The Impact of Environmental Protection on Chemical Plant Management: a Descriptive and Exploratory Analysis.

Joe C. Iverstine Jr
Louisiana State University and Agricultural & Mechanical College

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The Louisiana State University and Agricultural and Mechanical College, Ph.D., 1973
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THE IMPACT OF ENVIRONMENTAL PROTECTION ON CHEMICAL
PLANT MANAGEMENT: A DESCRIPTIVE AND EXPLORATORY ANALYSIS

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in
The Department of Management

by
Joe C. Iverstine, Jr.
B.S., Southeastern Louisiana University, 1964
M.B.A., Louisiana State University, 1970
December, 1973
This work is dedicated
to my wife, Kay Baker Iverstine
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TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>ACKNOWLEDGEMENT</th>
<th>LIST OF TABLES</th>
<th>ABSTRACT</th>
<th>Chapter 1: Impact of Environmental Protection on Chemical Plant Management: A Need for Assessment</th>
<th>Chapter 2: External Factors Affecting Pollution Control Pressure</th>
<th>Chapter 3: The Influence of Environmental Protection on Plant Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Page</td>
<td></td>
<td></td>
<td>1</td>
<td>19</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Overview of Environmental Protection Legislation</td>
<td>Geographic Location</td>
<td>Unit Downtime</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Purpose of the Study</td>
<td>Age of Plant</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Justification of the Study</td>
<td>Environmental Protection Agency and Activist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Research Design</td>
<td>Group Contacts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Scope and Limitations</td>
<td>Compliance Plans</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Preview of Succeeding Chapters</td>
<td>Industrial Complex Influence</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Participation with Municipalities in Treating</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Waste</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Air Pollution, Water Pollution or OSHA?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>41</td>
</tr>
</tbody>
</table>

v
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>THE EFFECT OF POLLUTION CONTROL ON MAJOR OPERATING FACTORS</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Pollution Abatement Effect on Product Yields</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>Change in Quality of Raw Materials and Finished Products</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>Pollution Control's Influence on Raw Material Price</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>The Effect of Environmental Protection on Power or Utility Costs</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Correlation Involving Manufacturing Costs</td>
<td>62</td>
</tr>
<tr>
<td>5</td>
<td>THE INFLUENCE OF ENVIRONMENTAL PROTECTION ON MANPOWER RELATED FACTORS</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>Effect on Number of Hourly Employees</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>Influence on First Line Supervisors</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>Effect on Training and Job Design</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>The Effect of Environmental Protection on Personal Stress and Employee Attitude</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Models of Stress and Personnel Attitude</td>
<td>80</td>
</tr>
<tr>
<td>6</td>
<td>THE EFFECT OF POLLUTION CONTROL ON MAINTENANCE COSTS AND PRIORITIES</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>Current Level of Maintenance Spending on Pollution Control</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>Maintenance Costs for Pollution Control Over Next Five Years</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>Possible Maintenance Reductions from Pollution Control</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>Priority Given Pollution Maintenance</td>
<td>87</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>7</td>
<td>THE INFLUENCE OF ENVIRONMENTAL PROTECTION ON CAPITAL BUDGET ALLOCATION</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>Current Capital Spending for Pollution Control</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>Pollution Control Spending Over Next Five Years</td>
<td>95</td>
</tr>
<tr>
<td>8</td>
<td>FACTORS INFLUENCING PLANT STRATEGY FOR ENVIRONMENTAL PROTECTION</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Plant Departmentation</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Technical Staff Assignments</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>General Approach to Pollution Control</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td>Land Acquisitions and Plant Expansions</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td>Ramifications of a Zero Discharge Order</td>
<td>107</td>
</tr>
<tr>
<td>9</td>
<td>CONCLUSIONS AND RECOMMENDATIONS</td>
<td>116</td>
</tr>
<tr>
<td></td>
<td>Conclusions</td>
<td>116</td>
</tr>
<tr>
<td></td>
<td>Recommendations for Future Research</td>
<td>123</td>
</tr>
<tr>
<td></td>
<td>A Final Note</td>
<td>124</td>
</tr>
<tr>
<td></td>
<td>BIBLIOGRAPHY</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td>APPENDIX</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>GLOSSARY OF TERMS</td>
<td>131</td>
</tr>
<tr>
<td>B</td>
<td>SURVEY - CONDUCT AND RESPONSE</td>
<td>136</td>
</tr>
<tr>
<td>C</td>
<td>EXPLANATION OF STATISTICAL PROCEDURES</td>
<td>144</td>
</tr>
<tr>
<td>D</td>
<td>QUANTIFICATION OF THE QUESTIONNAIRE; AN EXPLANATION OF VALUATION OR WEIGHTING PROCEDURES</td>
<td>149</td>
</tr>
<tr>
<td>E</td>
<td>SURVEY COVER LETTER</td>
<td>154</td>
</tr>
<tr>
<td>F</td>
<td>QUESTIONNAIRE</td>
<td>157</td>
</tr>
<tr>
<td>G</td>
<td>DATA FROM COMPUTER PROGRAMS</td>
<td>163</td>
</tr>
<tr>
<td></td>
<td>VITA</td>
<td>182</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>Survey Response by Response Day</td>
<td>142</td>
</tr>
<tr>
<td>A-2</td>
<td>Cumulative Survey Response</td>
<td>143</td>
</tr>
<tr>
<td>I</td>
<td>Computer Program</td>
<td>164</td>
</tr>
<tr>
<td>II</td>
<td>Computer Program</td>
<td>166</td>
</tr>
<tr>
<td>III</td>
<td>Computer Program</td>
<td>168</td>
</tr>
<tr>
<td>IV</td>
<td>Computer Program</td>
<td>170</td>
</tr>
<tr>
<td>V</td>
<td>Computer Program</td>
<td>172</td>
</tr>
<tr>
<td>VI</td>
<td>Computer Program</td>
<td>174</td>
</tr>
<tr>
<td>VII</td>
<td>Computer Program</td>
<td>176</td>
</tr>
<tr>
<td>VIII</td>
<td>Computer Program</td>
<td>178</td>
</tr>
<tr>
<td>IX</td>
<td>Computer Program</td>
<td>180</td>
</tr>
</tbody>
</table>
ABSTRACT

This study described and explored the impact of environmental protection legislation on the management and operation of the United States' chemical plants. The unit of study was the individual chemical plant, and the research instrument was a mailed survey to 1500 randomly selected plants of which 508 usable responses were received.

The findings indicate that water pollution legislation has a large effect on chemical plants since two thirds of the plants use waterways for disposal. OSHA compliance ranks second and air pollution third in overall concern to plant management. The EPA and ecological activist groups tend to apply pressure to the same plants, and older plants tend to receive more pressure, which indicates more severe pollution problems in such plants. Proximity to urban or residential areas has little effect on pressure brought to bear on plants.

Lack of demand is the primary reason for plant rate reductions, but pollution problems have caused shutdowns and rate constraints -- possibly a serious problem for isolated plants.

With control of pollution, plant yields are increased slightly. Raw material prices have risen slightly, and quality specifications have been elevated for both raw materials and finished products. Plant utility costs have been sharply elevated due to environmental protection.

More operators and mechanics are required due to pollution abatement. A less than proportional increase in number of foremen is
also being added, which produces a larger equipment responsibility and personnel span of control for first line supervisors. Job descriptions and training are being slightly altered. The consensus of plant personnel attitude toward pollution control pressures is slightly positive, and plant production managers experience a moderate degree of personal stress from ecological pressures.

Current maintenance spending for pollution control is 5.31 per cent of total maintenance outlay. This spending is expected to increase maintenance costs by 7.99 per cent over the next five years. Keeping the plant on stream has a slightly higher maintenance priority than pollution control, but adhering to preventive maintenance schedules has essentially the same priority as pollution abatement. Plants that currently are spending a high maintenance percentage on pollution are forecasting even higher percentages over the next five years. Capital allocation was virtually the same claimed by industry spokesmen.

The study concluded with findings that indicate that 44 per cent of the plants now have "in-house" environmental protection departments, and 9.29 per cent of the technical staff is assigned to pollution work. Production managers allocate 8.32 per cent of their time to pollution matters. Approach to pollution abatement over the next five years will be slightly directed toward control of existing pollution versus elimination of the source of pollution. The consensus of opinion indicates that pollution abatement will have a slightly negative impact on expansion at existing plant sites. Plant properties will be slightly enlarged to control existing pollution. Zero discharge targeted for 1985 is projected to have an average impact of moderate
to major capital outlay to comply with this goal. Fifteen per cent of the plants forecast closures if faced with a zero discharge mandate.
CHAPTER 1

IMPACT OF ENVIRONMENTAL PROTECTION ON CHEMICAL PLANT MANAGEMENT:

A NEED FOR ASSESSMENT

The United States chemical industry is one of the major contributors to the most highly developed economy and standard of living on our globe. The United States chemical industry employs 1.3 per cent of the nation's work force but contributes 1.70 per cent of the nation's payroll.¹ Chemical workers rank eleventh in per capita income out of sixty eight industrial groups. In the important category of balance of trade, the chemical industry has a positive balance of trade of $2.0 billion in comparison with a negative $2.8 billion for the total United States' economy.² The chemical industry has been a major deterrent to inflation by increasing wholesale prices by only 0.3 per cent per year during the period 1961-1971.³ During the same period, the chemical industry increased the wages paid to workers by 4.4 per cent per year.⁴ Thus, the United States chemical corporations may be regarded as an excellent corporate citizen in the classical economic view.

⁴Securities and Exchange Commission, Loc. cit.
Chemical companies have been widely criticized, however, for their impact on the environment. The industry has not only been cited because of the pollution from chemical plant operation, but also for the problems encountered when certain chemicals are used as raw materials in the production of goods of other industries. Examples of the latter include phosphate and tetra-ethyl lead producers being criticized for laundry detergent and gasoline pollution problems. Numerous ecological activist groups have brought social pressures to bear on chemical producers. These groups include the National Resources Defense Council, Sierra Club, Wilderness Society, National Audubon Society, and Friends of the Earth.

Overview of Environmental Protection Legislation

Water. More direct and consequential pressure for protection of the environment has been applied by governmental regulatory agencies. These agencies are taking steps to curtail all types of pollution in industry as a whole. Governmental protection of the environment began with the River and Harbor Act of 1899. Section 13 of that act required companies to obtain a permit to discharge any material into a public waterway. Until the advent of the Environmental Protection Agency (EPA), the Army Corps of Engineers administered the act. Both the Corps and the EPA relied on the 1899 Act to prosecute pollution violators until the passage of the Federal Water Pollution Control Act Amendments of 1972. Another milestone in the protection of our nation's waterways was the Federal Water Pollution Control Act of 1948 which was passed under President Truman's administration. The Federal Water Pollution Control Act of 1956 directed $53 million
in grants for studies into water pollution consequences and also authorized $500 million for construction of municipal sewage treatment works. The Water Quality Act of 1965 was passed under the administration of President Johnson, who vowed to bring all streams in the United States up to standards safe for swimming by the year 2000. This act set standards and administrative procedures for water pollution legislation to follow.

Protection of the nation's waterways is currently governed by the Federal Water Pollution Control Act Amendments of 1972. These amendments replace the Army Corps of Engineers with the EPA as the chief federal water pollution regulatory agency. The amendments also eliminate reliance on the 1899 Act for prosecuting pollution violators. The major provisions of the 1972 Amendments are deadlines of "best practicable control" by July of 1977, "best available control" by July of 1983, and a goal of "zero discharge" by 1985.

Interpretation of "best practicable" control gives the EPA a wide latitude of discretion in applying the law to individual plants. In determining best practicable control such factors as age of plant, economic impact on the plant, engineering aspects, type of process, and impact of control on energy consumption are considered. The EPA does not have enforcement flexibility, however, with respect to certain documented hazards. For example, no "waterborne process effluent" is permitted in the manufacture of aluminum sulfate, hydrochloric acid (by chlorine burning), lime and calcination, nitric acid, phosphorus and sulfuric acid (in sulfur-burning contact plants); and in the case of mercury-cell chlorine plants, mercury discharge is limited to 0.1 lb/day for the entire operation.
"without regard to capacity."5

The more stringent "best available control" that will be enforced July of 1983 will leave very little discretion with the EPA. The EPA expects to have gained much knowledge of what is "best available" through compliance plans submitted by individual plants and by visits to these plants. Therefore, types of control facilities will be somewhat standardized to that which is "best available." The EPA has until October 18, 1973 to define best practicable and best available control.

The 1972 Amendments also contain the controversial goal of "zero discharge by 1985." The economic impact of this standard is being carefully weighed by congressional fact-finding groups and subcommittees. Another provision of the 1972 Amendments is user charges for a manufacturer to use municipal treatment facilities. These manufacturers may be requested to help pay the capital and operating costs of such facilities.

Air. Unlike the history of water pollution control legislation, air pollution laws are relatively recent. The basic air pollution legislation began with the Clean Air Act of 1963. It was subsequently amended by the Motor Vehicle Air Pollution Control Act of 1965, the Clean Air Amendments of 1966, and the Air Quality Act of 1967.

The 1970 Clean Air Amendments to the 1967 Air Quality Act currently guide air pollution regulation. Under these amendments

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the EPA has established nationwide ambient air quality standards to be implemented by the states by May 31, 1975. There has been a great deal of debate over the ability of the states to meet these standards by that time. As of the beginning of 1973, eighteen states were given extensions in compliance plans. This action was subsequently rescinded by a federal appeals court at the petition of the National Resources Defense Council. The Supreme Court, however, has agreed to review this lower-court decision. Major protests to the ambient air standards come from auto manufacturers who claim that their 1975 models will not be able to meet established emission standards. Also, control problems with certain photo-chemical oxidants prevent certain plants from meeting the prescribed air standards.

To cope with air and water pollution standards, plants attempt to work closely with the EPA and state regulatory agencies. The state agencies actually administer control legislation; the EPA sets standards and rules on the acceptability of the individual state plans. A number of plants have already submitted compliance plans to meet the guidelines of their respective states. These compliance plans contain existing, planned, and tentative control measures. The state guidelines for ruling on compliance plans should be clearer and more uniform with the establishment of national ambient air quality standards and the forthcoming EPA definition of "best practicable" and "best available" control.

6"State's Compliance with Pollution Rule by Mid '75 Required," Baton Rouge Morning Advocate, February 2, 1973, p. 14-D.
Purpose of the Study

Both ecological activist groups and governmental regulatory agencies have brought pressure to bear on chemical plants for improvements in environmental protection. This pressure has had an impact on the management and operation of the individual chemical plant. The purpose of this research is to determine the manner in which environmental protection has changed certain aspects of chemical plant operation. Specifically, the study is designed to explore and probe the following areas:

1. The manner in which selected external factors have affected the environmental pressure brought to bear on the individual chemical plant. These factors include proximity to urban or residential areas; age of the plant, activity of ecological activist groups and regulatory agencies; participation with municipalities in treatment of sanitary sewage; size of the plant relative to the encompassing industrial complex; and the relative pressure of air pollution control versus water pollution control versus Occupational Safety and Health Act (OSHA) compliance.

They are believed to be relevant to pressure for improved pollution control. Also, information about these factors could be gained without revealing the identity of the respondent which is a policy of this study.

Knowledge of these factors may assist managers in the following ways:

(a) Guidelines for plant site selection.
(b) Formation of industrial complex pollution abatement
(c) Policies for sanitary sewage treatment.
(d) Relations with ecological activist groups.
(e) Setting of priorities to cope with air pollution, water pollution, or OSHA compliance standards.

(2) The determination of whether or not environmental protection has directly affected plant production capacity; if it has, to measure the resultant change in capacity. Insight into this effect may assist managers in the following areas:

(a) An additional input for forecasting capacity to predict shortages which may be served by expansions or new plant construction.
(b) Another determinant for engineering process design and sizing of equipment for a specified new plant capacity.
(c) Determination of intervening factors that may influence pollution control's impact on plant capacity.

(3) An assessment of the influence (if any) of environmental protection on major operating cost determinants such as yields, raw material prices and quality specifications, finished product quality requirements, and plant utility or power consumption. Recognition of the manner in which pollution control has affected a number of plants may help the individual plant manager place his own decisions and priorities in a better perspective to minimize total cost.

(4) An appraisal of the impact (if any) of environmental protection on plant staffing, work area assignments, training requirements, employee attitude, and personal stress. Insight into this impact may help managers in the chemical industry as follows:
(a) Determination of changes in labor costs because of changes in the required number of hourly employees.

(b) Modifications in training programs because of new work assignments that include environmental protection.

(c) Understanding of behavioral responses (attitude and stress) to pollution control to help personnel cope with environmental pressures.

(5) An assessment of the influence of environmental protection on maintenance costs and priorities: Knowledge of the percentage of maintenance costs allocated to pollution-related jobs and the priorities that these jobs receive may assist managers as follows:

(a) Preparation of maintenance budgets.

(b) Appraisal of priorities given pollution abatement jobs relative to jobs that may sustain production.

(6) The determination of the influence of environmental protection on capital budget allocation: This may help chemical process management as follows:

(a) Audit of capital budget allocations to environmental protection claimed by chemical industry spokesmen.

(b) Assistance in budget preparation by indicating factors that influence budget allocations.

(7) The determination of the impact of environmental protection on other plant criteria as follows: plant departmentation, technical staff assignments, general approach to pollution control, land acquisitions and plant expansions, and the consequences of a zero discharge order: These factors largely determine the ability of a plant to forecast environmental protection requirements and
develop methods to cope with these requirements. They were selected and grouped together because of their influence on plant management's pollution control strategy for achieving plant viability.

**Justification for the Study**

The major needs for this study are fourfold. First, by representing the impact of environmental protection on a profile of chemical plants, individual plant management can place their own decisions, priorities, and strategies in a better perspective. Second, the study should also reveal to corporate and divisional managers in the chemical industry the individual plant's problems in protection of the environment. Recognition of these problems may result in corporate or divisional assistance to the plants in the form of technical or engineering aid and larger maintenance or capital budgets.

Third, to social pressure groups and the regulatory agencies, the study may more fully assess the "cost of a cleaner environment." A number of the influences of environmental protection may be translated into higher manufacturing costs. Other influences, such as possible improvements in product yields, may result in lower costs. The expenses may be matched against benefits to give the resultant effect of environmental protection. Insight into this effect may assist governmental decision makers in achieving a desirable balance between economic considerations and a cleaner environment.

Fourth, the study is designed to contribute to knowledge. There is relatively little knowledge of the effect of environmental protection on the operation and management of the chemical plant. An objective of this study is to make a significant
contribution to any knowledge that currently exists.

An inspection of all dissertation abstracts back to 1965 (the year that major legislation was first passed) reveals only two related studies. In 1969 Austin Homer Montgomery, Jr., of North Texas State University conducted a study of the effects of water pollution control laws on industrial plant location. Montgomery did not consider air pollution or the impact of pollution controls on other plant criteria. A 1972 study by Terry Anthony Ferrar of Purdue University examined the management of pollution abatement facilities, primarily municipal waste treatment plants.

A review of other literature reveals several aggregate or industry reports on the effect of environmental protection on chemical companies. One such report was released by Irvin Schwartz of Chemical Week with the assistance of the Manufacturing Chemists Association. Schwartz's report reached two conclusions:

(1) The high cost of pollution control is holding down profits in the chemical process industry.

(2) Spending for control is still on the rise.

A similar report in scope and purpose was issued by Richard Lambert of the Manufacturing Chemists Association.

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Lambert noted that the chemical industry was spending $235 million for operation and maintenance expenses, $46.7 million for research and development, and assigning 6,868 people to full time work on pollution control -- to meet environmental protection standards.

A different study in purpose was conducted by Chase Econometric Associates for the Council on Environmental Quality. Chase developed an economic model centered around the effects of pollution spending for the chemical industry. Chase concluded that the implementation of existing laws for pollution control standards will require price increases of an additional ¼ per cent per year during the next ten years or the level of employment will drop by as much as ½ per cent per year during the same period. An assumption of this model is that pollution control will not affect the chemical industry production function.

The above industry reports primarily indicate the impact of environmental protection on aggregate capital spending and other influences on industry profits. The dissertations were specialized studies of a more limited scope and purpose. Hence, it does not appear that a study of this approach, purpose, and detail has been conducted.

Research Design

The approach to the study is to examine the effects of environmental protection on a profile of chemical plants. Specifically, the

9Schwartz, op. cit., p. 68.
research investigates the influence on the major elements of manufacturing cost —— labor, raw materials, utilities and maintenance. Also examined are external factors that may modify pressure brought to bear on the plants, effects on plant capacity, and factors that influence strategy for adapting to environmental protection. The elements of the study are as follows:

1. Proximity to urban and residential areas
2. Age of the plant
3. Activity of ecological activist groups and regulatory agencies
4. Participation with municipalities in treatment of sanitary sewage
5. Size of the plant relative to the encompassing industrial complex
6. Relative pressure of air pollution control, water pollution control, or OSHA compliance
7. Usage of public streams for disposal
8. Submittal and status of compliance plans
9. Frequency and duration of production downtime
10. Degree of plant rate constraints
11. Reasons for rate constraints
12. Product yields (raw material consumption)
13. Raw material and finished product quality specifications
14. Raw material prices
15. Utility or power costs
16. Number of operators, mechanics, and foremen
17. Job assignments
18. Training programs
19. Employee attitude
20. Production manager's personal stress
21. Current and 5 year projected maintenance allocation to pollution jobs
22. Maintenance priorities
23. Current and 5 year projected capital budget allocations to environmental protection
24. Establishment of environmental protection departments
25. Technical assignments to environmental protection
26. Production manager's time allocation to environmental protection
27. Land acquisitions and expansions
28. Pollution control policy ("contain" vs. "eliminate")
29. Impact of "zero discharge"

Research Instrument

Information about the above elements was received by a survey sent to 1500 plants. To overcome any isolated geographic influences,
the universe was taken to be producing chemical plants of the continental United States. The most practical method of securing information from this widely dispersed universe was through a mail survey. The expense involved in conducting a large number of personal interviews would have been prohibitive. The time and related expense required to secure answers to the 46 survey questions by a telephone survey was also prohibitive.

The plant production manager was selected as the recipient of the questionnaire. He is closely enough involved with the details of the operation to answer specific questions, and high enough in the plant hierarchy to ascertain the answers to more generalized questions. It is reasonable to presume that these production managers are qualified as "experts" in giving accurate responses to the survey questions.

