

Preface

We are pleased to provide you with our 2003 Annual Summary, based on activities underway and completed in 2002. The mission of the department includes achieving excellence in teaching, research and extension. In 2002, our undergraduate and graduate program names were changed from Agricultural Engineering to Biological Systems Engineering, so they now coincide with our department name which was changed in 1995. The Accrediting Board for Engineering and Technology (ABET) evaluated the undergraduate program in the fall of 2000. We received accreditation for another six years. The graduate program offers both Master of Science and Doctoral degrees. We have approximately 70 undergraduate and 35 graduate students. The department offers a wide range of courses with options in Machinery Systems Engineering, Food and Bioprocess Engineering, Natural Resources and Environmental Engineering, and Structural Engineering Systems.

The goal of our research program is to contribute new and valuable knowledge to the fields of food processing and instrumentation, electrical systems, machinery systems, construction, natural resources and environment, and agricultural safety and health. Research projects also serve to train graduate students and to increase the quality of undergraduate education. Our research program is financially supported by state and federal appropriations and by gifts and grants from industry, government agencies and individuals. This support is gratefully acknowledged. The gifts and grants continue to increase as a percent of budget.

Extension and outreach programs are an integral part of the department. Many of our Extension personnel are also involved in research and classroom teaching. Extension and outreach activities are directed toward providing continuing education opportunities for the citizens of Wisconsin and the nation. The mission is to extend research knowledge and assist in assimilating it into the community.

Since this report is a summary without a lot of detail, I encourage you to contact the specific project leader (indicated by a "*" behind the person's name) or me. Publications listed in this report are available upon request.

I welcome your comments on the Annual Summary and other departmental matters. Please visit our website, bse.wisc.edu, to keep informed of our activities. Also, do not hesitate to contact me: e-mail rschuler@wisc.edu; telephone 608-262-3310; FAX 608-262-1228; or mail your comments to:

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Professor and Chair

List of Abbreviations

AABP-NMC	American Association of Bovine Practitioners-National Mastitis Council	Engring.	engineering	MPN	most probable number
ABET	Accrediting Board for Engineering and Technology	EP	engineering practice	M.S.	Master of Science
AC	alternating current	ESW	Easter Seals Wisconsin	MT	magnetotelluric
AER	array electrode reactor	etc.	et cetera (Latin) meaning "and so forth" or "and others"	Mtg.	meeting
Agric.	agriculture or agricultural	EXAFS	X-ray absorption fine structure	MWPS	MidWest Plan Service
Amer.	America or American	F	Fahrenheit	NASA	National Aeronautics and Space Administration
ANSI	American National Standards Institute	FL	Florida	Natl.	national
AP	atmospheric pressure	ft	foot or feet	NC	North Carolina
Appl.	applied	g	gram(s)	NECA	National Electrical Contractors Association
ASAE	American Society of Agricultural Engineers	G	gravity	NFBA	National Frame Builders Association
Assn.	association	G'	elastic modulus	NIOSH	National Institutes for Occupational Safety and Health
ATP	adenodine tri-phosphate	G*	complex modulus	No.	number
BC	British Columbia	gal	gallon(s)	NRAES	Natural Resource, Agriculture, and Engineering Service
BD-SDC	barrier discharge reactor for small cavities	HI	Hawaii	OH	Ohio
B.S.	Bachelor of Science	hr	hour(s)	P	phosphorus
C	centigrade or Celsius	Hz	Hertz [cycles per second]	p.	page(s)
CA	California	IA	Iowa	PA	Pennsylvania
CALS	College of Agricultural and Life Sciences	i.e.	<i>id est</i> (Latin) meaning "that is"	PAA	polyallylamine hydrochloride
CD	compact disk	IFT	Institute of Food Technologists	PANI	polyaniline
Ch.	chapter	IL	Illinois	PEG	polyethylene glycol
CII	Construction Industry Institute	in	inch(es)	pH	potential hydrogen
CIP	clean-in-place	Inc.	incorporated	Ph.D.	Doctor of Philosophy
cm	centimeter(s)	Inst.	institute	pp.	pages
Co.	company	Int.	international	ppb	parts per billion
Conf.	conference	IU	international unit(s)	ppm	parts per million
Corp.	corporation	J	journal	Proc.	proceedings
C-PAM	Center for Plasma-Aided Manufacturing	K	potassium	psi	pounds per square inch
cr	credit(s)	kg	kilogram(s)	Pub.	publication
CSREES	Cooperative State Research, Education, & Extension Services	kW	kilowatt(s)	RNA	ribonucleic acid
Ctr.	center	L	liter(s)	rpm	revolutions per minute
d	day(s)	LA	Louisiana	s	second(s) [of time]
DC	direct current or District of Columbia	lbf	pounds force	Sch.	school
Dept.	department	lbs	pounds [of weight]	Sci.	science
dia.	diameter	LDL	long day lighting	Soc.	society
Div.	division	μm	micrometer(s)	Symp.	symposium
DM	dry matter	m	meter(s)	Tech.	technical
DMP	dense medium plasma	MCAA	Mechanical Contractors Association of America	Technol.	technology
DNA	deoxyribonucleic acid	MD	Maryland	TN	Tennessee
DVR	Division of Vocational Rehabilitation	mg	milligram(s)	Univ.	university
ed.	edition or editor	Mgmt.	management	US/U.S.	United States
eds.	editors	MI	Michigan	USDA	United States Department of Agriculture
e.g.	<i>exempli gratia</i> (Latin) meaning "for example"	min	minute(s)	UW	University of Wisconsin-Madison
EMS	emergency medical service	Minn.	Minnesota	V	volt(s)
		mL	milliliter(s)	Vol.	volume
		μm	micrometer(s)	W	Watt(s)
		mm	millimeter(s)	WPC	whey protein concentrate
		mM	millimolar(s)	WI or Wis.	Wisconsin
		MN	Minnesota	yr	year(s)
		mo	month(s)		
		mPa	millipascal(s)		

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Faculty

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Teaching / Research: wood structures

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Teaching / Research / Extension: natural resources

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Teaching / Research: food safety

Sundaram Gunasekaran, Professor, Ph.D.
Teaching / Research: food and bioprocess engineering

Awad S. Hanna, Professor, Ph.D.
Teaching / Research: construction management

Brian J. Holmes, Professor, Ph.D.
Extension / Research / Teaching: farmstead engineering

David W. Kammel, Professor, Ph.D.
Extension / Research: farm structures

K.G. Karthikeyan, Assistant Professor, Ph.D.
Teaching / Research: natural resources and environment

Richard G. Koegel, Professor, Ph.D.
USDA Agricultural Research Service: power and machinery

Richard E. Muck, Professor, Ph.D.
USDA Agricultural Research Service: structures and environment

James O. Peterson, Professor, Ph.D.
Extension: water quality
Director, Environmental Resources Center

Mark A. Purschwitz, Associate Professor, Ph.D.
Extension / Research: agricultural safety and health
Director, UW Center for Agricultural Safety and Health

Douglas J. Reinemann, Professor, Ph.D.
Extension / Research / Teaching: milking equipment and facilities, rural energy, stray voltage

Roger M. Rowell, Professor, Ph.D.
USDA Forest Products Laboratory: wood chemistry, composites

Ronald T. Schuler, Professor and Chair, Ph.D.
Extension / Research / Teaching: power and machinery
Chair, UW Biological Systems Engineering

Kevin J. Shinnors, Professor, Ph.D.
Teaching / Research: power and machinery

Richard J. Straub, Professor, Ph.D.
Teaching / Research: power and machinery
Director, UW Agricultural Research Stations

Anita M. Thompson, Assistant Professor, Ph.D.
Joined the BSE Faculty in October 2002.
Teaching / Research: natural resources and environment

Patrick W. Walsh, Professor, Ph.D.
Extension / Research: solid and hazardous waste management, legal liability
Program Leader, Community, Natural Resources and Economic Development Program (UW Cooperative Extension Service)

Faculty with Joint or Adjunct Appointments (Research activities and publications are not included.)

Mark R. Etzel, Professor, Ph.D. (UW Food Science)
Teaching / Research: food engineering

Robert J. Fick, Adjunct Assistant Professor, Ph.D.
Alliant Energy: rural energy

Richard W. Hartel, Professor, Ph.D. (UW Food Science)
Teaching / Research: food engineering

King-Jau (Sam) Kung, Professor, Ph.D. (UW Soil Science)
Teaching / Research: soil physics

Philip R. O'Leary, Professor, Ph.D. (UW Engineering Professional Development)
Teaching / Research: environmental quality

Aicardo Roa-Espinosa, Visiting Asst. Professor, Ph.D.
Dane County Land Conservation Dept.: urban conservation, agricultural engineering

Emeritus Faculty

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Theodore J. Brevik
Edward G. Bruns
Gary D. Bubenzer
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Calvin O. Cramer
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Marshall F. Finner
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Academic Staff

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William E. Enters, Research Specialist
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Andrew Hopfensperger, Distinguished Outreach Specialist
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Forest Products Laboratory), Ph.D.
Ziahua (Joe) Zhou, Research Associate, Ph.D.

Office Personnel

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Kelly D. Kruse, Program Assistant
Candice L. Pharo, Department Administrator
Debra K. Sumwalt, Program Assistant

Technical Personnel

Harold M. Bohne, Senior Instrument Maker
James F. Schwarz, Electronics Technician

Graduate Students

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Jeremy D. Balousek
Casey B. Behringer
Benjamin N. Binversie
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John E. Cudoc
Misty A. Davis
Klaus Doelle
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Joseph D. Grande
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John C. Panuska
Leah T. Sibley
Changhui Sun
Jeffrey B. Topel
Dongmei Wang
Tao Wang
Lan Xiao
Huai-Wen Yang
Chenxu Yu

TEACHING

One part of the department's mission is undergraduate and graduate education. The department is responsible for:

- ▲ Undergraduate Major – Biological Systems Engineering
- ▲ Graduate Program:
 - Master of Science – Biological Systems Engineering
 - Doctor of Philosophy – Biological Systems Engineering
- ▲ Technical Courses
- ▲ Farm and Industry Short Courses
- ▲ College of Agricultural and Life Sciences (CALs)
 - Student Advising

Agricultural Engineering

Currently there are about 70 undergraduate majors in Agricultural Engineering. The major consists of a core of courses taken by all students and four emphasis areas of which students choose one: machinery systems; structural engineering systems; natural resources and environment; food and bioprocess engineering. The following courses are dedicated to the Biological Systems Engineering major.

- Engineering Principles for Biological Systems, 3 cr
- Surveying Fundamentals, 1 cr
- Field Applications in Surveying, 1 cr
- Wood Manufacturing Processes, 1 cr
- Wood as a Building Material, 1 cr
- Structural Design for Agricultural Facilities, 3 cr
- Principles of Agricultural Machinery, 3 cr
- Tractor and Power Equipment, 3 cr
- Measurements and Instrumentation for Biological Systems, 3 cr
- Food Engineering Operations, 4 cr
- Food and Pharmaceutical Separations, 2-3 cr
- Engineering Properties of Food and Biological Materials, 3 cr
- Sediment and Bio-Nutrient Engineering and Management, 3 cr
- Irrigation and Drainage Systems Design, 2 cr
- Small Watershed Engineering, 3 cr
- On-Site Waste Water Treatment and Dispersal, 2 cr
- Topics in Natural Resources Engring., 1-3 cr
- Fundamentals of Biological and Agricultural Engineering Design, 2 cr
- Biological and Agricultural Engineering Design Laboratory, 2 cr

The curriculum consists of 128 credits and is accredited by the Accrediting Board for Engineering and Technology (ABET). In July 2001 our undergraduate program was

accredited for another six years, the maximum allowable. Our curriculum currently ranks within the top five undergraduate Biological Systems Engineering programs in the U.S. During 2001, 17 students received B.S. degrees in Agricultural Engineering.

Technical Courses

The department provides a number of service courses for other majors.

- Livestock Housing and Waste Management, 3 cr
- Irrigation Systems – Design and Use, 1 cr
- Drainage Systems, 1 cr
- Surveying Fundamentals, 1 cr
- Field Applications in Surveying, 1 cr
- Field Machines, 3 cr
- Spark Ignition and Diesel Engines, 2 cr
- Tractors, 1 cr

Farm and Industry Short Course Program

The department teaches the following courses for the Farm and Industry Short Course program of the College of Agricultural and Life Sciences (CALs).

- Agricultural Safety and Health, 1 cr
- Agricultural Energy Management and Wiring, 2 cr
- Farm Power, 2 cr
- Farm Machinery, 3 cr
- Livestock Housing, 3 cr
- Milking Systems and Design, 1 cr

Graduate Programs

Each year there are approximately 35 graduate students pursuing a Master of Science (M.S.) or Doctor of Philosophy (Ph.D.) degree in Biological Systems Engineering. In addition, our faculty advise several graduate-level students in other departments and in the programs of Water Resources Management and Land Resources Management of the Institute for Environmental Studies. The M.S. degree requires a minimum of 18 credits of course work and 6 credits of thesis work. A Ph.D. requires a minimum of 48 credits of course work and 24 credits of thesis work for a minimum of 72 credits beyond a B.S. degree in Biological Systems Engineering. Students who have bachelor's degrees in non-engineering fields may pursue a Master's degree in Biological Systems Engineering but must complete appropriate prerequisites.

RESEARCH

Biological Engineering

Field Testing Aerobic Units and Sand Filters

J.C. Converse*

Funding: Small Scale Waste Mgmt. Project; State of Wis.

Cooperators: UW Biological Systems Engring.; UW Soil Sci.

Effluent samples from pump chambers receiving aerobically treated effluent have been collected and analyzed for several types of advanced treatment units, single pass sand filters, and recirculating sand filters. At least ten homes/commercial units for each type have been sampled multiple times. Data analysis is currently underway.

Evaluation of Failing Septic Systems

J.C. Converse*

Funding: Small Scale Waste Mgmt. Project

Cooperator: UW Biological Systems Engring.

A study is underway to evaluate why some septic systems appear to be ponding or failing after a short time in operation. We will be evaluating the characteristics of the septic tank effluent including bacterial robustness, along with other factors such as mass loading rates and sand quality.

Effluent Quality in Mound Toes Receiving Septic Tank Effluent or Aerobically Treated Effluent

J.C. Converse* and E.M. Blasing

Funding: Small Scale Waste Mgmt. Project; Wis. Dept. of Commerce

Cooperator: UW Biological Systems Engring.

A study is underway to evaluate the effluent quality at mound or modified mound toes which are saturated or out the toe drain on sites with drains. Aerobically treated effluent from advanced treatment units, single pass sand filters, and recirculating sand filters is being loaded into the mounds. Sampling of the influent to the mounds is also being done. Sampling has been completed with data analysis underway.

Lignocellulosic Filters for Solids Removal in Recirculation Aquaculture Systems

J. Malison, R.M. Rowell*, V. Byrd and A. Krzysik

Funding: USDA Forest Service; UW-Madison

The overall goal of this project is to develop lignocellulosic (wood and non-wood fiber) filters that can remove solids and can serve as replacements for conventional biofilters for recirculation

aquaculture systems (RAS). Specific objectives are:

1. Evaluate various lignocellulosic fibers for their potential to remove settleable and suspended solids;
2. Evaluate various lignocellulosic fibers for their ability to adsorb ammonia;
3. Evaluate whether the biofilter can convert ammonia to nitrate and nitrite;
4. Test selected physical and chemical modifications and manufacturing processes to improve solids retention and ammonia absorption while maintaining high hydraulic conductivity;
5. Compare the performance of selected lignocellulosic filters with conventional solids filters and biofilters in yellow perch RAS.

Laboratory studies have tested a wide range of lignocellulosics for their capacity to trap solids under conditions similar to those found in RAS (e.g., 20°C, solid particles smaller than 100µ). Lignocellulosics have been shown to efficiently trap solids. Nine water RAS will be used to compare the newly developed lignocellulosic filters with conventional biofiltration.

Assessment of Milk Quality Management for Automated Milking Technology

D.J. Reinemann*, J.M. Helgren, F.S. Denes and P.L. Ruegg

Funding: USDA-Hatch

Cooperators: UW Biological Systems Engring.; UW Dairy Sci.

The objectives of this research effort are:

1. Assess performance of robotic milking systems in Wisconsin;
2. Evaluate the economic viability of robotic milking technology;
3. Identify key management factors to apply this technology successfully.

Research efforts are also being directed at defining the need for biosensors to detect abnormal milk. The Principal Investigator also offers support to coordinate the regulatory review of robotic milking technology being conducted by the Food and Drug Administration and National Conference of Interstate Milk Shipments and serves as U.S. representative for automatic milking to the committees of the International Dairy Federation and International Standards Organization.

