Date: August 5, 1955

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Title of Study: METAL FINISHES APPLICABLE TO THE SCHOOL SHOP

Number of Pages: 51 Candidate for What Degree: Master of Science

Under Direction of What Department: Industrial Arts Education and Engineering Shopwork

Scope of Study: The information presented in this study was derived from technical publications in the area of metal finishing. An attempt is made to note the significance of the subject by a survey of other studies and periodicals related to metal finishing in industrial arts metalworking courses. An interpretation of the processes of metal finishing which are adaptable to the metal shop is made in an effort to simplify the technicalities of the subject. The processes surveyed are divided into two broad areas of metal finishing. Those based on mechanical surface treatment are reviewed first. A detailed study of the chemical surface treatments is then made. Equipment to be used is discussed and comments are made on the fabrication of portions of the equipment.

Findings and Conclusions: The investigation resulted in the observation that there are many industrial finishing processes which can be adapted to the school shop. Some of these are presently used for finishing metal projects, while others are entirely new to industrial arts metalworking. Very few studies have approached the problem of metal finishing. Instructors may vary the mechanical treatment given metal to produce a finished surface with a minimum of revision in the present equipment of the metal shop. The tendency of most instructors is to use organic finishes. Metal finishes can be enhanced by using electroplating. Vitreous coatings are easily applied to small metal objects and represent a parallel to industrial experiences. A list of recommended equipment to broaden the finishing area is given. Five additional studies in the area of metal finishing are suggested as being of value to industrial arts metalworking. A final recommendation is made concerning the reporting of major researches in periodical literature.

ADVISER'S APPROVAL L. H. Bengtson

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By

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Bachelor of Science

Oklahoma Agricultural and Mechanical College

Stillwater, Oklahoma

1949

Submitted to the Faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE
1955

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ACKNOWLEDGMENT

The writer wishes to express his appreciation of the assistance and guidance given during the preparation of this report by his advisor, Mr. Leroy H. Bengtson, Associate Professor, School of Industrial Arts Education and Engineering Shopwork, Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma.

The first indication of the need for this investigation was from the metal shop instructors of the Tulsa Public Schools, Tulsa, Oklahoma. For their insight and encouragement, I am greatly indebted.

Also, I am sincerely grateful for the leadership and counsel given by my friend, Morris J. Ruley, Supervisor, Industrial Education Department, Tulsa Public Schools, Tulsa, Oklahoma.

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CHAPTER I

A LOST ART IN THE METAL SHOP

The art of metal finishing is indeed lost among the machines and workbenches, the routine and records, and the hurry and scurry of the industrial arts metal shop. The students of tomorrow will be those with the loss, for their heritage in an industrial world will be lacking in an understanding of the scope of metal finishing processes and techniques. The importance of all youth having equal opportunity for education is even more significant when the mobility of the population between the ages of eighteen and twenty-five is taken into account. The wise instructor is one who challenges students by guiding their experiences in the many metal finishing processes and who knows that even students with rural backgrounds have basically the same needs as urban students. All youth are destined to become users of industrial products, and possibly fabricators of industrial might.

Some benefit may be gained by taking a critical look at the efforts of metal shop instructors to see if the area of metal finishing has been overlooked. The avenue to enlightenment for both instructor and student is made shorter once the initial steps have been taken. It is not probable that the entire area of metal finishing lacks the attention of the instructor and student. There is, however, some question as to the impetus which the finishing program receives. The arousing of curiosity and presentation of new experiences may result in a better metal-working program and a better informed consumer.

Need for the Study. The writer has undertaken the preparation of a report on metal finishes for both the enlightenment of himself and others who might have a similar need. After a few months of instructing classes in metalwork, it was apparent that various industrial arts departments give lip service to the honorable objectives of:

> . . . developing an acquaintanceship with and some skill in using common tools, machines, and construction methods, a vocational foundation and a better understanding and appreciation of modern industry, and an ability to judge quality and design in the products of industry. (3, page 193)

The student inevitably resorts to a paint brush and a can of enamel or lacquer. With these tools, he is expected to simulate the quality of finish on our modern automobiles, and often with little or no previous instruction.

If these objectives are to be met throughout the industrial arts program, all students must have the opportunity to experience the techniques of industrial progress under proper guidance. The boy who today spoils the appearance of a project because of an inappropriate choice of finish, color clash, or lack of instructional preparation, will tomorrow be one of the first disgruntled consumers, wary, quizzical, and dubious concerning the products of a "mystical" American industry. In many cases, projects are left to be finished by the instructor or by an advanced student who is familiar with the equipment. The learning in this situation is often one of resentment.

Organic Coloring. The use of organic vehicles and pigments is generally accepted as the standard finish in school shops. However, a glance at a dime-store counter will reveal an amazingly different situation in the products of free enterprise. Some manufacturers have spent much labor and money in tooling up for a product, leaving the finish as a matter of fact item, and find that the product does not sell. Likewise, many teachers have observed the enthusiasm of students at the initial planning and fabrication steps of project completion only to have that enthusiasm wane and die due to the lack of "sales appeal" after finishing. Every student desires the admiration and commendation of not only the teacher, but also, and probably more important, that of his fellow students and parents. The "sales appeal" of a student's work provides for him pride and satisfaction in the completed project. All teachers of industrial arts should be aware of the necessity of aiding students in the selection of a proper type of finish, color, and application methods. For after all, is this not consumer education? Every student enters life as a consumer and continues consuming throughout his lifetime.

