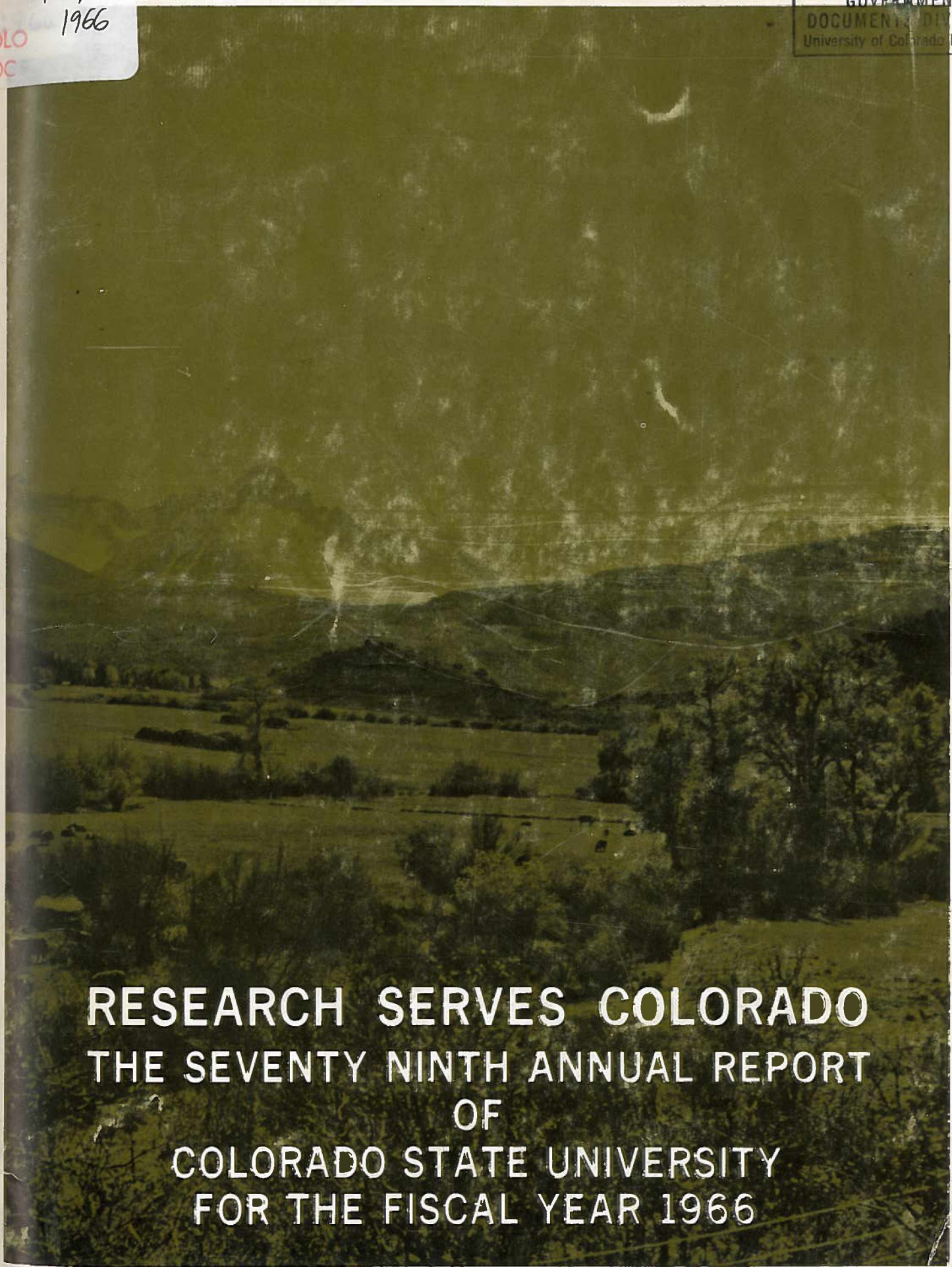


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RESEARCH SERVES COLORADO
THE SEVENTY NINTH ANNUAL REPORT
OF
COLORADO STATE UNIVERSITY
FOR THE FISCAL YEAR 1966

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Honorable John A. Love
Governor of Colorado
Denver, Colorado

Dear Sir:

In compliance with the Act of Congress entitled, "An Act to establish Agricultural Experiment Stations," approved March 2, 1887 and with Acts supplementary thereto, I herewith present the Seventy-ninth Annual Report of the Colorado Agricultural Experiment Station for the fiscal year 1966.

Respectfully,
Rue Jensen
Director

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**RESEARCH:
LEGACY OF THE FUTURE**

The university is an educational institution of the highest level. As such, it bears a great responsibility for advancing the frontiers of man's knowledge about himself and his environment. The prime mover in this never-ending struggle to shed light on the unknown is the university research program; it is there that the acquisition of knowledge for its own sake is a major facet of everyday life and is expected of all who go there to learn or teach. Derived from today's new knowledge are tomorrow's advancements in technology and application of knowledge which serve to improve the scale of living and the quality of life for all mankind.

We at Colorado State University accept this responsibility enthusiastically. Every day new ideas are developed which promise significant impact on tomorrow's world. Research is expensive and time consuming, but nothing of value comes easily. We fully intend to devote our monetary and personal resources to discharging our responsibility to the future.

None of us may live to see all the benefits derived from today's research, but this does not lessen our conviction that we can expect tomorrow's world to be all the better for our efforts today.

W. E. Morgan

William E. Morgan
President



OBJECTIVES OF RESEARCH

Formal research, a systematic inquiry for new knowledge, new ideas and new interpretations, is a major function of the University. All colleges and most departments support research programs, especially at the graduate study level.

The long term objective is to obtain basic information on problems and conditions of Colorado, the western region and the nation. While contemporary organizations may profit from these activities, future generations will be the major beneficiaries. The accumulation of basic knowledge eventually should provide a sound foundation for the development of industries and activities, including agriculture, that most efficiently utilize the resources of Colorado. At the present time, research on water conservation and management receives strong emphasis, but atmospheric, agricultural, physical and biomedical sciences are also stressed. The establishment of research facilities and the employment of creative scientists will contribute to the creation of broad research capability in the state.

The short-term objective is to obtain sufficient basic and applied information in selected areas to effect sound solutions to current problems in agriculture, other industries, and natural resource management. Information obtained will contribute to the programs having long term objectives.

A handwritten signature in cursive script that reads "Rue Jensen".

Rue Jensen
Vice-President for Research

COLORADO STATE UNIVERSITY RESEARCH FOUNDATION

In 1941, a group of faculty organized the CSU Research Foundation to help administer sponsored research contracts and grants. The Foundation was established primarily to handle patent matters resulting from inventions developed by the CSU faculty.

During the early years few projects existed and only an occasional contract or grant required administration outside the scope of the Agricultural Experiment Station. By 1957 however, it was necessary to create a staff to administer the increasing numbers of contracts and grants.

Starting with approximately \$400,000 in contract and grant expenditures in 1957, research projects administered by the Foundation grew rapidly and in fiscal year 1966 the total expenditures exceeded \$8,000,000.

At the close of fiscal year 1966, contracts and grants in force amounted to some \$23,000,000. Because of the large number of contracts and grants in force, the expenditure level is likely to be somewhat higher during the next fiscal year.

The Research Foundation serves the faculty by providing the fiscal management of research contracts and grants. The faculty member is thus relieved of mundane management problems and is free to devote his full attention to the research project on which he is working. Although the Foundation is a separate composite organization, it operates solely as the administrative arm of the university for research contracts and grants. It does not undertake research work in its own name or for its own account.

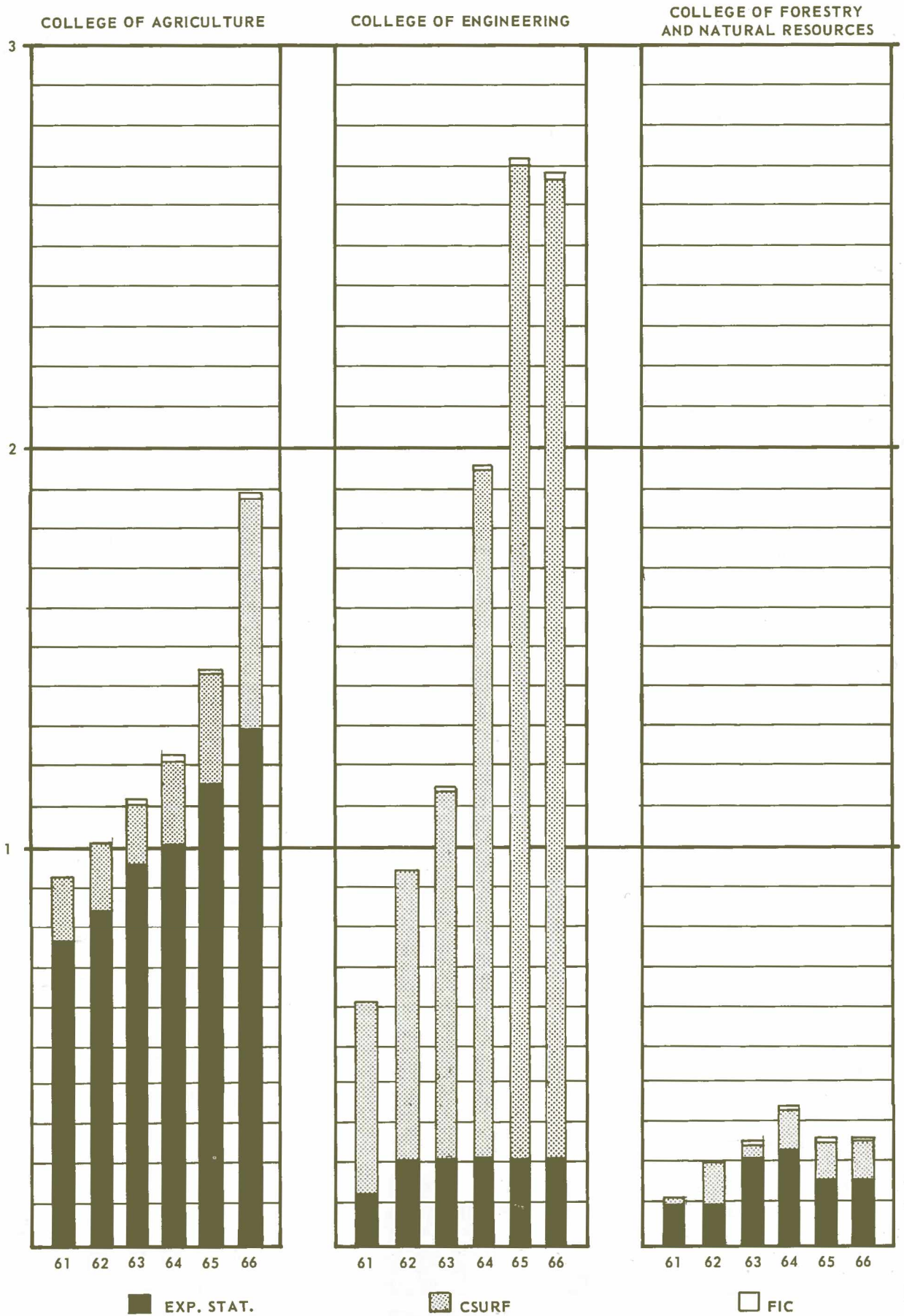
Since research and teaching go hand-in-hand, Colorado State University accepts only those research projects which can be conducted conveniently within the framework of the existing academic organization, and which will further the educational program. Projects of a purely commercial nature or those which are not compatible with the academic program are not accepted.

So successful has this program been to date that a large percentage of all graduate students presently enrolled in the university are supported in some way by the research program.

The expenditures by the Research Foundation in conjunction with contracts and grants encompass over 500 projects. Included are the international programs administered by the University, such as the veterinary college in Kenya, a cooperative project with the University of Peshawar, Pakistan, management of the SEATO Graduate School of Engineering in Bangkok, and AID programs for rural development in Nigeria and Brazil.

