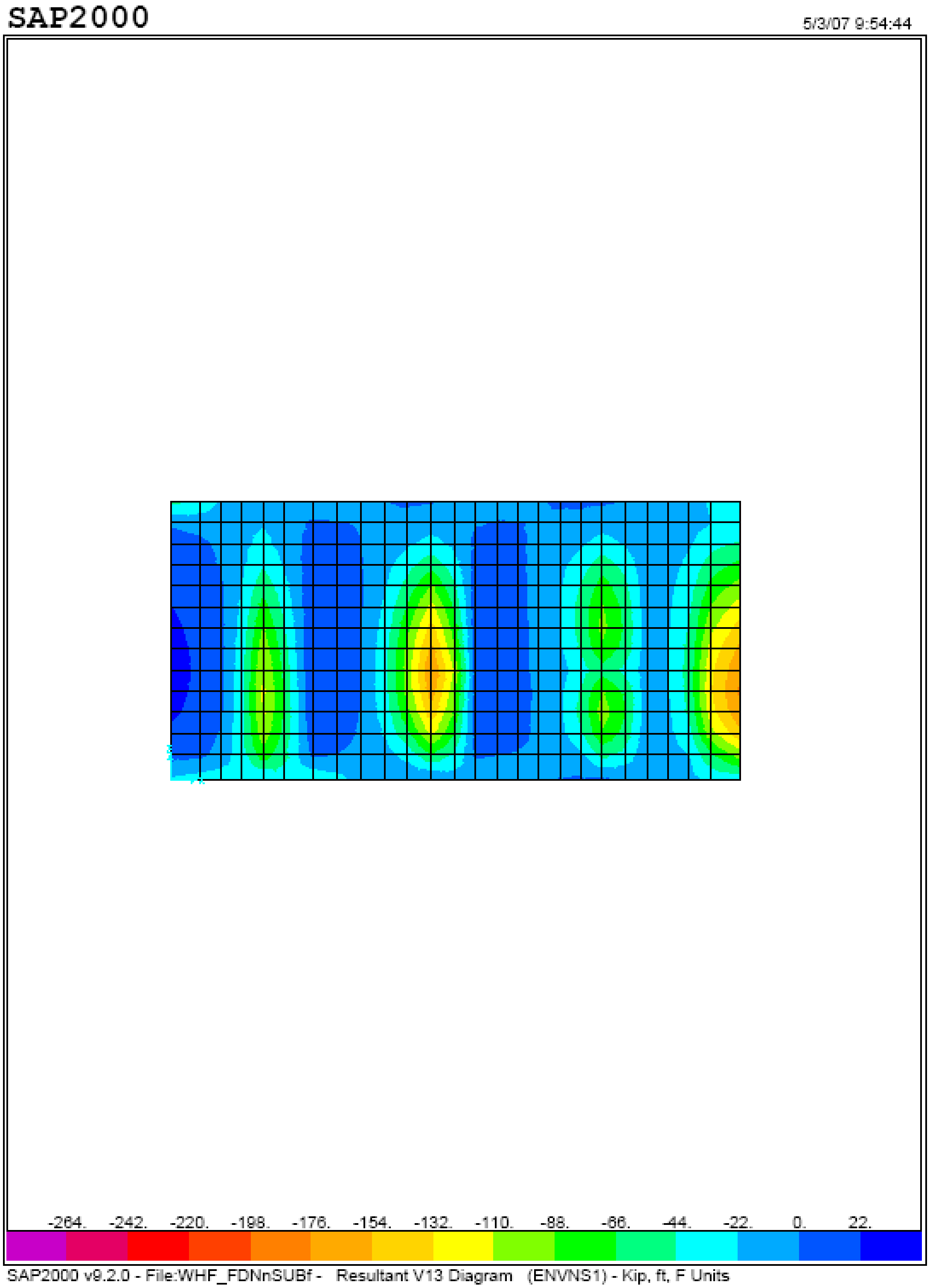
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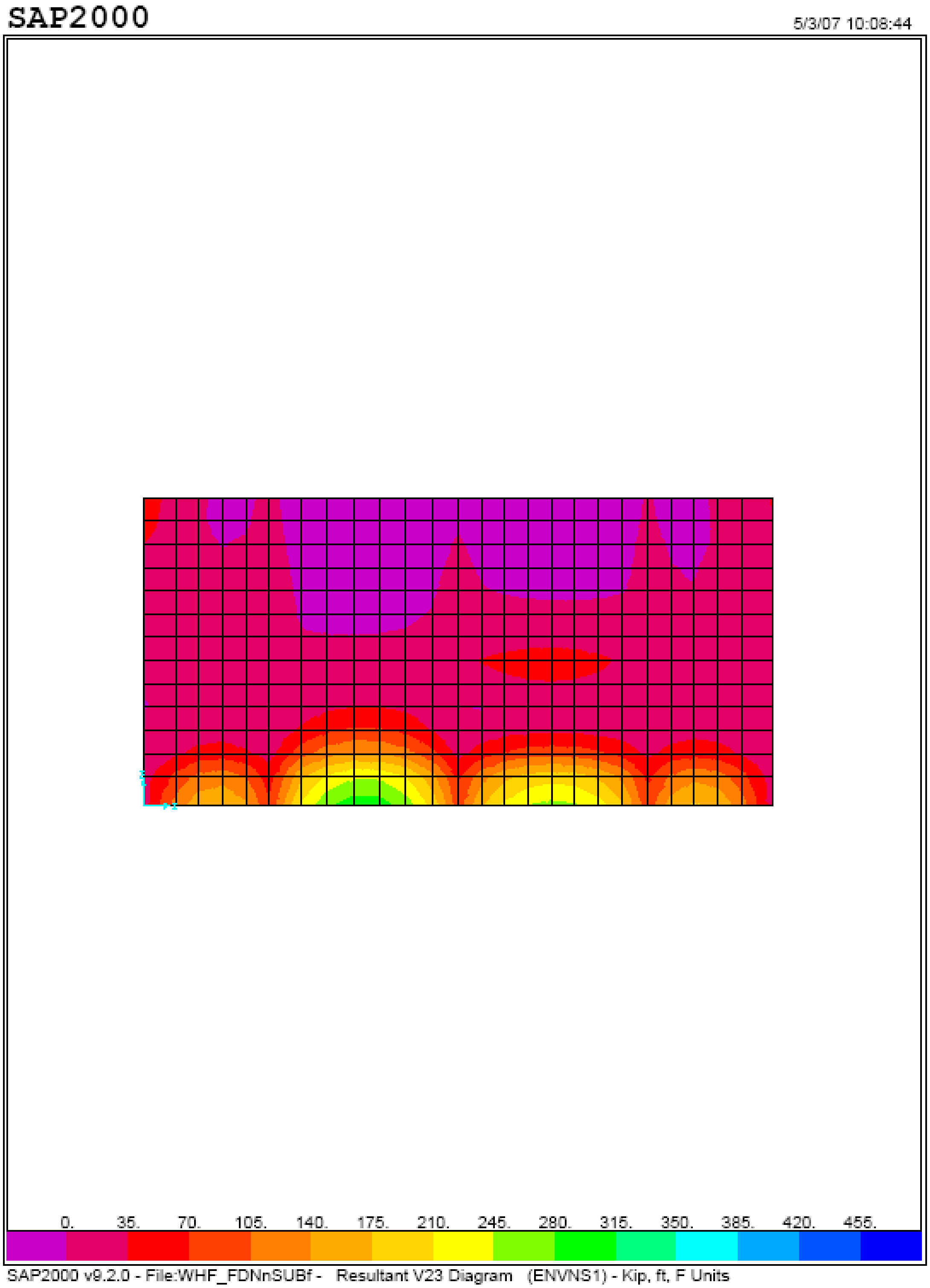
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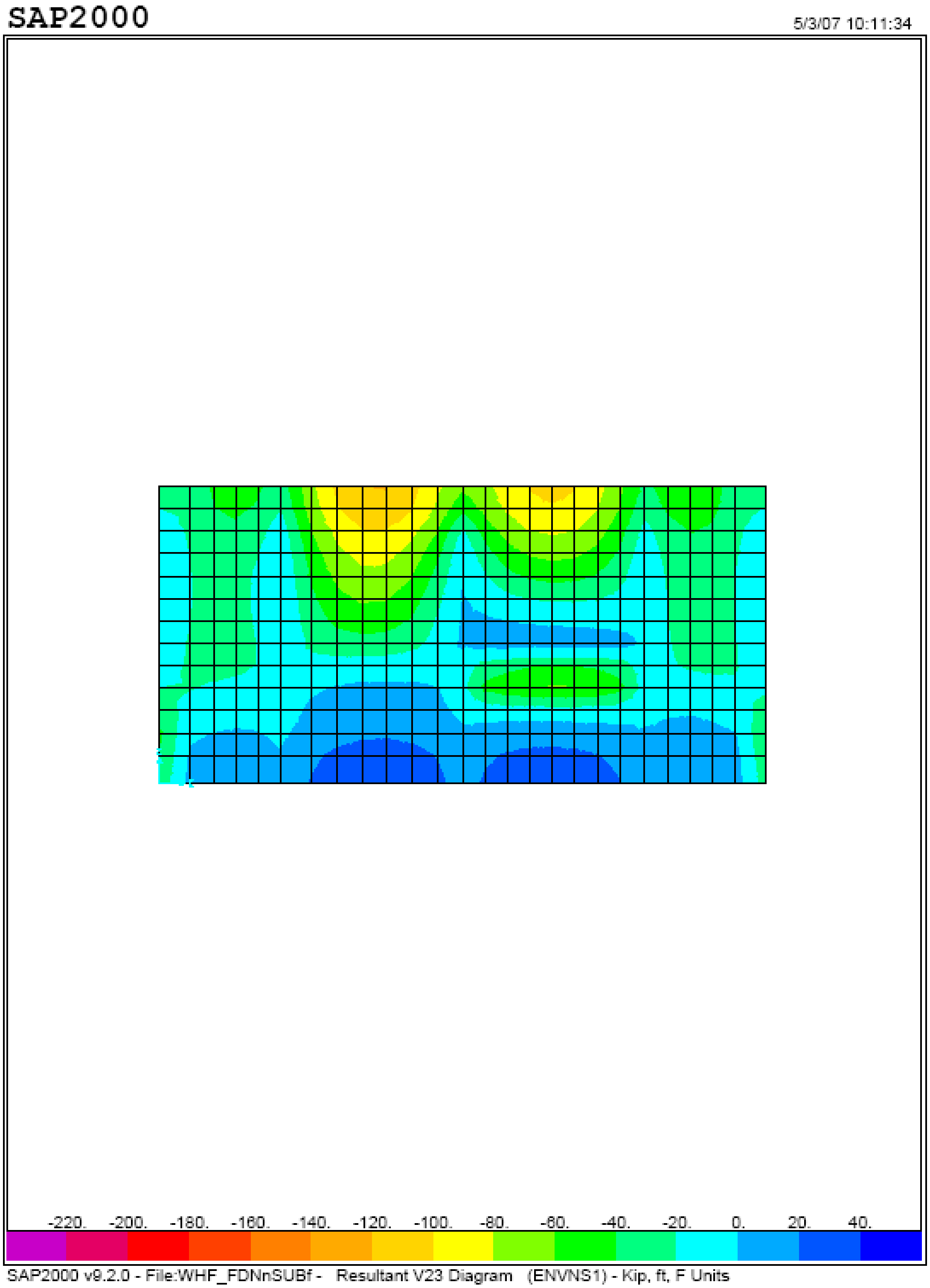
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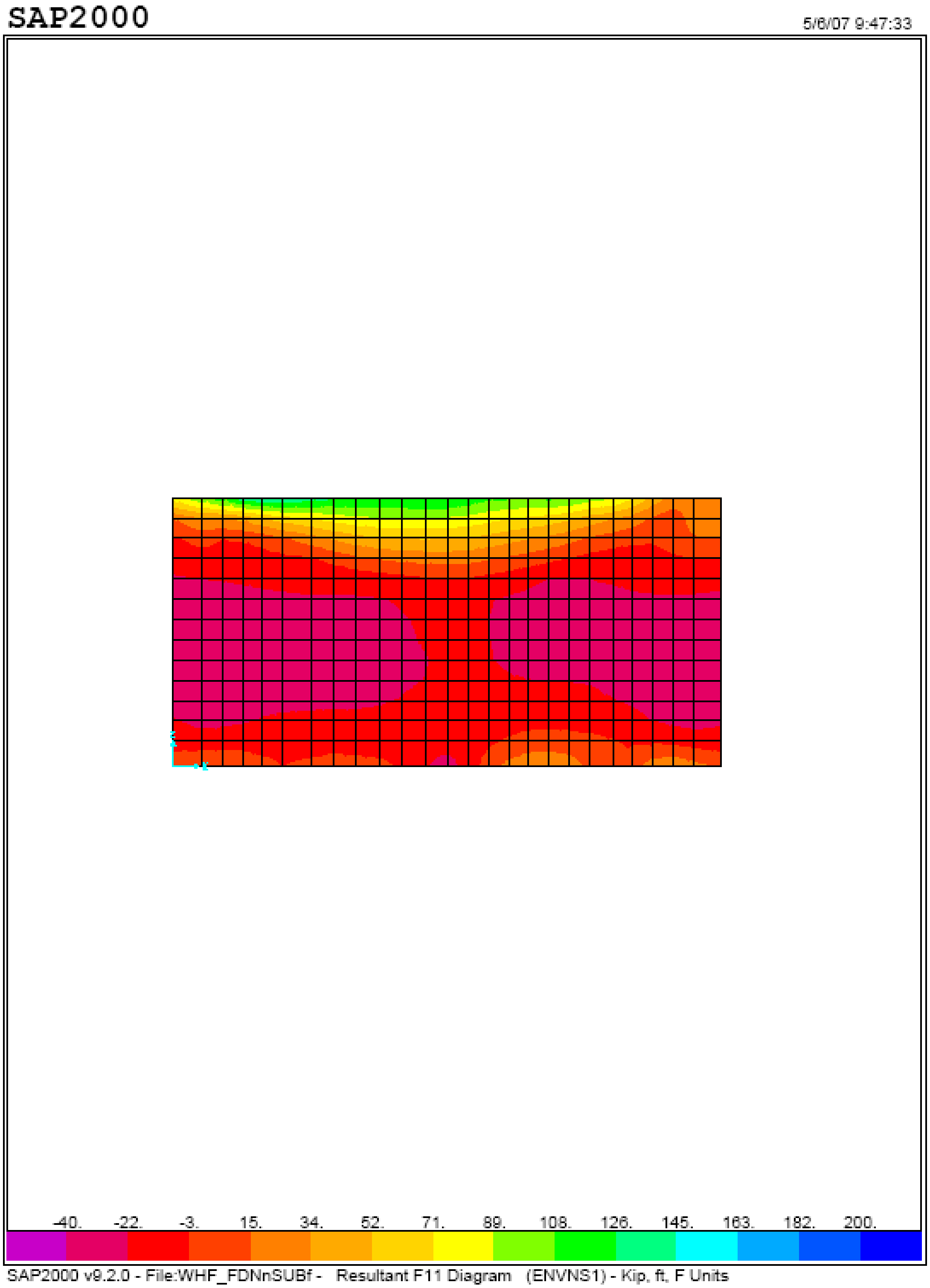
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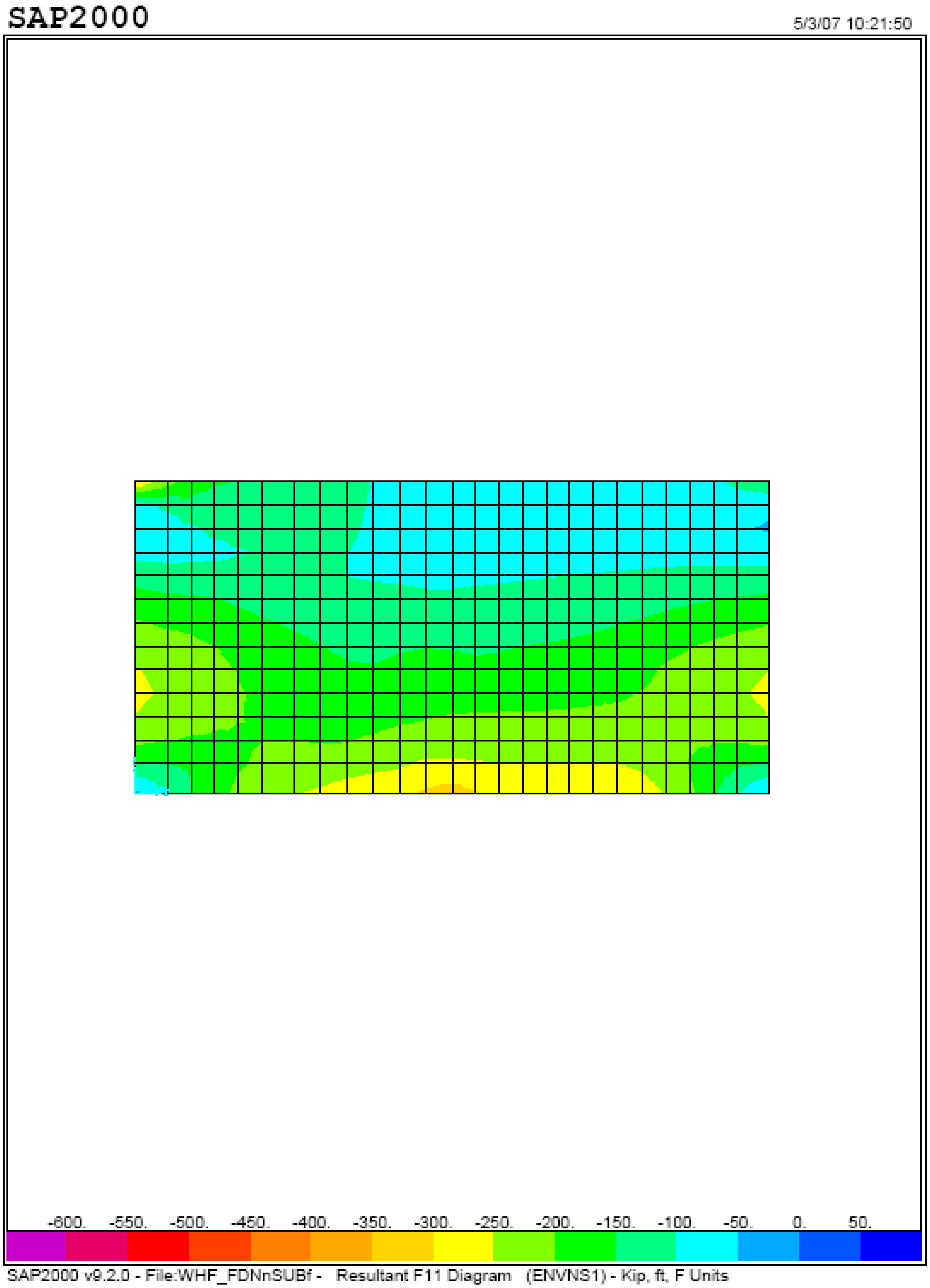
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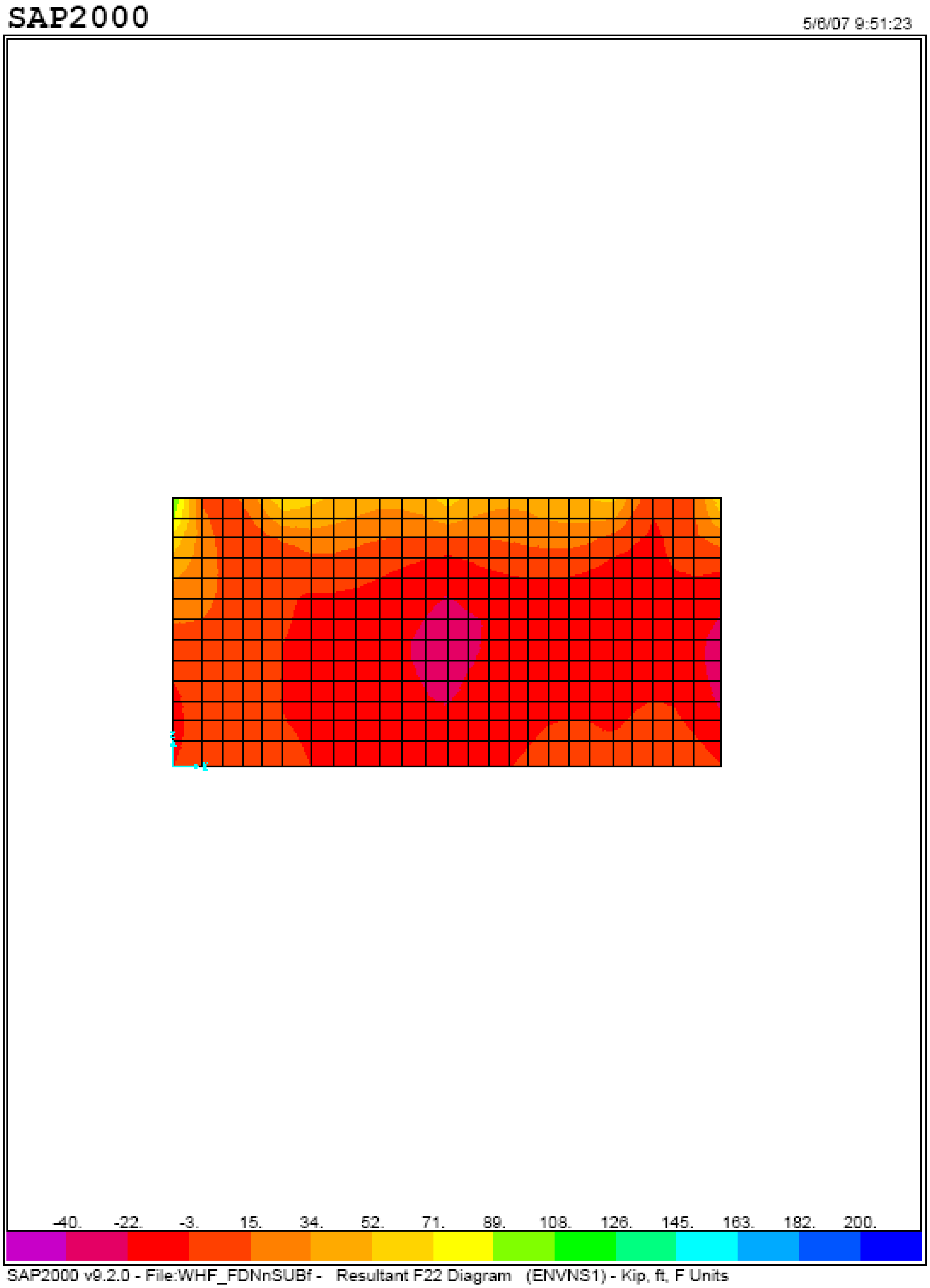
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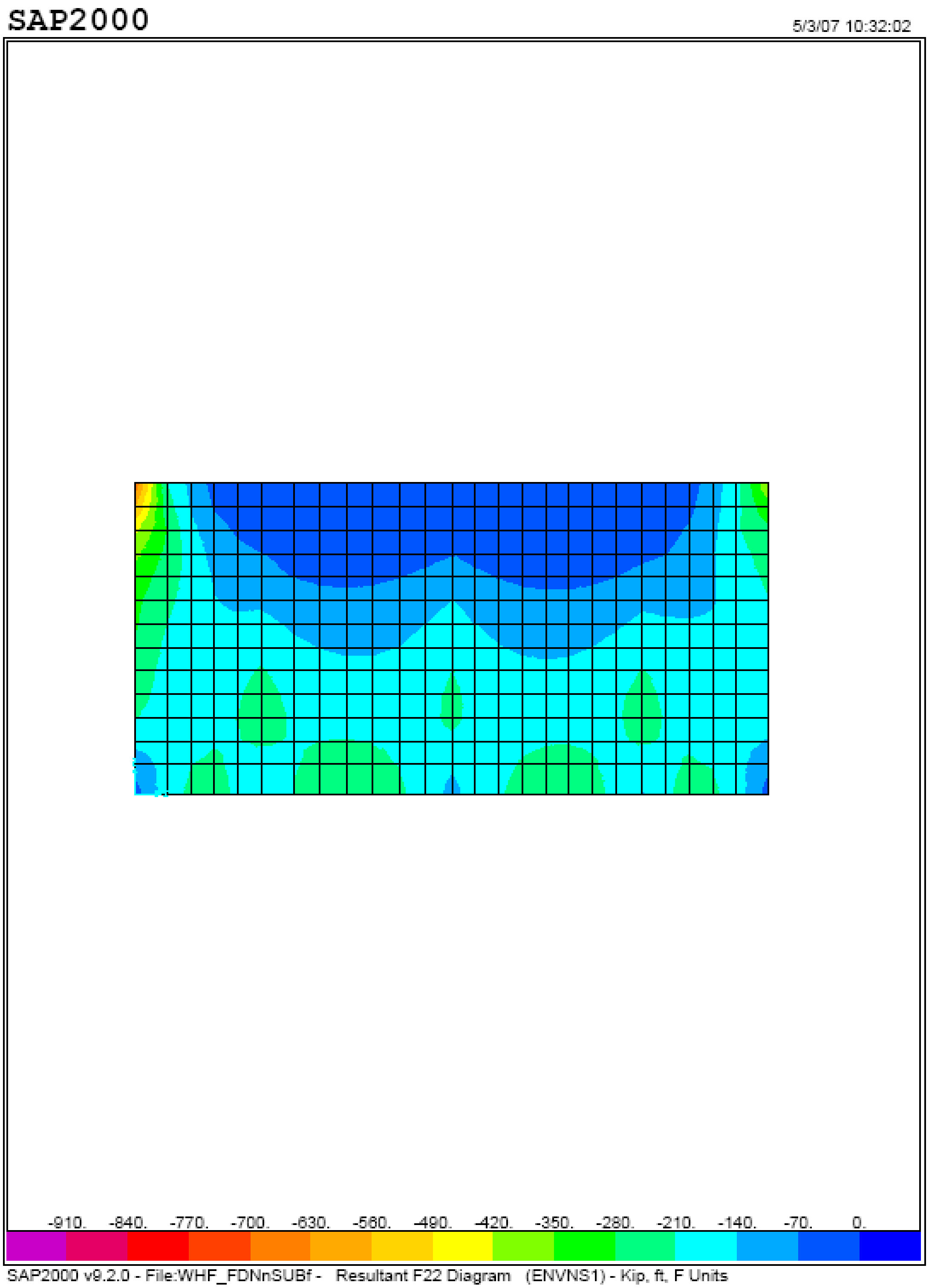
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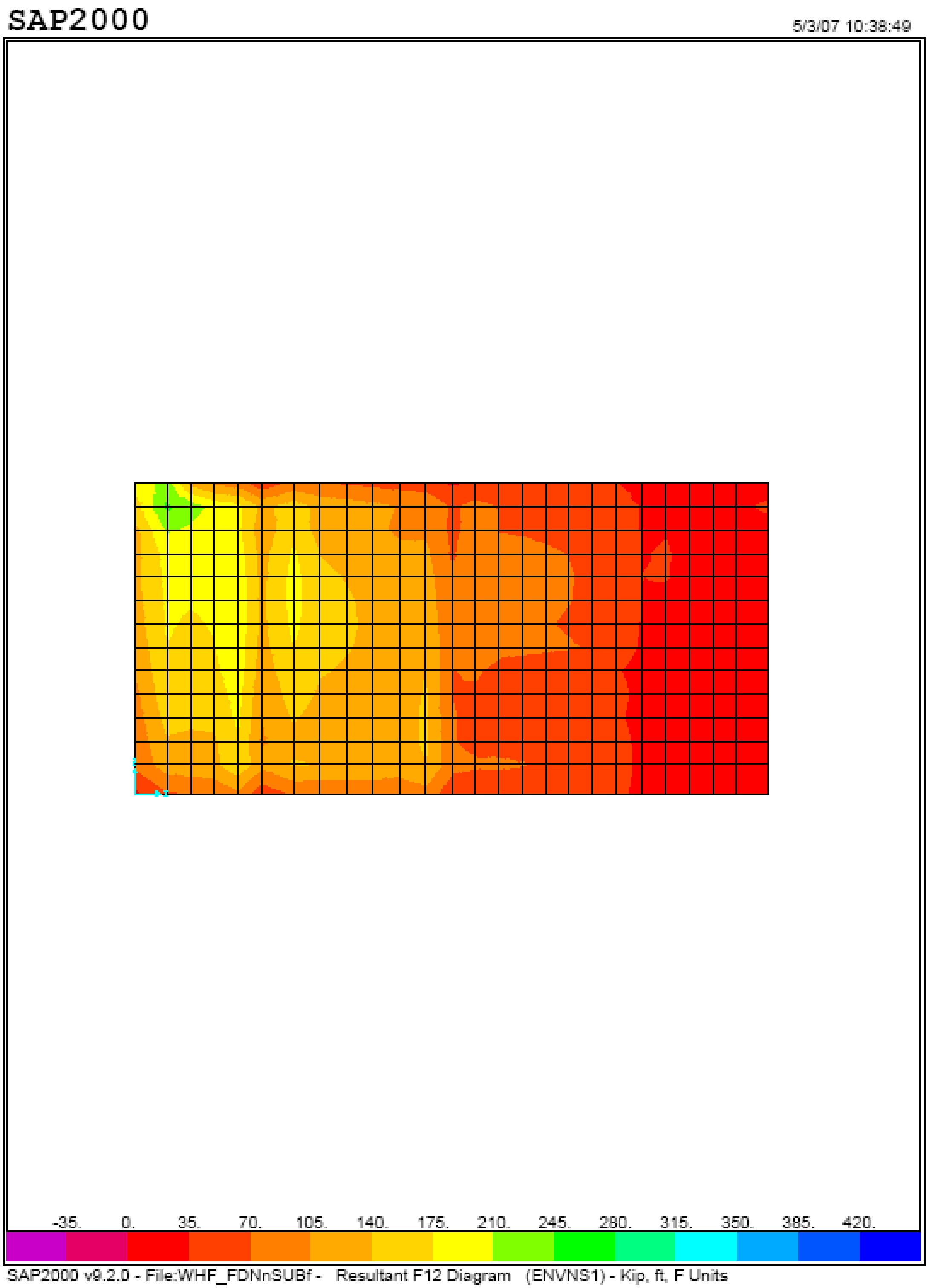
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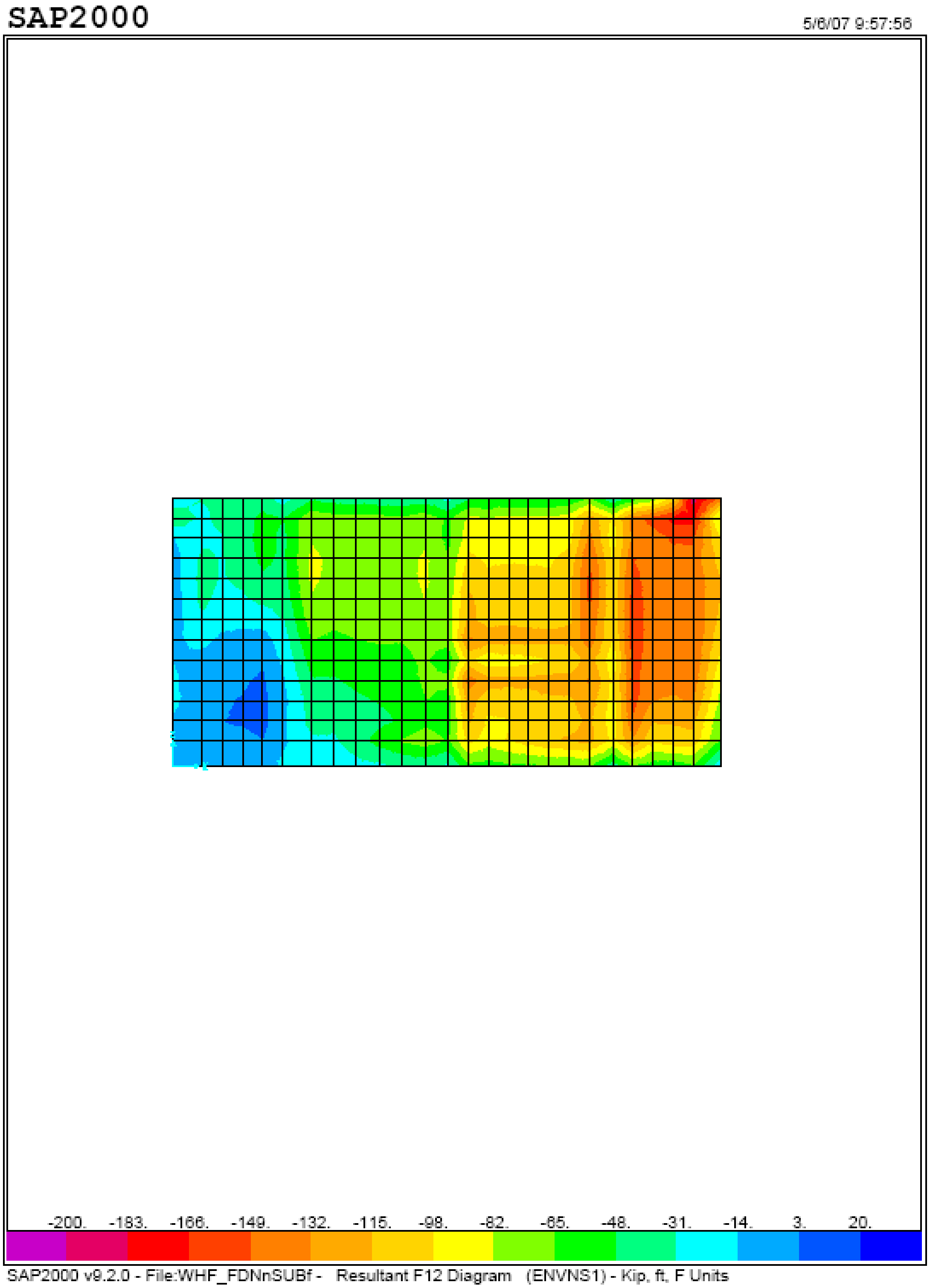
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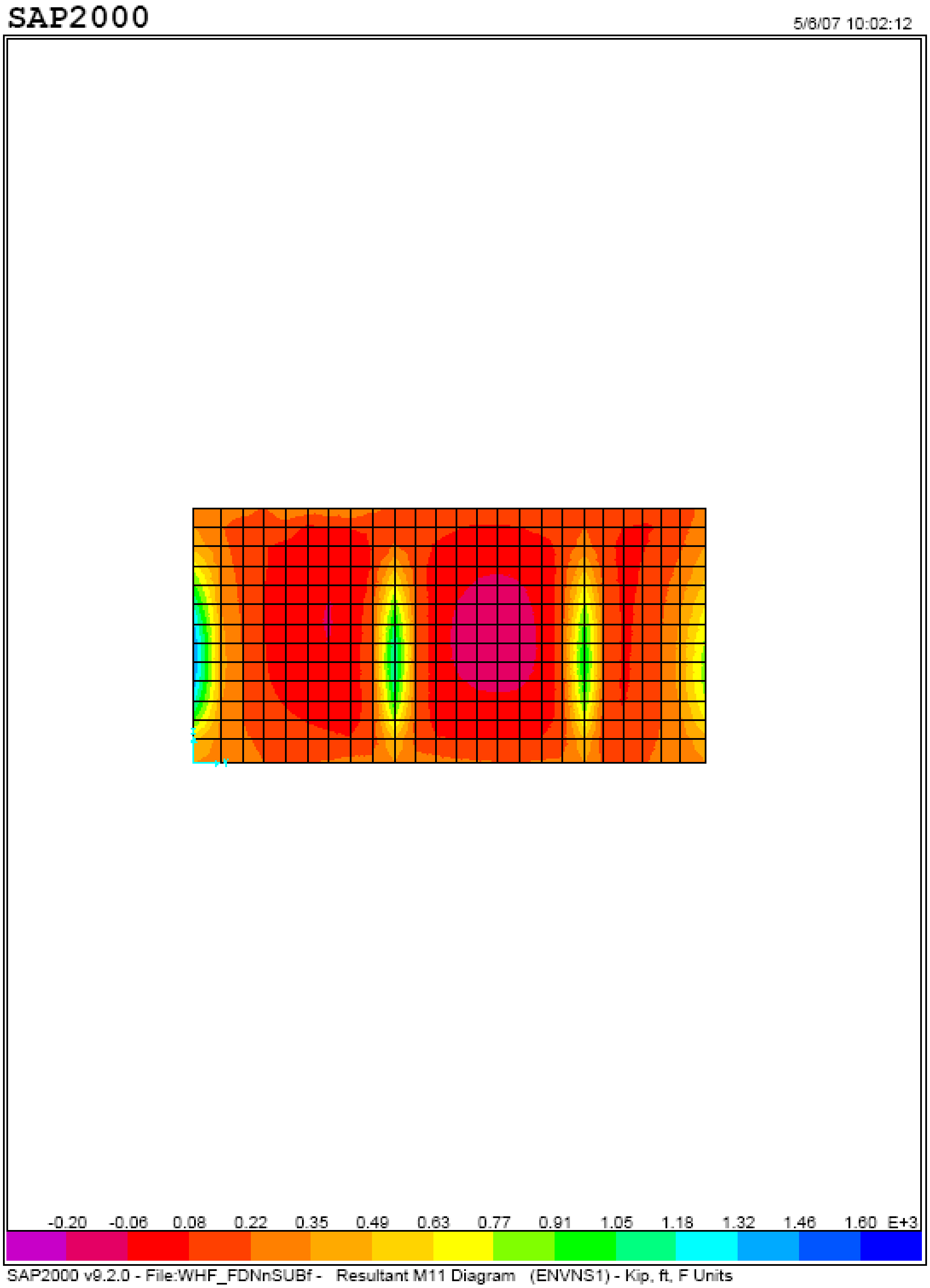