Witness the trend of finishes applied to automobile bodies to learn of the importance of finishes as correlated with better industrial processes and increased sales. In 1910 the standard automotive finish was black enamel requiring forty-eight hours or longer to dry. However, the late twenties were accompanied by demands for faster production methods. Consequently, japanning finish, a baked coating which at that time had a very limited range of dark colors, was used to reduce drying time to one-half that of former years. Production demands have set a tremendous pace in the last decade as illustrated by the insistance of Mr. Kettering of General Motors for an automotive finish which would dry in one hour. The zooming saleability of "two-tone" and now "tri-tone" finishes in no longer standard colors but in every pastel hue and brilliant color created by the chemist's wand is further proof that the finish of a product is of utmost importance.

Yet we seem harnessed to the finishing processes of yesteryear which relied on black enamel and the bristle brush. If finishing processes among metal fabricating plants applied to give the desired surface appearance represented nearly ten per cent of the total value of the products produced in 1946, surely a metalworking program in today's schools which allots even five per cent of the instructional effort to finishing could produce untold dividends. This would result in achieving the enriched objectives of exploration, of a better understanding through exploration of finishing processes, and of consumer knowledge based on facts experienced through exploration, craftsmanship and design qualities of the project, and certain skills in the basic processes, materials, and machines of metal finishing. It can be a challenge to the metal shop instructor to bring his students out of the "dark ages" when metal was black and therefore was finished in black. The methods and processes surveyed as adaptable to industrial arts metal shops are merely indicative of what may be undertaken in establishing a full program of metal finishing to enhance the student's learning opportunity in metalworking.

Definitions. The definitions presented in the following list are of terms which will aid in the understanding of the technical aspects of this report.

Anode. The positive electrode in electrolysis. (7, page xi)

Cathode. The negative electrode in electrolysis. (7, page xiii)

Electrochemistry. That branch of science which treats of the interconversion of chemical and electrical energy. (7, page xiv)

Electrode. A conductor of metallic class through which a current enters or leaves an electrolytic cell; at which there is a change from conduction by electrons to conduction by charged particles of matter. (7, page xiv)

Electrodeposition. The process of depositing a substance upon an electrode by electrolysis. (7, page xiv)

Electrolysis. Production of chemical change by passage of a current through an electrolyte. (7, page xv)

Electrolyte. A substance which when dissolved in a solvent (usually water) produces a conducting medium. 7, page xv)

Paint or Organic Coating. A mixture of pigment with some suitable liquid when spread in a thin film forms a solid. (4, page 1)

Porcelain or Vitreous Enamel. A glass which has been or can be caused to adhere to a metal or other enamel by proper application and fusion. (1, page 56)

It has not been the purpose to present a resume of the technical information which was surveyed. Therefore, the terms used in this study are elementary in the various fields of metal finishing.

Investigation Procedure. Initial research on the problem of metal finishes was done through a library study of the literature of the field. This enabled the writer to become further acquainted with the practices of the industry and the nomenclature. At this point, it was felt that additional information was needed which could only be obtained by visits to some of the various metal finishing plants. In order to evaluate and see in operation the processes and machinery, visits were made to the Southwest Metal Finishing Company, Tulsa, Oklahoma, and the Southwestern Porcelain Steel Corporation, Sand Springs, Oklahoma.

The second step was an additional library study of the literature of the industrial arts area of metalworking to learn of the efforts made previously to provide specific metal finishing experiences in the metal shop. It was anticipated that this survey would give an indication of the processes of metal finishing being used for instructional purposes and the relative importance of each by noting the frequency of mention.

The third step was to summarize the processes, materials, and equipment, with serious thought being given to those having special significance or adaptability for the metal shop. In that way, not only the current practices of the industry but also the newest innovations would receive equal consideration for this specific problem. As an outcome of the summary, certain recommendations can be made to aid in the establishment of a broad program of metal finishing in industrial arts metal shops.

Literature. A great deal of resource material consisting of books, periodicals, and trade literature is available. The inclusive title of the specific process of metal finishing was traced through numerous reference materials. This in turn led to further investigation of the detailed processes and materials. The reports made to several scientific societies were worthwhile in securing both historical and research data.

Organization of the Report. "A Lost Art in the Metal Shop" is intended to arouse interest and to present a true perspective of the significance of the problem. It prepares a reader for the ensuing chapters of historical, informational, and applicational nature. The chapter "Development of Metal Finishes" gives the background of metal finishing in three separate areas: (1) organic, (2) metallic, and (3) vitreous. The current trends are noted with thought toward the implications for school metal shops. The chapter "A Viewpoint of Industrial Arts Metalworking" is intended to present the philosophical attitude of the writer, as well as those attitudes which are necessary before the recommendations of this report are put into effect if the prescribed objectives are to be achieved. Each of the three areas of metal finishing has many individual processes as applied by industry. However, in "Metal Finishing Processes", an attempt is made to present authoritative information concerning those processes most adaptable to the metal shop. Consideration is given to the educational value, practicability for utilitarian purposes, and economical factors which are restraints on the extent to which the program can be carried. "Conclusions, Recommendations, and Operating Data" gives observed influences affecting a broadened program of metal finishing and records the factual information to be used in adopting the recommended practices. In addition to the bibliography, the appendices list the suppliers of equipment and materials which are surveyed by the report. This is intended to aid the individual instructor in the follow-up of his particular problem.