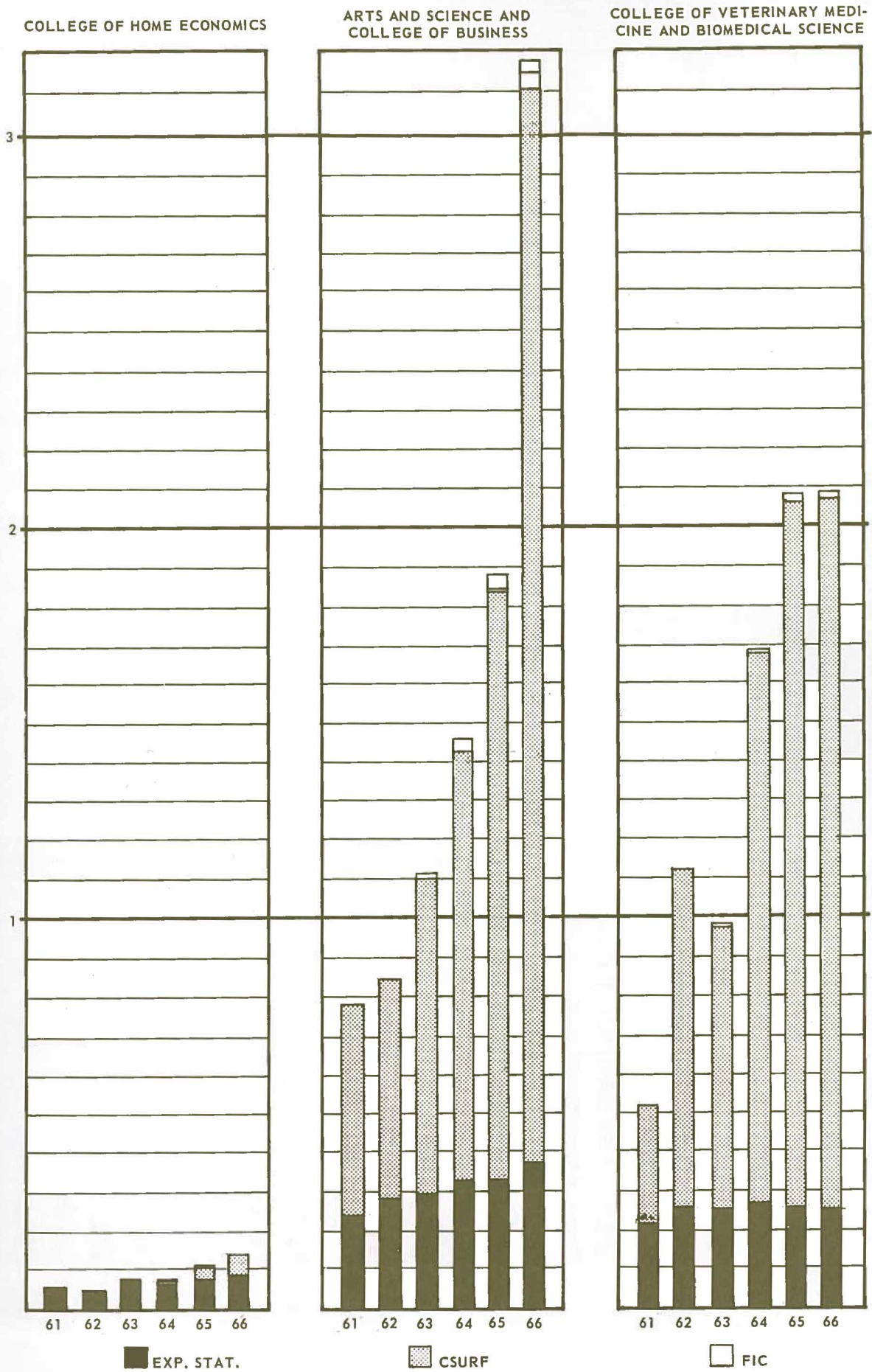
GROWTH OF RESEARCH BY COLLEGES

RESEARCH FUNDS IN MILLIONS OF DOLLARS



GROWTH OF RESEARCH BY COLLEGES

RESEARCH FUNDS IN MILLIONS OF DOLLARS



COLORADO STATE UNIVERSITY

STATEMENT OF EXPENDITURES FOR RESEARCH — FISCAL YEAR 1966

College	Total	CSU Research Foundation	Experiment Station	Faculty Improvement Committee	Facilities Development
Agriculture	\$ 2,144,232	\$ 795,287	\$1,290,944	\$ 9,716	\$ 48,235
Business	52,595	52,060	0	535	0
Engineering	3,204,389	2,819,755	203,330	6,205	175,099
Forestry and Natural Resources	280,711	121,898	157,549	1,264	0
Home Economics	117,299	44,907	72,392	0	0
Science and Arts	1,958,283	1,545,265	359,684	53,334	0
Veterinary Medicine and Biomedical Science	3,823,648	1,904,098	255,848	11,258	1,652,444
Other	720,135	354,312	291,994	2,745	71,084
Totals:	\$12,301,292	\$7,637,582	\$2,631,791	\$85,057	\$1,946,862

FINANCIAL STATEMENT

COLORADO EXPERIMENT STATION — FISCAL YEAR 1966

	Hatch	RRF	McIntire-Stennis	State Approp.	Other Sources*	Total
Carryover 7/1/65			2,497.79		24,965.39	27,463.18
Receipts	455,215.00	266,680.00	44,806.00	1,555,642.00	598,001.75	2,920,344.75
Total Income	455,215.00	266,680.00	47,303.79	1,555,642.00	622,967.14	2,947,807.93
Disbursements:						
Personal Services	391,629.18	183,403.32	19,034.03	971,247.67	190,804.61	1,756,118.81
Travel	7,483.44	14,363.43	2,136.99	32,766.92	14,470.95	71,221.73
Equipment	14,198.95	20,894.89	1,059.40	43,722.29	36,497.44	116,372.94
Supplies and Material	41,903.43	48,018.36	3,311.79	232,135.12	367,208.36	692,577.06
Plant M&O				275,770.00		275,770.00
Total Disbursements	455,215.00	266,680.00	25,542.21	1,555,642.00	608,981.33*	2,912,060.54
Balance 6/30/66			21,761.58		13,985.81	35,747.39
Sum of Disbursements and Balance	455,215.00	266,680.00	47,303.79	1,555,642.00	622,967.14	2,947,807.93
<u>*Disbursement of Other Sources Includes:</u>						
Research Sales					264,903.15	
Service Sales					218,171.11	
Grants					40,539.00	
ARS Contracts					85,367.07	

ADVANCED DEGREES AWARDED 1965-1966

	MASTER OF SCIENCE	MASTER OF ARTS	PH.D.	TOTAL
Agriculture				
Agronomy	11		2	13
Animal Science	4		3	7
Agriculture Economics	4			4
Entomology	1			1
Horticulture	2			2
Total Agriculture	22		5	27
Business				
Business	17	5		22
Total Business	17	5		22
Engineering				
Agriculture Engineering	1		1	2
Atmospheric Science	5		1	6
Civil Engineering	25		11	36
Electrical Engineering	15			15
Mechanical Engineering	5			5
Total Engineering	51		13	64
Forestry and Natural Resources				
Forest Management and Utilization	3			3
Forest Rec. and Wildlife Conservation	13		1	14
Range Management	4			4
Watershed Management	9		1	10
Total Forestry	29		2	31
Home Economics				
Food Science and Nutrition	1			1
Master of Home Economics	2			2
Total Home Economics	3			3
Science and Arts				
Botany and Plant Pathology	3	2	2	7
Chemistry	6	1	2	9
Economics	6			6
Education		44		44
Sociology — Anthropology	6			6
English		10		10
Geology	2			2
Hearing and Speech Science	13			13
Speech Arts		2		2
History		1		1
Industrial Arts		11		11
Languages		4		4
Mathematics and Statistics	7	1	3	11
Music		5		5
Physical Education		12		12
Physics	7	21	1	29
Psychology	13			13
Vocational Education		24		24
Zoology	4	1	2	7
Total Science and Arts	67	139	10	216
Veterinary Medicine				
Anatomy	1			1
Pathology and Microbiology	10		6	16
Physiology	2		2	4
Radiology and Radiation Biology	8		3	11
Veterinary Clinics and Surgery	2			3
Veterinary Medicine	3			3
Total Veterinary Medicine	26		11	37
GRAND TOTAL:	215	144	41	400

EXPERIMENT STATION

The Colorado Agricultural Experiment Station was created by the Hatch Act of 1887 which established agricultural experiment stations in each state and provided funds to assist in their operation and maintenance. The Act placed the experiment stations at the state agricultural colleges as integral parts of those institutions and charged them with promoting scientific investigations into the basic principles and useful applications of science relating to agriculture.

The McIntire-Stennis Cooperative Forestry Research Act of 1962 provided funds to promote research in forestry in land-grant colleges and agricultural experiment stations and in schools of forestry at other appropriately qualified state institutions.

State matching funds are required by both of the above Acts. The Experiment Station is therefore cooperatively supported by state and federal funds.

An integral part of Colorado State University, the Experiment Station consists of some 193 scientists, 67 graduate students, and numerous research laboratories. Most of the scientists engage in both research and teaching.

The research laboratories are located at the main campus of Colorado State University and at the branch stations at nine locations:

Eastern Colorado Range Station, Akron
Southeastern Colorado Branch Station, Springfield
Arkansas Valley Branch Station, Rocky Ford
San Juan Basin Branch Station, Hesperus
San Luis Valley Branch Station, Center
Western Slope Branch Stations
Orchard Mesa Unit, Grand Junction
Austin-Rogers Mesa Unit, Austin
Fruita Unit, Fruita
Mountain Meadow Research Center, Gunnison

In addition, cooperative research is conducted with the Agricultural Research Service on the main campus and at:

Central Great Plains Field Station, Akron
U. S. Potato Station, Greeley
Upper Colorado River Soil and Water Research Unit at Grand Junction

NATURAL RESOURCES CENTER

The major purpose of the Natural Resources Center is derived from the interdisciplinary character of many problems encountered by man's development and use of land, water, and atmosphere. Providing an organization for integrating research and education in these areas of interest permits the University's scientific community to better serve the people of the state and the nation.

The Natural Resources Center functions through a series of faculty committees, organized around problems of common interest in the natural resources area. Currently, some 200 of CSU's faculty are members of the center.

The Water Committee reviews research proposals submitted to the Office of Water Resources Research, Department of Interior, Washington, D. C. During the past year, the center received \$87,500 in an institutional allotment grant. In addition, five matching grants (federal-non-federal funding) were active with a total dollar value of projects of \$192,522. These five grants represent five areas of research in five departments.

The State Water Resources Liaison Committee organized a State Water Resources Conference. Some 125 participants from throughout the state met to discuss their water problems and to become acquainted with the research at the university.

The Committee on the Urbanization of Colorado held several faculty seminars. As a result, a proposal was funded through a community services grant from the Extension Service. The participants will be asked to identify the crucial problems which face the state as it becomes more urban. In addition, they will be requested to explore possible research and educational programs which could be directed toward these problems.

The Faculty Committee has been reviewing the activities and problems associated with public land policy. This committee has had several faculty discussions and has maintained liaison with interested groups in this field.

Other committees of the center have maintained faculty communication and faculty discussions in areas such as natural resources education, recreation, and water quality management.

**OFFICE OF
FACILITIES DEVELOPMENT**

The Office of Facilities Development, a newcomer among research administration departments at Colorado State University, administers federal grants for construction of research and graduate training facilities. The office is involved with the Planning Office and Campus Development Committee in the overall facilities planning of the campus; works with departmental and administrative committees in programming new facilities; and works with faculty in developing proposals to prospective sponsors for funds to construct such facilities. During fiscal year 1966, the following grant was received:

<i>Facility</i>	<i>Sponsor</i>	<i>Amount</i>
Engineering Research Center Addition	NSF ¹	\$608,350
Ongoing projects included:		
Atmospheric Science Facility	NSF	315,000
Irradiation Site Facility	NIH ²	30,227
Physiology Graduate Research Facility	NSF	459,750
	NIH	140,880
Radiation Environmental Stresses Laboratory	NIH	179,518
Radiation Laboratory (Biophysical Sciences)	NIH	109,192
600 Dog Pens	NIH	100,083
700 Dog Pens	NIH	181,158

¹ National Science Foundation

² National Institutes of Health

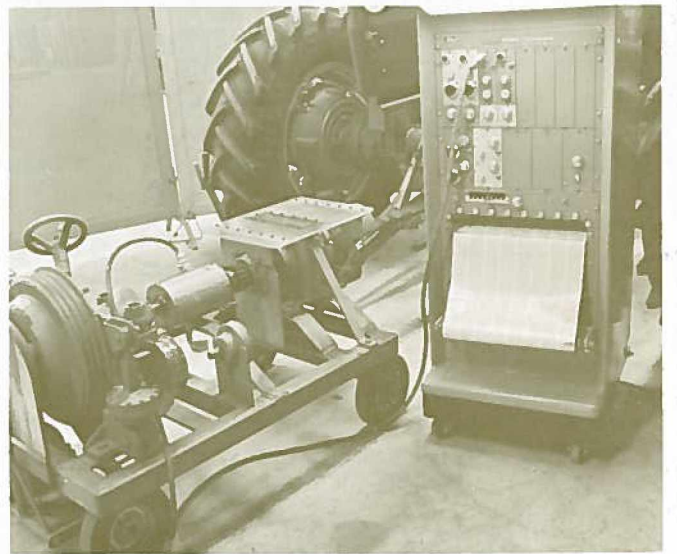
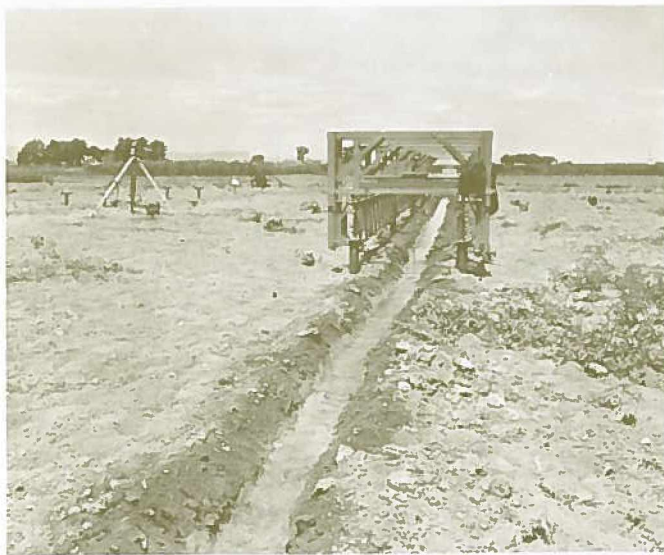
In addition to supervising facilities' grant funds, the office also administers proceeds from Research Foundation revenue bonds. These proceeds are being used to construct (1) a Communicable Disease Center Ecology Laboratory to house a Public Health Service research unit, \$1,300,000; (2) an underground irrigation system for the main campus, \$470,000; and (3) to purchase a research farm, \$200,000. Negotiations currently are under way for other such bond issues. During 1966, the office also negotiated and received title to the deactivated Poudre Canyon Atlas E Missile Site for the university. The site was valued in excess of \$14 million, including over \$4 million in equipment.

**FACULTY
IMPROVEMENT COMMITTEE**

The Faculty Improvement Committee recommends to the faculty proposals designed to improve the status of faculty members with respect to professional standing, working conditions, relationships, recognition, advancement, and other matters which may be recommended to improve the effectiveness and welfare of the faculty. In this capacity, it acts largely as an advisory body to other elements of university organizations.

The committee also administers a small appropriation of research funds. Grants are made both to the young, relatively inexperienced faculty member who has not yet established himself in research, as well as to the more experienced faculty member who desires to explore avenues of research which require basic investigation before a formal proposal is written to other prospective funding agencies.