Development of Field Tests of Milking Performance

D.J. Reinemann*, P.A. Ruegg, G.A. Mein, M.D. Rasmussen

Cooperators: UW Biological Systems Engring.; UW Dairy Sci.; UW Sch. of Veterinary Medicine; Danish Inst. of Agric. Sciences

This international team of researchers is assembling a bulletin for publication by the International Dairy Federation to give guidelines for evaluating milking performance that can be used in the field. These guidelines are based on our previous research as well as on a comprehensive review of the scientific literature on machine milking.

Milking System Clean-in-Place (CIP) Research

D.J. Reinemann*

Funding: West Agro

Cooperator: UW Biological Systems Engring.

Research continues to evaluate the efficacy of new cleaning methods, chemicals, and compounds for milking machines. Efforts are focused on evaluating test methods for field application including rapid assessment using ATP bioluminescence and refining bulk tank culture methods to diagnose cleaning failures.

Natural Resources and Environment

Removal of Heavy Metals from Acid Mine Drainage in a National Forest

R.M. Rowell*, J. Han and D. Eustice

Funding: USDA Forest Service; Wayne National Forest

Cooperator: Wayne National Forest

The Wayne National Forest contains many old mine sites that are contaminating the area's watersheds. This contamination results from low pH and the presence of soluble heavy metal ions (Mn, Zn, Fe and Al). The Forest Products Laboratory of the USDA Forest Service has installed a filtering system to neutralize the acid and remove targeted heavy metals from the Addis mine drainage discharge using lignocellulosic fiber-based filters.

An analysis of the discharge shows that the total concentration of heavy metals is about 800 ppm with high concentrations of Fe (47 ppm), Mg (75 ppm), and Al (16 ppm). The pH of the discharge is between 2.0 and 3.1 (average 2.8) with a flow rate between 1 and 8.5 gal/min (average 2 gal/min).

The filters were installed in Spring 2002. The first set of data shows that the fiber-based filters, along with a change in pH to 5, removes more than 90% of the heavy metals. A second data set will be obtained from continuing research during 2003.

Forest By-Products as Filtering Aids for Nutrients

K.G. Karthikeyan*, M.A. Tshabalala and D. Wang

Funding: USDA Forest Service Forest Products Lab

Cooperators: UW Biological Systems Engring.; USDA Forest Service Forest Products Lab

We investigated the suitability of using modified bark or wood fiber derived from southern yellow pine to function as phosphorus (P) sorbents. The sorbent preparation process included grinding, size fractionation, extraction for surface activation, and treatment with polyalylamine hydrochloride (PAA•HCl) or 3-chloro-2-hydroxypropyltrimethylammonium chloride. Scanning electron microscopy revealed surface morphology changes of the fibers due to extraction and chemical treatment. A greater than 200% increase in nitrogen content of PAA-bark compared to con-

trol (extracted bark) together with the appearance of a strong Cl peak in the EDXA spectra of the treated bark or wood fiber provided evidence that PAA•HCl attached to the bark. The surface charge of PAA-bark was positive in the pH range 2.5-8 and turned negative at pH greater than 8. By contrast, the surface charge of untreated bark remained negative throughout the pH range 2.5-9. Percent P removal decreased with increasing P concentration, with PAA-bark having a higher sorption capacity (11.96 mg P/g fiber) than PPA-wood (7.45 mg P/g fiber). Two distinct sorption regions, corresponding to high and low affinity sites, were identified, and the batch data were described using a multi-site Langmuir model. Both sorption capacity and binding energy decreased with increasing ionic strength due to competition for the available anion exchange sites. We propose that the mechanism for P sorption involves electrostatic attraction and/or specific interactions (between surface functional groups containing quaternary ammonium groups and orthophosphate anions) and ion-exchange (between chloride and orthophosphate anions).

Interfacial Soil Chemistry of Radionuclides in the Unsaturated Zone

K.G. Karthikeyan* and S.-J. Yoon

Funding: US Dept. of Energy

Cooperators: UW Biological Systems Engring.; Pennsylvania State Univ.; Brookhaven Natl. Lab

The reaction between REDOX/PUREX tank waste streams at the Hanford Department of Energy site and the surrounding soil is complicated by dissolution of the original minerals and subsequent formation of secondary solid phases under extremely alkaline conditions. In this research, clay minerals were reacted with simulated tank waste solutions comprising high levels of hydroxide, Al, Na, and nitrate. The purpose of this study was to examine the secondary amorphous silicate phases formed after reaction with the alkaline solution within a relatively short time. To examine *in situ* the nature of amorphous neophases formed by the incorporation of silicate ions released from the parent clay mineral, we used trace amounts of germanate ions as analogs for silicate ions. The neophase structure is being determined by Ge K-edge extended X-ray absorption fine structure (EXAFS) rather than silicon K-edge EXAFS in which the silicon scattering from the neophases would be obscured by the signal from the parent clay mineral not subjected to dissolution.

Si concentration increased with reaction time, providing evidence for the dissolution of hectorite reacted with the alkaline solution. However, a corresponding increase in Mg level was not observed. This may possibly mean that either the clay mineral dissolution occurs selectively at the tetrahedral silicate layer or that the dissolved Mg is immediately incorporated to solid phase by precipitation or sorption. The concentration of Al and Ge in the alkaline solution decreased noticeably after reactions at an elevated temperature (63°C), indicating incorporation of these elements into solid phases.

The secondary solid phase formation is not extensive enough, even after 120 hr reaction at 63°C, to be noticeable by ²⁹Si NMR. However, Ge K-edge X-ray absorption near edge feature of hectorite, which has a detectable Ge content (100 mg/kg) in the original mineral, changes after reaction with alkaline solution containing germanate tracer. The different near edge features imply that the Ge incorporated into the secondary solid phases has a different chemical environment from the Ge in hectorite. The Hanford site clay material does not have a detectable Ge content but shows similar Ge K-edge X-ray absorption near edge features to that of hectorite after reaction with germanate tracer under alkaline conditions. The structure of the amorphous secondary solid phase formed after the alkaline reaction with Hanford site clay material was determined using Ge K-edge EXAFS. Ge-EXAFS results suggest the initial secondary silicate phases formed in our experiments have a low-dimensional silicate structure (around 1.5 silica coordination), and the longer reaction yields silicate phases with a high-dimensional silicate structure (around 4 silica coordination). The presence of neighboring Si atoms also confirms that germanate ions served as a good tracer for silicate ions that were dissolved from the original clay mineral and relocated in the secondary silicate phases.

Phosphorus Dynamics in Soils Receiving Chemically Treated Manure

K.G. Karthikeyan* and M. Kalbasi

Funding: Wis. Fertilizer Research Council

An incubation study was conducted with three soils (I, II and III with 12, 66 and 94 mg/kg Bray-1 P), four manure treatments (1 untreated; 3 chemically treated with alum – Al, FeCl₃ – Fe, lime – Ca), and one fertilizer treatment at two rates (mono-calcium phosphate or MCP at 12.5 and 25 mg P/kg soil). A control was left untreated. Sub-samples were analyzed for water-soluble P (WSP) and Bray-1 P after each incubation period (1 d, 1 and 2 w, 1 and 3 mo). Distribution of P among different fractions (soluble and exchangeable; Al-, Fe- and Ca-bound; org-P; residual) was determined after 1 d reaction. WSP increased when soils received MCP and untreated or Ca-treated manure with the magnitude being proportional to the rate of P applied. WSP, however, decreased compared to control for soils II and III (high Bray-1 P) or increased slightly for soil I (low Bray-1 P) with application of Al- or Fe-treated manure. WSP decreased sharply between 1 d and 1 or 2 w incubation and then remained relatively constant for up to 3 months. With respect to control, Bray-1 P increased for all treatment types and soils in proportion to the rate of P addition in the following order: MCP > Ca-treated > Al-treated ≥ untreated > Fe-treated > control. Within each treatment, Bray-1 P decreased between 1 d and 1 or 2 w and then increased gradually for up to 3 months. Adding Al- or Fe-treated manure decreased P solubility with the effect being more pronounced in soils with high background P. On the other hand, applying Ca-treated manure or MCP increased both WSP and bio-available P.

A Systems Approach to Improving Phosphorus Management on Dairy Farms

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Funding: USDA-Natl. Research Initiative

Cooperators: UW Biological Systems Engring.; US Dairy Forage Research Ctr.; UW Soil Sci.; UW Agric. Research Stations

Interest in using corn silage is growing due to changes in animal farm dynamics and favorable economics compared to alfalfa. The extent of residue cover influences runoff and soil losses, and hence this practice will affect off-site phosphorus (P) migration. Since high-cut silage increases residue cover, this method could minimize water quality degradation that would otherwise result from harvesting corn for silage. We examined cropping system effects on sediment and P losses from no-till corn fields on a Plano silt loam soil at the Agricultural Research Station in Arlington. Treatments included conventional corn grain (CG) and low-cut corn silage (CS-L, 8 in.) and non-conventional high-cut silage (CS-H, 27 in.) Each treatment received one of three manure treatments: no manure, spring application, fall application. Simulated rainfall experiments (7.5 cm/hr for 1 hr) were performed, runoff from 1.5 × 2.0 m plots was collected, and a sub-sample was analyzed for total sediments, dissolved reactive phosphorus (DRP), and total phosphorus (TP). Within each treatment, timing of manure application had a significant effect on sediment load, DRP concentration, and TP load but had no effect on TP concentration. No trend for DRP load was observed. If manure was applied in spring, sediment load decreased by 80, 92 and 94% for CG, CS-H and CS-L, respectively, compared to no manure treatment. Fall applied manure produced smaller reductions in sediment load: 51, 54 and 69%, respectively. DRP concentration from all crop treatments were 5 times greater after spring manure application compared to no manure treatment. Plots with manure applied in the fall showed a smaller increase in DRP concentration. TP loads were highest when no manure was applied, intermediate with fall manure application, and lowest following spring application. These trends reflect the lower runoff volumes due to manure acting as a mulch layer.

Quantifying Phosphorus Losses from Agricultural Fields

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Funding: USDA-Natl. Integrated Water Quality Program, Integrated Research, Education and Extension Applications

Cooperators: UW Biological Systems Engring.; UW Soil Sci.; UW Space Sciences & Engring. Research Ctr.; UW Agric. and Appl. Economics; Wis. Discovery Farms Program

The goal of this research is to use a process-level model to quantify phosphorus (P) loss from farm fields under different management options and then to extend use of this model so as to recommend practices that minimize water quality degradation. The idea is to add sediment loss and P-chemistry components to

an existing Precision Agricultural-Landscape Modeling System (PALMS), evaluate key runoff parameters with measurements on several field plots, test the model over the entire sub-watershed using U.S. Geological Survey (USGS) stream monitoring data, test simple P-Index approaches for use by regulators and extension agents, and implement a new outreach strategy to combine the expertise of researchers, extension faculty, county extension agents, and agricultural consultants to implement best management practices using PALMS as a vehicle. The selected watershed is known to be subject to large P losses from USGS stream monitoring (0.5 mg P/L) and is a Wisconsin Discovery Farm, one of 30 such farms chosen from a pool of volunteer farmers to represent standard farming practices and to serve as a focus for research that will maintain profitability while improving environmental health. Therefore, this study will benefit directly from the Discovery Farm infrastructure, and results will be directly transferable to other Discovery Farms. Selected farms in Minnesota and Iowa will also be involved. PALMS will be used to do an economic analysis on three strategies to improve the sub-watershed by reducing P losses. Then one of the scenarios will be implemented, and monitoring data should reveal its efficacy.

Masuring and Modeling the Source, Transport and Bio-availability of Phosphorus in Agricultural Watersheds

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Funding: US Environmental Protection Agency (STA Program)- Nutrient Sci. for Improved Watershed Mgmt. Program

We will measure and model the sources, transport, and fate of bio-available phosphorus (BAP) in the mostly agricultural 604-km² watershed of Lake Mendota near Madison. This well-known eutrophic lake is affected by P loading from agricultural sources such as row crops, dairy operations, and land application of manure and commercial fertilizer. The research will complement an on-going non-point pollution abatement program to reduce P inputs to the lake through improved management of these agricultural sources. Our multi-disciplinary team provides the expertise in social science, outreach, environmental modeling, environmental chemistry, hydrology and sediment transport, environmental engineering, and limnology B – all of which are needed to accomplish our "systems" goals. Our focus is on the scale-dependent processes that link agricultural sources of P to watershed export of BAP. We have six major objectives.

1. Quantify the effects of manure management on BAP runoff.
2. Measure the amounts and spatial patterns of sediment and BAP in channels and streams acting as routes for transport through the watershed.
3. Clarify and quantify the in-stream processes governing the fate and transport of sediment P.
4. Evaluate and improve modeling tools (APEX, SWAT) for assessing P transport over a wide range of spatial scales.
5. Determine the relation of BAP losses to the scale of animal operations.
6. Integrate outreach with stakeholders, agency partners, and

other researchers through farmer-feedback procedures, agency assessments, and model refinement.

Knowledge gained will be crucial for effective state and national TMDL development and implementation.

Organic Solids and Phosphorus Removal from Animal Manure Using Chemical Treatment

K.G. Karthikeyan*, M. Kalbasi, K. Gungor and M.Z. Tekeste

Funding: USDA-CSREES Hatch

Treating dairy manure with lime (CaO), alum (Al₂(SO₄)₃), and ferric chloride (FeCl₃) can achieve good solid-liquid separation and can concentrate P in the solid phase. Batch level jar tests conducted on dairy manure containing 0.8% (low) and 1.6% (high) total solids (TS) indicate that very high removal (>90%) of dissolved reactive P (DRP), total dissolved P (TDP), and total P (TP) can be achieved with chemical addition. In the absence of coagulants, 43% of TP and 30% of TS were removed by gravity settling. Treatment performance varied with chemical type, dosage rate, and initial manure solids concentration. FeCl₃ and alum were similar in efficiency in concentrating P and solids from manure slurry (at the low TS level). A trend for P removal was observed as a function of chemical dosage: a sharp increase initially at low dosages (up to 4 mM as Al or Fe), followed by decreasing rates at intermediate dosages before leveling off between 80 and 100% removal. At 8 mM as Al dosage rate for low TS level, alum reduced solution DRP, TDP, and TP levels by 99, 92 and 92%, respectively. The corresponding values at high TS were 85, 86 and 89% for DRP, TDP and TP, respectively. The addition of FeCl₃ can achieve complete removal of all P forms from solution for the low TS manure at 12 mM as Fe. For high TS, the maximum DRP and TDP removal was 98 and 93%, respectively, at 20 mM dosage, and the corresponding value for TP was 72% at 16 mM. At the higher initial manure solids level, alum seems to be more effective in concentrating P in the solid phase than FeCl₃. Lime addition was more effective in concentrating DRP compared to the other P forms. At 40 mM as Ca dosage, lime removed 96, 70 and 69% of DRP, TDP and TP, respectively, for low total solids. Compared to alum and FeCl₃, lime was less effective for TDP and TP. This is especially true for TP. For example, at high initial TS, 20 mM as Al of alum removed twice as much TP as obtained using 80 mM as Ca of lime. Manure solids concentration significantly affected TP and TDP removal by lime addition. On the other hand, DRP removal was not influenced by the increase in manure solids concentration. Percent solids (TS) removal increased sharply at low alum and FeCl₃ dosages and leveled off at higher dosages. Maximum TS removal achieved by adding alum and FeCl₃ was 79 and 77% (low TS) and 65 and 70% (high TS), respectively. Lime also was effective in removing solids and, in fact, was more effective than alum and FeCl₃ at low dosages (<10 mM as Al/Fe/Ca), especially at the higher manure TS level. This trend between coagulants is opposite to that observed for TP, which may be attributed to differences in removal mechanisms for P and solids.

Occurrence of Antibiotics in Wastewater Effluents and their Mobility in Soils: A Case Study for Wisconsin

K.G. Karthikeyan*, W.F. Bleam and C. Gu

Funding: Wis. Dept. of Natural Resources; Wis. Dept. of Agric., Trade, and Consumer Protection

Cooperators: UW Biological Systems Engring.; UW Soil Sci.