A policy of this survey was that the responding plants remain anonymous. More candid responses and a higher response percentage was expected with this policy. If the responding plants had been required to identify themselves, there would have been a tendency to give "safe, desirable answers" to protect or enhance the corporate image. Moreover, because of the controversial nature of pollution control, many plants would not have responded to the survey if identifications had been

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10 The survey questionnaire and cover letter are included in Appendix E and F respectively to this study. Also included is an explanation of the valuation or weighting procedure for the questionnaire in Appendix D. The production manager, recipient of the questionnaire, reports to the plant manager or general manager. Individual production supervisors or superintendents report to the production manager.
sought. These contentions were verified by consulting two environmental experts, two production managers, and a plant manager in the chemical industry (three different companies were represented).

The questionnaire was pretested at Allied Chemical Corporation's Baton Rouge North Works by the production manager and five production superintendents. Also, two employees at Allied Chemical's Syracuse Works and one employee at Allied's Morristownship Headquarters were consulted in the pretest.

**Sample Selection**

The survey questionnaire was mailed to 1500 plants that were selected through a systematic random procedure. The systematic random sampling method was chosen because the plants were not serialized (assigned an identification number) in the 1972 *Directory of United States Chemical Producers*. This *Directory* contains 3983 plants and was used as the universe of chemical plants for the study. It includes all of the 137 members of the Manufacturing Chemist Association as well as almost all non-members. The *Directory* is the most complete listing of plants that is available. The systematic random sampling procedure involves selection of a simple random sample from the first $K$ elements. Then, every $k$th element is selected. $(100/k)$ per cent of the universe is the sample size.

A relatively large sample size of 1500 plants was selected in order to receive a representative profile of the universe. The larger the sample, the more narrow are the confidence limits about the parameters under study. Also, a large sample size allows the sample variance to be a consistent estimator of the universe
variance. The upper limit to the sample size was determined by the funds available for the conduct of the study.

**Statistical Procedures**

The data received from the responding plants was analyzed and reduced with the aid of a General Electric timesharing terminal at Allied Chemical's Baton Rouge North Works. The software was General Electric's Mark II - Statistical Analysis System or "STATSYST." The study was mostly descriptive and exploratory in nature by analyzing sample means, standard deviations, proportions, and bivariate correlation analysis.

Multiple regression analysis was used in several instances in an attempt to cite functional relationships. A model for predictive purposes was sought from this analysis. Selected variables were assigned a dependent variable role, and the variation in these variables was described to a certain extent by variation in other variables selected as independent variables. However, the study primarily used means, standard deviations, proportions, and bivariate correlation analyses (description of mutual interdependency between two variables) to draw conclusions and inferences. A more detailed and technical description of statistical procedures is described in Appendix C.

**Scope and Limitations**

The study is a description and analysis of the impact of

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11For a detailed description of the survey conduct and response, see Appendix B.
environmental protection on the producing chemical plants of the continental United States. The universe is highly heterogeneous containing large, small, old, new, organic, inorganic, rural, urban, etc., type of plants. The study is mostly descriptive and exploratory in nature. Inferences and conclusions will be drawn that are relevant to the stated purposes of the study.

Limitations of the study are primarily threefold. First, a more penetrating or in-depth study may have been possible if the range of plants under analysis were more limited. Instead of concentrating on all producing plants in the continental United States, a smaller number of plants may have been examined. This limited selection could have been based on similarities in geographic location, product line, age, size (in terms of capital or employment), etc. Also, a detailed case study of a single plant may have been possible. With a limited range of plants, perhaps better models could have been developed to cite functional relationships. The variances may also have been explained more precisely by linkage with common plant characteristics.

The second and third limitations stem directly from the survey policy of anonymous respondents. It was believed that a follow-up letter to improve return percentage was not practical because the letter would have had to be sent to all plants in the sample (1500 plants). The expected benefits of a follow-up letter did not appear to justify the additional expense. However, a

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12The relatively lengthy questionnaire contained 46 questions and $1030.00 was required for the 1500 plant survey. 524 plants responded of which 508 completed questionnaires were useable. This
follow-up letter may have been practical if it were possible to send it only to non-respondents. This may have reduced survey bias by lowering the set of plants that did not respond. Another limitation of anonymous respondents was that the variances and relationships from this analysis could not be linked to specific plant characteristics (size, company, location, products, etc.). A more adequate description and explanation of the impact of environmental protection may have been possible.

Preview of Succeeding Chapters

Chapter 2 examines external factors that may have influenced environmental protection pressure brought to bear on the chemical plant. Factors that are examined include proximity to urban or residential areas; age of the plant; activity of ecological activist groups and regulatory agencies; size of the plant relative to the encompassing industrial complex; submission of compliance plans; participation with municipalities in treatment of sanitary-sewage; and the relative pressure of air pollution control versus water pollution control versus OSHA compliance.

Chapter 3 examines the influence of environmental protection on plant production capacity. Percentage of downtime and shut down frequency is measured. Rate reductions are assessed together with a qualitative description of the basis for these reductions.

represents a somewhat high 34 per cent return. (See Raymond V. Lesikar, Report Writing for Business, 3rd edition, Richard D. Irwin Inc., Homewood, Illinois, 1968, p. 62 for a discussion of expected mail survey response rate.) With 524 plants having already responded, the expense of a follow-up letter to all 1500 plants appeared to outweigh the benefits of an even larger return. For further discussion, see Appendix B on Survey Conduct and Response.
Chapter 4 examines the influence of pollution control on the major elements of manufacturing cost. The effect on yields, raw material and product quality, raw material prices, and utility costs is assessed.

Chapter 5 assesses the effect of environmental protection on plant staffing, work area assignments, training requirements, employee attitude, and personal stress.

Chapter 6 analyzes the influence of pollution control on maintenance costs and priorities. Factors that influence these costs and priorities are discussed.

Chapter 7 discusses the current percentage of the capital budget that is being spent on pollution control. Also, this chapter examines the percentage of the five year forecasted capital budget that is allocated to environmental protection. Factors that affect this allocation are probed.

Chapter 8 discusses the basic elements of strategy to cope with environmental protection. Factors analyzed include plant departmentation, technical staff assignments, waste disposal policy ("contain" versus "eliminate"), land acquisitions and plant expansions, and the impact of a zero discharge order.

Chapter 9 concludes the study by summarizing findings and drawing a number of conclusions. Also, suggestions for future research are given.
CHAPTER 2
EXTERNAL FACTORS AFFECTING POLLUTION CONTROL PRESSURE

This chapter contains an analysis of selected external factors that may influence pollution control pressure brought to bear on chemical plants. These factors were selected because they are believed to be relevant to pressure for improved environmental protection. Also, information about these factors could be gained without revealing the identity of the respondent, which is a policy of this study.

These selected factors include geographic location (proximity to public waterways, urban areas, and suburban areas), age of the plant, activity of local regulatory officials and ecological activist groups, pollution abatement compliance plan requirements, plant size in terms of share of the encompassing industrial complex, and participation with municipalities in treating waste. The chapter concludes with a poll of the plants to determine the area of most concern — water pollution, air pollution, or Occupational Safety and Health Act (OSHA) Compliance.

Geographic Location

The first factor to be examined is the plant's geographic location. This includes the relationship with natural features such as lakes or rivers and proximity to man-made developments such as urban or residential developments. The distance to residential or urban areas may partly determine the level of community criticism of air,
noise, or odor pollution. Similarly, discharge of waste into a public stream may also cause criticism, particularly if the stream is used for recreational purposes.

**Usage of public waterways:** The survey discloses that chemical plants rely heavily upon public streams for disposal (includes return of cooling water pumped from the waterway). Survey question I-1 asked the respondents if they used public waterways for disposal:

2-1:
**Question:** Does your plant discharge "anything" into a public stream? (includes return of once through cooling water)

**Finding:** 338 of the 508 respondents discharge "something" (includes return of once-through cooling water) into a public stream or waterway.

Proportion: 0.66

Standard Error: 0.02

The above finding indicates that two out of three chemical plants rely upon public streams for disposal. This clearly establishes the fact that chemical plants are significantly influenced by pressure for improved water pollution control.

Although the proportion of plants discharging something into public waterways is substantial, it is likely that this proportion was somewhat higher several years ago prior to scrutiny of documented hazards such as arsenic, lead, or mercury. For instance, mercury cell chlorine-caustic producers are resorting to zero discharge by re-routing waste streams into waste pits rather than a public

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1An explanation of all statistical procedures is included in Appendix C to this study.
stream. The levels in these waste pits are controlled by solar evaporation. Also, a number of new plants as well as old plant renovations are now preparing for the goal of zero discharge by 1985 by including a zero discharge constraint in current capital construction.

**Proximity to urban areas:** Another geographic factor is closeness to urban or residential areas. Survey question 1-2 asked how close plants were to the nearest urban area:

2-2:
**Question:** What is your plant's proximity to the nearest urban area?

**Finding:** The average distance from the plant to the nearest urban area is 3.49 miles.

- **Mean:** 3.49 miles
- **Standard Deviation:** 5.92 miles

The standard deviation of 5.92 miles indicates a wide dispersion of locations with respect to proximity to urban areas. Many plants were located within urban areas, and others relatively far from the nearest urban area. The influence of proximity to urban areas on pollution control pressure is indicated by correlations with three indicators of the level of pollution control pressure. The first of these correlations is with expansion opportunity at existing plant sites:

2-3:
**Finding:** Correlation of distance from urban areas to the expansion possibilities at present plant site (increasing values indicate a positive expansion outlook) is +0.092.

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2A glossary of technical terms is included in Appendix A to this study.
Correlation Coefficient: +0.092
T-statistic: 2.050
Level Remaining Significant: 0.05

This correlation slightly supports the contention that the plants that have good possibilities for expansion (pollution problems that are not considered a serious deterrent to expansion) are also those plants that are greater distances from urban areas.

The second correlation involving proximity to urban areas is with the impact of zero discharge:

Finding: Correlation of proximity to urban areas to the impact of zero discharge (increasing values indicate a greater impact) is +0.033

Correlation Coefficient: +0.033
T-statistic: +0.033
Level Remaining Significant: 0.50

There is essentially no interdependency between the proximity to urban areas and the impact of zero discharge. The consequences stemming from zero discharge appear to be independent of geographic location.

The third correlation involves proximity to urban areas and frequency of unit outages per month caused by pollution problems:

Finding: Correlation of proximity to urban areas to frequency of unit outages per month due to pollution problems is -0.010.

Correlation Coefficient: -0.010
T-statistic: 0.02
Level Remaining Significant: 0.90

There is no interdependency between proximity to urban areas and frequency of unit outages per month caused by pollution problems. This analysis does not support the widely held opinion in the industry that those plants closest to urban areas are frequently required by the EPA to shut down their operations whenever pollution problems occur. If this contention were valid, a significant negative correlation would be exhibited.

The virtual absence of interdependency between the above three indicators of pollution control pressure and proximity to urban areas does not support the widely held belief in the industry that urban plants receive much more pressure than suburban or rural plants. Plant location close to an urban area is not significantly related to expansion constraints, severity of zero discharge, or shut down frequency because of pollution problems.

**Proximity to residential areas:** Plant proximity to residential areas may appear to have more of an influence on pollution control pressure than proximity to urban areas. Besides, survey results indicate that plants are typically closer to residential areas than urban areas. Survey question I-3 asked how close plants were to nearest residential areas:

2-6:
**Question:** What is your plant's proximity to nearest residential areas?

**Finding:** The average plant distance to the nearest residential area is 1.42 miles.
Mean: 1.42 miles
Standard Deviation: 2.91 miles

The average distance to the nearest residential area is approximately one-half the average distance to urban areas (3.49 miles).

By establishing the relationship between the proximity to residential areas and three indicators of the level of pollution control pressure, the study tested the bad neighbor concept of pollution control. This concept holds that a given plant's immediate neighbors are the most ardent critics of pollution, for they are the ones who are probably most affected by certain types of pollution. These offended neighbors may constitute the pressure group for improved controls at a given locale. The closer a plant is situated to neighbors, the greater the probability that a larger group of these neighbors will be offended by pollution and consequently apply pressure on responsible plants.

The first relationship to test the bad neighbor concept is the correlation between proximity to residential areas and pressure from ecological activist groups:

2-7:
Finding: Correlation of proximity to the nearest residential area to pressure from ecological activist groups (quantified in terms of number of communications between the given plant and activist groups) is -0.060.

Correlation Coefficient: -0.060
T-statistic: 1.350
Level Remaining Significant: 0.20

This finding indicates that there is only a very slight tendency
for those plants closest to residential areas to also be the same
plants that have more contacts with ecological activists groups.
Ecological activist groups may be more concerned about effects of
pollution on natural landscape such as rivers or lakes and respond
only to specific residential complaints.

The second correlation to test the bad neighbor concept is
between proximity to residential areas and EPA visits:

2-8:
Finding: Correlation of proximity to residential areas to EPA
visits is -0.020.
Correlation Coefficient: -0.020
T-statistic: 0.45
Level Remaining Significant: 0.70

There is essentially no interdependency between proximity to
residential areas and EPA visits. The frequency of EPA visits is in-
dependent of a plant's nearness to residential areas.

The third correlation analysis to test the bad neighbor concept
involves proximity to nearest residential areas and personal stress
experienced by the production manager as a result of pollution control
pressure.

2-9:
Finding: Correlation of proximity to residential areas to personal
stress experienced by the production manager is +0.0150.
Correlation Coefficient: +0.0150
T-statistic: 0.33
Level Remaining Significant: 0.80

This correlation exhibits essentially no interdependency between
proximity to residential areas and personal stress experienced by the production manager.

From the findings relating to geography, the bad neighbor concept is not supported by this study. The absence of support for the bad neighbor concept may indicate that regulatory officials are uniformly applying pressure for improved environmental protection and are not primarily responding to isolated public complaints.

Age of Plant

The age of the plant is a factor that may also affect pollution control pressure. Older plants which were constructed when controls were not as strict may not have the abatement facilities of some of the newer plants. The study reveals that the average chemical plant has been operating for over two decades. Survey question I-5 asked the age of the plants:

2-10:
Question: What is the average age of your plant?

Finding: The average age of the chemical plants is 23.27 years.

Mean: 23.27

Standard Deviation: 14.44 years

The standard deviation of 14.44 years indicates a wide dispersion of plant ages. This is indicative of the nature of the life cycle of chemical products. For example, plants that produce the staples that are used in a wide variety of other manufacturing operations generally tend to have older, more uniform plants. These include chemicals such as chlorine,
caustic soda, soda ash, benzene, and hydrochloric acid. Some other chemicals tend to have newer, shorter lived operations, compared to the above basic chemicals. These chemicals are generally substitutes for existing products due to an improvement in a chemical or physical property, the range of uses, or in manufacturing costs. Examples of these chemicals include a wide range of plastics: polyethylenes and polyvinylchlorides, and a myriad of synthetic fibers, such as acetates and polyesters. The life cycle of these products tend to be relatively short (less than fifteen years), and at the end of this cycle, their producing plants are shut down. This would explain the somewhat large standard deviation of 14.44 years.

The study has revealed two interesting correlations of plant age to indicators of pollution control pressure. The first such correlation is with EPA visits:

2-11:
Finding: Correlation of plant age to number of Environmental Protection Agency visits is +0.136.

Correlation Coefficient: +0.136.
T-statistic: 3.06
Level Remaining Significant: 0.01

This finding indicates that older plants tend to receive more EPA visits. An increased number of visits from the EPA is likely to increase the pressure brought to bear on the individual plant.

The second correlation is with number of contacts with ecological activist groups:

2-12:
Finding: The correlation of plant age to number of contacts with
ecological activist groups is +0.206.

Correlation Coefficient: +0.206.

T-statistic: 4.74

Level Remaining Significant: 0.001

This relationship indicates that older plants also tend to receive more contacts with ecological activist groups. Likewise, an increase in the number of such contacts is likely to bring about increased pressure.

Hence, the above two correlations indicate that the older plants tend to receive more contacts with pressure groups. It is likely then that as a general rule, older plants have tougher pollution problems than newer plants.

Prior to 1960, pollution abatement facilities were primarily installed to diminish personnel hazards and nuisances. Currently, environmental protection is probably a top consideration in the design and construction of new plants.

The fact that pressure in the form of contacts and visits is being applied to a number of these older plants may tend to discredit the leniency theory that some environmentalists and chemical process managers hold. This theory suggest that older plants that were constructed when environmental pressures were much less would not be subjected to as much scrutiny as newer plants. It is assumed that the number of visits by the EPA and number of contacts with ecological activist groups is a valid measure of the level of pollution control pressure brought to bear on a given plant. Another assumption is that pressure in the form of repeated visits from these groups is an
indication that these plants are not receiving leniency. With the qualification of these two assumptions, then the study generally indicates that age does not necessarily shield a plant from environmental protection scrutiny. The effect of plant age on specific internal plant factors will be probed in other sections of this study.

Environmental Protection Agency and Activist Group Contacts

Pollution control pressure translated into contacts with regulatory agencies and activist groups have other influences on plant operations. The study measured the number of such contacts. Survey questions 1-6 and 1-9 requested the number of contacts with ecological activist groups and the EPA respectively:

2-13: Question: What is the total communications you have had with ecological activist groups? (Does not include the EPA)
Finding: The average number of contacts between a given plant and ecological activist groups (not including the EPA) is 3.80.
Mean: 3.80
Standard Deviation: 6.48

2-14: Question: How many visits have you received from the EPA within the last year?
Finding: The average number of visits by the Environmental Protection Agency is 1.61 during the last year.
Mean: 1.61
Standard Deviation: 3.16

These findings indicate that activist groups such as The Sierra
Club, National Audubon Society, Friends of the Earth, and National Resources Defense Council are zealous in bringing pressure for improved pollution control to bear on local plants. These findings show that activist groups apply pressure to individual plants as well as corporate or divisional headquarters. The large standard deviation of 6.48 and the finding that older plants tend to receive more activist group contacts are indications that control pressure is not applied uniformly to plants in the industry. Some plants receive considerable pressure while others tend to be ignored.

The interdependency between EPA visits and ecological activist group contacts is depicted by the following correlation analysis:

2-15:

Finding: The correlation of the number of EPA visits to the number of ecological activist group contacts is +0.182.

Correlation Coefficient: +0.182

T-statistic: 4.13

Level Remaining Significant: 0.001

This positive correlation supports the contention that the plants that are getting the scrutiny from the activist groups are also the plants receiving EPA scrutiny. It may be that a number of these activist groups may bring about EPA pressure, but this study did not examine that possibility.

Compliance Plans

The EPA visits each plant to assist the respective states in administering environmental protection legislation. Each plant responds by submitting to their respective states a formal plan
outlining the steps to be taken in order to comply with environmental protection mandates. This compliance plan contains the current level of all plant effluents (water pollutants) and emissions (air pollutants) as well as a description of existing abatement facilities and explains all action taken to lower pollution levels since the last compliance plan or permit issuance. If the current pollution levels are in excess of permissible standards, then the plant must submit as a part of its formal plan a time table indicating the action planned to achieve permissible levels. The state regulatory agency will then accept or reject the compliance plan. If the plan is rejected, the state agency will generally cite the portion of the plan that is not satisfactory. The plant and the state agency will probably correspond a number of times to clarify the state's position on a rejected compliance plan. Often the company will not be informed whether its plan has been accepted or rejected because the state may not be certain as to what the permitted levels are. Also, a plan may be accepted provisionally with further guidelines to be issued on one or more of the plant's pollutants.

The preparation and submission of compliance plans are required of most plants in the chemical industry. Survey question 1-7a asked the plants about submission of compliance plans:

2-16:
Question: Have you submitted a compliance plan within the past 2 years to your state?
Finding: 412 of the 508 plants that responded submitted a compliance plan to their respective states within the past two years.
Proportion: 0.81
Standard Error: 0.02
It is likely that a majority of the 96 plants that did not submit compliance plans are currently in the process of submitting such plans. It may be that the small percentage of plants that are not required to submit plans are those rare operations that have no air or water pollution and use sanitary treatment facilities that have been previously approved.

Of the 412 plants that have submitted compliance plans, approximately two-thirds have been fully approved by their respective states. This was ascertained by survey question I-7b:

2-17:  
**Question:** Has your compliance plan been fully approved?  
**Finding:** Of the 412 plans submitted, 265 were fully approved by their respective states.  
  Proportion: 0.64  
  Standard Error: 0.02

Of the 147 plans not fully approved, 135 were rejected and 12 are currently being evaluated by the regulatory agency. The compliance plan is the primary instrument of pollution control pressure brought to bear by regulatory agencies. It is a contract between the plant and the plant's respective state. Failure to receive approval of the plan or failure to meet the deadlines outlined in the plan may result in heavy fines or shutdown orders by the regulatory agencies. The fact that 135 or 33 per cent of the responding plants' compliance plans were rejected indicates that more heavy fines and/or plant closings are likely to be ordered in the future by these state regulatory officials.
Industrial Complex Influence

The industrial composition of a given area may determine the difficulty in securing acceptance of compliance plans. For example, the aggregate pollution level of a complex of plants, possibly representing different industries, may be intolerable, whereas an individual plant's emission and effluent level may not be significantly over permissible standards. This particularly is true under the 197 Water Pollution Amendments which state that water quality standards preempt plant effluent standards when compliance with plant standards does not provide the desired water quality. This means that if a group of plants discharge waste into a given stream such that the water quality standards for that stream are not met, the plants must lower their effluents even though they are complying with individual plant effluent standards. Furthermore, an aggregation of plants is readily visible to the general public. Composite air pollution from a complex may result in public criticism even though each plant's emissions are in acceptable ranges.

On the other hand, plants in an industrial complex have the opportunity to organize their efforts in coping with pollution control pressure. It may be that the pressure is diluted when the plants are so organized. The organizations may take the form of industrial boards generally composed of the area plant managers. These boards meet to discuss common pollution problems. While many process secrets tend to

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\(^{3}\) Federal Water Pollution Control Act Amendments of 1972, PL 92-500.
be strictly guarded, pollution abatement techniques are freely dis-
cussed. Often mutual plant visits are scheduled to closely examine the
neighbor's abatement facilities.

This survey has probed into the nature of the industrial complex
surrounding a given plant. Survey question I-4 asked if other plants or
industries are located near the chemical plant:

2-18:
Question: Are there other plants or industries within a ten mile radius
of your plant with waste disposal that comes under environ-
mental legislation?

Finding: 484 of the 508 responding plants have other plants or indus-
tries within a 10 mile radius which have waste disposal that
comes under environmental legislation.