In short, the writer, in the initial teaching experiences in industrial arts metalworking, sensed a void in the lives of the students. The need of students to be informed of additional metal finishing techniques is real enough to warrant the investigation made in this report. Beginning with the historical importance of metal finishing and continuing through the most recent discoveries, the objective of an enrichment of the metal finishing program of the school metal shop is the ultimate goal.

CHAPTER II

DEVELOPMENT OF METAL FINISHES

The earliest efforts to paint and decorate surfaces were made on the walls of caves by prehistoric man before the Ice Age. It was not until the first metals, presumably of nonferrous nature, were discovered and refined, that a protective coating was applied to metal for that specific purpose. Metallic coatings consisted of dipped articles until the works of Galvani and Volta enabled experiments with high electromotive forces. Siliceous coatings or enamelings have been authoritatively dated as early as the Fourth Century before Christ. The Industrial Revolution and its repercussion gave impetus to the metal finishing industry as it is known today.

Part A

Early Organic Finishes

The use of organic materials dates with accuracy to the Paleolithic Period. Archeologists have found murals on the walls of caves in Spain which were sealed shut in the landslides of that age. The primary use of pigments prior to the Machine Age was for artistic and decorative purposes. Since the middle of the Nineteenth Century, the demand for coatings on metal surfaces, not only to decorate but also to protect, has increased in direct proportion with the increased use of metals.

First Industrial Coatings. Knowledge of processes in the manufacture of paints and varnishes was largely regarded as secret information.

The publication of a book on the formulation of varnishes in 1736 was left unrevised as the industry's handbook until about 1900. Paints and varnishes lacked the qualities desired by metal fabricators. With the aid of chemical research, new vehicles and driers were discovered which had specific advantages over the earlier standard products.

Growth Through Demand. The progress made by the organic finishing industries was very closely interwoven with the development of new uses for these finishes. W. von Fischer, in Organic Protective Coatings, explains the growth and the problems arising in this manner:

> None of the industrial arts . . . has been given as much attention by modern scientists. The reason is not difficult to find: it is the fact that modern technology is based on steel and on nonferrous metals.
>
> Metals are subject to chemical decomposition . . . .
>
> While the coatings of medieval origin were able to satisfy the more modest demands of the nineteenth century industrial era, with respect to protective properties, they were not good enough for the twentieth, as most of them were not originally adapted for the protection of metals. (5, page 3)

Since metals were the key to the growth of the finishing industry and more severe environments were encountered by metal products, the early organic finishes were found lacking not only in protective qualities but also in decorative qualities. The progress which was made in the metal working industries simply could not wait for the time-consuming finishing procedures. Thus the demand for time-saving finishes became an economic factor rather than just one of convenience.

Modern Practices. The recent progress in coatings is the result of the research and the close cooperation with allied areas of engineering. The organic finishing industry, once dependent altogether on the varnishes, has been forced to develop the synthetics, which are the product of the last thirty years of research in plastics. As a result of the new coating materials, there has been a continuing list of new methods of applying and drying finishes. Organic chemists are at work solving tomorrow's problems of not only corrosion protection but also protection from the extremes of heat and cold, air friction at sonic speeds, marine growth, and radioactive radiation.

The ancient arts of painting are not lost to antiquity. Neither are the great demands now pacing the organic finishing industry lost in confusion. The answer for many of the future problems lies in the combining of principles of the past with research of the present, thus producing metal finishes for the future.

Part B

Origin of Metallic Finishes

The earliest attempts or use of metals to clad other metals and thus impart new and different surface characteristics has gone unrecorded through the centuries. This lack of record is no doubt a result of the failure of the attempts. With early experimentation based on electricity and discovery of the fundamental laws of electrochemistry, metal finishing using metallics became first a laboratory reality and then an industrial process for the purpose of surface protection and enrichment.

Discovery and Development in the Nineteenth Century. Records of the earliest experimentation in electrochemistry are found in the notes of Priestly and Cavendish (1775), Galvani (1791), and Volta (1792). The obvious problem in the beginning of electrochemistry was one of basic electricity. Researchers simply could not obtain the higher potentials needed by using the galvanic cells as sources. The development of electrochemistry was advanced greatly by the introduction of Volta's pile (1800).

Volta's pile consisted of a series of zinc and silver plates laid on top of one another and separated in pairs by pieces of cardboard. The cardboard was then moistened with a salt solution and the resultant force was greater than the one volt which was obtainable in the galvanic cell.

The first electrolysis of water was carried out by Nicholson and Carlisle (1800) using Volta's pile. Researchers with these fundamental discoveries compiled data which later resulted in Faraday's and Ohm's experiments and the development of the laws bearing their names. By the end of the century, scientists were accepting the early theories which remained after justification through experiment as the basic laws of electrolysis and electrochemistry.

Recent Developments. Much advanced research has brought about new hypotheses and evolved new theories. With the recent discovery of many of the rarer metals, experimentation has only begun in attempting to electroplate films of these metals. The demand for quality control and cheaper materials and processes has received a great deal of attention from scientists of late.

One of the most remarkable developments making its way to the front of the plating field is the electroless deposition of nickel on a base metal through the use of solutions containing hypophosphite ions. The basic reaction was discovered by Wurtz in 1844. However, only recent chemical experimentation found a suitable catalyst to make the process feasible industrially.