In both these capacities, the Faculty Improvement Committee is vitally concerned with the improvement of the quality of the faculty as a whole. This, in turn, improves the overall intellectual atmosphere of the university and the quality of its graduates.



RESEARCH ACHIEVEMENTS

NEW SOIL TEST DIAGNOSES ZINC DEFICIENCIES

DEPARTMENT OF AGRONOMY

Dr. W. L. Lindsay reports the development of a new soil test which permits rapid, accurate diagnosis of zinc deficient soils. The extractant used is the chelating agent, ethylenediamine tetraacetic acid (EDTA), in an ammonium carbonate buffer. Unlike most soil tests, the new procedure precludes the dissolution of calcium and iron but dissolves zinc in proportion to the amount which is normally available to plants. The zinc content of the soil extract is then easily and accurately determined on an atomic absorption spectrophotometer.

The new test was examined on 42 Colorado soils, brought into the greenhouse and fertilized with different levels of zinc. On all soils having less than 1.4 parts per million of extractable zinc, corn showed a growth response upon the addition of zinc fertilizer. On the other hand, on soils having greater than 1.4 parts per million

of zinc, there was no response to added zinc. The test clearly delineated between zinc-responsive and non-responsive soils. Details of this study are included in the Ph.D. thesis of Dr. J. F. Trierweiler, carried out at Colorado State University under a research grant from Farmlands Industries, Inc. Other field tests now under way will check further the reliability of the new test for various crops, soils, and climatic conditions.

Development of this rapid and reliable soil test will be of considerable value to soil testing laboratories, fertilizer dealers, farmers and agronomists in many areas of the world where zinc deficiencies are becoming common nutritional problems. Numerous laboratories outside of Colorado already have requested information on the new method and are exploring its suitability in their areas.

GENETIC INFLUENCES ON BULL FERTILITY AND CALF LOSS IN BEEF CATTLE

DEPARTMENT OF ANIMAL SCIENCE

Among research projects important to the cattle industry have been recent studies conducted at the Colorado Experiment Station by Dr. H. H. Stonaker, Dr. L. C. Faulkner, Kent Riddle and graduate students James McNitt and Larry Theurer.

These studies offer convincing evidence that high levels of hybrid vigor are exhibited in bull semen characteristics and in viability of newborn calves. Conversely, the studies show selection offers little as a means for genetic improvement in these traits. These traits are of great importance in beef cattle, as they relate to the most important economic trait in cattle, size of calf crop. But the traits have not been extensively analyzed before in a population of cattle including inbreds, linecrosses, controls, and crossbreds as exists at the San Juan Basin Station.

Extensive semen-evaluation surveys indicate about 17 percent of Colorado's beef bulls have substandard semen quality. Genetic aspects of these differences could not be assessed in these surveys. But conclusive evidence that variations in semen quality are under at least partial genetic control comes from recent analyses on the San Juan Basin Station herd.

The structure or morphology of sperm cells, a critical aspect of semen evaluation, is greatly affected by inbreeding and hybridizing.

In contrast, the heritability estimates, useful because they indicate the additive genetic fraction of the genetic variance, are predominantly low for semen characteristics. This infers that bulls selected for superiority in semen traits would produce sons only very slightly

above average. Some of the heritabilities found were: semen quality, .14; concentration, .37; vigor, .13; percent alive, .06; and morphology, —.06.

The results show that to the degree semen evaluations indicate differences in conception rates, more highly fertile bulls can be produced by planned linecrossing. This has the practical disadvantage of compromising opportunities for producing maximum heterozygosity and hybrid vigor in the commercial progeny. It ultimately would indicate the rotation of bull batteries of linecrosses with each group of linecrosses derived from different lines.

Death losses of newly born calves are a major source of economic loss to the cattle industry. Average beef calf losses, birth to weaning, of 11.6 percent are reported for the Great Plains. Little knowledge has been available on the genetic opportunities to decrease these losses. These genetic influences are now known to be large.

Systematic hybridizing of Herefords through the crossing of unrelated inbred sires on linecross cows decreased death loss relative to control from 11.79 percent to 7.46 percent, a reduction of 37 percent. Linecross Hereford calves had even greater chances of survival than did three breed Hereford x Shorthorn-Angus crosses. Inbred Herefords had by far the largest death loss. Utilization of this technique by commercial cattlemen could add 38,000 calves annually to the Colorado calf crop from the present number of beef cows. This has an annual value of about \$4,500,000.

A SUSCEPTIBILITY RHYTHM TO MALATHION IN THE MIGRATORY GRASSHOPPER

DEPARTMENT OF ENTOMOLOGY

The migratory grasshopper, *Melanoplus sanguinipes* (F.), is an insect which each year causes either local or widespread damage in Colorado. Recent control methods have included poisoned baits and low-volume high-concentrate applications of certain insecticides. These highly concentrated insecticides may cause rapid selection, and thus a build-up of resistant populations. Further techniques must be found to aid in the control of economic species.

One new technique with preliminary data, based on work conducted by Dr. Stanley G. Wellso and E. Lee Frudden, is presented here.

Because biological organisms exhibit seasonal daily and metabolic rhythms, any disruption of these rhythms to the detriment of the destructive species will benefit us. Investigations on the time of treatment in respect to the percentage mortality of malathion-treated grass-

hoppers were initiated. Grasshoppers were treated topically with microliter amounts of a known concentration of malathion which normally killed 50 percent of the treated individuals in 24 hours. When grasshoppers were treated every three hours during the day and the subsequent mortality was checked for each treated group 24 hours later, the highest mortality occurred in those treated two hours after dusk. In fact, the mortality for both males and females was approximately 40 percent higher than for those grasshoppers treated three hours earlier.

These data indicate that natural populations may exhibit an increase in mortality to insecticides after dusk. These preliminary results must be verified by maintaining cultures of grasshoppers under controlled photoperiodic and temperature regimens, and testing them under these conditions.

FACTORS INFLUENCING SEED POTATO VIGOR

DEPARTMENT OF HORTICULTURE

The productivity of seed potatoes is determined primarily by the climatic environment where the seed potatoes are grown and freedom from disease. Many Colorado locations possess an excellent climate for production of high-performance, vigorous seed potatoes. Moreover, some locations, the San Luis Valley for example, are relatively free of certain insect vectors and diseases which plague other seed-producing regions. Nevertheless, considerable differences in productivity occur between potentially excellent seed lots.

Recent studies by Dr. Milton Workman and James Twomey have indicated that storage conditions, although of secondary importance to the factors mentioned above, are very important in permitting maximum yielding potential to be realized. This may not be unusual in that many biochemical changes occur in the seed potato between harvest and planting, and the storage environment would qualitatively and quantitatively influence these changes.

Experimental storage units have been constructed to provide variation and precise control of the following three experimental variables: temperature, oxygen, and carbon dioxide. Periodically during the storage season, potatoes are removed from the experimental units for laboratory study of physiological processes. In the

spring, the remaining seed potatoes are planted in replicated trials for productivity evaluation.

In one experiment, the sequence of temperatures to which the seed potatoes had been exposed from harvest until planting had a marked effect on seed vigor. For example, storing at 70°F after harvest followed by 39°F resulted in much lower production than when the 70°F was followed by 32°F.

In another experiment, slow continuous ventilation resulted in a 30 hundredweight per acre increase in premium potatoes over 10 ounces in weight. Carbon dioxide may be implicated here. For example, four percent carbon dioxide used with different oxygen concentrations decreased yield as much as 40 hundredweight per acre.

The percentage of oxygen in the storage environment is not extremely critical; seed stored in 1 percent oxygen performed as well as seed stored in 21 percent oxygen. However, some advantage was obtained by storing in 2.5 percent oxygen.

If further studies continue to support these findings, it may prove economically feasible to provide both precise temperature and atmosphere control to achieve maximum seed potato vigor.

SODIUM NITRATE IN DRINKING WATER FOR TURKEYS

DEPARTMENT OF POULTRY SCIENCE

Colorado turkey producers often have wondered how domestic water affects turkey growth and performance. With the encouragement and support of the Colorado Turkey Federation, Dr. E. W. Kienholz began to study the effect of different salts upon growth rate of turkeys.

Levels up to 18,000 ppm of magnesium sulfate (Epsom Salts) were given to turkeys in their water from the time they hatched until they were four weeks old. At the higher levels the birds drank more water, had very loose droppings and gained less weight; but these birds recovered when they were returned to normal water.

Levels of up to 2,000 ppm of nitrate were then placed in turkey drinking water until they were four weeks old. Again, the highest level depressed rate of growth, about 10 percent; but the birds again fully recovered when they were given normal water, and there was no indication of nitrite poisoning.

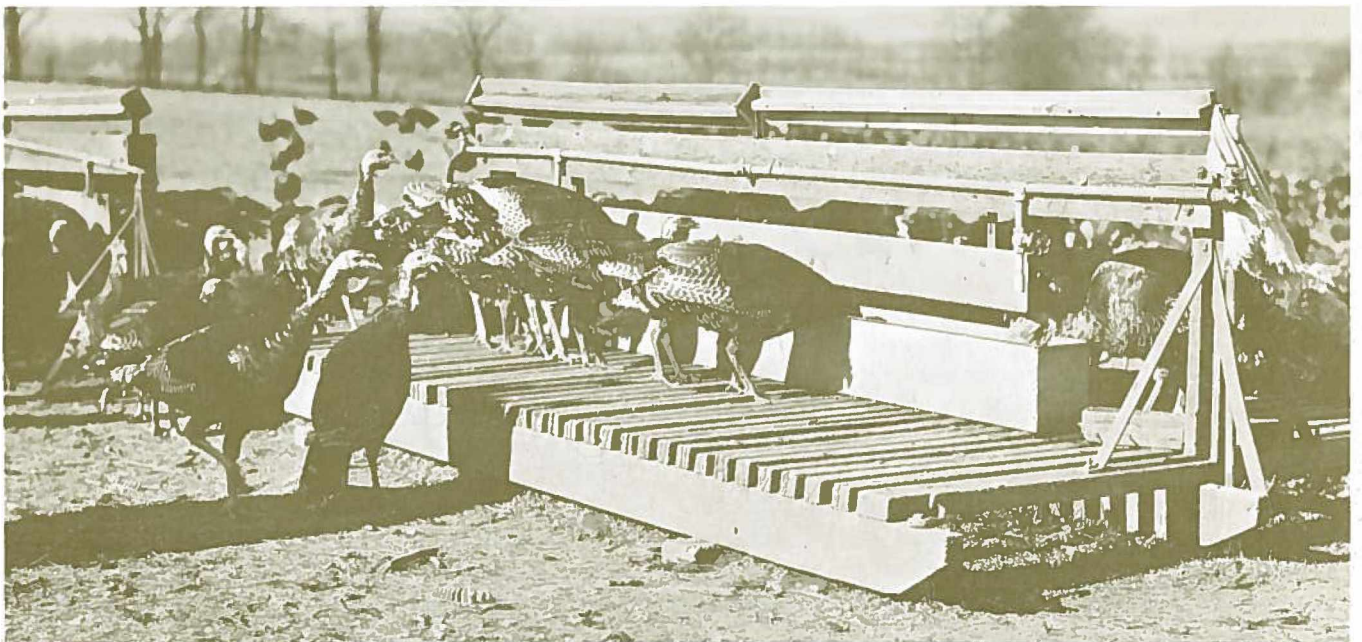
A most interesting phenomenon occurred during these studies. Turkeys which received 675 ppm nitrate as sodium nitrate in drinking water for four weeks, then normal water thereafter, were significantly heavier in body weight at eight weeks and continued to be heavier up to market age of 20 to 24 weeks of age.

Dr. Kienholz repeated this test three years and observed the same result each year with Bronze turkeys. He has thus concluded that sodium nitrate in drinking water gives a reliable delayed growth response, especially to Bronze males. The growth advantage is about $\frac{3}{4}$ pound per bird or about a five percent increase in body size above those not receiving the early sodium nitrate treatment.

Other nitrate salts have not produced such growth responses, nor have other sodium salts had any effect. Therefore, there must be something unique about sodium nitrate for this delayed effect. Also, the sodium nitrate treatment has not been beneficial for White turkeys, although this was tested in only one experiment. Three strains of Bronze turkeys have been tested, and in each case there was a consistent response. Therefore, there appears to be a strain response which is related to feather color in turkeys.

Many physiological measurements were made to determine why sodium nitrate produced this effect in Bronze turkeys. There are reports in biological literature that nitrates interfere with normal thyroid activity. However, measurements of radio-iodine uptake at four and 24 weeks of age showed no effect upon this thyroid function, nor was there any effect upon thyroid weight. Therefore, Dr. Kienholz feels certain that the thyroid is not involved directly in this phenomenon. Many other physiological measurements were made, and the only clue to the biochemical effect has been the observation that the early sodium nitrate treatment may have reduced testes size in these birds.

The research is continuing, with the major efforts being directed toward finding out if effect upon testes size is consistent in subsequent experiments. Also, effect of this treatment upon feed efficiency must be determined before any estimate of possible commercial application can be made. If these research results can ultimately be easily applied with no difficulties, there should be a considerable economic advantage from this application.



TWO-PHASE FLOW IN POROUS MEDIA

DEPARTMENT OF AGRICULTURAL ENGINEERING

The use of models for predicting the behavior of hydraulic structures of many kinds has been an indispensable tool in the design of such structures for many years. Engineers responsible for the design of sub-soil drainage systems and those concerned with the operation of petroleum and natural gas recovery schemes have tried to devise ways to properly scale models and extrapolate from their behavior to obtain information about the performance of field installations.

Because of the complexity of the interrelationship among the variables governing flow of two immiscible fluids in porous media, e.g., air and water or oil and gas, scaling models for such systems has been very difficult. Until recently, it has been impractical except for special cases.

Dr. A. T. Corey has shown how requirements for similitude for two-phase immiscible fluid systems in porous media can be stated in a simple way in terms of an easily measured parameter associated with pore-size distribution. He and the graduate students under his supervision have demonstrated the validity of this theory by comparing the behavior of models made similar according to their criteria. This development makes the use of models for studying two-phase immiscible fluid systems in porous media practical (for the first time) for a wide range of field situations and provides a new and valuable tool for the engineer in predicting behavior of drainage systems.

