

**HAL AMICK, P.E.**  
**Vice President**  
**Colin Gordon Associates**

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## **EDUCATION**

- Ph.D. University of California, Berkeley**  
Civil and Environmental Engineering, anticipated September 2004  
Concentration: Structural Engineering, Mechanics, and Materials  
**Dissertation: *Factors Governing the Controlled Modification of Concrete Damping***  
**Minor Fields: Geotechnical Engng., Mechanical Engng. (Material Behavior)**  
Committee: Paulo Monteiro (chair), Joseph Penzien, Lisa Pruitt, and Eric Ungar
- M.Eng. University of California, Berkeley**  
Civil and Environmental Engineering, December 1980
- M.S. University of California, Berkeley**  
Civil and Environmental Engineering, May 1976
- B.S. University of Wyoming**  
Civil and Architectural Engineering, May 1974

## **AREAS OF INTEREST**

- Building Dynamics** – Dynamics of floors and raised access floors; vibration measurement and signal analysis; structural modeling; soil dynamics; mechanical systems vibration control; dynamics of slabs-on-grade
- Advanced Technology Buildings** – Environmental sensitivity of research equipment, design criteria, competing criteria; sophisticated vibration isolation systems
- Concrete Technology** – Dynamic properties, damping, polymers, durability

## **REGISTRATION, PROFESSIONAL SOCIETIES, AND HONORS**

- Registered Civil Engineer (P.E.) in California (C 27655, since 1977)  
Member, American Concrete Institute (ACI)  
Member, American Society of Civil Engineers (ASCE)  
Member, Structural Engineering Institute (SEI)  
Senior Member, Institute of Environmental Sciences and Technology (IEST)  
Member, Structural Engineers Association of Northern California (SEANOC)  
Member, Tau Beta Pi, University of Wyoming  
Member, Sigma Tau, University of Wyoming

## **PROFESSIONAL ACTIVITIES**

- Member, Working Group 17 (Facilities), International Technology Roadmap for Semiconductors (ITRS)
- Member and Co-Chair, Working Group 200 (Planning of Nanoscale Science & Technology Facilities: Considerations for Design, Construction and Operation), Institute of Environmental Sciences and Technology (IEST)
- Member, Working Group 12 (Cleanroom Design), Institute of Environmental Sciences and Technology (IEST)
- Member, Working Group 24 (Measurement Documentation), Institute of Environmental Sciences and Technology (IEST)

Co-Chair, Buildings for Advanced Technology Workshop (BAT)  
BAT I – National Institute of Standards and Technology (NIST), Gaithersburg,  
MD, January 14-16, 2003  
BAT II –Arizona State University, Tempe, AZ, January 2004  
BAT III – Purdue University, West Lafayette, IN, February 2006

## EMPLOYMENT EXPERIENCE

1996-Present      Senior Consulting Engineer, Vice President, *Colin Gordon Associates*,  
Brisbane, CA.

1985-1996      Senior Consulting Engineer, *Acentech Incorporated* (1989-1996); *Bolt  
Beranek and Newman Inc.* (1985-1989),<sup>1</sup> Cambridge, MA (1985-1987) and  
Los Angeles, CA (1987-1996).

1983-1985      Instructor, *Sheridan Community College*, Sheridan, WY.

1981-1983      Assistant Professor, *Chadron State College*, Chadron, NE.

1980-1981      Computer Specialist, *Chadron State College*, Chadron, NE.

1978-1980      Consulting Engineer, *Liftech Consultants Inc.*, Oakland, CA.

1976-1978      Research Engineer, *Lawrence Berkeley Laboratory*.

## SELECTED CONSULTING PROJECTS

- *Advanced Measurement Laboratory*, National Institute of Standards and Technology (NIST), Gaithersburg, MD – Lead Vibration Consultant and Project Manager for vibration and acoustics consulting team for design and construction of a \$175 million, 5-building complex of research laboratories for metrology and other measurement sciences
- *Genentech Hall*, University of California at San Francisco, Mission Bay Campus – Lead Vibration Consultant for design and construction of a \$142 million biotechnology research building on the new UCSF campus; the building won “Special Mention” in the *R&D Magazine* 2003 “Lab of the Year” competition
- *Advanced Photon Source*, Argonne National Laboratory, Argonne, IL – Lead Vibration Consultant and Project Manager for vibration and acoustics consulting team for design and construction of one of the country’s premier high-energy light source storage rings
- *Duffield Hall*, Cornell University, Ithaca, NY – Structural Dynamicist for design of floor systems for what was one of the first dedicated nanotechnology research facilities to become operational.
- *Stanford Linear Accelerator Center (SLAC)* – Study of surface-to-depth vibration transmission characteristics for their entry in the Next Linear Collider (NLC) competition