Basic research performed by Ludwig Mond in England in 1890 has just recently led to the perfecting of gas plating and permitted its use in industry. The process of gas plating has far reaching significance for the metallic surfacing field. Any metallic compound capable of being vaporized, and having a decomposition temperature, may be used in the gas plating process. Some of the proven advantages over wet plating are: (1) no special tanks, (2) requires only seconds, (3) no electrolytes, (4) no solutions, (5) gas has little waste, (6) plate different alloys simultaneously, and (7) better quality of plate. There is little question as to the possibility of this process having a great significance in the future of the plating industry.

Plating metals has progressed from a very recent infancy to a "big boy" stage and is certainly receiving a large share of the research effort today. This impetus is sound, being based on the fact that an economical base metal, having the qualities of a rarer more expensive metal through plating on a film, is less costly than a product made from the plating metal. As the demand for these desirable qualities increases, more and more of the research will be directed to obtaining special qualities of the rarer metals.

Part C

Vitreous Coatings on Metals

This phase of metal finishing is sometimes referred to as enameling or porcelain enameling. The process involved is the fusing of a thin layer of glass to a metal surface. The application and method have changed through the thousands of years but the principle and finished surface remain the same. The process is one used widely in many fields; art, lapidary, gold and coppersmithing, and ceramics. During the past two hundred years this endeavor has become an industry in itself.

Early History of Enameling. The earliest traceable examples of enamels on metals are from the Egyptians. There is some evidence which points to an earlier use of the vitrified earths by the Siberians and Russians. However, the recovered specimens seem to justify its origin in the mid-Mediterranean countries. Egyptian specimens date back to the Fourth Century before Christ. The art spread to Persia and throughout the countries of Greece and Italy. Early examples of the art found in Britain were Roman imports. By the Twelfth or Thirteenth Century, enameling was common to the continents of Europe and Asia. The early work was almost entirely the result of artisans who used the process for surface enrichment. The protective quality of enamels was first used commercially in Austria and Germany in 1850. It was applied to sheet iron, and though lacking in many modern refinements, served as a satisfactory coating for many years. The new industrial demands of the late Nineteenth Century presented tremendous technical problems.

Demands of the Industrial Era. Early processors and chemists during the initial surges of the Industrial Revolution found that science was hampered by the lack of quality raw materials. The technology of metallurgy was insufficient to produce a constant composition in metals. This further hindered the advancement of the industry. As the demand for better products grew, answers to the problems of the time were found in analysis, the discovery of new sources of raw materials, and in new methods. Previous coatings had been painted on until a method of suspending the powdered enamel in clay and water was discovered. Thus, two methods of enameling evolved as the dry process and the wet process.

Porcelain Today. Science came to the aid of the enameler early in the present century. The chemical industry worked to develop standard colors and improved enamels. The steel industry developed enameling steels. Separate industries now supply the prepared vitreous powders to the user's specification. Present research is pointed toward better resiliency, heat conductivity, and bonding. The increased use of porcelain steel panels in the field of architecture presents many challenges to the industry. Recent development of ceramic coatings for aluminum broadened the field in still another direction.

The vitreous enamel industry is certainly worthy of exemplifying as an industrial arts with both heritage and modern significance. While the similarities between the school shop and factory might be far removed, the process of enameling can be undertaken with assured success. The instructor needs only to call upon the resources of the industry for information and materials.

It is certain that the closely allied industries represented by the metal finishing industries will continue to benefit from the advances made in chemical and metal manufacture. The scientific research being undertaken for the good of all will create new applications, materials, and methods. As growth and progress are made in the products of industry, the youth of today should become aware of that progress; and knowing, should have an appreciation of the efforts of those aiding in such great achievements. Thus, informed of the "how" and the "why" of the metal finishing industries, the student of today will become a more intelligent citizen of tomorrow in his consumption of the material wealth of the world.

CHAPTER III

A VIEWPOINT ON INDUSTRIAL ARTS METALWORK

The industrial arts curriculum in the secondary school where the course offering includes more than one subject area will usually have a course in metalworking. This may be a general metal shop, having further subject matter deliniation such as sheet metal, bench metal, forge, art metal, foundry, machine shop practice, or welding. In Oklahoma, general metalwork ranks second to woodwork. It would appear from this that the proper emphasis is being placed on metalworking in the secondary schools. Metalworking is one of the largest and most important areas of modern industry. The aim of the metalworking program in the secondary school is that of student exploration and broadening the experiences and understandings of youth as a part of their general education. The over-all viewpoint is one of helping each student to an intelligent understanding of industry and aiding him in developing the ability to make wise decisions concerning the environment of which he is a functional part.

Part A

Historical Beliefs

The educational philosophy of America is closely related with the early fundamentals of democracy. Our forefathers insisted that the function of education was to perpetuate those basic democratic beliefs from generation to generation. Drawing the best from the traditional educational policies of the continent and instilling homespun characteristics of the new freedoms has strengthened the nation as it has grown from the early narrow concept patterned in the traditionally academic areas to the broadened vision of the role of education in the democracy of today.

Early Philosophies. The philosophy of Pestalozzi and his achievements through that philosophy mark the point of departure from the narrow to the broad interpretation of democratic education. The six governing principles of his school may be enumerated as: (1) Every individual has a personality and the right to self-dignity; (2) Each child has innate potentials and the teacher is merely a guide through the beginnings of life's experiences; (3) An atmosphere of love must permeate the learning situation; (4) Learning to be real must be sensed; (5) Life is learned by living; hence, learning denotes action; (6) The action must be repeated to enhance the learning. With the success of Pestalozzi, others turned to the use of handwork as a means of education. The evolution of the changes which took place as a result of the Industrial Revolution placed an increased demand on the educated worker with some amount of skill in a trade. Both Calvin M. Woodward and John D. Runkle sought to incorporate the benefits of "manual training" in the program of general education. In Runkle's The Manual Element in Education, the position of industrial training is justified "solely on the broad ground of its educational value to all".