CLEAR AIR TURBULENCE

DEPARTMENT OF ATMOSPHERIC SCIENCE

Clear air turbulence is still one of the major hazards of aviation. It affects mostly fast-flying jet aircraft. On several occasions, clear air turbulence has resulted in damage to aircraft and in injury to passengers and crew. One case is on record where a B-52 aircraft lost its vertical stabilizer under severe turbulence conditions experienced over Colorado near the mountain ranges of the Rockies.

From flight measurements conducted over Australia during 1963, in which Dr. E. R. Reiter was one of the investigators, and from measurements over Soviet Russia, conclusions can now be drawn as to the physical nature of clear air turbulence (CAT).

In the thermally stable environment of the upper troposphere and of the stratosphere, especially near strong jet streams, CAT results from the breakdown of gravity waves forming on shallow interface layers between warm air on top and cold air below. If the air flow in these two layers shows a wind shear, waves will form. These waves, under certain conditions, tend to become rough and to break down into random eddies. These eddies, if they have enough kinetic energy, will bounce around an aircraft that flies through them. This, then, is called clear air turbulence.

Until now it has been extremely difficult to forecast clear air turbulence. CAT is a small-scale phenomenon. Eddies from 10 meters to 200 meters across cause most of the violent accelerations to an aircraft. Dr. Reiter's meteorological data, on the other hand, are collected by a network of stations which are 300 miles and more apart. Information is gathered twice a day at 12-hour intervals. From these relatively sparse data, it is impossible to make forecasts relating to a small-scale phenomenon. Therefore, meteorologists must resort to statistical techniques, looking for correlations between CAT occurrence and certain shapes of the upper flow pattern and/or certain areas in which strong vertical wind shear may be expected.

A fact well known to pilots is that CAT is relatively frequent over the Rockies and over the Allegheny Mountains. Present research efforts successfully tried to explain this fact from physical principles.

When atmospheric flow is forced to cross a mountain barrier, large waves tend to form in the lee of the mountains. Known as lee waves, these sometimes appear visible to the naked eye from the formation of the so-called lenticular clouds. These stationary, lens-shaped clouds are a sign to every experienced glider pilot that he may expect strong up- and down drafts over the mountain ridges. More often than not, these waves offer relatively smooth flying conditions. The up- and downdrafts associated with them are of such a large scale that an aircraft penetrating through them will not react in violent accelerations. Sometimes, however, strong clear air turbulence is associated with the presence of mountain waves. The problem is to find out when to expect CAT and when to expect smooth flying conditions.

This is done by theoretically calculating the wavelengths and the amplitudes of such lee waves. These waves usually measure approximately 10 km in length. Computing the vertical velocity associated with such wave flow, Dr. Reiter can estimate the kinetic energy of the perturbation motion. From statistical evidence gathered over Australia and over Soviet Russia, he found that this energy decays exponentially into smaller waves and small eddies. If an abundance of energy is available at wavelengths of 10 km, an increase is likely in energy of small-scale eddies somewhere downstream from the main mountain ranges that generate the lee waves. Dr. Reiter found a quantitative relation between the energy contained in lee waves and the energy subsequently experienced at CAT.

From this quantitative relationship, it was possible to forecast rather accurately the occurrence or nonoccurrence of clear air turbulence over mountainous terrain. The forecasting procedure worked out in cooperation between Dr. Harry Foltz and Dr. Reiter is presently being tested at the Numerical Weather Prediction Center in Washington, D. C. Hopefully, the forecasting technique will become operational and will aid commercial and military pilots who have to cross large mountain ranges in their aircraft. The forecasting methods developed here also foresee the use of satellite photographs if radiosonde data are sparse or not available over the forecasting area in question.



INFRARED STUDIES OF EVAPORATION SUPPRESSANT MATERIALS ON WATER

DEPARTMENT OF ATMOSPHERIC SCIENCE

The CSU Department of Atmospheric Science took part in a multiple university and government agency experiment on evaporation reduction conducted at Lake Hefner, Oklahoma, in August 1966.

Lake Hefner is a man-made lake near Oklahoma City. Evaporation rates from this lake in midsummer average approximately 30 million gallons a day.

The study was organized by the U. S. Bureau of Reclamation to test methods by which this evaporation might be suppressed. Other groups taking part in the field study included the Environmental Science Services Administration, the Sea-Air Interaction Laboratory and Oklahoma State University.

One requirement of the measurement program, directed by Dr. W. E. Marlatt, was to monitor temperature of the top 3-1000 inch of the water surface. An airborne infrared radiometer, an instrument designed to measure the temperature of an object without making contact with the object, was used. The principal objective of the CSU experiment was to determine whether evaporation suppressant (a common organic compound could be detected by looking at the surface temperature patterns on the lake.

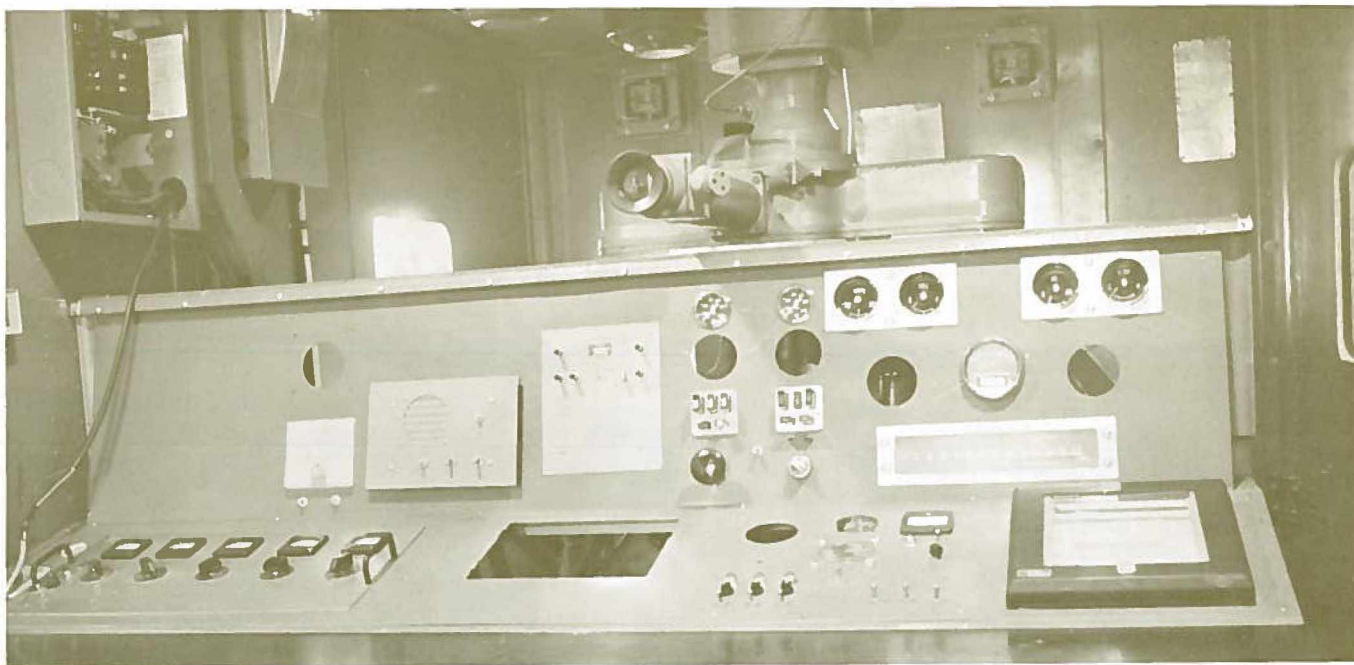
Since evaporation cools the water surface, suppressing the evaporation theoretically should cause the surface temperature to increase. Thus, suppressant-

covered areas of the lake should be warmer than surrounding areas.

Infrared, or heat, radiation is directly proportional to the temperature of the emitting body. Modern sophisticated technology has provided instruments which directly measure this radiation with a very high degree of accuracy. Dr. Marlatt has mounted one of these instruments in the undersection of a Piper Twin Comanche aircraft used for research by the Atmospheric Science Department.

Flights were made over Lake Hefner in a very precise manner during periods when the suppressant was on the lake surface. The data were plotted on a map of the lake by computer and analysis of these temperature patterns is currently being carried out.

It is anticipated that results of this experiment will provide new information on whether a large-scale warming of the water surface does occur under natural conditions when evaporation suppressant is applied to the water surface. If such warming does occur, accurate mapping of the suppressant would be possible either during day or night hours. This requirement is necessary for future use of suppressant, particularly on large bodies of water. Also important is the possibility of mapping evaporation rates using the surface temperature measurements in heat balance equations.



RESEARCH PERFORMED ON "PROJECT FALLOUT"

DEPARTMENT OF ATMOSPHERIC SCIENCE

With the advent of the first thermonuclear weapons tests in the atmosphere, observers noted that subsequent distribution of radioactive debris displayed characteristics which could not be explained satisfactorily on the basis of known properties of the general circulation of the atmosphere. In particular, these measurements revealed large, localized fallout peaks many months after testing ended, a mid-latitude peak in mean fallout intensity, and a well-pronounced radioactivity increase in the spring of each year.

As a first step toward solution of these problems, detailed case studies traced the origin of radioactive debris constituting these individual fallout peaks. Findings reported by Dr. J. D. Mahlman revealed conclusively that the debris from these peaks can be traced backward to the lower stratosphere and that this debris enters the troposphere in association with strong cyclogenesis. An exhaustive statistical analysis was then performed which clearly demonstrated that this cyclogenetic process is almost wholly responsible for the generation of localized fallout increases throughout the entire year and also for the mid-latitude fallout peak. However, the spring fallout maximum could not be explained by this process, thus suggesting that physical processes acting in the stratosphere itself must be held responsible.

In accordance with previous suggestions that the spring fallout maximum is related to the late winter sudden breakdown of the stratospheric polar westerly wind system, a two-month period encompassing such a breakdown was selected for analysis. This analysis dem-

onstrated that the large-scale waves in the stratosphere produce a very efficient northward and downward transport of radioactive debris after the breakdown of the winter wind regime, thus providing a probable physical mechanism for the spring fallout increase.

However, to claim a complete understanding of the processes leading to the spring peak, a firm knowledge of the mechanics of the stratospheric breakdown process is essential. Careful investigation showed conclusively that the pronounced temperature increases associated with the breakdown are caused by horizontal advection of heat and not by compression heating as often assumed.

To gain a more complete understanding of the mechanics of the breakdown process, a dynamical theory was formulated which permitted a general variation of atmospheric parameters in determining conditions for instability of the stratospheric circulation. Application of this theory to the real atmosphere predicted that the Antarctic winter stratospheric circulation is more stable than in Arctic regions. This is in complete agreement with observation and suggests a fundamental explainable difference between these two circulation regimes.

On the basis of the work performed, it appears that the basic features of the observed radioactivity distributions may be adequately explained by present knowledge. However, many of the more intricate features have proven to be very elusive. It is hoped that future studies will provide satisfactory answers to some of these more difficult questions.

DESIGN OF ALLUVIAL CHANNELS

DEPARTMENT OF CIVIL ENGINEERING

For several years, CSU has conducted basic and applied hydraulic research in civil engineering. Four interrelated areas of study conducted by Dr. D. B. Simons have received attention and recognition: The establishment of the regimes of flow and forms of bed roughness which occur in alluvial channels; quantitative geomorphology; river mechanics applicable to river basin development; and the design control and stabilization of alluvial channels.

REGIMES OF FLOW AND FORMS OF BED ROUGHNESS

Water flowing over alluvial material molds it into different shapes. Some are triangular in form, while others are quite rounded, depending upon velocity and other variables. The ability of a channel to convey a given quantity of water is closely related to the form of bed roughness. When angular bed forms occur, resistance to flow is large, the flow is highly turbulent, and average velocity is sufficiently small that channel banks are fairly stable and flow can transport only a small amount of sand-size and larger sediment. Conversely, if the channel is slightly steeper and the velocity larger, the bed roughness will change from the rough triangular form to a plane bed or to shapes that are smaller in amplitude, and more streamlined. With this type of bed roughness, the channel is much smoother, velocities may be twice as large as for the other case, the sediment transport is relatively large, and the channel is apt to be unstable.

QUALITATIVE GEOMORPHOLOGY

Knowledge of regimes of flow and forms of bed roughness has been further amplified by certain detailed

studies. These include the mechanics of sediment transport, resistance to flow, the occurrence of large sand bars, channel geometry, and evaluation of the effect of changing the magnitude of such variables as discharge, slope, sediment discharge, and the characteristics of the bed material on fluvial processes. Such knowledge is fundamental to more efficient water resources development and utilization.

RIVER MECHANICS

Development of our water resources requires detailed knowledge of: how a river will change as a result of water development, methods of channel stabilization, control of erosion, deposition methods of flood protection, and river improvements for navigation. The know-how and theories developed to achieve these goals are widely applied by various governmental agencies and consulting firms to canals and small and larger rivers.

DESIGN OF ALLUVIAL CHANNELS

A relative and physically sound method of designing stable conveyance channels has been developed. This was arrived at by utilizing knowledge gained pertaining to the shape of alluvial channels established by the flow, the types of bed roughness, the prediction of their occurrence, their effects on average velocity, the rate of sediment transport, how channel slopes vary with distance and size of bed material, methods of bank stabilization, methods of controlling entry of sediments to the channel, the influence of silt and clay sediments, and seepage forces caused by inflow or outflow through the bed and banks of the channel.

HYDROLOGY PROGRAM

DEPARTMENT OF CIVIL ENGINEERING

Hydrology research is being conducted by Dr. V. Yevjevich, W. U. Garstka, Dr. A. H. Barnes, Dr. G. L. Smith, Dr. R. D. Markovic, Dr. J. H. Morel-Seytoux and Dr. M. E. Holland.