Wastewater samples were collected from several locations in Wisconsin that were selected based on differences in treatment method, size of community served by the facility, receiving water body impacted by effluent discharge, and geographical location. Samples influent to and effluent from the secondary treatment systems (e.g., activated sludge, oxidation ditch) were collected from wastewater treatment facilities in Green Bay and Oshkosh (activated sludge treatment, surface water dischargers), Lake Geneva (oxidation ditch, groundwater discharger), Barron-Cameron, Hayward and Spooner (aerated lagoons and seepage cells, groundwater dischargers), and Middle River Health Care (oxidation ditch, surface water discharger). In addition, samples from three LaCrosse water supply wells were obtained. Wastewater and water samples were centrifuged and filtered through a 0.45 µm membrane filter. A USGS lab then analyzed them for 25 antibiotics. Eight antibiotic compounds were detected: three sulfonamides (sulfamethazine, soluble concentrations 0.05-0.21 µg/L; sulfamethoxazole, 0.01-0.5 µg/L; sulfadimethoxine, 0.01 µg/L), two tetracyclines (tetracycline, 0.23-4 µg/L; chlortetracycline, 0.02-1.2 µg/L), a fluoroquinolone (ciprofloxacin, 0.04-0.05 µg/L), one macrolide (erythromycin, 0.11-0.38 µg/L), and trimethoprim (0.01-0.55 µg/L). Preliminary results indicate that the activated sludge secondary treatment process can reduce concentration of antibiotics in the soluble phase. Samples from the LaCrosse wells had no measurable quantities of target antibiotics in the dissolved phase. We are currently performing bench-scale lab experiments to study the sorption behavior of ciprofloxacin and tetracycline to environmental sorbents such as Al and Fe hydroxides and humic substances. Using radio-labeled versions of these two antibiotics (2-¹⁴C-ciprofloxacin and 7-³H-tetracycline) we will quantify the extent of transformation occurring in the presence and absence of these sorbents.

Structures / Construction

Engineering Properties of Connections with Multi-Type Fasteners

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Funding: UW Biological Systems Engring.; Wis. Frame Builders Assn.; Walters Building Systems

The National Design Specifications for Wood Construction requires that design values for mixed fastener connections be based on tests or other analysis. This poses a problem for many post-frame building designers who have traditionally featured a combination of nails and bolts in their post-to-truss connections.

The goal of this study is to develop design methodology for connections featuring both nails and bolts. The approach involves a combination of laboratory testing and theoretical development. The latter will investigate yield theory equations for mixed fastener connections.

Laboratory testing began in December 2002 and involves double shear connection tests. A third of the specimens are nail-only joints, one-third are bolt-only joints, and the remaining third features both nails and bolts. Each test specimen consists of three 9.25- by 9.25-inch blocks (a main member and two side members) cut from nominal 2- by 10-inch diameter lumber. Four different test configurations are obtained by orienting the grain of the side and main members either perpendicular or parallel to the direction of applied load. All three configurations are being tested (per-per, par-par and par-per). This is not typical. Most connection studies only feature per-per or par-par tests (i.e., the grain of both side and main members run in the same direction – either perpendicular or parallel to the loading direction). In post-to-truss connections, however, members are perpendicular to each other. Consequently, connection tests in which the grain of the side and main members are perpendicular to each other are actually more appropriate for this experiment.

To study the influence of specific gravity on connection behavior, three different species of lumber were used to fabricate specimens: Southern Pine, Douglas Fir and Spruce-Pine-Fir.

Testing will be completed during the spring of 2003 with data analysis to follow.

Accuracy of Corrugated Metal Panel and Trim Installation

D.R. Bohnhoff*

Funding: UW Biological Systems Engring.; Natl. Frame Builders Assn.

In 1999, the National Frame Builders Association (NFBA) published *Accepted Practices for Post-Frame Building Construction: Framing Tolerances*. In preparing this document, UW-Madison researchers conducted an extensive field investigation to determine just how accurately post-frame building frames are constructed.

This framing tolerances document is intended as the first in a series on post-frame building construction. The Technology and Research (T&R) Committee of NFBA is now pushing for development of a second document focusing on installing corrugated metal panels and trim. As with the previous construction tolerances document, a field study must first be conducted to find out exactly how accurately such trim and panels are installed. As before, UW-researchers will conduct this field investigation.

The specifics of what data should be collected was largely established at the NFBA T&R Committee Meeting held during the 2002 International ASAE Meeting in Chicago. The Committee specifically identified the following: (1) panel plumbness; (2) roof-to-wall rib alignment; (3) misalignment of panel ends (e.g., saw-tooth effect); (4) size, number and location of dings/scratches; (5) number and location of panel crimps/kinks; (6) panel fit around openings; (7) number and location of fasteners that miss purlins/girts; (8) fastener alignment; and (9) number and location of over- and under-driven fasteners, irregular fastener patterns, and alignment of corner trim with panels.

The current goal of this research is to take measurements on about 50 different buildings during 2003, with no two surveyed buildings erected by the same crew.

Effect of Mechanically-Attached Face Plates on Strong Axis Bending of Posts

D.R. Bohnhoff* and M.H. Gadani

Funding: *UW Biological Systems Engring.*

Despite research demonstrating significant interlayer slip when mechanically-laminated assemblies are bent about an axis parallel to interlayer planes, it appears most practicing engineers still assume complete composite action when designing the assemblies. This statement is based on a review of structural calculations for post-frame buildings containing 3- or 4-layer vertically, mechanically-laminated posts to which face plates have been attached. A vertically-laminated post is designed to resist bending about an axis perpendicular to interlayer planes (i.e., about axis Y-Y). When a face plate is mechanically attached (i.e., nailed, screwed, etc.) to a vertically-laminated assembly, the plane of contact between the face plate and the rest of the assembly is parallel to the primary bending axis Y-Y and will be characterized by measurable interlayer slip when the assembly is bent about axis Y-Y.

Face plates are added to vertically, mechanically-laminated posts for three reasons.

1. Face plates increase uni-axial bending capacity about axis Y-Y where girts or similar bracing cannot be used or are spaced too far apart. Like girts, face plates keep individual laminations from buckling when the assembly is bent about axis Y-Y.
2. Face plates are added in bi-axial bending situations to significantly increase bending strength and stiffness about axis X-X.
3. Face plates can significantly increase a post's axial compressive strength by adding cross-sectional area in addition to decreasing buckling potential about axis X-X.

Without a face plate, the moment of inertia about axis Y-Y for a mechanically-laminated assembly is assumed to be no different from that of a solid-sawn member with the same outer dimensions. This assumption is good when:

1. All layers are approximately equal in size and stiffness;
2. There are no abrupt discontinuities in the individual layers;
3. The load is applied to all layers.

The concern is that when a face plate is attached to the assembly using nails, many engineers also treat the enlarged assembly as a solid-sawn component when calculating moment of inertia about axis Y-Y. This assumes complete composite action (and ignores interlayer slip) between the face plate and the rest of the assembly, resulting in an overestimation of assembly stiffness and underestimation of bending stresses. Because this assumption is made so often, it is important to quantify the effect of interlayer shear stiffness on assembly bending properties.

A series of lab tests and finite element analyses were conducted to quantify the effect of face plate fastener stiffness (i.e., interlayer shear stiffness) on post bending stress and stiffness. Selected for analysis were 4.5- by 5.5-inch and 4.5- by 9.25-inch posts with 5.5- by 1.5-inch face plates. This research showed that composite action between a post and a mechanically-attached face plate decreases with increases in post moment of inertia, simultaneous increases in post and face plate MOE, decreases in interlayer shear stiffness, and decreases in post length.

In addition, post end fixity significantly affects composite action, and adding a face plate with a measurably lower MOE than that of the post will only minimally reduce post bending stresses and displacements. Regardless of boundary conditions, if a face plate is attached with typical nails and individual nails are spaced no closer than one-foot on-center, post bending stress and post displacements will generally not be reduced by more than a few percent.

Lateral Load Distribution in a Metal-Clad Wood-Frame Building

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Funding: *USDA Hatch; USDA Natl. Research Initiative; UW Biological Systems Engring.; UW Graduate Sch.; Lester Building Systems*

This project involves constructing and testing a full-scale, metal-clad, post-frame building with the goal of gaining a better understanding of the complex distribution of load in this popular agricultural building system. The building was erected, instrumentation was installed, and initial tests were conducted in 2001. Research in 2002 was dedicated to testing and analysis of data.

As constructed, the building is 40 by 200 ft. Trusses are on 10-ft centers resulting in 20 bays. Trusses are pin-connected to posts, which, in turn, are pin-connected to concrete piers. Centered under each interior truss is a hydraulic frame loader (HFL) that is attached by rods to each end of the truss. An HFL can be set to operate in one of four modes: (1) north load, (2) south load, (3) lock, or (4) float. Although there are no HFLs under the endwall trusses, the endwall trusses can be either locked in place or allowed to float during a test.

Incorporating the ability to lock a frame, float a frame, or load a frame in either direction enables a tremendous variety of load configurations. This has several advantages.

1. Hysteresis effects associated with reverse loadings, permanent deformation, and creep can be explored.
2. The effects of reverse loading on an asymmetric building (e.g., a building with one open and one closed sidewall) can be investigated.
3. Variability in chord forces due to construction and strain gage accuracy can be isolated by comparing forces in chords on opposite sides of the building under opposing loads.
4. Long buildings can be loaded so that they behave as a series of short buildings.
5. Simple beam diaphragm panel tests can be closely simulated by locking every other frame and loading every other locked frame in the opposite direction.
6. Torque loadings that induce high sidewall shears can be investigated by locking the middle frame and loading frames on opposite ends of the building in opposite directions.
7. Two point loadings applied at different locations can be used to establish effective shear and bending stiffness properties of the diaphragm.

Using the versatility of the HFLs, 22 different loadings were applied to each of 10 different building configurations. Different

building configurations were obtained by adding and removing the ridge, chord reinforcing hardware, roof-to-sidewall fasteners, roof panel stitch screws, sidewall steel, and eave trim. This experimental design was replicated twice for a total of 440 building tests in 2002. During each test (which lasted several minutes), signals from 225 different transducers were recorded every 5 seconds.

Analysis of the tremendous amount of data collected from the full-scale building tests is on-going. Although this analysis is unlikely to be completed until some time in 2004, it is apparent from work to date that this research will result in the recommendation of major changes to ASAE EP 486, the current diaphragm design standard for metal-clad wood-frame buildings, and to ASAE EP 558, the current test procedure for metal-clad wood-frame diaphragms.

***In situ* Hydration of Dry Concrete Mix**

D.R. Bohnhoff*, D.W. Kammel, Z.D. Hartjes and N.P. Ryan
Funding: UW Biological Systems Engring.; Wis. Frame Builders Assn.

Through the years, many post-frame builders have placed dry concrete mixes into post holes and then backfilled the holes without adding water to the dry concrete mix (i.e., without hydrating). When placed in this fashion, it is assumed that water in the soil permeates into the mix, hydrating and growing cement particles to form a consolidated mass of concrete. Hydration of a dry concrete mix after the mix has been covered with soil is herein referred to as "*in situ* hydration".

In situ hydration was first used to form entire post footings. Such reliance on *in situ* hydration was largely restricted to smaller agricultural and other non-commercial buildings. As average post-frame building size increased and engineering became more advanced, forming post footings entirely out of non-hydrated concrete mix was phased out. Today, *in situ* hydration is essentially only used to form above-footing collars as part of a post uplift resistance system and under precast concrete footing pads to increase the size of the footing. When used under a precast concrete pad, concrete hydrated *in situ* need only have a compressive strength equal to the pressure at the bottom of the precast footing. Generally this is a relatively low pressure and one that a confined concrete dry mix may have prior to being hydrated. It is important to note that whereas infiltration of water into a soil mass reduces the bearing capacity of the soil mass, such infiltration will increase the bearing capacity of a dry concrete mix.

Relying on *in situ* hydration has several advantages.

1. Concrete gets used in small portions as needed, whereas truck deliveries of concrete would require simultaneous placement of all footings/collars.
2. Water is not required on-site.
3. Cold weather is a non-factor.
4. Time associated with clean concrete mixing and placement is eliminated.
5. Planning is easier; the construction schedule is not dictated by concrete delivery.

Although *in situ* hydration has been "practiced" for well

over a quarter of a century in Wisconsin, it is only allowed in the construction of agricultural and other code-exempt structures. Before Wisconsin code officials will allow use of concrete hydrated *in situ* in code buildings, its properties must be quantified, and guidelines/procedures for placement of concrete dry mixes must be established.

In 2001, as a first step in investigating the degree to which a dry concrete mix hydrates *in situ*, UW-Madison researchers conducted a field study of compression tests on cores removed from concrete collars hydrated *in situ* for less than a month. Since the average strength of these cores exceeded a respectable 2000 psi, a decision was made to conduct a more controlled laboratory study.

During the summer of 2002, six 300-gallon livestock tanks were filled with sand meeting requirements of ASTM C33. Buried in each tank were nine cylinders of dry concrete mix. Each cylinder was approximately 12 inches in diameter and 5.5 to 6 inches thick. The cylinders in each tank were buried at three different depths. Tanks were paired off and each pair was subjected to a different water treatment. Moisture was monitored at four depths in each tank using Echo moisture probes. Three cylinders were removed from each tank after being in place one month. Three more were removed after three months, and the last three were removed after being in place six months. As soon as the cylinders were removed, they were cored, and the cores were immediately capped and tested.

Analysis of the results of this study are on-going and will be presented at the 2003 ASAE International Meeting.

***S*team Stabilization of Aspen Fiberboards**

R.M. Rowell*, S. Lange and M. Davis
Funding: USDA Forest Service

Many techniques have been used over the years to dimensionally stabilize wood fiber composites against the swelling forces imparted when the fiber is compressed during fiberboard formation and when the fiber sorbs moisture after board formation. When a compressed fiber sorbs moisture, not only does reversible swelling take place (normal swelling of the fibers resulting from sorption of moisture), but the compressive forces imparted when the fibers are crushed in the board upon pressing (irreversible swelling) are relieved due to recovery of the original configuration through a cell wall memory.

Applying high temperature steam during fiberboard pressing, and cooling fiberboard while still under pressure, can greatly increase its dimensional stability. After pressing for four minutes at 200°C under steam pressure, aspen fiberboard showed less than 10% thickness swelling after a two-hour water soak as compared to more than 40% for non-steamed fiberboard. The stabilized boards were re-fiberized and a phenolic resin was added. The fibers were then hand formed into a mat and pressed into fiberboard again. Swelling in water of these phenolic-bonded boards was about the same as boards with no adhesive, but strength properties improved when the adhesive was used.

Effect of Absenteeism and Turnover on Labor Productivity for Electrical Contractors

A.S. Hanna*

Funding: *Electrical Contracting Foundation*

In the 1980s, the construction industry had one of the worst productivity problems in the nation. It was the only industry with consistently negative production growth. Absenteeism is still neglected, both during labor negotiations and by researchers, and remains a serious problem.

Absentee rates in the electrical construction industry have been reported as high as 20% on some projects. The associated costs are considerable and are passed on to consumers. Some managerial steps can reduce the absentee rate, e.g., limiting the number of paid days off and giving benefits to those with better attendance records. Such practices, however, have not solved this problem or its effects. Productivity for electrical contractors still suffers, and little has been done even to address absenteeism, and research is needed on how to mitigate its effects.

We have two major objectives for this project.

1. Quantify the effects of absenteeism on labor productivity.
2. Offer a solution to reduce the impact of absenteeism on labor productivity.

To achieve these, we will collect productivity data and attendance records to analyze temporal trends and possible correlations.

Quantifying Productivity Losses for Electrical/Mechanical Contractors

A.S. Hanna*

Funding: *Electrical Contracting Foundation; Mechanical Contractors Assn. of America*

The purpose of this research is to develop an overall study to quantify the impact of certain productivity factors on labor efficiency similar to *Bulletin PD 2* developed by the Mechanical Contractors Association of America (MCAA). *Bulletin PD 2* lists 16 causes of productivity loss and the anticipated percentage of loss when the conditions are minor, average, and severe. The origin of the percentages is unknown and unsupported by industry data. Several court cases have rejected the use of MCAA *Bulletin PD 2* because of lack of data supporting the productivity loss values.

The second purpose of this study is to develop a "how to" manual that addresses causes of productivity losses and anticipated percentage of loss when conditions are minor, average, and severe. This study is also intended to be used in association with the National Electrical Contractors Association publication 5071, *The Effect of Multistory Buildings on Productivity* (1975) which describes the impact of weather, congestion, material shortage and distribution, supervision, and tools.

Once all productivity loss factors have been identified and matched with the corresponding activities, the total labor hour requirement is given by:

$$\Sigma[(\text{unimpacted work hours}) + (1 + \text{research factors}) \times \text{impacted work hours}].$$

Cost Effectiveness of Innovative Crew Scheduling

A.S. Hanna*

Funding: *Construction Industry Inst.*

Contractors and owners have several crew scheduling options when they need to complete a project on time or to compress or accelerate a schedule. Among these options are overtime, shift work, rolling or straight 4 10-hr days, staggered 7 10-hr days, and variable length shifts. Many owners and contractors currently use several of these scheduling methods with or without understanding the full impact on project outcomes. There are adequate studies about the impact of scheduled overtime on labor productivity, but information about the effect of innovative scheduling techniques on labor efficiency is limited.