Proportion: 0.95
Standard Error: 1 x 10^{-3}

These findings indicate that chemical plants are almost always
situated in a general industrial area. Only twenty-four of the respon-
dents were in isolation. Thus, the chemical plant's pollution problems
tend also to be the problems of an industrial complex.

The study measured the proportion of the industrial complex that
a given chemical plant occupies. Survey question I-10 checked the size
of the chemical plant relative to the surrounding industrial complex:

2-19:
Question: What percentage of the manufacturing, mining, and processing
industry within a 20 mile radius of your plant does your
plant account for?

Finding: The average percentage of the encompassing industrial complex
that a given plant occupies is 11.41 per cent.

Mean: 11.41 per cent

The researcher, representing Allied Chemical Corporation, has per-
sonally participated in such discussions with Kaiser Chemical Corpora-
tion, Ethyl Corporation, and Hooker Chemical Corporation.
Standard Deviation: 20.57 per cent

This indicates that the typical chemical plant does not dominate its industrial complex in terms of size. The large standard deviation of 20.57 per cent indicates, however, that the range of dominance is substantially broad. Many chemical plants may be just satellites that supply raw materials to a larger manufacturing operation. Examples of such installations include chlorine-caustic plants supplying bleaching and digesting agents to paper mills, and gasoline additive producers, such as tetra-ethyl lead, supplying its products to refineries. In contrast, the chemical plant itself may be the focal point in the complex. One example is ethylene, propylene, or some other gas producer supplying a plastics plant.

The degree of complex dominance was analyzed in terms of its correlation with one general indicator of the level of pollution control pressure -- the number of contacts with ecological activist groups:

Finding: The correlation of industrial complex share to number of contacts with ecological activist groups is +0.101.

Correlation Coefficient: +0.101

T-statistic: 2.27

Level Remaining Significant: 0.05

This analysis indicates a slight tendency for those plants that are more dominant in their respective industrial complexes also to be those plants that have received more contacts with ecological activist groups. This finding slightly supports the general contention that environmentalists seek out and apply pressure to the larger
members of an industrial complex.

Participation with Municipalities in Treating Waste

Plants in an industrial complex have a number of common pollution control problems. Similarly, plants and municipalities have essentially one common pollution control problem -- the treatment of sanitary sewage. Certain plants compound the problems of municipal waste treatment by using municipal facilities. Survey question I-12 asked if plants use municipal waste treatment facilities:

2-21:
Question: Does your plant use municipal waste treatment facilities?
Finding: 224 of the 508 respondents use municipal waste treatment facilities.
Proportion: 0.44
Standard Error: 0.02

(283 plants do not use municipal waste treatment facilities and 1 plant did not respond to the question.)

Plants that do use municipal waste treatment facilities may tend to contribute to any overload or inadequacy of these facilities. Consequently, Section 204 of the Federal Water Pollution Control Act Amendments of 1972 states that federal grants to assist in construction of municipal waste treatment facilities will not be given unless private users (plants and businesses) pay a fair share of the operating and maintenance costs of such facilities; also, a fair share of the capital costs will be levied against the users of new facilities. In addition,

\textsuperscript{5}Federal Pollution Control Act Amendments of 1972, PL 92-500, Section 204.
Section 307 of the Amendments establishes pre-treatment standards for discharge into municipal waste treatment plants; the municipal treatment facility will not accept any pollutant in waste from plants that will prevent the municipal facility from meeting its own effluent standards.6

It is expected that more plants will construct their own sanitary sewage treatment facilities for reasons other than the restrictions imposed by the 1972 Amendments. The reasons are as follows: (1) The pollution abatement cost facing many plants is so large that addition of sanitary sewage treatment to this expenditure would be relatively minor. (2) The installation of a sanitary sewage treatment facility would give many plants a complete pollution abatement system. (3) Many states are allowing tax deductions for pollution abatement expenditures.

On the other hand, a small number of plants have excess capacity in their privately owned sanitary sewage treatment facilities. To relieve the burden on overloaded municipal treatment works, these plants treat municipal waste in their treatment plants. Survey question I-11 asked if plants treat or assist in treating municipal waste:

2-22:

**Question:** Does your plant treat or assist in treating municipal waste?

**Finding:** 37 of 508 responding plants treat or assist in treating municipal waste.

Proportion: 0.07

Standard Error: 0.01

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6Ibid. Section 307.
It may be that a segment of these plants provide the only treatment facility in the area. Such may be the case if a plant were built in an isolated area with subsequent development of a small residential or urban area in the vicinity of the plant. Another incentive for the treatment of municipal waste may be to gain the good will of such a gesture. It may be that assisting a municipality with its waste disposal problem may bring reciprocal consideration from the state in acceptance or rejection of compliance plans.

**Air Pollution, Water Pollution, or OSHA?**

This chapter concludes with a poll of the plants to determine the area of most concern -- water pollution, air pollution, or OSHA (Occupational Safety and Health Act) compliance. By knowing the industry ranking of these areas, an individual plant manager may place his own priorities in a better perspective. Air and water pollution abatement is concerned with lowering emissions and effluents that exit the plant property, while OSHA is concerned with protection of personnel within the plant from general safety hazards, excessive noise or heat, and harmful exposure to chemical pollutants. Survey question 1-8 requested selection of air pollution, water pollution, or OSHA compliance as the area of most concern:

2-23: Which of the following is of most concern to your plant management -- water pollution, air pollution, or OSHA compliance?

**Finding:** The 508 responding plants voted as follows as to the area of most concern:

(a) water pollution: 195 (38.4\%)

(b) OSHA compliance: 153 (30.1 per cent)
(c) air pollution: 137 (27.0 per cent)
(d) did not indicate: 23 (4.5 per cent)

This finding indicates that all three areas provide concern to managers of plants in the chemical industry. The significance of this is that priorities and resources not necessarily be allocated in a manner that totally neglects any one of the areas.

It was expected that water pollution would be selected as the leading area of concern in the survey. As shown previously in this chapter (2-1), two out of three plants discharge something into a public waterway. The fact that chemical plants rely heavily on the nation's waterways for waste disposal certainly increases the probability that a large number are being highly scrutinized by water pollution regulatory agencies.

Conversely, it was not expected that OSHA compliance would be selected by such a high percentage (30.1) as the area of most concern. It is likely that two specific occurrences explain this finding. First, OSHA officials and inspectors have been very active by visiting a large number of plants and issuing many citations. Secondly, the era of wage and price controls has tended to take a key issue from plant unions -- the negotiation of wages and fringe benefit improvements. To fill this vacuum, a number of union officials have tended to substitute safety and working conditions as the key issue in collective bargaining. They are seeking to write into labor contracts a highly detailed and restrictive safety clause. With the safety issue in the forefront, the rank and file have a tendency to be concerned
over safety and may call for an OSHA inspection themselves.

The number of plants that voiced the most concern over air pollution may be explained quite simply. It is likely that air pollution problems are not as generalized in the chemical industry as water pollution or safety problems. Those plants that do have air emission problems together with water pollution and OSHA scrutiny may likely select air pollution as the area of most concern because of the complexity of control and the difficulty in sampling and measurement of air emissions.
CHAPTER 3

THE INFLUENCE OF ENVIRONMENTAL PROTECTION ON PLANT CAPACITY

The preceding chapter analyzed selected external factors thought to have a bearing on the pollution control pressure felt by chemical plants. This chapter and the subsequent chapters describe the influence of this pollution control pressure on selected internal plant factors.

Unit Downtime

It is possible that the influence on plant output holds the greatest potential economic consequence of environmental protection. Survey question II-a-1 ascertained unit downtime as percentage of time in response to pollution control pressure:

3-1.

Question: What are your unit outages due to pollution control problems as a per cent of time?

Finding: The average downtime due to pollution control problems expressed in terms of per cent of time is 1.08 per cent of a 24 hour day.

Mean: 1.08 per cent

Chapter 2 placed pollution control pressure in a dependent variable role and used selected external factors that may affect this pressure as independent variables. This chapter and the subsequent chapters view pollution control pressure as the independent variable and internal plant factors (production rates, costs, manpower, etc.) as dependent variables influenced by environmental protection.
Standard Deviation: 2.95 per cent

The average downtime of 1.08 per cent of a 24 hour day is significant because of the direct reduction in plant capacity. For plants that are operating at capacity, downtime because of pollution problems reduces output. For other plants, this downtime becomes restrictive if other limits to production such as product demand are relieved.

Another reason that the 1.08 per cent downtime of a 24 hour day is significant is because of the value placed on stream time (time that the plant is in operation) in the chemical industry. Chemical process units generally run continuously or adhere to a rigid schedule of batch cycles. Some large units do not shutdown completely more frequently than once every two to three years. As a general rule, matching of sales and output is achieved by adjusting plant rates rather than shutting the plant down. Outages (shutdowns) are generally costly in terms of raw material loss and equipment damage. It can therefore be said with certainty that the chemical industry places a high value on continuous operation at some percentage of plant capacity.

For particular plants, downtime due to pollution problems seriously restricts output. The standard deviation of 2.95 per cent represents a wide dispersion relative to the mean of 1.08 per cent. From this dispersion, it is likely that a number of plants experience prolonged downtime which causes severe economic penalties from production loss. One possible explanation for prolonged downtime is that a plant may produce

2The chemical industry has historically approximated the national average capacity utilization of 80-90 per cent.
or use such hazardous chemicals as phenol, arsenic, lead, or mercury. Excessive effluents from these operations may result in high fines, lawsuits, or even jail terms for members of plant management. To avoid these consequences, total shutdowns are sometimes necessary when pollution controls malfunction.

The more typical case of plant downtime due to pollution problems is a process upset that temporarily causes a low yield which overloads the purification system such as a distillation column with the unconverted raw material. The distillation column effluent may then overload waste treatment facilities if such facilities exist, or may be discharged at a high pollutant level directly into a public waterway. Other typical upsets may take the form of problems with recycle-reclaim systems or malfunctions of the waste treatment equipment.

Often these operating problems are readily visible with such signals as a flare stack burning brightly (Unconverted, unsaturated hydrocarbons emit a bright yellow-orange light coupled with a heavy, black smoke.); heavy smog hanging over a plant (Scrubbers and electrostatic precipitators are not removing solids.); or, the receiving stream of a plant's effluents turns cloudy, becomes discolored, or has a foam or a slick on its surface (signifying a myriad of problems).

Plant managers may choose to shut down the operation if these difficulties occur instead of continuing production and risking penalties from regulatory agencies. This is even more likely if the upsets are broadcast by the visible means of detection mentioned above as opposed to discovery by sampling and analytical testing. A pollution signal that almost assuredly will result in a suspension of operations is a fish-kill. The discharge of a material that results in fish and
other marine life floating on top of a stream may cause severe penalties.

**Plant Outage Frequency**

Plant outages ordinarily cause losses other than those arising directly from the absence of production. These penalties may be in the form of raw material losses, energy losses, high labor costs, product contamination, or process equipment damage. One or more of these penalties usually occur with a shutdown. The outage frequency per month due to pollution problems was surveyed. Survey question II-a-2 asked about plant outage frequency:

**Question:** What is your outage frequency per month?

**Finding:** The average number of outages per month due to environmental problems is 0.78.

Mean: 0.78 outages/month

Standard Deviation: 2.04 outages/month

The average outage frequency of 0.78 per month or approximately 9 per year represents significant costs. The standard deviation of 2.04 outages per month represents a wide dispersion relative to the mean. Some plants apparently experience repeated shutdowns while others experience essentially no process interruptions.

Ironically, outages because of excessive pollution may result in even greater pollution at the beginning of the outage period. For some operations, the only possible shutdown procedure entails stopping the reaction and emptying the reactors. 3

3Failure to follow this procedure may cause heavy sludge formation
Consequently, unreacted raw materials or process liquors may be discharged into treatment facilities or directly into a public stream. Not only does this represent an economic penalty in the form of raw material losses, but it also creates even greater pollution levels.

The raw materials or process liquors that are lost during a shutdown also ordinarily possess a large amount of heat. During an era in which energy shortages are more frequent and energy costs rising, the loss of process heat may be quite costly. Large amounts of steam, coal, oil, or natural gas may be consumed to attain the process reaction temperature. The specific heat of process reactors and vessels may be significant. Having these vessels cool during a shutdown incurs an energy penalty because of the increased amount of fuel needed to raise the temperature back to normal. It is likely that fuel consumption increases markedly with plant upsets and outages.

The effects of unit outages may not be confined to raw material and energy losses. An outage sometimes requires additional operators or maintenance personnel to shut the unit down or start it up again. There usually is many control points to monitor, valves to turn, pumps to shut down and start-up, and other mechanical maneuvers to perform. In contrast, sustaining the unit on-stream normally requires relatively few personnel. Consequently, high labor cost in the form of overtime sometimes accompanies a plant outage.

in the process due to precipitations and solidification of the materials or may create potentially explosive mixtures with unstable raw materials in combination and unreacted.

Plants often have holding tanks or ponds to collect and recycle spills and losses during outages.
Another type of shut down penalty may be incurred through product contamination or recycle. If unconverted (unreacted), or partially converted, process liquors are pumped to the product storage as a result of an outage or start-up, then the product storage usually becomes contaminated and fails to meet quality specifications. If this is the case, it may be necessary to recycle the material in the storage back through the reactor to convert unreacted raw materials into the finished product. A possible alternative is to sell the product at a distressed price.

A final penalty stemming from unit outages may be process equipment damage. The process equipment may be vulnerable to corrosive materials created during outages; may endure excessive thermal shock from heating and cooling cycles; may be damaged through vibration or imbalance; or may be such that the useful life of the equipment is contingent upon a high stream time percentage.

On the other hand it is likely that outages due to pollution problems at a few plants may have little or no effect. The nature of these operations are such that they are shut down routinely for maintenance. If the operation is forced to shut down due to

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5An example is the high speed compressor or turbine that surges or has a temporary back flow while at a low through-put.

6An example is the asbestos diaphragm that separates chlorine from sodium hydroxide and hydrogen in an electrolytic chlorine cell. If a current is not passing through this diaphragm, as it does not during an outage, then it tends to disintegrate.
pollution problems, management can take the opportunity to perform scheduled equipment repairs. Hence, it would not be necessary to shut down at the regularly scheduled outage time because repairs would have been completed previously. Nevertheless, such plants are exceptions to the general rule that outages are detrimental to the chemical industry.

Rate Reductions

The effect of environmental protection may not result in total unit outages, but may cause a reduction of plant rates. Rate reduction occurs when a process upset produces a higher than normal level of pollution or when for some reason pollution control equipment cannot process effluents/emissions at the normal rate. When either condition occurs, a rate reduction often allows pollution control devices to effectively remove pollutants with their usual effectiveness. In such cases, rate reduction meets the problem until the production process can be adjusted, or until response of control equipment can be effected.

Rate constraint due to pollution problems was assessed in the study by survey question II-b.

3-3:  
**Question:** What is your rate constraint (as per cent of capacity) that is caused by pollution problems?

**Finding:** As a result of pollution problems, the average plant rate constraint is 1.39 per cent of capacity.

Another obvious penalty from a plant outage is the lack of contribution to fixed costs. Chemical plants almost always represent large capital investments and severe penalties usually result from having this investment idle.
Mean: 1.39 per cent
Standard Deviation: 4.26 per cent

Similar implications noted from the 1.08 per cent downtime (finding 3-1) may also apply to this 1.39 per cent rate reduction.

Qualitative Analysis of Rate Constraints

The study examined the significance of rate reduction caused by environmental protection by comparing this constraint with other reasons for plants operating at less than capacity. The reasons compared with pollution control problems include demand, changing technology (process or equipment obsolescence) and "other" (includes myriad of reduction reasons: operating technique or control difficulties, maintenance problems, product quality specification variances, shortage of raw materials or supplies, labor slow downs, etc.).

The semantic differential was used to rank reductions caused by pollution problems with these three respective categories. Sales, changing technology, and "other" respectively constituted one end of three different continuums and "environmental" was placed at each of the other ends. Of the 508 plants that responded, 247 indicated that they were operating at less than capacity. Survey questions II-c-1, II-c-2, and II-c-3 asked these 247 plants to compare rate reductions due to pollution problems to rate reductions caused by demand, changing technology, and "other" reasons for operating at less than capacity.

See Appendix D for a description and explanation of this procedure.
capacity:

3-4: Question: How does demand rank with pollution problems as the reason for your operating at less than capacity?

Finding: On a scale from 1 to 7, with "environmental" on the low end and "sales" on the high end of the scale respectively, the average of the 247 plants was 5.27 (between "slightly" and "mostly" sales).

Mean: 5.27

Standard Deviation: 1.70 (-1 is between "slightly" environmental and neutral and +1 is "entirely" sales with a value of 6.97)

3-5: Question: How does changing technology rank with pollution problems as the reason for your operating at less than capacity?

Finding: On a scale from 1 to 7, with "environmental" on the low end and "changing technology" the high end of the scale respectively, the average of the 247 plants was 4.53 (between neutral and "slightly" changing technology).

Mean: 4.53

Standard Deviation: 1.29 (-1 is between "slightly" environmental and neutral and +1 is "mostly" changing technology with a value of 5.82)

3-6: Question: How does "other" rank with pollution problems as the reason for your operating at less than capacity?

Finding: On a scale from 1 to 7 with "environmental" on the low end and "other" on the high end of the scale respectively, the average of the 247 plants was 4.45 (between neutral and "slightly" other).

Mean: 4.45

Standard Deviation: 1.38 (-1 is "slightly" environmental with a value of 3.07 and +1 is "mostly" other with a value of 5.83).
As expected, demand is the primary reason for operation at less than capacity. Demand was cited by 65 plants as "entirely" the reason, by 83 plants as "mostly" the reason, and by 28 plants as "slightly" the reason for unit slow downs when compared to pollution problems. This is a total of 176 plants, or 71 per cent of the plants operating less than capacity that are directed to the demand end of the scale. As noted, the mean was 5.27, which is a decided indication that demand is the primary reason for plant rate curtailment. Changing technology had only 112 plants or 45 per cent directed to its end of the scale, and similarly, "other" had 88 plants or 26 per cent directed to its end of the scale. Most of the plants had no indicated priority (a neutral position) for either end of the scale when changing technology and "other" were compared to pollution problems.

A sum total of 21 plants in the three comparisons indicated that they were "entirely" restricted by pollution problems. In addition, only 30 and 31 plants were "mostly" and "slightly" curtailed by environmental protection respectively. It is therefore concluded that rate reduction due to pollution problems is not a major reason at this time for plants operating at less than capacity.

Relationship Between Plant Rates and Other Factors

Three correlation analyses involving plant operating rates and other variables are relevant to the description of the influence of pollution control pressure on these rates. One such relationship is the correlation between the percent of time that a plant is down due to pollution problems and the number of contacts from ecological activist groups:
Finding: The correlation of percent of time that a unit is down due to pollution problems to number of contacts with ecological activist groups is +0.153.

Correlation Coefficient: +0.153

T-statistic: 3.48

Level Remaining Significant: 0.001

This correlation means that the plants that have experienced increased percentage of down time due to pollution problems tend also to be the plants that have more contacts with activist groups. The pollution problems that force plant shutdowns also draw attention from environmentalist groups. It cannot be ascertained from correlation analysis, however, which factor, if either, is causal.

A second correlation that is important is between percentage of down time from pollution problems and percentage of a complex size that a given plant holds:

Finding: The correlation of percent of time that a unit is down due to pollution problems to percentage of a complex size that a given plant holds is 0.012.

Correlation Coefficient: 0.012

T-statistic: 0.27

Level Remaining Significant: 0.80

There is essentially no interdependency between these two variables. Hence, down time is not related to size within a given complex.

A third correlation is between rate constraint as percentage of capacity caused by environmental protection and the age of the
Finding: The correlation of rate constraint due to pollution problems as percent of capacity to plant age is +0.176.

Correlation Coefficient: 0.176

T-statistic: 4.03

Level Remaining Significant: 0.001

This correlation means that plants which have an increasing level of rate reductions due to pollution problems tend also to be older plants. This finding supports the generalization developed about plant age in the preceding chapter that older plants were not designed to meet highly stringent pollution control standards, and consequently, the influence of environmental protection legislation is more severe on these older plants. Additional relationships involving plant rates and other variables influenced by environmental protection will be found in subsequent chapters.
CHAPTER 4
THE EFFECT OF POLLUTION CONTROL ON MAJOR OPERATING COSTS

It was stated in Chapter 3 that production curtailments may hold the greatest potential economic penalty of environmental protection for plants operating near capacity. The influence of pollution control on operating costs, however, may markedly affect a large number of plants independently of production rates. Operating expenses are normally labor costs, raw material costs, maintenance expenses and utility expenses. In addition, product quality specifications may have a significant bearing on a number of operating costs.

Raw material costs and utility expenses tend to be the dominant operating costs in the chemical industry. The industry is a high volume processor of raw materials and tends to consume large amounts of fuel. Fuel, translated into energy, is required in chemical processing to initiate, complete, or control chemical reactions.

Labor costs tend not to be dominant in the chemical industry because the operations have traditionally been characterized by a

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1The influence of environmental protection on labor costs will be discussed in Chapter 5 and the effect on maintenance costs will be analyzed in Chapter 6. Typical chemical plant operating costs are divided as follows:

- Raw Material = 50 per cent
- Utilities = 15 per cent
- Maintenance = 15 per cent
- Labor = 10 per cent
- Supplies = 5 per cent
- Miscellaneous = 5 per cent
high investment per employee. Because of a high level of automation, an individual operator controls large areas. Computerized processes have tended to further expand the areas assigned to operators.

**Pollution Abatement Effect on Product Yields**

The volume of raw materials processed at the individual plant has tended to become increasingly larger because of a substantially expanded scale of operation in the industry. For example, fifteen years ago, the minimum capacity needed to profitably sustain operations in a chlorine plant was approximately 200 tons per day. Currently, that minimum scale of operation has increased to approximately 500 tons per day of chlorine.

Because of the large volumes of raw materials processed, product yields are extremely important. Yields are especially important if the large volumes of raw materials are also accompanied by a high unit cost for these materials. As a general rule, however, the unit price of raw materials in the chemical industry is inversely related to the volume of these materials. For example, a sodium carbonate plant with an output of 1500 tons per day pays only $0.50 per ton of brine and $8 per ton of limestone to produce the product. In contrast, a specialty chemical that is used in the manufacture of 5 tons per day of hexylresorcinoI (an antiseptic) may cost $1200 per ton.