STOCHASTIC HYDROLOGY

Research activities in stochastic hydrology use the most modern scientific methods of investigation of hydrologic phenomena which are governed by chance, like rainfall and runoff distribution in time and area. Basic objectives are to better understand the nature of available water resources and to describe them by proper mathematical methods in order to better plan, design, and operate water resources projects. Special emphasis is placed on development of more efficient methods in planning and operating water storage capacities. Results have been astonishingly good, and the program already has acquired national and international fame as one of the leading of its kind in the world. That many students from this country and abroad apply for graduate and research work associated with this project confirms its positive results. Dozens of scientific publications already emphasize the contribution of this project.

FLOODS FROM SMALL WATERSHEDS

Large watersheds are well gaged, and a minimum amount of small watershed runoff is observed. Rural development, highway drainage, cross-drainage of irrigation canals, water supply and flood defense of communities, and other problems require knowledge of small watershed hydrology. A basic project on small watershed hydrology is established in the Hydrology Program; and at the moment, priority has been given to floods from small watersheds because of special importance. The objective is to develop methods of predicting floods and their characteristics for many applications. The research is being developed in three directions:

1. Hundreds of floods from experimental watersheds from this country and abroad are used as research material, with the first 500 flood events already being used in current research.
2. A research facility to simulate rainfall-runoff relationships of a one-acre area is being constructed in an outdoor hydrologic laboratory to study reaction of small river basins to precipitation for various river basin characteristics. It is planned not only to study the rainfall-runoff relationship on this physical facility but also to study erosion problems later by rainfall as well as by pollution of surface and ground water by chemicals.
3. Analytical study is carried out to attain maximum results of the above two approaches. The experimental

facility has a basic objective to contract investigation in space and in time. This means there is no need to wait years and years for large floods to occur because they can be simulated at the facility without difficulty. Instead of studying many small river basins of various characteristics around the country, a one-acre area can be reshaped every time a new type of basin is to be investigated.

HYDROLOGIC ASPECTS OF WEATHER MODIFICATION

Congress has asked the Department of the Interior, through the U. S. Bureau of Reclamation, to develop operational engineering approaches for weather modification in high mountains in order to increase water supply in arid and semi-arid regions. The Office of Atmospheric Water Resources of the U. S. Bureau of Reclamation has given a project to the Hydrology Program of the Civil Engineering Department to investigate hydrological aspects of weather modification. This means that runoff from high mountain river basins is the final gage of the success or failure of weather modification attainments. The investigations in the Hydrology Program are being carried on prediction of water yield from high mountain river basins from their topography. The study of criteria for selection of river basins which promise the best weather modification attainments is underway. New scientific methods are being developed to determine whether weather modification does significantly change water yield. Being studied are several other hydrological research topics which are not only important to weather modification control but also have general significance for advancement of the knowledge of natural water resources.

PREDICTION OF FLOOD WAVE ATTENUATION IN ARTIFICIAL CHANNELS

For several years, research has been conducted in developing new methods for computing floods moving through storm drains and other artificial water channels. It is expected that about \$40 billion will be invested in the next 25 years in urban, suburban, and highway storm drainage. If the new methods can either cut the cost by a small percentage or significantly decrease risk of flooding, both attainments will have great economic benefit. The objective is to develop new methods in designing storm drains of various kinds. An 825-foot long pipe, three feet in diameter and movable from 0 to 4 percent slope on a hillside in the outdoor laboratory, has been used as the main physical research facility. The research has progressed to such an extent that new methods will be developed for storm drain design in the near future.



MECHANICS OF LOCAL SCOUR

DEPARTMENT OF CIVIL ENGINEERING

Bridges are designed to accommodate a flood of certain magnitudes. Rebuilding less costly bridges periodically is cheaper than building expensive bridges which may survive any foreseeable flood. In other words, some bridges may be expected to fail when floods in excess of certain magnitudes occur. However, a great many other bridges designed on the basis of insufficient knowledge have failed at a discharge much smaller than the design magnitude.

Scour holes created around bridge piers by flowing water are a major cause of bridge pier foundation failure. Bridge piers normally are supported by friction piles. If the scour depth is great enough to uncover the supporting piles, friction between the piles and the surrounding soil will be reduced and piers may settle.

Bridge designers have over-designed their bridge foundations to avoid this type of failure. To reduce the tremendous amount of expense involved in either over-designing the bridge foundation or rebuilding damaged bridges, knowledge concerning the magnitude of maximum scour depth and how this depth is related to different flow conditions is essential.

The purpose of research being conducted by Dr. H. W. Sher is to study the basic mechanism of local scour, i.e., scour due to the pier alone. It has been shown that the mechanism of scour at a blunt-nosed pier is the strong horseshoe vortex system upstream of a blunt-nosed pier. The mechanism which forms the horseshoe vortex is the pressure field induced by the

pier. When the pressure field is strong enough, the coming flow boundary layer separates ahead of the pier and rolls up to form the horseshoe vortex. Piers at which the horseshoe vortex system does not form are called sharp-nosed. Maximum scour occurs at the upstream end of a blunt-nosed pier. This study is limited to blunt-nosed piers. The magnitude of maximum scour is investigated analytically using the momentum principle, by attempting to integrate the Navier-Stokes equation in the boundary layer in the scour hole, and by trying to specify the relation between the strength of the horseshoe vortex and local scour.

The analysis shows that the strength of the vortex initially is a function of the pier Reynolds number. Since the mechanism of scour is the horseshoe vortex, the depth of scour should be a function of the pier Reynolds number also. This is confirmed by all available reliable data (mainly from research laboratories). Combining a uniform flow equation with the pier Reynolds number, a design curve to estimate maximum local scour depth is established. This design curve indicates that the old engineering rule of thumb of assuming the maximum scour depth to be less than the flow depth is conservative in most practical cases.

The effect of angle of attack (when the flow direction is not the same as the axis of pier on maximum scour depth) and some methods of reducing scour by modifying the pier shape are also investigated both theoretically and experimentally.

DISPERSION PROCESSES IN OPEN-CHANNEL FLOW

DEPARTMENT OF CIVIL ENGINEERING

To control pollution in streams and rivers, it is essential that discharge of contaminants be regulated so as not to exceed capacity of the flow to maintain the concentration of contaminants within acceptable limits. The capacity of a flowing stream to accomplish this by the mechanisms of transport and dispersion depends in a general way on physical and chemical properties of the contaminant, and the physiographic characteristics of and amount of flow in the stream system. Due to the complexity of the inter-relationships, however, knowledge of these characteristics does not suffice for the prediction of transport and dispersion capacities in specific situations.

In research leading to his Ph.D. dissertation, "Dispersion of Mass in Open-Channel Flow," (CSU, March 1967), Dr. William W. Sayre (of the U. S. Geological Survey Water Resources Division unit at the Foothills Engineering Research Center) made a significant contri-

bution toward solution of this problem. Applied were a variety of mathematical techniques, including the Aris moment transformations and finite difference methods using a digital computer. Applying these techniques to the differential equations for the dispersion of particulate and liquid contaminants in a turbulent shear flow, he obtained solutions which describe the dispersion process in considerable detail. With this procedure, solutions can be easily and quickly obtained for a wide variety of boundary and initial conditions which are related to the characteristics of the contaminant, the channel and the flow. Results obtained from this method were found to agree well with experimental results obtained earlier by Sayre and F. M. Chang in a flume in the CSU Hydraulic Laboratory. The outlook for the adaptability of this analytical procedure to less ideal situations in the natural environment is encouraging.

FLUID MECHANICS PROGRAM

DEPARTMENT OF CIVIL ENGINEERING

Working in concert, research scientists and engineers of the Fluid Mechanics Program have in a pioneering effort extended the capabilities of man to simulate atmospheric motions in the lower layer of the atmosphere. Through basic experimental and analytical research of both laboratory flows in wind tunnels and actual atmospheric flows, a body of knowledge has been obtained which permits laboratory simulation of many atmospheric phenomena to be accomplished with confidence. Particular types of geophysical flows in which original contributions have been made through research in the Fluid Dynamics and Diffusion Laboratory include the following:

Simulation of stably stratified flow over complex terrain

Simulation of mountain lee wave phenomena

Mechanics of water-wave generation by wind

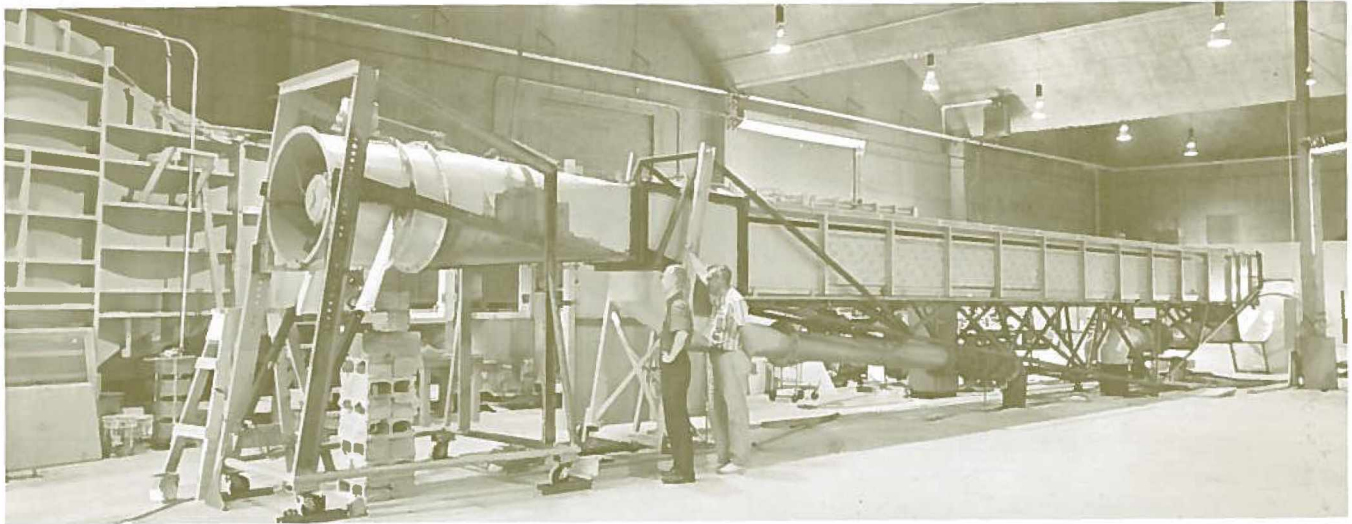
Similarity of turbulence and diffusion for flows in the laboratory and atmospheric surface layer

Structural aerodynamics—simulation of real wind effects on tall structures

Agricultural aerodynamics—simulation of air flow through orchards, etc.

National and international recognition of accomplishments by the fluid mechanics research team in geophysical fluid mechanics has resulted in many invitations to present research findings at international meetings, and in invitations to serve as consultants to federal, state, and private groups in the United States.

The research group which has evolved laboratory simulation of atmospheric flows from an art to a science is made up of the following: Dr. J. E. Cermak, Dr. E. J. Plate, V. A. Sandborn, Dr. G. J. Binder, Dr. R. N. Meroney, and Dr. H. Chuang. During the past year, this group, working with 30 graduate students and foreign visiting scientists, has produced over 40 professional papers, technical reports, and theses.



AIR-SEA INTERACTION STUDY AT CSU

DEPARTMENT OF CIVIL ENGINEERING

Wind blowing over the surface of a river generates waves which profoundly affect velocity and depth of the river flow and turbulence of the river. Velocity and depth are the quantities which determine sediment transport and water discharge in a river. Turbulence is the agent by which, for example, the oxygen needed for decomposition of degradable water pollutants is transported from the surface into the interior of water where it is needed. Thus wind waves contribute in an essential way to the river's beneficial (or destructive) action.

To determine quantitatively the effects of wind on the flow of water in open channels, or streams, a study of wind-water interactions has been initiated by Dr. Erich J. Plate. The program is of long range. It was started by constructing a special facility in which a model of an open channel, or a water flume, and a wind tunnel are super-imposed in such a way that wind generated by a large ventilation fan can blow with or against the flow of water in the flume. The facility was completed and checked out in the summer, 1963. Since then, a number of studies have been conducted in it by Dr. Plate and his students. They are aided also by Dr. G. M. Hidy of the National Center for Atmospheric Research (NCAR) in a joint CSU-NCAR program to determine exchange processes (such as evaporation) due to wind action on the water surface.

As a first objective, the group studied the nature of the wind-generated waves and the process of generation. This has been the subject of much controversy and discussion in recent years, and a conclusive statement is still missing. Many mechanisms have been proposed to explain how a smooth water surface can suddenly become ruffled if a gust of wind springs up. None of these is entirely satisfactory and some are not at all in agreement with experimental findings.

This study has shed some light on the sequence of the generation process. It also confirms a highly complicated model for the growth of waves, which had been proposed some 10 years ago. At the same time, development of wind profiles over the waves was studied, and an analytical model which explains the wind field over small waves was constructed. These studies, aside from their intrinsic value for the understanding of the physics of air-sea interactions, are important in establishing rules by which data from a small laboratory facility can be extrapolated to natural situations.

More practical investigations were in recent months directed at determining evaporation rates from water. With wind blowing over the water surface, the evaporation rate is enormously increased because the vapor layer existing over the water surface will, under no-wind conditions, protect the surface from evaporation. With wind, this layer is stirred up and so mixed that it no longer prevents evaporation. A law giving water velocity distributions corrected for wind; and a careful and systematic investigation of the effects of river flow on size and speed of wind waves are other practical results obtained from the study.

Future research is directed at consolidating the initial results by broadening the range of variables which are studied, and the study of diffusion processes in the water. How are water pollutants mixed when wind blows over the water? Is it possible and economical to enhance mixing by artificial wind? Can wind effectively increase oxygen content of water flow? These are some of the questions which Dr. Plate would like to answer. Some of the answers may be significant enough to affect river engineering practices in the not-too-distant future, when evaporation from rivers and water pollution problems must be taken into account in evaluating the feasibility and economics of a river engineering project.