This study has qualitative and quantitative elements. The objective of the qualitative element is to develop a document that details best practices and suitable use of innovative scheduling techniques in terms of when to apply, conditions for successful application, and cost implications including potential productivity losses and safety concerns. The objective of the quantitative element is to quantify the impact of innovative scheduling techniques on labor productivity and project performance in terms of cost and schedule.

This research will focus on shift work, rolling and straight 4 10-hr days, staggered 7 10-hr days, variable length shifts, and other innovative scheduling techniques proposed by the research team. Cost impact of the techniques will also be investigated.

This work involves setting several research hypotheses and collecting data from contractors and owners in several geographical regions. Research hypotheses include issues such as whether a rolling 4 10-hr day is as cost-effective and productive as a 40-hr week. Data collection requires the development of a data collection form which will be sent to several contracting and owner organizations across the country. Statistical methods will be used to develop models used by the construction industry to quantify the cost impact of innovative scheduling techniques.

Quantifying Impact of Mechanical and Electrical Changes

A.S. Hanna* and J.S. Russell

Funding: *Construction Industry Inst.*

Changes during construction occur on most construction jobs. Traditional methods of estimating the impact of changes have typically yielded erroneous results. The material cost of a change is easily quantified. The difference in labor required for the changed work as compared to the original work is theoretically quantifiable, but the results are often wrong when compared to the actual labor required on even the best managed jobs. This may lead to the application of "factors" that can be accurate but often are neither accurate nor rational as the situation changes. These factors are rarely explainable or understandable. Some previous research has tried to determine the impact of different variables on the overall impact of the change.

The Mechanical Contractors Foundation and the Electrical Contracting Foundation, the research arms of the Mechanical Contractors Association of America (MCAA) and the National Electrical Contractors Association (NECA), began a study of the impact of change orders on labor productivity in 1997. It was contracted to the University of Wisconsin. To date, more than 50 projects are in the database for each industry, and a preliminary methodology has been determined and tested for evaluating the data. Construction Industry Institute (CII) staff have met with the researchers and the representatives of MCAA and the Electrical Contracting Foundation. These two organizations have agreed to fund the research contract if CII agrees to coordinate oversight of the project and to form a joint research team of about 8 CII members, 4 MCAA members, and 4 NECA members.

The development of a rational method for determining the impact of changes during construction on labor productivity will yield more accurate estimates of total actual impact of mechanical and electrical changes. Our objective is to increase the accuracy of estimating the actual impact of mechanical and electrical changes on labor estimates for these trades.

The study will focus on the impact of changes on labor productivity. The scope will be limited to projects located in North America. The focus will be on the mechanical and electrical trades. Both commercial and industrial projects will be studied.

Safety and Health

Implementation of the National Occupational Research Agenda

L.J. Chapman*, A.C. Newenhouse, M.G. Miquelon and K.G. Josefsson

Funding: US Centers for Disease Control and Prevention; Natl. Inst. for Occupational Safety and Health

Cooperators: UW Biological Systems Engring.; various Wis. grower and dairy organizations; UW Cooperative Extension Service

This project will evaluate the effectiveness of two production agriculture interventions that seek to reduce traumatic and musculoskeletal injuries. We will build on two on-going efforts: an intervention among dairy producers now completing its fourth year and an intervention with fresh market vegetable growers now completing its third year. We have three specific aims.

1. Continue the interventions for two more years. We will reduce hazards and thereby injuries by encouraging Wisconsin dairy producers and vegetable growers in a 4-state region (WI, IA, MI, MN) to adopt safer and more profitable production methods through a specially-designed information dissemination effort via print media, public events, university extension, the Internet, and other channels that producers and growers already use to gather information about new production methods. We began to continue the interventions in the first year of this application (Mar00).
2. Evaluate the effectiveness of the interventions. We will refine and continue for two additional years a number of process evaluation methods and annual mailed questionnaires that are largely outcome evaluation methods. We will continue to mail these

questionnaires to separate, population-based probability samples from each study group (dairy n=1200/yr, vegetable n=300/yr) and to controls (300 Maryland dairy farmers, 50 strawberry growers) to determine: a) if our materials are reaching and being received well by the target audiences; b) if farmer adoption or awareness of each innovation or perception of relative safety or profit advantages are changing; c) if farmer-reported injuries or musculoskeletal discomfort associated with the innovations are changing. We will also solicit farmer perceptions about barriers to adopting the innovations we have been promoting and about how to make our intervention effort more persuasive. We will evaluate each of the two additional intervention years (Feb01, Feb02).

3. Add new production method innovations to each intervention. We will seek out farmer reports about production method innovations that could improve both safety and profits, and then study and quantitatively evaluate hazard-reducing and profit-enhancing aspects of the best candidates. We will then develop materials and a promotion plan for one or more innovations that can be added to each of the two on-going intervention efforts each year. We began this work at the start of the project (Sept99).

Wisconsin Dairy Traumatic Occupational Injury Intervention

L.J. Chapman*, A.C. Newenhouse, K.G. Josefsson and M.G. Miquelon

Funding: US Centers for Disease Control and Prevention; Natl. Inst. for Occupational Safety and Health

Cooperators: UW Biological Systems Engring.; various Wis. grower and dairy organizations; UW Cooperative Extension Service

This project will implement and evaluate the effectiveness of an intervention in the workplace intended to prevent and reduce traumatic agricultural injuries. We will build on our on-going intervention among the 21,000 Wisconsin dairy operations that constitute 20% of the nation's operations and employ more than 73,500 workers. Our intervention strategy will encourage adoption of production practices that are more profitable as well as safer. The work methods and equipment used in each dairy operation largely determine what hazards workers are exposed to. The operation's manager largely determines the work methods and equipment used. Our intervention improves information flow to managers to persuade them to adopt certain production methods that maintain profitability as well as improve safety, thereby reducing traumatic injuries. In this application, we have three specific aims.

1. Continue for three more years an information-dissemination intervention among Wisconsin dairy producers that will reduce traumatic injuries by persuading operation managers to adopt safer and more efficient work methods. We will reduce hazards and thereby injuries by improving information flow to operation managers to persuade them to adopt production methods that are both safer and more profitable. We will continue this theory-based intervention with a specially-designed information dissemination effort using sources that dairy producers already rely on

for information about new production methods (e.g., other farmers, print media, public events, university extension, other private and public sector resource people, and the Internet).

2. Conduct annual, large-sample, mailed questionnaire-based scientific evaluation of the information dissemination intervention that includes both process and outcome measures. We plan to refine and continue, for three more years, to administer mailed questionnaires that tap both process and outcome measures to separate, rolling, population-based probability samples of the study group (n=800/yr) and a control group (n=400 Maryland farmers). We intend to determine: a) if our materials are reaching the target audience and which intervention aspects are most effective, and b) whether producer adoption and awareness of each production method have increased. We will collect information about injuries, barriers to adopting the production methods, and how to make our intervention effort more persuasive.
3. Add one or two traumatic injury-reducing production methods to the intervention in each of the three additional intervention years. We will seek out reports from farmers and others about emerging production methods that may improve safety and profits. We will evaluate hazard-reducing and profit-enhancing aspects of the best production methods. We will add one or more of these new production methods with the clearest labor-saving and injury reducing advantages to the intervention to promote statewide.

Community Partners for Healthy Farming Specialty Growers Intervention Project

L.J. Chapman*, A.C. Newenhouse, M.G. Miquelon and K.G. Josefsson

Funding: US Centers for Disease Control and Prevention; Natl. Inst. for Occupational Safety and Health

Cooperators: UW Biological Systems Engring.; various Wis. grower and dairy organizations; UW Cooperative Extension Service

We will conduct and evaluate an intervention to reduce or prevent work-related injuries and diseases in farm workers, farm owner-operators, and their families. This proposal describes an effort to reduce musculoskeletal, traumatic injury, and other job-related problems among small scale, labor-intensive growers of tame blueberries, strawberries, raspberries, and other berries across a 4-state region. We have three specific aims.

1. Learn what berry growers have done to create a safer and, at the same time, more profitable workplace in Wisconsin and other north central states (MI, MN, IA). Also, search out relevant technologies and management practices used elsewhere in the US and abroad. Then, in collaboration with a subset of berry growers and grower resource people, identify, select, and study with quantitative methods a few (n=3 to 6) especially promising production methods that have the potential to improve both safety and profitability and that can form the basis of the intervention. We intend to complete most of this work in the first year.
2. Conduct a region-wide intervention to convince berry growers in the four states (n=2300) to adopt a few promising (safer and

more efficient) production methods with an information dissemination effort via print media, public events, university extension, the Internet, and other information channels that growers already use to gather information about new production methods. Begin the intervention in the first year.

3. Evaluate the intervention with process and outcome measures including an annual, population-based, probability sample mailed questionnaire (n=200 to 250) to determine: a) if the materials are reaching and are being well-received by the target audience; b) if grower adoption, awareness, and perceptions of relative safety or profit advantages associated with the innovations are changing; and c) if grower-reported injuries or musculoskeletal discomfort associated with the innovations are changing. Evaluate each year of the three intervention years.

Changing Demographics of Dairy Producers: Needs Assessment for Safety and Health Management Strategies

M.A. Purschwitz*

Funding: US Centers for Disease Control and Prevention; Natl. Inst. for Occupational Safety and Health (through Midwest Ctr. for Agric. Research, Education, and Disease and Injury Prevention)

Cooperators: UW Biological Systems Engring.; Professional Dairy Producers of Wis.; Natl. Farm Medicine Ctr.

The aim of this project is to determine the needs of progressive dairy farms for agricultural safety and health management strategies as these farms increase in size and managerial and technological complexity. A large group of dairy producers was surveyed.

A total of 342 surveys have been and continue to be analyzed. Regarding demographics, 80% of respondents were under 50 years old and more than 82% had herds of 100 cows or more. Almost 61% plan to expand their herds during the next one to five years. About 60% had 6 or more employees, meaning that under Wisconsin law they are required to carry workers compensation insurance, yet only 49% indicated they had it. More than 69% had fewer than 11 employees, so they were not subject to OSHA enforcement. About 46% had breeding bulls on their farms.

Regarding indicated safety needs: 52% of respondents indicated a need for information on developing an employee safety program; 50% need example policies and/or material for employee manuals; 44% need a farm inspection guide; 43% need safety training videos; 37% need training guides or lesson plans on safety; 34% need information on controlling or eliminating hazards; and 33% need train-the-trainer programs. Spanish-language materials were desired by 52% of respondents.

Regarding preferred (not ranked) sources of information, county extension offices were selected by 66% of respondents, farm media by 59%, Internet by 36%, private consultants by 21%, and commercial companies by 15%.

Only 21% of respondents indicated there was no barrier or hindrance to safety training or improvements. Time as a barrier/hindrance was selected by 45% of respondents; knowledge by 29%; lack of money by 28%, and language/translation by 24%.

Food Engineering and Processing

A Novel Plasma-Enhanced Way to Deposit Diamond-Hard Carbon Thin Layers under Atmospheric-Pressure and Room-Temperature Environments

F.S. Denes*, S.O. Manolache and L.E. Cruz-Barba

Funding: UW Biological Systems Engring.; UW Ctr. for Plasma-Aided Manufacturing

Our recent experimental results prove that predeposited high molecular weight C-, H- and O-, C- and H-based polymer thin layers, and even surface layers of similar solid-state polymeric substrates are converted under SF_x and hydrogen atom and proton generated SF₆ and H₂ plasma environments into "diamond-hard" carbon layers at low or atmospheric pressure conditions and room temperature during plasma-conversion times as short as 2 to 4 minutes. These findings open up a very attractive, novel way to synthesize scratch- and wear-resistant large-area surfaces with applications in the fields of advanced biosensors and bioactive materials.

Immobilization of Active Biomolecules (e.g., Enzymes) on Plasma-Functionalized Organic and Inorganic Substrate Surfaces to Design and Develop Biosensors with Applications in Food Processing Industries

F.S. Denes*, S.O. Manolache, A.J. Martinez and L.E. Cruz-Barba

Funding: USDA Natl. Integrated Food Safety Initiative Award; Robert Draper Technol. Innovation Fund; Fulbright Award; Natl. Sci. Foundation Int. Collaboration Award (UW and Univ. of Guadalajara); Motorola Funds

Cooperators: UW Forest Ecology and Mgmt.; UW Sch. of Human Ecology; Univ. of Guadalajara

Low- and atmospheric-pressure, non-equilibrium H₂-, SF₆-, NH₂-NH₂-, SiCl₂-, and SiH₂Cl₂-, hydrazine-, radio frequency-plasma techniques were combined with gas-phase, one- and multi-step, *in situ* dry-chemistry reaction mechanisms for surface functionalization of several polymers including polyethylene, cellophane, glass, silicon, and silica. Active α -chymotrypsin, papain, and horseradish peroxidase were immobilized onto the plasma-exposed surfaces. Continuous wave and modulated radio frequency-plasma reactions were used for functionalization of inorganic and organic macromolecular substrates.

It was shown that regardless of the nature of the polymeric (natural and synthetic) substrates, properly selected plasma environments offer a very efficient, dry-chemistry way for functionalization and subsequent wet-chemistry immobilization of various enzymes. It was also shown that the lengths of the spacer chain molecules (the relative distance of an enzyme to a carrier) play a significant role in the activity of immobilized enzymes and probably specific optimal surface densities and that the distances between enzymes and substrates are required for each enzyme/carrier system. The immobilized enzymes are stable; they retain most of their activities after several washing/assay cycles.

A novel surface-functionalization route was developed by taking advantage of inert gas plasma-generated surface free radical sites. Analytical data indicate that the plasma-generated free radical species interact efficiently under *in situ* conditions with stable functional-group-precursors in the absence of plasma state. Efficient implantation of primary amine functionalities onto various polymer surfaces has been demonstrated. It was also shown that plasma-deposited diamond-hard carbon island-structures can retain biologically active macromolecules while the surface-layer system exhibits excellent wear-resistant properties.

Plasma-Enhanced Deposition of Antifouling Macromolecular Layers on Material Surfaces Usually Involved in Food Processing Technologies

F.S. Denes*, S.O. Manolache, A.C.L. Wong, H. Jiang, B. Dong and Y. Wang

Funding: USDA Natl. Integrated Food Safety Initiative Award; Hatch

Cooperator: UW Food Research Inst.

If bacteria attach to surfaces, biofilms may form and create economic and health problems in many settings, including those of food and medical industries. Developing new technologies to prevent or at least attenuate biofilm formation is highly desirable.

In this study, plasma-enhanced deposition of polyethylene glycol (PEG)-type structures are examined as possible antifouling materials, and the resulting antifouling mechanisms are investigated. PEG chains are highly flexible and can cause an intense entropic repulsion of protein molecules due to reduced degrees of conformational freedom of protein macromolecular chains. PEG is also highly water-soluble and, as a result of hydrogen bonds created between the oxygen atoms of PEG and water molecules, a water molecule-based shield is created around PEG macromolecular chains that may contribute to their antifouling behavior.

Three different approaches were considered for depositing PEG-type layers onto stainless steel and silicon rubber surfaces.

1. Deposit thin layer PEG-type networks from various plasma-generated, charged and neutral, volatile, precursor molecular fragments.
2. Graft PEG molecular chains onto SiCl₂H₂-, H₂- and SiCl₄-plasma-functionalized surfaces.
3. Generate antifouling layers by cross-linking predeposited PEG structures under oxygen and argon-plasma, radio frequency-plasma environments.

It was shown that all plasma-deposited PEG-type structures exhibit significantly reduced bacterial attachment and biofilm formation in the presence of a mixed culture of *S. typhimurium*, *S. epidermidis*, and *P. fluorescense*. Biofilms developed on these coated surfaces were less stable and easier to remove than those on uncoated surfaces. Future research will involve optimizing plasma-deposition processes to generate highly effective antifouling layers. Antifouling characteristics will be related to the chemical nature and morphologies of PEG-type structures.

Recently it was demonstrated that PECVD-deposition of diamond-hard carbon thin layers can accommodate into plasma-processes generated nano-cavities stable, wear-resistant biologically active layers.

Interactive Cellulosic Materials for the New Millennium

F.S. Denes*, S.O. Manolache, H.M. Kim, R.A. Young, S.

Gunasekaran, L.E. Cruz-Barba and A.J. Martinez

Funding: USDA Competitive Grant

Cooperator: UW Forest Ecology and Mgmt.

Radio frequency-plasma-enhanced surface modification investigations were initiated to implant specific functionalities (e.g., primary amine, carboxylic and aldehyde functionalities) onto cellulosic substrate surfaces such as additive-free paper for the subsequent immobilization of active biomolecules. Covalently immobilized diamine-oxidase onto functionalized paper surfaces will be used as biosensors for high sensitivity and specific identification of histamine in the presence of Nessler's reagent.