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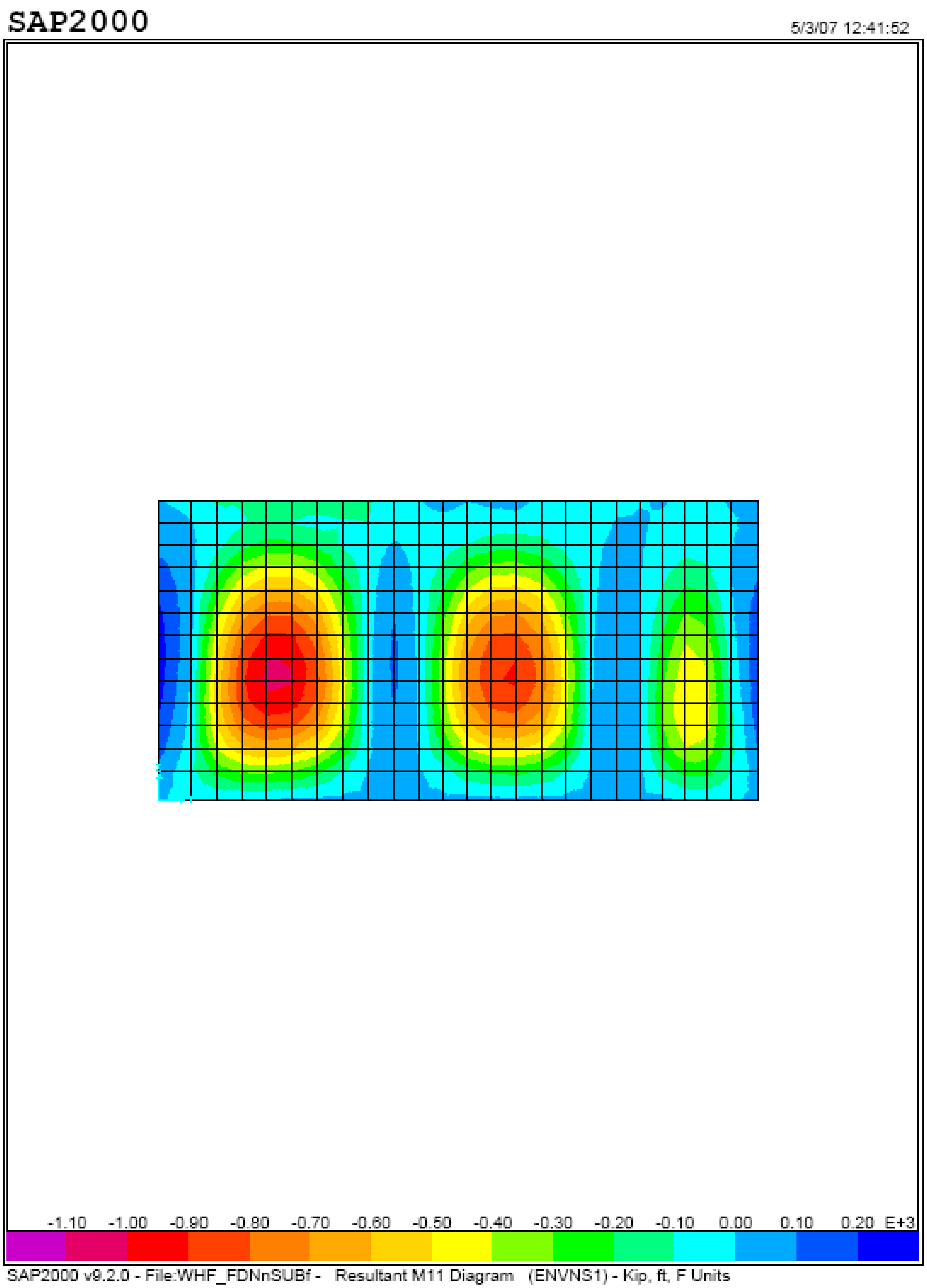
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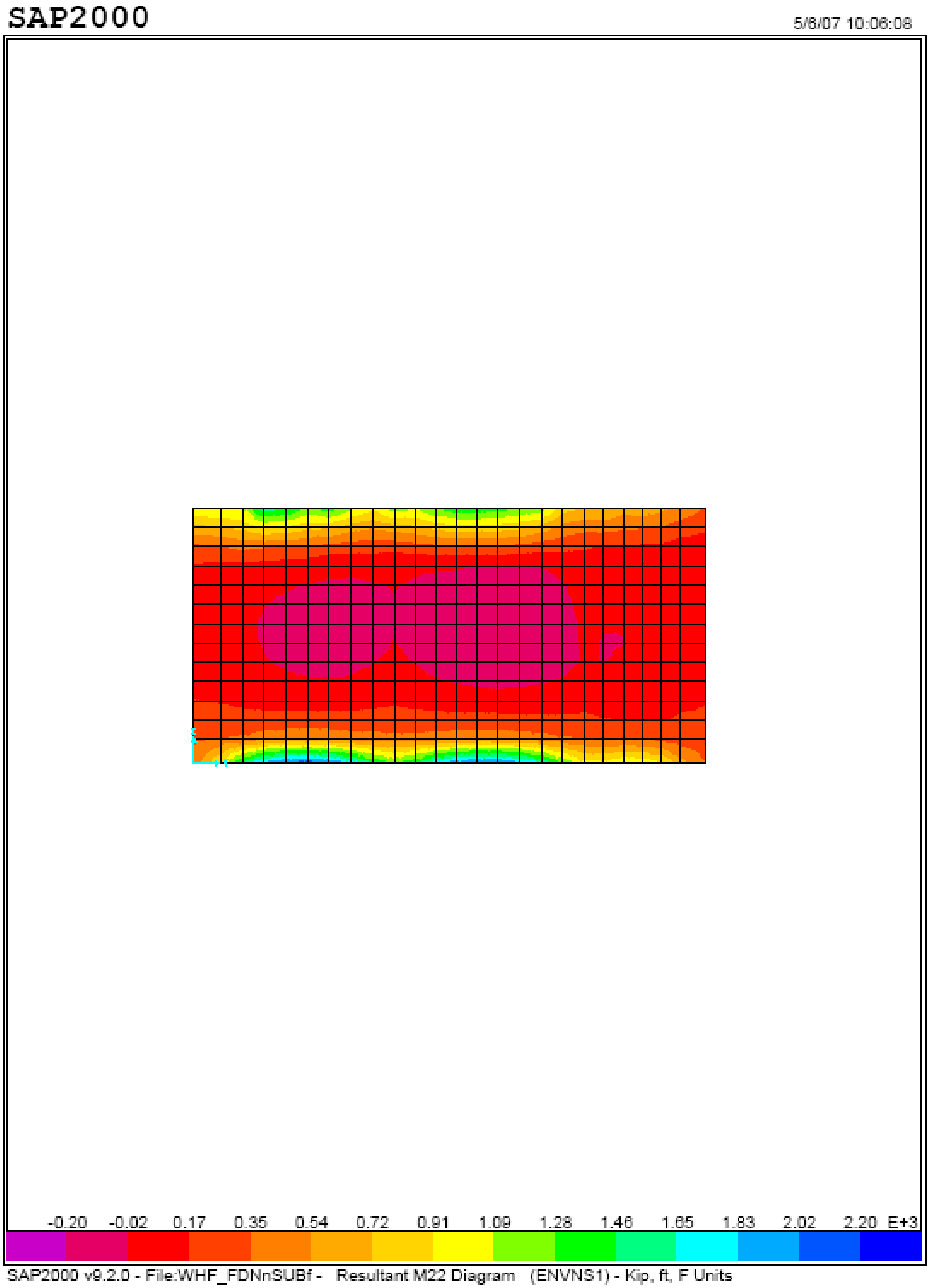
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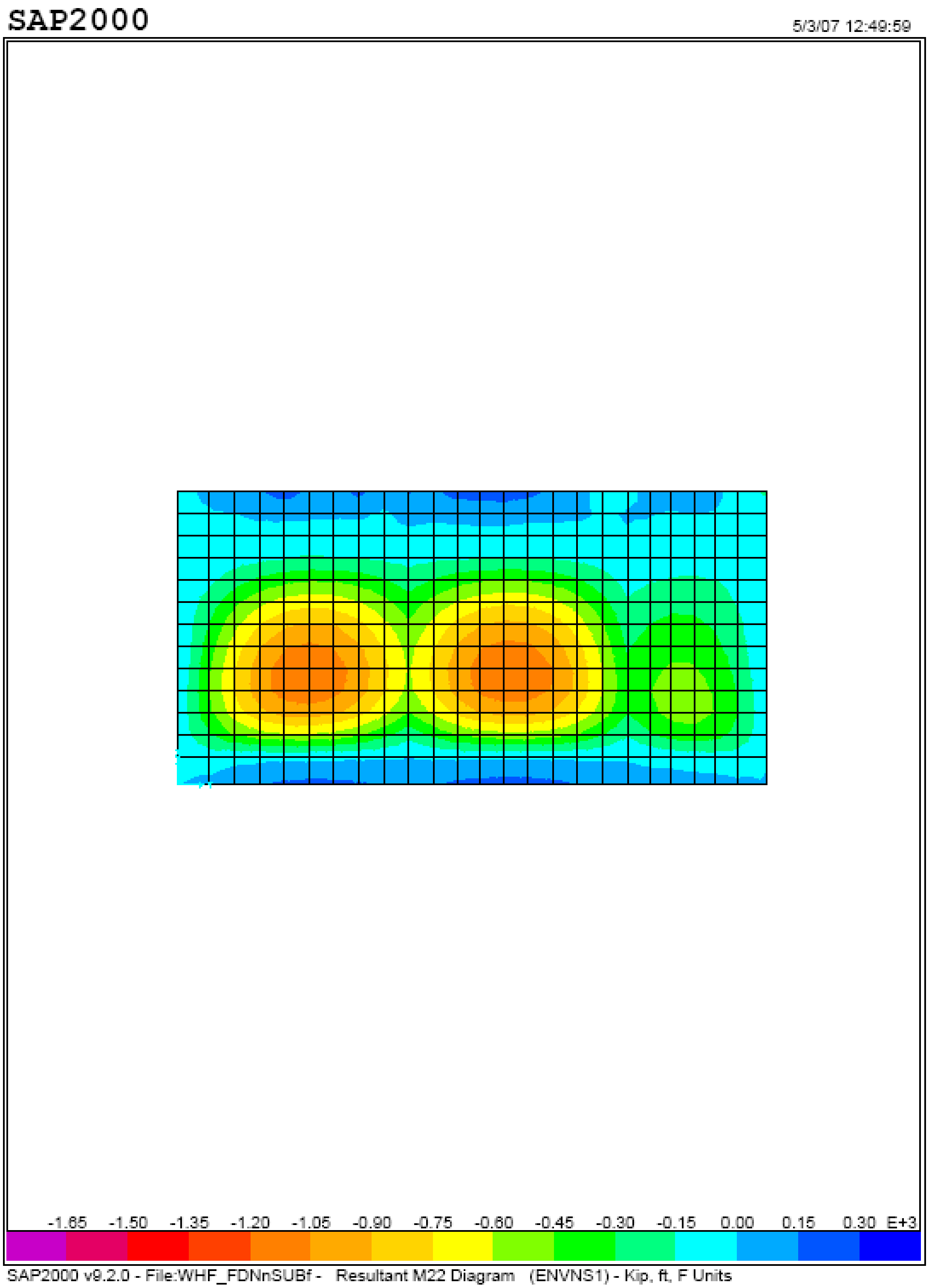
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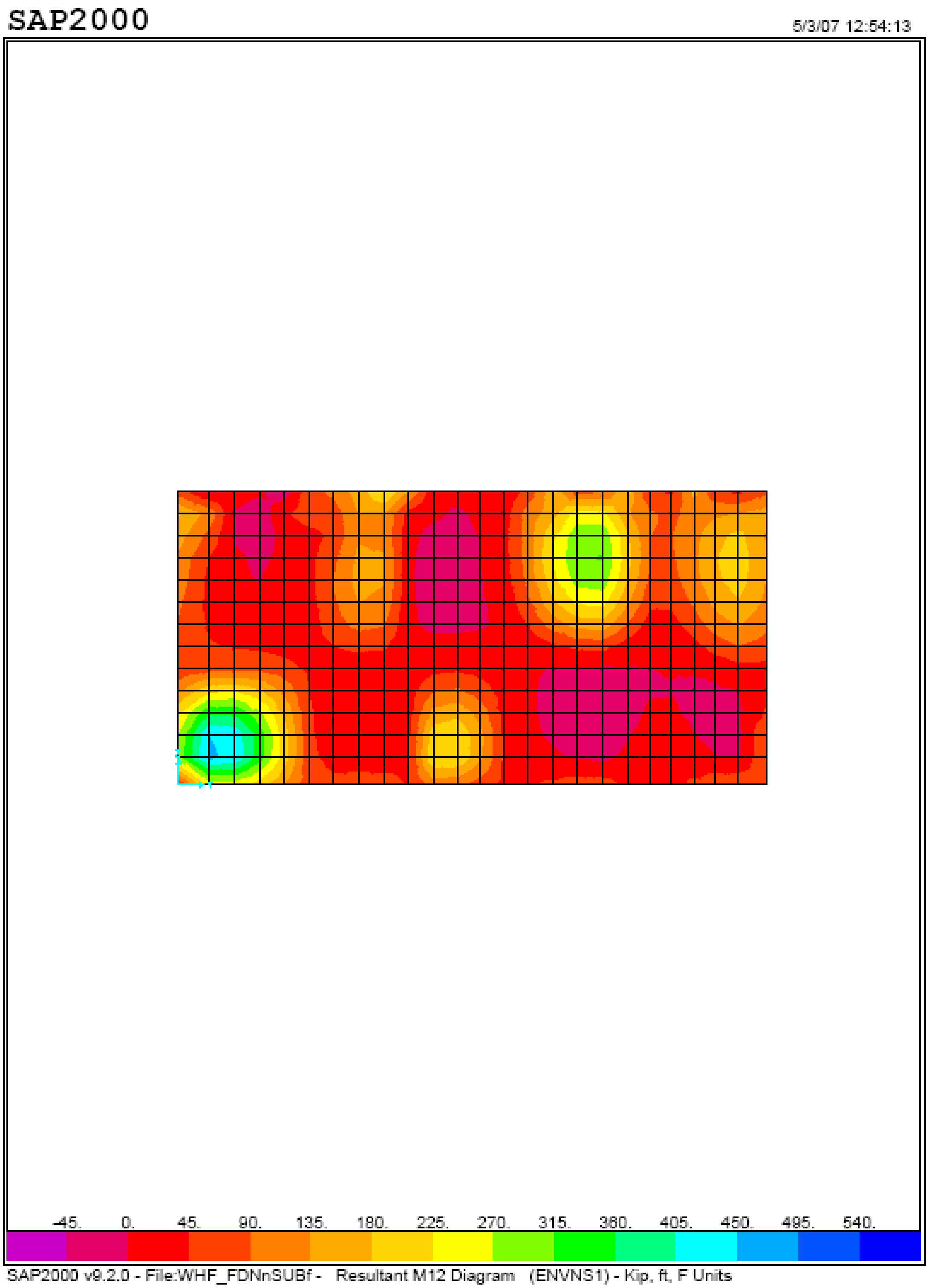
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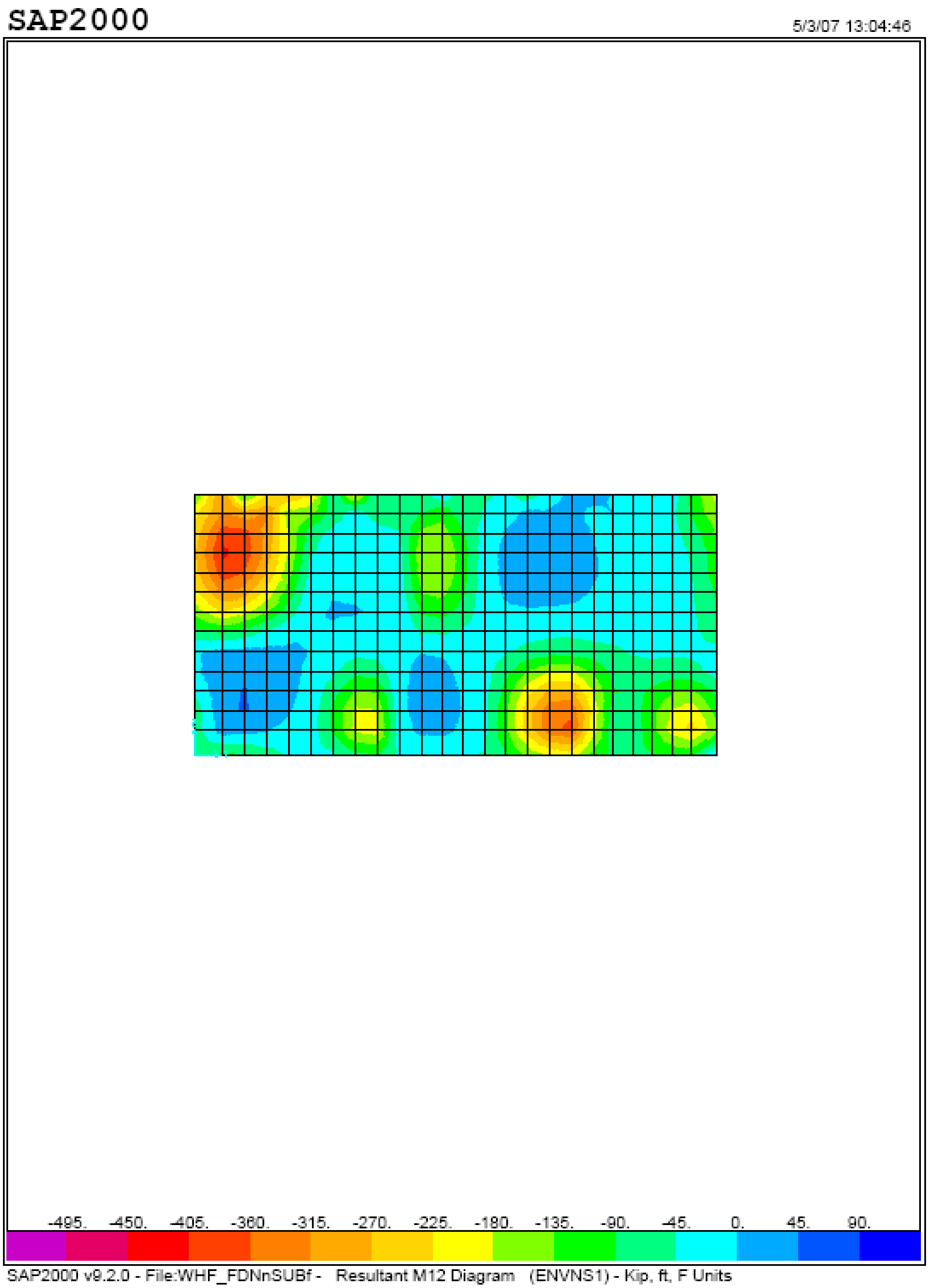
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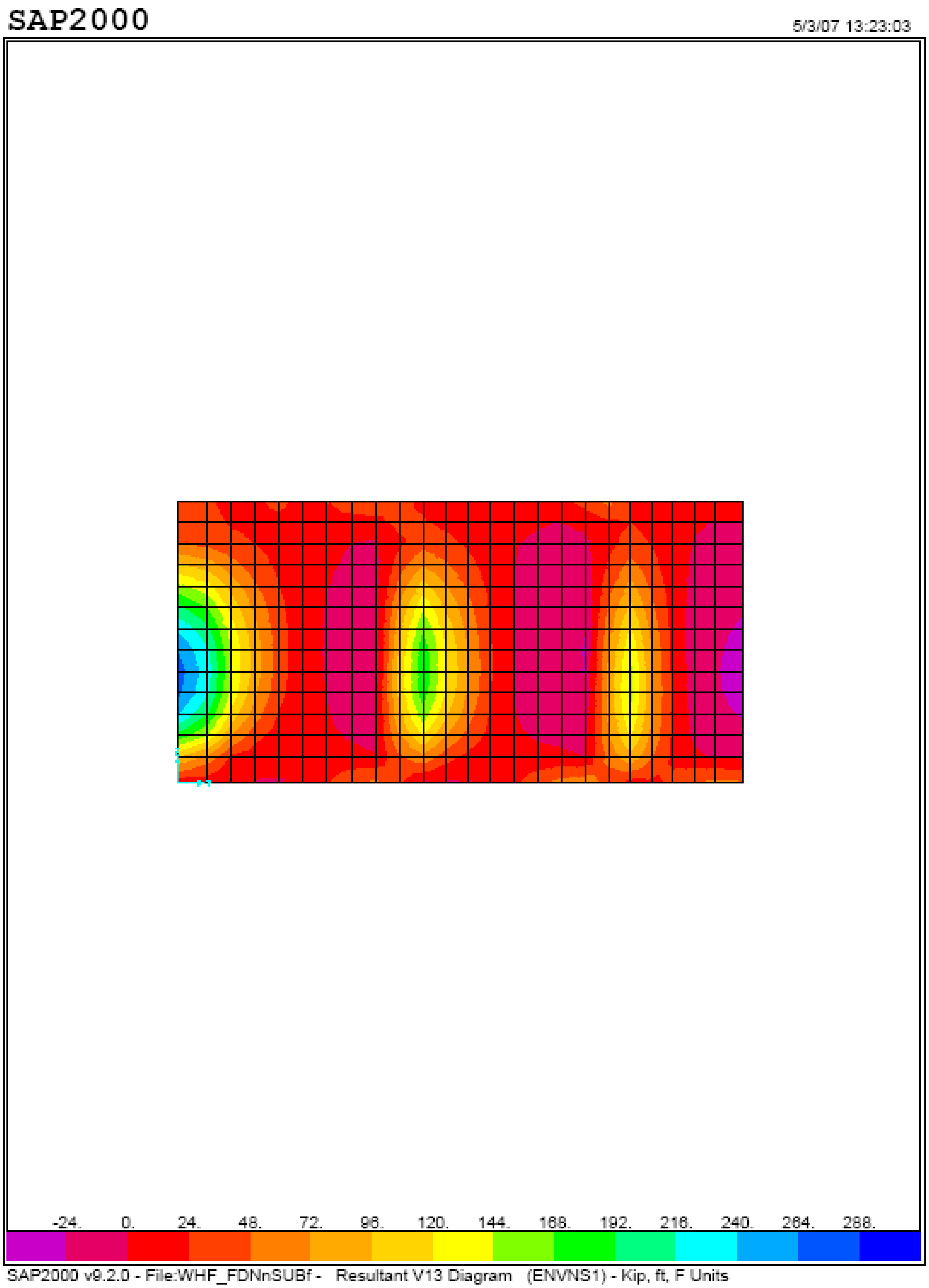
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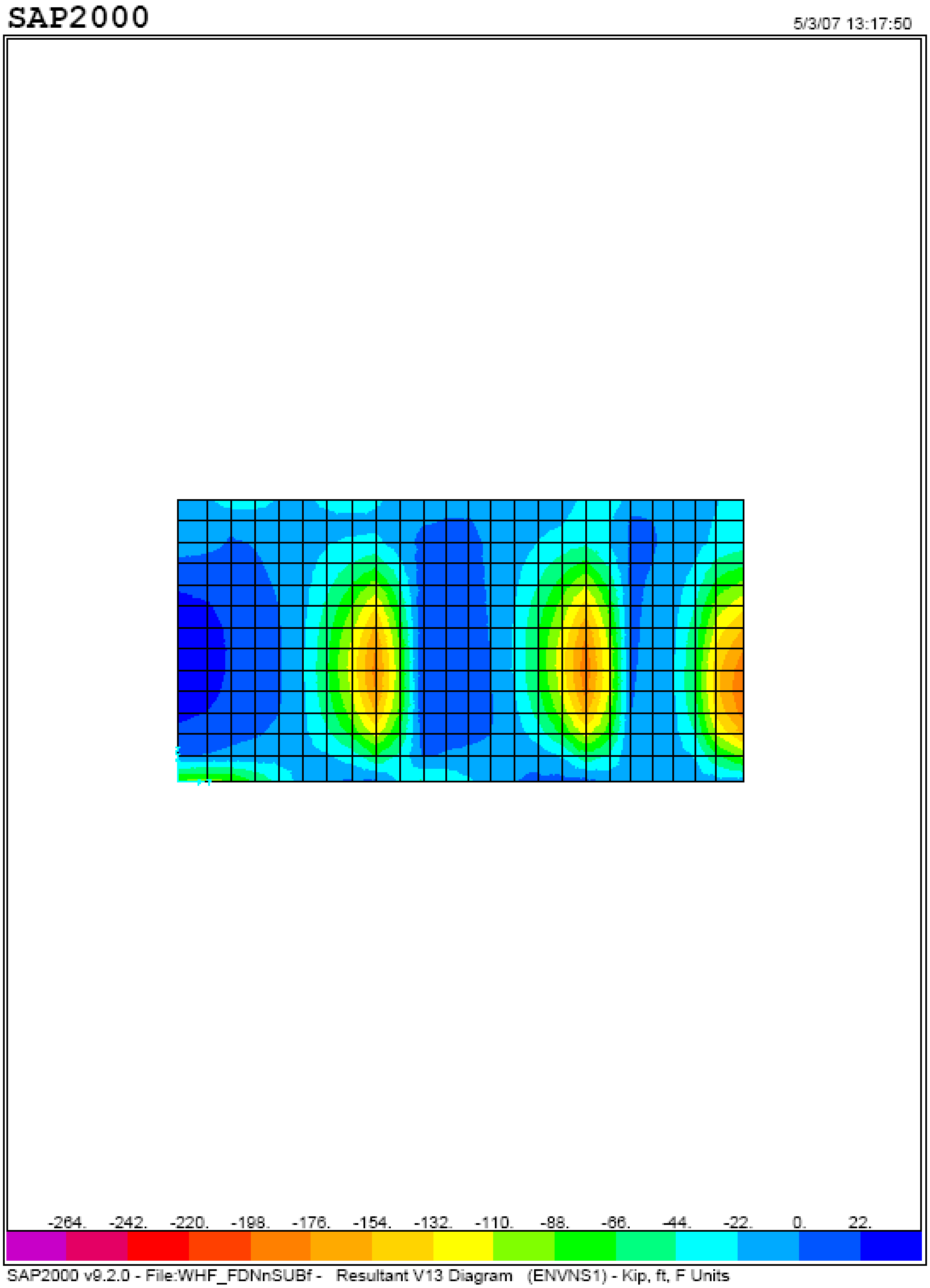
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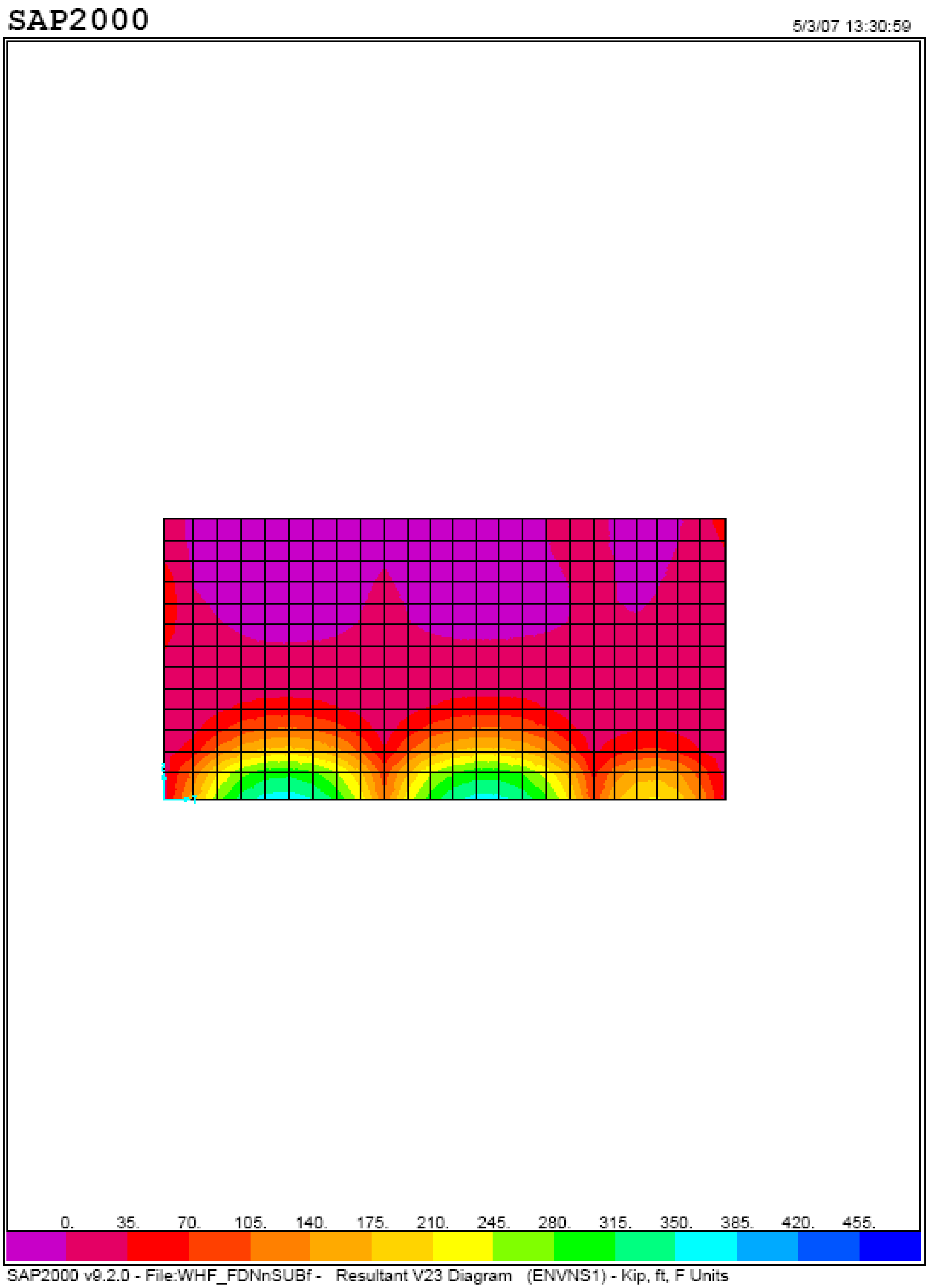
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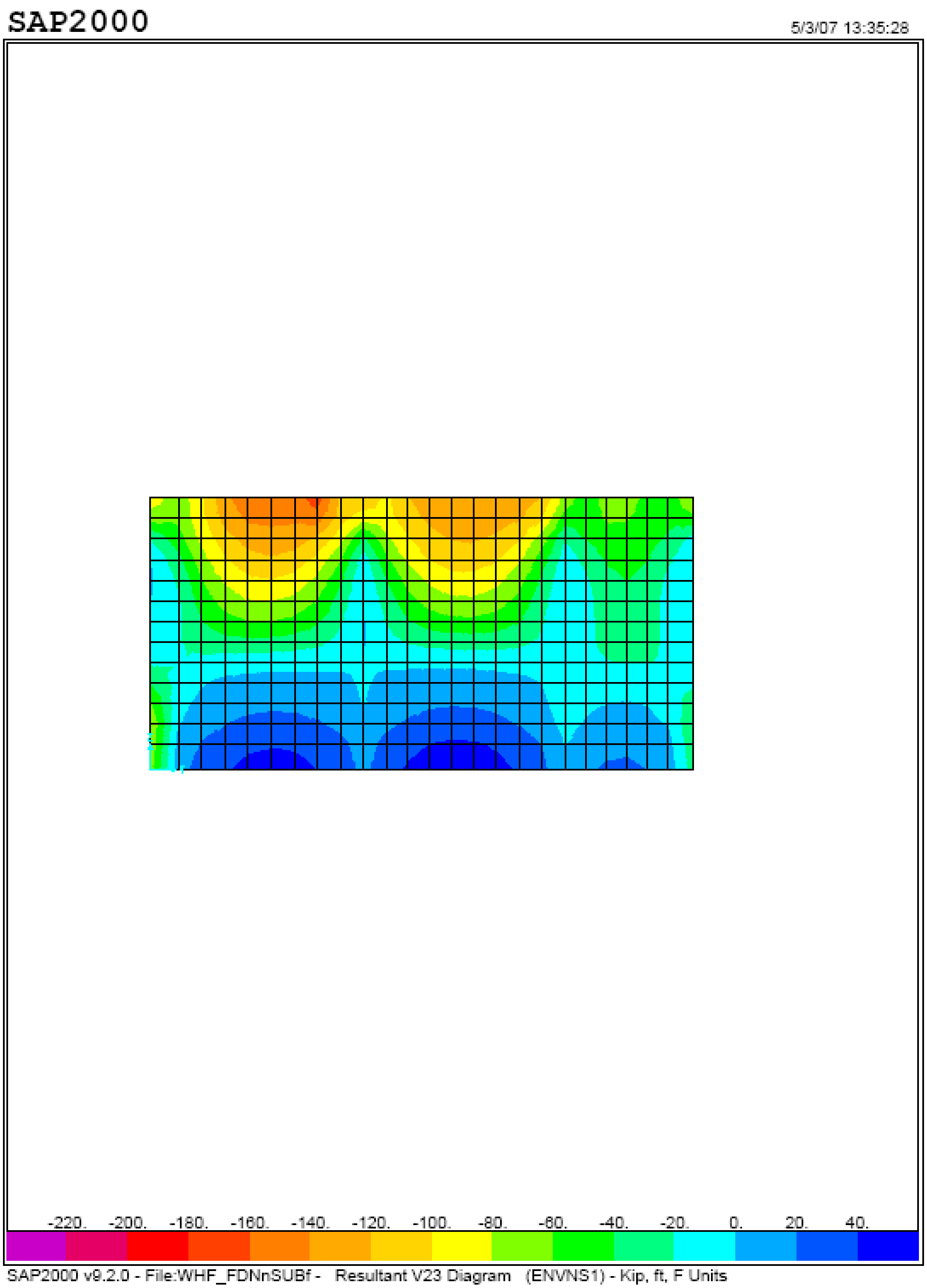