ANTIBIOSIS OF ARTEMISIA

DEPARTMENT OF FISHERY AND WILDLIFE BIOLOGY

Sagebrush is an abundant native plant species of the West. The digestibility of various sagebrush species has been questioned by several workers although deer, antelope, and domestic sheep are known to consume varying amounts. Objectives of a study by Dr. Julis G. Nagy were to find out the volatile oil content and composition of various sagebrush species and subspecies and the antibacterial effects of the volatile oils on aerobic and anaerobic rumen bacteria.

Sagebrush collections were done mostly in parts of Colorado and Wyoming. The oil content was analyzed by gas chromatography and the antibacterial effects of the oils were studied on common aerobic bacteria and

on rumen bacteria obtained from wild as well as from captive deer rumen contents.

Dr. Nagy found that oil content and composition vary according to seasons of the year, species, subspecies, and probably according to soil characteristics. All bacteria tested were sensitive to the action of volatile oils. Rumen bacteria of both wild and captive deer possessed approximately the same sensitivity to the action of the oils. Cellulose digestion is completely stopped when the concentration of the oils in *in vitro* experiments reaches 1.0 part of oils to 1000 parts of cellulose broth. Most of the rumen bacteria are killed at 1.6 parts of oils to 1000 parts of rumen fluid nutrient broth.

MECHANICAL PROPERTIES OF COLORADO WOODS

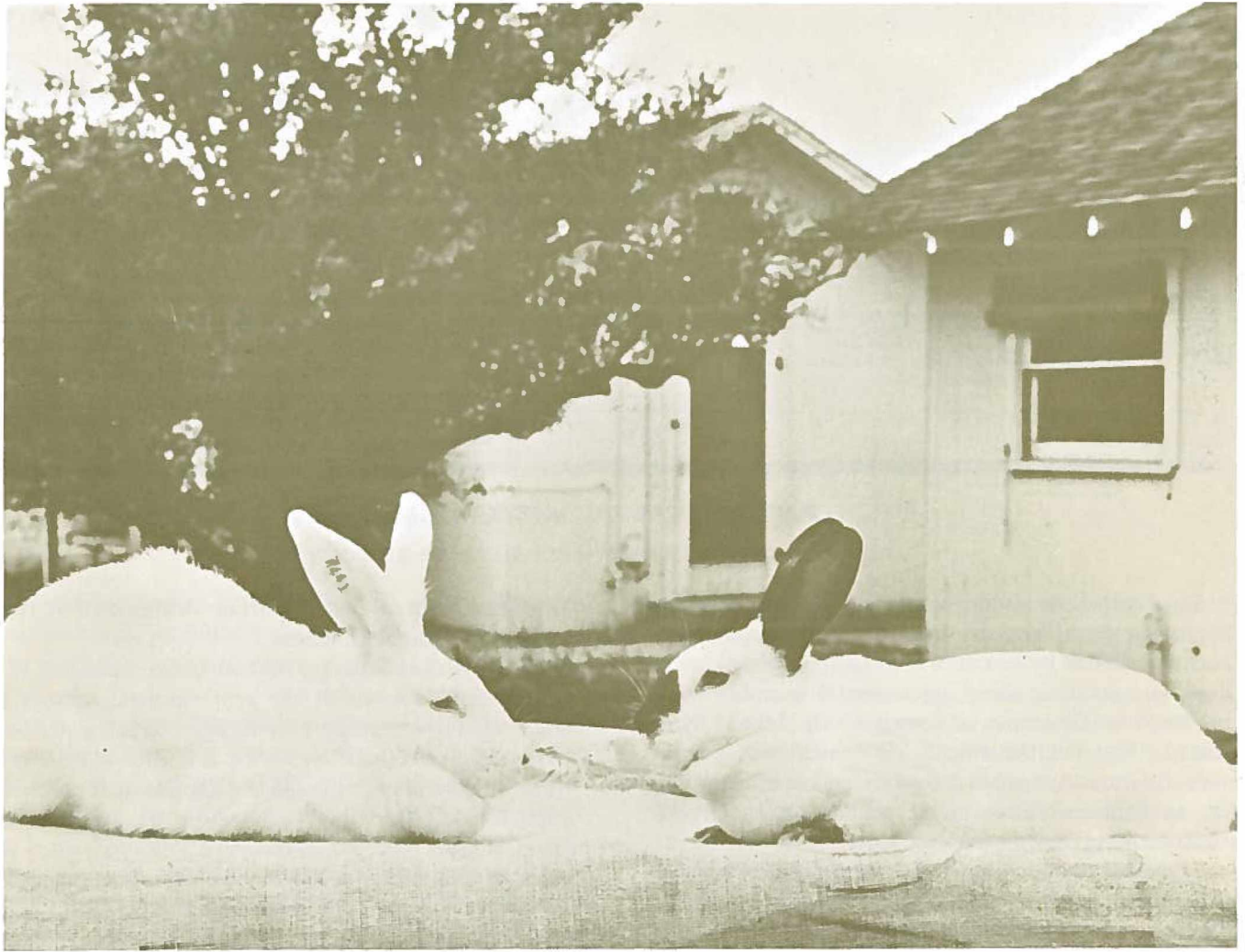
DEPARTMENT OF FORESTRY AND WOOD SCIENCE

Limited information has hampered effective use of Colorado tree species and has made it difficult for producers to market their material. The primary purpose of research by Dr. Jozsef Bodig and Dr. Harry E. Troxell is to evaluate properties of Colorado timber and, by making results available to users and producers, to promote increased and more efficient utilization. Initial effort has been concentrated principally on structural properties.

In the first phase of this study, testing and evaluation have been concentrated on Engelmann spruce, the most important commercial wood species in Colorado. Lumber was collected from several sawmills in the state and tested both non-destructively and destructively. Stiffness is the characteristic most often used in grading lumber non-destructively. This research is based mostly on this characteristic, including correlations to other de-

structive strength properties such as tension, compression, bending, shear and nail-holding capacity.

Much technical information has been collected from basic strength properties to engineered structures such as floor joists and trusses. Most of these findings confirm a prediction that Colorado species are much stronger and can be utilized more effectively than they are today. Many strength properties such as shear, compression, and nail-holding capacity have been found predictable non-destructively, and these are new findings pioneered in CSU's Wood Utilization Laboratory. As a result of this study, several Colorado cities have revised their building code to permit use of locally produced lumber. The Federal Housing Administration now permits the use of Engelmann spruce in certain types of residential construction. The research presently is concentrating on the same problems for lodgepole pine.



RODENTS AND RABBITS ON RANGELANDS

DEPARTMENT OF RANGE SCIENCE

Certain small mammals have marked effects on such land resources as forage, plants, timber, soil and watersheds. They often hinder man's attempts to improve conditions on the land, compete with large herbivores for forage, delay forest establishment, and damage erosion control structures. On the other hand, they may be beneficial in soil formation and help to control some insects. It is necessary to understand the biological relationships among all elements on the land eco-system in order to develop land and animal management techniques. Production of forage, timber, water, and protecting soil against erosion will become more efficient as more is learned about the ways in which rodents and rabbits affect land resources.

Dr. R. M. Hansen and Dr. T. A. Vaughan have developed methods of determining populations, food preference and consumption, reproductive capacity, and other important features of small mammals. These methods have been used to obtain fundamental informa-

tion in several vegetation regions of Colorado from alpine to the plains.

White-tailed jackrabbits in the Gunnison area eat plants of importance to cattle in all seasons except winter, thereby being in direct competition. Some females produce three or four litters per year, indicating high population potential. Black-tailed jackrabbits in eastern Colorado also eat the same kinds of plants as do cattle on sandhills range. After snowmelt, 24 per cent of the ground surface in the alpine is occupied by rodent burrows, soil casts, or mounds. The effect of this disturbance on spring runoff and silt loads has not been evaluated. These alpine mammals mostly eat forbs of little importance to large herbivores, but some of them live on insects that are injurious to important range plants. When rodents and rabbits are abundant, they may consume or destroy up to 25 percent of the forage produced; and population control is indicated.

WATER QUALITY CHARACTERISTICS OF A MOUNTAIN STREAM

DEPARTMENT OF RECREATION AND
WATERSHED RESOURCES

The primary objective of an investigation by Dr. J. R. Meiman and Dr. S. H. Kunkle is to determine physical and biological characteristics of water quality derived from headwaters streams under essentially "natural" conditions. This represents the first phase of a long-term study to determine impact of land use on mountain watersheds and water quality. Land use practices studied or yet to be investigated include grazing, recreation, reservoir construction, fire, logging, and road building.

Water samples were collected at varying periods and streamflow regimes over a two-year period from 10 stations, including locations above and below grazing and recreational use areas. Field and laboratory determinations were made on the following: suspended sediment, turbidity, dissolved solids, pH, water temperature,

streamflow, and fecal coliform, fecal streptococcus and coliform bacteria.

Under "natural" conditions in the study area, both physical parameters and bacteria groups were found to have a strong relationship to flow and season of the year. Summer storms were very important in raising levels of sediment, turbidity, and bacteria concentrations. The bacteria groups gave a much better indication of grazing and irrigation impact than did the physical parameters. The fecal coliforms described contamination more effectively than the coliforms; the fecal streptococci were far less effective than the other two groups in describing animal pollution. Pollution from campsites use was not detected.

EFFECT OF VITAMIN A ON AMINO ACIDS

DEPARTMENT OF FOOD SCIENCE AND NUTRITION

An investigation of the effects of fat-soluble vitamins, protein levels, and protein supplemented with methionine on the concentrations of free amino acids in the plasma and on levels of lipids in plasma and liver of rats has been in progress. Two significant finds are reported by Dr. Inez Harrill.

Increased concentrations of vitamin A under certain conditions reduced the level of the amino acid phenylalanine in the blood of rats. Abnormal accumulation of phenylalanine, usually due to a genetic defect, results in mental retardation; any substances found to reduce the level of this amino acid in the blood may help control the undesirable effects resulting in mental abnormalities.

Studies of variations in protein, vitamin D, and zinc content of the diets has indicated that concentration of the amino acid lysine in plasma decreases when vitamin D is added to a low-protein diet either with or without supplementary zinc. An apparent relationship between vitamin D, protein, and zinc of the diet is indicated. The practical significance is not now known, but the findings may help explain the variability of results in studies attempting to measure human amino acid requirements. In other words, vitamin D, which man obtains naturally from food, from food additives, and from sunshine, may affect his protein needs.

VARYING FATS IN BAKED PRODUCTS

DEPARTMENT OF FOOD SCIENCE AND NUTRITION

Under the direction of Dr. Ferne Bowman, the Food Science section of the College of Home Economics for many years has carried on investigations designed to help homemakers and the baking industry adjust recipes to insure success for baked products at high altitudes. Leadership in these investigations has been possible because a high altitude baking chamber enabled researchers to adjust pressures to simulate altitudes from sea level to 10,000 feet. Previous studies of high altitude baking have given homemakers and others tested recipes for use at high altitudes. The research has made it possible to answer inquiries from world-wide sources

—Peace Corps volunteers and American and foreign personnel living at high altitudes throughout the world.

Present investigations have been concerned with the use of current types of shortening in products baked at altitudes of 5,000, 7,500, and 10,000 feet. Modified lard, corn oil, a commercial shortening, hydrogenated shortening, and a new type margarine have been used. These types of shortening are of particular interest because the kinds and amounts of fat which man consumes may be related to the incidence of certain cardiovascular diseases. Results of the investigations will therefore be of ultimate value in regulating the type of fat in the diet.



SAFE USE OF FEED LOT HORMONES

DEPARTMENT OF BIOCHEMISTRY AND
DEPARTMENT OF BOTANY AND PLANT PATHOLOGY

Diethylstilbestrol (DES) is a potent female hormone (estrogen) produced by chemical synthesis and used to fatten cattle in feedlots. Over 90 per cent of the compound is excreted practically unchanged as manure which often is used in truck farming. The work was undertaken because of the possibility that the potent estrogen may be absorbed by plants and become part of the human food chain. The project was operated cooperatively between scientists in the Departments of Biochemistry (Dr. M. L. Hopwood) and of Botany and Plant Pathology (Dr. Robert G. Hacker).

Excreta were collected from a steer before and after administration of DES labeled with radioactive carbon to identify the material or metabolites of the material at extremely low levels (parts per billion). Radish, pinto bean, wheat, onion, and lettuce plants were grown in a greenhouse in pots containing two soil types (acid, alkaline) and manure from the steer. The plants were harvested and the soil and parts of the plants were analyzed

for radioactivity. In addition, the estrogenic potency of the material in soil or plants was determined by bioassay in immature mice.

Radioactivity was found in all plant parts regardless of the soil in which the plants were grown. The radioactive material in the plants did not behave like estrogen except in lettuce roots and radish leaves grown in alkaline soil. The acid soil environment destroyed the DES completely, but the alkaline environment removed only two-thirds of its activity as an estrogen. There were differences in metabolites among the two soil types. Little of the radioactivity was leached from soil, and plants removed only traces of the radioactivity in the soil. Fungi and bacteria growing in the soils were capable of metabolizing DES and some species could employ it as a sole nutrient. There does not appear to be any hazard to human health from using feedlot excreta to fertilize edible plants.

MICROWAVE EXCITATION IN ANALYTICAL EMISSION SPECTROSCOPY

DEPARTMENT OF CHEMISTRY

Increasing awareness of the importance trace quantities of impure substances have to many diversified fields of research, ranging from solid state physics to air pollution control and the chemistry of living organisms, has led to a demand for increasingly sensitive methods for detecting these materials in trace amounts. Techniques which can detect and identify amounts of a substance in concentrations ranging from one part per million to one part per billion or trillion are needed. In addition to having high sensitivity, the technique should be rapid, require a minimum of operator training, and the equipment cost should be low enough to make the technique economically available to a large number of laboratories.