Design and Development of Novel Atmospheric Pressure Plasma Installations with Potential Scaling-Up Possibilities for Pilot and Industrial Technologies

F.S. Denes* and S.O. Manolache

Funding: US Naval Research Lab.; Vyskase (gift); Elf Atochem

Cooperators: UW Mechanical Engring.; UW Biological Systems Engring.

Three original (patents and patent disclosures) atmospheric pressure (AP) plasma reactors were designed and developed at the Center for Plasma-Aided Manufacturing (C-PAM) and the Biological Systems Engineering Department at UW-Madison. The reactors are the dense medium plasma (DMP) reactor, the array electrode reactor (AER), and the barrier discharge reactor for small dimension cavities (BD-SDC).

The DMP reactor is based on a digitally controlled, rotating, interchangeable pin array electrode system which generates a volume character of the plasma processes due to the presence of an intense cavitation developed in the reaction media. It can be operated using DC or AC power, and it allows extremely efficient modification of various liquid media (e.g., solutions, suspensions, etc.) in the presence of inert or reactive gases.

The AER installation eliminates the drawbacks of conventional AP gas-phase techniques by using a multi-cylinder/wire electrode array system which allows plasma-exposure of various substrates under static or continuous flow system conditions. This electrode configuration assures a uniform flow of plasma gases or gas mixtures through a multitude of cylindrical individual discharges. With the AER, both metal and dielectric materials can be surface-treated uniformly, while the presence of a low dimension gap between the electrode system (usually associated with conventional AP reactors) is not required.

With the BD-SDC tools, electrical discharges can be generated in low dimension dielectric cavities, channels or capillaries by adapting a special electrode/cavity configuration. Embedding the electrodes into dielectric materials and maintaining a certain position of the cavity-, capillary- or channel-volumes relative to these electrodes, AP discharges can be initiated and sustained in capillaries with inner dimensions smaller than 1 mm under batch- or continuous-system modes.

Development of Atmospheric Pressure Plasma Technologies for Efficient Decontamination and Disinfection (Including Spores) of Surfaces, Air and Water

F.S. Denes*, S.O. Manolache and A.C.L. Wong

Funding: UW Food Research Inst.; Amer. Meat Inst.; Wis. Energy Ctr.

It was shown that under specified dense medium plasma (DMP) reactor experimental conditions, more than 10^5 bacteria/mL of *Listeria monocytogenes* or a bacterial cocktail of 16 different environmental isolates are inactivated in 10 s at power consumption as low as 200-300 W. It was also shown that aromatic contaminants of 600-1000 ppm concentration are reduced to 2-3 ppb in only 25 s. If nascent colloidal silver particles are present in the contaminated water, the disinfection process is even more efficient. (Colloidal silver nanoparticles can be generated simultaneously with the plasma process by using silver electrodes.) Experiments are underway to evaluate the efficacy of the DMP system for the disinfection of fresh orange juice.

The array electrode reactor (AER) allows efficient disinfection of various static or moving substrate surfaces such as metals, glass and polymers. Potential applications include disinfecting conveyor belts and cutting blades. The AER can also disinfect incoming or recycled air, which opens up a novel route to develop advanced technologies to eliminate aerosol-based contamination in ready-to-eat food processing locations. Preliminary tests indicate that bacteria and highly-resistant spores deposited on stainless steel coupon surfaces can be annihilated under both air and oxygen AER plasma environments with treatment times as short as two minutes.

Future research will focus on understanding the discharge-induced reaction mechanisms responsible for killing bacteria and spores and on optimizing plasma parameters and data acquisition to evaluate possible scaling-up of plasma technologies for industrial applications.

Dense Medium Plasma (DMP) Synthesis of Hybrid Iron/Iron-Oxide and Carbon-Based Magnetic Nanoparticle Systems with Applications in the Area of Targeted, Localized Anti-Cancer Drug Delivery

F.S. Denes*, S.O. Manolache, Y. Ma and D.M. Vail

Funding: UW University-Industry Relations

Cooperators: UW Sch. of Veterinary Medicine

Using benzene as a reaction medium and iron or stainless steel electrodes, hybrid carbon and iron/iron-oxide nanoparticle systems were synthesized. It has been shown that owing to the very low iron content of the ordered nanoparticles (0.05-0.1%), these particles exhibit magnetic properties. *In situ*, plasma-enhanced animation of nanoparticles allowed the covalent immobilization of Doxorubicin (anti-cancer drug) onto the particle surfaces. The novel hybrid drug system is under testing to evaluate the efficiency of anti-cancer activity and targeted, localized drug delivery at the UW School of Veterinary Medicine.

Synthesis of Electrically-Conductive Polymeric Thin Layers for the Development of Electric-Signal-Based Transducers for Biosensor Applications

F.S. Denes*, S.O. Manolache, L.G. Paterno, S. Alvarez-Blanco, Y. Ma and L.E. Cruz-Barba

Funding: Fulbright Award; EMBRAPA-Brazil Award; UW Biological Systems Engring.

Development of transducer systems for biosensors based on electric signals would significantly increase detection speed and would allow direct, computer-aided evaluation of the multitude of signals which are generated simultaneously by different molecular recognition processes. Changes in impedance as a result of interaction between analyte molecules and molecular recognition biocomponents of the sensors (e.g., enzymes, antibodies, oligonucleotides) would permit design and development of differential electronic detection systems. The connections between the biomolecules selected for the molecular recognition processes and the signal evaluation system should be achieved using conducting organic molecular wiring (integrated circuitry based on doped, conjugated organic polymers). This would also allow development of controlled functionalization and subsequent covalent connection of desired biomolecules to organic metals.

Horseradish peroxidase immobilized onto plasma functionalized polyethylene and glass surfaces was used to synthesize thin layer polyaniline (PANI – conjugated, electrically conductive polymer) structures. The enzyme-synthesized PANI structures have molecular weight distributions comparable to the molecular weight distribution of free-enzyme-synthesized PANI. These results open up additional ways to synthesize electrically conductive thin layers directly on various polymeric substrate surfaces, with potential applications in advanced molecular recognition technologies in the future.

PANI and polythiophene thin layer structures were also synthesized by crosslinking predeposited aniline oligomers onto various substrate surfaces under NH_3 -plasma conditions. It was demonstrated that this novel synthetic route allows significantly improved retention of precursor structure in the nascent plasma-polymer layers compared to conventional plasma processing of aniline. Aromatic conjugation can be preserved in this way which is required to achieve significant electrical conductivities.

Recent investigations target conversion under SF_6 - and H_2 -low and atmospheric plasma environments tetrapyrrol-type, predeposited thin-layer structures into electrically conductive conjugated networks, with potential applications in MEMs and biosensor technologies.

Rheological Properties of Soluble Leaf Protein Gels

S. Gunasekaran*, R.G. Koegel and B.P. Lamsal

Funding: USDA Dairy Forage Research Ctr.

Soluble leaf proteins (SLP) are a potential source of food protein which have good nutritional and functional properties such as solubility, emulsification, and foaming. Little information exists about the rheological properties of leaf protein concentrates. Our objective was to investigate the small-strain rheology of SLP solutions during gelation and large deformation properties

of SLP and SLP-whey protein isolate (WPI) mixed gels.

SLP concentrates were prepared by freeze-drying acid precipitated proteins (pH 3.5) from clarified alfalfa juice. SLP solutions (5, 10, 15% w/v) were prepared by dissolving freeze-dried concentrates in double-distilled water. The solution was stirred for 1 h and centrifuged at 10,000 G for 10 minutes. Storage (G') and loss (G'') moduli were monitored in a dynamic rheometer with cone and plate geometry during temperature sweep from 25 to 90°C and back to 25°C. Gels were formed by heating SLP solutions and WPI+SLP (at 1:1 and 3:1 ratios) solutions in molds at 90°C for 60 minutes and cooling overnight at 4°C. They were tested in compression to 80% deformation to determine their strength. The G' values obtained during temperature sweep ranged from 50 to 180 Pa for 5 to 15% protein solution, which increased to 1 to 2 kPa, respectively, while cooling back to 25°C. Though gels were weak, they exhibited distinct gelation temperatures of 61, 63 and 69°C for 5, 10 and 15% solutions, respectively. Compression tests also confirmed the weak gel properties of up to 15% SLP solutions. Gel strength improved substantially when WPI was added to SLP. The more WPI fraction added, the stronger the gel was. In all cases, gels were opaque.

Results indicate that stable gels could be made in combination with WPI and other protein systems, making it easier to incorporate SLP in food and non-food systems.

Functionally-Modified Egg White Albumen Hydrogel

S. Gunasekaran*, R. Gundloori and J. Li

Funding: S.C. Johnson and Sons, Inc.

Egg white albumen (EWA) can form a gel at certain temperatures due to covalent disulfide bond formation. The gel is opaque with limited swelling ability. Modifying the functional groups, such as the lysyl residues, in the protein would allow developing a novel hydrogel with improved functional properties. Our objectives were to incorporate carboxylic groups into EWA molecules by modifying them with ethylenediaminetetraacetic dianhydride (EDTAD) and to investigate swelling and adsorption (of copper and phosphate) behaviors of the modified hydrogels.

An EWA solution (5% w/v) was prepared in deionized water and adjusted to pH 11–12. Various amounts of EDTAD were added to EWA solutions while stirring to obtain different extents of EWA modification. The reaction was conducted for 3 h. Then the solution was dialyzed using 6–8,000 Dalton membrane and was freeze-dried. The modified EWA solution of 15% concentration was heated to 80°C for 1 h in special stainless steel molds to prepare the EWA hydrogel. Swelling and absorption studies were conducted using the dry hydrogel. The extent of EWA modification increased from 23 to 100% with increasing ratio of EDTAD/EWA from 0.06 (w/w) to 0.2 (w/w). Introducing carboxylic group, increasing temperature, and increasing time resulted in increased swelling ratios of the EWA hydrogels. The introduction of carboxylic group had the most significant effect. Swelling of EWA increased with increasing modification rate and

was higher in deionized water and in buffer solution. The cupric chloride and calcium phosphate adsorption experiments indicated that cupric adsorption capacity of the modified EWA hydrogel was substantially enhanced, while phosphate adsorption capacity remained the same.

The ability of the modified EWA gels to swell and absorb metals and other agents will allow developing EWA gel systems for value-added non-food uses.

Effect of Heating Rate on Gelation of Whey Protein

S. Gunasekaran*, M.M. Ould Eleya and J. Li

Funding: Dairy Mgmt., Inc.; S.C. Johnson and Sons, Inc.

Whey proteins are widely used as functional ingredients due to their ability to form heat-induced gels. Factors that are known to influence gelation of whey protein include protein concentration, pH, ionic strength, presence of other substances, and heating conditions (e.g., temperature, heating rate). Unlike pH, temperature and ionic strength, the influence of heating rate on whey protein gelation is less understood. Our objective was to investigate the effect of heating rate on rheological properties of whey protein isolate (WPI) gel.

WPI was dissolved in a 0.1 M phosphate buffer (pH 7) to prepare a 15% WPI solution. The WPI solution was heated from 25 to 90°C at different constant heating rates (0.1, 1, 5, 10 and 20°C/min) using a dynamic rheometer. The WPI gel was then cooled to 25°C at a constant rate of -5°C/min and held for 60 minutes. Frequency sweep experiments in the range of 0.01 to 100 Hz and stress sweep tests in the range of 1 to 100,000 Pa were conducted. Similar experiments were performed using a mixture of 15% WPI + 1% Xanthan gum. The results show that the gelation temperature (T_{gel}) of WPI increased from 56°C at the heating rate of 0.1°C/min to 87°C at the heating rate of 20°C/min. A similar trend of increasing T_{gel} with heating rate was observed for the gelation of the WPI-Xanthan mixture. At a given heating rate, the T_{gel} of the WPI-Xanthan mixture was lower than that of the WPI. Frequency spectra of WPI gels indicated that G' increased inversely with the heating rate. Stress sweep test results showed that the linear viscoelastic region (critical stress) varied with the heating rate.

These results suggest that protein aggregation occurs slowly relative to the heating rate when the heating rate is too fast. This may allow a way of modifying gel structure and texture.

Whey Protein-Based pH-Sensitive Hydrogels

S. Gunasekaran*, M.M. Ould Eleya and L. Xiao

Funding: Dairy Mgmt., Inc.

Hydrogels are three-dimensional networks formed by hydrophilic molecular chains linked together by chemical and/or physical bonding. Hydrogels which undergo large changes in volume in response to small changes in such external stimuli as pH and temperature are being studied with much interest. These smart hydrogels can be used for many new applications including

controlled drug delivery. They can be prepared using various proteins and polysaccharides. Our objective was to develop pH-sensitive hydrogels that can be used as carriers of biologically-active substances (e.g., pharmaceuticals) from whey protein concentrate.

Gelation kinetic and rheological properties of whey protein gels were investigated using dynamic and uniaxial compression rheological tests. Different protein concentrations (12, 15, 18%) and pHs (5.1, 5.7, 6.2, 6.8, 7.2, 10) were tested. The gels were prepared by isothermal heating at 80°C. The swelling behavior of whey protein hydrogels and the release kinetics of a model drug from such hydrogels were also investigated in various pH media. Gelation time, equilibrium gel modulus, failure stress and failure strain were pH- and concentration-dependent. The swelling behavior of whey protein hydrogels was pH-sensitive. The equilibrium swelling ratio was relatively low at acidic pH and decreased as the pH of the medium increased. The swelling ratio was minimal around the protein isoelectric point and then increased as the pH of the swelling medium was increased. The pH at which the hydrogel was prepared also affected the swelling behavior. Gels made from whey protein solutions with high basic pH had high pH-sensitivity during swelling. Release kinetics of a model drug (e.g., caffeine) from whey protein hydrogels indicated a Fickian diffusion release mechanism.

These results show that biodegradable and pH-sensitive whey protein hydrogels are suitable for many novel applications in food and bioprocess systems.

Evaluation of Mixing Performance of a Model Mixer with Two Moving Paddles by Numerical Simulation

S. Gunasekaran*, C. Yu

Funding: USDA-Natl. Research Initiative

Mixing is an important unit operation in the manufacture of various foods. Better mixer design and more precise control of mixing are desirable to improve the quality and consistency of the final products. Traditional mixer designs are based on trial-and-error which, given the complexity of the problem, has not optimized mixer designs to maximize their performance. Numerical simulation is a powerful alternative to investigate mixer performance. Our objective was to develop a mathematical model to evaluate the mixing performance of a model two-paddle internal mixer based on the flow field created during mixing and to implement a numerical scheme to solve this model.

Finite element method was used to simulate the flow field created during the mixing process. The Bird-Carreau model was considered to characterize the material property. Mesh superposition technique was used to enforce the boundary conditions created by the moving paddles. Parameters such as the flow number, segregation scale, mixing efficiency, dispersion index, and percentiles were defined and calculated from the flow field to evaluate the mixing performance. The numerical simulation was implemented successfully to evaluate the mixing performance of different mixer designs. The model two-paddle internal mixer

performed better under dispersive mixing conditions (i.e., good evolution of dispersion index) than under distributive mixing conditions (i.e., nonzero but small mean mixing efficiency and nonzero segregation scales). Cyclic behavior was observed in the mixing operation.

The numerical simulation procedure we have developed will enable evaluating the effect of specific design changes. This will help improve the mixing performance of industrial mixers.

Investigating the Pasta Filata Process during Mozzarella Cheesemaking

S. Gunasekaran* and C. Yu

Funding: Dairy Mgmt., Inc.

The pasta filata process of heating and stretching cheese curd is typical of many Italian cheeses such as Mozzarella. Changes in manufacturing variables during this process can affect composition and functional properties in the cheeses. Therefore, a better understanding of this process would facilitate accurate control and help improve equipment design and product quality. Our objectives were to experimentally determine system variables such as specific mechanical energy (SME) and exit temperature (TE) which can be used to characterize the pasta filata process and to investigate how the system variables affect various cheese properties.

Cheese curd was made both by traditional starter culture methods and direct-acid method. The pasta filata process was performed in an open-channel, twin-screw extruder under different operating conditions. We measured the dynamic evolution of power consumption and filled section and determined system variables. Molten curd from this process was analyzed, and the moisture content, fat-in-dry-matter (FDM), and free-oil release were determined. Dynamic rheological tests were conducted to determine G_0 as a measure of network structure. Relationships between system variables and cheese properties were established. The cheese microstructure was studied by scanning electron microscopy and effects of the pasta filata process on microstructure were investigated. The moisture content of the cheese decreased linearly with increased SME. A quadratic relation was established between moisture content and TE. For FDM, quadratic-type relations were established for both SME and TE which suggests that it is possible to optimize cheese yield by adjusting the pasta filata process operating parameters. The microstructure observations further supported the results.

