COMPRESSOR RESEARCH

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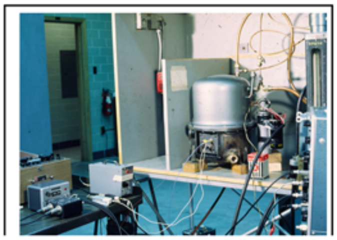
INTRODUCTION

The Ray W. Herrick Laboratories developed as a cooperative enterprise between Purdue University and primarily American industry, and to a lesser extent the federal government. It grew out of the need of the air conditioning and refrigeration industry for university contact: first, to educate industry-oriented engineers with advanced degrees for their research and development laboratories, and second, to utilize the pool of talent that is available at a university of the professional stature of Purdue for research on industry-related questions.

Gifts from industry and grants from the government joined the investment of Purdue University in establishing the facility as part of the School of Mechanical Engineering. The faculty and the academic program provided the students with the proper education. Industry provided research projects of relevance. This cooperative venture nurtured the growth of the Laboratories to a community of approximately 90 people of faculty, staff, and students.

The Laboratories now provide an atmosphere of cooperation within the University itself. Faculty and students from all Schools of Engineering and the Sciences are willing to participate in research programs, if called upon. There are active research programs funded by a wide spectrum of industries: for example, the tire industry and the watch industry, in addition to programs funded by government agencies. However, a large portion of the research effort is concerned with compressors, which justifies and necessitates this special report on the compressor research activities to date.

This report attempts to summarize the research effort in compressors so far, give a listing of the many theses that were generated in this area, and provide information on the faculty who are most active in this area. For the prospective graduate student who would like to work in this challenging applied research area, this report outlines questions of application, support, etc. For the prospective industrial research sponsor, this report outlines the steps needed to get a research program started in this area.



Finally, this report outlines the activities of the Ray W. Herrick Laboratories in Compressor Research Conferences and Compressor Analysis and Design Workshops. This effort is considered to be important, both from the viewpoint of an international information exchange in this area, and from the viewpoint of the continuing education mission of Purdue University.

SUMMARY OF COMPRESSOR RELATED RESEARCH THESES

The compressor research activity of the Ray W. Herrick Laboratories is summarized in the theses generated by its graduate students. The complete listing is given by the author, degree, title, and major professor.

In general, copies of theses may be obtained from several sources, such as ProQuest (http://www.proquest.com/products_pq/descriptions/pqdt.shtml). (However, some of the recent theses may still be confidential and will not be available until declassified. Another source would be the Interlibrary Loan Office, Purdue University Libraries, West Lafayette, Indiana, 47907. Their website is: https://www.lib.purdue.edu/access/ill/td/.

Early research focused on experimental procedures. For instance, the first strain gage measurements on a vibrating reed valve in an operating refrigerating compressor were conducted here. Since the early sixties, research has expanded into the area of mathematical simulation of total compressors, predicting valve reed vibrations and stresses, gas oscillations, acoustic radiation, etc. The advent of high speed compressors has made dynamic considerations mandatory, and research is therefore quite challenging to students in this area. Research has been done on air as well as refrigerating compressors. In general, the research can be thought of as serving three goals: Noise and Vibration Control, Thermodynamic Performance Improvement, and Increased Reliability.

The Ray W. Herrick Laboratories are internationally recognized as a research center in the compressor area.