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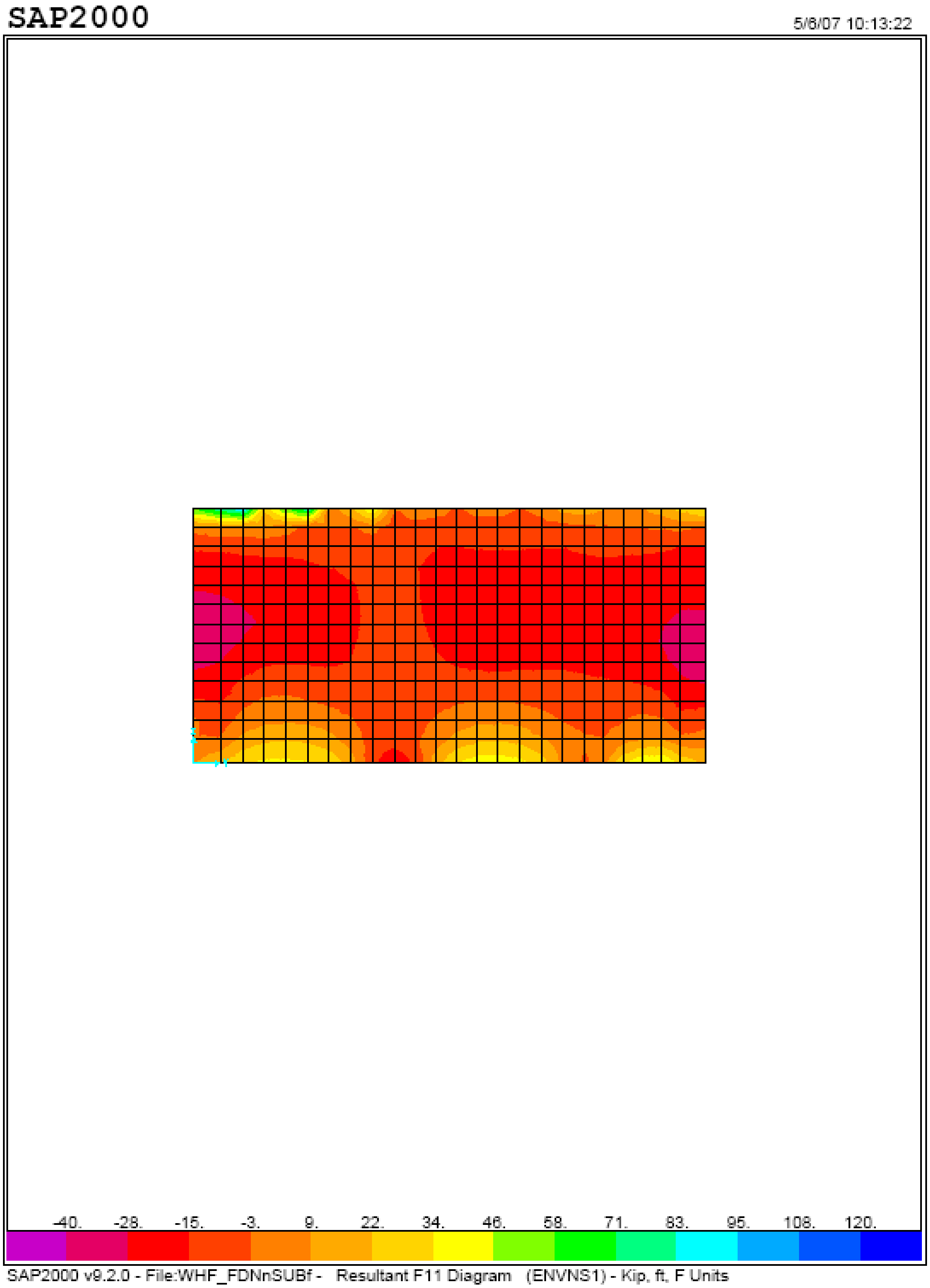
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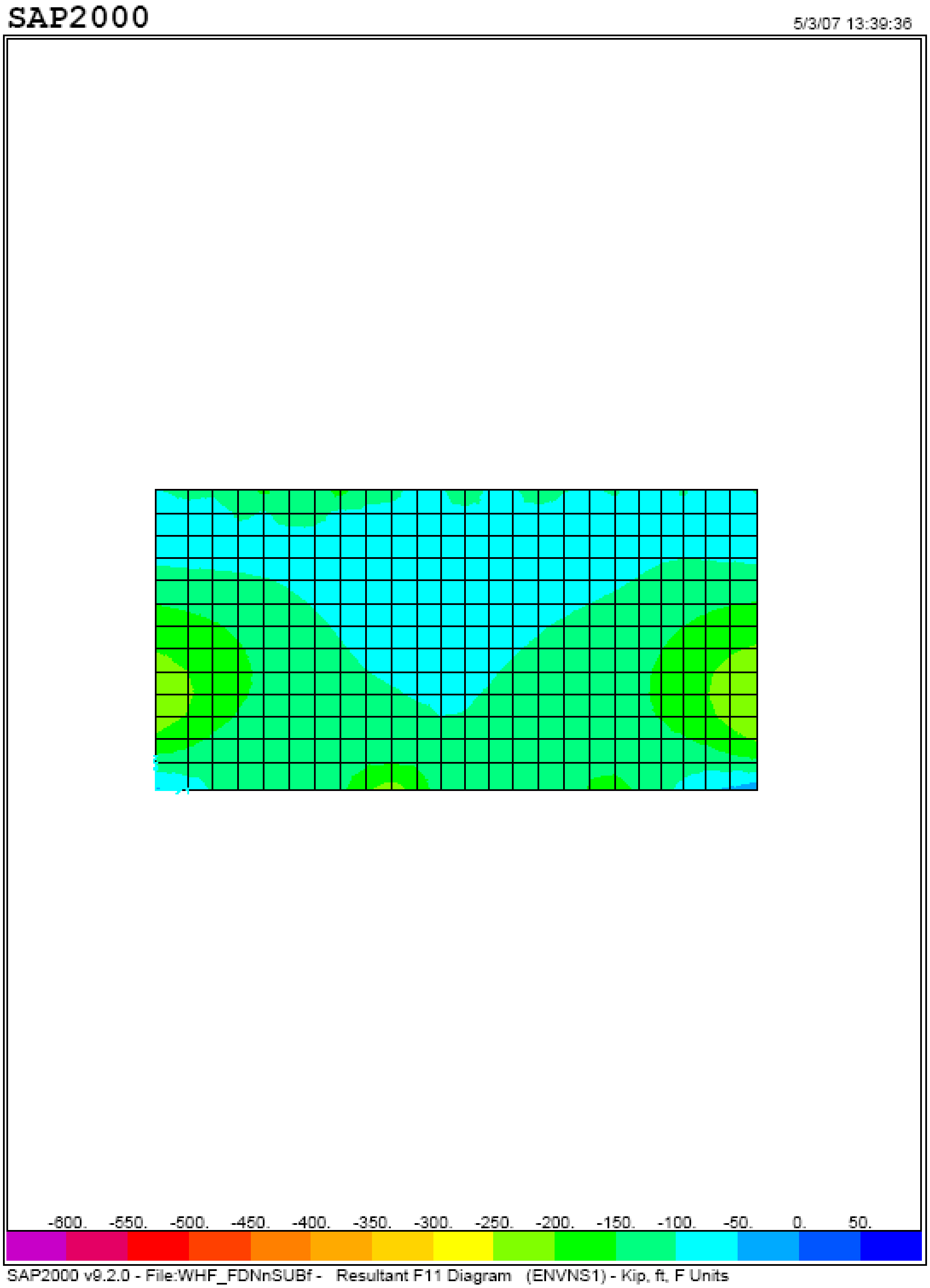
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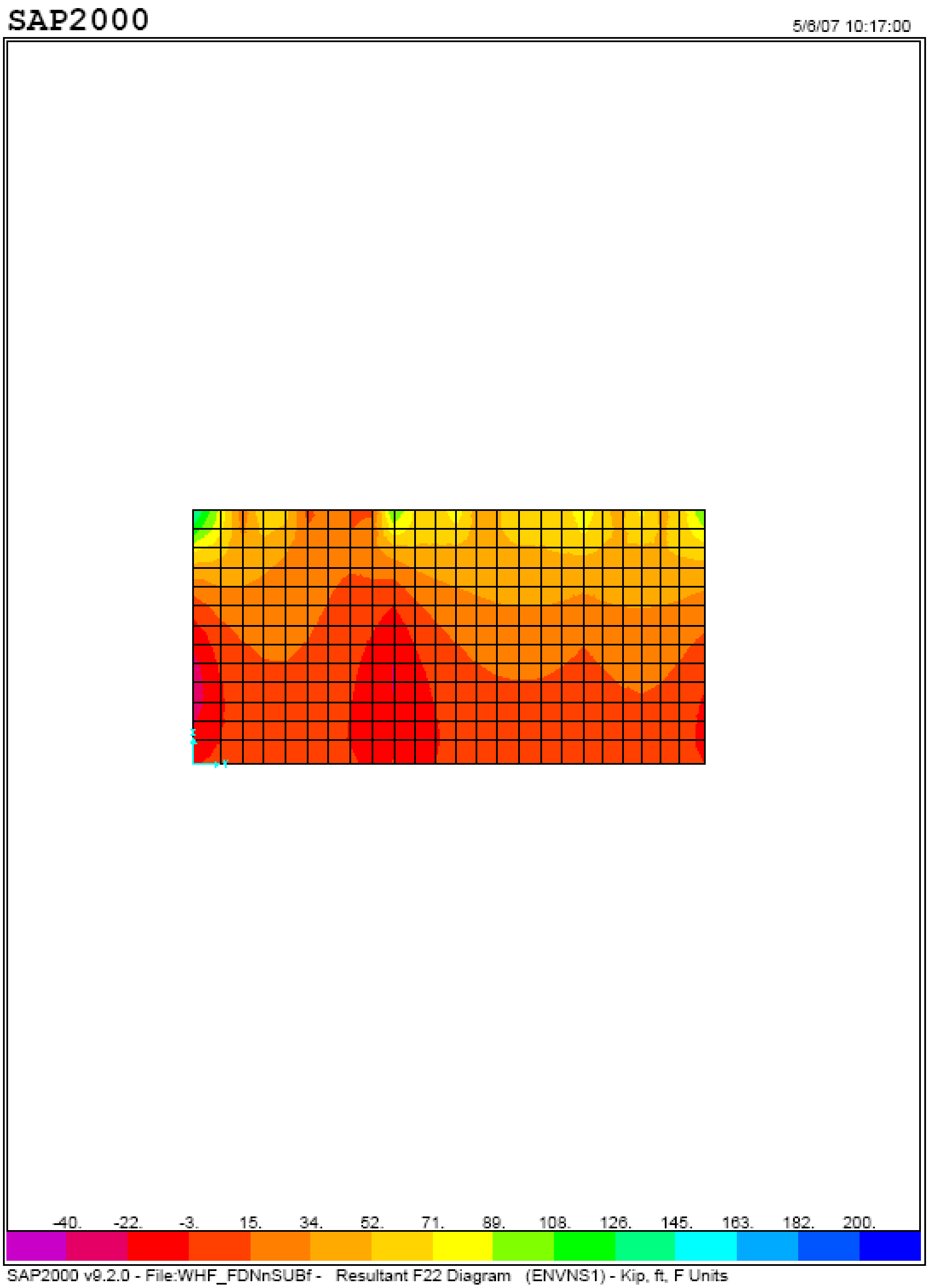
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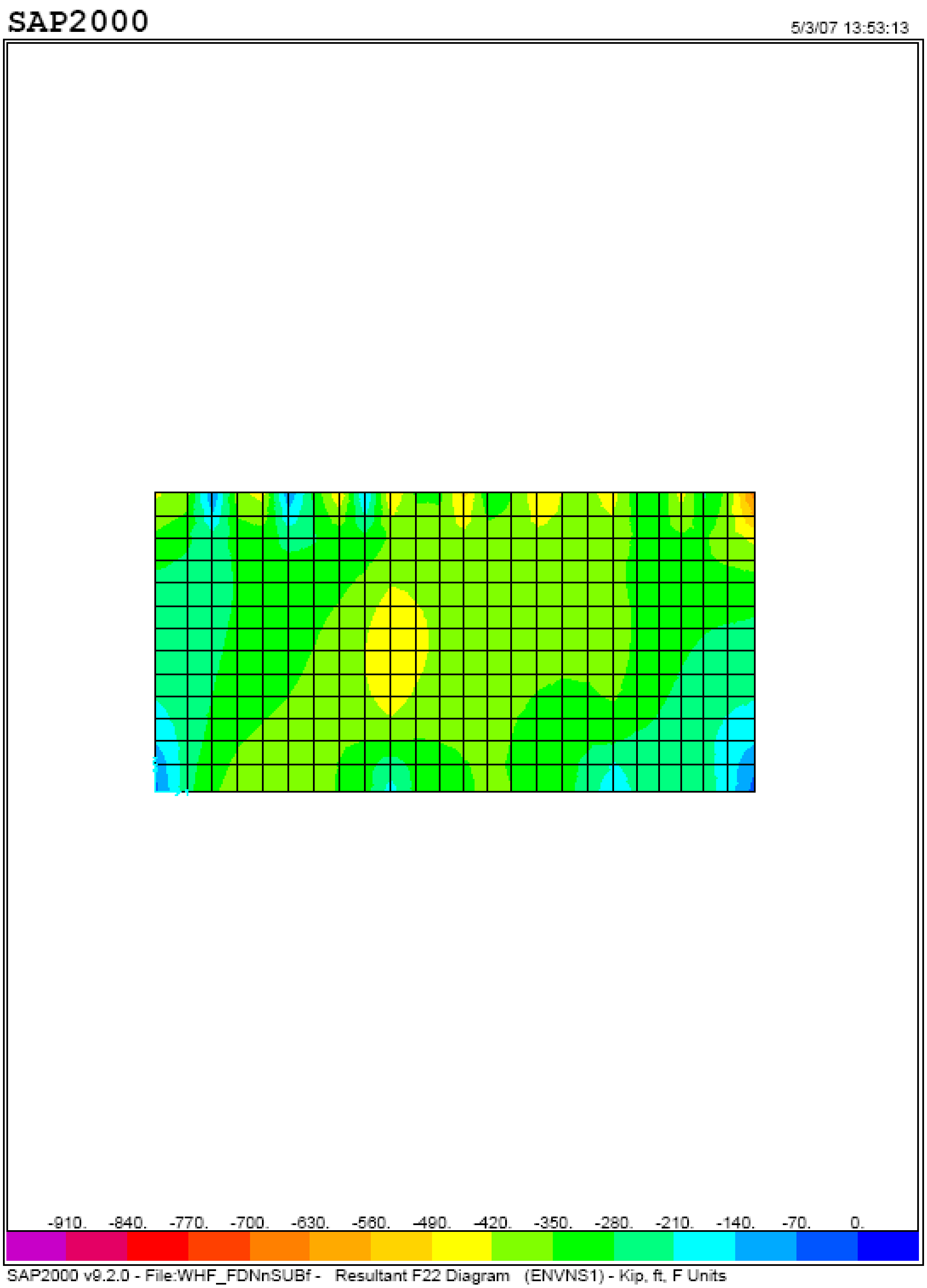
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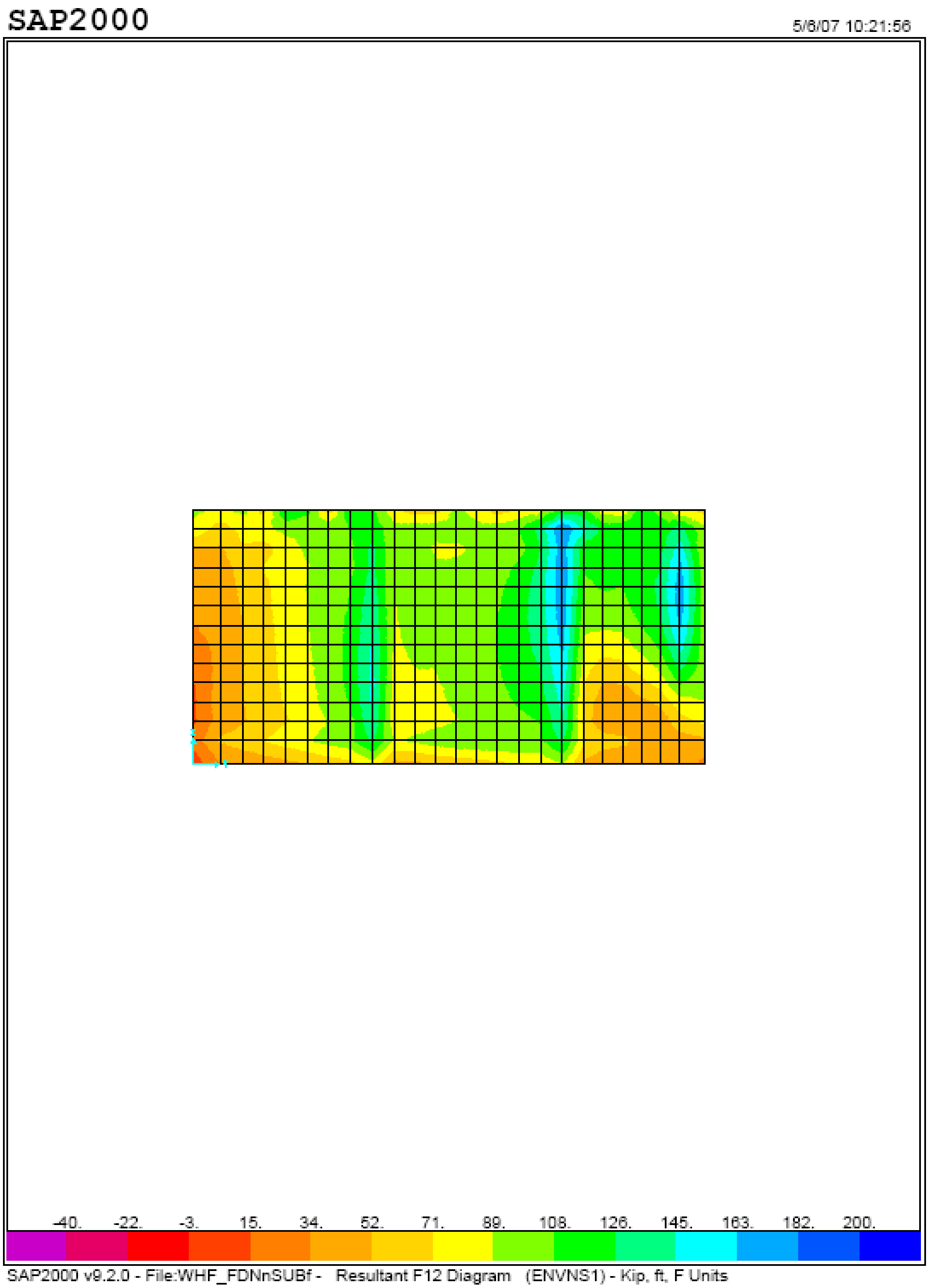
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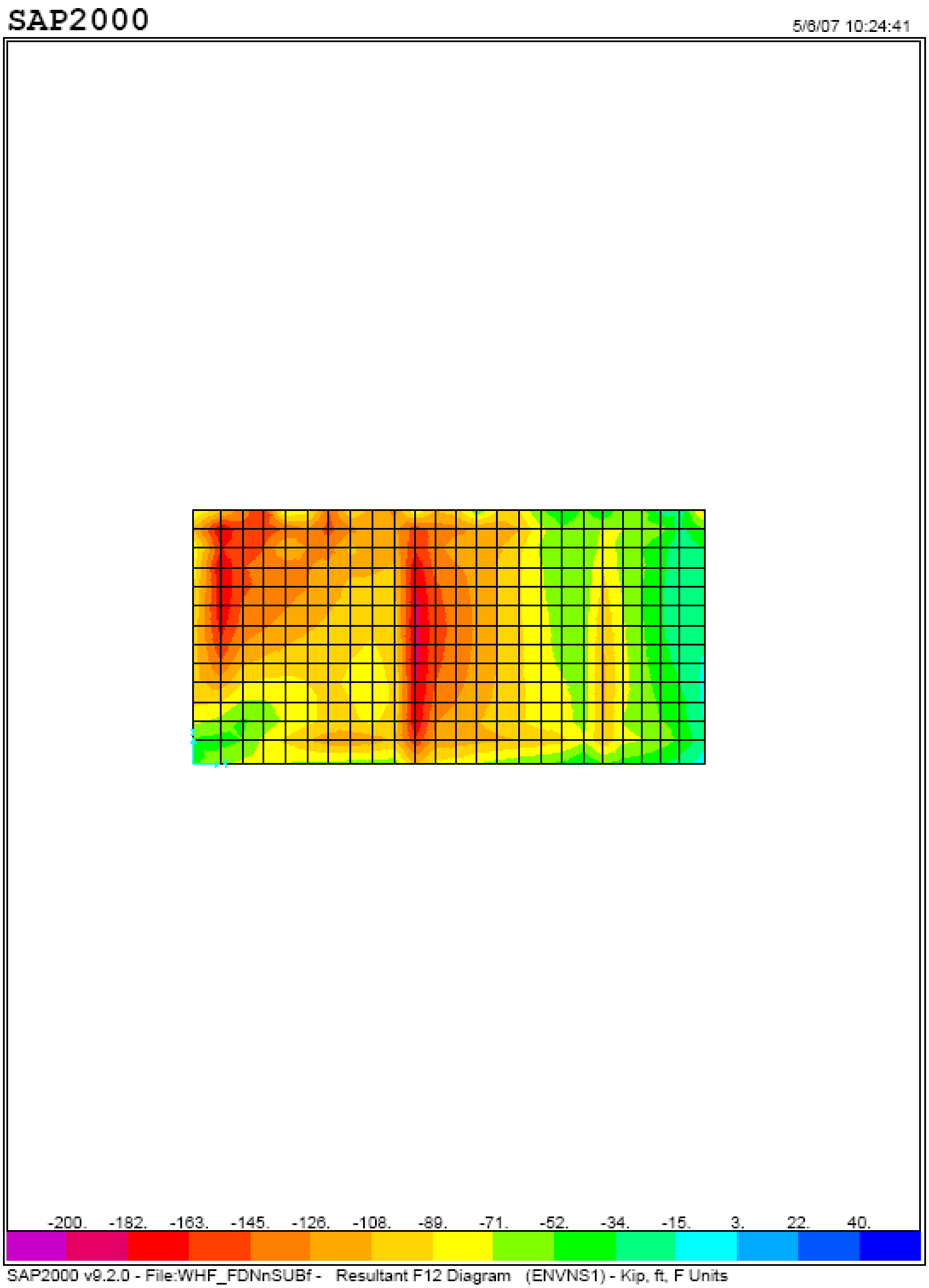
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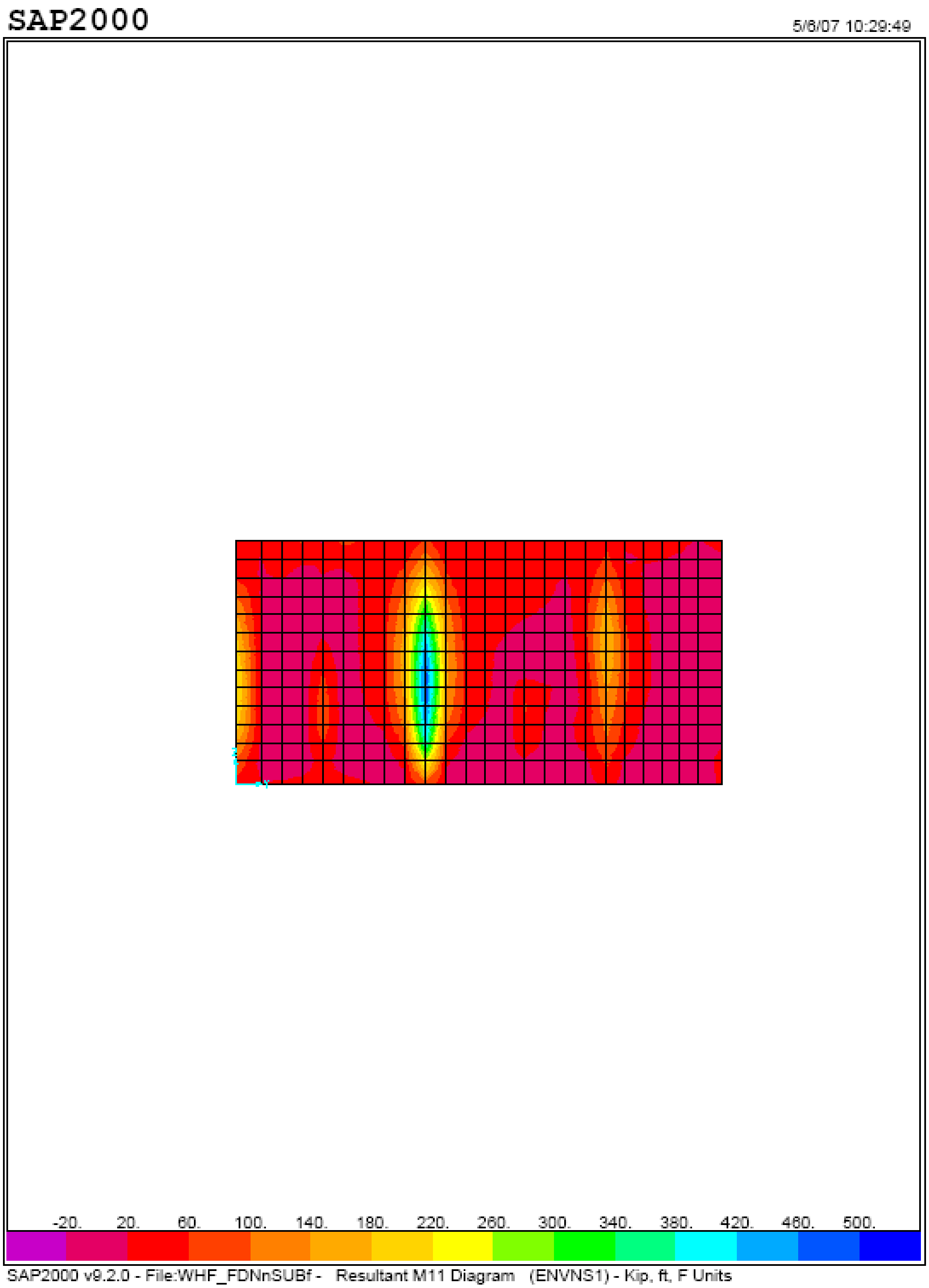
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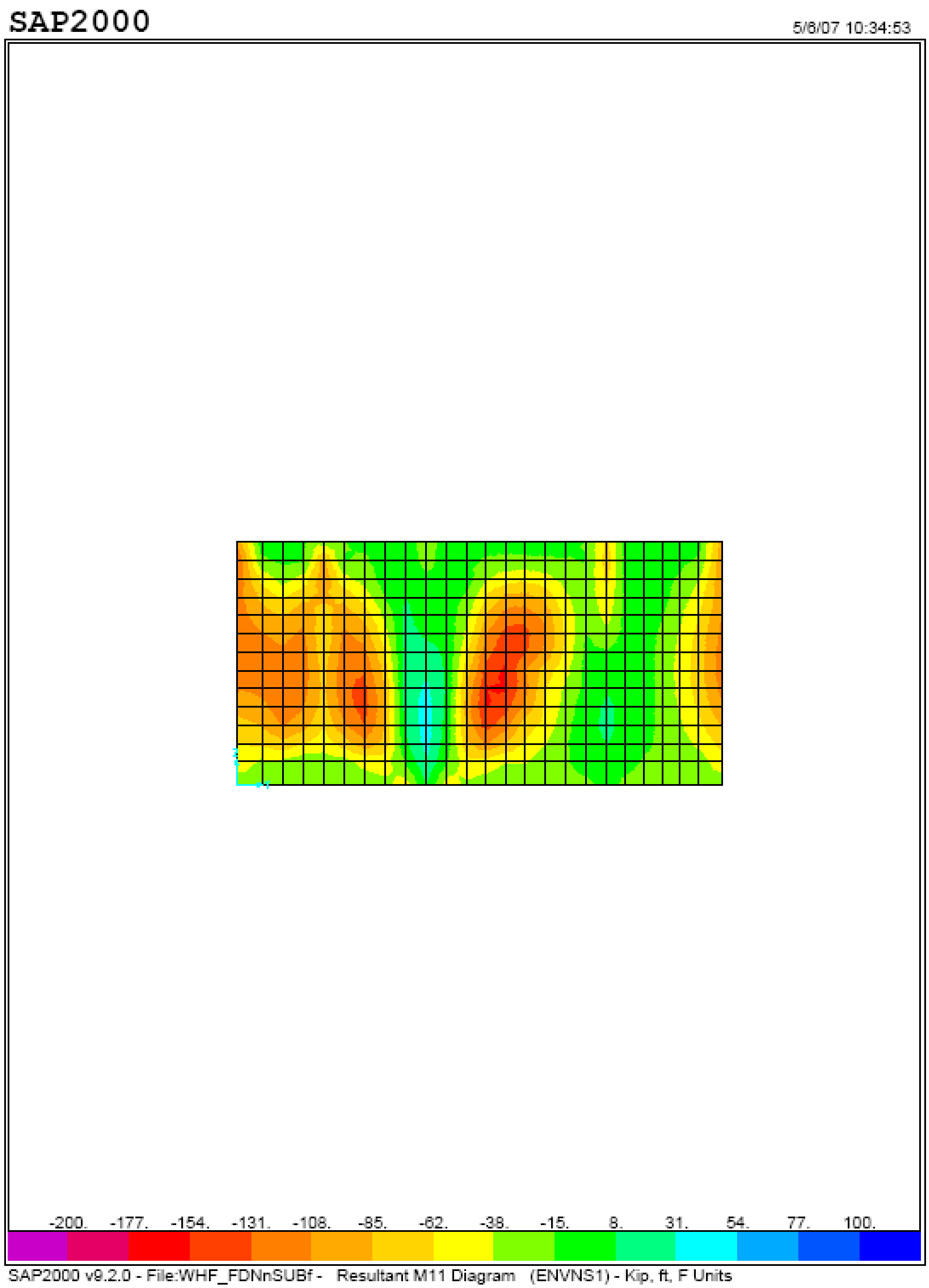
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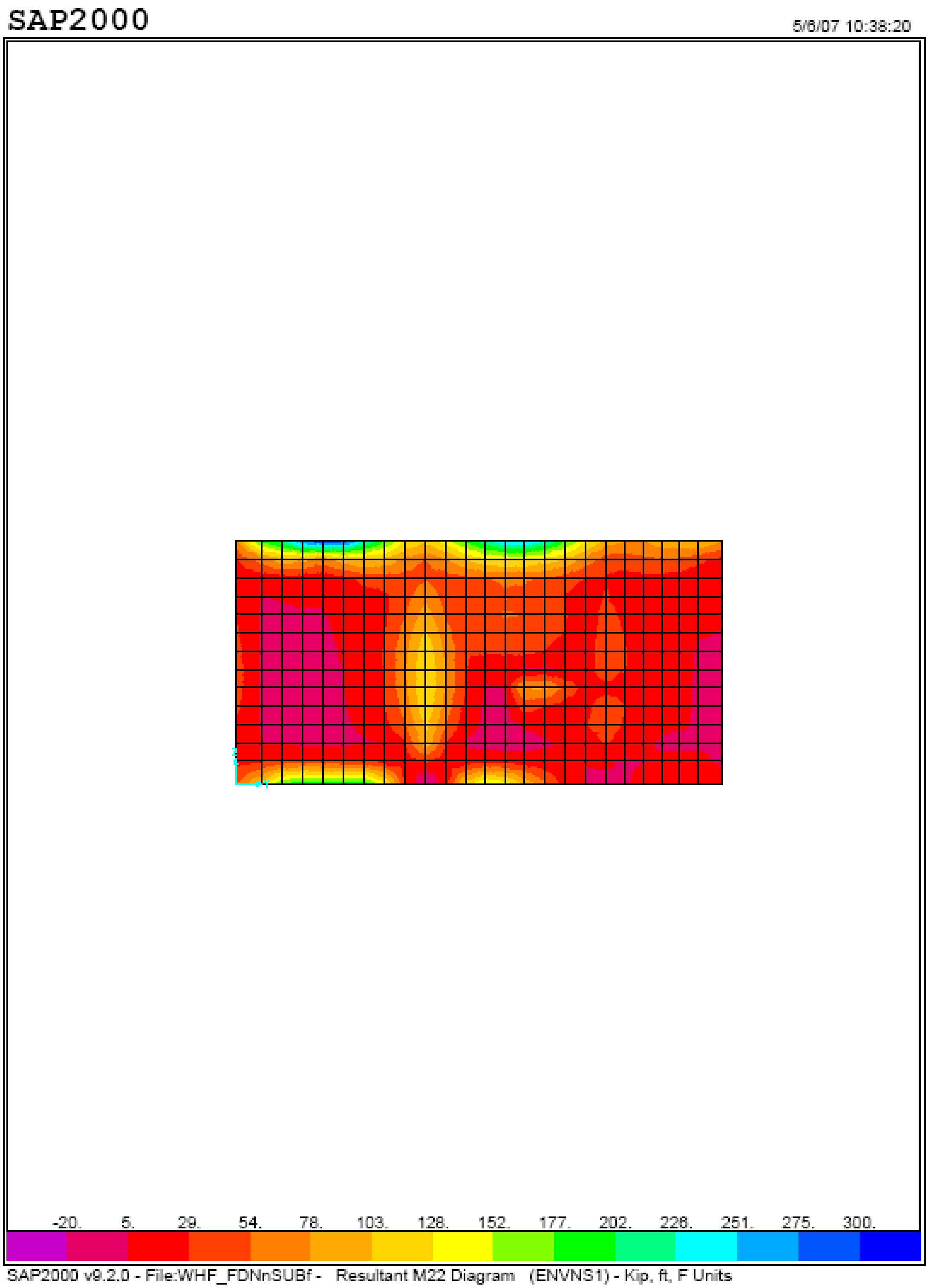