These results can be used to optimize the pasta filata process to improve yield and quality of Mozzarella cheese.

Plasma-Induced Modification of Xanthan Gum

S. Gunasekaran*, F.S. Denes and S.N. Jampala

Funding: Hatch

Xanthan gum (XG) is one of the most popular polysaccharides in food and bioprocess industries. XG has a negative charge and size similar to many other polysaccharides of interest in bioengineering. If XG can be modified in a controlled manner,

several end-use applications can be improved. Cold plasma technologies open up novel, efficient routes to modify natural polymeric materials. The hydroxyl groups on the primary and secondary carbon atoms offer opportunities to incorporate new and useful properties. Because energy levels of plasma species are comparable to bond energies of common organic compounds, surfaces exposed to plasma species can be conveniently modified/functionalized under selected discharge parameters. Our objective was to investigate the effect of various cold plasma treatment parameters on implantation of additional functionalities onto XG structure.

The surface chemistry of argon (Ar) and oxygen radio frequency (RF) plasma-treated XG under various external plasma treatment conditions was studied. XG was also functionalized under 13.56 MHz RF-SiH₂Cl₂-plasma conditions and, consequently, *in situ* aminated by ethylene diamine. Survey and high-resolution X-ray photoelectron spectroscopy (ESCA), fluorescamine labeling technique, FTIR analysis, residual gas analysis and scanning electron microscopy (SEM) were performed to examine the treated XG surface morphology. ESCA spectra of Ar-plasma treated samples indicated an increase in surface areas of O-C=O and O-CO-O. O₂-plasma treated surfaces indicated a significant increase in O-C-O concentration. The modification took place even at low pressure and low power conditions and was not extensively influenced by external plasma processes. ESCA spectra show the presence of C-Si and C-N in SiH₂Cl₂-plasma treated and subsequently aminated samples. The intense brightness of functionalized XG in fluorescamine labeling indicated the presence of primary amine groups. FTIR measurements supported the ESCA observations. SEM images revealed several chunky and coated granule structures.

Cold plasma reaction is an efficient non-enzymatic way to modify industrial polysaccharides. This will lead to creating new and improved functionalities.

Changes in Cheese Microstructure during Melting

S. Gunasekaran* and S. Ko

Funding: Krenz Funds

Meltability is one of the most important functional properties of many cheeses. It varies with cheese type, composition, and age. As cheese melts during heating, its structure changes continually depending on the status of fat globules and protein matrix. The exact mechanism of the events as cheese melts has not been fully elucidated. Our objectives were to investigate the effect of heating on cheese microstructure using confocal laser scanning microscopy (CLSM) and to obtain quantitative data on changes in the two-dimensional (2D) and three-dimensional (3D) microstructural features.

Mozzarella cheese samples were sliced and stained with 0.1% Nile Red. The samples were fixed on the CLSM stage and heated from 25 to 70°C. For each sample, 41 layers of 2D sections were obtained at 0.5 μm intervals for every 5°C temperature increase. The 2D CLSM image layers were processed and analyzed. The image processing steps included color extraction,

median filtering, background correction, depth compensation, and segmentation. The processed layers were reconstructed to a 3D structure for visualization and 3D analysis of fat globule structure. Various 2D properties (area, perimeter, circularity) and 3D image properties (volume, surface area, sphericity) of fat globules were computed and analyzed. The circularity and sphericity values of fat globules from 25 to 70°C were used to determine cheese meltability, which decreased after the softening temperature. The softening temperature determined from 2D and 3D image analysis of Mozzarella was 40.4 and 41.1°C, respectively. The quantitative image properties were used to evaluate *in situ* changes in cheese microstructure during heating.

The results will help in understanding how microstructural changes relate to macroscopic changes in melting cheese.

Rheology of Fluid Foods for Dysphagic Patients

S. Gunasekaran*, J.A. Robbins and M.M. Ould Eleya

Funding: Gift

Patients suffering from swallowing disorders (dysphagia) are usually treated with a multidisciplinary approach that includes diet modification which consists of either altering the viscosity of liquid foods by adding food thickeners or using ready-to-serve pre-thickened fluid foods. Viscous fluid foods prevent aspiration by slowing the bolus flow through the oropharynx. To manage dysphagia safely, it is important to understand the rheological properties of fluid foods given to dysphagic patients. Our objective was to determine rheological properties of several fluid foods and two barium sulfate suspensions used to diagnose dysphagia.

Steady-state flow properties, thixotropy, dynamic response, and creep recovery behavior of six fluid foods and nectar- and honey-like consistency barium sulfate solutions were investigated using a dynamic rheometer. All samples exhibited the shear-thinning behavior described by the Cross model. Shear stress-shear rate relationships were described by the Herschel-Bulkley model. Barium sulfate suspensions of honey-like consistency exhibited higher viscosity, higher yield stress, and higher elastic modulus than their fluid food counterparts. In contrast, barium sulfate suspensions of nectar-like consistency showed lower viscosity, lower yield stress, and lower elastic modulus than their liquid food counterparts. Frequency spectra of nectar-like samples were similar to that of a macromolecular solution with both G' and G'' increasing with increased frequency, whereas those of honey-like samples were gel-like with a little dependency of G' and G'' over frequency. Stress sweep experiments showed that the viscoelastic linear region of fluid foods and barium sulfate suspensions extended up to about 10 Pa.

These results suggest that the ready-to-serve fluids on the market exhibit rheological properties significantly different from those of diagnostic barium sulfate suspension. Therefore, there is a need to develop fluid foods with rheological properties that match exactly those of the diagnostic fluids.

Electric Power and Energy Systems

Exposure of Dairy Cattle to Electrical Events and Their Biological Consequences

D. Alumbaugh*, L.G. Sheffield and D.J. Reinemann

Funding: Wis. State Legislature

Cooperators: UW Civil and Environmental Engring.; UW Dairy Sci.; UW Biological Systems Engring.

This project will employ the magnetotelluric (MT) method to estimate the strength of electric currents generated in the earth by man-made sources including those originating from an electric power distribution system. The MT method measures naturally-occurring electromagnetic fields to investigate the earth's electrical properties. Traditional uses of MT data analysis include oil, mineral, and groundwater exploration.

Using a new method in biology, called array hybridization, we will assess the impact of electrical exposure on messages produced in the immune system. This method allows us to assess several thousand messages in a single sample. Unlike other studies in which relatively few measurements are taken, this method allows us to assess essentially every messenger RNA produced in a tissue. This greatly reduces the chances of missing potentially important measures because they were not included in a study. Because message production in the immune system is a critical link between the environment and a cow's health, these measurements provide critical information on the impact of electrical exposures on dairy cattle.

Farm Energy and Stray Voltage Program

D.J. Reinemann*, M.A. Cook, R. Kasper, J. Roberts and D. Hansen

Cooperators: UW Biological Systems Engring.; Wis. Public Service Commission; Wis. Dept. of Agric., Trade, and Consumer Protection

The objective of this program is to promote safe, efficient use of electrical energy in rural areas. Issues addressed include energy conservation and load management technologies for farms and food processing plants, electrical safety and power quality on farms, detection and mitigation of stray voltage, renewable energy sources, and distributed generation prospects for farms. Educational activities include the following:

- Presentations at Wisconsin Farm Technology Days and other agricultural events;
- Presentations at county, state, and national seminars;
- Support of Midwest Rural Energy Council educational efforts;
- Stray Voltage Investigators Training courses;
- Support of other state agencies with rural energy activities.

Pulsed Current Impact Assessment Tests

D.J. Reinemann* and P.D. Thompson

Funding: Electric Power Research Inst.; Power Electronics Applications Ctr.

Cooperators: UW Biological Systems Engring.; UW Dairy Sci.; Wis. State Div. of Energy; Phasor Labs

Reading electric meters by direct observation entails considerable expense and inconvenience and presents opportunities for human error. Electric utilities are adopting various remote meter-reading technologies: radio transmission; telephone transmission; using power lines to carry a signal to and from meters. Power line signals can be encoded in a number of formats. In one system, signaling pulses synchronized with the 60-Hz line frequency are injected onto the power line serving a meter by a signaling device contained within the meter.

This study examined the sensitivity of dairy cattle to electrical transients similar to those produced by automatic meter-reading devices. Several different pulse waveforms were investigated, encompassing the range of waveforms that might be encountered in practice. We observed cows in order to find the lowest signal amplitude at which they twitched or showed some other behavioral effect. (Previous work in our Milking Research and Instruction Lab has shown that behavioral changes occur at lower currents than such physiological changes as water consumption.) Based on the sensitivities determined by the study, standards can be set for the maximum allowable signal pulse amplitude when using this system.

We found no interaction between the high frequencies generated by the automatic meter-reading devices and the underlying 60-Hz signal. We also found that cows were less sensitive to the signaling pulses than they were to 60-Hz current and that they became progressively less sensitive as the duration of the signaling pulse was shortened.

Wisconsin Focus on Energy Programs for Agriculture

S.A. Sanford* and S.G. Gruder

Cooperators: UW Biological Systems Engring.; UW Cooperative Extension Service

The mission of the Wisconsin Focus on Energy Program is to reduce energy use and increase energy efficiency. It involves energy conservation, renewable energy, and energy use by agriculture, industry and businesses, government, and residents. The website www.focusonenergy.com gives details about who qualifies for programs, grants, and incentives.

Programs include free energy audits and grants to help with purchase of energy-conserving equipment such as variable speed vacuum pump controls and precoolers for dairy farms, pump retrofitting for irrigation systems, and high-efficiency dryers or automated control systems for grain drying. Grants are also available for feasibility studies and cash incentives for installation of wind turbines, solar panels, manure digesters for bio-energy, etc. Residential energy conservation programs cover lighting, insulation, some appliances, and heating and cooling systems.

Agricultural Energy Management Assessment System

D.J. Reinemann*, G.W. Jackson and S.A. Sanford

Funding: Wis. Focus on Energy

Cooperators: UW Biological Systems Engring.; UW Soil Sci.

This project will develop and test agricultural energy management assessment support materials. Energy management tools will be developed with various levels of technical detail targeted at several specific user groups. A simple self-assessment tool will be developed for producers to use and will be available as a web-based tool. This interactive agricultural energy management assessment system will be incorporated into the Farm-A-Syst and Wisconsin Environmental Management Assessment programs as well as the Wisconsin Focus on Energy local energy service provider resources. More detailed energy audit tools will be developed for energy service providers. The program will be piloted in several counties where energy auditors and extension agents will be trained to use these tools. Programs will be offered at Wisconsin Farm Technology Days and at regional seminars.

A Study to Evaluate the Impacts of Increasing Wisconsin's Renewable Portfolio Standard

P.D. Thompson*

Funding: Wis. State Div. of Energy

Cooperators: UW Biological Systems Engring.; Wis. State Div. of Energy; Wis. Public Service Commission; Union of Concerned Scientists; Sustainable Energy Advantage; LaCapra Assoc.

A "Renewable Portfolio Standard" is a regulatory mechanism by which electric utilities are required to develop renewable sources (hydro, wind, biomass, etc.) of electricity to supply a specified percentage of their retail sales. Wisconsin has a Renewable Portfolio Standard in place, which requires an increasing percentage of renewable power each year until the target of 2.2% is reached in 2011.

Under the present standard, Wisconsin utilities already generate enough electricity from renewable sources to nearly meet the 2005 requirement, and, because they can carry forward credit for a surplus generated in the years before 2005, they won't have to bring new capacity on line until 2011.

This project will determine potential availability and cost of additional sources of renewable energy in Wisconsin. That information will then be input into a computer model of electricity supply. The output will be a projection of the cost and pollution effects of replacing additional conventional electrical generating capacity with electricity generated from renewable sources. It is anticipated that the results of this study will provide a factual basis for decisions on potential future changes in the Renewable Portfolio Standard.

High Volume Low Speed (HVLS) Fan System Performance

D.W. Kammel*

Funding: Wis. Public Service Corp.; Wis. Focus on Energy

High volume low speed fans (HVLS) are configured as large diameter paddle fans with 10 foils (blades). The foils range from 4 to 12 ft long, making the fan's diameter approximately 8 to 24 ft in diameter. The foils are positioned horizontally attached to a hub mounted on a 3/4- to 1-HP motor shaft. The fans operate at speeds between 117 and 50 rpm (8- to 24-ft diameter). They have been used in industrial buildings to circulate air at a low velocity (3 mph). The fans have also been used in poultry and livestock barns to provide supplemental cooling of animals by increasing air circulation and air velocity in the barn. Horizontal velocity data at the cow level (5 ft from floor) were collected on several dairy farms that had installed these fans to document velocities achieved with different fan arrangements.

Horizontal velocities were measured in several different barn arrangements to determine if current design guidelines for the use of these fans are adequate. HVLS fan spacing of 60 ft apart seems to be a reasonable compromise based on the velocity data collected. HVLS fan mounting height varied between 14 and 18 ft. Installers used a reference for mounting height of one foot higher than the height of the overhead door to prevent fans being hit by equipment. Horizontal velocities in the barn are turbulent, similar to a light breeze. In most cases, air movement above 100 fpm was observed over most of the barn area. Calculated air volume moved by a 24-ft fan ranged from 117,500 cfm to 150,000 cfm. Velocity data collected in this study suggest that a velocity of 200 to 299 fpm can be achieved over the feed bunk in a 4- or 6-row barn layout. A velocity of 100 to 199 fpm was documented over the interior row of freestall platforms for 4- or 6-row barn layouts. A velocity less than 100 fpm was measured at the outside row of freestall platforms for a 6-row barn. Each fan used approximately 14.5 kW/day of energy. The energy cost to run a single fan was approximately \$1/day. Additional velocity data will be collected for other fan arrangements and conditions.

Machinery and Harvesting

Factors Affecting Bunker Silo Densities

R.E. Muck*, B.J. Holmes and P. Savoie

Funding: USDA Agric. Research Service; UW Biological Systems Engring.; Agric. and Agri-Food Canada

Cooperators: USDA Dairy Forage Research Ctr.; UW Biological Systems Engring.; Agric. and Agri-Food Canada

The objective of this work is to identify factors which contribute to density of silage in bunker silos. Knowing these factors will help producers understand what practices they must perform to achieve high density in their bunker and stored silage. Attaining high densities in silos is important for two primary reasons.

1. High densities reduce spoilage that occurs during storage and feedout.

2. The higher the density, the greater the silo's capacity.

Higher densities usually reduce annual storage costs per ton by increasing the amount of crop entering a silo and decreasing storage losses. Our objective was to determine which forage conditions and packing practices result in high density forage.

A forage packing simulation tower was constructed in the machinery laboratory of the USDA Dairy Forage Research Center. The tower is a 3-sided steel box which stands about 8 feet tall. Plexiglass panels are bolted onto the open front to enclose the forage in the box. Weighed quantities of forage are placed into the enclosed box to simulate forage layers placed into a bunker silo. A hydraulic cylinder forces a steel plate down onto the forage, simulating the packing process. The depth of the forage layer is measured before and after compression. Factors which may affect the final density that have been measured and varied include: forage type (hay, whole plant corn), moisture content, layer thickness, packing force, frequency of applying force, force duration, and total depth of forage.

Results from tests during the summer and fall of 2002 are being analyzed. Some results suggest that a higher force causes higher density, that lower moisture content has higher dry matter density, and that layer thickness and time of compaction are not significant in estimating two parameters in a logarithmic model. Dry matter density is also significantly higher for alfalfa compared to grass and for a short chop length (10 mm) compared to a long chop length (19 mm).

Pressed Bag Silo Densities and Losses

R.E. Muck* and B.J. Holmes

Funding: Crop Storage Inst.; USDA Agric. Research Service
Cooperators: USDA Dairy Forage Research Ctr.; UW Agric. Research Stations

Our objectives for this work are to answer two questions.

1. How much forage is stored in a silo bag?
2. What are the dry matter losses of forage stored in silo bags?

Pressed bag silos are becoming increasingly popular with livestock producers because they offer a relatively inexpensive means of making silage and provide more flexibility in silage management than traditional tower or bunker silos. However, little is known about forage density and losses in bag silos. This study, initiated in 2000, intends to obtain estimates of both losses and density under good management and possibly the factors influencing variations in density and losses across bags.

The filling of 25 bags in 2000 and 22 bags in 2001 was monitored at three UW experiment station farms (Prairie du Sac, Arlington, West Madison). The weights of all loads added to bags were recorded. Samples were taken of each load for moisture, ash and quality analyses, and particle size. The length of bag filled by each load was marked on the bag to get within bag variation in density by load. The major crops ensiled were alfalfa and whole-plant corn. The weights of both good and spoiled silage being removed from bags are being recorded, and periodic samples are being taken for moisture, ash, and quality analyses.