LISTING OF COMPRESSOR RELATED THESES

	Name	Degree	Thesis Title	Major Prof.
1.	R. G. McCullum	MSME 8/58	High Temperature Viscosity Measurements of Fluorinated Hydrocarbon Compounds in the Vapor Phase	O. W. Witzell
2.	R. J. Wensley	MSME 8/58	Apparatus for the Determination of the Viscosity of Refrigerants in the Liquid Phase	O. W. Witzell
3.	S. Vigander	MSME 6/59	On the Use of Resonators as an Acoustic Muffler in Fluid Flow Machinery	R. C. Binder
4.	R. W. Cassady	MSME 6/59	The Techniques of Obtaining Internal Temperatures and a Temperature Profile of a Hermetic Compressor	W. E. Fontaine
5.	C. Y. Tsui	MSME 8/59	Viscosity Measurements for Several Fluorinated Hydrocarbon Vapors at Elevated Temperatures and Pressures	E. J. Wellman
6.	R. T. Driftmyer	MSME 6/60	Explosions in Water Cooled Refrigeration Systems Equipped with a Hermetic Compressor	J. T. Agnew
7.	O. J. Wilbers	MSME 1/61	Viscosity Measurements for Several Fluorinated Hydro-carbon Vapors	O. W. Witzell
8.	R. L. Lowery	Ph.D. 6/61	High Speed Compressor Valve Noise and Vibration Study	R. Cohen
9.	P. R. Ukrainetz	Ph.D. 1/63	Compressor Valve Stress Studies in Conjunctionwith Accelerated Life Tests	R. Cohen
10.	R. Gluck	Ph.D. 1/63	Development of Fatigue Life Index as a Criterion for Evaluating Compressor Leaf Valve Design	R. Cohen
11.	J. R. Dedelow	MSME 1/63	A Study of a Freon Gas Lubricated Hydrostatic Thrust Bearing	J. R. Dixon
12.	M. G. Pottinger	MSME 1/63	Pressure Oscillations in the Exhaust Chamber of a Refrigeration Compressor	R. Cohen
13.	V. J. Riley	MSME	The Viscosity of Liquid "Freon-11" and	O. W. Witzell

	1/63	"Freon-12" at Temperatures to -110˚C	
14. H. L. Oh	MSME 6/63	Effect of Certain Discharge Configurations on Valve Stress and Valve Noise	R. Cohen
15. R. V. Cadman	MSME 8/63	Measurement of Valve Displacement as a Function of Time	R. Cohen
16. A. G. Doige	Ph.D. 1/66	A Stress and Vibration Analysis of a Leaf-Type Compressor Valve	R. Cohen
17. M. W. Wambsganss	Ph.D. 1/66	Mathematical Modeling and Design Evaluation of High-Speed Reciprocating Compressors	R. Cohen
18. D. A. Coates	MSME 8/66	Design and Digital Computer Simulation of a Reciprocating Free Piston Electrodynamic Gas Compressor	R. Cohen
19. L. L. Faulkner	MSME 8/66	Stress Concentrations in Refrigeration Compressor Crankshafts	J. F. Hamilton
20. W. E. Gatley	Ph.D. 1/67	Development and Evaluation of Methods for Design of Mufflers in Small Refrigeration Systems	R. Cohen
21. C. Y. Tsui	Ph.D. 1/67	Discharge Phenomena of a Vibrating Poppet Type Valve	R. Cohen
22. J. G. Payne	Ph.D. 8/67	Photoelastic Stress Analysis and Dynamic Simulation of Compressor Ring Valves	R. Cohen
23. R. V. Cadman	Ph.D. 8/67	A Technique for the Design of Electrodynamic Oscillating Compressors	R. Cohen
24. G. T. Kinney	MSME 1/68	Mathematical Simulation of the Vibration of a Refrigeration Compressor	J. F. Hamilton
25. E. M. White	MSME 1/69	Application of Mathematical Model to High Speed Reciprocating Compressors	R. Cohen
26. B. D. Kotalik	MSME 6/69	Computer Simulation of a Five Horsepower High Speed Reciprocating Compressor	W. Soedel
27. M. J. Stevenson	MSME 8/69	A Computer Simulation of a Rotary Vane Compressor	B. Qvale
28. C. N. Johnson	Ph.D.	Fractional Horsepower, Rotary Vane	J. F. Hamilton