The influence of environmental protection on product yields was assessed by the study. Survey question III-A asked how pollution

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The yield is the ratio of the weight of the finished product to the weight of the raw material used to produce that finished product.
control has affected product yields.

4-1:
Question: How has pollution control changed your product yields?

Finding: Product yields were increased 0.33 per cent by pollution control.

Mean: 0.33 per cent increase

Standard Deviation: 2.47 per cent

On the average, yields were slightly increased. The standard deviation of 2.47 per cent, however, represents a wide dispersion relative to the mean of 0.33 per cent. This indicates that many plants also experience lower yields as well as higher yields as a result of pollution control. A yield reduction stemming from pollution control may be due to process design changes or changes in control points. For example, a reactor may render the best yield at a relatively low reactor pressure. To achieve this low pressure, however, may require venting to the atmosphere (possibly through a scrubber). This venting may cause intolerable air emissions (or overload the vent scrubber), and consequently, a mandate may be issued requiring less venting, which will of necessity produce a higher reactor pressure. With the higher pressure, the yield is lower.

Increases in yields sometimes result from (1) a process of "tightening up" by repairing leaks and maintaining in better operating condition collection systems for spills, which has the effect of increasing yields by reducing losses and pollution levels or (2) the design and installation of a reclamation system resulting from a mandate that forbids the discharge of a certain process stream.
The finding was tested to determine if the average increase of 0.33 per cent stemmed from sampling error alone. An assumed zero (0) sample mean was used for testing whether or not the mean of 0.33 per cent was significantly different from zero (0). The standard deviation of 2.47 per cent and sample size of 508 was used in both cases. It was discovered that the means of 0.33 per cent and 0.00 per cent were significantly different or represented different universes at an alpha level of 0.05 (two-tailed test).

This slight increase in yields of 0.33 per cent may not appear to be of any importance, but it is—because of the large volume of raw material processed in the industry. As noted previously, raw material cost is the dominant manufacturing expense in the chemical industry, and this confirmed improvement in product yield represents substantial economic benefit.

Change in Quality of Raw Materials and Finished Products

Environmental protection may also be improved by a higher quality of raw material feedstocks from suppliers. For example, highly regulated metallic impurities such as lead, arsenic, or mercury must be at a very low level in a number of industrial chemicals because these impurities have a tendency to find their way into effluents and emissions of customers using these chemicals. The survey measured the change in quality of raw materials as well as finished products that were required to meet pollution standards. (As previously, the seven point

3

The two means (0.33 percent) and (0.00 per cent) were not significantly different or represented the same universe, however, at an alpha level of 0.02 (two-tailed test).
semantic differential scale was used with "much higher quality" and "much lower quality" at the ends of the continuums.

Response to survey question III-b assessed the quality change required of raw materials:

4-2:

**Question:** What is the change in quality of your raw materials required to meet pollution control standards?

**Finding:** The change in quality required of raw materials to meet pollution standards averaged 4.40 (midway between "neutral" and "slightly higher quality.")

**Mean:** 4.40 (neutral to slightly higher quality)

**Standard Deviation:** 0.850 (range is placed between neutral and slightly lower quality and +1s is placed between slightly higher and moderately higher quality.)

Raw material quality requirements are slightly higher. Suppliers of raw materials are having to lower the level of impurities, but not by much.

Response to survey question III-c measured the quality change required of finished products:

4-3:

**Question:** What is the change required in quality of your final product to meet environmental protection standards?

**Finding:** The change in quality requirements of finished products to meet pollution standards imposed by customers averaged 4.34 (between "neutral" and "slightly" higher quality.)

**Mean:** 4.34 (neutral to slightly higher quality)

**Standard Deviation:** 0.854 (same placements as 4-3 above)

Likewise, finished product quality requirements are slightly elevated. Finished product specifications have been increased in the
industry.

The following correlation analysis indicates the relationship between these two quality changes:

4.4
Finding: The correlation of change in quality required of raw materials to change in quality required of finished products to meet pollution standards is +0.533.

Correlation Coefficient: 0.533
T-statistic: 14.18
Level Remaining Significant: 0.001

This is a high level of interdependency between these two quality changes. The plants that require improved raw material quality also tend to be the same plants that are required to improve the quality of their finished products.

This relatively high correlation coefficient (+0.533) together with the similarity of means of the quality change required of raw materials and finished products (4.40 and 4.34 respectively) indicate a possible chain effect. For example, the producer of a certain chemical receives an order from his customer that the product quality must be improved to assist in a waste disposal problem. The producer then informs his suppliers that certain specifications must be improved on his raw materials to assist in achieving the required finished product quality. These suppliers may then require their raw material vendors to also improve the quality of the feedstocks. This process may proceed for a number of cycles, forming a multiple quality improvement resultant. It is likely that any quality improvement imposed upon a given producer may promote a multiple quality improvement
effect for a number of chemical producers.

**Pollution Control's Influence on Raw Material Price**

These quality improvements may influence raw material prices. The study measured the effect of environmental protection on raw material prices through responses to survey question III-d: (Again, the 7 point semantic differential was used to measure opinion.)

4-5:

**Question:** What is the perceived change in the price of your raw materials that was caused by pollution control regulations?

**Finding:** Price changes of raw materials as a result of pollution control averaged 4.41 (midway between "no change" and "slightly higher" prices).

Mean: 4.41 (between "no change" and "slightly higher" prices)

Standard Deviation: 1.29 (-1s is placed between "no change" and "slightly lower" prices and +1s is placed between "slightly" and "moderately" higher prices)

The effect of environmental protection has been to slightly elevate prices of raw materials. It is likely that this slightly higher price is a result of higher quality requirements imposed on raw materials (finding 4-2). The burden of this price increase is probably being passed along from industrial consumer to industrial consumer and eventually will reside with the domestic consumer.

**The Effect of Environmental Protection on Power or Utility Costs**

Another major manufacturing expense that may be affected by pollution control is power or utility cost. This study surveyed (question III-e) the influence of environmental protection on
internal or external generating stations (whichever applies) that supply power to the 508 responding plants.

### Question:
What is the impact on your plant utility costs?

### Finding:
Environmental protection has resulted in an average increase in utility costs of 5.32 per cent.

- **Mean:** 5.32 per cent
- **Standard Deviation:** 4.81 per cent

Chemical plants are large consumers of energy and power. Hence, this increase of 5.32 per cent in utility costs represents a significant increase in manufacturing expense. For example, a chlorine plant that produces 500 tons per day of chlorine may spend approximately $2 million in power costs each year to operate the electrolytic cells. This average increase in power cost of 5.32 per cent elevates the operating cost of this plant by approximately $106,000 per year. Many other types of chemical processes are heavy consumers of electricity or heating fuel. The standard deviation of 4.81 per cent indicates that a number of plants are severely affected by pollution control increase in power or utility costs, and that a number of plants are hardly affected at all.

It is likely that the severe effect on power costs is due to a number of reasons. First of all, nearly all electrical and steam generating plants have water treatment facilities to remove contaminants that would foul boiler tubes and the steam side of process equipment. The removal of these contaminants in power water treatment facilities yields a solid and liquid mixture that requires disposal. With increased pollution control standards, disposal of
water treatment waste has required increased expenditures, both for capital equipment and operating costs.

Another reason for the marked effect of environmental protection on power operation may be the tighter standards on air emissions. Conventional (as opposed to nuclear generating plants) power operations must burn some type of fuel to heat boilers and drive generators and turbines. This fuel is usually coal, oil, or natural gas. Although natural gas burns cleanly, coal and oil burning generally results in a high level of air emissions. Consequently, purification devices such as scrubbers or electrostatic precipitators are required on power plant flue stacks. These devices require capital outlay as well as maintenance and operating costs.

Finally, power plants may have significant thermal pollution problems which does not affect the typical manufacturing plant. The change in temperature of a few degrees may drastically affect the ecology of a stream or waterway. A big drawback in the use of nuclear fuel in power generation is the enormous cooling requirements of nuclear reactors and the resultant thermal pollution. Conventional power plants are affected to a lesser degree.

Consequently, power generating plants have water pollution, air pollution, and thermal pollution problems. Increased capital outlays and operating costs are required to meet pollution control standards for internal generating stations. Utility companies probably pass the burden of these costs on to industrial customers by rate increases. Because of their monopolistic nature, utility companies generally must justify rate increases. It is likely that they readily cite environmental protection as a basis for increased rates. Hence, the study
has indicated that either directly or indirectly, environmental protection has resulted in higher utility costs for chemical plants.

**Correlation Involving Manufacturing Costs**

This inquiry into the effect of environmental protection on the major elements of manufacturing cost has revealed four relevant correlation analyses. The first correlation analysis is between yield changes and raw material price changes in response to environmental protection:

4-7:
Finding: The correlation yield changes to raw material price changes induced by pollution control is -0.122.

Correlation Coefficient: -0.122
T-statistic: 2.74
Level Remaining Significant: 0.01

This analysis indicates that those plants which experience higher yields as a result of environmental protection tended also to be plants that experience lower raw material prices. Conversely, those plants that suffered lower yields tended to be those plants that paid higher prices for raw materials. One possible explanation of this correlation may be that a lower yield implies a greater raw material consumption for a constant level of output. A plant that is experiencing lower yields and increased raw material purchases may exhaust the capacity of existing raw material suppliers. This may prompt these suppliers to increase unit prices, or it may force the plant to buy raw materials from other suppliers who charge higher prices.
A second correlation is between yield changes due to pollution control and plant age:

Finding: The correlation of pollution control induced yield changes and plant age is +0.032.

Correlation Coefficient: 0.032
T-statistic: 0.72
Level Remaining Significant: 0.50

There is essentially no interdependency between yield changes and plant age. This indicates that the impact on yields is independent of plant age. The effect of "tightening up" and other procedures to reduce raw material losses is not significantly different in old or new plants.

A third correlation is between plant age and changes in utility costs caused by environmental protection:

Finding: The correlation of pollution control induced changes in utility costs to plant age is +0.168.

Correlation Coefficient: 0.168
T-statistic: 3.81
Level Remaining Significant: 0.001

This correlation indicates that older plants tend also to be those plants that experience increased utility costs. This analysis supports the generalization that newer plants have pollution control facilities included in the design and operation of power stations to meet requirements of environmental protection, whereas, older plants may be required to direct additional funds to meet pollution
standards.

A fourth correlation analysis is between changes in utility costs and changes in the price of raw material as a result of environmental protection:

**Finding:**

The correlation of pollution control induced changes in plant utility costs to changes in the price of raw materials is $0.284$.

- Correlation Coefficient: $0.284$
- T-statistic: $6.64$
- Level Remaining Significant: $0.001$

This analysis indicates that plants that experience increased raw material prices also tend to be the same plants that experience increased plant utility costs. One possible explanation for this finding stems from cost accounting procedures used in some chemical plants. Under the direct standard cost system, plants treat utility components such as steam or electricity as raw materials. These utilities are assigned standard prices and consumption factors, and consumers of power in operating sections are required to explain power usage variances. The old rule of thumb that distinguished utilities or supplies from raw material designation was that if any part of a material ultimately resided as a component of the finished product, then it was a raw material. Under this guideline, utilities are generally not treated as raw materials. Now some plants have discarded this guideline and do treat utilities as raw materials. Thus, utilities and raw materials would then become synonymous and changes would be perfectly correlated or have a coefficient of $1.0$. It is likely that
this may be the reason underlying this significant level of
interdependency. More relationships involving operating costs and
other plant factors will be analyzed in subsequent sections of this
study.
CHAPTER 5
THE INFLUENCE OF ENVIRONMENTAL PROTECTION
ON MANPOWER RELATED FACTORS

An additional operating expense that may be influenced by environmental protection is the plant labor cost. Labor costs may be affected through charges in number of employees and training requirements. The influence of environmental protection on the human factor may be evidenced, however, in such ways as the level of involvement of the production manager in environmental protection problems and resultant personal stress experienced. It may be manifested in the manner that the plant rank and file react to pollution control pressure. The reaction, either positive or negative, may significantly influence work attitudes. This chapter explores these areas.

Effect on Number of Hourly Employees

Environmental protection may alter the number of employees required by the chemical plant. Newly designed processes and waste treatment facilities may require additional operators and maintenance personnel. Likewise, units that are unable to cope with pollution standards may be forced to cease operations with a consequent lay-off of employees. This study surveyed the change in number of operators and mechanics caused by environmental protection. Survey question

1An operator is any hourly employee whose primary job function is...
IV-a asked about changes in the number of operators:

5-1:  
**Question:** How has pollution control affected the number of your operators?

**Finding:** Pollution control has resulted in an average increase of 0.90 per cent in the number of operators.

Mean: 0.90 per cent  
Standard Deviation: 3.53 per cent

It is likely that the additional operators are required to man newly installed waste treatment equipment. The standard deviation of 3.53 per cent is large relative to the mean of 0.90 per cent. This indicates that fewer operators as well are required at some plants. It is probable that closure of units due to pollution problems have resulted in lay-offs of operators.

Survey question IV-b asked about changes in the number of mechanics:

5-2:  
**Question:** How has pollution control affected the number of your mechanics?

**Finding:** Pollution control has resulted in an average mechanic increase in the range of 1.69 per cent.

Mean: 1.69 per cent  
Standard Deviation: 4.54 per cent

Pollution control has resulted in a larger increase (1.69 per cent) the control of equipment. A mechanic is any hourly employee whose primary job function is maintenance of equipment.
in the number of mechanics than the increase in operators (0.90 per cent). A possible explanation may be that pollution maintenance may entail stopping leaks and an overall "tightening up" of existing plant facilities in addition to maintaining new waste treatment equipment. The large standard deviation of 4.54 per cent relative to the mean of 1.69 per cent may indicate that fewer mechanics are likewise required in units that experienced closure and employee lay-offs.

The following correlation indicates the relationship between changes in the number of operators and mechanics caused by environmental protection:

\[ r = 0.517 \]

**Finding:** The correlation of changes in number of operators to changes in number of mechanics caused by pollution control is +0.517.

- Correlation Coefficient: 0.517
- T-statistic: 13.59
- Level Remaining Significant: 0.001

This correlation indicates that plants that experience changes in the number of operators tend also to be those plants that experience changes in the number of mechanics. A possible explanation may be that the primary reasons for census changes are plant closures and installation of new waste treatment equipment. Both would tend to affect the number of operators and mechanics in a similar manner.

**Influence on First Line Supervisors**

Environmental protection may also influence the number of foremen or line supervisors. The survey measured the change in the number
of foremen resulting from added pollution control duties by responses
to survey question IV-d:

5-4:
Question: What is the change in the required number of your foremen
or shift supervisors caused by added environmental pro­
tection responsibilities?

Finding: On the average, the number of foremen were increased by
0.63 per cent.

   Mean: 0.63 per cent

   Standard Deviation: 2.24 per cent

The percentage increase in the number of foremen (0.63 per cent)
is less than both the percentage increase in number of operators
(0.90 per cent) and the percentage increase in the number of mechanics
(1.69 per cent). This indicates that foremen crew sizes or span of
control have been increased.

Two correlations indicate the relationship between the change in
number of foremen and the change in the number of hourly workers. The
first correlation is between the change in number of foremen and the
change in the number of mechanics:

5-5:
Finding: The correlation of changes in number of foremen to changes
in number of mechanics required by pollution control is
+0.384.

   Correlation Coefficient: 0.384

   T-statistic: 9.37

   Level Remaining Significant: 0.001

This indicates that the plants that require additional foremen also
tend to be the same plants that require additional mechanics.
The second correlation is between the change in number of foremen and the change in number of operators:

5-6:
Finding: The correlation of change in number of foremen to changes in number of operators to meet pollution standards is +0.380.
Correlation Coefficient: 0.380
T-statistic: 9.27
Level Remaining Significant: 0.001

This relationship indicates that the plants that require additional foremen likewise tend to be the same plants that require additional operators.

These two positive correlations together with the +0.517 correlation (finding 5-3) of changes in the number of operators to changes in the number of mechanics indicate that plants which require additional operators also tend to be those plants which require additional mechanics and additional foremen as well. The increase in number of foremen, however, is not in direct proportion to increases in the number of hourly workers.

One explanation for the difference in percentage increase between foremen and hourly workers may be that process coverage by the foreman has been changed. Survey question IV-c asked how process coverage by foremen had been altered by environmental protection:

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2Process coverage constitutes the total amount of chemical process equipment assigned to an individual foreman.
The seven point semantic differential was used with "much greater area of coverage" and "much less area of coverage" constituting the ends of the continuum.

5-7: 
**Question:** What is the change in process coverage by your foremen or shift supervisors as a result of environmental protection?

**Finding:** The average change in process coverage due to pollution abatement is 5.00 ("slightly" greater area of coverage).

**Mean:** 5.00 ("slightly" greater area of coverage)

**Standard Deviation:** 0.91 (-1s indicates "neutral" with regard to area of coverage and +1s indicates "moderately" greater area of coverage)

Process coverage by the foreman has been slightly increased. It is likely that the increase in coverage is due to the assignment of new waste treatment equipment to existing foremen. This new equipment may require additional operators and mechanics who report to these existing foremen. Hence, the foremen tend to have increased crew sizes.

**Effect on Training and Job Design**

Additions to plant staff of both foremen and hourly employees as well as expanded coverage by foremen may influence job descriptions for process operators and training requirements for hourly workers and foremen. A process operator job description is a detailed outline of all facets of a particular operating job. It generally contains qualifications (both physical and educational) required to enter as a trainee, a list of assigned equipment, major control points, and
process objectives, a summary of potential safety hazards and general statement of working conditions, and an assessment of the accountability and responsibility relative to other jobs for classifying purposes.

The class of a job (first class, second class, etc.) normally determines the wage rate. The effect of pollution control on job design or description for process operators was assessed, through responses to survey question IV-f. A scale from 0 to 7 was used to measure the change; 0 = no change and 7 = total revision.

5-8:
Question: How has pollution control affected job descriptions for your operators?

Finding: The average change in job description caused by pollution control was 1.28 (barely greater than "slight change").

Mean: 1.28 ("slight change")

Standard Deviation: 1.37 (-1s would be placed at "no change" and +1s placed at "moderate change").

It is likely that this change in job description is of minor importance. It may be that pollution control involves only a slight revision in equipment assignments to include abatement facilities.

A standard deviation of +1 represents only a "moderate change" in job description.

Changes in personnel training may be related to changes in job descriptions. Survey question IV-e asked how personnel training had been affected. A scale from 0 to 5 was used to measure the change; 0 = no change and 5 = large increase in training.

5-9:
Question: How has pollution control affected training requirements of your plant personnel (both hourly and salaried)?
Finding: The average change in personnel training due to pollution control was 1.61 (a small increment of training over "slight increase").

Mean: 1.61 ("slight increase")

Standard Deviation: 1.40 (1s is placed slightly greater than "no change" and +1s is placed at moderate increase).

This change in training requirements is similar to the change in job descriptions. It is likely that extensive training requirements and large scale revisions in job descriptions pertain mostly to those individuals directly involved with pollution abatement equipment. The abatement facilities installed to date are apparently not extensive enough to markedly affect training or job design for the total plant.

There are two correlations involving changes in operator job description necessitated by environmental protection. The first correlation is between changes in job description for operators and process coverage by foremen:

Finding: The correlation of change in job description for operators to change in process coverage by foremen is +0.457.

Correlation Coefficient: 0.457

T-statistic: 11.56

Level Remaining Significant: 0.001

This correlation indicates that plants that have increased changes in job descriptions for operators tend also to be the same plants that have increased changes in process coverage by foremen. It may be that pollution problems affect both area of foreman coverage and operator job descriptions in a similar manner. For example, a
process that requires new filters on waste water discharge would have expanded foreman coverage to include these filters as well as changes in an operator's job description to encompass the operation of these filters.

The second correlation is between the changes in operator job descriptions and plant rate constraints.

5-11: Finding: The correlation of change in operator job description to rate constraint is +0.223.

Correlation Coefficient: 0.223

T-statistic: 5.22

Level Remaining Significant: 0.001

This analysis indicates that plants that have rates curtailed by pollution problems also tend to be those plants that have increased changes in operator job descriptions. It is likely that these plants are revising operator job descriptions in an effort to cope with production curtailments. These revisions usually include assignments of new pollution control equipment and changes in operating techniques to resolve problems that cause rate constraints.

Summary of the Influence on Labor Costs. The influence of environmental protection on operator job design and personnel training requirements appears to be of minor importance. It is likely that increases in training and related expenses are of little significance. The increases in census of 0.90 per cent, 1.69 per cent, and 0.63 per cent for operators, mechanics, and foremen respectively, however, represent increases in labor costs of the same percentage for each of
these groups. Hence, the influence of environmental protection on plant labor cost appears to be primarily manifested in increases in the number of personnel. Since labor costs represent a relatively small percentage of total operating costs, this influence is not very significant.

The Effect of Environmental Protection on Personal Stress and Employee Attitude

The foregoing assessment of the influence of environmental protection on census, process assignments, and training requirements is primarily related to the plant's labor cost. Pollution control pressure may be manifested, however, in other ways that are not directly translated into cost. These influences are behavioral in nature, and may be significant in that they may partly determine the ability of personnel to adapt to pollution control pressure. The behavioral influences examined are personal stress experienced by the production manager and consensus of personnel attitude toward pollution control pressure.

The production manager was selected as the individual to poll for stress experienced as a result of pollution control pressure. It is expected that this individual is low enough in the hierarchy to be involved with the details of the operation while at the same time at a high enough level to participate in discussions with the regulatory agencies and environmental activist groups. Survey question IV-h measured the stress experienced by the production manager. A scale from 0 to 7 was used to measure the stress; 0 = no stress and 7 = extreme stress.
How much personal stress have you as the production manager experienced because of pollution control pressure?

Personal stress experienced by the production manager as a result of pollution control pressure was 2.97 ("moderate" degree).

Mean: 2.97 ("moderate" degree)

Standard Deviation: 1.92 (−1σ is placed at "slight" degree of stress while +1σ is placed at "significant" degree of stress)

It is apparent that plant production managers are experiencing a definite amount of personal stress because of pollution control pressure. The manner in which this stress may be manifested depends to a certain extent on the individual production manager and on intervening factors. An example of intervening factors are the corporate performance standards established for the production manager and the extent that environmental protection may prevent him from achieving these standards.