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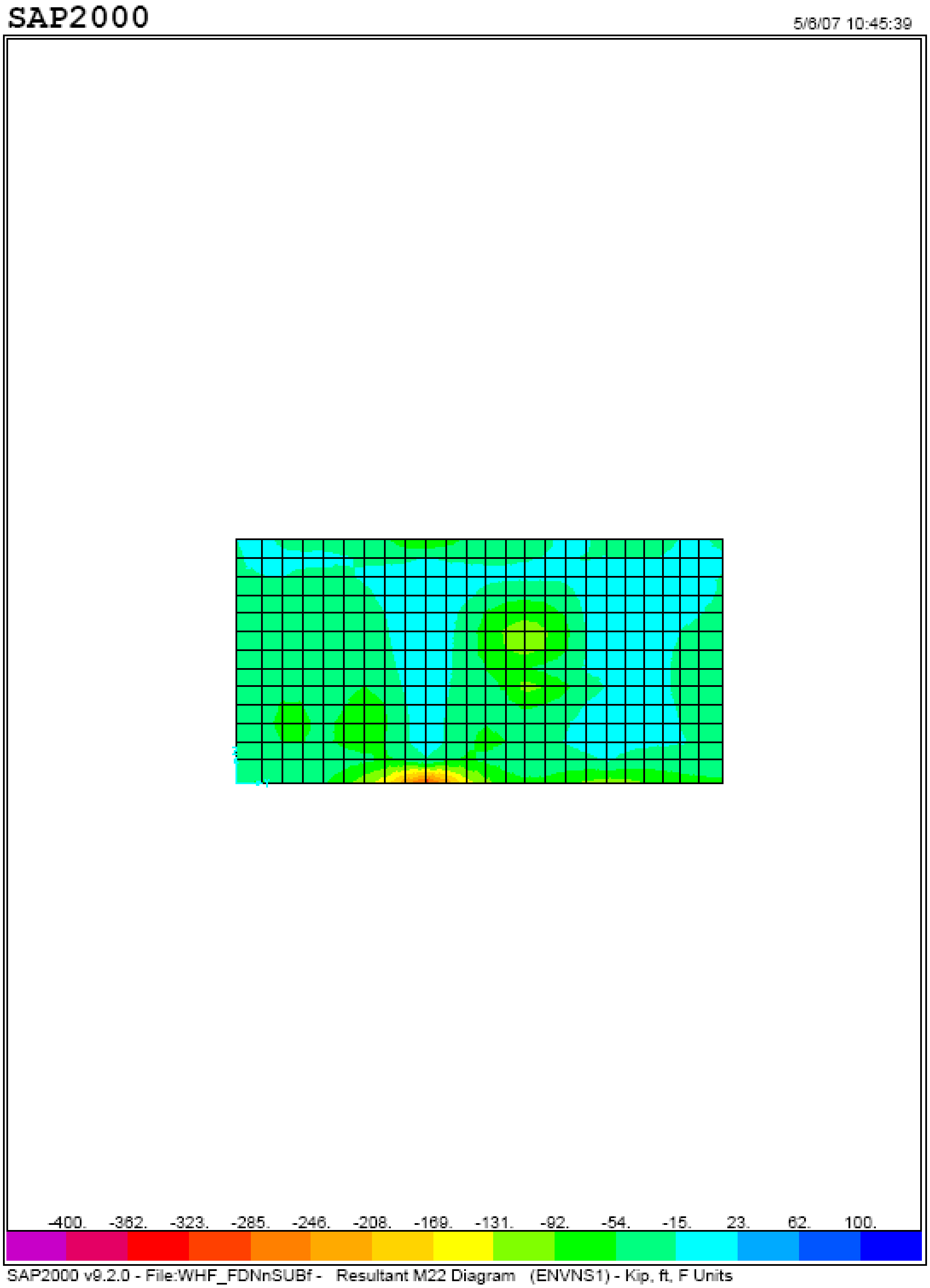
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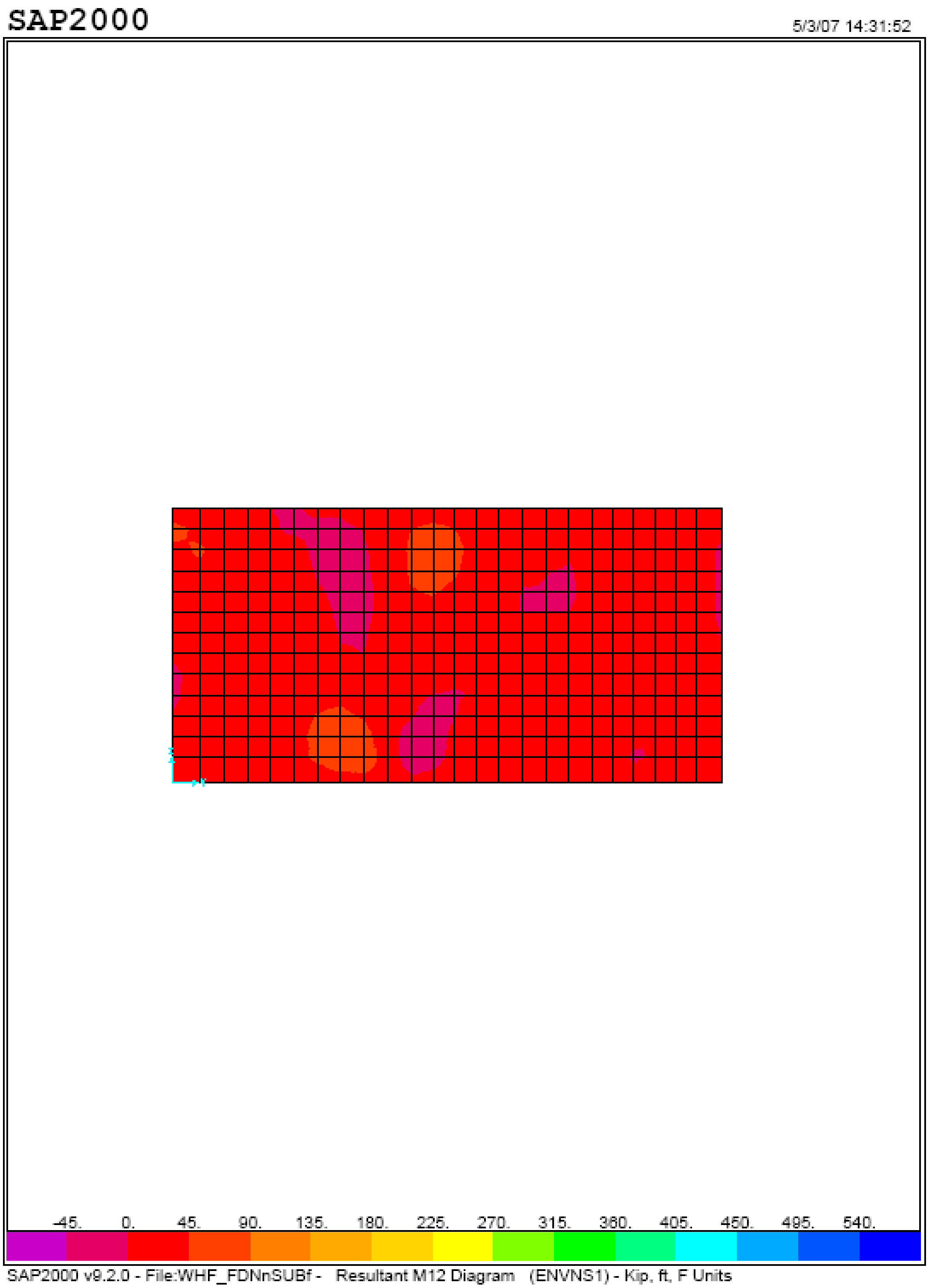
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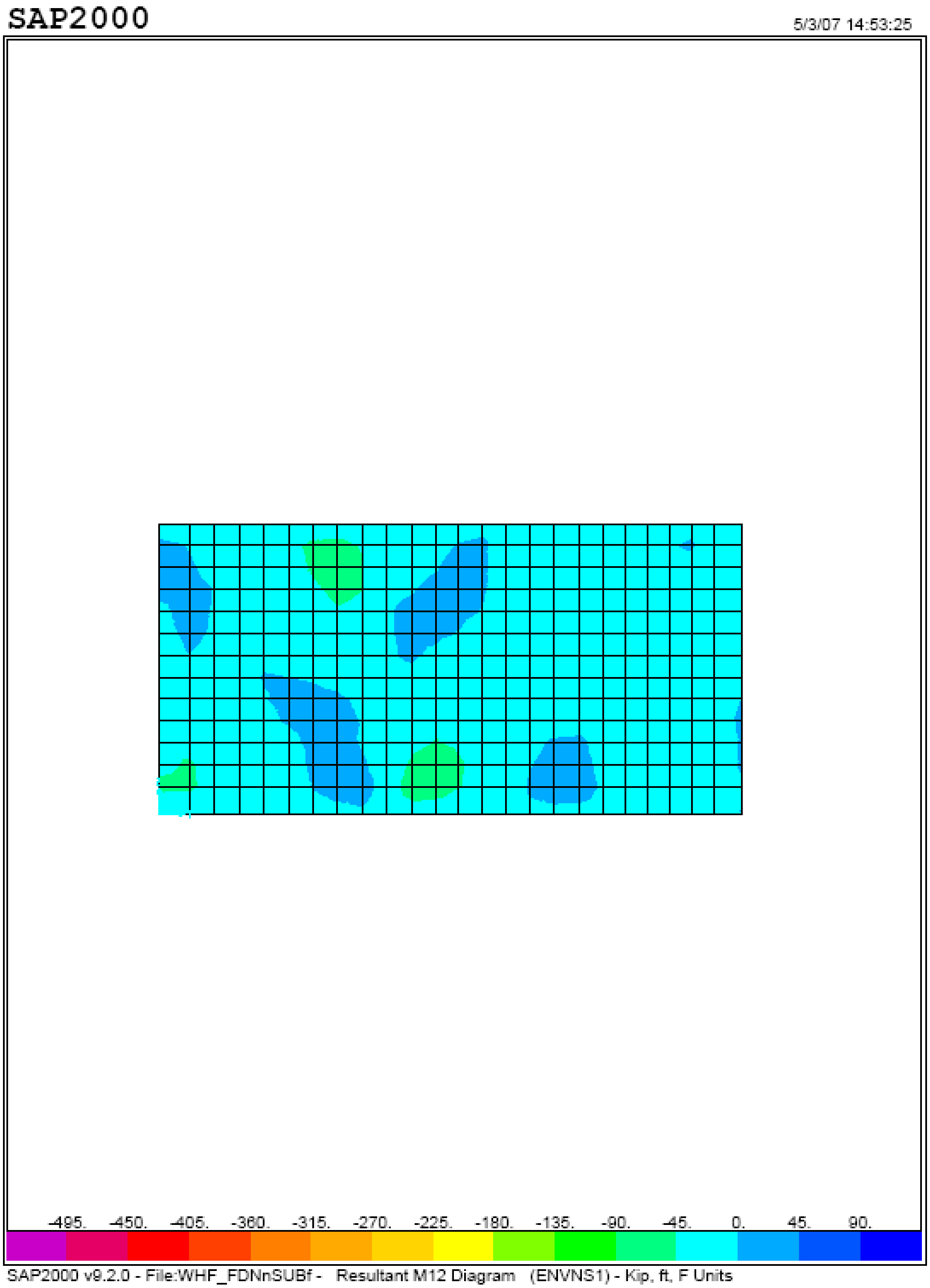
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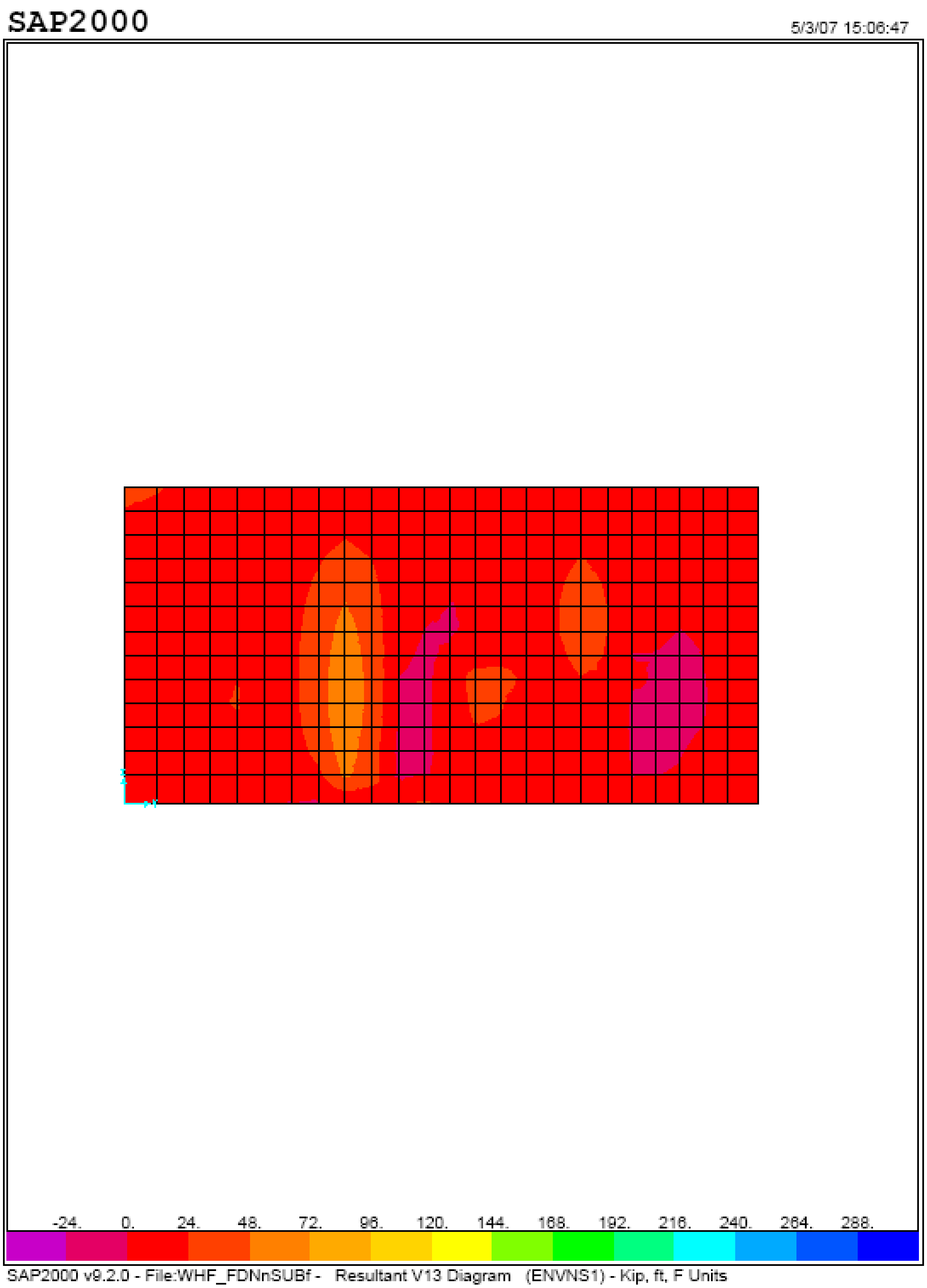
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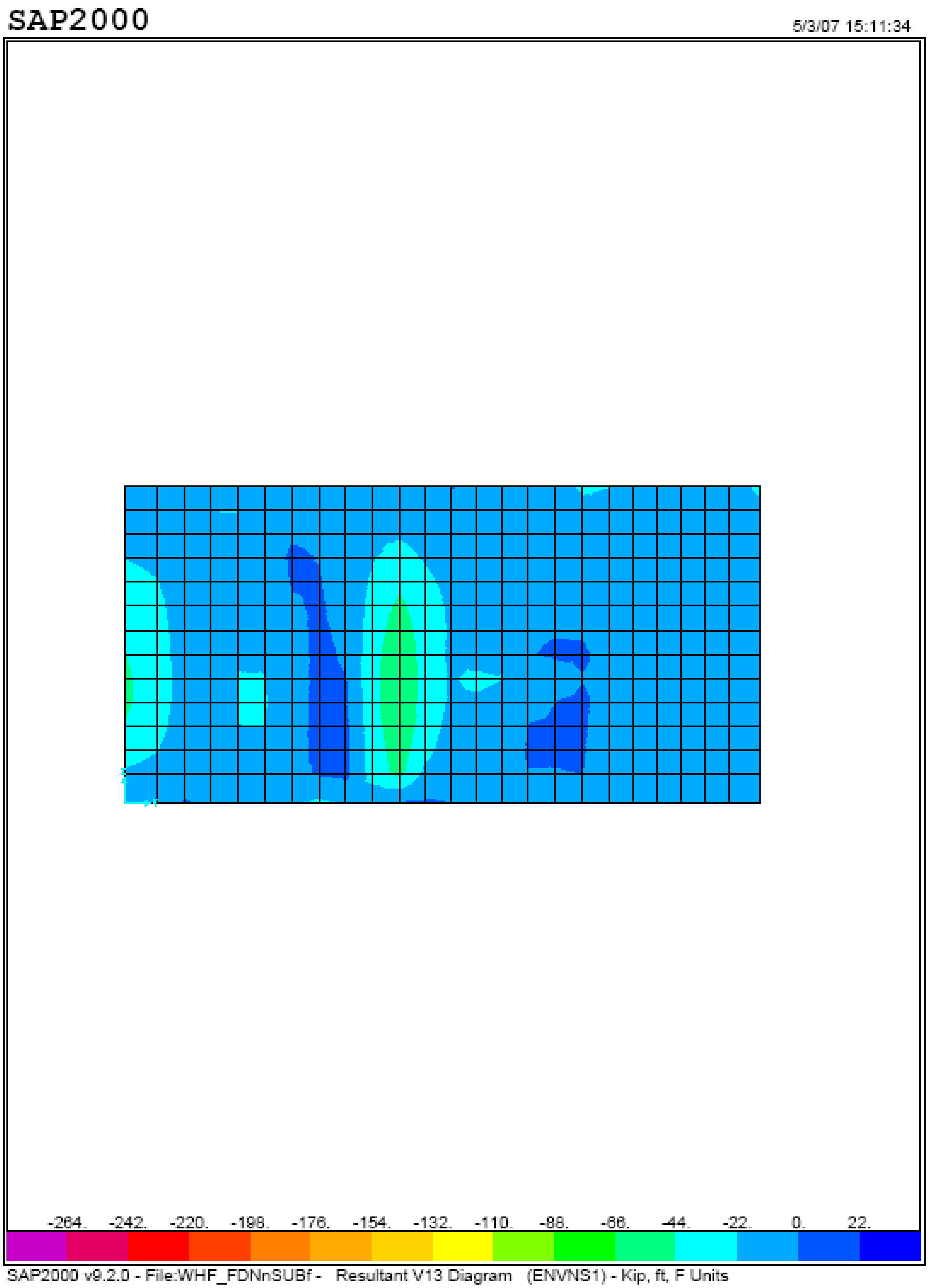
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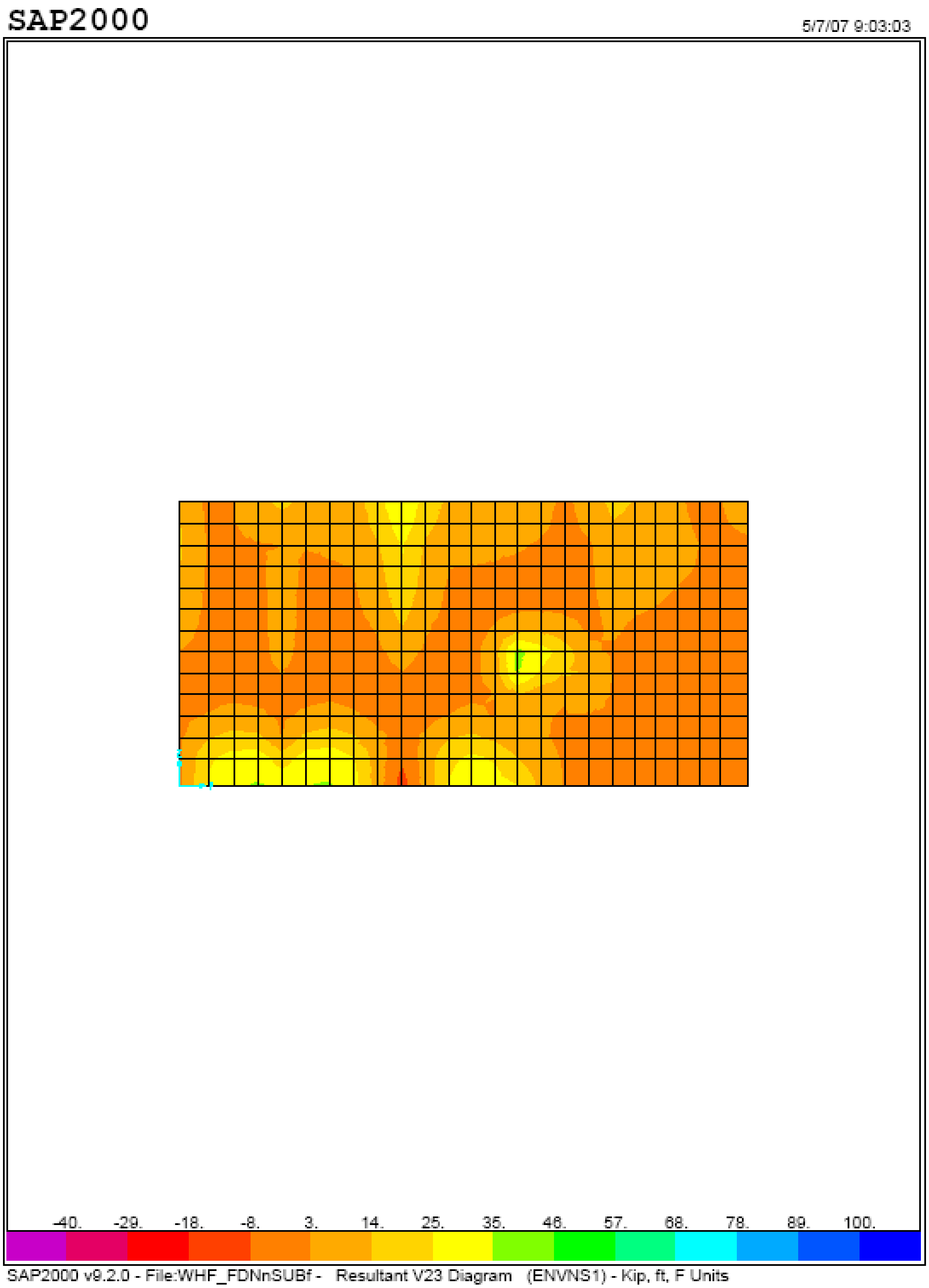
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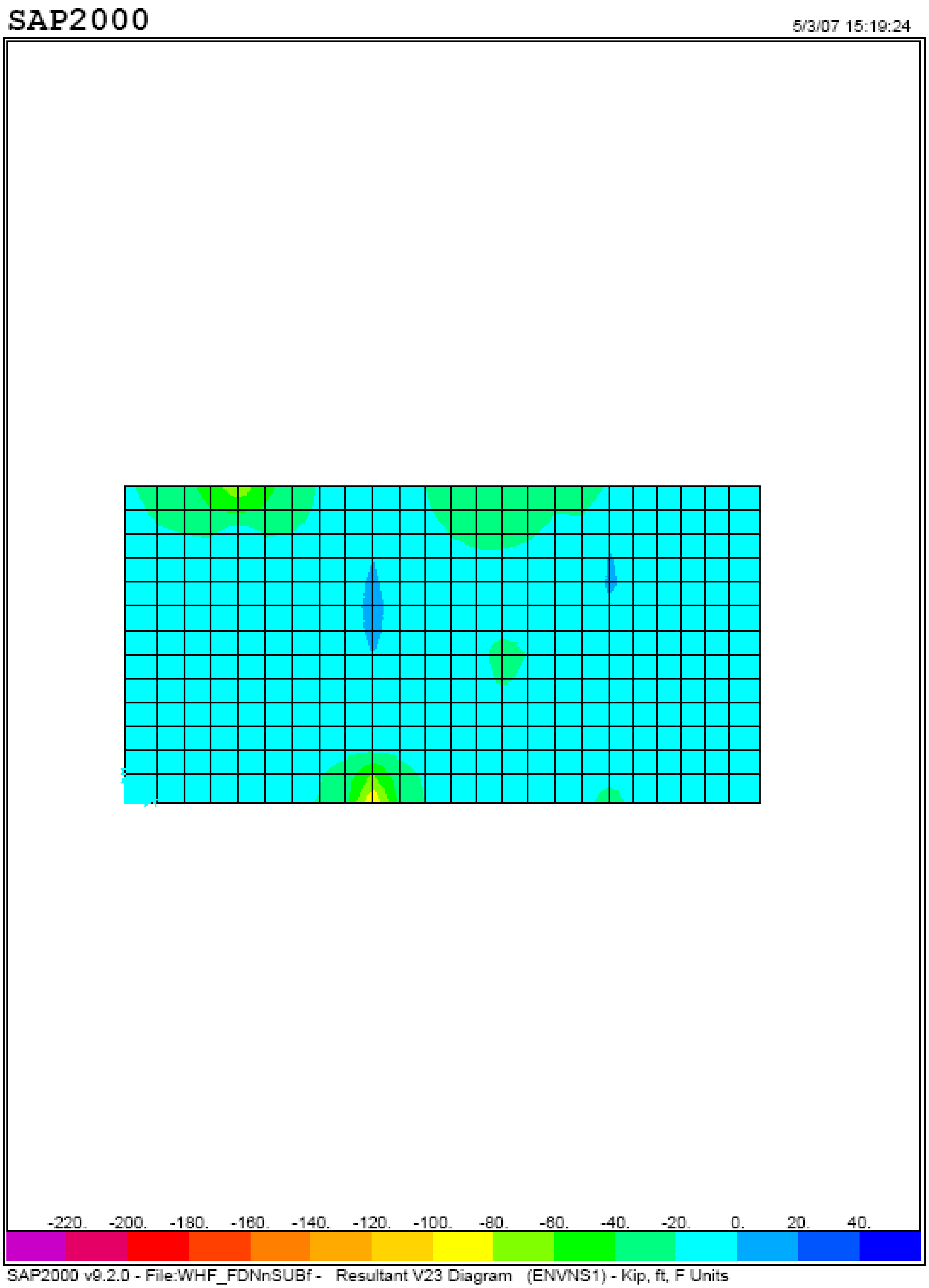
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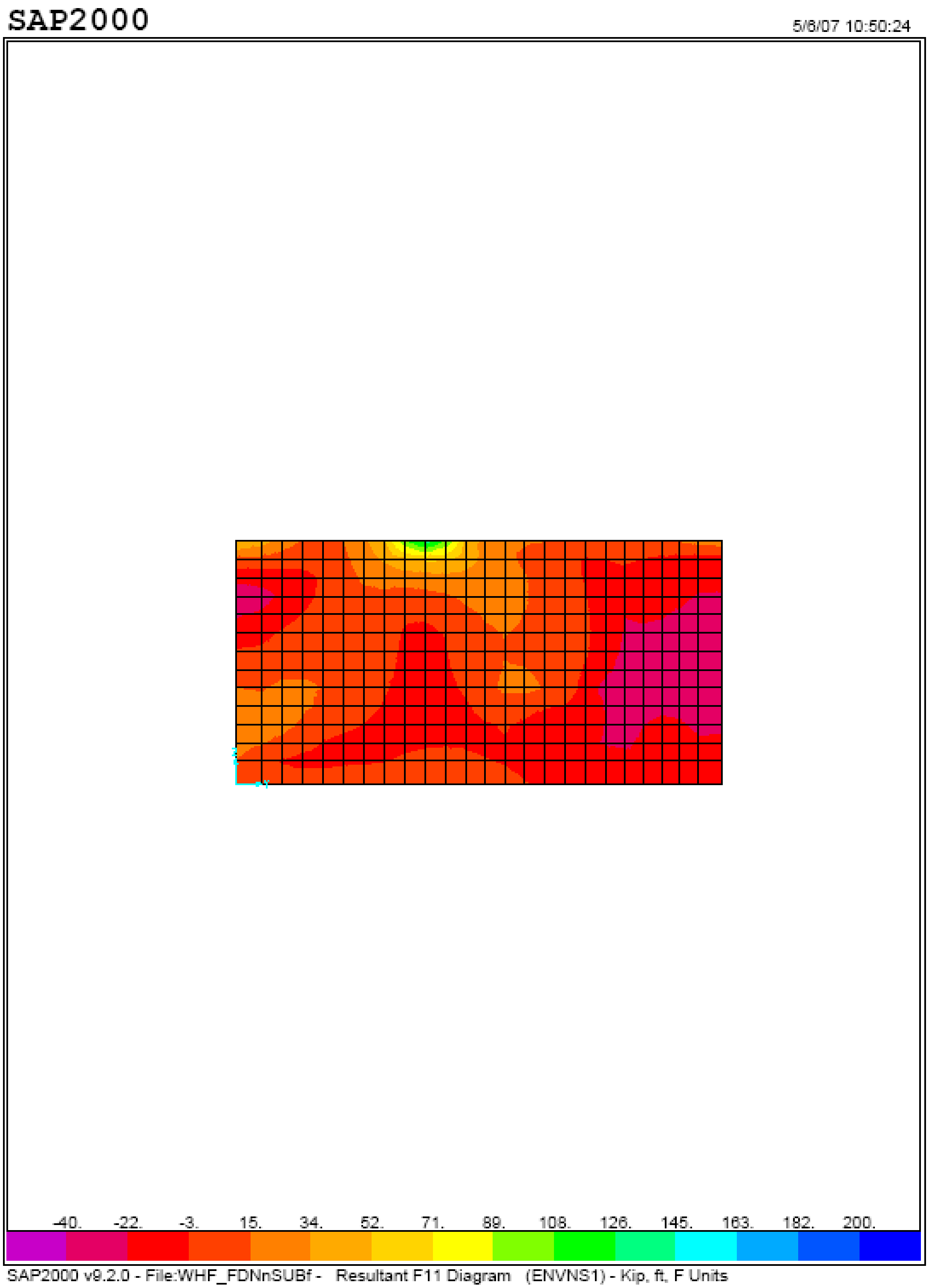
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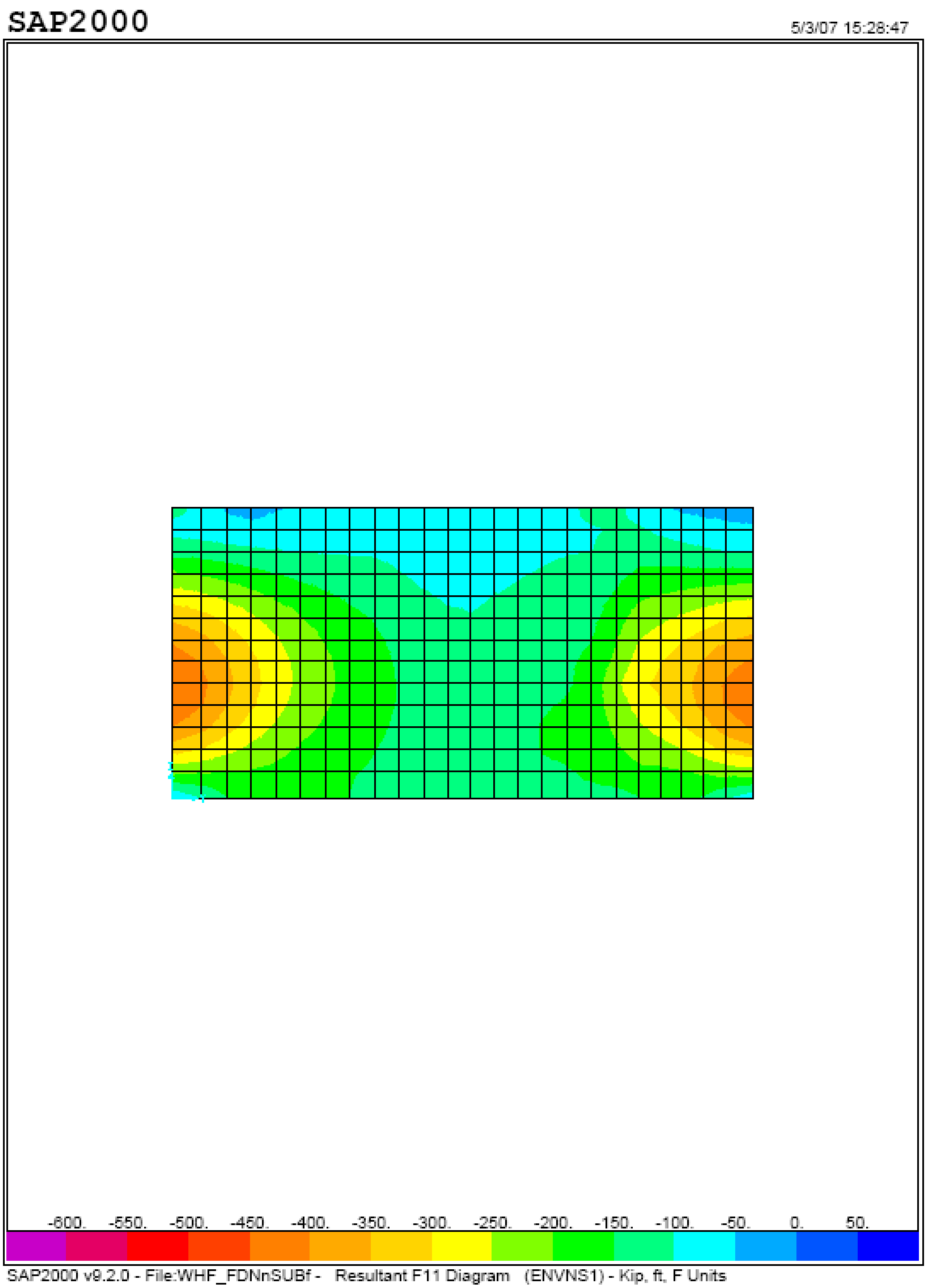
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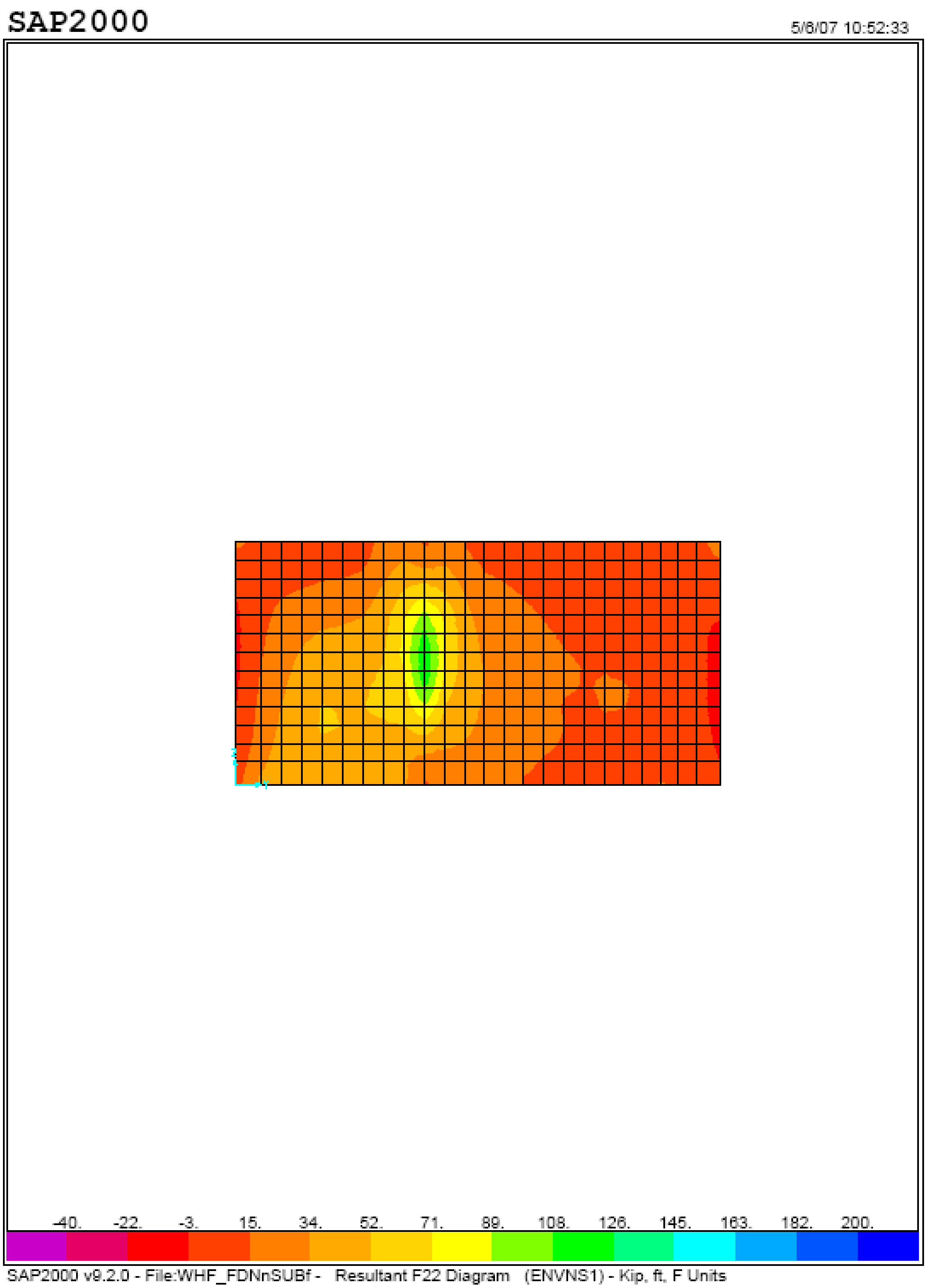