Changing Patterns and Influences. Based on the concepts of John Dewey, Fredrick G. Bonser wrote:

> Industrial arts, when considered as a school subject, must justify itself on the same basis as other subjects. From this standpoint, it will at once appear that primary

> emphasis will not be placed upon the production of industrial commodities, but rather upon intelligence and cultivated taste in their choice and use. In no single field will all of the children function as producers, but from every field worthy of study they will all function as consumers. The largest problems are those of developing an appreciative understanding of industry as it is at the present time, realizing its social problems, and cultivating intelligent judgment and appreciation in the selection and use of industrial products. (2, page 454)

The principle of this subject area in the curriculum for the good of all the students soon led to the necessary differentiation between it and the subjects offered solely as a basis for acquiring skills preliminary to employment. The inferred conditions that not all students are producers, yet all are consumers, is the underlying difference between the modern industrial arts curriculum and the vocational curriculum.

The growth of the industrial force in this country has provided a reason for the co-existance of an understanding of the industrial nature of the land as well as the acquiring of those skills necessary to further the development and growth of industry. It is the function of the school to prepare youth for living regardless of the purpose to which that formal education may be applied.

Part B

Present Philosophy in Industrial Arts

The place of industrial arts in general education is not because of its inclusive nomenclature denoting generalities nor is it because of its objectives being similar to other school subjects. Its place is based on its industrial implications. This source is the mainspring of our present environment and the better this environment is understood and controlled the greater the social and cultural benefits for all.

Definitions. The following definitions are given as an aid to understanding the contents of this study.

General Education.

> . . . the organized effort of the society to cause its youth to become aware of the social culture and to help youth in becoming an asset to themselves and to society. (10, page 1)

Industrial Arts.

> Industrial arts is a group of school subjects that contribute to the attainment of the goal of general education by furnishing guided experiences in the use of tools, materials and machines, and insights into those phases of industry that have become an important part of our social culture. (10, page 1)

Manual Training

> . . . seeks to utilize a child's innate desire of activity to the developing of its bodily and mental powers by systematic exercise. (6, page 11)

Industrial Education.

> . . . all forms of shopwork and industrial drawing taught for any purpose whatsoever. (10, page 2)

Objectives. "The objectives of education encompass four aspects of democracy." Dr. William G. Carr, writing in Policies for Education in American Democracy, further defines these four objectives as:

1. Objectives of Self-Realization
   - The Inquiring Mind -- The educated person has an appetite for learning.
   - Speech -- The educated person can speak the mother tongue clearly.
   - Reading -- The educated person reads the mother tongue effectively.
   - Writing -- The educated person writes the mother tongue effectively.
   - Number -- The educated person solves his problems of counting and calculating.
   - Sight and Hearing -- The educated person is skilled in listening and observing.

Health Knowledge -- The educated person understands the basic facts concerning health and disease.
Health Habits -- The educated person protects his own health and that of his dependents.
Public Health -- The educated person works to improve the health of the community.
Recreation -- The educated person is participant and spectator in many sports and other pastimes.
Intellectual Interests -- The educated person has mental resources for the use of leisure.
Esthetic Interests -- The educated person appreciates beauty.
Character Interests -- The educated person gives responsible direction to his own life.

2. Objectives of Human Relationships

Respect for Humanity -- The educated person puts human relationships first.
Friendships -- The educated person enjoys a rich, sincere, and varied social life.
Cooperation -- The educated person can work and play with others.
Courtesy -- The educated person observes the amenities of social behavior.
Appreciation of the Home -- The educated person appreciates the family as a social institution.
Conservation of the Home -- The educated person conserves the family ideals.
Homemaking -- The educated person is skilled in homemaking.
Democracy in the Home -- The educated person maintains democratic relationships.

3. Objectives of Economic Efficiency

Work -- The educated producer knows the satisfaction of good workmanship.
Occupational Information -- The educated producer understands the requirements and opportunities for various jobs.
Occupational Choice -- The educated producer has selected his occupation.
Occupational Efficiency -- The educated producer succeeds in his chosen vocation.
Occupational Adjustment -- The educated producer maintains and improves his efficiency.
Occupational Appreciation -- The educated producer appreciates the social value of his work.
Personal Economics -- The educated consumer plans the economics of his own life.
Consumer Judgment -- The educated consumer develops standards guiding his expenditures.
Efficiency in Buying -- The educated consumer is an informed and skillful buyer.

Consumer Protection — The educated consumer takes appropriate measures to safeguard his interests.

4. Objectives of Civic Responsibility

Social Justice — The educated citizen is sensitive to the disparities of human circumstance.
Social Activity — The educated citizen acts to correct unsatisfactory conditions.
Social Understanding — The educated sitizen seeks to understand social structures and social progress.
Critical Judgment — The educated citizen has defenses against propaganda.
Tolerance — The educated citizen respects honest differences of opinion.
Conservation — The educated citizen has regard for the nation's resources.
Social Application of Science — The educated citizen measures scientific advance by its contribution to the general welfare.
World Citizenship — The educated citizen is a cooperative member of the world community.
Law Observance — The educated citizen respects the law.
Economic Literacy — The educated citizen is economically literate.
Political Citizenship — The educated citizen accepts his civic duties.
Devotion to Democracy — The educated citizen acts upon an unswerving loyalty to democratic ideals. (11, page 192)

Industrial Arts Objectives. The objectives of industrial arts as outlined in Industrial Arts in Oklahoma are as follow.