The standard deviation of 1.93 represents a wide dispersion relative to the mean of 2.97. This indicates that respondents tended to be somewhat opinionated on this subject. It is possible that some of the respondents may have indicated "no stress" out of contempt for these pressure groups. Nevertheless, the average of 2.97 ("moderate" degree) indicates that environmental protection has

3This was the one question asked on the survey that evoked written comments by the respondents. These comments generally followed selection of "extreme degree" of stress. The gist of the comments were that "they are going to shut us down, they are killing us, or they are unreasonable". One respondent claimed that pollution control pressure gave the production manager preceding him a heart attack.
resulted in increased stress experienced by production managers.

The second behavioral response that was examined is the consensus attitude of the plant rank and file toward pollution control pressure. The consensus attitude of the rank and file is indicated by responses to survey question IV-g: (The seven point semantic differential was used with "very negative attitude" and "very positive attitude" on either end of the scale.)

5-13:
Question: What is the consensus attitude (positive or negative) of the personnel in your plant toward pollution control pressure?

Finding: The consensus of personnel attitude toward pollution control pressure is 4.98 ("slightly" positive).

Mean: 4.98 ("slightly" positive)

Standard Deviation: 1.38 (−ls placed at midpoint between "slightly" negative and neutral and +ls placed at midpoint between "moderately" positive and "very" positive)

The study reveals that there is a definite tendency on the part of personnel to have a consensus attitude that is positive. With apparent threat to job security from potential shutdowns caused by pollution problems, it was expected that consensus attitude would be somewhat negative. Nevertheless, personnel appear to have a somewhat positive consensus attitude toward environmental protection, and this may aid chemical plants in adapting to pollution control pressure.

An analysis of five correlations may better describe the influence of environmental protection on the behavioral factors described above. The first correlation is between personal stress experienced by the production manager and the number of contacts with ecological activist
Finding: The correlation of personal stress experienced by production managers to number of contacts with ecological activist groups is +0.193.

Correlation Coefficient: 0.193
T-statistic: 4.40
Level Remaining Significant: 0.001

This relationship means that plants that have an increased number of contacts with ecological activist groups also tend to be the same plants in which the production manager experiences increased personal stress.

The second correlation is between personal stress experienced by the production manager and the number of visits from the EPA:

Finding: The correlation of personal stress experienced by production managers to number of visits from the EPA is +0.188.

Correlation Coefficient: 0.188
T-statistic: 4.29
Level Remaining Significant: 0.001

Likewise, the plants that have an increased number of visits from the EPA also tend to be the same plants in which the production manager experiences increased personal stress.

These two correlations are very close. This indicates almost the same level of interdependency between contacts from these two groups and personal stress. The plants that have more contacts with either the EPA or ecological activist groups have a tendency to be those
plants in which the production manager experiences a greater degree of personal stress.

The third correlation relates personal stress to downtime.

5-16: Finding: The correlation of personal stress to percent of forced downtime is +0.181.

Correlation Coefficient: 0.181

T-statistic: 4.12

Level Remaining Significant: 0.001

This correlation indicates that those plants with increased percentage of forced down time due to pollution problems also tend to be the same plants in which the production manager experiences increased personal stress. It is likely that pollution problems severe enough to force shut downs would also cause an increased level of personal stress experienced by the production manager.

The fourth correlation is between consensus personnel attitude and percentage of forced downtime due to pollution problems:

5-17: Finding: The correlation of consensus personnel attitude to percentage of forced down time is -0.025.

Correlation Coefficient: -0.025

T-statistic: 0.56

Level Remaining Significant: 0.60

There is essentially no interdependency between unit down time and consensus employee attitude. It was expected that some directed response (either positive or negative) would result from pollution control pressure that forced a unit down. Employees may be pleased
because they did not have any work to perform during the shutdown, or they would be upset because they were subject to lay-offs or had a great deal of work to perform upon start-up. The analysis indicates that neither case sets a trend to link with down time.

The fifth correlation relates consensus personnel attitude and changes in employee training requirements:

5-18:
Finding: The correlation of consensus personnel attitude to change in personnel training requirements is -0.003.

Correlation Coefficient: -0.003
T-statistic: 0.07
Level Remaining Significant: Not significant at 0.90 level

There is essentially zero correlation or no interdependency. It was expected that pollution problems that forced changes in training would also evoke an attitudinal reaction. Such is not the case.

Models of Stress and Personnel Attitudes

To this point the study has used analyses of sample means, standard deviations, proportions, and bivariate correlation analyses to explore and describe the influence of environmental protection on chemical plants. Now an attempt is made to establish functional relationships by using multiple regression analysis. Models are formulated that use selected factors as dependent variables which are described as a function of selected independent variables.4

4A technical explanation of this procedure is indicated in Appendix C to this study.
Two such models attempt to explain the variation in personal stress experienced by the production manager by the variation in selected independent variables.

5-19:

\[ y = 0.049 X_3 + 0.097 X_4 + 2.77 \]

\( y \) = personal stress experienced by production manager (range of values 1 to 7)

\( X_3 \) = communications with ecological activist groups

\( X_4 \) = visits from the EPA

Coefficients not significant at 0.05 level:

\( X_1 \) = proximity to residential areas

\( X_2 \) = age of plant

Multiple Regression Coefficient: 0.25

\( F \) - Ratio: 8.28

\( F(0.05) \): 2.37

5-20:

\[ y = 0.102 X_3 + 0.047 X_4 + 1.965 \]

\( y \) = personal stress experienced by the production manager (range of values 1 to 7)

\( X_3 \) = unit downtime as percent of time

\( X_4 \) = communications with ecological activist groups

Coefficients not significant at 0.05 level:

\( X_1 \) = consensus of personnel attitude

\( X_2 \) = percent of complex size that a plant holds

Multiple Regression Coefficient: 0.27

\( F \) - Ratio: 9.73
As seen from the above relationships (5-19 and 5-20) the variation in personal stress experienced by the production manager as a result of pollution control pressure is not explained adequately by variation in the selected independent variables. The coefficients for the proximity to residential areas and plant age were not significant at the 0.05 level in equation 5-19 and hence are not relevant for explaining the level of personal stress. Likewise, the coefficients for consensus of personnel attitude and percentage of complex size that a plant holds were not significant at the 0.05 level in equation 5-20, and hence are not relevant for explaining the level of personal stress. In equation 5-19 communications with ecological activist groups and visits from the EPA have significant coefficients, but yield a multiple regression coefficient of only 0.25. Similarly, unit downtime as percent of time and communications with ecological activist groups have significant coefficients but also yield a low multiple regression coefficient of only 0.26.

The above two equations can hardly be termed complete models, explaining and predicting levels of personal stress stemming from pollution control pressure. The eight independent variables selected for this analysis appeared likely to influence personal stress related to pollution problems. Only four of the eight independent variables, however, had significant coefficients at the 0.05 level. Therefore, the significance of these two models lies in the fact that the variation in the eight selected independent variables did not adequately explain the variation in personal stress.
Another model was constructed in an attempt to cite the variables that explain the variation in the consensus of personnel attitude toward pollution control pressure. The variables selected were those closely associated with the individual employee, that is, employee turnover, changes in foreman, and modifications in training requirements:

Personnel attitude toward pollution control pressure was selected as the dependent variable; the independent variables chosen were changes in (a) number of operators (b) number of mechanics (c) number of foremen (d) training requirements.

None of the regression coefficients were significant at the 0.05 level and the multiple regression coefficient of 0.07 was also not significant at the 0.05 level.

Again, the significance of this analysis lies in the fact that none of these selected independent variables had any influence on personnel attitude. Therefore, the consensus of personnel attitude is definitely a function of other factors.
CHAPTER 6

THE EFFECT OF POLLUTION CONTROL ON MAINTENANCE COSTS AND PRIORITIES

Another operating expense that may be influenced by environmental protection is plant maintenance cost. Both maintenance labor and material resources represent strategic elements of a chemical plant's operating budget. Maintenance management tends to be a competitive variable in the chemical industry. Processes used by different companies tend to be similar with regard to performance, rates, yields, and particular operating costs. A discretionary element is the level at which these processes are maintained. The objective is to maintain operations without sacrificing production or yields so that total operating costs are minimized.

The traditional function of maintenance spending in the chemical industry has been to promote a high level of stream time and high product yields. At times in recent years, however, environmental protection has tended to preempt these traditional operating considerations. This chapter analyzes the influence of pollution control on current allocation of maintenance funds, forecasted effect on future spending, and the influence on traditional plant maintenance priorities.
Current Level of Maintenance Spending on Pollution Control

As noted above, environmental protection has tended to divert maintenance funds away from traditional plant maintenance jobs. The survey measured the current percentage of maintenance spending that is directed to pollution control by responses to survey question V-a:

6-1; Question: What percentage of your current maintenance spending is being allocated to pollution abatement jobs?
Finding: The average percentage of maintenance spending directed to control of pollution is 5.31 per cent.
Mean: 5.31 per cent
Standard Deviation: 6.33 per cent

This average of 5.31 per cent of total maintenance spending can be placed into proper perspective with an example. A typical chemical plant has a capital outlay of $10 million. A guideline for normal maintenance spending is in the range of 5 per cent of plant capital. Therefore, this typical plant probably has a maintenance budget of approximately $500,000. A 5.31 per cent of this budget would result in a $26,550 expenditure for repairs directed at pollution control.

Maintenance Costs for Pollution Control Over Next Five Years

Maintenance costs for pollution abatement may increase total maintenance spending in the future. Survey question V-b asked about the increase in maintenance spending due to pollution control over the next five years:
What effect will pollution control have on your total maintenance spending over the next five (5) years?

Average increase in total maintenance costs forecasted over the next five years due to pollution control is 7.99 per cent.

Mean:  7.99 per cent
Standard Deviation:  8.37 per cent

Maintenance activity to control pollution will significantly increase total maintenance spending. The ever-present tightening up (repairing pipe leaks, leaking valves, and bad pump packing) may be joined by direct maintenance and troubleshooting of new abatement facilities (filters, chemical treatment controls, aerators, etc.). Also maintenance personnel will perform new types of jobs that are different from traditional maintenance duties. This new type of work includes dredging of waste pits, shoring-up and maintaining walls or levies of waste ponds, patching liners in waste ponds, and the proper disposal of maintenance supplies such as lubricants, paints, industrial detergents and degreasers, and certain types of insulating materials such as asbestos compounds.

Possible Maintenance Reductions from Pollution Control

There may be a number of isolated conditions whereby maintenance costs may actually be reduced by pollution abatement. For example,

1Traditional maintenance duties include routine repairs, turn-arounds (annual or semi-annual unit outages to perform a back-log of work that requires a shutdown), and simple construction jobs (other than capital equipment installation).
A unit that emits corrosive vapors and particulates may attack and destroy unprotected structural supports, instruments, and vehicles in that area. Likewise, a pipe leaking a corrosive liquid may damage insulation, electrical conduits, instrument air tubing, and possibly ground-out motors. Pollution abatement that controls these emissions and leaks may also reduce maintenance requirements in these areas.

The survey acknowledged the potential reduction of maintenance spending from pollution control through responses to survey question V-c: (For example, a 7.99 per cent increase in maintenance spending that up-graded area conditions would be canceled if a 7.99 per cent reduction in outlay would follow.)

6-3:
Question: What are your potential maintenance reductions from improvements in pollution control over the next five (5) years?

Finding: Average potential maintenance reductions forecasted from improvements in pollution control is 0.90 per cent.

Mean: 0.90 per cent
Standard Deviation: 2.14 per cent

This potential maintenance reduction of 0.90 per cent is not projected to substantially off-set the current forecasted maintenance increase of 7.99 per cent over the next five years.

Priority Given Pollution Maintenance

A significant indicator of the influence of environmental protection on chemical plant management is the priority rendered pollution maintenance jobs compared to traditional plant maintenance jobs. The survey included a ranking of pollution control priority with
priority to keep the plant on-stream and priority to adhere to pre-
scribed preventative maintenance schedules respectively. Survey 
questions V-d-1 and V-d-2 ascertained this ranking: (The seven point 
semantic differential was used for responses to both questions.)

6-4:
**Question:** How does your pollution related maintenance priority rank 
with your maintenance priority to keep the plant on stream?

**Finding:** The average priority chosen when comparing keeping the 
plant on stream with pollution control was 4.59 ("slight" 
priority given to keeping the plant on stream).

Mean: 4.59 (slight priority to keep plant on stream)

Standard Deviation: 2.06 (-ls placed at "slight" priority 
for pollution control and +ls placed at "high" priority for keeping the 
plant on stream)

6-5:
**Question:** How does your pollution related maintenance priority rank 
with your priority to adhere to preventive maintenance 
schedules?

**Finding:** The average priority chosen when comparing adherence to 
preventive maintenance schedules with pollution control 
was 3.90 (a "stand-off" or no directed consensus of 
opinion).

Mean: 3.90 ("stand-off")

Standard Deviation: 2.02 (-ls and +ls placed at "moderate" 
priority for respective choices.)

It is likely that pollution control has made a significant im-
pression plant management's priorities. Only a "slight" priority 
given to keeping the plant on stream when compared to pollution control 
is indicative of the high priority given pollution control. Likewise, 
having an equal priority with adherence to preventive maintenance 
schedules is also indicative of the high priority rendered pollution
Maintenance and Pollution Control Relationships

Three correlations that involve maintenance priority provide additional insight into this analysis. The first correlation is between current maintenance spending for pollution control and maintenance priority (keeping the plant on stream vs. pollution control):

6-6:
Finding: The correlation of current maintenance spending for pollution control to maintenance priority (keeping plant on stream vs. pollution control) is -0.126.
Correlation Coefficient: -0.126
T-statistic: 2.85
Level Remaining Significant: 0.01

This correlation means that plants that are currently spending more for pollution control also tend to be the same plants that give pollution control a higher priority when compared with keeping the plant on stream.

The second correlation relates current maintenance spending for pollution control and maintenance priority (adherence to preventive maintenance schedules vs. pollution control):

6-7:
Finding: The correlation of current maintenance spending for pollution control to maintenance priority (adherence to preventive maintenance schedules vs. pollution control) is -0.174.
Correlation Coefficient: -0.174
T-statistic: 3.98
Level Remaining Significant: 0.001
Likewise, this correlation indicates that plants that currently spend more for pollution control also tend to be the same plants that give pollution control a higher priority when compared with adherence to preventive maintenance schedules. Both of the above correlations support the contention that those plants currently spending more of their maintenance funds on pollution control also tend to give pollution control jobs a higher priority.

The third correlation relates maintenance priority (keeping the plant on stream vs. pollution control) and maintenance priority (adhering to preventive maintenance schedules vs. pollution control):

6-8; Finding: The correlation of maintenance priority (keeping the plant on stream vs. pollution control) to maintenance priority (adhering to preventive maintenance schedules vs. pollution control) is +0.656.

Correlation Coefficient: 0.656
T-statistic: 19.55
Level Remaining Significant: 0.001

This high level of correlation indicates that as a general rule, those plants that give pollution control a high priority are also the plants that render this priority over both keeping the plant on stream and keeping preventive schedules alike. The converse of this generalization is also indicated.

Another correlation relates current and future maintenance spending:

6-9; Finding: The correlation of current maintenance spending for pollution control and forecasted spending for pollution control over the next five years is +0.621.
Correlation Coefficient: 0.621
T-statistic: 17.82
Level Remaining Significant: 0.001

This correlation means that plants that are spending a higher percentage of their maintenance funds on pollution control at present tend also to be those plants that forecast spending a higher percentage of their maintenance funds on pollution abatement over the next five years.

A multiple regression model was formulated in an attempt to explain and predict maintenance spending plans for pollution control over the next five years:

6-10:

\[ y = 0.820 \times_1 + 3.492 \]

\[ y \] = percent that maintenance costs are expected to increase over the next five years due to pollution control.

\[ \times_1 \] = current percent of maintenance spending directed at pollution abatement.

Coefficients not significant at 0.05 level:

\[ \times_2 \] = age of plant

\[ \times_3 \] = maintenance priority - keeping plant on stream or pollution control.

\[ \times_4 \] = maintenance priority - keeping preventive maintenance schedules or pollution control.

Multiple Regression Coefficient: 0.62

F - Ratio: 80.35

F Ratio (0.05): 2.24
The multiple regression coefficient of 0.62 indicates that this model explains a majority of the variation in spending plans for the next five years by variation in one independent variable. The current percentage of maintenance funds spent on pollution control is an important indication of what a given plant plans to spend on pollution control during the next half decade. This indicates that plants that rely on maintenance to improve pollution control are likely to continue to do so over the next five years. This maintenance spending may be in lieu of capital spending for environmental protection. The other independent variables in this model are not significant.
CHAPTER 7
THE INFLUENCE OF ENVIRONMENTAL PROTECTION ON
CAPITAL BUDGET ALLOCATION

A trade-off of maintenance spending is capital equipment installation. When a piece of major operating equipment reaches a high maintenance level, it may be more profitable to spend capital funds to purchase a new or modified piece of equipment. In a like manner, maintenance spending for pollution control may be saved in certain circumstances by capital improvements. For example, a plant that has a high effluent level from leaking and corroded pipes may attempt to perform maintenance repairs and patch or change out bad sections of this pipe, or it may spend capital funds and replace all of the pipe with a material of construction that is more highly resistant to corrosion (capital).

The major portion of capital spending for pollution abatement, however, does not necessarily represent a trade-off of maintenance funds. This capital is mostly allocated for new equipment to control existing pollution or to modify processes to eliminate the source of pollution. These outlays can be in existing plants or included with the site selection, design, and construction of new plants.
Current Capital Spending for Pollution Control

The level of capital spending on pollution control for the chemical industry was noted in Chapter 1. This study generally audits industry claims by estimating pollution capital expenditures from the plant's perspective versus an aggregate of company-wide estimates. Survey question VI-a asked what percent of the most recently formulated capital budget was devoted to pollution control:

7-1:

**Question**: What percent of your most recently formulated capital budget is allocated to pollution projects?

**Finding**: The average percent of the most recently formulated capital budget that was directed at pollution abatement was 13.14 per cent.

Mean: 13.14 per cent

Standard Deviation: 9.74 per cent

The 13.14 per cent of capital spent on pollution compares closely with the 12.2 per cent from the *Chemical Week Report*. There is no significant difference between the 13.14 per cent allocation from this study and the 12.20 per cent allocation from industry estimates. The difference between these two means was tested by using the standard deviation of 9.74 per cent from this relatively large sample of 508 plants as the universe standard deviation. This test indicates that both the 13.14 per cent allocation and the 12.2 per cent allocation

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2Conversely, this industry estimate provided one way to test the validity of the findings in this study.
were representative of the same universe at confidence level of 95 per cent. Hence, from both the industry forecast and this assessment of 508 plants, the per cent of capital spending for pollution control was recently in the range of 12.20 per cent to 13.14 per cent.

A correlation indicates the relationship between current spending of capital funds for environmental protection and the induced changes in finished product quality requirements because of pollution control:

**Finding:**
The correlation of most recent percentage of capital spent on pollution abatement to changes due to pollution control in quality requirements of finished products is +0.120.

Correlation Coefficient: 0.120

T-statistic: 2.70

Level Remaining Significant: 0.01

This correlation indicates that there is a slight tendency for plants which spent a greater percentage of their capital budget on pollution abatement also to be the same plants that have higher finished product quality requirements necessitated by environmental protection. It may be that the target of part of this capital spending is to remove contaminants from finished products.

**Pollution Control Spending Over Next Five Years**

The capital spending for pollution control forecasted for the next five years is also compared with projections by industry spokesmen. Survey question VI-b asked the plants their forecasted allocation of capital funds for environmental protection for the next five years:
What percent of your forecasted five year capital budget is allocated to pollution control projects?

The average percent of capital budget to be spent over the next five years for pollution abatement is 14.13 per cent.

Mean: 14.13 per cent
Standard Deviation: 10.07 per cent

This average of 14.13 per cent also compares quite closely with industry forecasts of 13.80 per cent. This is no significant difference between these forecasts of 14.13 per cent and 13.80 per cent.

A correlation analysis shows the relationship between the most recent (1972) allocation of capital funds and the five year forecasted allocation of capital funds to pollution control:

The correlation of 1972 pollution control capital spending to the five year forecast for pollution control capital spending is +0.671.

Correlation Coefficient: 0.671
T-statistic: 20.34
Level Remaining Significant: 0.001

This correlation indicates that plants which have recently (1972) allocated a large percentage of their capital budget to pollution control also tend to be the same plants which forecast a large

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3 Schwartz, loc. cit.

4 The difference between these two means was tested at a confidence level of 95 per cent. The means were shown to represent the same universe.
percentage of their capital budget for environmental protection over the next five years. For some plants a very plausible explanation is that the current spending is part of a multi-year program outlined in a compliance plan. The entire industry is preparing for the established deadlines of "best practicable" control by 1977 and "best available" control by 1983. A plant that has major pollution capital work to accomplish in order to meet these deadlines is likely spending at a high level for the next several years. The level of current and future capital outlays for pollution abatement are primary means of complying with environmental protection mandates. The lack of such outlays likely indicates that a plant is either one of a small minority and has no major pollution problems or is planning to close its plant.
CHAPTER 8
FACTORS INFLUENCING PLANT STRATEGY
FOR ENVIRONMENTAL PROTECTION

This chapter is concerned with an analysis of the strategic factors that are likely to influence the ability of a plant to forecast environmental protection requirements and develop methods to cope with these requirements. These factors include plant departmentation, technical staff assignments, general approach to pollution control ("contain" vs. "eliminate"), land acquisitions and plant expansions, and the projected ramifications of a zero discharge order.

Plant Departmentation

An environmental protection department has been added to some chemical plants in recent years. This department joins the traditional plant departments which include production, maintenance, personnel, technical, utilities, accounting, distribution, and quality control. Duties of the environmental protection department generally consist of receiving information and guidelines from regulatory agencies, coordinating the implementation of these guidelines with other plant departments, and preparing replies which include compliance plans back to the regulatory agencies.

Because of the heavy reliance on sampling and analytical testing, the environmental protection function originally tended to be placed in the quality control department of a number of plants. The scope
of the environmental service function today, however, transcends these activities. Currently the environmental protection group works with engineering and technical groups in the design of new process and equipment; with accounting and financial groups in preparation of capital budgets which include environmental protection projects; with production superintendents and supervisors to determine process adjustments necessary in order to comply with pollution standards; with maintenance supervision to ensure that proper priority is being given pollution related repairs; and also the quality control group for sampling and testing to determine pollution levels. Hence, a new department has been created in a number of plants to perform the above duties.\(^1\) Survey question VII-a asked about the establishment of plant environmental protection departments.

8-1;
Question: Do you have an "in-house" environmental protection department consisting of more than one man?