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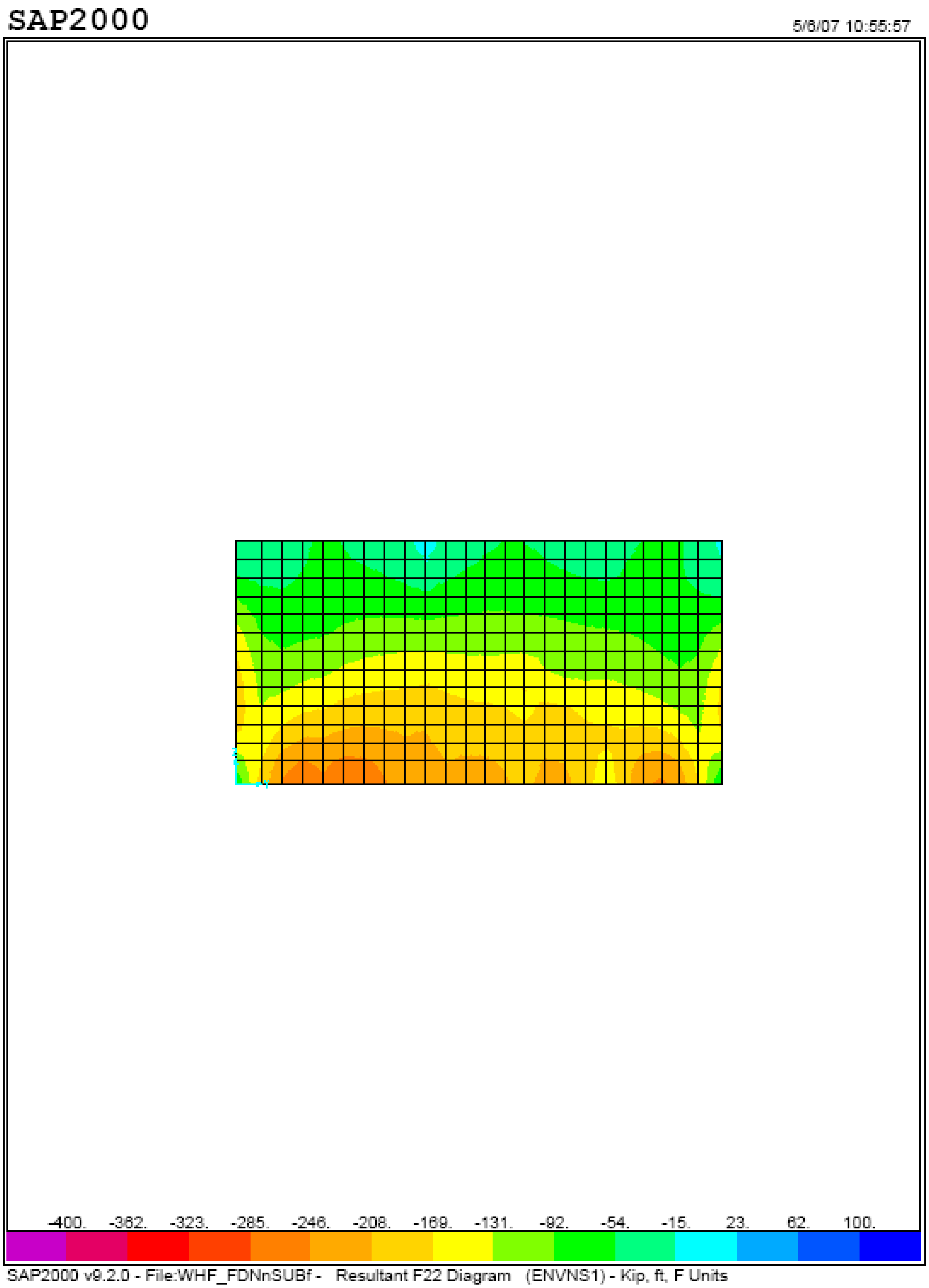
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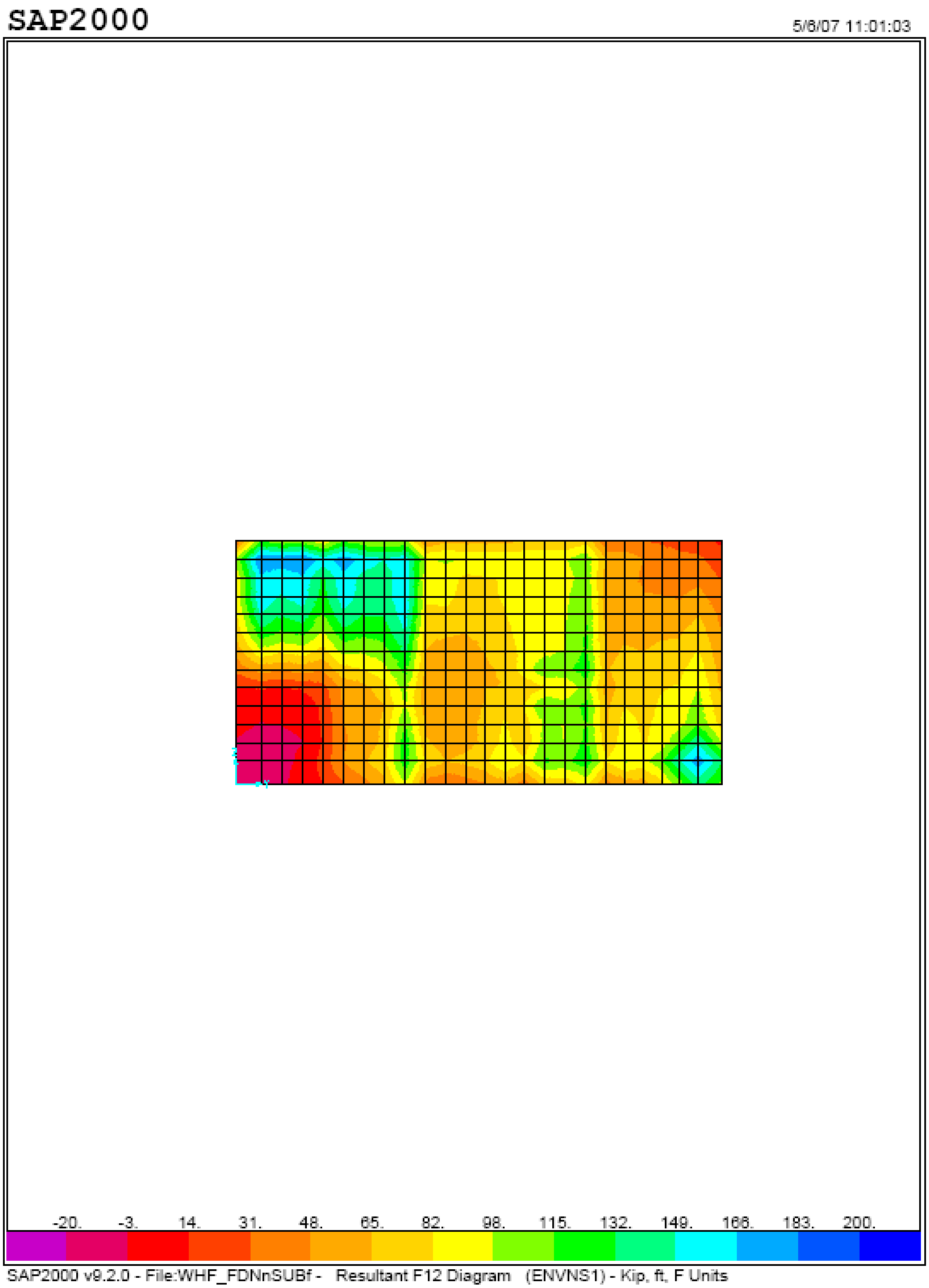
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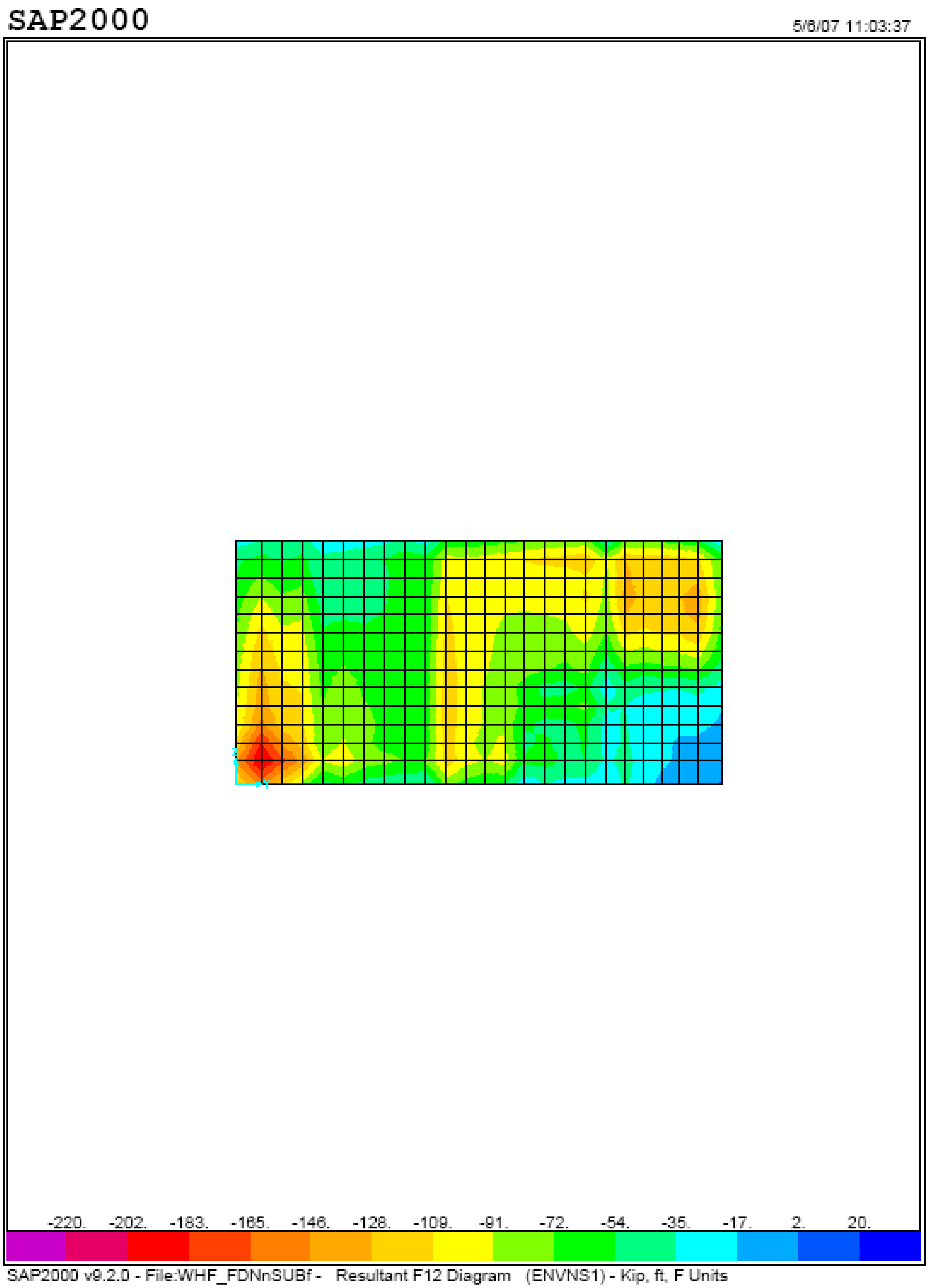
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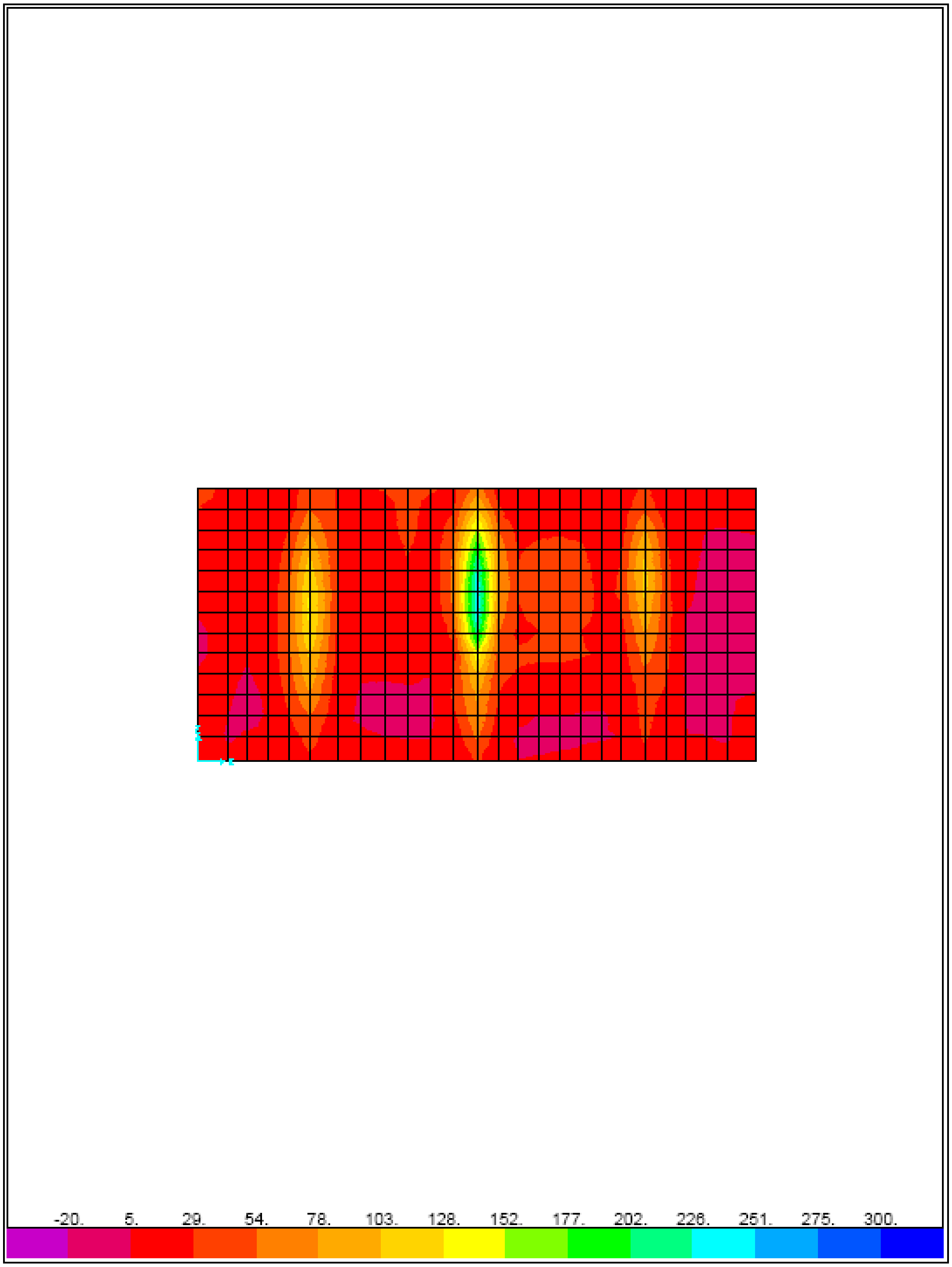

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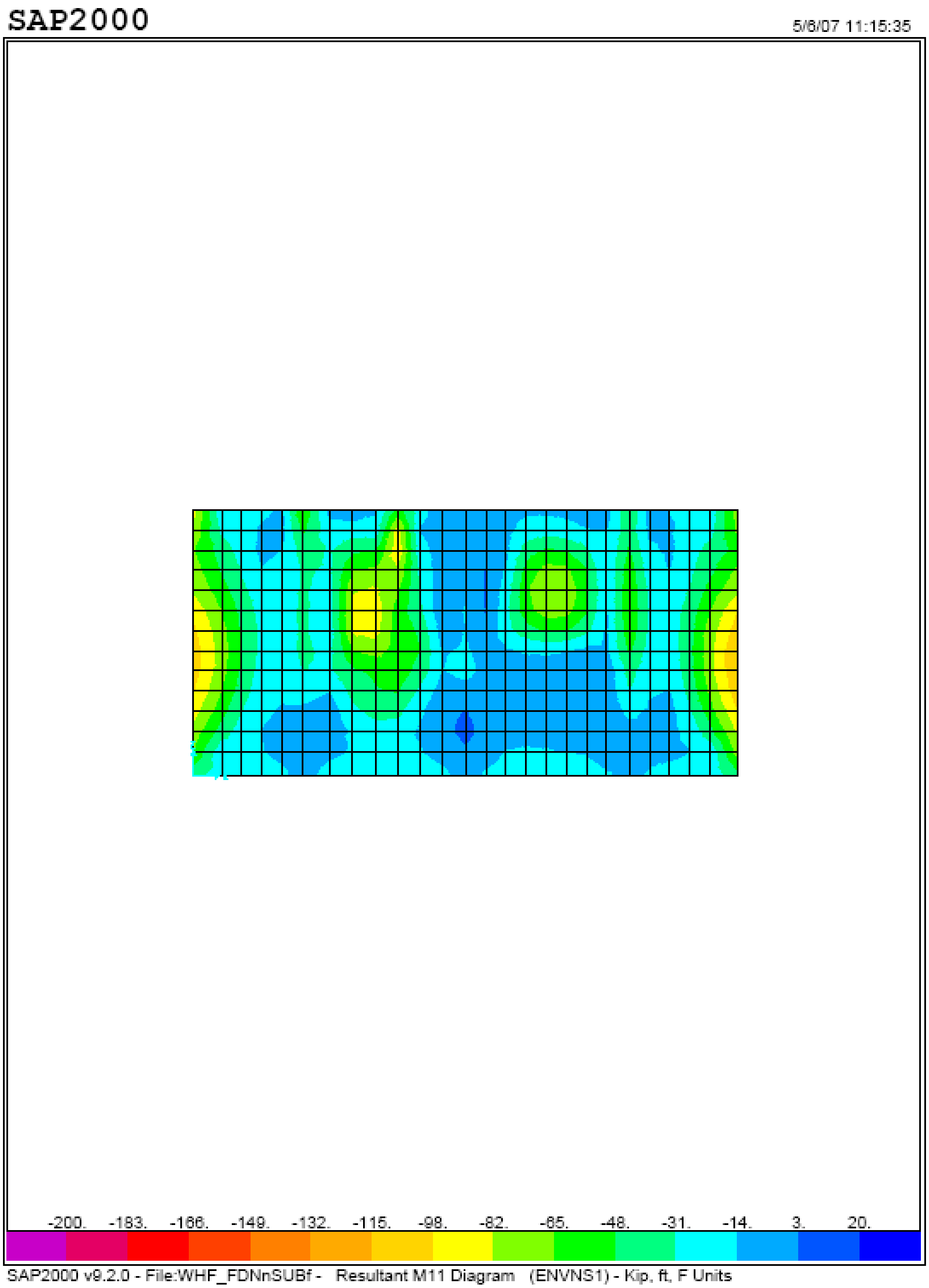
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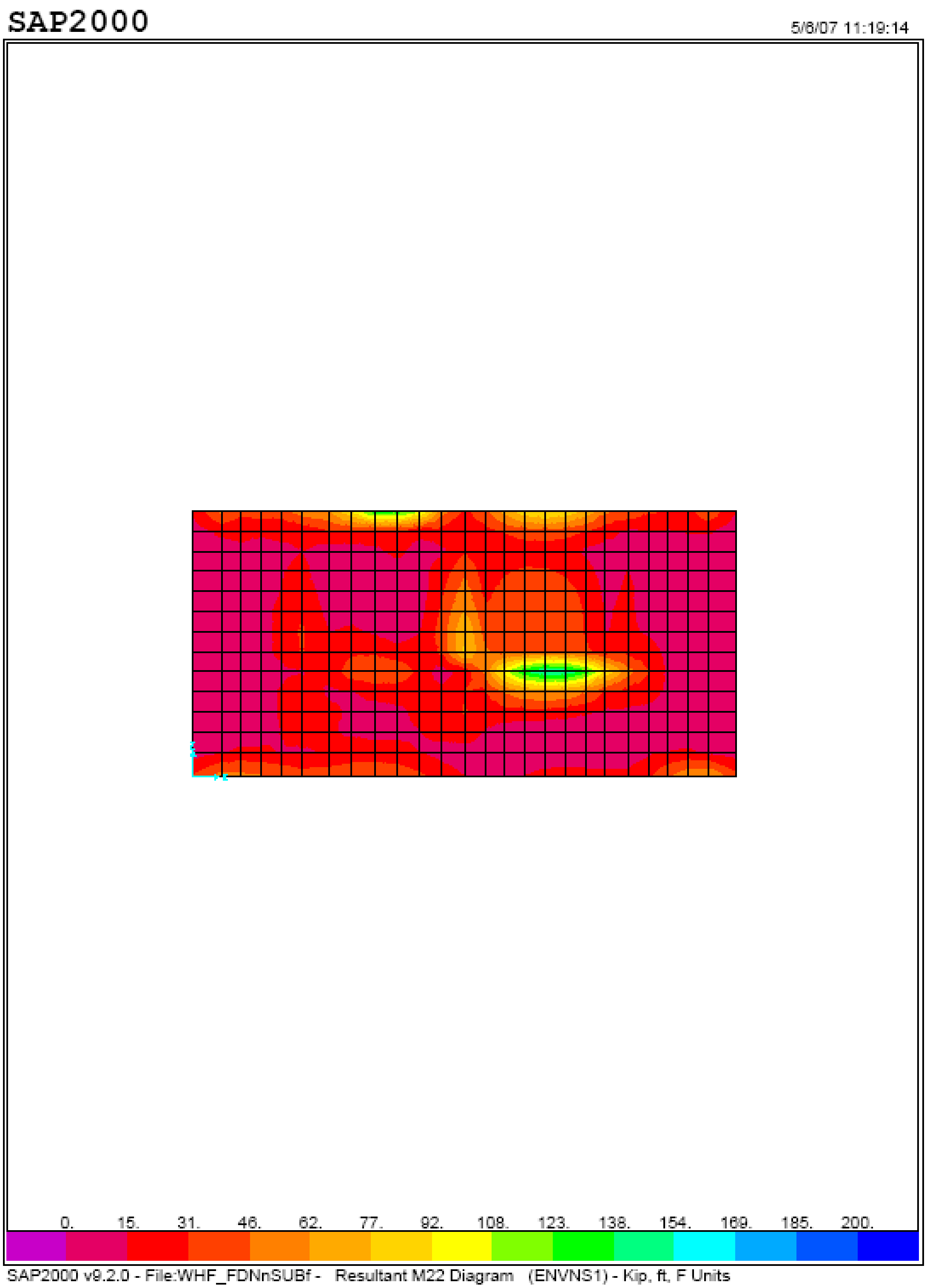
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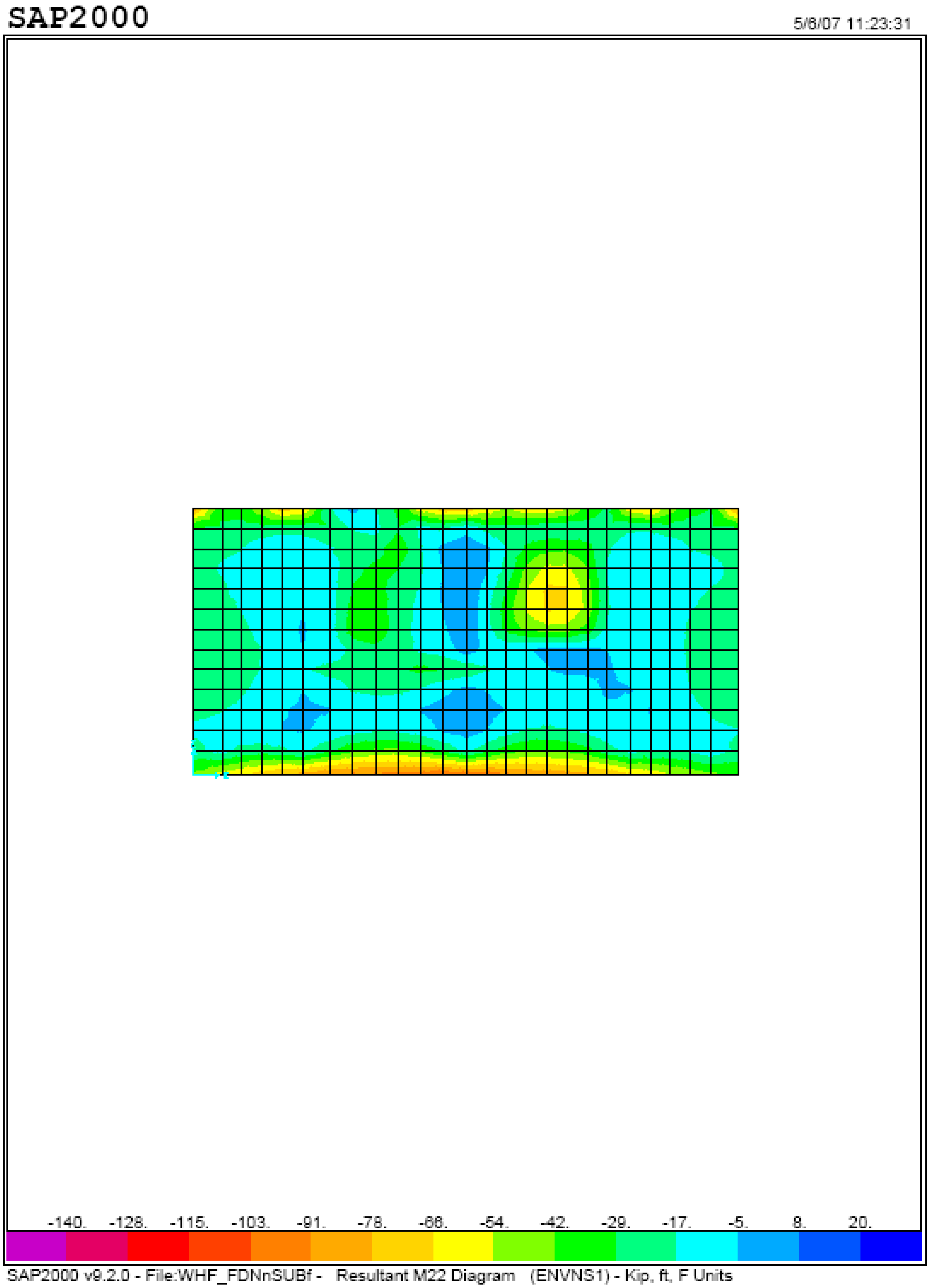
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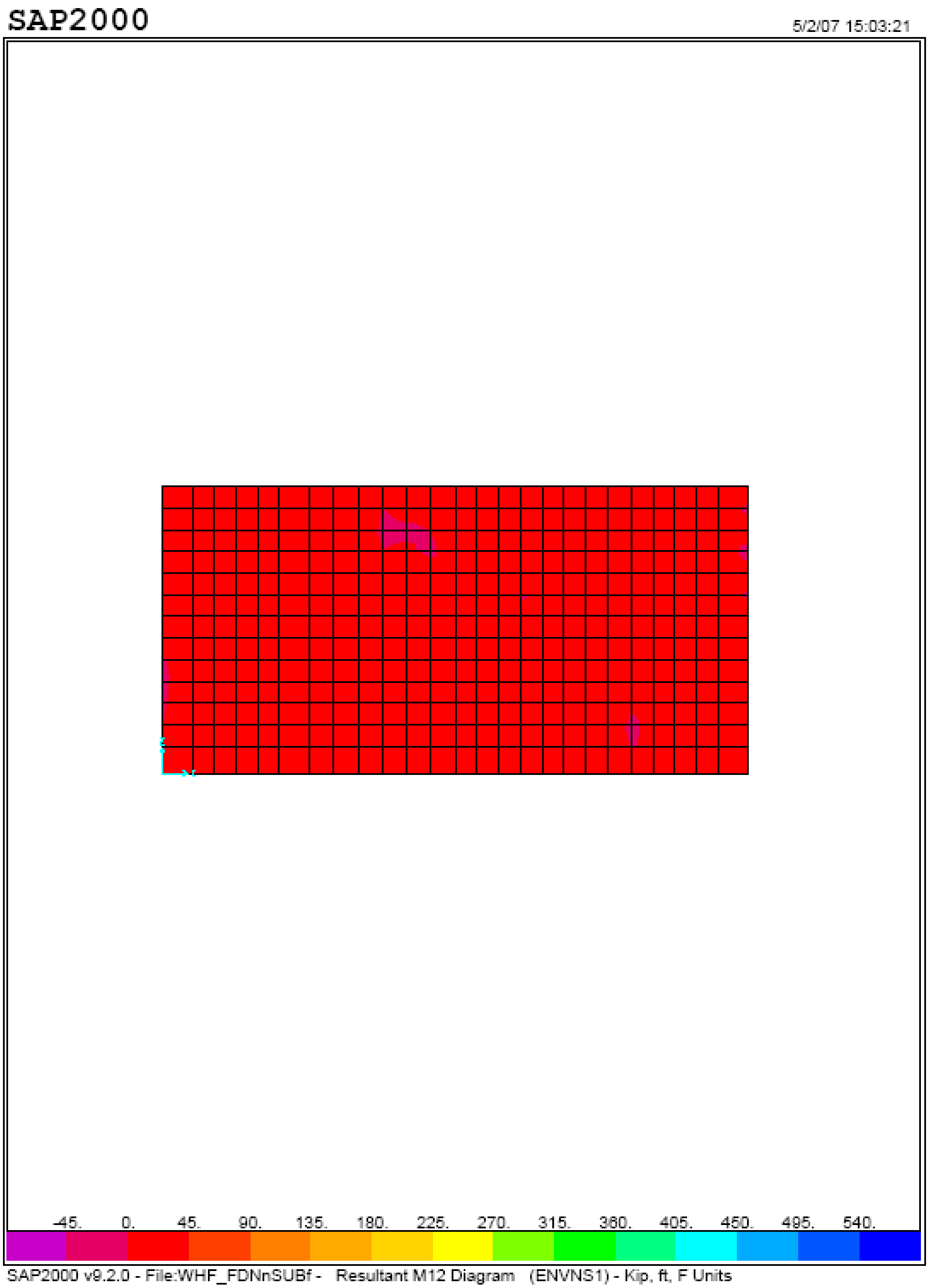
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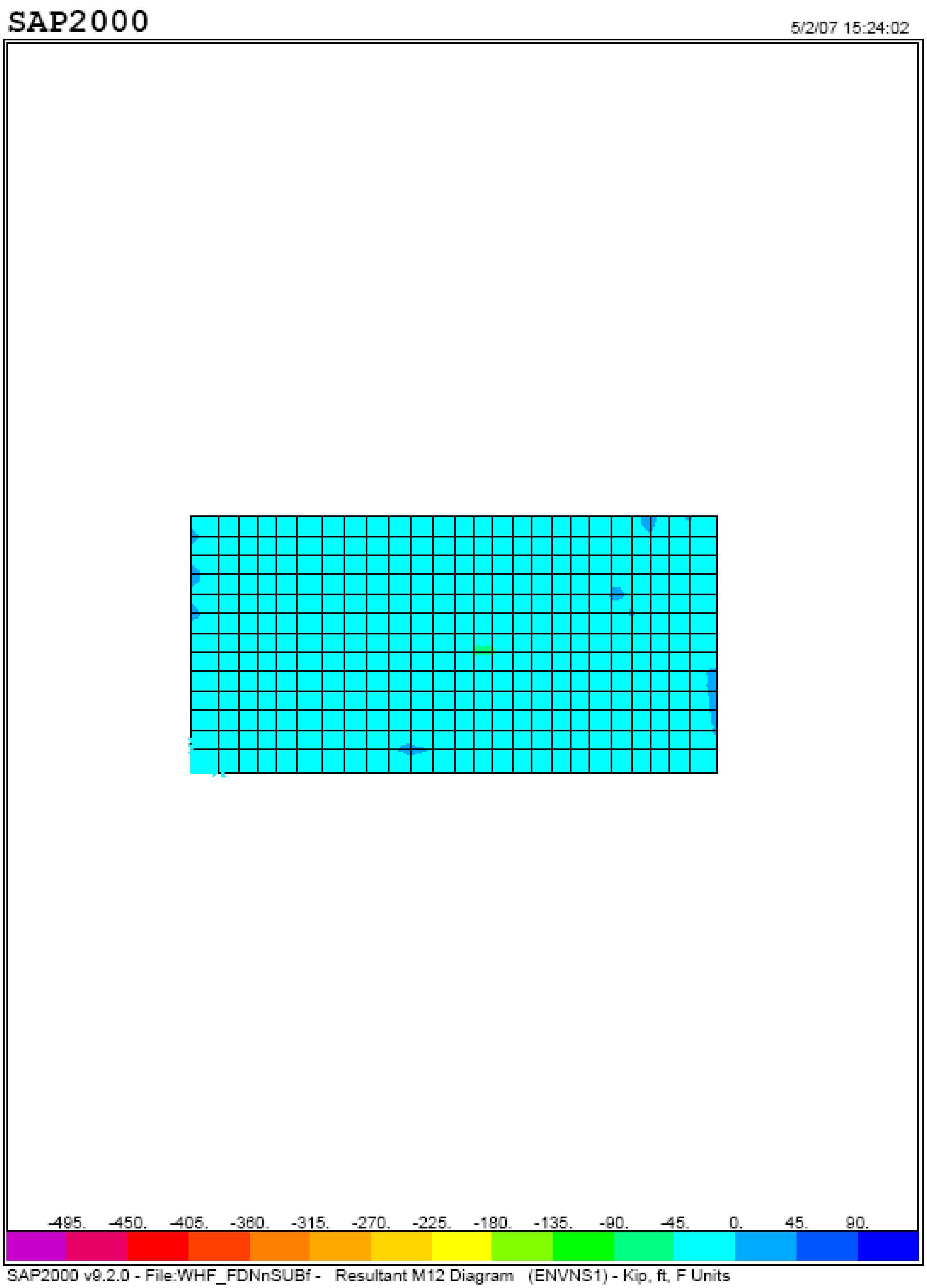