## REPRESENTATIVE CONSULTING CLIENTS

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<sup>1</sup> Acentech Incorporated was a division of Bolt Beranek and Newman (BBN) that was spun off as a separate corporation in 1989. Thus, the employment period covering BBN and Acentech is treated as one.

## Government Agencies

Department of Energy: Argonne National Laboratory, Lawrence Berkeley National Laboratory, Sandia National Laboratories, Brookhaven National Laboratory, Oak Ridge National Laboratory, National Renewable Energy Laboratory, Stanford Linear Accelerator Center

Department of Defense: Naval Research Laboratory, Naval Facilities Command, Naval Sea Systems Command

Department of Commerce: NIST, NOAA

NASA: Goddard Space Flight Center, Jet Propulsion Laboratory

## Universities

Cornell University; University of California (Berkeley, San Francisco, Santa Barbara; UCLA, Irvine, San Diego, Davis); Purdue University; University of Alberta; University of Utah; Northwestern University; MIT; Louisiana State University; University of Southern California; Arizona State University; University of Washington

## Private Sector

Motorola; M.D. Anderson Cancer Center; Genentech; Amgen; TSMC; Kodak; Texas Instruments; Samsung; Infineon; IDT; National Semiconductor; Seagate

## BIOGRAPHIES

*Who's Who of Science and Engineering*

*Who's Who of America*

## PAPERS, PRESENTATIONS, AND OTHER PUBLICATIONS (including submittals)

### Chapters in Books

E. E. Ungar, **H. Amick**, and J. A. Zapfe, "Vibration Considerations for Sensitive Research and Production Facilities," Chapter \_\_\_ in *Structural Dynamics of Micro- and Opto-Electronic Systems*, Ephraim Suhir and T. X. Yu, editors, Springer, in preparation.

M. Gendreau and **H. Amick**, "Micro-Vibration and Noise," Chapter 29 in *Semiconductor Manufacturing Handbook*, Hwaiyu Geng, editor, McGraw-Hill, 2005.

E. Ungar, D. Sturz, and **H. Amick**, "Vibration Control Design of High-Technology Facilities," Technical Addendum in *Architectural Acoustics Design Guide*, James Cowan, McGraw-Hill, 2000, pp. 215-229

### Peer Reviewed Journals

B. Xiong, **H. Amick**, & M. Gendreau, "The Effect of Buildings on Ground Vibration Propagation," to appear in *Noise Control Engineering Journal*.

**Amick, H.**, and P. J. M. Monteiro, "Temperature and Frequency Effects on Properties of Polymer-Modified Concrete," manuscript submitted to *Materials Journal of the American Concrete Institute*, in review

Gendreau, M. and **H. Amick**, "'Maturation' of the Vibration Environment in Advanced Technology Facilities," *J. Institute of Environmental Sciences and Technology* (2005)

**Amick, H.**, "A discussion of the paper 'Dynamic properties impact toughness and abrasiveness of polymer-modified pastes by using non-destructive tests' by W.G. Wong, Ping Fang, J.K. Pan," [*Cem. Concr. Res.* 33(9) (2003) 1371-1374], in *Cement and Concrete Research* 36(11) November 2006, pp. 2104-2105

**Amick, H.**, and P. J. M. Monteiro, "Experimental Determination of Modal Damping in Concrete Beams," *Materials Journal of the American Concrete Institute*, May-June 2006, pp. 153-160.

**Amick, H.**, B. Sennewald, N. C. Pardue, C. Teague, and B. Scace, "Analytical/Experimental Study of Vibration of a Room-Sized Airspring-Supported Slab," *Noise Control Engrng. J.*, March/April 1998, Vol. 46, no. 2, pp. 39-47 (March/April, 1998).

**Amick, H.**, "On Generic Vibration Criteria for Advanced Technology Facilities: with a Tutorial on Vibration Data Representation," *J. Inst. Env. Sci.*, pp. 35-44, (Sept/Oct, 1997).