Finding: 224 of the 508 plants in the survey have an "in-house" environmental protection department consisting of more than one person.

Sample Proportion: 0.44
Standard Error: 0.02

Approximately one half of the plants now have environmental protection departments. It is likely that most of these groups have been

\(^1\)The supervisor of this department (probably an analytical chemistry specialist) generally reports to the production manager, technical manager, or plant manager.
in existence only since the mid 1960's. This was the period when lawmakers began passing major environmental protection legislation.

For those plants that do not have a separate environmental protection department, an individual or possibly a committee performs the duties of this department. In some plants the production manager may be responsible for a number of functions related to environmental protection. The survey assessed the involvement of the production manager in environmental protection matters by responses to survey question VII-c:

8-2; Question: What percent of time that you, as production manager, devote to environmental protection problems?

Finding: The average per cent of the production manager's time allocated to pollution problems is 8.32 per cent.

Mean: 8.32 per cent
Standard Deviation: 8.00 per cent

The production manager spends on the average approximately 3.3 hour per week (40 hours per week times 8.32 per cent) on pollution problems. It is likely that this percentage increases significantly with smaller plants. Smaller plants may not be able to support an environmental protection department or even a staff specialist. Someone in the organization, such as the production manager, has to coordinate pollution control activity.

Technical Staff Assignments

The environmental protection department may coordinate pollution control activity, but the development of methods to cope with pollution standards typically rests with the plant technical or engineering
specialists. Historically, the technical staff has concentrated on projects directed to increase production rates, raise product yields, improve product quality, lower maintenance, reduce manpower, and other related improvements. These activities were almost exclusively devoted to improving profits.

Now pollution abatement has a tendency to divert technical staff resources away from the above traditional duties. The survey measured the percent of plant technical manpower now allocated to environmental protection by responses to survey question VII-b:

8-3: Question: What is the percentage of your total engineering or technical manpower that is devoted to environmental protection?

Finding: The average percent of total engineering or technical manpower devoted to environmental protection is 9.29 per cent.

Mean: 9.29 per cent

Standard Deviation: 9.25 per cent

It is likely that this 9.29 per cent of the plant technical staff has been assigned projects related to compliance plans submitted to respective states (81 per cent of the plants surveyed submitted compliance plans). These compliance plans normally contain deadline schedules that include feasibility studies and designs of new abatement facilities or process modifications as well as projected dates of installation. Feasibility studies as well as designs are generally done by technical personnel.

The new pollution control equipment or process modification is normally a capital expense and as such is included in the capital budget. The following correlation relates percentage of technical
Finding: The correlation of percentage of technical manpower devoted to pollution problems to percentage of the next five year capital budget allocated to pollution abatement is $r = 0.543$.

- **Correlation Coefficient:** $0.543$
- **T-statistic:** $14.61$
- **Level Remaining Significant:** $0.001$

This correlation indicates that the plants that have a high percentage of their five year forecasted capital budget allocated to pollution control also tend to be the same plants that have a higher percentage of their technical staff assigned pollution control projects. Hence, it is likely that technical assignments to environmental protection probably culminate with capital equipment installations.

**General Approach to Pollution Control**

A general guideline or direction is needed before technical personnel can develop methods to cope with pollution control standards. This guideline provides the necessary scope for pollution control projects. For a given pollution problem the direction tends to characterize either of two distinct approaches to pollution control. These approaches are to contain the existing pollution or to eliminate the source of the pollution. An approach of containment of existing pollution directs technical personnel to the study and design of
waste treatment facilities. An approach of elimination of the source of pollution directs technical personnel to the design of new or modified production processes.

Survey question VII-e asked which of the above two approaches will tend to dominate the plant pollution control policy over the next five years: (The two approaches, "contain" and "eliminate", were placed on opposite ends of a 7-point continuum. "Entirely, large majority, and majority" constituted the degree of domination for each approach. The neutral position was "no significant change" to either approach.)

8-5:

Question: What direction will the major pollution control technology advancements take at your plant over the next five years?

Finding: The average choice between controlling existing pollution or eliminating the source of pollution was 4.21 (between "neutral" and "majority" orientation to control existing pollution).

Mean: 4.21 (between "neutral" and "majority" control of existing pollution)

Standard Deviation: 1.38 (-1s placed at "majority" eliminating sources of pollution and +1s placed between "majority" control of existing pollution and "large majority" control of existing pollution.)

There is very slight tendency for plants to control existing pollution versus eliminating the source of existing pollution. The 0.21 deviation from the neutral position (4.21 - 4.00) is however, very small relative to the standard deviation of 1.38.2 This indicates a

2The average of 4.21 is, however, significantly different from the neutral position of 4.00 at a 95 per cent level of confidence.
wide dispersion of approaches toward pollution control. Both approaches tend to be predominate in varying degrees in the plants with the consensus approach slightly favoring containment of existing pollution. This indicates that plants have a tendency to explore a wide range of alternatives to improve environmental protection.

A slight tendency to contain existing pollution rather than eliminating the source, however, is supported by two points. The first point is that eliminating the source of pollution generally is more costly because of required process revisions. These revisions may entail extensive capital outlays and increases in operating costs. The second point is that a process revision designed to eliminate the source of a pollutant may result in the creation of a source of another pollutant that is equally scrutinized and regulated. 3

Land Acquisitions and Plant Expansions

Land acquisitions may be required in order to contain existing pollution or eliminate the source of pollution. The land may be needed to locate waste treatment facilities for containing existing pollution, or it may be needed to locate new processes or process additions for eliminating the source of existing pollution. Although additional land is usually required to control water pollution, it may also be required to locate air pollution control equipment.

3 For example the conversion of chlorine cells by many plants from mercury-type to diaphragm-type in order to eliminate mercury pollution resulted in consequent lead and asbestos pollution problems from the diaphragm cell.
Installation of waste treatment equipment for containing pollution has a tendency to occupy large areas of plant property. These facilities sometimes are waste ponds that are relatively shallow in depth (3 to 6 feet) compared to their area. There are three reasons why waste ponds have these dimensions. First, ponds may be used for solar evaporation and require a large surface area for exposure to the sun for evaporation of liquids. Second, deeper ponds require costly structural support of the walls. Third, water seepage has a tendency to "float the pond" for deep ponds installed in an area that has a high water table.

Survey question VII-f asked about land acquisitions necessary over the next five years to meet pollution control standards:

8-6: Question: What are your land acquisitions projected over the next five years to meet pollution control standards (as percent site size)?

Finding: The average land acquisitions as percent of present site size projected over the next five years to meet pollution control standards is in the range of 2.67 per cent.

Mean: 2.67 per cent

Standard Deviation: 8.10 per cent

The small average increase in plant property size of 2.67 percent is deceptive. The standard deviation of 8.10 per cent represents a very wide dispersion about the mean. This dispersion is explained by the fact that 34 of the 508 respondents (6.7 per cent) projected land acquisitions of greater than 8.0 per cent of their present site size while 415 of the 508 respondents (81.7 per cent) did not foresee any environmental protection related land acquisitions. It appears that
the necessity for land acquisition is an isolated problem confronting particular plants. For these plants land purchases for environmental protection is likely to present a severe problem.

A major problem in using land for waste ponds or disposal dumps is the current protest from land conservationists. These groups claim that land is a scarce national resource and that private ownership of this land does not encompass the right to "destroy or defile" it by using it for waste ponds or dumps. These land conservationists lobby for the total elimination of pollution rather than containing it within the boundary of private property.

**Plant Expansions**

Land is also purchased to locate new producing facilities. These expansions may be to produce a new product(s) or to expand the capacity of existing operations. Pollution considerations are likely to weigh very heavily on expansion plans. Expansion prospects at existing locations are examined by this study.

The survey defined a "positive" expansion outlook as the possibility for expansion at present location that will produce products used in pollution control or the opportunity to meet pollution control standards with lower costs and consequences compared to an assessment of pollution problems facing competitors. A "negative" expansion outlook was defined as a poor opportunity to meet environmental protection standards required of a new facility with lower costs or consequences compared to the assessment of costs and consequences facing competitors. Survey question VII-d asked about expansion outlook: (The survey used the 7 point semantic differential with highly negative and highly positive expansion outlook on each end of the scale.)
Question: What is the expansion outlook at your present location with regard to environmental protection problems facing your competitors?

Finding: The average prospect of expansion at present locations with regard to pollution problems facing the respective plant and its competitors is 3.78 (between "slightly" negative outlook and neutral).

Mean: 3.78 (between "slightly" negative outlook and neutral)

Standard Deviation: 1.68 (-1s placed at "moderately" negative outlook and +1s placed between "slightly" and "moderately" positive expansion outlook).

The consensus of the responding plants indicates that environmental protection has a slightly negative impact on plant expansion at present plant sites. The significance of this finding is that the consensus expansion outlook is in fact slightly negative for the chemical industry. One plant's failure to expand and increase or maintain its market share because of pollution problems will not be totally offset by a competitor filling this void because he may not necessarily have as severe pollution problems. This slightly negative outlook may result in certain chemical shortages in the future.

Ramifications of a Zero Discharge Order

The study concludes with an analysis of the 1985 goal of zero discharge as stated in the Federal Water Pollution Control Act Amendments of 1972. This goal is the most controversial provision.

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4Federal Water Pollution Control Act Amendments of 1972, PL 92-500.
of water pollution legislation.\textsuperscript{5}

This study assessed (question VII-g) the impact of zero discharge by having the responding plants select from the following alternatives that which best described their plant's course of action if faced with a zero discharge order in 1985:\textsuperscript{6}

- No impact (0)
- Minor capital outlay (1)
- Moderate capital outlay (3)
- Major capital outlay (5)
- Shut down (7)

Question: What would be the impact on your plant of a "zero discharge order" to be enacted by 1985?

Finding: The average impact of zero discharge to be enacted by 1985 is 4.23 (between "moderate" and "major" capital outlay).

Mean: 4.23 (between "moderate" and "major" capital outlay)

\textsuperscript{5}There is even controversy over the definition of "zero discharge." It has been debated whether or not a plant may return the mud and silt back to the river that is taken in with the river water used in the process.

\textsuperscript{6}The numbers in parenthesis (0, 1, 3, 5 or 7) are the values placed on that selection. This weighting system was used instead of a "0-4" or "1-5" for two purposes: First, the expanded scales give a better amplification and description of results; secondly, the interval of "one" between "no impact" (0), and "minor capital outlay" (1) was inserted, because "minor capital outlay" could possibly include only monitoring devices to verify zero discharge; these monitoring devices, as such, do not remove or retard pollution.
A zero discharge order to be enacted in 1985 will have a profound impact on United States' chemical plants. This conclusion is based both on the average of 4.23 (between "moderate" and "major" capital outlay for zero discharge) and the number of respondents that claimed zero discharge in 1985 will force a plant closure. Fifteen percent, or 76, of the 508 responding plants indicated that zero discharge in 1985 would shut them down. The Directory of Chemical Producers lists 3983 plants from which this survey sample was drawn. This 15 per cent sample proportion applied to the universe of 3983 plants indicates that 597 chemical plants in the United States will be forced to close in 1985 if the zero discharge goal becomes the standard.

The impact of this finding may be tempered by the likelihood that some of these plants plan to close even in the absence of a zero discharge order. Also, technology may be developed between now (1973) and 1985 that would enable other doomed plants to meet a zero discharge order. Nevertheless, the forecasted impact of zero discharge in 1985 is substantial.

Six correlations indicate factors that are relevant to the impact of a 1985 zero discharge order. The first correlation is between zero discharge impact and plant age:

Finding: The correlation of zero discharge impact to plant age is +0.162.
Correlation Coefficient: 0.162
This finding indicates that the impact of zero discharge will have a tendency to be more severe in older plants. As noted in Chapter 2, older plants are generally not equipped with the sophisticated pollution control facilities of newer plants.

A second correlation is between zero discharge impact and change in plant utility costs due to pollution control:

8-10:
Finding: The correlation of zero discharge impact to pollution control induced changes in plant utility costs is +0.275.

Correlation Coefficient: 0.275
T-statistic: 6.44
Level Remaining Significant: 0.001

This correlation indicates that zero discharge impact will tend to be greater in plants that also have higher utility costs because of pollution control. It may be that a plant's most difficult pollution problem stems from its internal power generating station. Zero discharge from this generating station may be difficult to achieve.

A third correlation is between zero discharge impact and the effect of environmental protection on expansion outlook at existing plant locations:

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7 The expansion outlook was measured on a "1" to "7" scale with "1" = highly negative outlook and "7" = highly positive outlook.
Finding: The correlation of zero discharge impact to the effect of environmental protection on expansion possibilities at the existing plant site is -0.263.

Correlation Coefficient: -0.263

T-statistic: 5.96

Level Remaining Significant: 0.001

This analysis indicates that the plants that have negative expansion outlooks due to pollution problems tend also to be the same plants that would be more severely affected by a zero discharge ruling. Conversely, the plants that have the more positive prospect for expansion tend also to be those plants that would be affected by zero discharge. It is reasonable to expect that the plant that would have difficulty in meeting the stated zero discharge goal in 1985 is not likely to consider favorably an expansion in 1973.

A fourth correlation is between zero discharge impact and plant outage frequency per month:

Finding: The correlation of zero discharge impact to plant outage frequency per month caused by pollution problems is +0.213.

Correlation Coefficient: 0.213

T-statistic: 4.81

Level Remaining Significant: 0.001

This correlation indicates that the plants that are having trouble meeting current pollution standards so that outages are required also tend to be the plants that will find it more difficult to meet the zero discharge goal for 1985.
A fifth correlation relates zero discharge impact to the allocation of the five year capital budget to environmental protection:

Finding: The correlation of zero discharge impact to percentage of the next five year capital budget devoted to pollution control projects is +0.286.

Correlation Coefficient: 0.286

T-statistic: 6.49

Level Remaining Significant: 0.001

This correlation means that plants that will be more severely affected by zero discharge have a tendency to allocate a higher percentage of their five year capital budget to pollution controls. For those plants that expect to remain viable, a high capital outlay over the next five years may soften the zero discharge impact in 1985.

A sixth correlation relates zero discharge impact and percentage of technical staff assigned to pollution control projects:

Finding: The correlation of zero discharge impact to percentage of technical staff devoted to pollution work is +0.231.

Correlation Coefficient: 0.231

T-statistic: 5.22

Level Remaining Significant: 0.001

This relationship suggests that plants that will be more severely affected by zero discharge have a tendency to currently assign a greater percentage of their technical staff to pollution control projects if viability is a goal. Probably those plants which foresee difficulty in meeting future control standards are now assigning to
technical personnel the task of developing methods to meet future standards.

Three models were formulated in an attempt to establish a functional relationship that explains the variation in the forecasted zero discharge impact in 1985:

8-15:

\[ y = 0.016 X_1 + 0.100 X_2 + 1.442 \]
\[ y = \text{impact of zero discharge} \]
\[ X_1 = \text{age of the plant} \]
\[ X_2 = \text{pollution control induced change in utility costs} \]

Coefficients not significant at 0.05 level:
\[ X_3 = \text{change in the price of raw materials} \]
\[ X_4 = \text{change in yields} \]

Multiple Regression Coefficient: 0.30
F-Ratio: 12.48
F-Ratio (0.05): 2.24

8-16:

\[ y = -0.285 X_2 + 0.179 X_3 + 4.664 \]
\[ y = \text{impact of zero discharge} \]
\[ X_2 = \text{expansion outlook at present site} \]
\[ X_3 = \text{outage frequency (unit outages/month)} \]

Coefficients not significant at 0.05 level:
\[ X_1 = \text{approach to pollution control (contain vs. eliminate)} \]
\[ X_4 = \text{proximity to urban areas} \]

Multiple Regression Coefficient: 0.33
F-Ratio: 15.84
\[ F - \text{Ratio} (0.05) = 2.24 \]

8-17:

\[ y = 0.042 x_1 + 0.023 x_3 + 3.678 \]

\( y \) = impact of zero discharge

\( x_1 \) = percent of five year capital budget allocated to pollution projects

\( x_3 \) = percent of time that the production manager allocates to environmental protection

Coefficients not significant at 0.05 level:

\( x_2 \) = percent of technical people assigned to pollution work

\( x_4 \) = consensus of personnel attitude toward environmental pressures

Multiple Regression Coefficient: 0.32

\[ F - \text{Ratio} = 14.22 \]

\[ F - \text{Ratio (0.05)} = 2.24 \]

Unfortunately, none of the above three models adequately explained the variation in forecasted zero discharge impact. This is evidenced by the low multiple regression coefficients of 0.30, 0.33, and 0.32.

Independent variables that had significant coefficients at a confidence level of 95 per cent include plant age, changes in plant utility costs, expansion outlook at existing plant location, plant outage frequency, five year capital budget allocation to pollution projects, and the percentage of time that the production manager is involved with environmental protection. Those independent variables that were not significant, and as such, are not relevant to explaining the variation in zero discharge impact include changes in price of raw materials, changes in yields, approach to pollution control.
contain vs. eliminate), proximity to urban areas, percentage of technical staff assigned pollution control projects, and consensus of personnel attitude toward pollution control pressure.
CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

This study set out to describe the impact of environmental protection on chemical plants in the United States. The responses of 508 chemical plants indicate that pollution control pressure has had, is having, and will have substantial impact on the chemical industry.

Conclusions

A number of conclusions can be drawn from the findings of this study. The following paragraphs state and explain the conclusions by referring to the findings from which the conclusions are derived.

Plant Geography

Two thirds of the chemical plants rely on public waterways for disposal (includes return of cooling water pumped from a waterway). Because of the reliance on public waterways for disposal, water pollution legislation has a significant bearing on the chemical industry.

The location of a plant with respect to urban or residential areas has little influence on the pollution control pressure brought to bear on plants. The study tends to support the position that pollution control pressure is becoming more standardized and uniformly applied and is not necessarily in response to complaints from plant neighbors who may be offended by pollution.

Plant Age

Older plants generally tend to have greater pollution problems. This conclusion is based on the following findings: (1) Older plants
receive more pressure in the form of visits from both the EPA and ecological activist groups. (2) Environmental protection has forced greater production curtailments in older plants. (3) Pollution control has resulted in a greater increase in power costs in older plants. (4) The impact of zero discharge has been forecasted to be more severe in older plants. Apparently newer plants have been equipped with pollution control devices so that the influence of environmental protection is not as great as in older plants. It is expected that older plants will also require similar control devices to meet environmental protection standards.

**Compliance Plans**

Thirty-three per cent of the compliance plans submitted to respective states were rejected. These rejections may have been due to unwillingness of plants to meet standards, standards may be impractical, confusion may exist between the plant and the state over what the standards are, and problems may exist between the state and the EPA on what the standards should be. Whatever the reason for rejection, one out of three compliance plans rejected indicates that there is difficulty in administering environmental protection regulations. This difficulty may result in reappraisal of standards, compromises, and/or increased pressure on plants for compliance.

**Production Curtailment**

Chemical plants are averaging 1.08 per cent downtime (as per cent of total time), rate constraints of 1.39 per cent of capacity, and nine outages per year due to environmental protection. Even so, lack of product demand is the consensus reason for operating at less than capacity. For most of the plants, production loss that results from pollution
problems can be offset by temporarily increasing rates above normal after an outage.

Despite the accuracy of the statement that most chemical plants can recover (in a production sense) from a shut down and that lack of demand rather than pollution problems causes production at levels below those desired, it would not be correct to say that shut downs or production curtailments present no problem. First, outages tend to be detrimental to a chemical plant (pp. 44-47). Also, it is possible that constraints due to pollution problems may be contributing to the current shortage of certain chemicals (oil fins, aromatics, natural gas chemicals, fat-based chemicals, and chlor-alkalies). This possibility arises because statements about general industry capacity do not reflect the demand/supply situation for specific chemicals. Two adjacent plants may be operating at 70 per cent and 100 per cent of capacity respectively, and the only difference is that the two plants produce different chemicals. Although their average spare capacity is, say, 15 per cent, the fact of the matter is that there is 30 per cent spare capacity for one chemical and zero spare capacity for the other. A production curtailment in this plant producing at 100 per cent would not result in much change in a statistical sense, but would have great effect on suppliers and users of that chemical.

Product Yields

Product yields have been increased by 0.33 per cent as a result of pollution control. Since chemical plants consume raw materials of

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great value (high volume and/or unit cost), slight improvements in raw material consumption results in large economic benefits.

These benefits may more than offset the expense involved in reducing raw material losses and pollution levels in some plants. Other plants may have only a fraction of pollution abatement costs offset by improved raw material recovery. Any benefits represent direct economic gains because of the likelihood that pollution abatement expenses would have been required regardless of expected benefits. It is also likely that some plants have lowered pollution levels and increased yields through improvements in operating technique, process surveillance, and elimination of poor employee practices. The expense involved in these pollution control improvements probably has been negligible.

**Power Costs**

Plant power or utility costs have been increased by 5.32 per cent as a result of environmental protection. Chemical plants are large consumers of energy, and this increase in plant power costs significantly elevated manufacturing expense. This assessment was made in March of 1973, and since that date, natural gas shortages have forced certain plants to convert to fuel oil in their power generating stations. Environmental protection requires that the fuel oil be of a low sulfur grade. The conversion to low sulfur fuel oil is expected to raise plant power costs even higher than the 5.32 per cent increase measured by this study.

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2 The exact value of raw materials lost in a chemical operation depends on the degree of processing or "value added" by the operation at the stage at which the raw material is lost.

3 Low sulfur fuel specifications are intended to control the emissions of oxides of sulfur.
Personnel Attitude

There is a definite tendency on the part of chemical industry personnel to have a positive attitude toward pollution control pressure. With apparent threat to job security from potential plant closings caused by pollution problems, it was expected that consensus attitude would be somewhat negative. This positive attitude may aid chemical plants in adapting to pollution control pressure. On the other hand, it is quite possible that the positive attitude would change quickly and drastically if reductions in force and layoffs should occur.