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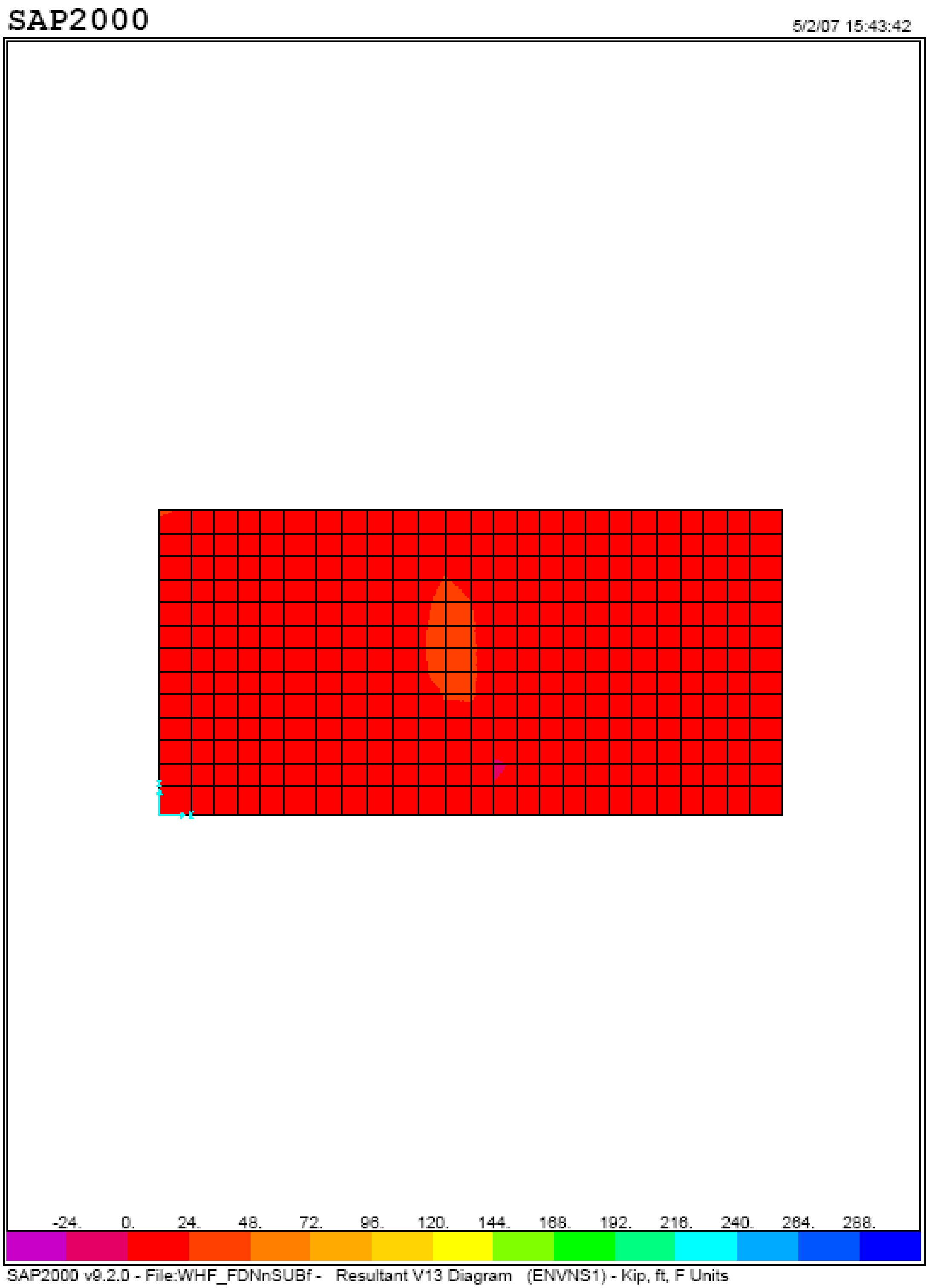
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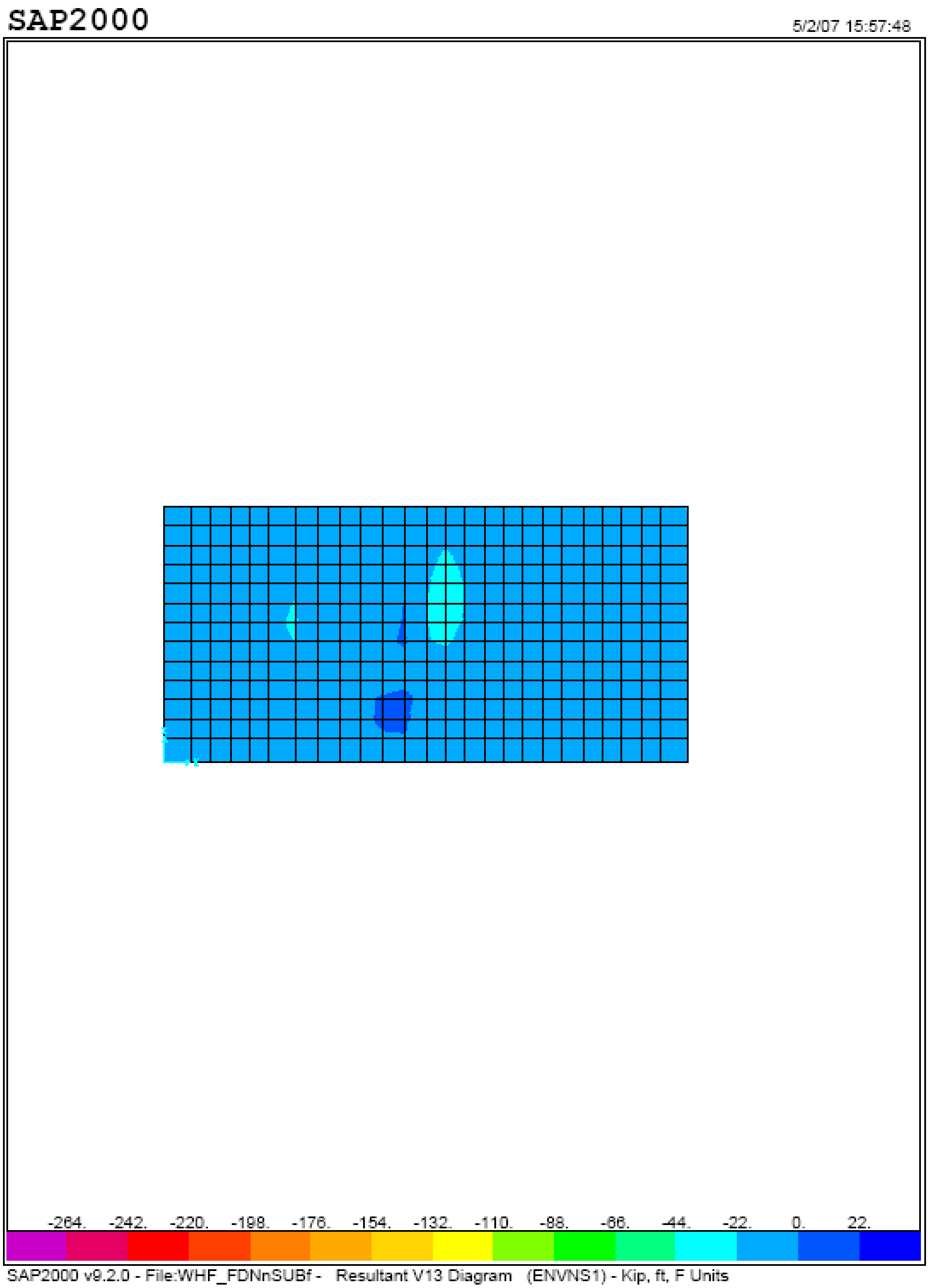
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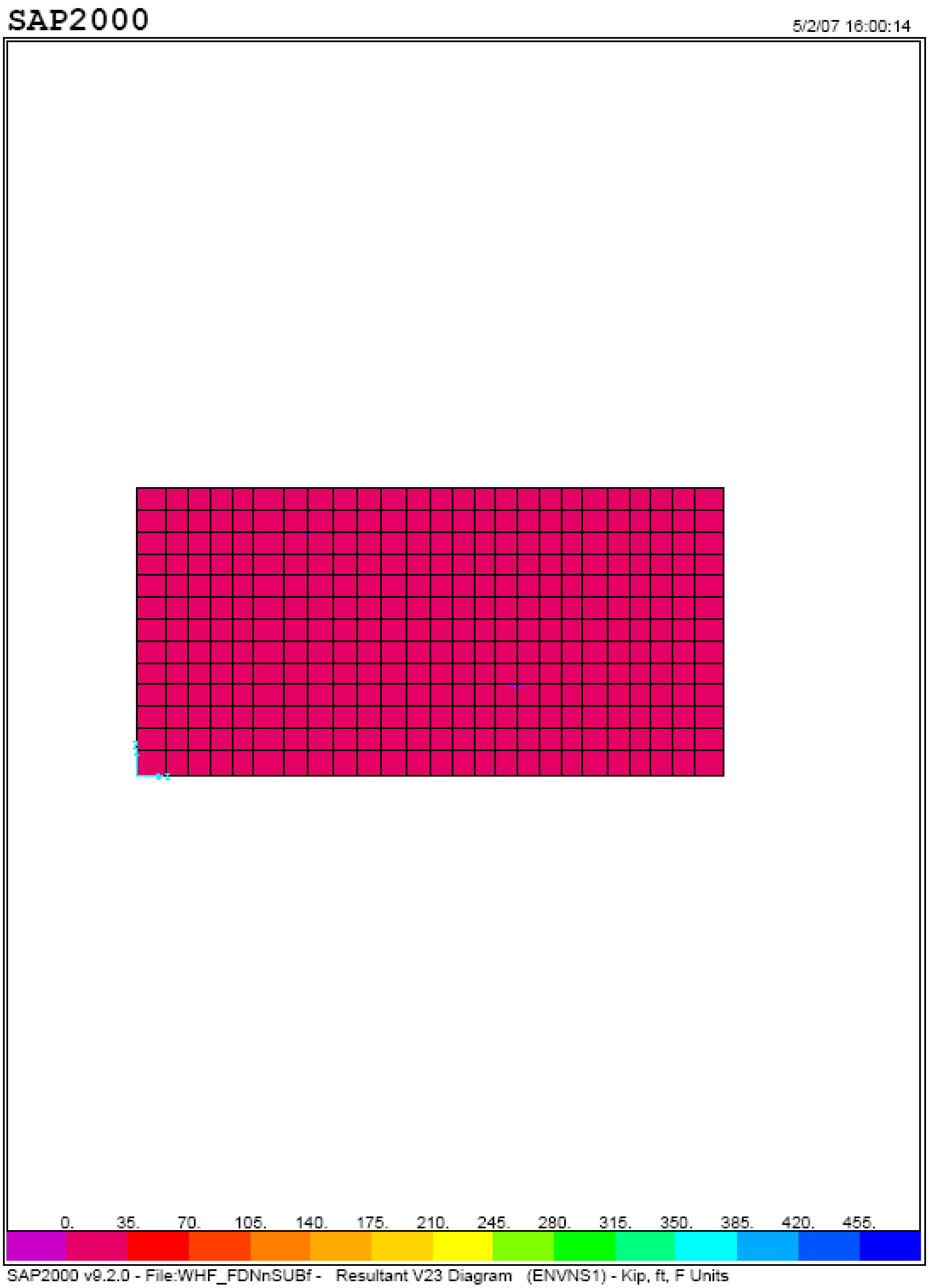
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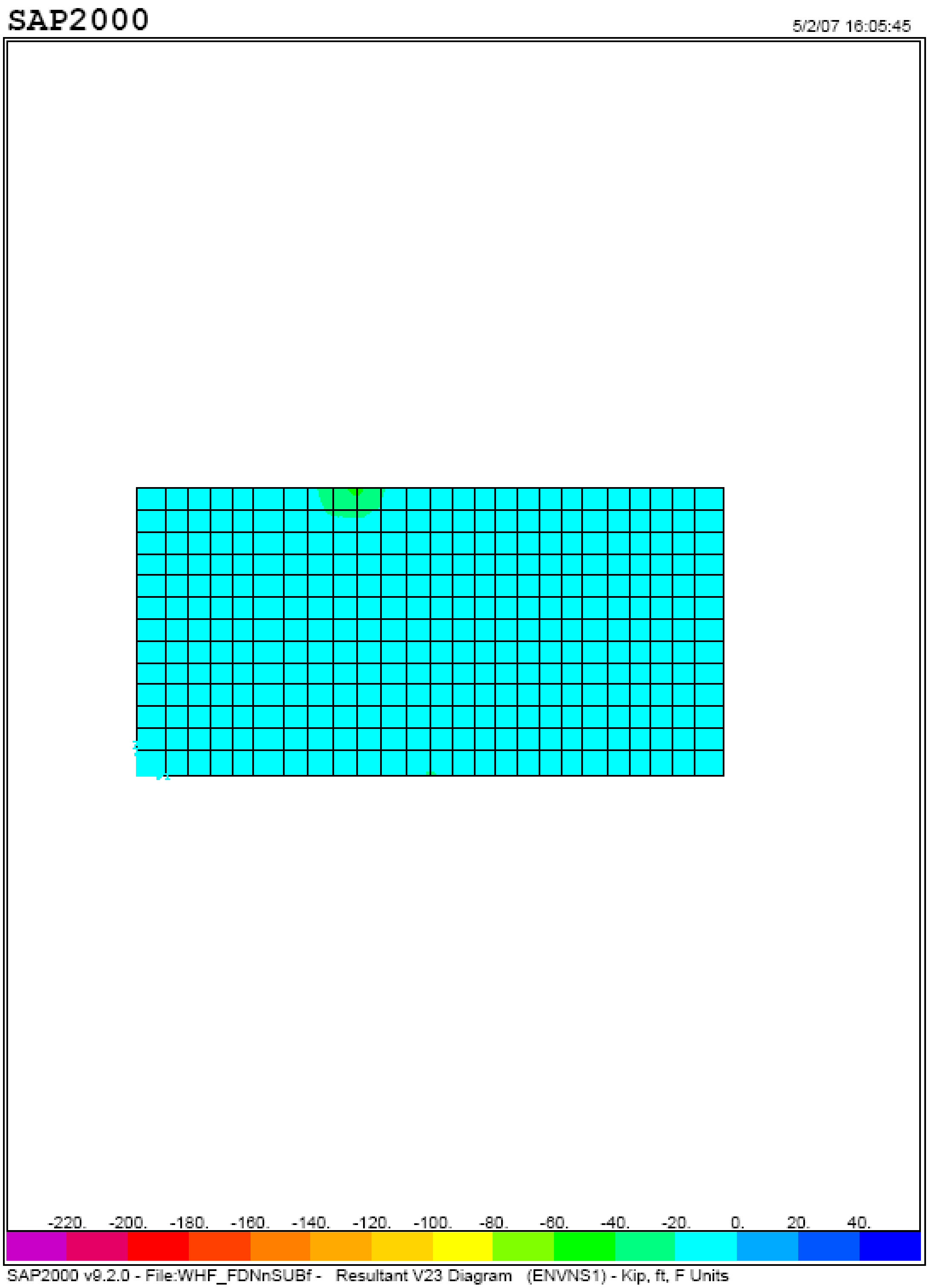
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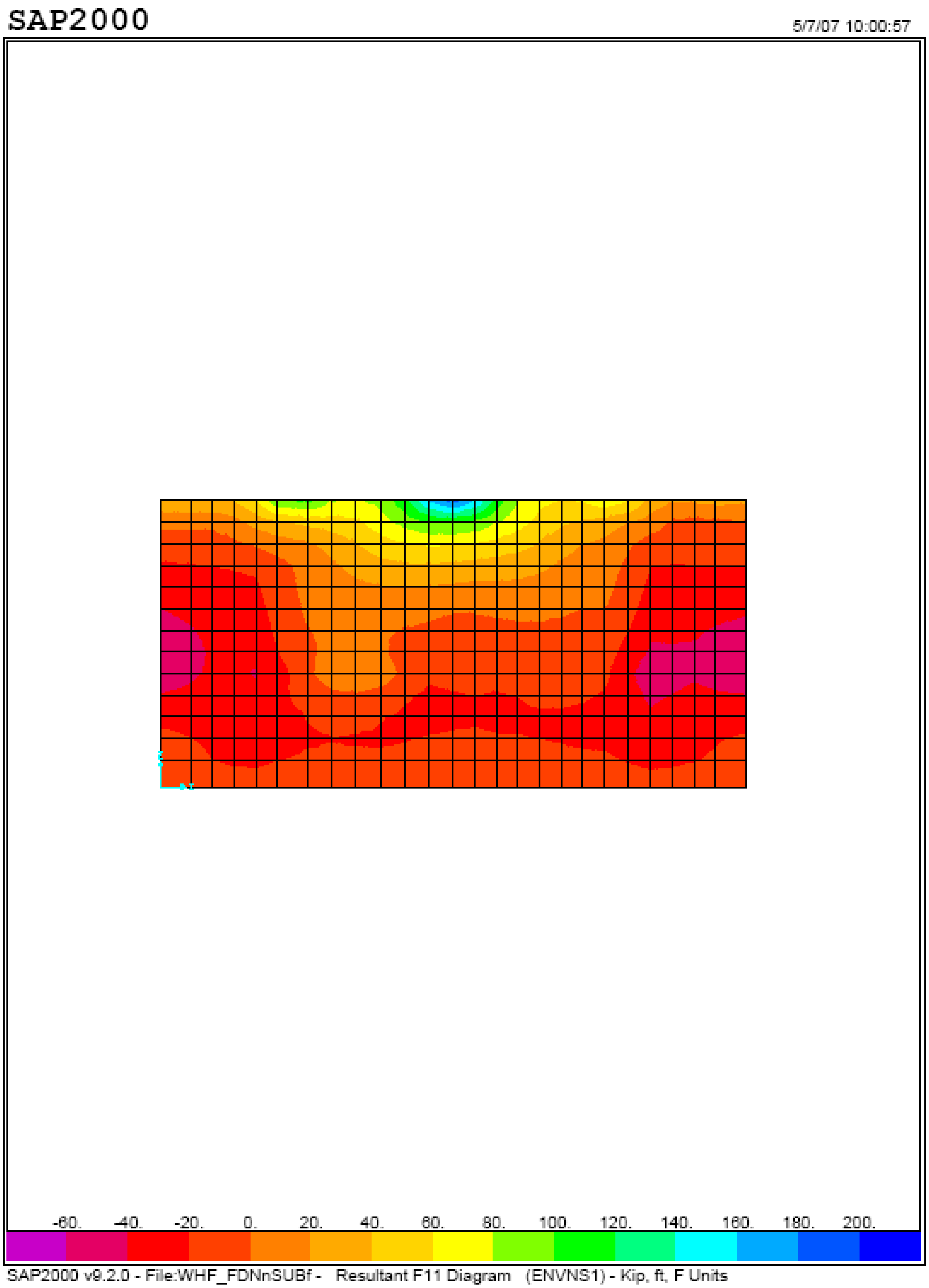
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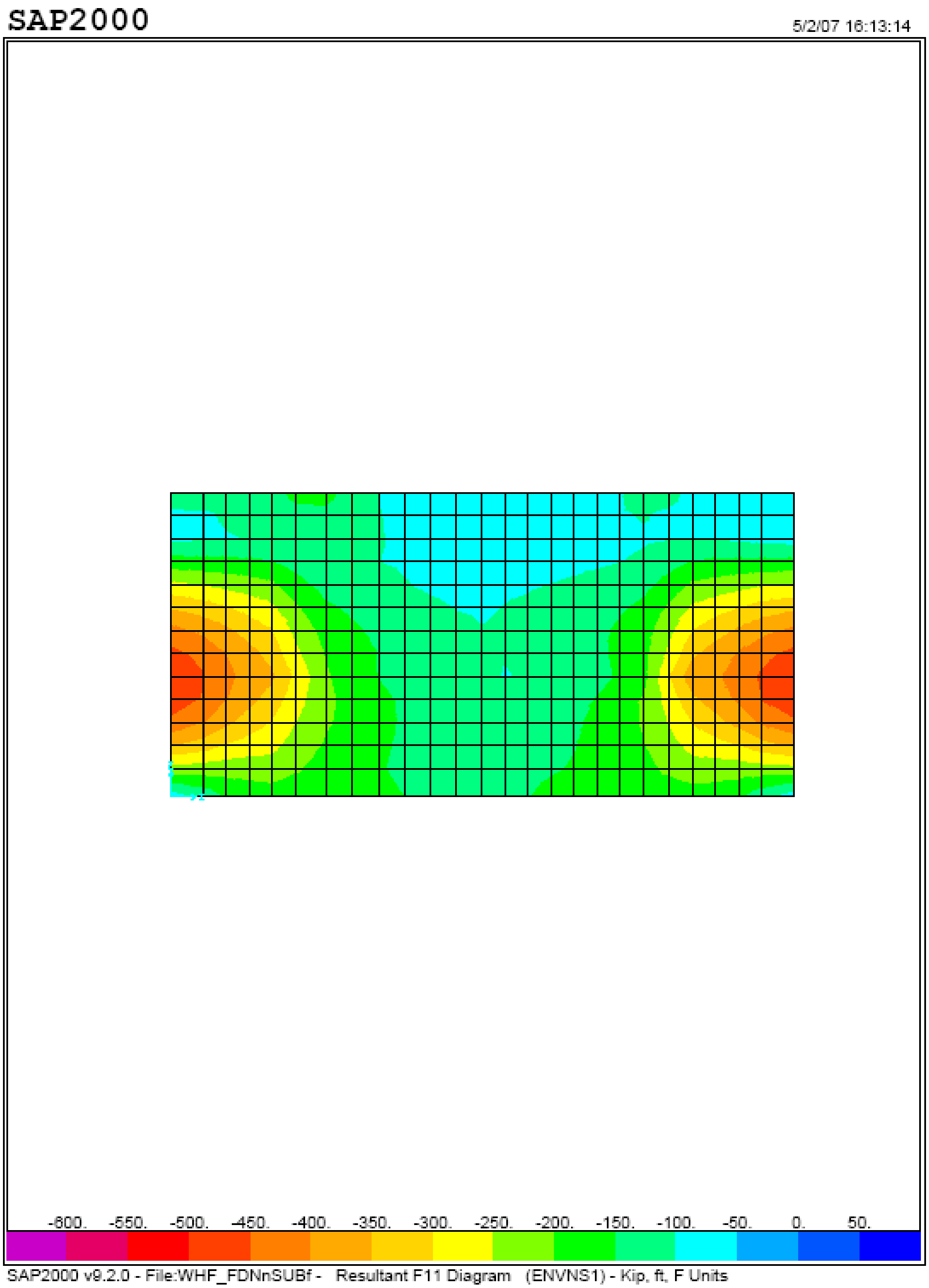
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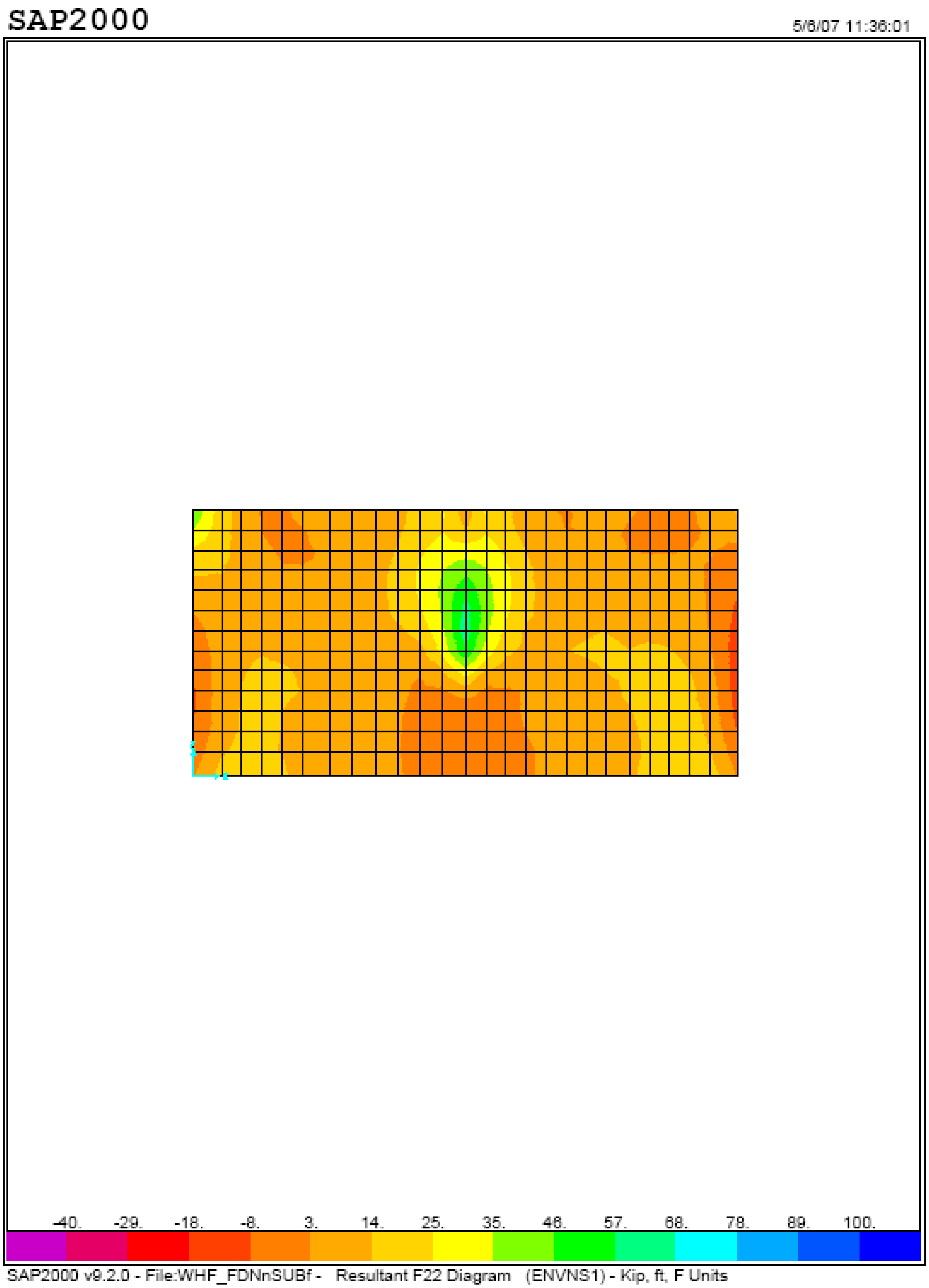
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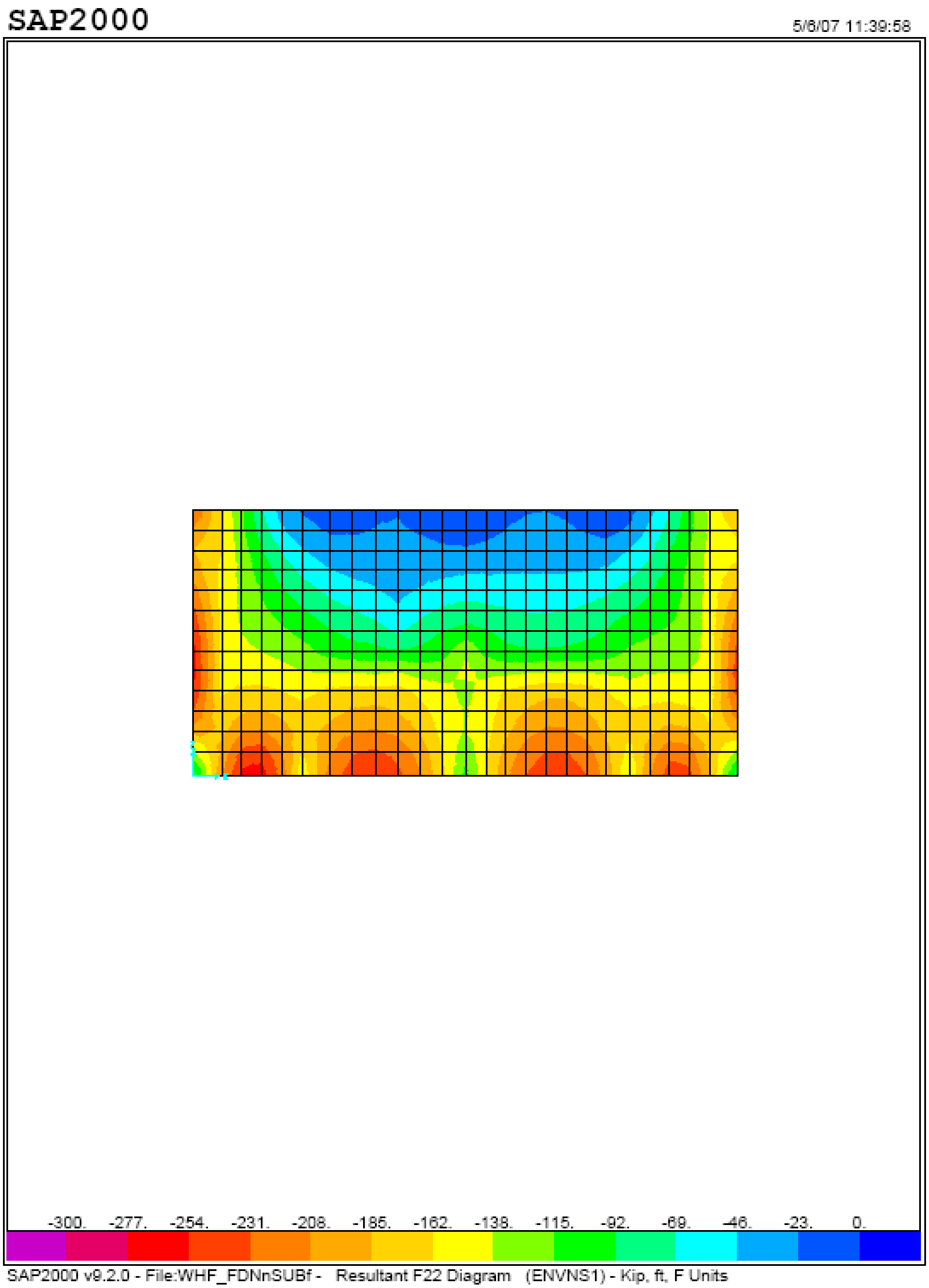
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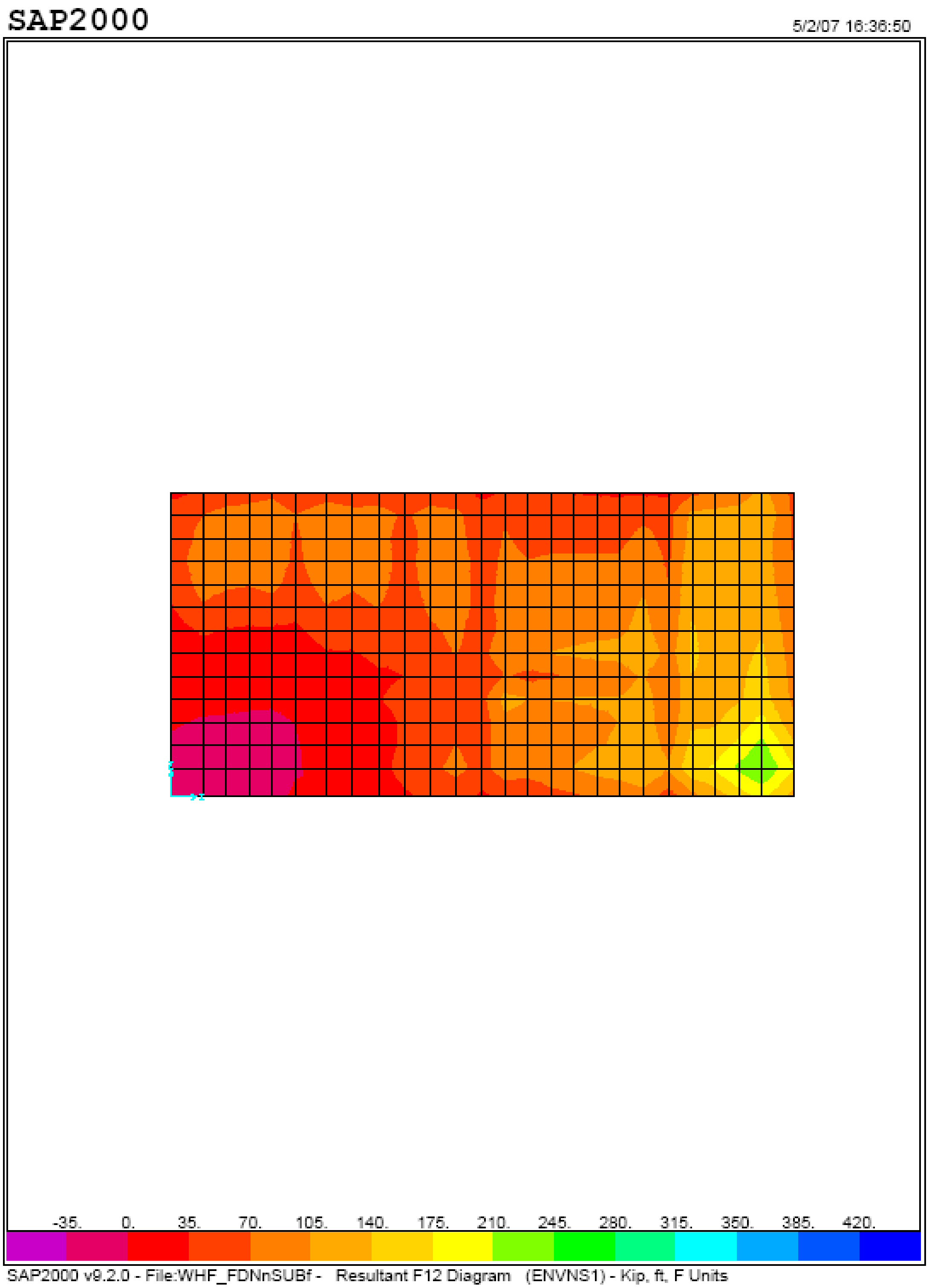
-115.