Witherspoon, P. A., J. E. Gale, K. Iwai, and **H. Amick**, "Observations of a Potential Size Effect in Experimental Determination of the Hydraulic Properties of Fractures," *Water Resources Research*, v. 15, no. 5, (October 1979)

### Conference Proceedings

N. Simos, M. Fallier, and **H. Amick**, "Ground Motion Studies at NSLS II," Proceedings EPAC2008, *European Particle Accelerator Conference, EPAC'08, Genoa, Italy, 23 to 27 June 2008, Paper No. MOPC50*

N. Simos, M. Fallier, and **H. Amick**, "Comparative Study of Vibration Stability at Operating Light Source Facilities and Lessons Learned in Achieving NSLS II Stability Goals," Proceedings EPAC2008, *European Particle Accelerator Conference, EPAC'08, Genoa, Italy, 23 to 27 June 2008, Paper No. MOPC49*

N. Tang, C. Wu, B. Xiong, M. Gendreau and **H. Amick**, "Dynamic Features of Precast Waffle Slabs in Cleanroom Design," presented at *IMAC XXVI Conference and Exposition on Structural Dynamics*, Orlando, Florida, 4-7 February 2008.

B. Xiong, **H. Amick**, & M. Gendreau, "The Effect of Buildings on Ground Vibration Propagation," *Proceedings of Noise-Con 2007*, Reno, Nevada, 22-24 October 2007.

**H. Amick**, M. Gendreau, & N. Wongprasert, "Centile spectra, measurement times, and statistics of ground vibration," *Proceedings of the Second International Symposium on Environmental Vibrations: Prediction, Monitoring, Mitigation and Evaluation (ISEV2005)*, Okayama University, Okayama, Japan (20 to 22 September 2005)

**H. Amick**, "Modification of concrete damping properties for vibration control in technology facilities," *Proceedings of SPIE Conference 5933: Buildings for Nanoscale Research and Beyond*, San Diego, CA, 31 Jul 2005 to 1 Aug 2005

**H. Amick**, M. Gendreau, T. Busch, and C. Gordon, "Evolving criteria for research facilities: vibration," *Proceedings of SPIE Conference 5933: Buildings for Nanoscale Research and Beyond*, San Diego, CA, 31 Jul 2005 to 1 Aug 2005

J. Montgomery, D. Clare, **H. Amick**, P. Haswell, J. DiBattista, and M. Medhekar, "Use of vibration criteria in the selection of building systems for nanoscale research facilities," *Proceedings of SPIE Conference 5933: Buildings for Nanoscale Research and Beyond*, San Diego, CA, 31 Jul 2005 to 1 Aug 2005

**H. Amick**, N. Wongprasert, J. Montgomery, P. Haswell, and D. Lynch, "An experimental study of vibration attenuation performance of several on-grade slab configurations," *Proceedings of SPIE Conference 5933: Buildings for Nanoscale Research and Beyond*, San Diego, CA, 31 Jul 2005 to 1 Aug 2005

T. Busch, M. Gendreau, and **H. Amick**, "Vibration and noise criteria used to evaluate environmental impacts of transportation projects on sensitive facilities," *Proceedings of SPIE Conference 5933: Buildings for Nanoscale Research and Beyond*, San Diego, CA, 31 Jul 2005 to 1 Aug 2005

A. Soueid, **H. Amick**, and T. Zsirai, "Addressing the environmental challenges of the NIST Advanced Measurement Laboratory," *Proceedings of SPIE Conference 5933: Buildings for Nanoscale Research and Beyond*, San Diego, CA, 31 Jul 2005 to 1 Aug 2005

**H. Amick** and P. J. M. Monteiro, "A "Toolbox" of Damping Treatments for Concrete Structures," *Proc. Structures 2005*, April 20-24, 2005, New York, NY.

**H. Amick**, "Damping Properties of Polymer-Modified Concrete," *Proc. 75<sup>th</sup> Shock and Vibration Symposium*, October 17-22, 2004, Virginia Beach, VA.

**H. Amick** and P. J. M. Monteiro, "Vibration Control Using Large Pneumatic Isolation Systems with Damped Concrete Inertia Masses," *Proc. 7<sup>th</sup> Intl. Conf. on Motion and Vibration Control, (MoViC 04)*, Paper 118, August 8-11, 2004, Washington University, St. Louis, MO.