	8/69	Refrigerant Compressor Sound Source Investigation	
29. L. L. Faulkner	Ph.D. 8/69	Vibration Analysis of Shell Structures Using Receptances	J. F. Hamilton
30. J. D. Haseltine	MSME 1/70	Part-Load Performance of Reciprocating Compressors	B. Qvale
31. R. R. McConnell	MSME 1/70	Prediction and Measurement of Instantaneous Compressor Crankshaft Speed	R. Cohen
32. D. A. Coates	Ph.D. 1/70	Design Technique for Performance Optimi-zation of a Small Rotary Vane Compressor	R. Cohen
33. R. H. Harrison	MSME 6/70	Mathematical and Experimental Analysis of the Vibration of a Refrigerating Compressor	J. F. Hamilton
34. R. F. Schult	MSME 8/70	Performance Optimization of 1/3 Horsepower Rotary Vane Compressor Using a Computer Simulation	R. Cohen
35. E. Padilla	MSME 8/70	Computer Simulation of a Two-Cylinder Refrigeration Compressor with Special Attention to the Cylinder and Cavity Interactions	W. Soedel
36. D. D. Schwerzler	Ph.D. 6/71	Mathematical Modeling of a Multiple Cylinder Refrigeration Compressor	J. F. Hamilton
37. J. A. Adams	Ph.D. 6/71	The Prediction of Dynamic Strain in Ring Type Compressor Valves	J. F. Hamilton
38. T. J. Trella	Ph.D 1/72	Computer Simulation of the Vibrating and Acoustic Behavior of a Reciprocating Compressor Discharge Valve	W. Soedel
39. R. P. Beldam	MSME 1/72	Experimental Verification of Digital Computer Rotary Compressor Simulation	J. F. Hamilton
40. C. H. Gerhold	MSME 1/72	Mathematical Model of a Single-Cylinder Compressor	J. F. Hamilton
41. M. Moaveni	Ph.D. 1/72	The Prediction of Dynamic Strain in Leaf-Type Compressor Valves with Variable Mass and Stiffness	J. F. Hamilton/ R. Cohen
42. J. P. Elson	Ph.D.	Gas Pressure Oscillations and Ring Valve	W. Soedel

	6/72	Simulation Techniques for the Discharge Process of a Reciprocating Compressor	
43. J. M. Hughes	MSME 6/72	A Study of Heat Transfer and Valve Phenomena in a Reciprocating Compressor	B. Qvale/ J. Pearson
44. R. P. Adair	MSME 6/72	Instantaneous Heat Flow Through the Cylinder Walls of Reciprocating Compressors	B. Qvale/ J. Pearson
45. W. R. Thornton	Ph.D. 8/72	Noise Identification and Reduction for a Rotary Vane Compressor	J. F. Hamilton
46. D. E. Mosiman	MSE 8/73	The Feasibility of Rotating Hermetic Compressors	W. Soedel/ W. Leidenfrost
47. R. A. Shryock	MSME 8/73	Acoustic Investigation of a Small Rotary Vane Compressor	D. R. Tree
48. L. F. LaFrance	Ph.D. 8/74	The Development of a Nonlinear Constrained Optimization Algorithm for Application to Simulated Systems	J. F. Hamilton
49. S. Wolverton	MSME 8/74	Application of Experimental Methods to Compressor Design	W. Soedel
50. K. H. Reddy	Ph.D. 8/74	Computer Simulation of a Reciprocating Compressor with Special Emphasis on the Prediction of Dynamic Strains in Ring Type Valves	J. F. Hamilton/ W. Soedel
51. R. V. Firth	MSME 8/74	Calculation of the Natural Frequencies and Mode Shapes of a Compressor Discharge Line by Using Finite Elements	J. F. Hamilton
52. E. Sandgren	MSME 5/75	Computer Simulation of a Two-Cylinder Reciprocating Compressor and Associated Discharge System Using Acoustical	K. M. Ragsdell/ W. Soedel Impedances
53. J. M. Baum	MSME 5/75	Computer Simulation of a Four-Cylinder Air Conditioning Compressor with Special Attention to Discharge Cavity Interactions	W. Soedel
54. R. Singh	Ph.D. 12/75	Modeling of Multicylinder Compressor Discharge System	W. Soedel
55. D. A. Feldmaier	MSME	Noise Identification of a Rotary Vane	D. R. Tree