One class of materials important in trace quantities is metals, especially those thought of as "less common". Among these are cadmium, cobalt, selenium, and many others. The techniques currently most widely employed for trace metal determination are the so-called spectrographic methods. These involve heating the sample to form a vapor of hot or "excited" metal atoms, the quantities of which are determined by measuring either their characteristic emission or absorption of light. These techniques currently can detect concentrations as low as parts per million for most metals, and for a few, parts per billion.

To extend these detection limits into the parts per trillion range, a new technique has been developed

under the direction of Dr. J. H. Gibson. This technique takes advantage of the principle that the hotter the metal, the more sensitive is the spectrographic method. The system which offers the highest conveniently available laboratory temperature is the so-called "plasma jet." The plasma or hot ionized gaseous discharge is capable of producing temperatures as high as 20,000°C, three to 10 times hotter than temperatures in conventional spectrographic techniques.

The method developed in this laboratory uses high temperature plasma formed by passing microwave energy into argon gas. As the sample under study is introduced into the plasma, the characteristic light emitted is focused on a spectrograph and the intensity is measured and recorded electronically. The measured intensity is then related to the amount of the particular trace metal of interest in the sample.

Using this technique, as little as one-trillionth of a gram of metals such as iron, silver, cobalt, and copper has been measured. Because of the very high sensitivity, it is possible to do trace analyses (in the parts per million range) on as little as one-millionth of a gram of sample. In addition, the equipment is relatively inexpensive and the method simple and rapid. The technique offers particular advantages to such fields as air pollution studies and certain biological studies where only very small quantities of material may be available for analysis.

TOWARD A BASIC THEORY FOR PHYSICS

DEPARTMENT OF PHYSICS

Physics is at present a collection of deductive theories, many of which do not specify explicitly all concepts and postulates upon which they are based. The time is ripe for a single deductive theory upon which all of physics can be built, because of the great progress in mathematics during the last 50 years in understanding what constitutes a deductive theory and how to formulate it. There is now also a tremendous accumulation of experimental facts on fundamental particles that are begging for theoretical explanation. Physicists the world over are using many approaches to solve this problem, but one approach which is neglected is the careful examination of the foundation upon which present ideas of fundamental particles are based. This approach was very decisive in the development of the theory of relativity, and may well provide the needed break in the present problem.

In working on this problem, Dr. Saul A. Basri begins with recognition that science is a human activity and objectivity is nothing but a measure of the high degree of agreement among different humans on certain classes of their observations. Thus, it is natural that a deductive physical theory should start with living humans in the role of observers, and lead to the concept of the objective universe in as precise a manner as possible. This, as well as the exact formulation of the concepts of particles, events, clocks, length measuring

instruments, and all other basic concepts of space-time geometry, Dr. Basri has accomplished in two recent publications. The theory has been pushed as far as the derivation of the equations of motion of a particle in an arbitrary gravitational field. Work is now in progress to derive the field equations, and extend the theory to the microscopic domain.

Although Einstein's general theory of relativity is about half a century old, its operational meaning has not been completely clear. This is because a rigid coordinate system is not possible in a time-varying gravitational field, and standard clocks which agree with each other when compared at the same place may have different relative rates at different places and times. Moreover, two clocks that are synchronized with a third clock may not even be synchronous with each other.

In a paper on relativity, Dr. Basri showed for the first time how an actual coordinate system can be constructed in an arbitrary gravitational field, and what the specification of physical events in such a field entails. From this study, it turns out that in such a complicated environment, synchronization of clocks is not only arbitrary, but also impractical. Thus, a method is given to describe the motion of a particle without synchronization of clocks, and the equations of motion were derived on the basis of this method.

ECONOMIC ANALYSIS OF AIR POLLUTION

DEPARTMENT OF ECONOMICS

Air pollution is an increasingly important problem in our urban centers. It receives greatest attention when the level of pollutants becomes critical, but each day the community is exposed to varying levels of pollution depending on weather conditions and rates of emission. An efficient air pollution control program must consider not only the occasional crisis but also the daily accumulation of air pollution damage.

Dr. D. C. Ogden's work is some of the first reported in professional economic journals dealing with the economics of air pollution. The problem is analyzed within an airshed, the area in which the dispersal and dilution of pollutants must take place. A probability model is developed which predicts the economic cost of air pollu-

tion and thereby the benefits to be derived from abatement. The objective of the model is to allow economic criteria to be applied to air pollution control. Alternative abatement programs can be compared in terms of their benefit-costs to the community.

The model develops a conceptual framework which uses meteorological and engineering data to predict the probable range of air pollution within a given airshed, and a conceptual framework to predict the probable damage resulting from various levels of predicted pollution. From this information, a benefit function for abatement is derived. The cost of alternative abatement programs can be compared with the benefits derived from the abatement.

NEW SOURCES FOR HISTORICAL RESEARCH

DEPARTMENT OF HISTORY

Max Weber is one of the great social scientists of the 20th century. His influence is growing today even though he died in 1920. He was a creative genius whose conceptions and ideas have stimulated an enormous literature in half a dozen disciplines. In Germany, he was also regarded as a significant political thinker, in many ways reflecting the political attitudes of the middle class in Germany after 1870. He was also a fascinating and complex personality—liberal, humanitarian, but also extremely nationalistic and prone to revere the charismatic leader in history.

In 1963-1964, Dr. Bruce B. Frye was in Germany doing research on middle class political behavior during the Weimar period (1918-1933.) There he found a letter which Max Weber had written, shortly before Weber's death, to Carl Petersen, the leader of the German Democratic Party. The letter was in the Petersen family's archives in Hamburg. The letter apparently was not used by Weber's widow when she wrote her classic biography of him, nor was it included in the most significant

studies of his political importance for Germany. Yet, it clarifies many of his attitudes on several controversial issues; and it reveals much of the personality and political values of a major figure in German intellectual and political history.

From this research has come an article by Dr. Frye which is published in the June 1967 issue of "The Journal of Modern History." Dr. Frye's article includes the text of the letter in German; his translation of it; a 2,000-word introduction to the letter, placing it in its historical context and explaining the circumstances under which it was written; and finally, extensive footnotes explaining references to people and things mentioned in the letter.

The publication of such documents constitutes a valuable service to the historical community, since scholarly history depends upon the discovery, editing and publication of contemporary source materials such as the Weber letter.

FANTASY FOR HARP, STRING ORCHESTRA AND FLUTE

DEPARTMENT OF MUSIC

In June of 1966, "Fantasy for Harp, String Orchestra and Flute," by Wendel Diebel of the Music Department, was published by International Music Service of New York City. This original composition was commissioned by Miss Susann McDonald, internationally known harpist and teacher. It was financed through a grant by the Colorado State University Faculty Improvement Committee. The premier performance was given under auspices of the Colorado State University Fine Arts Series in its Festival Concert in April, 1963.

Thor Johnson conducted, and Susann McDonald was the soloist.

Since that initial performance, the composition has been performed by a number of symphony orchestras in various parts of the nation. Critical reception of the "Fantasy" has been highly favorable. Critics have called it "one of the finest pieces of writing ever for the harp," "the most beautiful work for the harp that we have ever heard," and praised it in similar terms.

MORALITY WITH HUMOR

DEPARTMENT OF ENGLISH

Four novelists—Richardson, Fielding, Smollett, and Laurence Sterne—virtually created the novel form in English. Dr. Arthur Cash, of the Department of English, has become a widely recognized authority on the work of the fourth of these, the 18th century English clergyman, Laurence Sterne. Sterne's novel, *A Sentimental Journey through France and Italy*, has been translated into every European language and many others. It has had a profound effect upon world literature by inspiring a century and a half of sentimental novel writing. Through this it has had an obviously significant effect on the manners and mores of western civilization. There has perhaps been no more influential novel.

Dr. Cash began a study of *Sentimental Journey* in the belief that it had not generally been properly read and understood. His premise was that it is not a sentimental novel in the sense of most of its imitations, but essentially a comic work. To develop his point, Dr. Cash turned to Sterne's sermons, which have been little read because Sterne was believed to be a very unphilosophic

man. On the contrary, Dr. Cash found that the sermons reveal a coherent, well-developed ethical and religious system and that the ideas in the sermons applied directly to the *Sentimental Journey*.

The task confronting Dr. Cash was complex. He had to demonstrate that Sterne was a sound moralist, that the novel truthfully represented his moral view, and that read in this manner it was a very amusing work. To accomplish this, he turned to a study of 18th century ethics. He compared the novel both to Sterne's sermons and to the major developments of the time in moral philosophy.

The resulting book was submitted in the International Monograph Competition of the Modern Humanities Research Association and was the selection for 1964. In 1966, the book, *Sterne's Comedy of Moral Sentiments: the Ethical Dimension of the "Journey,"* was published by the Duquesne University Press with a foreword by Sir Herbert Read.

BLINDNESS IN ELK

DEPARTMENT OF ANATOMY AND
DEPARTMENT OF PATHOLOGY

Studies on blindness in elk (*Cervus canadensis*) have been conducted by Dr. R. W. Davis, Dr. Y. Z. Abdelbaki, Dr. J. L. Adcock and Dr. C. P. Hibler. This condition, of hitherto undetermined cause, has been observed in Arizona, Colorado, New Mexico and Wyoming. Bilateral blindness, without opacity of the ocular refractive media (a condition in which both eyes appear to be clear), is the dominant clinical feature. The disease frequently ends in death.

An anatomic and pathologic investigation utilizing tissues of blind elk is in progress. The primary purpose of the study has been to determine the type and distribution of lesions associated with blindness and to identify the causative agent.

Elaeophora schneideri, an intra-arterial nematode (small thread-like round worm in an artery), was found in the cephalic arterial system (blood vessels supplying the head) in 60 per cent of blind elk studied. Pathologic findings indicate that blindness is a result of ischemic damage (deficient blood supply) in the brain, eyes, and optic nerves. This damage is believed to be caused by circulatory impairment resulting from the presence of *E. schneideri* (the parasite) and nodular lesions in the cephalic arterial system.

E. schneideri is a common parasite of deer and domestic sheep in mountainous regions of the western and southwestern United States, but has not previously been reported in elk.

ELECTRON MICROSCOPY

DEPARTMENT OF ANATOMY

During the years of Dr. G. P. Epling's undergraduate teaching in the Department of Anatomy, he became inquisitive about diseases which were apparently not caused by infections, but were based solely on changes of structure in altered environments. In this category, heart failure in high altitudes (high mountain disease) and emphysema in cattle caught his interest. Ordinary light microscopes revealed only enough information to "whet his intellectual appetite," so he sought answers via the use of the electron microscope.

His work currently involves studies of lungs and hearts of cattle from Montana, Wyoming, and Colorado, in addition to experimental swine and hamsters. Results of his research are centering on the cells which line the body's smallest blood vessels, and cells which control the volume of blood that can pass through them.

In terminal congestive heart failure at high altitudes, he has shown that damage to the cells lining the blood vessels (possibly caused by a lack of oxygen) may be a cause for damaged heart muscle cells, resulting in heart failure.

He has shown that in bovine emphysema, the cells lining the air spaces of the lung are damaged by an agent (possibly an inspired gas from the stomach, as cattle belch) which is one of the earliest observable changes in this disease.

Although his work concerns cattle primarily, the results are also directly applicable to the same diseases in man.

He has also observed cells which may be of significance in explaining a means of blood-vessel volume control for many organs of all mammalian species.



EFFECTIVE BOVINE VIBRIOSIS VACCINE DEVELOPED

DEPARTMENT OF MICROBIOLOGY

While bovine vibriosis had been recognized as a cause of poor calf crops for many years, it was long considered only a potential threat to range cattle. In 1959, when Dr. A. B. Hoerlein initiated the vibriosis project at CSU, the disease was suspected in several Colorado beef cattle herds, but had been definitely diagnosed in only two. With the help of a newly developed diagnostic technique, it was determined by the fall of 1962 that 45 of 83 herds studied because they had reproductive problems were infected with vibriosis. Not only were the infected herds found in every geographic area of Colorado, but in the surrounding states as well. The infected herds had pregnancy rates of 30 to 70 percent and correspondingly low calf crops. More alarming was the rapid spread of the disease to uninfected herds where it was often disastrous.

Artificial insemination and isolation procedures previously shown to provide effective control of vibriosis were not applicable to western range conditions. Previous attempts to immunize cattle against vibriosis had failed. The infection is unique compared to other diseases since the bacteria do not invade the body tissues. Vaccination could therefore reasonably be theorized to be impossible. However, it was well known that convalescent cows were generally immune and would reproduce normally. Having no feasible alternative, immunization experiments were initiated in 1960.

By 1961 it was shown that the resistance to vibriosis

could be increased by the injection of living *Vibrio fetus* (the causative bacteria). This significant discovery led to a series of experiments in which killed bacteria were studied in various doses and combined with adjuvants to enhance the immune response. In the spring of 1963, the controlled experiments at CSU were augmented by vaccination trials in three infected Colorado range herds. During the summer of 1964, large-scale trials in range cattle in three states were carried out to test a commercially prepared vaccine. The results of these field trials and parallel controlled experiments at CSU became the basis for USDA approval of the commercial vaccine for general use in 1965.

The vaccine has now been shown effective for two breeding seasons in numerous beef cattle herds throughout the country. Pregnancy rates in vaccinated herds have all been over 90 percent in the absence of other diseases, with most being in the area of 95 percent. In addition to this increased calf production, culling rates in the cow herds have been drastically reduced resulting in a reduction of the numbers of replacement heifers. It has been estimated that the annual calf crop in an infected herd can be increased 20 percent. If 10 percent of the cattle in Colorado are infected herds (a conservative estimate), the annual increase in calves would be worth more than \$3,000,000. Other states having more infection will benefit even more.

NUCLEAR FALLOUT IN THE WILD DEER FOOD CHAIN

DEPARTMENT OF RADIOLOGY AND
RADIATION BIOLOGY

In 1962, Colorado State University initiated research on the extent to which certain radioisotopes from nuclear fallout accumulate in wild deer and in components of their environment. The investigation was carried out to provide estimates of potential hazards to the deer or to humans who might consume the animals in the event of high-level radioactive contamination of the landscape.