1. Industrial arts is complementary to the other school subjects and provides opportunity to apply knowledge learned in the other school subjects.

2. Develops an appreciation of applied knowledge and skills.

3. Provides a knowledge of industrial drawing, the language of industry, and methods of expressing ideas by means of drawing.

4. Contributes to later vocational efficiency.

5. Stimulates students' knowledge and appreciation of good design.

6. Instills a satisfaction in personal creative achievement.

7. Develops the ability to analyze a job into its processes and organize them into correct procedure.

8. Contributes to consumer knowledge and induces an appreciation of the value of industrial materials and the need for their conservation.

9. Trains in industrial and home safety.

10. Acquaints students with industrial information and induces a recognition of the standards of industrial attainment.

11. Develops avocational interests.

12. Trains individuals to be more resourceful in dealing with the material problems of life.

13. Stimulates correct attitudes toward an orderly shop and home and their environment.

14. Aids in making vocational choices.

15. Develops qualities of leadership.

16. Develops cooperative attitudes in work habits.

17. Develops an appreciation of the dignity and importance of the occupation of one's neighbor. (10, page 24)

Metalworking, in order to achieve status as an industrial arts subject, has contributed substantially to these objectives. It need not be reiterated that metalworking in the industrial arts program continues to broaden the experiences of youth. However, metalworking as a part of the total school program can and should become a more vital link between the student and modern industrial materials and practices. The area of metal finishing holds a wealth of information and applications from which the metalworking subjects might draw additional resource material.

CHAPTER IV

METAL FINISHING PROCESSES

Modern metallurgical advances have broadened the horizon of metal finishing to infinity. Every metal article must have a surface treatment. While the application of such treatment may differ, the necessity of the treatment is always present. Technological development has changed the former hand operations to machine operations. There is much to be learned by the student in both categories of operations, whether the surface is finished mechanically or chemically.

Part A

Mechanical Surface Treatments

A basic rule for any cutting operation is that "the cutting tool must be harder and sharper than the material being cut". This rule definitely applies to the abrading of metal surfaces to produce a finished surface. These cutting materials remain inert at rest and only perform the task set forth when in motion. The processes include grinding, lapping, polishing, buffing, peening, scratch brushing, and abrasive blasting.

Grinding. The removal of metal through the use of bonded abrasive wheels is classified as a finishing technique because of the many school shop project applications. In the majority of shops a standard bench or pedestal grinder is used for rough grinding. The use of the same equipment for finish work would merely involve the purchase of an aluminum oxide or silicon carbide wheel of suitable grit size. It is obvious that hand-held work will invariably produce a surface consisting of many dished areas. This irregularity is not undesirable, however, if the optical texture of the surface can be maintained in parallel.

Flat surface planes may be finished by grinding with a rotary pattern using a mounted cupped wheel in the drill press. The use of a holding jig is recommended for small or irregular shapes.

Finish grinding of cylindrical parts involves the centering of the work in a lathe, in which case a tool post grinder, flexible shaft grinder or portable grinder may be used with a properly selected wheel to produce very fine results. It should be mentioned here that the hand grinding of cylinders and cones on a grinder is an important learning situation for beginning metalworking students. This involves not only manipulative skills but in the case of tools it also teaches proper angles and care of working surfaces and points.

Lapping. Lapping is the grinding off of small amounts of metal to obtain a highly polished surface. The application of lapping as a finishing process can be accomplished by even elementary students. Hand lapping is satisfactory in most cases where mild steels or softer metals are used. In the case of tool steel or hardened steels, machine lapping can be performed on the lathe, drill press, or other machines. Lapping compound is a flour abrasive usually an aluminum oxide. When combined with water, oil, or grease, it forms a paste which adheres to the metal surface and is thus rubbed into the surface providing a very fine cutting action. Many decorative lap patterns can be applied to metal surfaces.

Polishing. Polishing may be considered either as a complete surface finish in the case of some projects or as a means toward obtaining a more refined surface. It is the abrading that usually follows grinding and precedes buffing. However, many surfaces now left unfinished or painted could profitably be polished. O. A. Ludwig, in Metalworking Technology and Practice, defines polishing as "the changing of a rough, uneven surface with irregular scratches to a surface with very fine, uniform, parallel cuts or grooves which cannot be seen with the naked eye".

Polishing in the metal shop may consist of strictly hand operations as in the case of beginning students finishing small objects. It may also consist of such machine operations as those of a mounted polishing wheel, paste wheel, or coated abrasive belt.

Hand operations are comprised for the most part of using the various grades abrasive, usually with cloth backing, through to very fine abrasives such as crocus, rouge, and pumice. The beginning student will no doubt consider this a rather tedious process to obtain a very highly polished surface. This ability to produce a polished surface, however, is a basic skill, and is not to be overlooked in the haste to mechanize the work and the student.

Likewise, draw-filing and scraping are far from obsolete methods of hand polishing. Proper techniques in draw-filing will produce a brushed or dull finish on most types of metals, the fineness of the work depending on the type of file selected and the cutting angle.