-92.
-69.
-46.
-23.
0.
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant F22 Diagram (ENVNS1) - Kip, ft, F Units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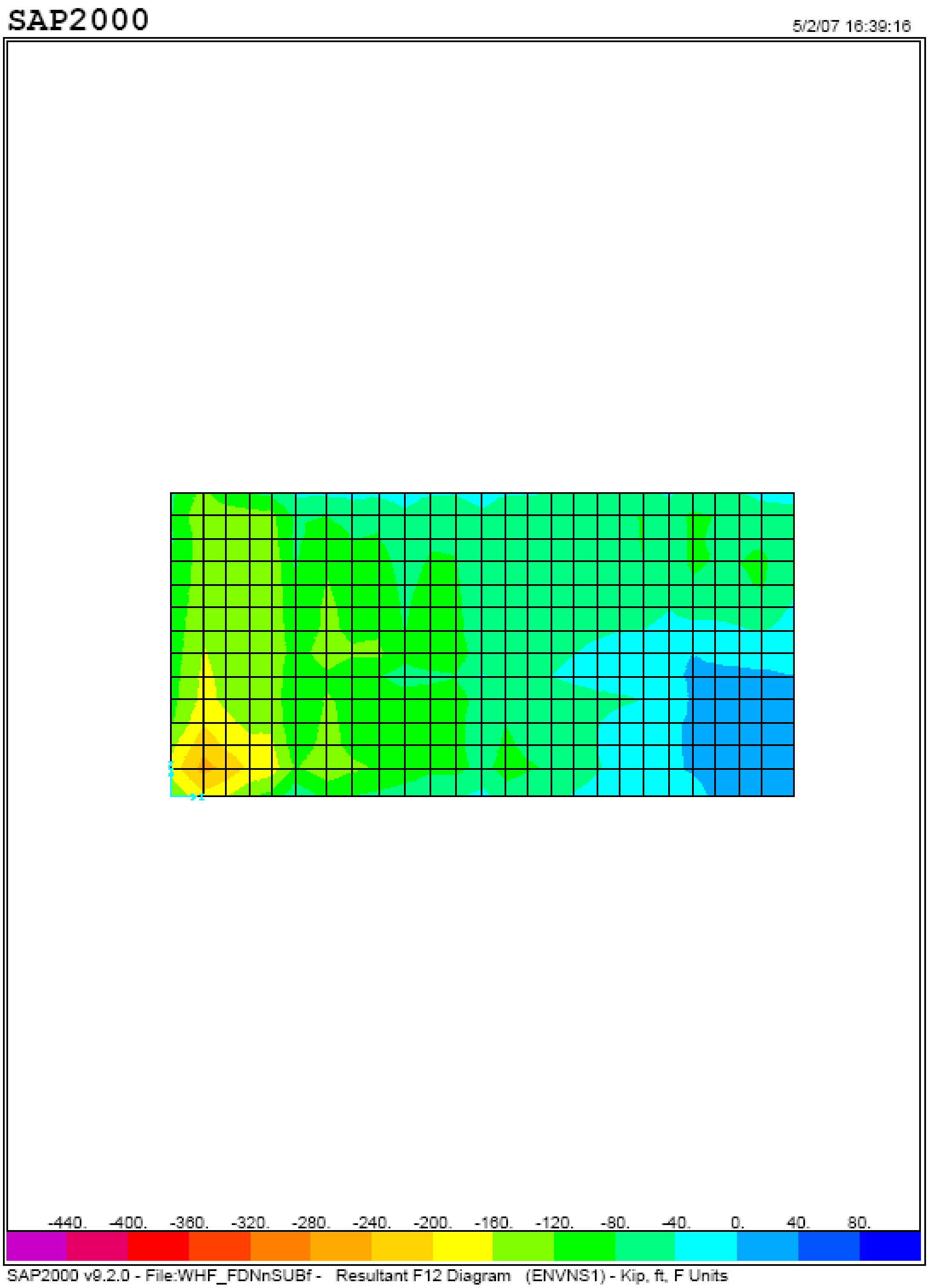
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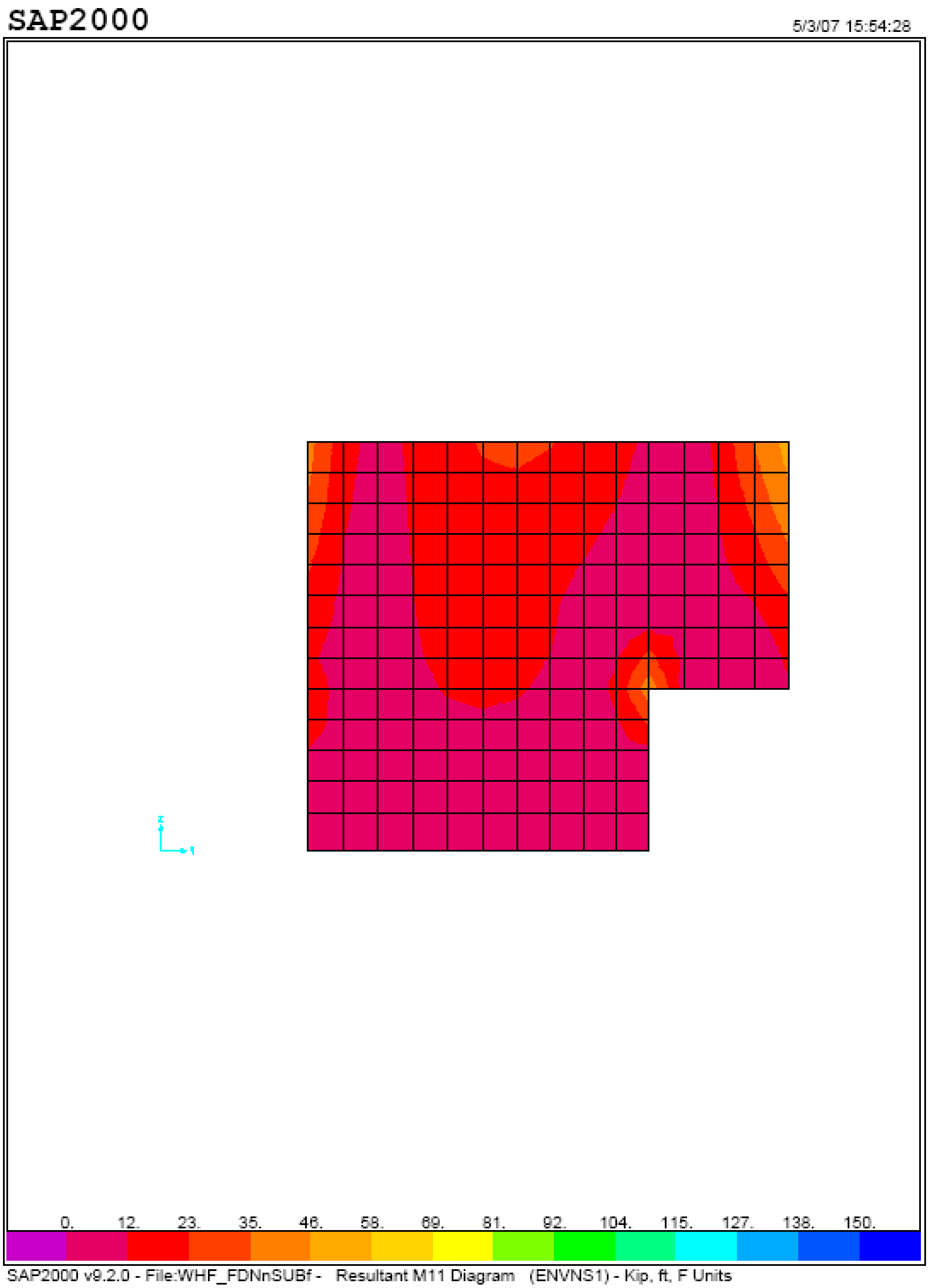
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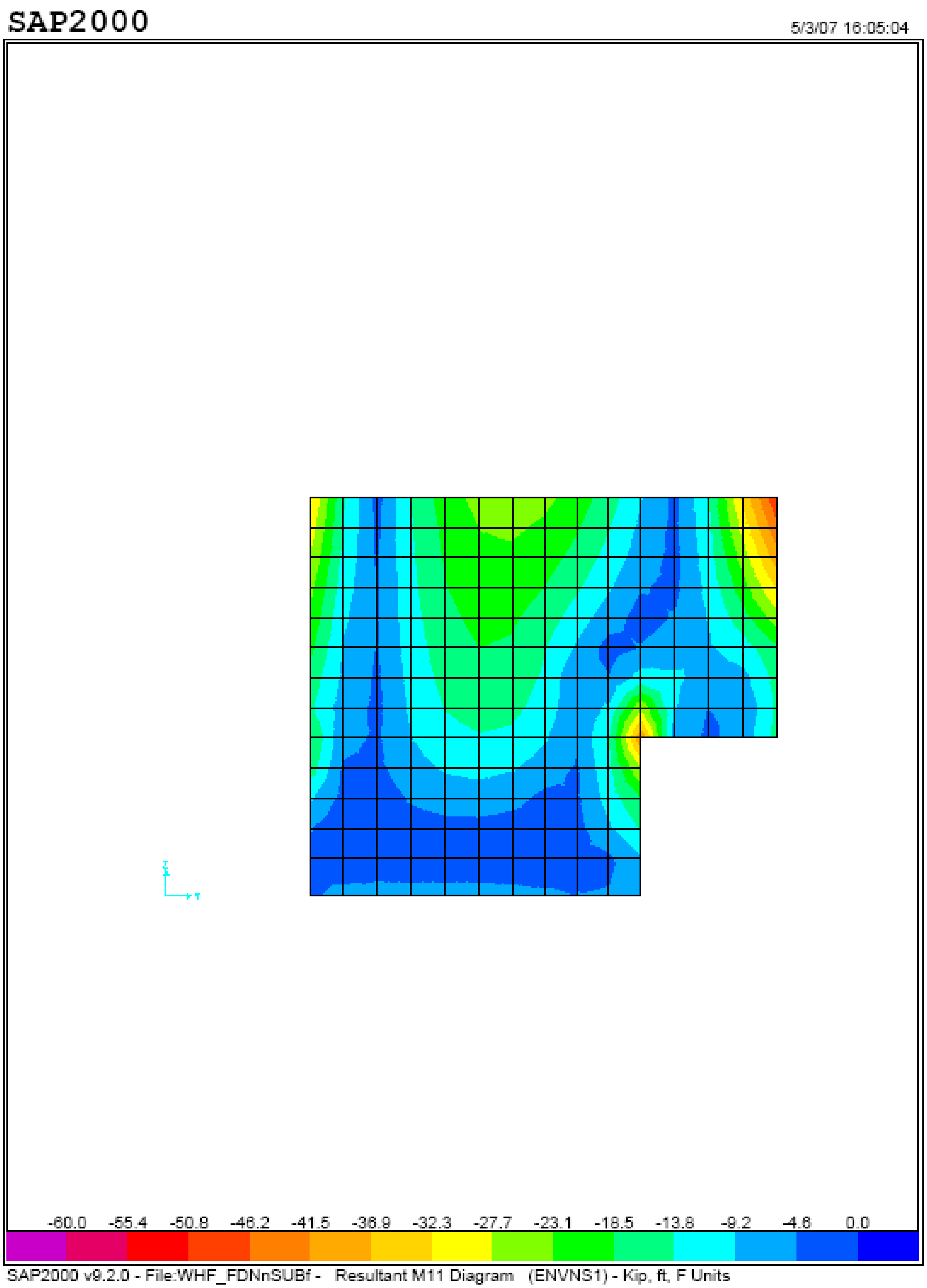
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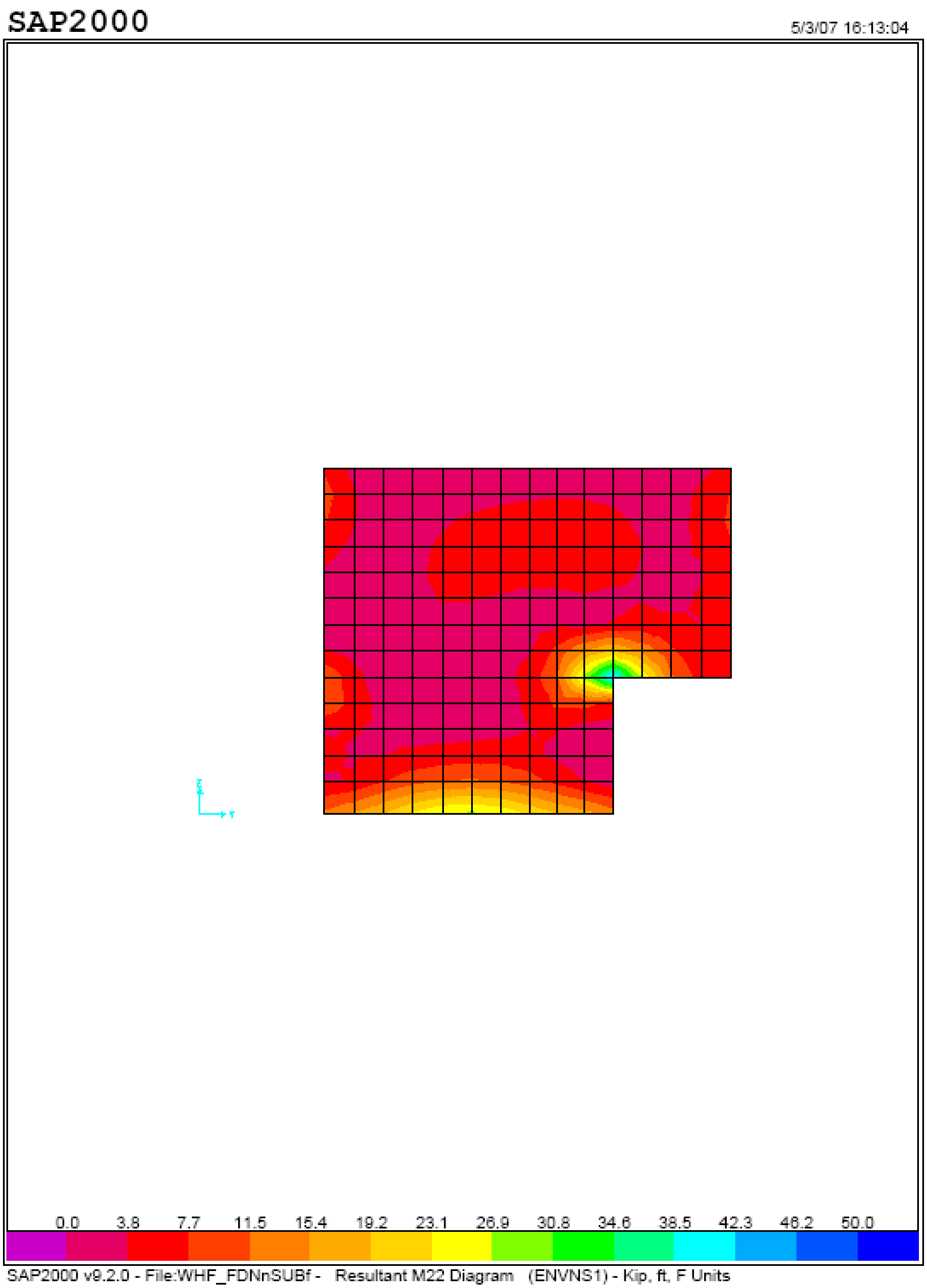
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7.7
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26.9
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34.6
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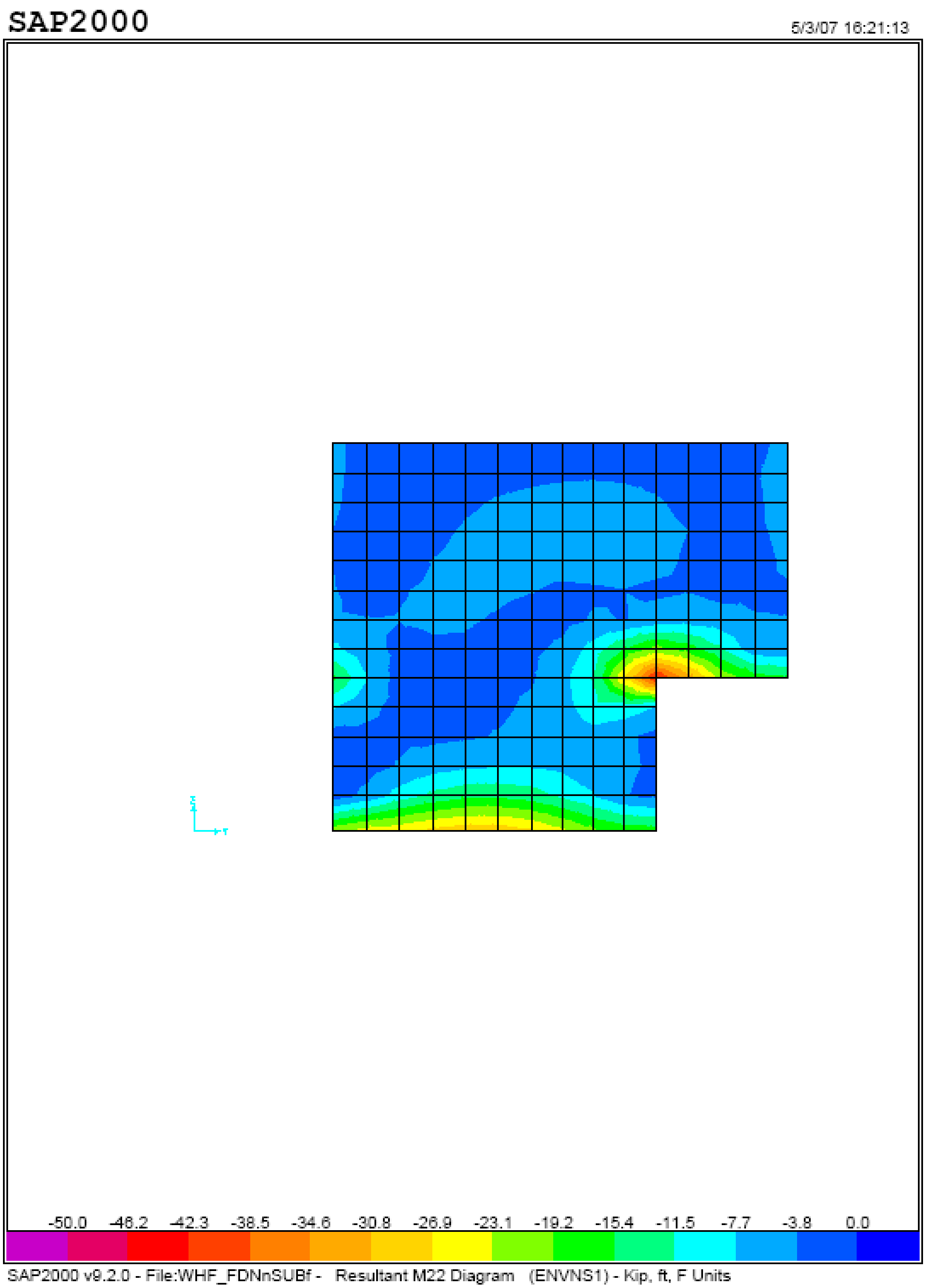
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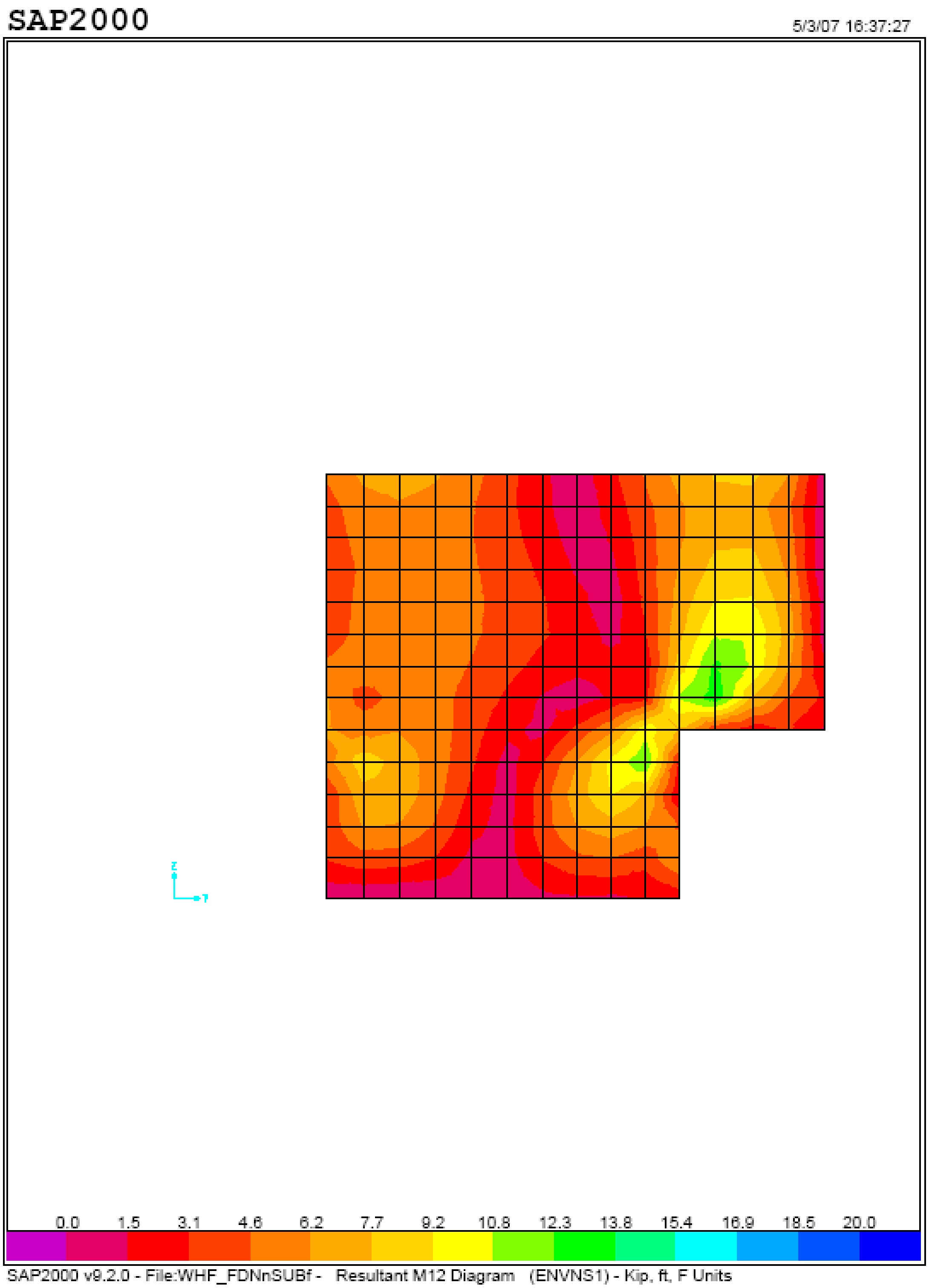
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12.3
13.8
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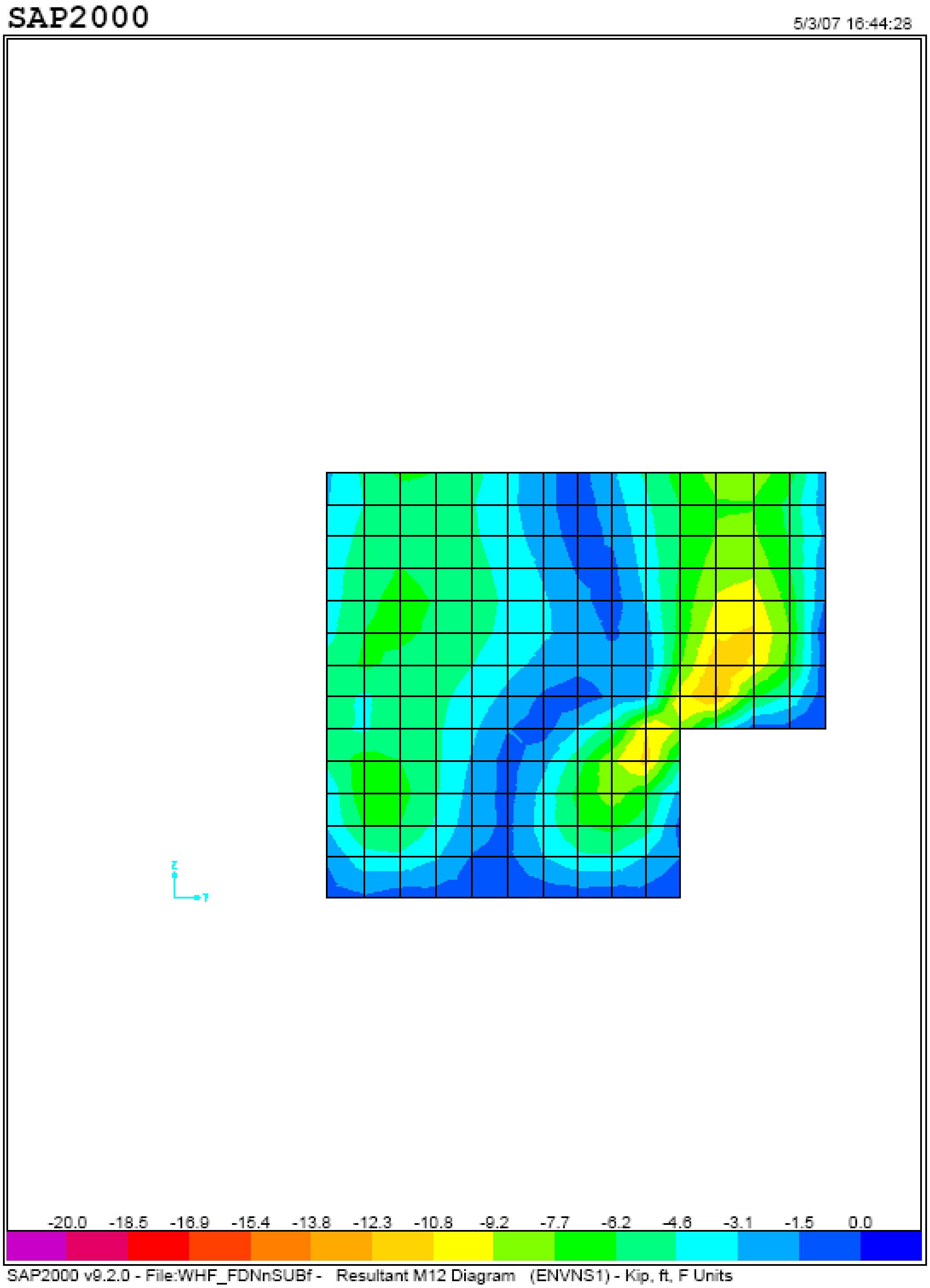
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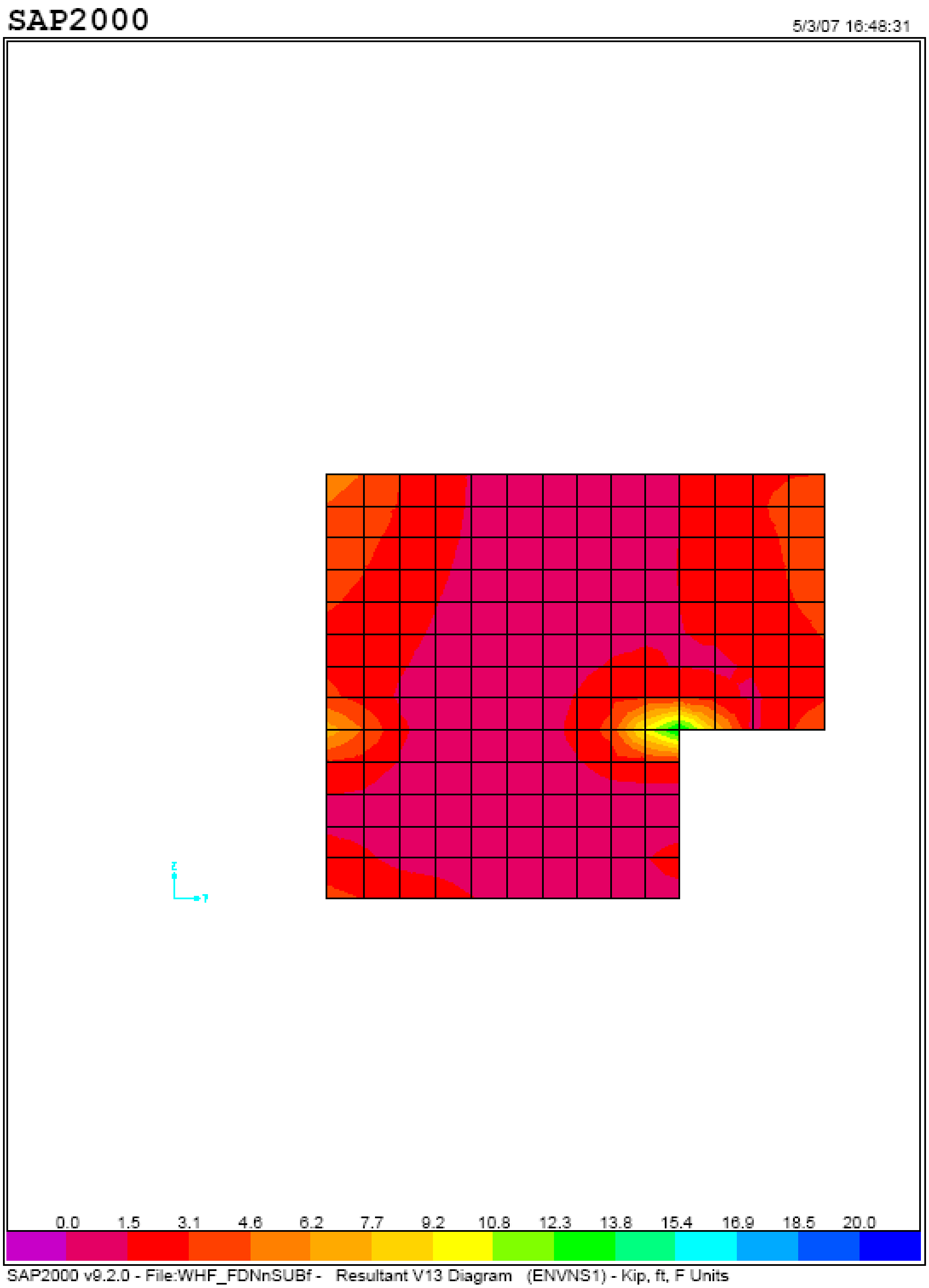
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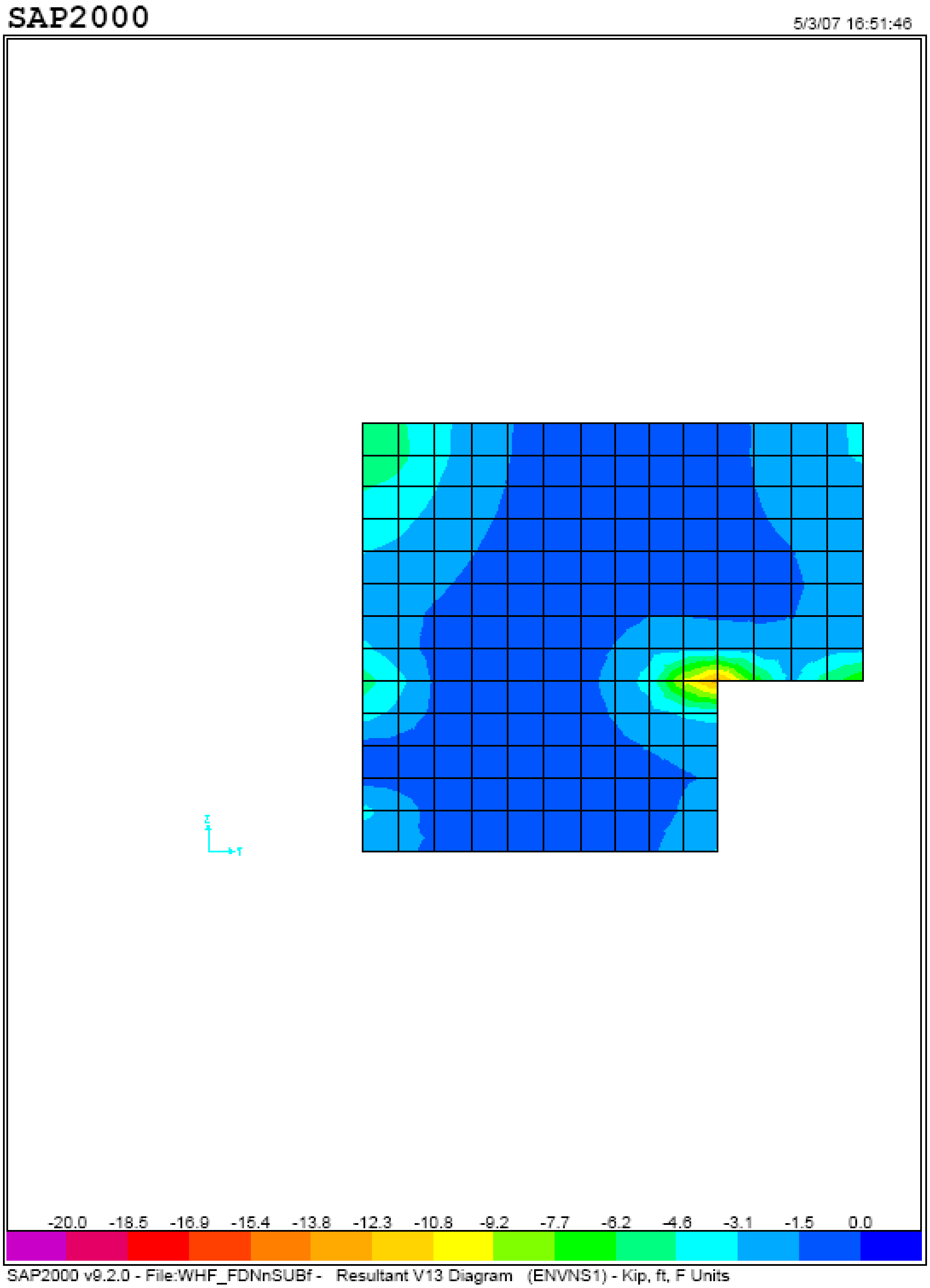
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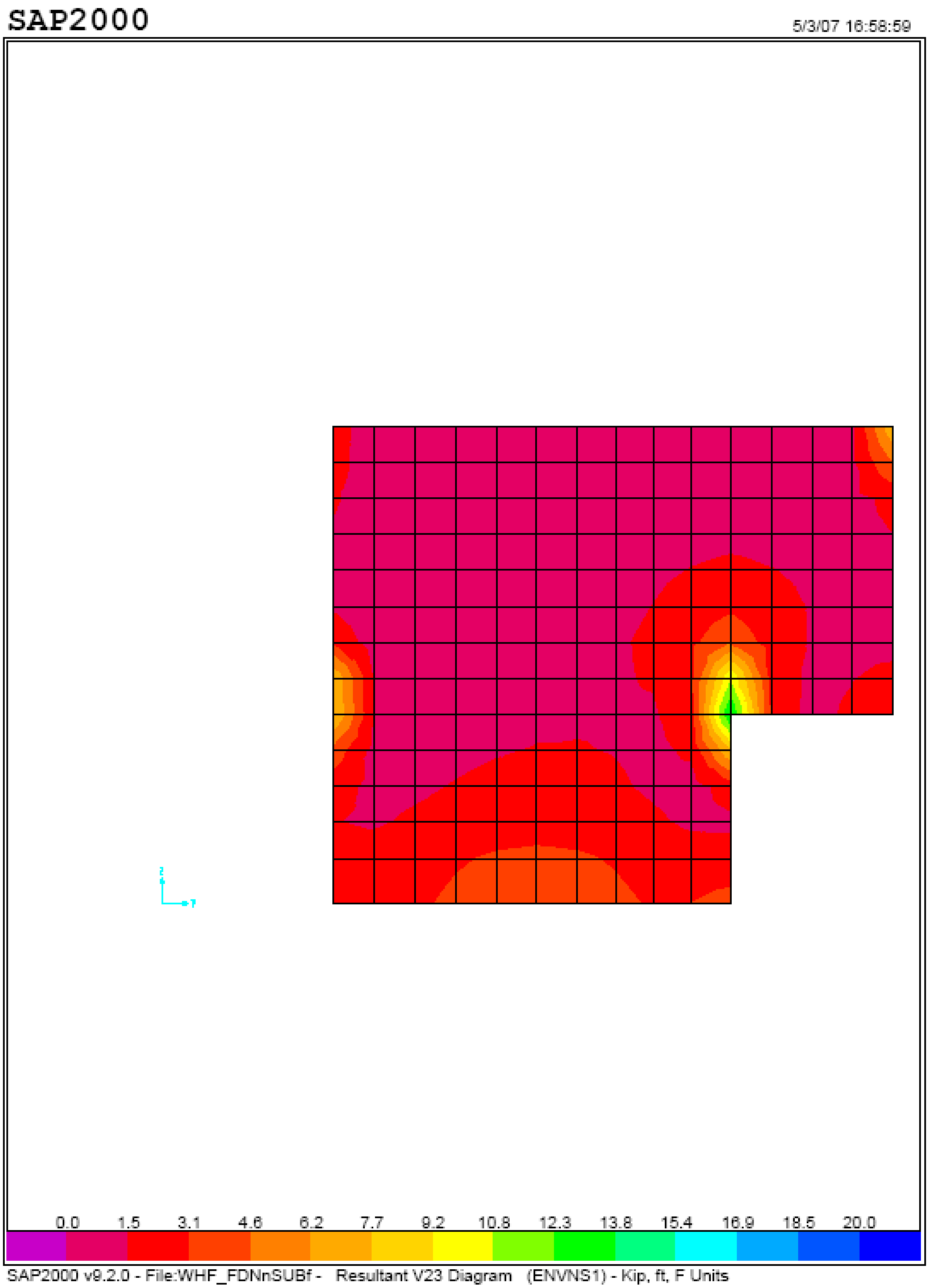
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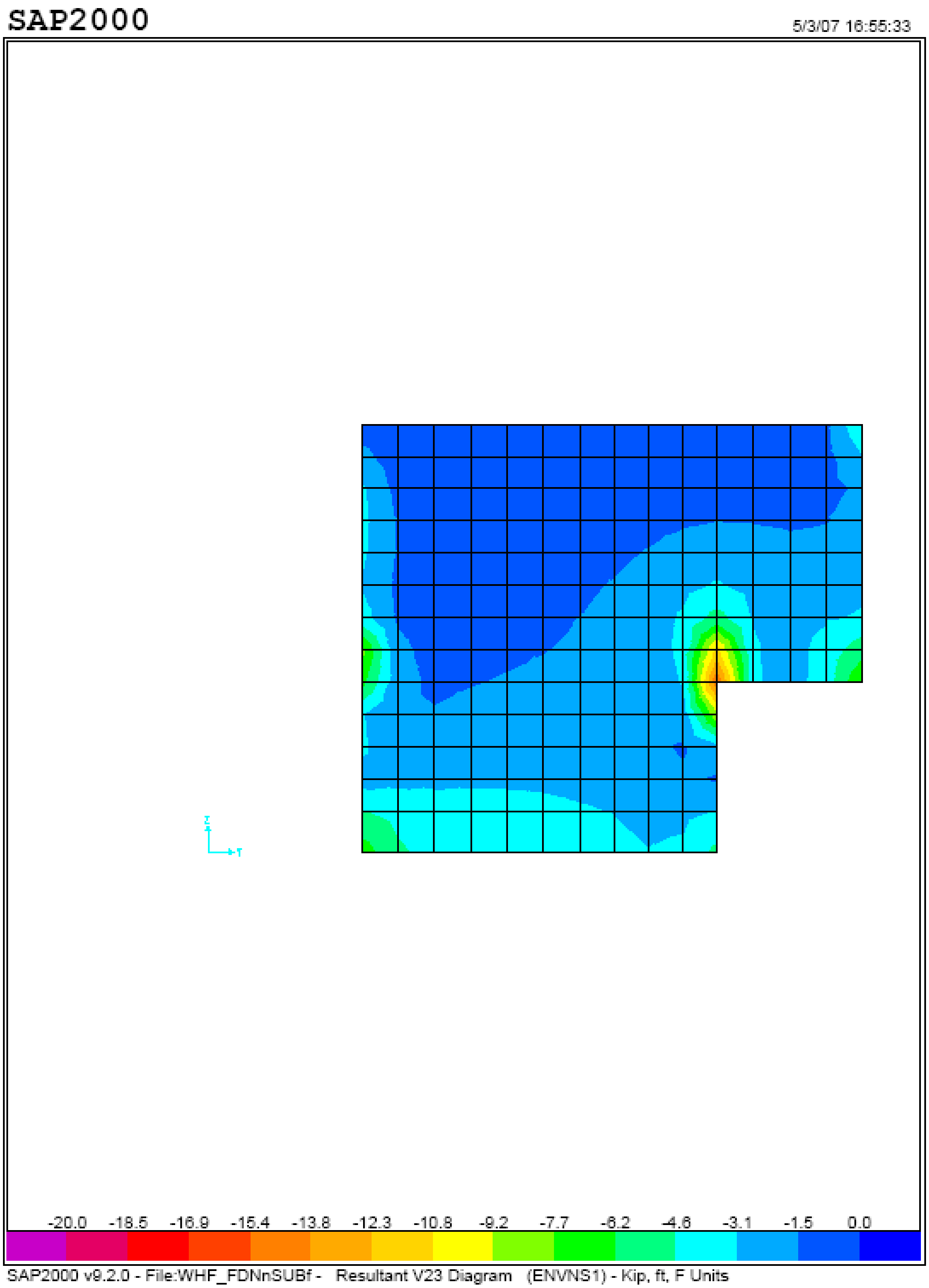
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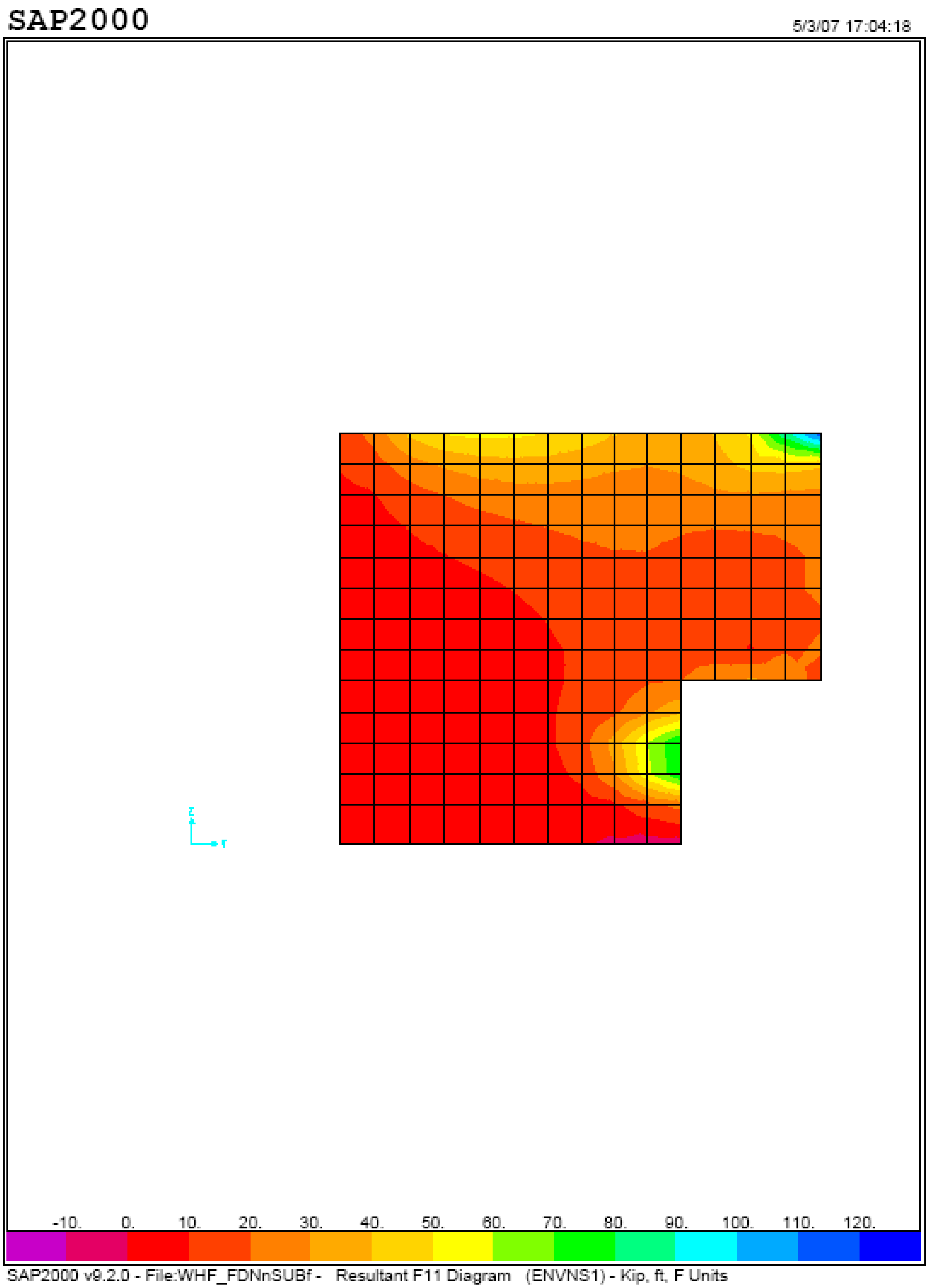