Resource Allocation and Staff Assignments

The impression of environmental protection on chemical plant managers is revealed by the manner in which resources and personnel have been allocated to control of pollution. From the findings of this study, it can be concluded that environmental protection is considered to be a major factor in the operation of the chemical plant. This conclusion is based on the following findings related to discretionary resource allocation and staff assignments. (1) Current maintenance spending for pollution control is 5.31 per cent of total maintenance outlay. (2) Pollution control has only a slightly lower maintenance priority than keeping the plant on stream. (3) Pollution control has the same maintenance priority as adherence to preventive maintenance schedules. (4) Pollution capital spending is currently 13.14 per cent of the total capital budget. (5) Forty-four per cent of the plants have an environmental protection department consisting of more than one person. (6) Pollution control work is assigned to 9.29 per cent of the plant technical staff.
Approach to Pollution Control

There is a slight tendency for the approach to pollution control to be oriented toward containment of existing pollution rather than elimination of the source of pollution. Containment of pollution within the confines of the plant draws criticism from land conservationists. These groups claim that land is a scarce national resource and that private ownership of this land does not encompass the right to "destroy or defile" it by using it for waste ponds, dumps, or pollution pits. Land conservationists may bring more pressure to bear on chemical plants to eliminate the source of pollution rather than containing it within plant property.

Land conservationists may receive support from OSHA officials who monitor and regulate exposure of personnel to pollutants within plant property. These officials may require elimination of the source of pollution if containment constitutes a hazard for plant personnel. The significance of this possibility is indicated by the finding that OSHA compliance was of most concern to 30.1 per cent of the responding plants compared to 38.4 per cent that selected water pollution and 27.0 per cent that selected air pollution as the area of most concern. Pressure from land conservationists and OSHA officials may require a change to elimination of the source of pollution. This is likely to result in major capital outlays for process revisions.

Expansion Outlook

The consensus of the plants' expansion outlook indicates that pollution problems will have a slightly negative effect on plant expansion at existing locations. One plant's failure to expand and increase or maintain its market share because of pollution problems will not be
totally offset by a competitor filling this void, since the competitor will probably also have pollution problems. This slightly negative outlook may result in certain chemical shortages in the future.

Zero Discharge

A 1985 zero discharge mandate will, if production managers have correctly assessed the situation, force the closure of 15 per cent of chemical plants in the United States. Although some of the plants would have closed anyway (obsolescence or declining product demand), and although new technology may give other "doomed" plants a reprieve before 1985, it is evident that many existing plants will not be prepared in 1985 for zero discharge.

The pessimism surrounding the future for these plants is likely to have an effect even if zero discharge is not enforced in 1985. If plant personnel genuinely believe that pollution problems will eventually force a closure of their plant, the plant will ordinarily fall victim to a self fulfilling prophesy. Personnel will seek new jobs or transfers to other plants. Critically needed capital funds may be withheld because the pay-back period cannot be extended beyond the expected closure date. Maintenance funds will be spent on only those repair jobs that are absolutely necessary to sustain present operations. Innovations and improvements will likely cease. Expansion plans will be postponed indefinitely. Viability no longer will be a plant goal. Closure will be inevitable, and ironically, pollution problems may be secondary compared to other economic considerations in the final decision for closure. It is expected that pollution problems will initiate the process of self fulfilling prophesy for many chemical plants.
Recommendations for Future Research

This study may be expanded in at least three different ways. First of all, it was expected that the advantage of having anonymous respondents were greater than the disadvantages. The major advantages were anticipated to be a greater response percentage and more candid answers because plants tend to be very cautious in openly committing themselves on this controversial issue. Major disadvantages were that variances could not be linked to characteristics such as company, region, size, or product line, and the return rate could not be improved practically by a follow-up letter to non-respondents. A suggestion for future research is that a similar study be conducted that requires information on plant characteristics described above so that significance of variances may be demonstrated.

A second possibility for expanding the study is to use essentially the same methodology and perform a similar inquiry in several years. This analysis would then indicate influences of environmental protection through time as well as updating the effect of pollution control on chemical plants. This would add a dynamic feature to this research.

A third possibility for extending the study is to limit the scope of the research to less than the entire United States chemical industry. Perhaps additional insight can be gained by examining a certain segment of the plants. This segment may be based on plant size (capital outlay, area, or employment), type of chemical produced (inorganic or organic), type of process (continuous or batch), region, state, or plant age. With this limited scope, a more in-depth inquiry may be possible.

A final suggestion for future research is to expand and more adequately develop models that explain and predict plant reaction to
environmental protection. The scope of this study did not allow significant improvements (higher multiple regression coefficients) to the models presented in Chapters 5, 6, and 8. The primary value of the models that were presented is in representing the factors that are not significant. Research done with a different scope, methodology, and expertise may more adequately develop models that explain and predict plant response to environmental protection.

**A Final Note**

This study concludes with three points. First, it is clear that the influence of environmental protection on the chemical industry is not confined to the chemical industry. Other industries most affected are those that deal directly with chemical plants either as suppliers of raw materials, equipment, supplies, and services or as customers for products produced in the chemical plants. These industries are likely to be affected by changes in the demand, cost, and output structure of the chemical industry. Because the chemical industry is a vital part of our industrial society, all other facets of our economy are indirectly affected.

A second point is that it is obvious that environmental protection has a direct influence on other industries. Industries likely to be affected include petroleum, iron and steel, non-ferrous metals, food processing, mining, pulp and paper, glass, etc. It is suggested that this study on the influence of environmental protection on chemical plants may be useful to the managers of plants in these other industries. It is likely that there are numerous problems common to the chemical plant and other industrial plants.
The third point is directed to policy makers and scholars in our society who initiate, administer, and study change. Protection of the environment mandates significant change for industry in the United States. The effect of this change on chemical plants may provide an input to assist in the ongoing administration of environmental protection as well as the study and formulation of policy for the future enactment of other types of change in our society.
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"Researchers Try to Develop Degradable Plastics for Packaging", Chemical Week, Vol. 109, No. 23 (Dec. 8, 1971), pp. 45-47.


Schwartz, Irvin, "The High Cost of Pollution Control", Chemical Week, May 24, 1972, pp. 59-69.


"State's Compliance with Pollution Rule by Mid-'75 Required", Baton Rouge Morning Advocate, February 2, 1973, p. 14-D.


APPENDIX A

GLOSSARY OF TERMS
GLOSSARY OF TERMS

abatement - decreasing or halting pollution to achieve environmental standards.

aeration pond - a pond that collects and exposes effluents to the atmosphere for cooling and restoration of dissolved oxygen level by spraying into the air.

amalgum - a mixture of two metals united by physical bonding; one metal of the mixture is usually mercury.

"best available" - pollution control guideline for 1983 that generally is interpreted to mean best control system in the industry for a particular application.

"best practicable" - pollution control guideline for 1977 that is interpreted to mean best control system within limits of company resources, age of plant, and other considerations.

chlorine cell - an electrolytic cell that produces chlorine, hydrogen, and sodium hydroxide by passing direct current (d.c.) through a brine (sodium chloride) solution.

compliance plan - a formal plan submitted to respective state regulatory agencies outlining current status of pollution abatement programs (both air and water) and the steps planned to comply with environmental standards; plan includes deadlines for completion of each step.

contract maintenance - plant repair work performed by a contractor on a fee basis; maintenance personnel are employed by the contractor and not the plant.

control system - a plant mechanical system that consists of a sensing device, a controller transmitter, and a regulating mechanism such as a pneumatic or electrical control valve.

cyclone separator - a funnel shaped vessel that separates solids from a liquid or gas stream by centrifugal force acting on the difference between specific gravities of the solid and the liquid or gas in the stream.

decant - removal of liquid from settled solids originally in suspension.
dissolved oxygen - the oxygen content in a liquid at a given temperature.

distillation column - a column that utilizes heat to separate liquids in a mixture by acting on the difference in boiling points.

documented hazard - an element or compound that is known to have harmful effects upon exposure to humans; examples are toxic (poisonous) and carcinogenic (cancer causing) materials.

down time - the amount of time that a chemical plant is not in operation.

dust collector - device that draws dust from process equipment through a vacuum system; the dust is separated by filter bags and is dumped back into the system at an appropriate place.

effluent - liquid discharged outside the plant property from the plant sewer system.

electrostatic precipitator - device that removes particulate solids from a vent stack by acting on static charges possessed by these solid particles.

emission - gaseous discharge outside the plant property from plant vent system.

evaporator - a vessel that uses heat and/or a vacuum to remove liquid from a process stream to elevate concentrations.

filter - device that physically separates solids from a liquid or gas by a screening process.

gas turbine - a rotary mechanism driven by the direct combustion of natural gas.

generator - device that generates electricity from steam boilers, gas turbines, or hydropower.

holding tank - a tank that stores process liquid between reactors or purification systems.

job description - a detailed breakdown of a particular job including job objectives, duties, control points, working conditions, and qualifications for apprenticeship (physical and educational).

lining - a coating or cladding inside of a vessel or pipe that is resistant to process chemicals.
maintenance - repairs and improvements to equipment that will primarily benefit plant operation in the current fiscal year.

mechanic - any employee who is assigned the task of repairing process equipment.

operator - any employee who directly monitors and controls a chemical process.

outage - a plant shutdown during which chemical reactions are stopped and finished products are not produced.

oxidation pond - a pond that kills bacteria through exposure to air or some oxidizing agent such as chlorine.

packed tower - a cylindrical vessel that has numerous uniform plastic or ceramic elements "poured" or placed in this vessel; the purpose is to gain maximum exposure between two phases (gas-liquid, liquid-solid, or solid-gas).

planning and scheduling - the concept of improving maintenance workflow by having non-routine jobs planned in detail to secure parts and necessary supporting services (cranes, welding machines, scaffolds, etc.).

precipitate - solid that is formed in a solution.

process - the "chemical plant" that normally consists of raw material(s) feedings a reactor(s) which feed purification system(s) to produce the finished product.

production manager - the manager accountable for production or plant output.

project work - large scale undertakings that require coordination of a number of special groups - engineering, research and development, construction contractors, legal, marketing, etc.

pump gland - the chamber that holds the packing or seal around the shaft of a pump to prevent leakage from the pump casing.

purification system - an assortment of process equipment to remove contaminants from the product produced in reactors.

rate constraint - a factor that decreases plant output to less than capacity.

reaction - the mutual action of raw materials undergoing chemical change.

reactor - the vessel that contains and promotes the chemical reaction.
reboiler - the steam chest on the bottom of the distillation column that heats the process liquids for distillation.

recycle - the collection of spills and leaks for return to the process.

scrubber - a vessel that exposes a gas vent to a liquid to remove pollutants.

secondary waste treatment - the oxidation of liquid sanitary waste to kill bacteria.

solar evaporation - removal of liquid from waste ponds by exposure to the sun.

start-up - the process of beginning the chemical reaction by starting the feed of raw materials and supporting facilities that promote the chemical reaction.

sump - a below-grade pit that collects spills for processing or return to the system.

total outage - complete plant shutdown including stopping the chemical reaction, purification systems, and any supporting facilities such as utilities.

valve - a device for regulating flows; they are manual or automatic; they can be used for safety purposes (relief valve).

waste pond - generally a shallow pond for collecting plant waste for solid settling, solar evaporation, or chemical treatment.

yields - the ratio of weight of finished product to the weight of raw material used to produce that finished product.

zero discharge - (to be interpreted fully by EPA) no pollutants exit a plant's property.
APPENDIX B

SURVEY - CONDUCT AND RESPONSE

Definition of the Universe

A systematic random sample of 1500 plants was selected from the Directory of United States Chemical Producers. The Directory lists 3983 operating chemical plants in the United States. These 3983 plants are taken to be the universe for this research study. The Manufacturing Chemists Association discloses, however, that approximately 10,000 plants exist in the United States, but these include numerous small distribution terminals, compounders, and other such operations. Such units do not actually engage in chemical process reactions and subsequently are excluded from this study. The listing of plants in the Directory of Chemical Producers is taken to be a significantly complete listing, for it contains all the producers and their subsidiaries listed on the New York and American Stock exchanges, as well as the fifty-three largest chemical producers that constitute Chemical Week's business index. A total and complete listing is available only from the Manufacturing Chemist Association, and the Association has made it a policy not to release such a listing. This list was requested, but the request was denied with an explanation of the non-disclosure policy.
Survey Preparation

The survey sent to these 1500 plants included a cover letter, a 46-element questionnaire, and a self addressed, stamped return envelope. The cover letter and questionnaire are included in Appendix E and F to this study. The questionnaire was pre-tested by seven individuals from three Allied Chemical locations including Baton Rouge, Louisiana; Syracuse, New York and the Corporate headquarters at Morristown, New Jersey. Minor corrections and modifications were made to the questionnaire, and the 1500 member survey was dispatched.

The survey addressee was the plant production manager. This individual was selected as opposed to the plant manager, general manager, or location executive (titles of the top manager at the plant vary from location to location and company to company) because the production manager is more closely involved in the details of the operation and would be more qualified to answer some of the in-depth survey questions. Conversely, a lower ranking addressee would not possess the knowledge to answer some of the general survey questions.

The cover letter included identification of the researcher, purpose of the study, and instructions for answering the questionnaire. The fact that the researcher was a production superintendent at Allied Chemical's Baton Rouge North Works was emphasized in the cover letter. It was expected that this position of the researcher would improve the probability of reply versus an "outsider" attempting to conduct a similar study. This expectation was proven valid for a number of replies because twelve responses were sent to the researcher's plant office in lieu of using the self-addressed return envelope addressed to the
researcher's residence. In addition, three companies called the Allied Chemical's Baton Rouge North Works employee relations superintendent to inquire if the researcher was, in fact, employed at that location.

Also, to enhance the response rate and improve the probability of valid replies, the respondent was requested not to disclose his or his company's identity. The influence of environmental protection on plant operations is controversial, and candid answers to the survey's questions were believed to be more likely with anonymous respondents. The obvious drawback to the non-identity aspect of the survey was that a follow-up letter could not be practically issued because of the lack of respondent identity. Consequently, the survey contains a set of non-respondents that was not reduced through a follow-up letter.

Additionally, due to the controversial nature of the study, the survey extensively used ranges and the semantic differential. This negated direct written responses as well as facilitated completion of the questionnaire. The use of ranges adversely affected precision for some inquiries. The semantic differential, however, promoted precision by providing a means of conveying precise responses to attitudinal type questions.

**Response Rate**

The number of usable responses totaled 508. Of the 1500 questionnaires mailed, sixty were returned not opened due to a variety of reasons (plant shutdown, unclaimed, addressee moved - no forwarding address, etc.). Also sixteen returned questionnaires were not
usable because of incompleteness or misunderstanding of response
directions. In addition to these sixteen invalid responses, six
plants returned blank questionnaires with an explanation of their
policy not to respond to surveys.

On the other hand, twenty-two plants chose to identify themselves
together with a letter of encouragement and interest in the survey
findings. Five plants included a return envelope to receive an
abstract of the study. Moreover, the Illinois Manufacturing Association
received a copy of the survey from an Illinois chemical plant included
in the sample. They forwarded three related studies that they had
undertaken in the state of Illinois in response to EPA pressure. They
also requested a copy of the abstract.

Altogether, the response rate was somewhat rapid. Tables A-1
and A-2 describe the rate by response day and cumulative response
respectively.

The total usable 508 replies represent a 35.27% return of the
1440 questionnaires received (1500 less 60 returned - unopened). It
also represents 12.75% of the universe of 3983 plants listed in the
Directory of Chemical Producers. The response is considered to be
adequate for a valid, meaningful study.

Data Reduction - Analysis

The data from the questionnaire was quantified for reduction and
analysis. Analyses and relationships were formulated with the aid
of General Electric's time sharing computer network. Specifically,
a time sharing terminal was used at Allied Chemical's Baton Rouge
North Works. The software used was General Electrics Mark II -
Statistical Analysis System or "STATSYST." The researcher ran nine program matrices using STATSYST to yield means, standard deviations, multiple regression analyses, covariance matrices, and correlation matrices.
Table A-1

Survey Response by Response Day

<table>
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<th>Questionnaire Received</th>
<th>Response Day*</th>
<th>Questionnaire Received</th>
<th>Response Day*</th>
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*Response day is defined as that day that mail is delivered; therefore, Sundays and holidays are not included as response days.
Table A-2

Cumulative Survey Response

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APPENDIX C

EXPLANATION OF STATISTICAL PROCEDURES
APPENDIX C

Explanation of Statistical Procedures

Sample Proportions:

Sample proportions used in the study are binomially distributed
and defined as the number of "successes" divided by the number of
trials contained in the sample (sample size is defined as number of
responding plants):

\[ p = \frac{x}{n} \]

\( p \) = sample proportion
\( x \) = number of successes
\( n \) = sample size (number of trials)

The standard error derived from the sample proportion is
determined as follows:

\[ s_{ep} = \left( \frac{p(1-p)}{n-1} \right)^{\frac{1}{2}} \]

\( s_{ep} \) = standard error of the proportion

For further explanation, see C. T. Clark and L. L. Schkade, Statistical
Methods for Business Decisions, Southwestern Publishing Co.,
Dallas, Texas, 1969, pp. 298-299.

Sample Means and Standard Deviations:

The sample means described in the study are defined as the
sum of the response values divided by the number of responses. The
responses can take on only those specific values defined by the
ranges available to survey questions. Thus, the answers to survey questions form discrete probability distributions which approximate the binomial distribution (has a wide range of applicability to reality). With large sample sizes such as the 508 respondents to this survey, the normal distribution closely approximates the binomial distribution. Hence, the unit normal curve with area (probability) related to standard deviations can be used to assist in the interpretation of the data from these findings. For further explanation and proof of this procedure, see Roger L. Burford, *Statistics: A Computer Approach*, Charles E. Merrill Publishing Company, Columbus, Ohio, 1968, pp. 160-163.

**Correlation Analyses:**

Sample correlation coefficients are expressions used in this study to measure the interrelationship between two independent variables. This sample correlation coefficient is the maximum likelihood estimator of the universe correlation coefficient (the probability of obtaining the universe correlation coefficient from a set of sample values is a maximum). The sample correlation coefficient has a range from +1 to -1. A positive sign denotes a direct relationship and negative sign denotes an inverse relationship. Values approaching unity (either positive or negative) indicate a very close linear relationship. Values approaching zero are interpreted to mean that the two variables covary in absolute independence of one another and are not related linearly.

The sample correlation coefficient \( r \) is subject to sampling error. Each value of \( r \) derived in this study is tested to determine if a value other than zero is obtained only because of sampling
The "T-Statistic" following each correlation coefficient is used as a test statistic. It is computed as follows:

\[ t = r \left( \frac{n-2}{1-r^2} \right)^{\frac{1}{2}} \]

- \( t \) = correlation coefficient
- \( n \) = sample size

This T-Statistic is checked with \( t \) values of \( n-2 \) degrees of freedom and different levels of significance in a \( t \)-distribution table. If the absolute value of this test statistic is greater than the table values corresponding to a given level of significance, then the correlation coefficient is significant at that given level; if not larger than the table value, then it is not significant at that given level. The study uses the term "level remaining significant" and that means that the \( r \) value is significant at that level but not necessarily lower. For example, the T-Statistic for finding \((2-3)\) is 2.050. It is significant at the 0.05 level, but not significant at the 0.02 level. The study did not attempt to perform a test of significance lower than the 0.001 level. For additional explanation and illustration of this procedure, see C. T. Clark and L. L. Schkade, pp. 558-570 as referenced in discussion of sample proportion.

**Multiple Regression Analyses:**

Multiple regression analyses are used in the study to portray selected dependent variables as a function of selected independent variables. The coefficients of the independent variables were derived from the survey data with the aid of the G.E. STATSYST program.
These coefficients were subjected to a test of significance at the 0.05 level by using T-Statistics. The procedure was similar to that used to test the significance of correlation coefficients (again, see Clark and Schkade, Statistical Methods for Business Decisions, pp. 632-635 for additional explanation).

The value of the multiple regression models lies in their ability to explain variation in the dependent variables by variation in the independent variables. A measure of such value is the multiple regression coefficient which is the percentage of the variation in the dependent variable that is explained by variation in the selected independent variables. This multiple regression coefficient is subject to sampling error and is tested for significance by using the F-ratio test:

\[
F = \frac{R^2}{\frac{1 - R^2}{n-r}}
\]

\[
R^2 = \text{multiple regression coefficient}
\]

\[
r = \text{number of variables}
\]

\[
n = \text{sample size}
\]

This F-ratio was compared with a F-ratio table value at the 0.05 level of significance. If greater than the table value, then it is significant at the 0.05 level. (Again, see Clark and Schkade, pp. 636-638 for additional explanation.)
APPENDIX D

QUANTIFICATION OF THE QUESTIONNAIRE: AN EXPLANATION
OF VALUATION OR WEIGHTING PROCEDURES

Questionnaire Classification

The questionnaire (Appendix F) used in the survey contained 46 questions of six different types:

Type 1: Direct question that solicited a "yes" or "no" answer.
   (Questions I-1, I-4, I-7a, I-7b, I-11, II-12, VII-a)

Type 2: Question that requested selection of the appropriate range that best suited the respondent's plant; one of the alternative ranges was "open-ended" to include all possible replies.
   (Questions I-2, I-3, I-5, I-6, I-9, I-10, II-a-l, II-b, III-a, III-e, IV-a, IV-b, IV-d, V-a, V-b, V-c, VI-a, VI-b, VII-b, VII-c, VII-f)

Type 3: Question that solicited one of three possible responses.
   (Question I-8)

Type 4: Question that had a seven point semantic differential response. (Questions II-c-1, II-c-2, II-c-3, III-b, III-c, III-d, IV-c, IV-8, V-d-1, V-d-2, VII-d, VII-e)

Type 5: Question that requested selection of one of four possible degrees of impact. (Question IV-e)

Type 6: Question that requested selection of one of five possible
degrees of impact. (Questions IV-f, IV-h, VII-g)

Questionnaire Valuation

Questions of type 1 and type 3 did not require a valuation technique. They were used only to determine sample proportions. The balance of questions required a weighting procedure for quantification and data reduction, and the researcher was guided by his survey pretest and procedures for constructing attitude measuring scales by Boyd and Westfall.¹

Type 2 questions solicited the selection of the appropriate range that best suited the respondent's individual situation. Ranges were used for these questions instead of direct requests for specific numbers because of two reasons. First of all, the selection of a range is easier for the respondent and facilitates completion of this lengthy questionnaire. Secondly, the researcher speculated that due to the controversial nature of pollution abatement, respondents would be very hesitant in releasing direct information. The researcher's objective in selecting the range interval sizes was to make them small enough about the predicted modal value to gain close approximations of the actual respondent's data while at the same time encompassing a high percentage of the possible answers. For example, small ranges were placed about the predicted modal value, and an "open-ended" alternative was placed at one extreme to include those responses significantly different from the expected selections. The researcher

was successful in selection of range sizes for only 5.9% of the total
responses were in the "open-ended" range. A thorough investigation
and examination was made to subjectively assign the most likely
values to those replies that were in the "open-ended" range. An
example of this subjective technique was used for question 1-5. The
question requested selection of the range that most closely approximated
the age of the plant. A number of respondents selected the "open-ended"
range, "greater than 30 years". A review of the history of the chemical
industry indicates that numerous chemical plants were built during the
late 1920's, just prior to the Great Depression. It was not until
the late 1930's that wide spread construction resumed. Therefore, the
researcher assigned "44 years" to those values that were "greater than
30 years old." Similar subjective techniques were applied to the
balance of the 5.9% replies that were in "open-ended" ranges.