A polishing wheel can easily be constructed in the metal shop. The wheels available are made of muslin, canvas, felt, and leather. These cover a wide range of flexibility, application, durability, and resultant finish. The versatility and moderate cost of the cotton fabric wheel has resulted in its wide spread use throughout the metalworking trades. Ordinary flake or ground hide glue should be made up using care not to overheat as this will reduce the glue strength. Old glue will lack strength as well as lose its flexibility. The correct proportion of glue and water should be rigidly adhered to because the necessary holding qualities vary with the different grit size. Table I may be used as a guide for these proportions.

TABLE I

PERCENTAGE OF DRY GLUE FOR
OPTIMUM HOLDING QUALITY ON POLISHING WHEELS

Grit Size	Per Cent of Dry Glue by Weight
No. 30	50
36	45
46	40
60	35
80	33
100	30
150	25
220	20

A new wheel should have glue sizing applied to both the face and the sides then allowed to dry. Both the wheel and selected abrasive should be heated to 120°F., the glue applied, and then immediately rolled in the abrasive. A second coating may be applied for a long life wheel. The rigid surface of the wheel may be struck with a bar to break loose the various leaves or folds and provide resilient and free cutting qualities.

The most widely used abrasive for polishing wheels is aluminum oxide. However, silicon carbide may be used. To prevent tearing the abrasive from the wheel and overheating the glue, a surface speed of about 6000 feet per minute should be selected. This, incidentally, may be the governing factor in selecting the proper diameter wheel for a particular motor or arbor.

The paste wheel, so named because the glue and abrasive are mixed into a paste prior to application, is now "headed up" through the use of a glue base sizing available in bar form. A layer of glue is built up on the wheel by alternately turning the motor on and off and applying the bar to the wheel below a speed which would tend to throw the material off. Then it is run at full speed until dry. A layer of greaseless compound is then bonded to the initial coating in the same manner. A polishing head may be built up and ready for use in less than ten minutes without removal from the spindle. This procedure is recommended in school shops.

The coated abrasive belt is highly adaptable to various machines already in use in the metal shop. Abrasive belts may be purchased ready made to size or in rolls and the belts may be made up as needed for different uses. A belt has the undesirable feature of only one layer of abrasive grain; on the other hand, the area available to do the work is considerably more than that of a wheel. As a result, the belt tends to run cooler. For strictly flat surfaces, a band saw may be adapted with an abrasive belt to do very fine polishing work.

A recent development by the Carborundum Company of Niagara Falls, New York, called the Port-A-Belt is adaptable to any straight spindle machine such as a grinder, drillpress, lathe, or portable power hand tool. It is designed to incorporate a back idler wheel and rubber contact wheel so that all types of surfaces, flat, concave, or convex, can be polished.

Buffing. Buffing operations in the school shops are probably the least like industry of any single finishing process in which instruction is attempted. By listing the perceived defects noted in various shops, it is hoped that certain standards for buffing will be attained in the future.

Errors in buffing procedure include: (1) Buffing raw materials which have had no preparation; (2) buffing materials which though processed have been improperly prepared for the buff; (3) selecting buffing wheel which does not suit the material or the finish; (4) using an abrasive or compound which cuts either too fast or not at all.

The buffing operation is undertaken for one or more of the following reasons. (1) The abrasive action of the buff does remove a certain amount of material. Thus, it will smooth down some of the surface irregularities. (2) A small amount of burnishing action takes place, especially on the softer metals, to produce a high lustre. This action is dependent upon the pressure, speed, heat of the buff, and hardness of the abrasive. (3) With the presence of heat, certain fatty acids used as binders in the compound react with the metal surface to produce definite surface and color characteristics. This chemical action is most prevalent on copper, brass, and to a lesser degree on aluminum.

The buffing compound which is applied to the cloth wheel usually contains one of these abrasives: tripoli, silica, lime, aluminum oxide, rouge, crocus, emery, or pumice bound by tallow, stearic acid, pitch, wax, or a petroleum product. The almost universal use of buffing compounds is traceable to the wide range of results obtainable and the economy plus the speed of the operation.

The selection of the buffs for the school shop should cover the multi-purpose needs of that particular shop. For instance, a spiral sewn buff is harder and cuts faster than a loose buff. Yet a loose buff having a fast cutting compound may produce more desirable results than a slower cutting compound on a hard buff. The average metal shop will have need for the following buffing wheels with the appropriate compound listed: (1) A hard buff spirally sewn of canvas compounded with coarse aluminum oxide or emery for fast cutting of ferrous metals; (2) a hard buff spirally sewn of muslin compounded with medium or fine tripoli for fast cutting of non-ferrous metals; (3) a loose buff of pleated muslin compounded with a very fine aluminum oxide for ferrous metals; (4) a loose buff of cotton flannel compounded with a very fine iron-oxide (rouge) or pumice. Several improved-design buffs are available commercially which incorporate the feature of a folded or pleated edge contacting the buffed surface rather than the end fibers of the cloth. A buff of this nature is recommended for the finish operations.

Steel may be buffed at speeds as high as 9,000 surface feet per minute. However, the softer metals require slower speeds which should be approximately 6,000 surface feet per minute. The following computation will aid in figuring appropriate size wheels or wheel rpm.

Surface feet per minute = Circumference of buff in feet x RPM

Hence, a 6" buff used for soft metals would turn at 3750 RPM in order to reach a speed of 6,000 SFM.