	12/76	Compressor with Special Emphasis on the Cylinder Pressure	
56. D. L. Strader	MSME 12/76	Computer Simulation of Dynamics of Refrigeration Cycle	W. Soedel
57. W. A. Reed	MSME 8/77	Internal Leakage Effects in Sliding Vane, Rotary Compressors	J. F. Hamilton
58. S. Steinke	MSME 12/77	Compressor Noise Study of a 1.75 Horsepower Hermetically Sealed ReciprocatingCompressor	D. R. Tree
59. M. Dhar	Ph.D. 5/78	Transient Analysis of Refrigeration System	W. Soedel
60. J. Koster	MSME 5/78	Part Load Performance Analysis of Centrifugal Chillers	K. Hawks
61. D. Rauen	MSME 8/78	Simulation of Underwater Breathing System (non-thesis)	W. Soedel
62. E. Pollak	Ph.D. 12/78	Performance Study of Oscillating Electro-dynamic Compressors	W. Soedel
63. P. Pandeya	Ph.D. 12/78	Performance Analysis of a Positive Displacement Refrigerating Compressor	W. Soedel
64. D. Powder	MSME 5/79	Measurements and Interpretation of the Vibrations of a Spring Supported Compressor	W. Soedel
65. M. Franzen	MSME 5/79	Mathematical Simulation of Refrigeration Compressor Vibrations	J. F. Hamilton
66. K. Nishioka	Ph.D. 5/80	Nonlinear Analysis of Electromagnetic Linear Motor Compressors	W. Soedel
67. S. Jenkins	MSME 5/80	Reduction of Transmitted Vibration Forces Through the Support Springs of a Compressor	J. F. Hamilton
68. S. Thomas	MS 5/80	A Study of the Test Method for Prediction of Air Conditioning Equipment Seasonal Performance	D. R. Tree
69. T. Hirahara	MSE 5/80	Crank Shaft Deflection in Multicylinder Refrigerant Compressors (non-thesis)	J. F. Hamilton

70. T. W. Bein	MSME	A Computer Model of a Single Screw Air 12/80	J. F. Hamilton Compressor
71. V. Yee	Ph.D. 12/82	Analytical and Experimental Study of High Speed Rotary Sliding Vane Compressor Dynamics with Application to Transfer Slot Design	W. Soedel
72. J. C. H. Yang	Ph.D. 12/83	Computer Aided Design of Multicylinder Reciprocating Compressor	J. F. Hamilton
73.M. Waser	MSME 5/84	Noise Transmission Characteristics of the Hermetic Shells of Fractional Horse Power Refrigerant Compressors	J. F. Hamilton
74. N. Gupta	MSME 5/84	Analysis of the Transient Motion of a Compressor	R. J. Bernhard
75. M. Seidel	MSME 5/85	Transient Vibrations of Compressor Discharge Tubes	R. J. Bernhard
76. S. M. Price	MSME 8/85	Identification of High Frequency Noise Paths and Noise Mechanisms in Reciprocating Hermetic Compressors	R. J. Bernhard
77. D. Jankov	MSME 8/85	Valve Failure Detection in Refrigeration Compressors	W. Soedel
78. J. S. Kim	Ph.D. 5/86	Three Dimensional Transient Stress Wave Propagation in a Plate with Application to Compressor Valve Failure Analysis	W. Soedel
79. B. Roys	MSME 8/86	On the Acoustics of Shell Enclosed Compressors with Special Attention to Gas Pulsations on the Suction Side	W. Soedel
80. R. Srikanth	MSME 5/87	How the Design of the Suction Return Affects Compressor Efficiency	H. D. Thompson
81. M. A. Beaty	MSME 8/87	Energy Losses to Friction in a Reciprocating Refrigerator Compressor	C. Krousgrill
82. W. A. Meyer	MSME 8/87	An Investigation into Heat Transfer Processes in a Small Hermetic Refrigeration Compressor	H. D. Thompson
83. H. A. Chung	MSME 12/87	Linear and Nonlinear Mathematical Modeling of the Steady State Vibration of Sealed	J. F. Hamilton