In 2000, the range of moisture contents at ensiling were 41-70% wet basis with alfalfa silage averaging 53% and corn silage averaging 62%. Dry matter (DM) densities ranged from 10.3 to 17.7 lbs/ft³. Alfalfa averaged 13.8 lbs DM/ft³, and corn silage averaged 12.3 lbs DM/ft³. The data have not yet been thoroughly analyzed for the factors influencing density. DM densities were higher in dryer crops, 0.2 and 0.3 lb DM/ft³ per percentage unit of DM content for alfalfa and corn silage, respectively. Losses from a bag are determined after it is emptied. To date, all bags filled in 2000 at Prairie du Sac and West Madison Research Stations have been emptied. At Arlington, only half the bags filled in 2000 have been emptied. Preliminary results of losses for the emptied bags are tabulated below.

Type of Loss	Range	Average	Average Minus Worst 3 Bags
Gaseous/Seepage	-0.3 to 15.7	8.4	7.9
Spoilage*	0.0 to 25.4	5.8	1.9
Total	-0.3 to 38.2	14.2	9.7

*Spoilage loss is that silage rejected by the cattle feeder.

Half the bags had no spoiled silage or just minor amounts at the ends. Moldy silage occurred largely in crops ensiled too dry (> 40% DM). When visible mold was not present, higher losses appear related to lower feed out rates (taking < 1 ft/day from the face). Three bags (two hay crop, one corn) had major losses (> 25%). In one case, losses were attributed to bird damage on the top of the bag that was not noticed immediately. Spoilage losses were most often found in overly dry, porous silages, whereas high gaseous losses were found at lower feed out rates (< 1 ft/d). Results from the 2001 harvest season have not been completely analyzed.

Mapping Soil and Field Characteristics to Understand Soybean Yield

R.T. Schuler*, R.P. Wolkowski, C.R. Grau and A.E. MacGuidwan
Funding: Wis. Soybean Marketing Board; North Central Soybean Board

Cooperators: UW Biological Systems Engring.; UW Agronomy; UW Soil Sci.; UW Plant Pathology; UW Environmental Remote Sensing Ctr.; Univ. of Missouri; Univ. of Illinois; Iowa State Univ.; Michigan State Univ.; South Dakota State Univ.

The primary goal of this six-state project is to understand soybean growth and yield variability in production fields by mapping soil and field characteristics. Each state has two production fields involved in this study. More specific objectives include:

1. Derive relationships of soil and field characteristics to soybean growth and yield;
2. Establish guidelines for using soil and field characteristics and measurements as an aid for soybean production systems;
3. Implement activities to improve coordination of research on mapping soil and field characteristics and the relationship of these characteristics to soybean yield.

Four fields in corn and soybean production located north of Madison in Dane County, 40-60 acres each, were identified for intensive geo-referenced data collection. Soil samples were collected on 1-acre grids and analyzed for P, K, pH, and soybean cyst nematodes. Data on plant stand, plant height, and weed stand were collected during the growing season. Remotely-sensed aerial data from satellite (three dates) and aircraft (one date) were collected late during the growing season. A handheld radiometer was also used to collect additional remotely-sensed data. Fields were scouted for pests and other anomalies such as equipment malfunctions, operator errors, and soil compaction.

Results of the 1-acre grid soil sampling indicate these fields have no cyst nematode problems, and nutrient levels and organic matter vary across them. Some of this geospatial variability was similar to the soybean yield variability. Preliminary analysis of the remotely-sensed data indicates similar patterns.

Similar data are being collected in the five other states on two fields each. In addition, University of Missouri researchers collected soil data on two fields using automated sensors for soil and field characteristics such as soil conductivity, topography, and electromagnetic properties. An order one soil survey was conducted on the same two fields. Researchers at the University of Illinois are focusing on the data analysis, and Iowa State researchers are refining a soybean growth model.

In Wisconsin data, field observations indicate equipment malfunction such as planter and sprayer skips and wheel traffic impact due to late pesticide application. Affected areas were mapped. White mold infestations were rated and mapped in the soybean field. Equipment malfunctions and operation and white mold infestations were observable in the remote sensing and yield data. Yield had a high degree of correlation with white mold infestation and topography.

Using Remotely-Sensed Data to Diagnose Soybean Yield Limiting Factors

R.T. Schuler*, R.P. Wolkowski, A.E. MacGuidwan and C.R. Grau
Funding: Wis. Soybean Marketing Board; North Central Soybean Board

Cooperators: UW Biological Systems Engring.; UW Soil Sci.; Univ. of Missouri; Univ. of Illinois; Iowa State Univ.; Michigan State Univ.; South Dakota State Univ.; UW Environmental Remote Sensing Ctr.

The focus of this six-state project is managing crop production using remote sensing to identify problems in production fields. Specific objectives of this study are:

1. Determine the relationships between remotely-sensed data and biotic factors;
2. Apply the developed relationships to field scale remotely-sensed data for mapping patterns of crop stress;
3. Integrate remotely-sensed data with soil and field characteristics to predict potential yield limiting factors;

4. Provide suggested procedures for use of remotely-sensed data as an aid to soybean production decisions;

Six model systems were established, with each of the six states being involved in three to five systems. Each state project involved soil and field characteristics related to water stress. The remaining models were phytophthora seedling/root rot, soybean cyst nematode, herbicide injury, white mold, and insect damage. Wisconsin dealt with soybean cyst nematodes and white mold. In 2002, the soybean plots experienced no white mold problems, so this model was not evaluated.

Research plots were established in a production field on the David Farm near East Troy, Wisconsin. This study evaluated interactions of fungicide seed treatment, herbicide, brown stem rot, and soybean cyst nematode by researchers in the UW Plant Pathology Department. Another added feature of this set of plots was pH variation across the eight replicates from 6.0 to 8.2. Plot size was increased to 20 × 25 feet to provide improved evaluation of the remotely-sensed data having a spatial resolution of three feet. Eight soybean varieties were planted with different levels of resistance to soybean cyst nematode and brown stem rot. Remote sensing was done with a handheld radiometer several times during the growing season and once from low-flying aircraft. The aircraft was equipped with two sensors providing multispectral (3 wavelengths) and hyperspectral (120 wavelengths).

Interaction between soil pH and variety resistance was very apparent in the remotely-sensed data and yield data. Also, some varieties had distinctive remotely-sensed data characteristics. Based on visual observations of the remotely-sensed data, some varieties could be identified easily in each replicate that often had no relation to yield.

Krusenbaum Dairy Farm Study

J.L. Posner*, R.T. Schuler and G.G. Frank

Funding: UW Agronomy; UW Biological Systems Engring.

*Cooperators: UW Agronomy; UW Biological Systems Engring.;
UW Ctr. for Dairy Profitability*

Field machinery use and cost is being tracked on the Krusenbaum Dairy Farm near East Troy, Wisconsin. Since 1990 scientists have followed changes and decision-making during the transition from a confinement dairy to a rotational grazing dairy and to organic milk production. Machinery inventory has been significantly reduced since the transition began. Machinery cost has not been significantly reduced because initially tractors and tillage machinery were purchased as used. Later, forage equipment was purchased as new. The time associated with machinery operation has been substantially reduced.

EXTENSION

Dairy Production

Improved Lighting in Dairy Barns

K.G. Josefsson* and D.W. Kammel

Funding: US Centers for Disease Control and Prevention; UW Cooperative Extension Service

Cooperators: UW Cooperative Extension Service; UW Animal Sci.; Univ. of Illinois; Clemson Univ.; Ruud Lighting, Inc.; Retrolite Corp. of Amer.; R&G Miller and Sons, Inc.

Lighting in dairy barns is often well below standards for workplace lighting. Lack of proper lighting has been shown to result in lower productivity, lower quality of workplace, and more frequent occupational injuries. Based on research with "photo-period control" in dairy cattle, investing in better lighting systems in dairy barns is highly profitable if the lights are operated according to a consistent schedule to create an artificial day length of 16 to 18 hours. The main advantage is increased milk production.

This emerging management technique, long-day lighting (LDL), faces challenges in several respects:

- X Lack of consistent, research-based lighting recommendations;
- X Aggressive marketing of lighting equipment to dairy farmers with management and installation instructions contradicting research-based recommendations;
- X Reports by county extension agents that most farmers with freestall barns who adopted LDL didn't achieve the light levels necessary to obtain the expected yield increase;
- X Farmers who have not yet adopted LDL wanting to combine it with milking cows three times a day, while recommendations for LDL call for a 6-hour dark period per day which is difficult to achieve with a 3x milking schedule;
- X Recent research on photoperiod control for dairy cows suggesting that a dominant LDL practice of constant artificial day length year round may only create a yield increase during the first lactation after LDL is implemented.

During 2001, lighting recommendations for dairy barns were evaluated and revised in cooperation with the University of Illinois and Clemson University. These revised recommendations were incorporated in an updated tip sheet distributed to county extension agents and lighting equipment manufacturers and distributors. They are also available at <http://bse.wisc.edu/hfhp/>.

Our experiment installing LDL in a freestall barn was evaluated. Yields were greater than the average effects reported previously, but loss of light intensity due to dirt and debris on lamps and reflectors was greater than expected. Results and general advice on LDL were shared with dairy farmers and industry professionals at two field days/barn meetings and at the UW Arlington Agricultural Research Station's Annual Dairy Day. Proceedings were distributed to county extension agents. Installation and management advice has been provided upon request to county extension professionals, farmers, and electricians. It was also disseminated via agriculture print media.

Milking Technology and Facilities

D.J. Reinemann*, P.L. Ruegg, N. Cook and K.V. Nordlund

Cooperators: UW Biological Systems Engring.; UW Dairy Sci.; UW Sch. of Veterinary Medicine

Use of automated milking parlors is rapidly increasing in Wisconsin, and robotic milking machines have been introduced. Our program prepares agricultural professionals and dairy operators to effectively transition from stanchion barn milking systems to automated milking parlors or robotic milking systems. Educational programs for University students, county extension agents, and other agricultural professionals were developed. They were offered in the Biological Systems Engineering Department's Milking Research and Instruction Laboratory in cooperation with UW Extension's Team Quality Milk led by Dr. Pamela Ruegg of the Dairy Science Department and Drs. Ken Nordlund and Nigel Cook from the Veterinary School. Other educational activities include presentations at county, state, and national meetings and seminars, development of computer-assisted milking center design aids, and news releases.

Dairy Production and Profitability

B.J. Holmes*, D.R. Reinemann, D.W. Kammel and K.G. Josefsson

Funding: UW Cooperative Extension Service

Cooperators: UW Biological Systems Engring.; UW Healthy Farmers, Healthy Profits Program; UW Dairy Sci.; UW Ctr. for Dairy Profitability; Univ. of Minnesota; Univ. of Illinois; Iowa State Univ.; MidWest Plan Service

Increasing profitability on dairy farms requires proper selection of facilities for housing, feeding, and milking. The following strategies have been proposed.

1. Enhance milk production efficiency by improving cattle environment including long day lighting which has the benefit of improving the safety of producers while working in the barn.
2. Reduce electric hazards by improving efficiency of electrical energy use.
3. Increase milk harvesting profitability by properly selecting milking equipment and facilities.
4. Improve efficiency of feed storage and handling through better methods of providing balanced diets and adequate feeding space.
5. Enhance dairy industry modernization by encouraging selection of profitable facilities.
6. Protect water quality through improved methods of handling and storing manure and milking center wastewater.

In collaboration with companies, other universities and other UW departments, faculty have planned and participated in conferences on a variety of dairy-related topics. We have developed publications and software to inform farmers and their advisors on farmstead planning, feed storage, feeding, milking, animal housing, and manure handling systems.

Faculty have aligned themselves with self-directed teams such as the UW Extension's Dairy Team and the Four-State Dairy Programming effort. Faculty have assumed leadership roles within the Dairy Team. Extension educational programs related to dairy will be coordinated within a team.

The Dairy Modernization workgroup of the UW Cooperative Extension Service Dairy Team developed and is marketing a collection of materials on a *Low Cost Parlor and Dairy Housing and Manure Management Alternatives* CD for use by agents, instructors at vocational/technical schools, and farmers to help with decision-making when transitioning from stall barn milking to milking in a remodeled parlor and housing cows in freestall barns.

Maintaining Forage Quality from Harvest through Storage and Feeding

B.J. Holmes*, R.T. Schuler, K.J. Shiners, R.E. Muck and K.G. Josefsson

Funding: UW Cooperative Extension Service; UW Biological Systems Engring.; USDA Dairy Forage Research Ctr.

Cooperators: Team Forage of UW Cooperative Extension Service; UW Agronomy; UW Healthy Farmers, Healthy Profits Program

Forage is an extremely valuable component of the feed for dairy and beef animals. The quality of forage as delivered has a significant impact on the production efficiency of these animals. However, losses in feed quantity and quality through harvest, storage, and feeding are very high on many dairy and livestock farms. The following practices contribute to these losses.

1. Hay exposed to precipitation.
2. Hay harvested too moist.
3. Hay stored without adequate protection from precipitation.
4. Hay and corn silage harvested too dry or too wet.
4. Haylage and corn silage inadequately packed and/or covered in bunker silos, piles, and silo bags.
5. Haylage and corn silage improperly removed from bunker silos, piles, and silo bags.
6. Corn silage improperly processed.
7. Improper use of inoculants and additives, presumably to enhance forage fermentation and preservation.

Presentations have been made at Wisconsin Forage Council meetings, Forage Field Days, and county extension meetings to encourage producers to improve management in these areas. Articles on these subjects have appeared in conference proceedings, in the *Minnesota/Wisconsin Engineering Notes* newsletter, and on the UW Extension's Team Forage website <http://www.uwex.edu/ces/crops/uwforage.htm>. Spreadsheet software was developed as a decision aid and is also at this website.

Forage production members of Team Forage have encouraged producers to select appropriate varieties, to properly adjust equipment, and to harvest at the correct stage of maturity to enhance yield and quality. Our group has been working to preserve and feed as much of that quality and yield as possible. As such practices are adopted, the efficiency of forage production and livestock feeding will improve. The Harvest and Storage

Work Group of Team Forage has established a website <http://www.uwex.edu/ces/crops/uwforage/storage.htm> to provide access to publications and software related to these topics.

Electric Power and Energy Systems

Energy Conservation and Renewable Energy Education

P.W. Walsh*, S.D. Brachman and S.G. Gruder

Funding: Wis. Energy Conservation Corp.

Cooperators: UW Cooperative Extension; Wis. Focus on Energy; Extension Solid and Hazardous Waste Education Ctr.; Wis. Renewable Energy Network

The Wisconsin Focus on Energy program (described above, p. 21) promotes adoption of energy conservation and renewable energy technology by Wisconsin's businesses, citizens, and governments. In collaboration with public and private sector partners, this program works through UW-Extension offices to deliver energy education to their state-wide clientele regarding adoption of improved energy management techniques, technologies to save and generate energy, and incentives available through the Wisconsin Focus on Energy program to stimulate adoption of energy conservation and renewable energy technology.

Environmental Quality

Improving Water Quality

B.J. Holmes*, D.W. Kammel, R.T. Schuler, G.D. Bubenzer, J.O. Peterson and D.J. Reinemann

Funding: UW Cooperative Extension Service

Cooperators: UW Biological Systems Engring.; UW Environmental Resources Ctr.; UW Soil Sci.; UW Nutrient and Pest Mgmt.; UW Ctr. for Dairy Profitability; USDA Natural Resource Conservation Service; Wis. Dept. of Agric., Trade, and Consumer Protection

The collaborators developed a series of educational materials and seminars to educate communities and agencies about water quality issues. The following topics are included.

- X Proper storage and handling of fertilizers, pesticides, and fuel to minimize losses to water resources.
- X Regulations and standards to store and handle manure aimed at reducing the amount of manure and nutrients entering surface and groundwater.
- X Demonstrations of equipment and management to practice conservation tillage techniques that have proven effective in reducing soil erosion.
- X Self-assessment techniques (FarmXAXSyst program) to determine farmstead practices posing high risks to groundwater and surface water quality and that of water drawn from the farm well.
- X Control of erosion and runoff from urban areas.

X A survey of grazer overwintering practices that could affect surface runoff of nutrients.

X Developing an environmental management system (EMS) for dairy farms to reduce environmental risk and increase environmental protection.

Wisconsin is one of three pilot states selected to develop and test EMS's for dairy farms, and efforts are underway to do so. (See "Wisconsin Pilot of Dairy Environmental Management Systems" below.) Some materials we developed in previous years have been used as the basis of this new EMS project.