The standard 7 point semantic differential was used for questions
of type 4. This type question was used to discern priorities and
measured opinions.

Questions of type 5 and 6 used a modification of the Thurstone or
"equal-appearing interval" scale. These scales measured the varying
degrees of ecological impact on selected plant parameters. The type
5 question used "no change," "slight increase," "moderate increase,"
and "large increase" as possible selections. These four response
alternatives were considered to be adequate in portraying the impact.
An additional selection was added to type 6 questions because more
precision and discrimination was required of these responses. For

\[2\text{Ibid., p. 329.}\]
type 5 and type 6 questions, an interval of "one" was placed between "no change" (0) and "slight change" (1) because the researcher believed that "slight" could possibly include just an awareness of environmental protection, without any explicit changes. Intervals of two (2) were placed between the other alternatives because they represented definite "increments of change" in response to environmental protection. This procedure for assignment of values to the intervals was based on the opinions and perceptions of the individuals used in the questionnaire pretest. It is believed that the deployment of this interval valuation achieved accurate response discrimination for data reduction and reporting of results from these questions.
APPENDIX E

SURVEY COVER LETTER
March 17, 1973

(Inside Address)

Dear Sir:

We in the chemical processing industry have never experienced such a significant, uniform, and sustaining force on the conduct of our business and our lives as has been the environmental or ecological movement. To assess the impact a number of reports have been written in trade journals as well as released from the Manufacturing Chemist Association. These reports were written from a macro-level of analysis giving aggregates and composites. For the expediency of aggregation and generalization, many significant details are necessarily omitted.

To more clearly assess the impact of the environmental movement on the chemical processing industry, I have embarked upon a micro-level study of the individual chemical plants. This study will culminate in a doctoral dissertation at Louisiana State University. The enclosed questionnaire is designed to reveal and assess the multifaceted impact of the ecological movement on plant operations. Objectives of the study are to give additional information to the leaders of our industry that may bring about adjustments to improve operations and facilitate the difficult task of plant management. To social pressure groups as well as the regulatory agencies, it may depict the effects of such control pressures so that "reasonable judgments" can off-set a tendency to hysteria.

The study is not intended to probe into proprietary areas. To protect against such an invasion, two safeguards are used: first the responses are to be strictly non-identifiable and secondly, the use of "ranges" negates a request for direct information. 1500 such questionnaires are being sent out so tracing down an individual respondent would be nigh impossible and no such attempt is planned anyway.

The questionnaire is very simple. Not a single word of prose nor a single number is requested. Responses to questions are made with a simple check (X). Not all of the information asked is readily available to you, so give your best estimate, or "guestimate." Perception plays a key part in some of the replies, so indicate "what you feel" as well as "what you know." Some of the replies ask for a simple "yes or no." Others have a range of possible answers. For example, if your plant is located 4 miles to the nearest residential area,
indicate this as follows:

Less than __1 mile__ 3 miles X 5 miles _ 8 miles_ 16 miles

Greater than 16 miles __.

Other responses reflect positions of attitudes of varying degree of intensity between two poles or criteria. For example, if environmental controls have forced a moderate increase in area of coverage by shift supervisors, please indicate as follows:

Greater ____ X _______ no ________ Less
area ________ ____ _________ area

of much moderately slightly change slightly moderately much of Coverage Coverage

Please asstempt to answer all questions and again indicate "what you feel" as well as "what you know." Also, respond to each question with only a single check (X). Won't you please take a few minutes and fill out the enclosed questionnaire? Then place it in the self-addressed and postage paid envelope for return. Not only will it do me a great personal favor, but may in some small way help all of us to adapt to this great force -- environmental controls. I use the pronouns, "we" and "us", for I am a production superintendent at Allied Chemicals' Baton Rouge North Works.

Thank you very much for your time.

Sincerely yours,

Joe C. Iverstine

Enclosure
APPENDIX F

QUESTIONNAIRE
QUESTIONNAIRE

I. General Information

(1) Does your plant discharge "anything" into a public stream? (includes return of once through cooling water).
___yes     ___no

(2) What is your plant's proximity to nearest urban area?
Within urban, Less than __2 miles___ 4 miles ___ 8 miles ___ 16 miles, Greater than 16 miles ___

(3) What is your plant's proximity to the nearest "residential areas"?
Less than ___ 1 mile ___ 3 miles ___ 5 miles ___ 8 miles ___ 16 miles, Greater than 16 miles ___

(4) Are there other plants or industries within a 10 mile radius of your plant with waste disposal that comes under environmental legislation?
___yes     ___no

(5) How old is your plant?
Less than ___ 2 years ___ 4 years ___ 8 years ___ 16 years ___ 30 years, Greater than 30 years ___

(6) Total communications with ecological activist groups (does not include EPA).
___No contacts, Less than ___ 3 times ___ 6 times ___ 9 times ___ 15 times, More than 15 times ___

(7) Have you submitted a compliance plan within the past 2 years to your state?
___yes     ___no

If yes, has this plan been fully approved? ___yes ___no.

(8) Which of the following is of most concern to your management? (Please select only one)

Air Pollution  Water Pollution  CSHA Compliance

(9) How many visits have you received from the EPA within the last year?
___None, Less than ___ 2 ___ 4 ___ 8 ___ 10 ___ 15, Greater than 15 ___

(10) What percentage of the manufacturing, mining, and processing industry within a 20 mile radius of your plant does your plant account for.
Less than ___ 4% ___ 15% ___ 25% ___ 50% ___ 75% ___ Greater than 75% ___

(11) Does your plant treat or assist in treating municipal waste?
___yes     ___no

(12) Does your plant use municipal waste treatment facilities?
___yes     ___no
II. Production (applies to existing units still in operation)

(a) Downtime due to environmental controls:

(1) Unit outages as % of time:

<table>
<thead>
<tr>
<th>%</th>
<th>Less than 2%</th>
<th>4%</th>
<th>6%</th>
<th>10%</th>
<th>Greater than 20%</th>
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<tr>
<td></td>
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</tbody>
</table>

(2) Frequency (unit outages/month):

<table>
<thead>
<tr>
<th>%</th>
<th>Less than 2%</th>
<th>4%</th>
<th>6%</th>
<th>10%</th>
<th>Greater than 12%</th>
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<tbody>
<tr>
<td></td>
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</table>

(b) Rate constraints due to environmental controls (as % of capacity):

<table>
<thead>
<tr>
<th>%</th>
<th>Less than 3%</th>
<th>5%</th>
<th>8%</th>
<th>12%</th>
<th>Greater than 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(c) If less than capacity, reasons compared to environmental constraints (select sales, technology and/or other as compared to environmental)

DUE TO:

<table>
<thead>
<tr>
<th>%</th>
<th>Entirely</th>
<th>Mostly</th>
<th>Slightly</th>
<th>Slightly</th>
<th>Entirely</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

III. Yields, Quality, and Utility Costs (as affected by environmental controls)

(a) Change in yields:

(1) No change

(2) Increase: Less than 2% | 4% | 6% | 10%, Greater than 10%

(3) Decrease: Less than 2% | 4% | 6% | 10%, Greater than 10%

(b) Change in quality of raw materials required to meet environmental standards:

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<tr>
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<th>Higher</th>
<th>Lower</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Moderately</td>
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<tr>
<td></td>
<td>Slightly</td>
<td>No change</td>
</tr>
<tr>
<td></td>
<td>Slightly</td>
<td>Moderately</td>
</tr>
<tr>
<td></td>
<td>Much</td>
<td></td>
</tr>
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</table>

(c) Change in quality required of your final product to meet standards:

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<tr>
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<th>Higher</th>
<th>Lower</th>
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</thead>
<tbody>
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<td>Much</td>
<td>Moderately</td>
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<tr>
<td></td>
<td>Slightly</td>
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<td></td>
<td>Slightly</td>
<td>Moderately</td>
</tr>
<tr>
<td></td>
<td>Much</td>
<td></td>
</tr>
</tbody>
</table>

(d) Perceived change in price of raw materials that was caused by environmental legislation:

(1) No perceived change

(2) Do not know if change caused by environmental problems

(3) If change caused by environmental problems, please specify
(a) Impact on plant utility costs:

(1) No change
(2) Lower costs: Less than 2% 4% 6% 8% 10%, Greater than 10%
(3) Higher Costs: Less than 2% 4% 6% 8% 10%, Greater than 10%

IV. Manpower (as affected by environmental controls):

(a) Change in number of operators

(1) No change
(2) Fewer: Less than 2% 4% 6% 12% 20%, Greater than 20%
(3) More: Less than 2% 4% 6% 15%, Greater than 15%

(b) Change in number of maintenance personnel (including contract maintenance)

(1) No change
(2) Fewer: Less than 2% 6% 12% 20%, Greater than 20%
(3) More: Less than 2% 4% 8% 15%, Greater than 15%

(c) Change in process coverage by foreman or shift supervisor caused by environmental controls.

Greater area less area
of coverage of coverage

Much Moderately Slightly No change Slightly Moderately Much

(4) Change in required number of foremen and shift supervisors caused by added environmental responsibilities:

(1) No change
(2) Fewer: Until shutdown
(3) More: Less than 2% 4% 6% 8%, Greater than 8%

(e) Change in personnel training required by ecological forces (both salaried and hourly).

No change Slight increase Moderate increase Large increase

(f) Change in job design or description for operators:

No change Slight change Moderate change Large change Total revision

(g) Consensus of personnel (hourly and salaried) attitude toward ecological pressures:

Positive

Very Moderately Slightly No response Slightly Moderately Very

Negative

(5) Personal stress experienced by production manager as a result of environmental related problems (strictly your opinion).

None Slight Moderate Significant Extreme degree degree degree degree
V. Maintenance

(a) Estimated % of maintenance costs directed primarily at controlling or reducing emissions and effluents:

0%, Less than 2% 6% 10% 20%, Greater than 20%

(b) Estimated % maintenance costs will increase through maintaining pollution control facilities to be installed over next 5 years:

0%, Less than 4% 8% 16% 30%, Greater than 30%

(c) Possible reduction of current maintenance spending due to fewer leaks, less emissions, and related pollution control measures that may also reduce corrosion and/or attack of equipment:

No reduction, Less than 1% 2% 5% 10%, Greater than 10%

(d) Priority rendered maintenance directed at pollution control as compared to other maintenance priorities:

1) Keeping Plant on stream


POLLUTION CONTROL

2) Keeping preventive maintenance schedules


POLLUTION CONTROL

VI. Capital Budget:

(a) Percent of capital budget devoted to pollution control:

0%, Less than 4% 8% 12% 20%, Greater than 20%

(b) Percent of capital budget over next 5 years predicted to be devoted to pollution control:

0%, Less than 5% 10% 15% 25%, Greater than 25%

VII. Technology, Administration, and Planning:

(a) Do you have an "in-house" environmental service department consisting of more than one man? Yes No

(b) Percent of total engineering or technical manpower devoted to environmental problems:

0%, Less than 5% 10% 15% 25%, Greater than 25%

(c) Percent of time that you, as production manager, devote to environmental problems:

0%, Less than 5% 10% 15% 25%, Greater than 25%
(d) Impact on expansion outlook at present location (for example, positive outlook would include production of products for pollution control or enjoy much favorable position relative to competitor's ecological problems; whereas negative outlook would include decreasing probability of expansion due to pollution problems facing your plant):

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<th>Negative</th>
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<td>Highly</td>
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<tr>
<td>Slightly</td>
<td>Slightly</td>
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<tr>
<td>No impact</td>
<td>No impact</td>
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<td>Slightly</td>
<td>Moderately</td>
</tr>
<tr>
<td>Moderately</td>
<td>Highly</td>
</tr>
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</table>

(e) Major pollution control technology advancements seen for your location over the next 5 years:

- No significant changes
- or
- Directed at controlling existing pollution:
  - Entirely
  - Large majority
  - Majority
  - Large
  - Entirely majority

(f) Land acquisitions projected over next 5 years to meet control standards (as percent of present site size):

- Less than
- 4%
- 8%
- 15%
- 30%
- Greater than 30%

(g) Impact of a "zero discharge order" on your plant forecasted for 1985:

- No impact
- Minor capital outlay
- Moderate capital outlay
- Major capital outlay
- Shut down outlay
APPENDIX G
DATA FROM COMPUTER PROGRAMS
PROGRAM I

\( y \) = personal stress experienced by production manager

\( X_1 \) = proximity to residential areas

\( X_2 \) = age of plant

\( X_3 \) = communications with ecological activist groups

\( X_4 \) = EPA visits

**Multiple Regression Analysis**

<table>
<thead>
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<th>Standard Error</th>
<th>T-statistic</th>
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<td>( X_4 )</td>
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Intercept = 2.477

F-Ratio = 8.278

Multiple Regression Coefficient = 0.249

**Covariance Matrix**

\[
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X_1 & X_2 & X_3 & X_4 & Y \\
X_1 & 8.49 & -8.69 & -1.13 & -0.19 & 0.08 \\
X_2 & -8.69 & 208.60 & 19.24 & 6.17 & 1.39 \\
X_3 & -1.13 & 19.24 & 42.01 & 3.74 & 2.41 \\
X_4 & -0.19 & 6.17 & 3.74 & 9.98 & 1.15 \\
Y & 0.08 & 1.39 & 2.41 & 1.15 & 3.71
\end{bmatrix}
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<tr>
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**Correlation Matrix**

<table>
<thead>
<tr>
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<th>X₃</th>
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<tr>
<td>Y</td>
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<td>0.050</td>
<td>0.193</td>
<td>0.188</td>
<td>1.000</td>
</tr>
</tbody>
</table>
PROGRAM II

Y = personal stress experienced by production manager

X₁ = attitude of personnel
X₂ = plant's percentage of complex size
X₃ = unit downtime as percent of total time
X₄ = communication with ecological activist groups

Multiple Regression Analysis

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-statistic</th>
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Intercept = 1.965

F-Ratio = 9.731

Multiple Regression Coefficient = 0.268

Covariance Matrix

<table>
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<tr>
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<th>X₂</th>
<th>X₃</th>
<th>X₄</th>
<th>Y</th>
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**Correlation Matrix**

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<tr>
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</table>
PROGRAM III

Y = consensus attitude of personnel
X₁ = change in number of operators
X₂ = change in number of maintenance personnel
X₃ = change in number of foremen
X₄ = change in personnel training

**Multiple Regression Analysis**

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Coefficient</th>
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Intercept = 4.716
F-Ratio = 0.687
Multiple Regression Coefficient = 0.074

**Covariance Matrix**

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**Correlation Matrix**

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PROGRAM IV

Y = percent time production manager spends on environmental problems

X₁ = change in process coverage by foremen
X₂ = change in job description for operators
X₃ = age of plant
X₄ = rate constraint as percent of capacity

Multiple Regression Analysis

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<tr>
<th>Independent Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-statistic</th>
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Intercept = -0.709

F-Ratio = 15.827

Multiple Regression Coefficient = 0.334

Covariance Matrix

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**Correlation Matrix**

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PROGRAM V

Y = impact of zero discharge
X₁ = age of plant
X₂ = impact on plant utility cost
X₃ = change in price of raw material
X₄ = change in yield

Multiple Regression Analysis

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<tr>
<th>Independent Variable</th>
<th>Coefficient</th>
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<th>T-statistic</th>
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Intercept = 1.442
F-Ratio = 12.479
Multiple Regression Coefficient = 0.300

Covariance Matrix

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**Correlation Matrix**

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PROGRAM VI

Y = Impact of zero discharge
X₁ = change in control technology
X₂ = impact on expansion at present site
X₃ = outage frequency (unit outages/month)
X₄ = proximity to urban areas

Multiple Regression Analysis

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<th>T-statistic</th>
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Intercept = 4.664
F-Ratio = 15.837
Multiple Regression Coefficient = 0.334

Covariance Matrix

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**Correlation Matrix**

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PROGRAM VII

Y = percent maintenance costs increase over next 5 years
X_1 = percent maintenance costs at present
X_2 = age of plant
X_3 = maintenance priority: on stream vs. pollution
X_4 = maintenance priority: preventive maintenance vs. pollution

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<th>Independent Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-statistic</th>
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<tbody>
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Intercept = 3.492
F-Ratio = 80.355
Multiple Regression Analysis = 0.624

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**Correlation Matrix**

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PROGRAM VIII

Y = percent technical staff assigned to pollution work
X₁ = change in quality of raw material
X₂ = change in quality of finished product
X₃ = percent of most recent capital budget for pollution
X₄ = percent of capital budget over next 5 years for pollution

Multiple Regression Analysis

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<th>T-statistic</th>
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Intercept = 3.237

F-Ratio = 66.094

Multiple Regression Coefficient = 0.587

Covariance Matrix

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<tr>
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<td>0.85</td>
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<td>9.74</td>
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<tr>
<td>$X_4$</td>
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<td>10.07</td>
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</tr>
<tr>
<td>$Y$</td>
<td>9.29</td>
<td>9.21</td>
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</tbody>
</table>

**Correlation Matrix**

<table>
<thead>
<tr>
<th></th>
<th>$X_1$</th>
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<th>$X_3$</th>
<th>$X_4$</th>
<th>$Y$</th>
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<tr>
<td>$X_1$</td>
<td>1.000</td>
<td>0.533</td>
<td>0.078</td>
<td>0.028</td>
<td>0.020</td>
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<tr>
<td>$X_2$</td>
<td>0.533</td>
<td>1.000</td>
<td>0.120</td>
<td>0.035</td>
<td>0.083</td>
</tr>
<tr>
<td>$X_3$</td>
<td>0.078</td>
<td>0.120</td>
<td>1.000</td>
<td>0.671</td>
<td>0.527</td>
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<tr>
<td>$X_4$</td>
<td>0.028</td>
<td>0.035</td>
<td>0.671</td>
<td>1.000</td>
<td>0.542</td>
</tr>
<tr>
<td>$Y$</td>
<td>0.020</td>
<td>0.083</td>
<td>0.527</td>
<td>0.542</td>
<td>1.000</td>
</tr>
</tbody>
</table>
PROGRAM IX

\( Y = \text{impact of zero discharge} \)

\( X_1 = \text{percent capital budget over next 5 years devoted to} \)

\( X_2 = \text{percent technical staff assigned to pollution work} \)

\( X_3 = \text{percent of time that production manager spends on pollution} \)

\( X_4 = \text{consensus of personnel attitude toward pollution pressure} \)

**Multiple Regression Analysis**

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-statistic</th>
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<tr>
<td>( X_1 )</td>
<td>0.042</td>
<td>0.001</td>
<td>4.241</td>
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<tr>
<td>( X_2 )</td>
<td>0.015</td>
<td>0.011</td>
<td>1.339</td>
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<tr>
<td>( X_3 )</td>
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<td>0.001</td>
<td>2.068</td>
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<tr>
<td>( X_4 )</td>
<td>-0.095</td>
<td>0.059</td>
<td>-1.616</td>
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</table>

Intercept = 3.678

F-Ratio = 14.219

Multiple Regression Coefficient = 0.319

**Covariance Matrix**

\[
\begin{array}{cccccc}
  \text{X}_1 & \text{X}_2 & \text{X}_3 & \text{X}_4 & \text{Y} \\
\text{X}_1 & 99.77 & 50.15 & 24.86 & -0.80 & 5.57 \\
\text{X}_2 & 50.15 & 85.64 & 31.45 & -0.71 & 4.17 \\
\text{X}_3 & 24.86 & 31.45 & 68.12 & 0.38 & 3.03 \\
\text{X}_4 & -0.80 & -0.71 & 0.38 & 1.98 & -0.22 \\
\text{Y} & 5.57 & 4.17 & 3.03 & -0.22 & 3.80 \\
\end{array}
\]
<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
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<tr>
<td>X₂</td>
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<tr>
<td>X₄</td>
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<td>1.41</td>
</tr>
<tr>
<td>Y</td>
<td>4.22</td>
<td>1.95</td>
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</table>

**Correlation Matrix**

<table>
<thead>
<tr>
<th></th>
<th>X₁</th>
<th>X₂</th>
<th>X₃</th>
<th>X₄</th>
<th>Y</th>
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<td>X₂</td>
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<td>1.000</td>
<td>0.412</td>
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<td>0.231</td>
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<td>X₃</td>
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<td>0.412</td>
<td>1.000</td>
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<td>-0.054</td>
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<td>Y</td>
<td>0.286</td>
<td>0.231</td>
<td>0.188</td>
<td>-0.082</td>
<td>1.000</td>
</tr>
</tbody>
</table>
VITA

Joe C. Iverstine, Jr., the son of Joe C. Iverstine and Rita Mae Addison Iverstine, was born in Tickfaw, Louisiana on December 24, 1942. He received his elementary and high school education in Hammond, Louisiana, graduating in May, 1960.

He received the degree of Bachelor of Science from Southeastern Louisiana University in 1964. In December, 1964, he became a technical assistant at Allied Chemical in Baton Rouge, Louisiana. He married the former Ethel Kay Baker of Ocilla, Georgia on January 1, 1966.

In January, 1966, he began taking evening courses at Louisiana State University and received the degree of Master of Business Administration in 1970. He continued with evening courses there until the fall semester of 1972. At that time he became a full time student and worked part time at Allied Chemical. He was a Special Lecturer teaching business policy in the College of Business Administration during the 1972-73 term.

He is at present a candidate for the degree of Doctor of Philosophy in Management. He recently was Superintendent of Alkali Operations at Allied Chemical, but is currently an Associate Professor at Southeastern Louisiana University.
Candidate: Joe C. Iverstine, Jr.

Major Field: Management

Title of Thesis: The Impact of Environmental Protection on Chemical Plant Management: A Descriptive and Exploratory Analysis

Approved:

Edmund R. Gray
Major Professor and Chairman

James L. Fraynham
Dean of the Graduate School

EXAMINING COMMITTEE:

Stephen W. Brown
Raymond L. Groth
Michael S. Hodges
F. Max Helton

Date of Examination:

November 19, 1973