		Refrigeration Compressors	
84. J. Kim	Ph.D. 5/88	Simulation of a High Speed Hermetic Compressor with Special Attention to Gas Pulsations in Three Dimensional Continuous Cavities	W. Soedel
85. M. Krueger	MSME 5/88	Theoretical Simulation and Experimental Evaluation of an Hermetic Rolling Piston Rotary Compressor	J. F. Hamilton
86. M. P. Hsu	Ph.D. 5/89	Investigation of Natural Mode Measurement on Shells Using Hand Held Transducers with Special Attention to Compressor Shells	W. Soedel
87. T. Berther	MSME 5/90	Condition Monitoring of Check Valves in Reciprocating Pumps	P. Davies
88. R. Andrews	MSME 8/90	Noise Source Identification in Twin-Screw Compressors	J. D. Jones
89. D. Brown	MSME 8/90	Noise Source Identification of a Multi-Cylinder Reciprocating Automotive Air Conditioning Compressor	P. Sherman
90. K. L. Koai	Ph.D. 8/90	Mathematical Modeling of Twin Screw Compressors with Special Attention to Gas Pulsations in Three-Dimensional Gas Paths	W. Soedel
91. J. Frabotta	MSME 8/91	Investigation of Noise Generation Mechanisms and Transmission Paths of Fractional Horsepower Reciprocation Piston and Rolling Piston Compressors	J. D. Jones
92. D. T. Huang	Ph.D. 12/91	On the Free and Forced Vibration of Plate-Shell Combinations Using the Receptance Methods	W. Soedel
93. H. J. Kim	Ph.D. 12/92	Computer Simulation of Gas Pulsation Generated Sound in Compressors	W. Soedel
94. J. E. Huff, Jr.	MSE 12/92	Development of a Measurement Technique to Evaluate Rotor Chatter in Twin Screw Compressors	J. D. Jones
95. Z. Liu	Ph.D. 12/93	Simulation of a Variable Speed Compressor with Special Attention to Supercharging Effects	W. Soedel

96.	G. P. Adams	Ph.D. 12/93	Modelling and Computer Simulation of Rotor Chatter and Oscillating Bearing Forces in Twin Screw Compressors	W. Soedel
97.	T. M. Rossi	Ph.D. 12/95	Detection, Diagnosis, and Evaluation of Faults in Vapor Compression Cycle Equipment	J. E. Braun
98.	F. Pan	Ph.D. 12/95	A Study of Piezoelectric Transducers in Application to Active Control of Reciprocating Compressor Noise	J. D. Jones
99.	Y. K. Kim	MSME 12/95	The Analysis and Simulation of Gas Pulsations in a Valve-Muffler System of a Rolling Piston Compressor	W. Soedel
100.	J. E. Navarro de Andrade	MS 12/95	Investigation of Rotary Compressor Oil Carry-Over	V. Goldschmidt
101.	B.L. Minner	MSME 8/96	Design Optimization for Thermoacoustic Cooling Systems	J. Braun
102.	P. C. C. Lai	Ph.D. 12/96	A General Procedure for the Analysis of Gas Pulsations in Thin Compressor or Engine Manifolds and Thin Shell Type Mufflers	W. Soedel
103.	N. P. Halm	MSME 12/97	Mathematical Modeling of Scroll Compressors	E.A. Groll/ J.E. Braun D.R. Tree
104.	A. Causey	MSME 8/98	Non-thesis. Compressor Load Stand; Commissioning and Control Strategies	J.E. Braun/ E.A. Groll
105.	Y. Chen	Ph.D. 12/2000	Mathematical Modeling of Scroll Compressors	E.A. Groll/ J.E. Braun
106.	J. S. Baek	Ph.D. 8/2002	Development of a Work Producing Expansion Device for a Transcritical Carbon Dioxide Cycle	E.A. Groll/ P.B. Lawless
107.	B. Hubacher	MSME 12/2003	Experimental and Theoretical Performance Analysis of Carbon Dioxide Compressors	E.A. Groll
108.	C. Buhr	Ph.D. 12/2003	Active Control of Rotating Stall in Compressors	S. Fleeter/ M. Franchek