Wisconsin Pilot of Dairy Environmental Management Systems

B.J. Holmes* and G.W. Jackson

Funding: UW University-Industry Relations; Partners for Livestock Environment Mgmt. Systems (USDA-IFAFS); Wis. Milk Marketing Board

Cooperators: UW Biological Systems Engring.; UW FarmXAX Syst/HomeXAX Syst; UW Cooperative Extension Service; private industry; Wis. Dept. of Natural Resources; Wis. Dept. of Agric., Trade, and Consumer Protection; UW Agric. Research Stations; UW Nutrient and Pest Mgmt.; USDA Natural Resource Conservation Service

This research is taking place on 30 dairy farms. Its objectives are:

1. Develop and pilot test a computerized environmental assessment tool which will identify areas where dairy producers are doing a good job of minimizing environmental risk and those areas which need improvement;
2. Present the results of this project to those public and private entities which can influence the decisions about using this technique to improve dairy management for environmental protection.

Businesses throughout the world have adopted formal practices of business management in order to abide by procedures which will help them progress. Through these procedures they identify their strengths and weaknesses and embark on a process of continual improvement. The International Standards Organization (ISO) has established standards by which businesses can follow prescribed procedures and become certified as having followed these procedures. ISO Standard 14001 was developed to help businesses work toward environmental protection. ISO 14001 established the basis for standardized environmental management systems (EMS). Businesses other than agriculture have been voluntarily adopting this standard if they can see opportunities to improve their economic, social and environmental status. Some adopted ISO 14001 because customers require them to use EMS's to qualify as their suppliers.

This research was initiated as part of a 9-state pilot project to determine if EMS's could be used in livestock production as a way of managing such production with reduced environmental risk and better environmental protection. Six assessment worksheets have been developed to date. Paper copies of these worksheets have been tested on about 30 farms. A computerized version will be tested on dairy farms in early 2003. A guide-

book is being written to assist in adapting EMS's for agriculture. This guidebook will be tested with dairy farmers in the summer of 2003. An advisory committee was formed to encourage acceptance of AgEMS by the dairy industry. Committee members met twice in 2002 for educational/orientation meetings. An EMS is nearly complete at the UW Agricultural Research Station (ARS) in Marshfield and another has been started at the ARS in Arlington. EMS development is also planned for facilities at UW-Platteville and the USDA Dairy Forage Research Center farm in Prairie du Sac. By developing EMS's at these research facilities, we are gaining invaluable experience prior to working on EMS's on commercial dairy farms.

Invasive Species Control Education

P.W. Walsh*, A.L. Beall and B. Woods

Funding: Wis. Dept. of Natural Resources

Cooperators: UW Cooperative Extension; Wis. Dept. of Natural Resources; Sea Grant Program; UW-Stevens Point Lakes Partnership; UW Environmental Resources Ctr.

Invasive species continue to threaten the biotic diversity of Wisconsin's plant and animal communities. In an effort to stop the introduction and spread of exotics in Wisconsin's environment, UW-Extension has joined with the Wisconsin DNR and Sea Grant to develop a statewide program to educate Wisconsin citizens by addressing the threat of invasives and describing control methods. Targets include aquatic invasives such as the zebra mussel and plant invasives including purple loosestrife.

Domestic On-Site Wastewater Management

J.O. Peterson*, J.C. Converse and E.J. Tyler

Funding: UW Cooperative Extension Service

Cooperators: UW Biological Systems Engring.; UW Environmental Resources Ctr.; UW Soil Sci.; Wis. Dept. of Commerce

Unsewered areas of Wisconsin depend upon septic systems for wastewater disposal. The Small Scale Waste Management Project develops and improves siting, designing, installing, and operating criteria for safe use of on-site treatment and disposal systems. Extension programs bring UW research results and applications to site evaluators, installers, designers, regulators, maintainers, and the general public.

Winter workshops have been held annually at two to five sites on topics such as the following:

- X Soil properties and description;
- X Soil treatment and dispersal systems;
- X Evaluation and maintenance of on-site systems;
- X Design of distribution systems;
- X Pre-treatment systems;
- X Design of mound and at-grade soil dispersal systems.

As information becomes available and needs are identified,

topics are added and agendas are revised. Educational presentations are made at the Annual Winter Meeting of the Wisconsin On-Site Waste Recycling Association and via the statewide Educational Teleconference Network. Both types of presentation include reviews and updates on research from the Small Scale Waste Management Project, an exploration of research needs, and extensive interaction on progress being made nationally.

Field sessions on soil properties and system operation and maintenance are scheduled as needed.

Machinery and Harvesting

Agricultural Field Machinery

R.T. Schuler*, J.K. Shinnors and J.W. Nelson

Funding: UW Cooperative Extension Service; Wis. Farm Technology Days, Inc.

Cooperators: UW Biological Systems Engring.; UW Soil Sci.; UW Agronomy; UW Dairy Sci.; various county extension agents

The focus of the agricultural machinery program is the proper operation, maintenance, and selection of agricultural field machinery. Specific machines and systems receiving the most attention in 2002 were mower-conditioners, forage harvesters, balers, planters, grain drills, and conservation tillage equipment.

Forage harvesting remains the primary interest of Wisconsin forage producers. New cutting and conditioning technology (specifically, intensive conditioners, impeller conditioners, and disk cutterbars) continues to generate questions on its merits. Large square bales are growing in use because of very high productivity. However, these bales must be baled at lower moisture for proper storage due to their greater density compared to small rectangular bales. Producers have raised many questions on ways to reduce storage losses in large square bales.

In some areas of Wisconsin, soil conditions in fall 2002 were wet during harvest, resulting in field operations leading to potentially excessive soil compaction. Many crop producers recognize the potential for yield loss from compaction and had questions about determining the extent of the problem in their fields and about alleviating the detrimental effects of excessive compaction. Various tillage practices were recommended as a means of reducing the effects of compaction on crop yield.

The annual Wisconsin Farm Technology Days provides an opportunity to work with the farm machinery industry to demonstrate field machinery and to reach thousands of farmers. Field demonstrations at Farm Technology Days allow comparison of machines harvesting forage as chopped silage and bales. Other demonstrations were of mower-conditioners, rakes, mergers, and bunk facers. Forage silage samples were collected from the forage harvester demonstrations, and a particle analysis was done. Forage samples were collected from the windrows to analyze the drying rate of the material from mower-conditioner demonstrations. The primary factor influencing the drying rate was windrow width. These results were displayed on panels in the field.

Safety and Health

AgrAbility of Wisconsin

R.T. Schuler*, S.L. Hicken, J.M. Grettie, M.A. Purschwitz and C.A. Skjolaas

*Funding: USDA-CSREES; UW Cooperative Extension Service
Cooperators: UW Biological Systems Engring.; Easter Seals
Wis.; Wis. Div. of Vocational Rehabilitation*

This program is a partnership between UW Cooperative Extension Service and the FARM Center of Easter Seals Wisconsin (ESW) to provide education and assistance to farmers with disabilities and to disabled members of their families. Extension staff provide education and awareness of AgrAbility through extension/outreach activities. ESW's role is to give on-farm help via worksite assessments and development of individual plans.

During its 12 years, AgrAbility of Wisconsin has provided direct assistance to about 1000 disabled farmers and disabled members of their families. Disabilities addressed include cancer, lower back pain, spinal cord injuries, amputations, respiratory and cardiac problems, and visual and hearing impairments.

A close relationship has developed with the Wisconsin Division of Vocational Rehabilitation (DVR) which provides on-site support to farmers to implement their assistive technology plans and to refer them to the AgrAbility program. Examples of assistance provided are computer software, air-suspension tractor seats, added tractor steps, powered feed carts, milking pipelines, personal transport machines, and tractor lifts.

Awareness of this program is created through staffed displays at machinery shows and demonstrations and presentations at county, area, and statewide events. A quarterly newsletter is prepared and sent to county extension offices, DVR offices, rural hospitals, and current and former clients. Staff personnel continue an in-depth awareness program through radio programs, newspaper articles, and visits to key community people and events. An advisory committee meets annually and provides excellent support and increased awareness.

National AgrAbility Project

R.T. Schuler*, C.A. Skjolaas, M.E. Novak, M.F. Beck, S.D.

Grunder, R.H. Meyer and T. Willkomm

*Funding: USDA-CSREES; UW Cooperative Extension Service
Cooperators: UW Biological Systems Engring.; Natl. Easter Seals*

The National AgrAbility Project provides training and educational support for the 21 state AgrAbility projects. The projects provide education and assistance to disabled farmers, described above for AgrAbility of Wisconsin. The national project requires a joint effort between state Cooperative Extension staff and staff from a non-profit disability organization, which is National Easter Seals. Training and education are provided through a national workshop, monthly newsletters, quarterly technical news, and e-mail. The website www.agrability-project.org was developed and will be further refined to provide information to state project staff

and the general public. The website provides access to an assistive technology database listing more than 700 items. A photo library recently became available to staff of state projects. The monthly newsletter is distributed electronically only. A National Workshop was planned and held in Nashville to provide training for state staff.

Evaluation of all aspects of the project is a major component and has been initiated. A needs assessment for the state projects was developed and implemented. Plans have begun to determine how well the state projects are meeting the needs and expectations of the farmers whom they are serving. An impact survey has been developed that will indicate how well AgrAbility is meeting the needs of farmers with disabilities.

Farm Machinery Systems Safety

M.A. Purschwitz*, R.T. Schuler and C.A. Skjolaas

Funding: UW Cooperative Extension Service

Cooperator: UW Biological Systems Engring.

Farm tractors and other machines are involved in the majority of incidents resulting in fatal or permanent injury. The most effective method of preventing injuries involves hazard control (removing or guarding hazards). Safe, proper operation is still necessary but cannot be depended upon to completely prevent machine-related injuries. Numerous presentations, media interviews, and information requests on machinery safety are handled. We prepare an annual state farm fatality report which highlights machinery-related fatalities. Safety information is added to the Internet website for the UW Center for Agricultural Safety and Health. In-depth instruction on machine hazards and hazard control is a major component of the UW's Farm and Industry Short Course class, "Agricultural Safety and Health".

Youth Agricultural Safety and Health

C.A. Skjolaas*, M.A. Purschwitz and R.T. Schuler

Funding: UW Cooperative Extension Service

Cooperator: UW Biological Systems Engring.

Youth are at risk of serious and fatal farm injuries. Each year several Wisconsin children and youth, from preschool through high school age, die from farm work or worksite-related injuries. Youth must learn proper, safe behaviors in a farm environment, both to avoid hazards as bystanders and to work safely. Youth must also learn fundamental injury and illness prevention techniques, such as hazard control, and must be motivated to apply such techniques during their lifetimes.

This program includes presentations to youth at a variety of meetings, both in and out of a school setting. Presentations and planning assistance are provided to youth safety day camps throughout the state. Safety materials are being developed for extension agents and, within 4-H and vocational agricultural programs, for children and youth. Close contact is maintained with county extension agents who work with youth and agricultural education instructors. The tractor and machinery certification program described under the section "Youth Education" (below) is part of this overall youth safety and health programming.

Youth Education

Tractor and Machinery Operation Certification Program

C.A. Skjolaas*, M.A. Purschwitz and R.T. Schuler

Funding: UW Cooperative Extension Service

Cooperator: UW Biological Systems Engring.

Federal child labor laws require specific training on tractor and machinery operation for youth ages 14-15 working on farms other than those of their parents. Wisconsin law requires such training for youth 12 to 16 years old who operate tractors or other farm machines on public roads. Training programs are conducted by county extension agents working with youth and by agricultural education instructors with help from many volunteers. Greater standardization was brought into the program statewide and help was offered to counties that had not previously offered programs. Supplemental materials such as an instructor training manual were developed, and instructor training was offered statewide. These efforts have resulted in more than a thousand youth successfully completing certification programs annually.

Mechanical Sciences (Youth Development)

R.T. Schuler*, C.A. Skjolaas and J.W. Nelson

Funding: Cooperative Extension Service; Wis. Rural Insurance

Cooperators: 4-H Youth Development; Natl. Engring., Sci. and Leadership Mgmt. Team; Lincoln Welding; Deere and Co.

Approximately 16,000 youth participate in these Mechanical Science projects at the county level. About 2000 county volunteers direct them. Staff from Biological Systems Engineering provide technical support for the 4-H mechanical science projects including woodworking, tractor, small engine, bicycle, electricity and aerospace.

In 2002, 50 4-H youth participated in the state mechanical events: tractor, small engine, bicycle, and aerospace. Twenty county agricultural and youth development extension agents and county youth development volunteers supported state events. Winners at the state level go on to the National 4-H Engineering, Science, and Leadership Event held at Purdue University. Wisconsin staff is responsible for the small engine activity at the national event and is part of the management team that plans and conducts this event.

Future Farmers of America Agricultural Mechanics Events

R.T. Schuler*, J.W. Nelson, C.A. Skjolaas and J.M. Grettie

Funding: UW Cooperative Extension Service

Cooperators: UW Biological Systems Engring.; Wis. Future Farmers of America

In 2002, 22 teams took part in the state Agricultural Mechanics event. Each year the top teams from four area Agricultural Mechanics contests take part in a statewide event organized by Biological Systems Engineering staff. Guidelines are developed for the four area events. The state event also gets input from faculty at UW-River Falls, UW-Platteville, and the Fox Valley Technical College who direct area events. Biological Systems Engineering staff also help plan the national event and provide

training for agricultural educators in Wisconsin.

AWARDS

Faculty and Staff

Larry J. Chapman. Honorable mention, 2002 NIOSH Alice Hamilton Award – Educational Materials Category for *Simple Solutions: Ergonomics for Farmworkers* (NIOSH Pub. No. 2001-111), ed. by S. Baron, et al.

Astrid C. Newenhouse, Marcia G. Miquelon, K. Gunnar Josefsson, Christopher M. Brunette, Larry J. Chapman. Honorable mention for *Healthy Farmers, Healthy Profits Project* poster presentation at National Small Farm Conference, Albuquerque, NM, Sept. 17-20, 2002.

James O. Peterson. Wisconsin Clean Water Achievement Award granted by the Wisconsin Dept. of Natural Resources.

Kevin J. Shinnars. Researcher Award from the Wisconsin Forage Council for his work designing forage harvesting equipment (crop processors, conditioning systems, yield monitoring sensors and systems).

Students

Nathaniel Q. Altfeather (undergraduate). Won First Place (\$10,000) in Brainstorm: the Schoof's Prize for Creativity awarded by the UW College of Engineering. Nate developed the Check Meter, a lightweight, clamp-mounted, unidirectional accelerometer that measures negative acceleration so rowers and rowing teams can improve rowing efficiency.

Karl F. Crave (undergraduate). Received one of ten National Agri-Entrepreneurship Awards from Future Farmers of America (FFA) for creating Crave Painting and Repair LLC, a business specializing in painting buildings for farmers and rural property owners.

Jill A. Grodecki (undergraduate). 2002 Outstanding Undergraduate Agricultural Engineering Student of the Year awarded by the Wisconsin Section of ASAE for academic achievement and leadership in UW-Madison's ASAE-recognized Pre-professional Club (President for 2001-02).

Jill A. Grodecki (undergraduate). Elected first Vice-President of ASAE Council for Student Pre-professional Clubs with responsibility to be liaison between the committees and the officer group.

Jason M. Helgren (graduate student). Led UW-Madison's Future Truck Team to First Place in the national competition sponsored by Ford Motor Co. and the Department of Energy to design a truck that operates with cleaner emissions and uses less fuel without compromising truck performance.

Jacob Holl (undergraduate) and **Matthew Holl** (undergraduate last year, now M.S. candidate in Mechanical Engineering) placed third (\$4,000) in the G. Steven Burrill Technology Business Plan Competition for their Dairyland Biomass Renewable Energy (DBRE) project. The third member of the team was Elyse Eisenberg from the School of Business.

Brian M. Huenink (graduate student). 2002 Outstanding Agricultural Engineering Graduate Student of the Year awarded by the Wisconsin Section of ASAE for academic achievement and leadership in UW-Madison's ASAE-recognized Pre-professional Club (past President, Chair of Lawnmower and Snowblower Clinic, Co-leader of UW-Madison's 2002 National Quarter-scale ASAE Tractor Competition team).

Robert L. Silha (undergraduate). One of four U.S. graduating engineering students selected for the 5-year Fiat Graduate Development Program which trains and develops young engineers for future management positions with an international background and work experience within the Fiat Group. Rob will spend 18 months in Italy, 18 months in either the U.K. or France, and then finish training in the U.S. at CNH Global (the agricultural machinery company resulting from the merger of Case and New Holland).

Scott R. Waletzko (undergraduate). Received ASAE Student Honor Award at the 2002 International ASAE Meeting in recognition his scholarship and his activity in UW-Madison's ASAE-recognized Pre-professional Club (President for 2000-01, co-leader of UW-Madison's 2002 National Quarter-scale ASAE Tractor Competition team), and activities with the annual UW-Madison Engineering Expo and meetings of the Wisconsin Section of ASAE and ASAE.

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