It was found that radioactive fallout levels during the period 1962-66 were sufficient to be measured in air, soils, plants, deer, and humans; but insufficient to constitute a biological hazard. The highest short-term radiation doses found in the tissues of deer were doses to the thyroid gland from Iodine 131.

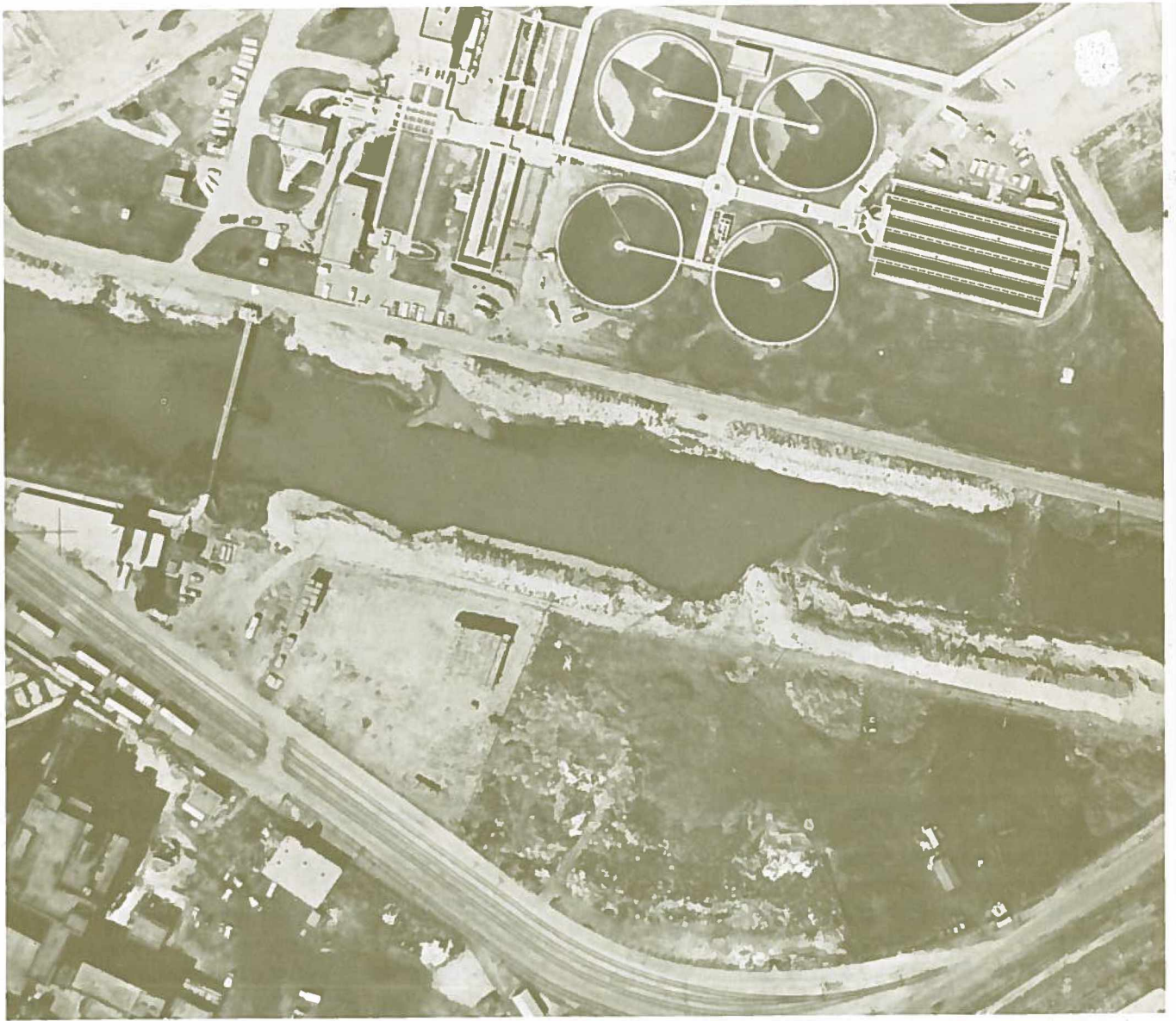
Dr. A. H. Dahl and Dr. F. W. Whicker have estimated that fallout would have to be increased by a factor of at least 100 over that in 1962 and maintained at the level for several years to produce increases in thyroid adenomas (tumors). Evidence also indicates that at least a 500-fold increase in fallout over the levels deposited in 1962 would be needed to increase the probability of bone cancer from strontium 90 in deer.

Deer contained much higher levels of fallout radio-

activity than humans during the study. For example, deer bone was more than 35 times higher than human bone in strontium 90 content. These and other data suggest that safety for the human population with respect to fallout radioactivity does not necessarily imply safety to man's natural resources.

Consumption of deer flesh by humans could lead to comparatively high ingestion of Cesium 137 since deer flesh contained an average of five to 13 times higher concentrations of the nuclide than beef or pork. Deer thyroids were found to be extremely sensitive indicators of nuclear testing with increases in Iodine 131 being correlated with American, Chinese, and Russian tests. Cesium-137 levels in deer flesh were maximal in 1963, while Strontium 90 concentrations in deer bone were greatest in 1964.

Information on the influence of environment on the distribution and movement of radioactive fallout in the Front Range of the Colorado Rocky Mountains has been obtained. Some work has been completed on the physiological behavior of Cesium 137 and Strontium 90 in deer.



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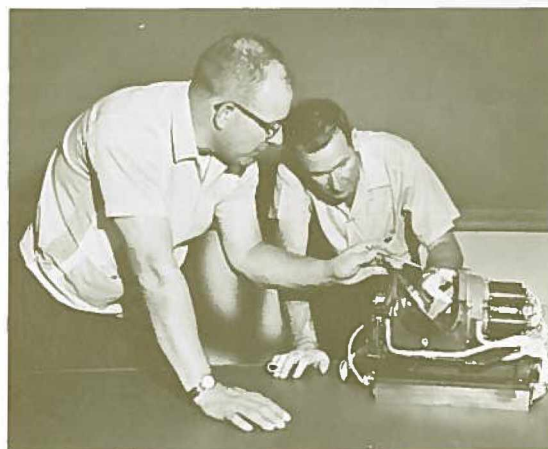
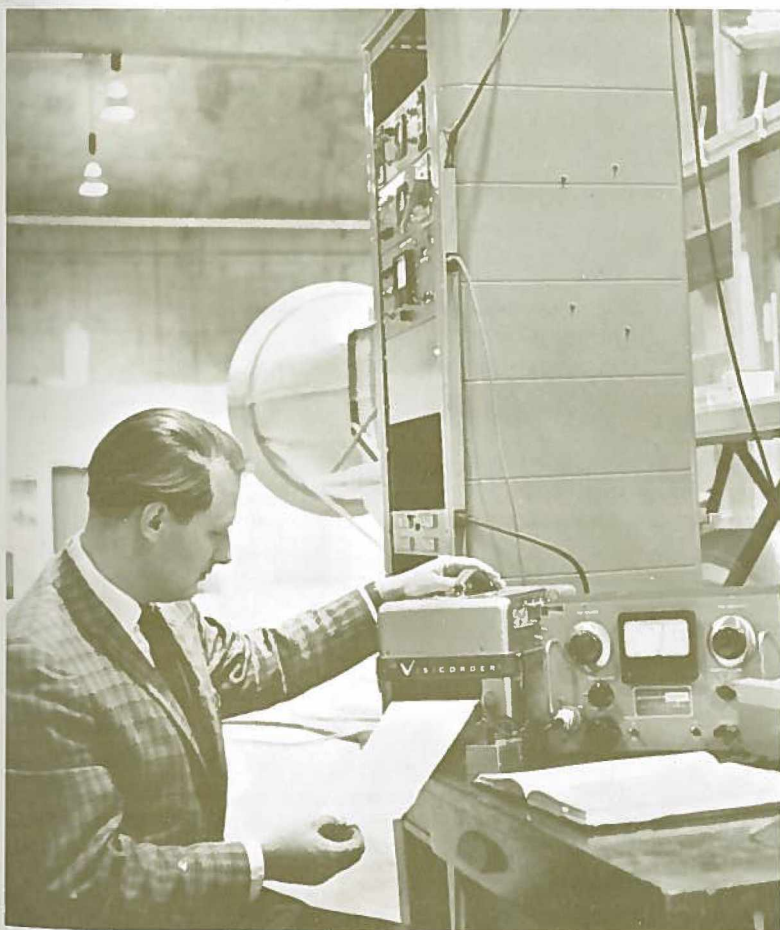
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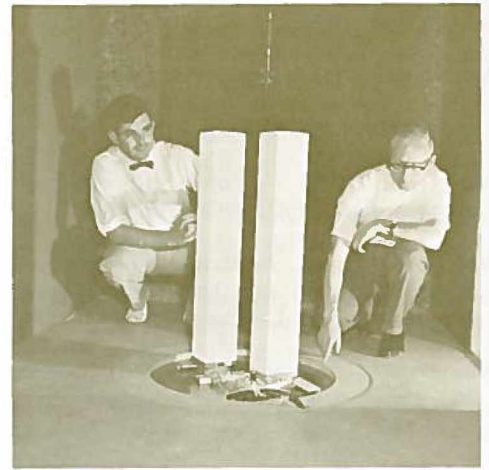
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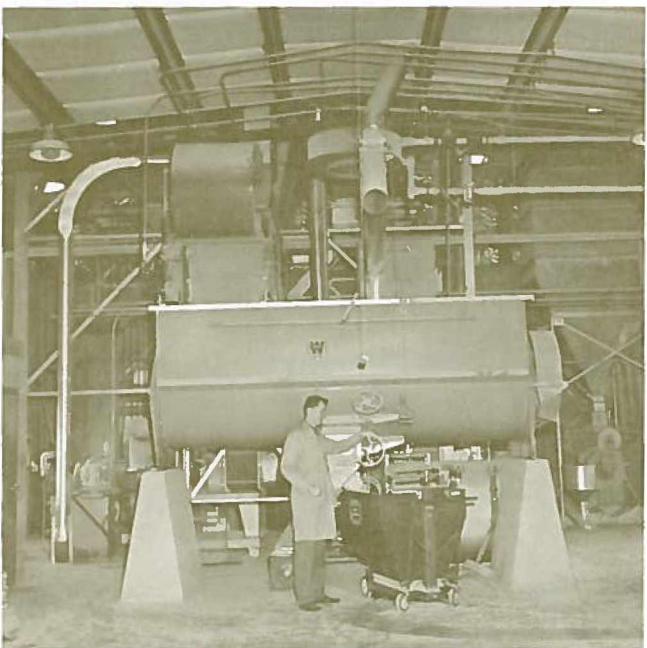
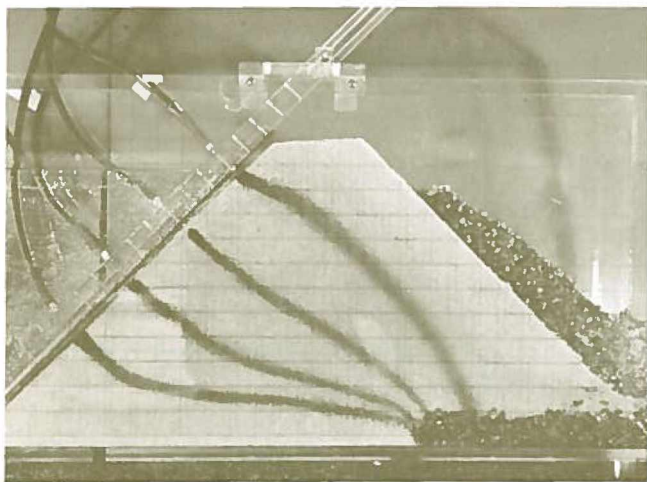
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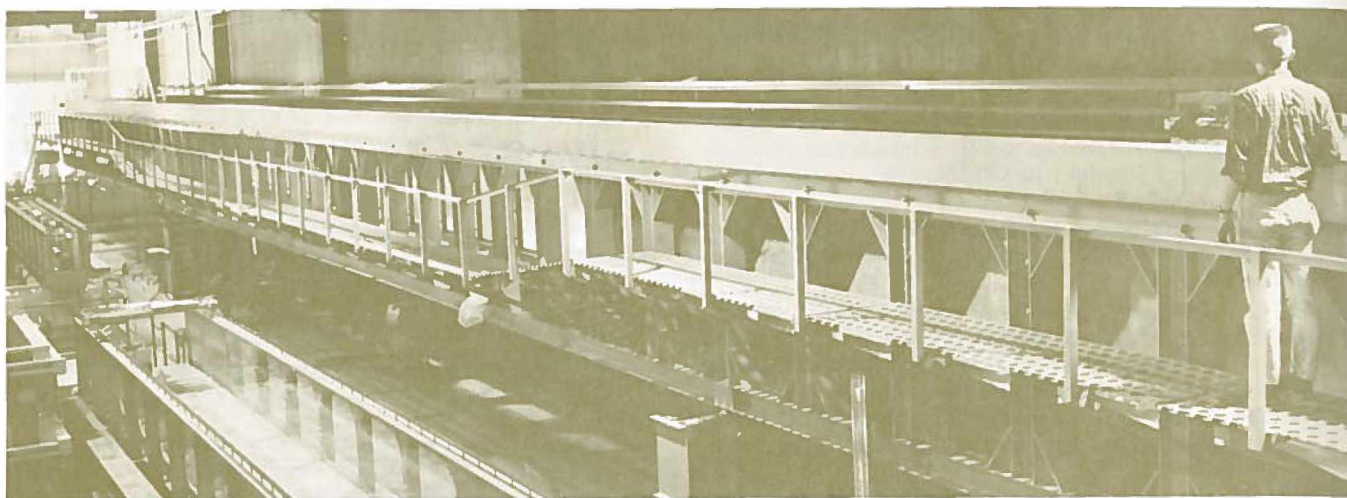
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