109.	J. Park	Ph.D. 08/2004	Modeling and Simulation of a Multi-Cylinder Automotive Compressor	D.E. Adams
110.	J.-H. Kim	Ph.D. 12/2005	Analysis of a Bowtie Compressor with Novel Capacity Modulation	E.A. Groll
111.	J. Hugenroth	Ph.D. 5/2006	Liquid Flooded Ericsson Cycle Cooler	E.A. Groll/ J.E. Braun/ G.B. King
112.	J. Lim	Ph.D. 12/2006	Statistical Energy Analysis for a Compact Refrigeration Compressor and Model Improvement	J.S. Bolton/ R.J. Bernhard/ C.M, Krousgrill
113.	M. Jovane	Ph.D. 8/2007	Modeling and Analysis fo a Novel Rotary Compressor	J.E. Braun/ E.A. Groll
114.	A. Sathe	Ph.D. 8/2008	Miniature-Scale Diaphragm Compressor for Electronics Cooling	E.A. Groll
115.	W. Kim	MSME 12/2009	Evaluation of a Virtual Refrigerant Charge Sensor	J.E. Braun
116.	I. Bell	Ph.D. 5/2011	Theoretical and Experimental Analysis of Liquid Flooded Compression in Scroll Compressors	J.E. Braun/ E. Groll
117.	M. Vargo	MSME 5/2011	Non-Thesis: Compressor Performance Testing	J. Braun
118.	M. Mathison	Ph.D. 8/2011	Modeling and Evaluation of Advanced Compression Techniques for Vapor Compression Equipment	J.E. Braun/ E. Groll
119.	B. Shaffer	Ph.D. 5/2012	Performance Analysis of Non-Metallic Dry Running Scroll Compressors	E. Groll
120.	C. Bradshaw	Ph.D. 8/2012	A Miniature-Scale Linear Compressor for Electronics Cooling	E. Groll
121.	S. Ramaraj	MSME 12/2012	Vapor Compression Cycle Enhancements for Cold Climate Heat Pumps	E. Groll
122.	Y. Song	MSME 5/2013	Modeling and Experimental Validation of a Multi-Port Vapor Injected Scroll Compressor	J. Braun/E. Groll

123. S. Ebling	MSME 8/2013	Carbon Dioxide Compressor Load Stand	E. Groll
124. S. Caskey	MSME 12/2013	Cold Climate Field Test Analysis of an Air-Source Heat Pump with Two-Stage Compression and Economizing	E. Groll
125. C. Bach	Ph.D. 5/2014	Refrigerant Side Compensation for Air-Side Maldistribution of Evaporators and Its Effects On System Performance	E. Groll/J. Braun/T. Horton
126. H.Cheung	Ph.D. 8/2014	Inverse Modeling of Vapor Compression Equipment to Enable Simulation of Fault Impacts	J. Braun
127. U. Upathumchard	MSME 12/2014	Waste Heat Recovery Options in a Large Gas-Turbine Combined Power Plant	E. Groll
128. C. Wani	MSME 2015	Non-thesis: Organic Rankine Cycle Using Scroll Expander	E. Groll
129. S. Dharker	MSME 8/2015	CO_2 Heat Pumps in Commercial Building Applications with Simultaneous Heating and Cooling Demand	E. Groll
130. B. Woodland	Ph.D. 8/2015	Methods of Increasing Net Work Output of Organic Rankine Cycles for Low-Grade Waste Heat Recovery with a Details Analysis Using a Zeotropic Working Fluid Mixture and Scroll Expander	J.E. Braun
131. K. Bansal	MSME 8/2015	Modeling and Evaluation of Scroll Expanders for a Liquid-Flooded Ericsson Power Cycle	E. Groll/ J.E. Braun
132. A. Krishna	Ph.D. 12/2015	Analysis of a Rotating Spool Expander for Organic Rankine Cycle Applications	E. Groll
133. F. Accorsi	MSME 8/2016	Experimental Characterization of Scroll Expander for Small-Scale Power Generation in An Organic Rankine Cycle	E. Groll