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50.
60.
70.
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120.
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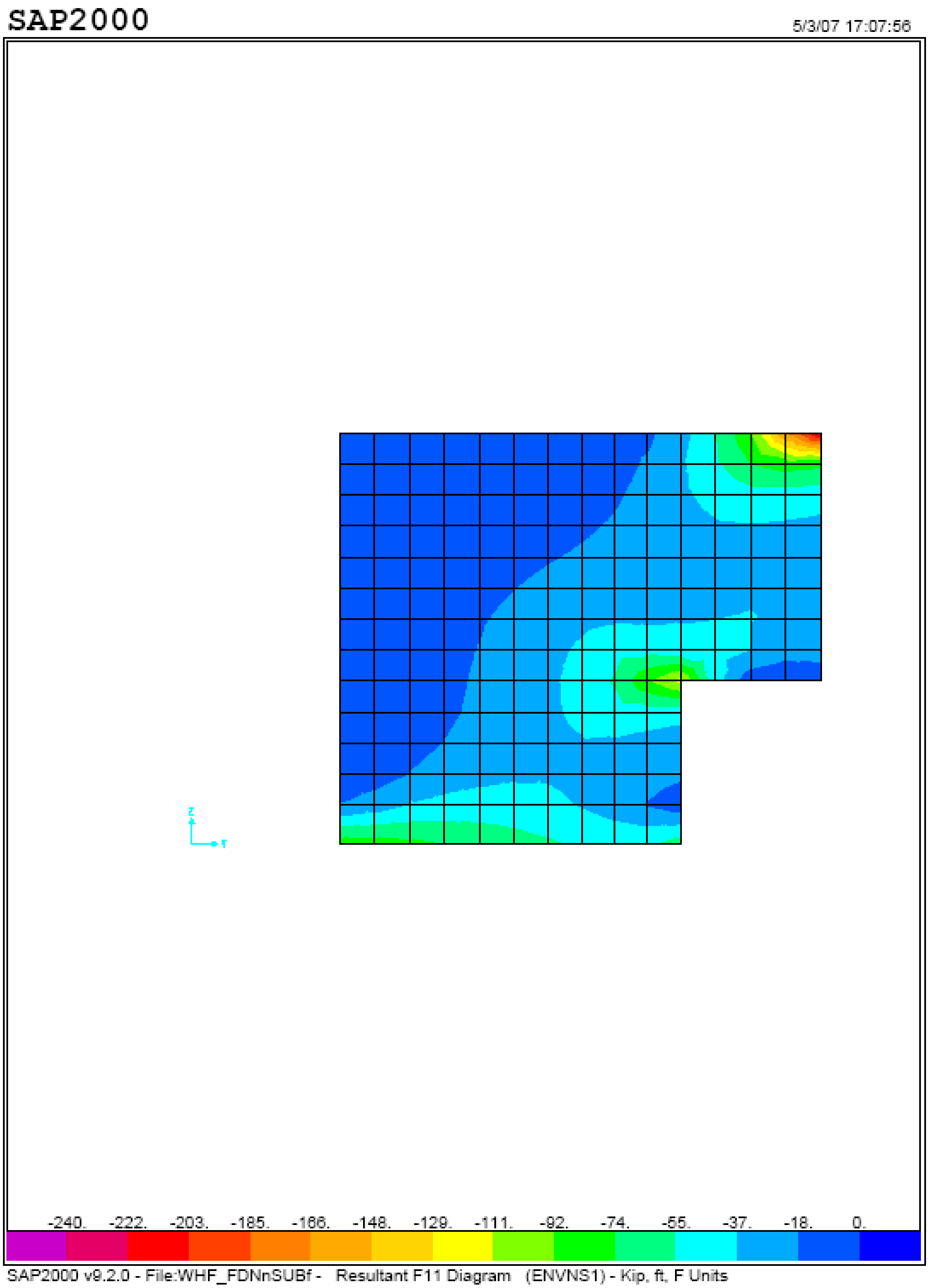
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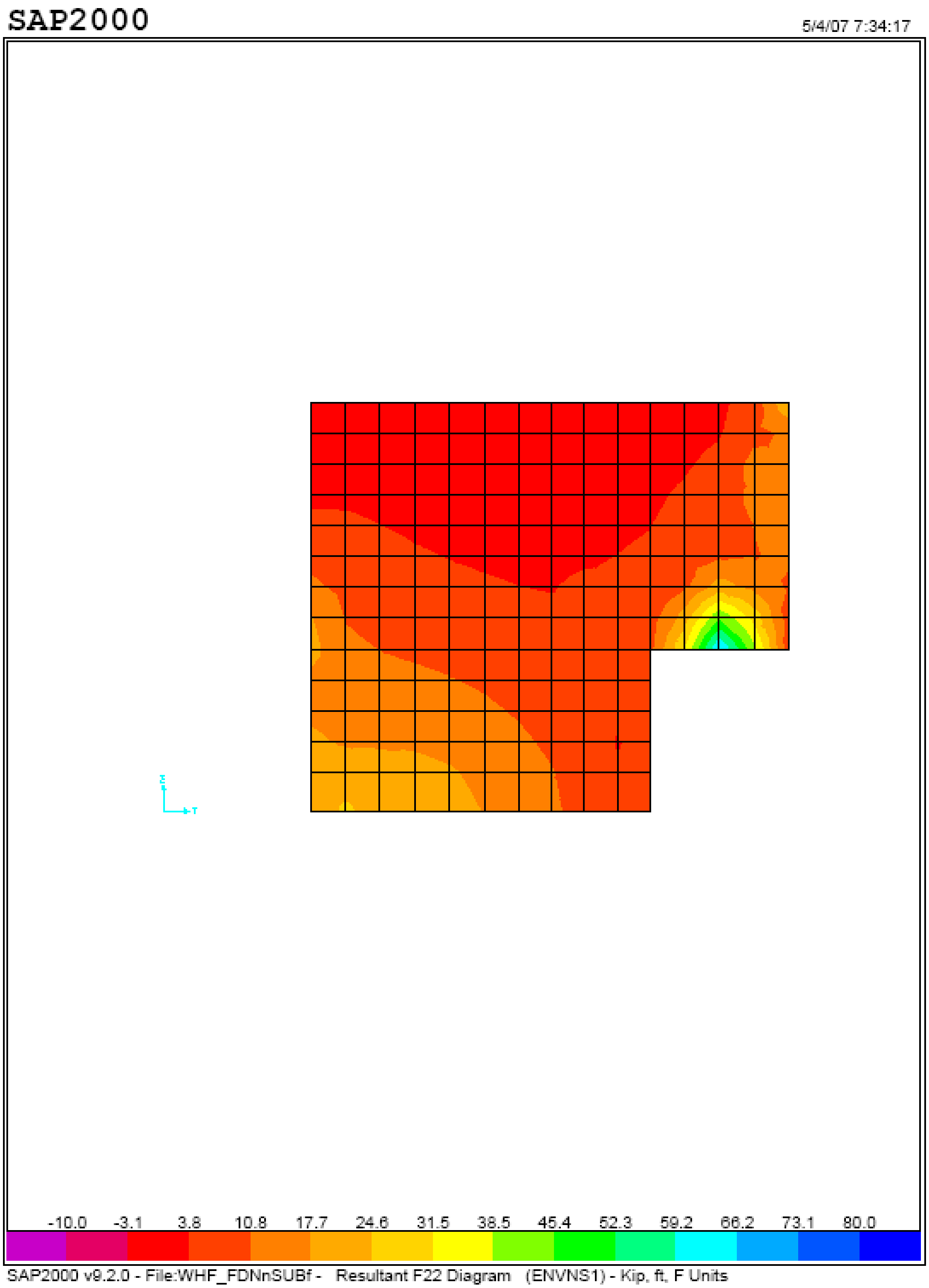
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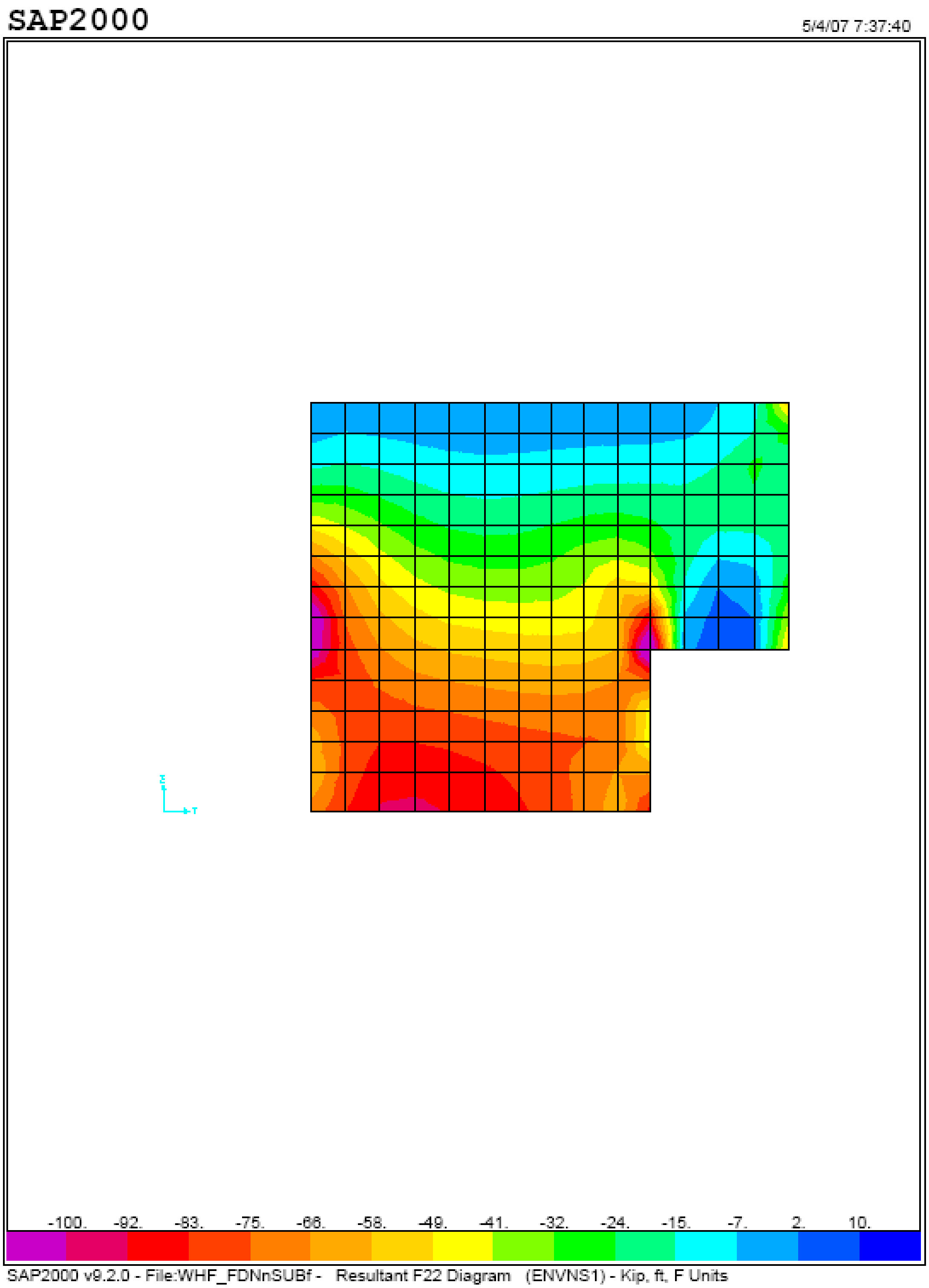
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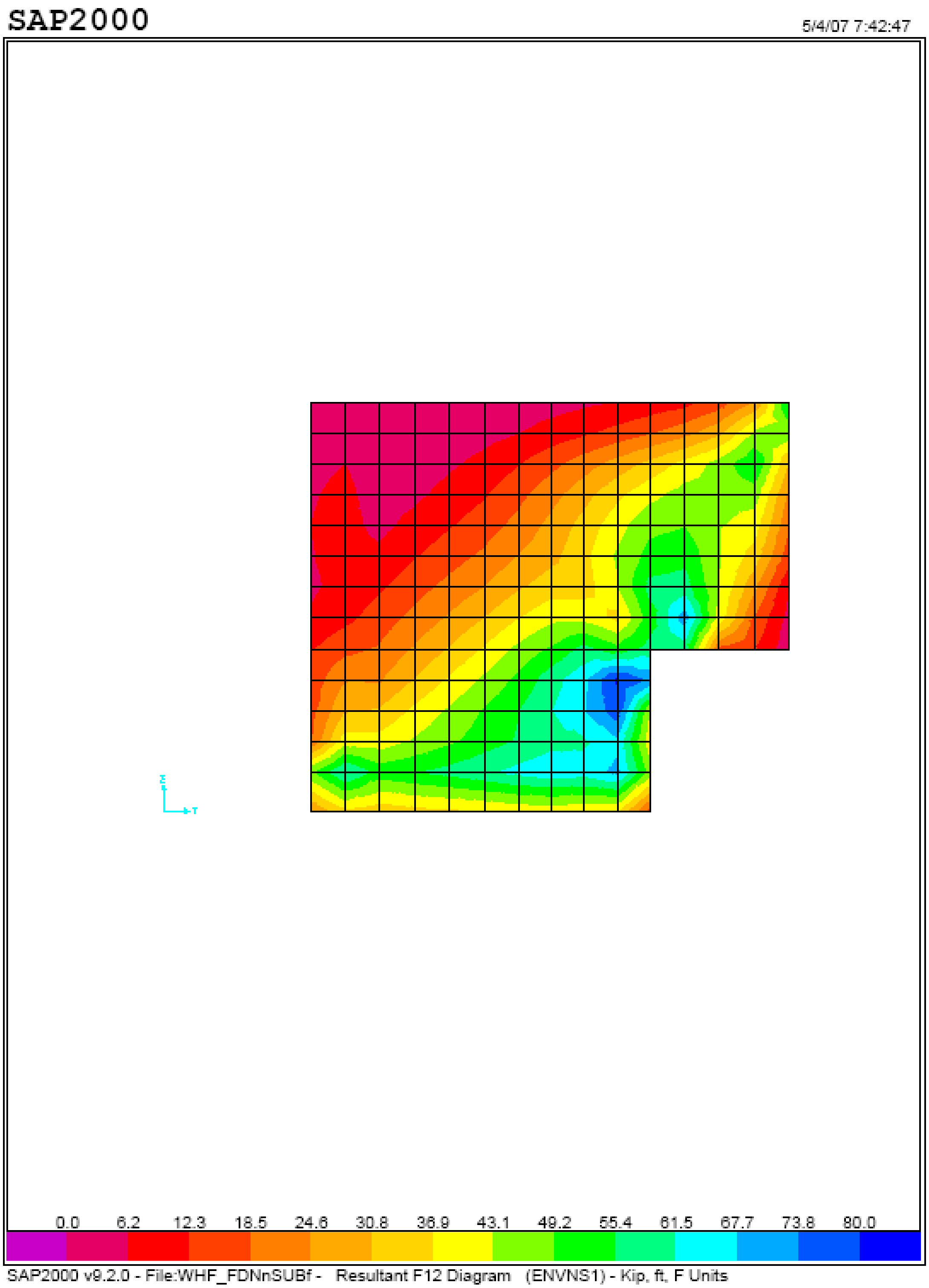
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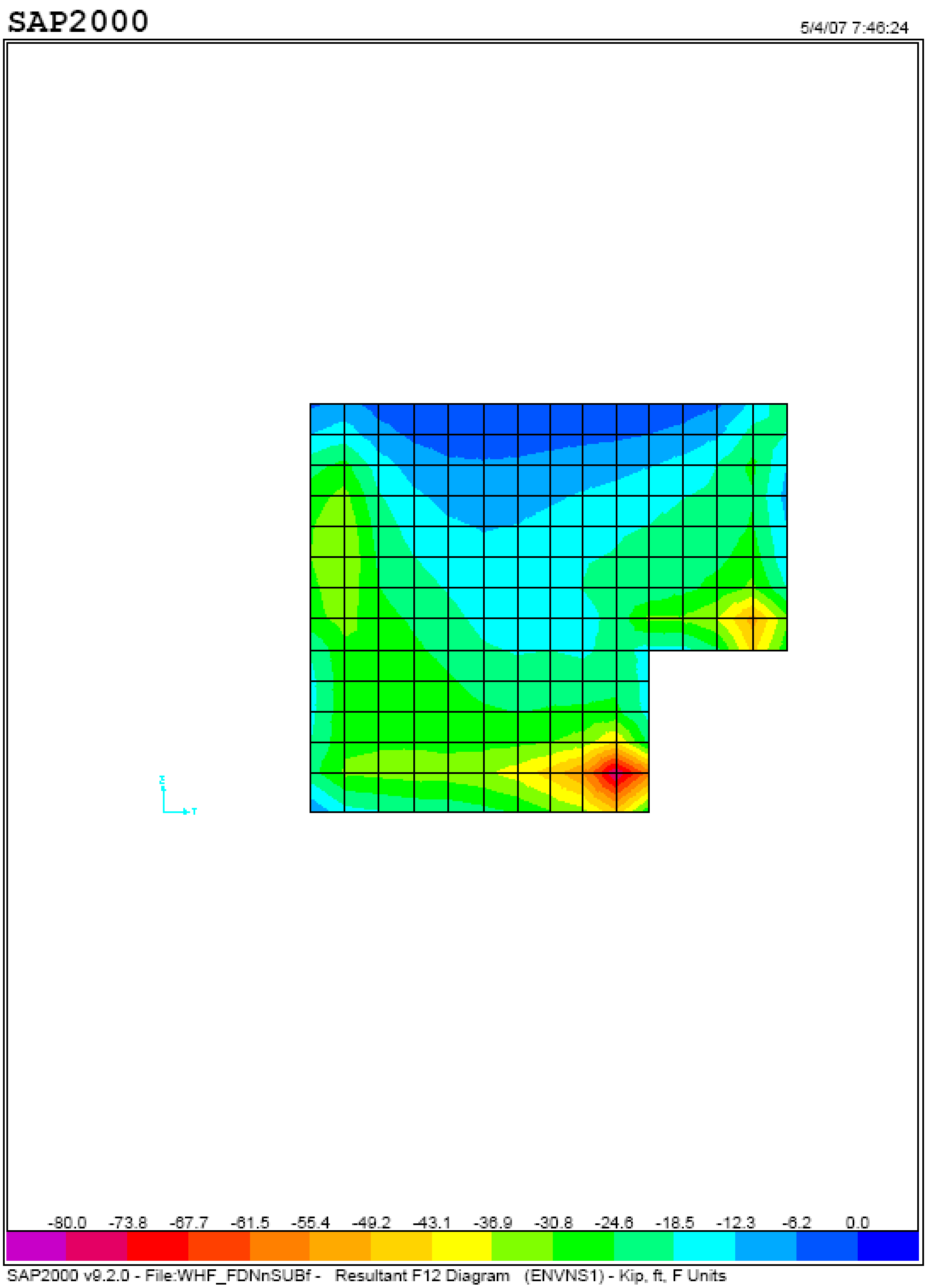
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-18.5
-12.3
-6.2
0.0
SAP2000 v9.2.0 - File:WHF_FDNnSUBf - Resultant F12 Diagram (ENVNS1) - Kip, ft, F Units

ATTACHMENT D

SAP2000 INPUT & OUTPUT FILES

(1 CD included)

Listed below are the files that are pertinent to this calculation:

Files	Remarks
• README.txt	Description of CD
• WHF_FDNnSUBh.SDB	SAP2000 Input
• GMAT_jt_masslnk.xls	Grade Basemat Tributary Link Elements for Input to SAP2000
• PMAT_jt_masslnk.xls	Pool Basemat Tributary Link Elements for Input to SAP2000
• WHF_FDN&SUB_BSREAC.xls	Base Reactions
• WHF_FDN&SUB_GDxyz1.xls	Grade Basemat Deflections
• WHF_FDN&SUB_PDxyz1.xls	Pool Basemat Deflections
• WHF_FDNnSUB_GJtReac1.xls	Grade Jt Reactions
• WHF_FDNnSUB_GJtReac2.xls	Grade Jt Reactions
• WHF_FDNnSUB_PJtReac.xls	Pool Jt Reactions