Gendreau, M. and **H. Amick**, "'Maturation' of the Vibration and Noise Environments in Semiconductor Production Facilities," Presented at ESTECH 2004, 50<sup>th</sup> Annual Technical Meeting, Institute of Environmental Sciences and Technology (IEST), Las Vegas, Nevada, Phoenix, Arizona, April 28, 2004

**H. Amick**, T. Xu, and M. Gendreau, "The Role of Buildings and Slabs-on-Grade in the Suppression of Low-Amplitude Ambient Ground Vibrations," presented at the 11<sup>th</sup> Intl. Conf. on Soil Dyn. & Earthquake Engng. (11<sup>th</sup> ICSDEE) & the 3<sup>rd</sup> Intl. Conf. on Earthquake Geotech. Engng. (3<sup>rd</sup> ICEGE), 7-9 January, 2004, Berkeley, CA.

M. Gendreau, **H. Amick** and T. Xu, "The Effects of Ground Vibrations on Nanotechnology Research Facilities," presented at the 11<sup>th</sup> Intl. Conf. on Soil Dyn. & Earthquake Engng. (11<sup>th</sup> ICSDEE) & the 3<sup>rd</sup> Intl. Conf. on Earthquake Geotech. Engng. (3<sup>rd</sup> ICEGE), 7-9 January, 2004, Berkeley, CA.

T. Xu, **H. Amick**, and M. Gendreau, "Vibration Design of 300 mm Wafer Fab," *Proc. SEMI Tech. Symp. (STS)*, March 12-14, 2003, SEMICON China 2003, Shanghai, China

**H. Amick**, M. Gendreau, and C. G. Gordon, "Facility Vibration Issues for Nanotechnology Research," *Proc. Symp. on Nano Device Technology 2002*, May 2-3, 2002, National Chiao-Tung University, Hsinchu, Taiwan.

**H. Amick** and A. Bayat, "Meeting The Vibration Challenges Of Next-Generation Photolithography Tools," *Proc. ESTECH 2001*, 47th Annual Technical Meeting, IEST, Phoenix, Arizona (April 2001).

**H. Amick** and M. Gendreau, "Construction Vibrations and Their Impact on Vibration-Sensitive Facilities," *Proc. Sixth Constr. Cong.*, American Society of Civil Engineers (ASCE), Orlando, Florida, February, 2000, pp. 758-767.

**H. Amick**, M. Gendreau, and A. Bayat, "Dynamic Characteristics of Structures Extracted from In-situ Testing," *Proc. Intl. Soc. for Opt. Engng. (SPIE)*, Vol. 3786, Denver, CO (July 1999).

**H. Amick**, "A Frequency-Dependent Soil Propagation Model," *Proc. Intl. Soc. for Opt. Engng. (SPIE)*, Vol. 3786, Denver, CO (July 1999).

**Amick, H.**, "Vibration Data Representation for Advanced Technology Facilities," *Proc. 12<sup>th</sup> Engrng. Mech. Conf.*, American Society of Civil Engineers, pp. 302-305, (May, 1998).

**Amick, H.**, and A. Bayat, "Dynamics of Stiff Floors for Advanced Technology Facilities," *Proc. 12<sup>th</sup> Engrng. Mech. Conf.*, American Society of Civil Engineers, pp. 318-321, (May, 1998).

**Amick, H.**, A. Bayat and Z. Kemeny, "Seismic Isolation of Semiconductor Production Facilities," *Proc. Seminar on Seismic Design, Retrofit, and Performance of Non-Structural Components, Seminar ATC 29-1*, Applied Technology Council, pp. 297-312, (January, 1998).

**Amick, H.**, "Optimizing the Placement of a Road between Two Research Buildings - a Case Study," *Proc. Inter-Noise 96*, pp. 1293-1296 (August, 1996).

**Amick, H.**, B. Sennewald, N. C. Pardue, C. Teague, and B. Scace, "Analytical/Experimental Study of Vibration of a Room-Sized Airspring-Supported Slab," *Proc. Inter-Noise 96*, pp. 1553-1556 (August, 1996).

Pardue, N.C., and **Amick, H.**, "NIST - Advanced Technology Laboratories: Metrology Laboratories & Vibration Control," *Proc. NCSL Workshop & Symp.: Impact of Metrology on Global Trade*, Dallas, Texas (July, 1995).