COMPRESSOR RESEARCH NOT REFLECTED IN THESES TITLES

In addition to the theses listed in the previous chapter, many more research reports on various aspects of compressors have been written, usually for research sponsors. As a rule, these reports are kept confidential, and are therefore not listed. Topics are often different from the theses topics, mainly since not everything found on a sponsored research program is eventually incorporated in a thesis. In some cases, although the student's support came from a sponsored research program, his thesis was written around a detailed question which was part of the research program and caught his fancy. For instance, the Laboratories have done extensive work on the noise control of large centrifugal compressors, but the graduate student on the project and his major professor decided that the student should write his thesis on the stiffening of shells.

Then there are theses in other areas whose findings have influence on compressor design. In addition to the ones that are listed here, there are many more in the areas of vibrations, acoustics, thermodynamics, fluid mechanics, heat transfer, control, etc. Also, considerable work that was or can be applied to compressors has been published by the Herrick faculty and students in journals and conference proceedings. Areas are, for instance, flow area modeling, impact stress analysis, valve reed similitude, instrumentation design, acoustics, etc., and some listings may be found in the Publications listing.

PAST AND PRESENT SPONSORS

Among past and present industrial sponsors of research related to compressors are:

American Standard
Aspera SpA, Italy
Bell and Gossett ITT
Bendix-Westinghouse
Robert Bosch GmbH (West Germany)
Carlyle Compressor Company
Carrier Corporation
Chrysler Corporation, Airtemp Division
Copeland Corporation
Cummins Engine Company
Danfoss A/S, Denmark
Mario Dorin SpA, Italy
Dunham-Bush, Inc.
E. I. duPont de Nemours and Company
S.A. Embraco, Brazil
Frick Company
General Electric Company
General Motors Corporation, Frigidaire Division
Gibson Products Corporation
GoldStar Company, Korea
Joy Manufacturing Company
L.G. Electronics
Mitsubishi Electric Corporation, Japan
Mitsubishi Heavy Industries, Ltd., Japan
Nanjing Aotecar Refrigerating Co., Ltd.
Necchi, S.p.A., Italy
Panasonic (Matsushita), Japan
Sanden Corporation, Japan
Shanghai Hitachi Electrical Appliances Co.,LTD
Tecumseh Products Company
Toshiba Corporation, Japan
The Trane Company
United States Army
United States Air Force
United Technologies Carrier Corporation
Vilter Manufacturing Corporation
Westinghouse Electric Corporation
Whirlpool Corporation
York Division, Borg-Warner Corporation
Zanussi Eletromeccanica S.p.A., Italy

Many sponsors have had or have research programs with the Ray W. Herrick Laboratories that stretch over many years, involving as many as four students at a time.

HOW TO INITIATE SPONSORED RESEARCH

The prospective sponsor should contact the Director of the Herrick Laboratories or one of the members of the faculty and ask for a preliminary meeting. At this meeting, the sponsor can state his interests, and the degree of his desired involvement can be discussed. After this meeting, the Herrick Laboratories faculty will write an informal technical research proposal, which will be discussed with the sponsor at one or more subsequent meetings. An informal budget will be presented at that time. After an informal agreement on the proposal and budget has been reached, the proposal will be formally processed through Purdue University offices for administrative approvals. The approved technical proposal and budget will then be forwarded to the sponsor by the Purdue Research Foundation, along with an agreement form for execution by the sponsor.