Nugent, R. E., and **H. Amick**, "Protecting Vibration Environments with Zoning and Land-Use Ordinances," *Proc. Intl. Soc. for Opt. Engng. (SPIE)*, Vol. 1619 (November, 1991).

**Amick, H.**, S. Hardash, P. Gillett, R. Reaveley, "Design of Stiff, Low-Vibration Floor Structures," *Proc. Intl. Soc. for Opt. Engng. (SPIE)*, Vol. 1619 (Nov. 1991).

**Amick, H.** and S. Bui, "A Review of Several Methods for Processing Vibration Data," *Proc. Intl. Soc. for Opt. Engng. (SPIE)*, Vol. 1619 (Nov. 1991).

**Amick, H.**, A. M. Yazdanniyaz, K. S. Pearsons, R. E. Nugent, "A Review of Noise Issues in Semiconductor Clean Rooms," *Proc. Noise-Con '90*, pp. 247-252 (Oct. 1990).

Gordon, C. G. and **H. Amick**, "Groundborne Vibration - Thoughts on Control by Foundation Design and Other Techniques," *Proc. Inter-Noise 89*, Newport Beach, California (Dec. 1989)

Nugent, R. E. and **Amick, H.**, "Vibration Considerations in Zoning," *Proc. Inter-Noise 89*, Newport Beach, California (Dec. 1989)

Gordon, C. G. and **H. Amick**, "Vibration and Noise Control in State-of-the-Art Clean Rooms," *Proc. Microcontamination 89*, Anaheim, California (Oct. 1989)

### **Presentations without Proceedings**

**H. Amick** and M. Gendreau, "'Vibration Kills' and other Lessons from the Trenches," presented at Acoustics'08, June 29 – July, 2008, Paris, France.

**H. Amick**, "Visually Observable Vibration Sensitivity of a Laboratory Bench Microscope," presented at InterMicro 2007, July 9-13, 2007, Chicago, IL.

**H. Amick**, A. Chasey, and M. Gendreau, "Tool or Facility – What Should it Be?-- Reconciling differences between production equipment needs and facility support," presented at 1<sup>st</sup> ISMI Symposium on Manufacturing Effectiveness, 25-28 October 2004, Omni Hotel Austin, Austin, Texas

**H. Amick**, M. Gendreau and T. Xu, "Actual Vibration and Acoustics Measures on a Completed Nanotech Building -- Duffield Hall," invited presentation for the 2004 International Conference "Nanotechnology Research Space – The Next Step," August 15-16, 2004, Ithaca, NY, Tradeline Conference Series

**Amick, H.** and M. Gendreau, "Getting the Right Vibration and Acoustics Performance at the Right Cost," invited presentation for the 2003 International Conference on Nanotechnology Research Facilities and Labs, October 9-10, 2003, San Antonio, TX, Tradeline Conference Series

**H. Amick**, "Building Vibrations in Advanced Technology Facilities," Invited Presentation to CE 397 Structures Seminar at the University of Texas, 8 October 2003, Austin, Texas

**H. Amick**, M. Gendreau, and C. G. Gordon, "Vibrations of Raised Access Floors," Invited Paper, presented at the First Pan-American/Iberian Meeting on Acoustics; 144th Meeting of the Acoustical Society of America, 2-6 December 2002, Cancun, Mexico

**H. Amick** and M. Stead, "Vibration Sensitivity of a Laboratory Bench Microscope," Invited Paper, presented at the First Pan-American/Iberian Meeting on Acoustics; 144th Meeting of the Acoustical Society of America, 2-6 December 2002, Cancun, Mexico

**H. Amick**, "Building Vibrations in Advanced Technology Facilities," Invited Presentation, Structural Engineers Association of Northern California (SEAONC), San Francisco, CA (9 October 2001).

**H. Amick**, "Vibrations of Steel-Framed Floors," SEAONC Seminar, San Francisco, CA (21 Aug 2001).

**Amick, H.**, P. Burge, S. Bui, N. Pardue, and S. Kramer, "Siting Selection for the Advanced Technology Laboratories, National Institute of Standards and Technologies (NIST): Consideration of Transportation-Induced Vibrations," Transp. Res. Bd. Summer Conf., Boston, Massachusetts (July, 1995).

Sennewald, B., R. Stewart, N. Pardue, and **H. Amick**, "Facilities for Standards Laboratories," 1994 NCSL Workshop & Symposium, Chicago, Illinois (August, 1994).

Nugent, R. E., and **H. Amick**, "Protecting Vibration-Sensitive Facilities from Transportation Vibrations," Transportation Research Board Summer Conference (July, 1992).

Witherspoon, P.A., J. E. Gale, and **H. Amick**, "Observations on Stress-Dependent Fracture Permeability using Large Diameter Granite Core," presented at Fall Annual Meeting, American Geophysical Union, San Francisco (December 1976)

### **Other Publications**

**H. Amick** and M. Stead, "Vibration Sensitivity of a Laboratory Bench Microscope," *Sound & Vibration*, v. 41, No. 2, pp. 10-17 (February 2007).

**Amick, H.**, L. Vitale, and B. Haxton, "Nanotech I: Site Parameters" and "Nanotech II: Case Studies and Trends," *R&D 2007 Laboratory Design Handbook*, pp. 38-45 (November 2006).

**Amick, H.**, L. Vitale, and B. Haxton, "Site Investigation Criteria for Nanotech Labs," *R&D Magazine*, pp. 36-37 (May 2006).

**Amick, H.**, "Reducing Floor Vibrations: A polymer admixture provides increased damping in concrete," Construction of Nanotechnology Facilities," *Concrete International*, (April 2006).

**Amick, H.**, "Buildings for nanotechnology: A look back at the genesis of a new building type," *Semiconductor FabTech*, pp. 57-63, January 2006.

**Amick, H.**, "Going Nano," letter to the editor in *ENR*, p. 5, October 10, 2005.



- Amick, H.**, and P. J. M. Monteiro, "Instalaciones para nantecnología," *Construccion y Tecnologia*, Instituto Mexicano del Cemento y del Concreto, Mexico, June 2005, pp. 26-32.
- Amick, H.**, "Can Vibration be Controlled with Damped Concrete?" *Semiconductor Fabtech*, No. 26, June 2005, Cleanroom Section.
- Amick, H.**, and M. Gendreau, "On the Appropriate Timing for Facility Vibration Surveys," *Semiconductor Fabtech*, No. 25, March 2005, Cleanroom Section.
- Amick, H.** and P. J. M. Monteiro, "Construction of Nanotechnology Facilities," *Concrete International*, Vol. 26, Issue 3, pp. 68-72 (March 2004).
- H. Amick** and E. E. Ungar, "Vibration Control," seminar presented at Buildings for Advanced Technology Workshop, January 14-16, 2003, National Institute of Standards and Technology, Gaithersburg, MD
- H. Amick** and A. Bayat, "Meeting The Vibration Challenges Of Next-Generation Photolithography Tools," *Sound & Vibration*, Vol. 36, No. 3, pp. 22-24 (March 2002).
- H. Amick**, "Designing for Vibrations in the Laboratory," *LABoratory: Earl Walls Associates Quarterly Report*, Fall 2001, Vol. 6, No. 1, pp. 3-4.
- Kim, J. J., and **H. Amick**, "Active Vibration Control in Fabs," *Semiconductor International*, (July, 1997).
- Sennewald, B. and **H. Amick**, "Vibration Control in Labs: How Quiet Can You Get?" *R&D Magazine*, pp. 19LS-20LS (March, 1996).
- Nugent, R. E., and **H. Amick**, "Vibration Considerations in Land Use Planning," *AEP Environmental Monitor*, pp. 5-8 (Summer, 1992).
- Ungar, E. E., D. H. Sturz, and **H. Amick**, "Vibration Control Design of High Technology Facilities," *Sound and Vibration* (Jul. 1990).
- Amick, H.** and C. G. Gordon, "Specifying and Interpreting a Site Vibration Evaluation," *Microcontamination* (Oct. 1989).
- Amick, H.**, "Vibrating Buildings," *Development Magazine*, pp. 43-45 (May/June 1988).
- Amick, H.**, P.A. Witherspoon and J.E. Gale, "Stress-Flow Behavior of a Fault Zone with Fluid Injection and Withdrawal," *Min. Eng. Rep. 77-1*, Univ. of Calif., Berkeley (May 1977)