To accommodate needs for confidentiality, it is possible to withhold publication of a thesis for up to two years after contract termination.

While continuing sponsorship of research stretching over several years is desirable, both from the viewpoint of the Herrick operation and the maximum benefit to the sponsors, budget commitments do not have to exceed one year. Contracts are usually fixed price contracts.

Often the prospective sponsor is unsure what would constitute an acceptable research project. It is suggested that he contact the Ray W. Herrick Laboratories anyway, as there are few worthwhile projects that cannot at least generate a master's thesis. The faculty will take the responsibility to add to the project any necessary additional academic requirements. In these cases, this means that the sponsor received information above and beyond what he has contracted for.

A NOTE TO OUR FOREIGN FRIENDS

A foreign visitor is usually surprised that the compressor research operation of the Herrick Laboratories is completely different from what he is accustomed to. He will be dismayed because the faculty may be unable to answer a question on some specific design detail of some specific brand of compressor, but will be agreeably surprised about the depth of knowledge in particular scientific areas applying to compressor design; for example, heat transfer or vibrations. He will also be surprised to find faculty members involved not only in compressor research but, for instance, also in combustion oscillation. The reason is simply the different characters of the higher education systems in the United States. Chairs for piston machinery, or even fluid machinery, in general do not exist. No single professor has the mission to be the expert in a given applied area such as compressors. Rather, there are professors specializing in the engineering science disciplines. They will, if needed, apply this specialized knowledge to industrial design. These disciplines are thermodynamics, fluid mechanics, heat transfer, vibrations, stress analysis, automatic control, acoustics, etc. This applies in general also to the course content of the academic curriculum.

It is felt that the advantages of this system outweigh the disadvantages. The Ray W. Herrick Laboratories program in compressor research is an attempt to preserve the advantages and eliminate the disadvantages by a cooperative approach to applied research. Thus, the specialists in acoustics, vibration, thermodynamics, etc., bring their full knowledge to bear on every research project, even if it is only in an informal consultation capacity.

A NOTE TO PROSPECTIVE GRADUATE STUDENTS

In general, the graduate student who works on a sponsored project can expect an appointment as a half-time Graduate Research Assistant. Master's degree candidates are expected to write a thesis related to their project research. This thesis can also be the final report to the project sponsor. In addition, the student is expected to write progress reports to the sponsor during the course of his research. Material in the progress reports can be incorporated in the thesis. The Ph.D. candidate is, of course, required to write a dissertation.

Students often ask what constitutes an acceptable thesis. A suggested minimum requirement for a Master's thesis is that the student utilize graduate-type coursework and produce results that are of a certain importance to the compressor industry. Publishability in refereed professional journals is not required, but many of our Master's degree graduates have published their work subsequently. However, a Ph.D. thesis has to contain material that is publishable in professional journals, be of a sufficient degree of difficulty to prove the candidate's qualification, and has to be in its subject matter of high interest either to the compressor industry or to one of the engineering science disciplines. Publications of former Herrick Laboratories Ph.D. candidates can be found in almost all major journals. This testifies to the quality of the Herrick Laboratories programs.

In all fairness, it has to be pointed out that applied research, in this case on compressors, is in some cases more difficult than what is often called basic research; since sooner or later the applied question leads to a basic investigation also. It is certainly more time-consuming, since the student is expected to become both broad and deep in outlook. He will also enter into a relationship of responsibility with the sponsoring company, and has to handle most communication with the sponsor himself. The rewards are a good and tough engineering education, no matter if on the Master's level or on the doctoral level. Graduates of the Ray W. Herrick Laboratories do, as a rule, very well for themselves in industry or government positions. A large percentage of the Ph.D. candidates have entered successful academic careers in major universities.

Students who are interested in joining the Ray W. Herrick Laboratories should formally apply to the Graduate School of Purdue University by writing to the Graduate Office of Mechanical Engineering, Purdue University, West Lafayette, Indiana 47907, U.S.A., and indicate their interest in the Laboratories on the application form.

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