Peening. Peening metal surfaces has the advantage of not only adding to the surface enrichment but also increasing the tensile strength of the material. The advocation of industrial "shot peening" or burnishing is beyond the needs of the school shop. There are, however, many just applications of hand peening which can be readily paralleled by description to give the student an understanding of the mechanical process used by industry.

Several of the variable factors to be included for consideration in hand peening are the size of the peening media, the rigidity of the backing article, and the ductility of the material. Hand peening is also dependent upon the force of the media exerted upon the material. It is this factor which varies widely from student to student and at different times within the same student. To arrive at a satisfactory finish, the student must learn to control these variables. The peening hammer and suitable backing article, such as sand bag, hard or soft wood, rubber pad, etc., comprise the necessary tools for the hand peened finish.

Scratch Brushing. Scratch brushing is often overlooked in the school shop as a finishing technique. In addition to being used for rust, paint and scale removal, these brushes made of steel or brass wire will impart an even dull finish to the material. A brush of considerably smaller wire diameter and lower bristle strength will produce a finer finish. Also the hardness of the material's surface and the amount of pressure applied to the work are factors influencing the resultant finish. Machines mounting abrasive or buffing wheels may be used to turn wire brushes for scratch brushing. However, somewhat slower surface speeds are recommended. These range from 4,200 to 6,500 surface feet per minute.

Abrasive Blasting. This one technique, if applied to the finishing operations of a metal shop, will increase the quality of presently used organic treatments, improve the deposit adhesion in electrodeposits, and vary the effect of present total surface coverage by using masks to cover one type of finish and then blasting certain portions to give contrast or highlight areas. The student often finds that shortly after a project has been placed in service the paint begins to peel or flake. This is due primarily to an improperly prepared surface prior to painting. Unseen films of grease and oil, areas of scale formation, or acid and alkali residue cause paint peeling and flaking. If a metal surface is not to be polished to a high gloss and a slight tooth to the surface is not objectionable, abrasive blasting is recommended not only as a finishing process but also as a cleaning process prior to other surface treatments.

If abrasive blasting has been employed for a cleaning operation rather than for finishing, the work can be plated following the blasting. Small cabinets suitable for containing and recovering the abrasive can be constructed in the metal shop. The following features should be incorporated in their construction: (1) a hinged top or end for admitting work; (2) rubber or neoprene gauntlets secured in the sides through which the work may be manipulated; (3) an opening through which the pressure line may be passed; and (4) a filtered opening to allow the blast air to escape but retain the abrasive. Most of the leading manufacturers of pressure spray equipment also have a variety of abrasive guns or nozzles.

Two types of abrasives are available for the process. The first is a metal shot which is usually round and can be procured in standard sizes. The other is grit abrasive which may be obtained in regular grit sizes as well as the flours. The work being done and the desired effect is to a great extent the determining factor in the selection of the abrasive. It has been assumed that the shop is already equipped with an air compressor capable of at least 80 p.s.i.

Part B

Chemical Surface Treatments

Within the mystic realm of the chemistry formulae lie an untold experience for teacher and student alike. While there is a dearth of technical information available to the chemist, it seems that as of old these secrets are locked between the covers of little used or understood publications. The average metal shop instructor will naturally hesitate to introduce a subject in which he has little or no background. Therefore, realizing that information and training for the teacher have been lacking, that literature in the field needs interpretation and explanation, and also that as a metal finishing process electroplating and painting can and should be two of the few finishing techniques in which students in the metal shop are given instruction, it is the objective of the following paragraphs to influence the hesitant instructor by providing information and explanation concerning the plating process and to call the attention of teacher educators to the void experienced by most instructors of metal work in the chemical finishing processes.

Organic. The common organic coatings given metals in the school shop are classified as paints, lacquers, or enamels. The chemical differentiation is primarily in the base composition and the drying reaction. It is impossible to even consider that any one shop could offer students a complete stock of type and color from which to choose. It is not impossible to conceive that every metal shop should offer some color choice as well as experiences in the different methods of application.

The paint brush is still very definitely a tool of industry and the home. To omit instruction in its use and care would leave this area of finishing without foundation. Likewise, to provide only the brush and paint can deprives the student in learning of the many methods of application and of the basic skills in the use of those tools and processes.

Each type of organic finish has characteristics which are best suited for the project utilizing those qualities. The actual selection of coating is an elimination of those not having the desired qualities. The instructor may need to perform this selection for beginning students. However, the matter of choosing and applying the finish should soon become a student responsibility so that learning may be motivated creatively.

Paints in current use are for the most part applied with a bristle brush. Pressure spray systems have replaced the slow, tedious brushing operations in industry. Recently, such industrial methods as roller coating, dipping, and flow coating have become widespread both in industry and with the home craftsman. Lacquers have increased in popularity in the school shop. This is due to the rapid drying rate, color range, and dual method of application. Students may brush on the finish for several projects and then, using spray equipment, become acquainted with the techniques of spray painting without changing medias. Enamels also possess qualities which enable both brush and spray application.

Equipment used for one type of organic finish may be used for another. In this respect, the variation of type and method is a considerable advantage for instructional purposes. The resultant economics are not to be overlooked in establishing or broadening the finishing opportunities of the school shop.

Rapid or accelerated drying is not a requirement of the school shop finish as it is in industry. Yet, the addition of a small infra-red lamp oven for rapid drying has several advantages. It will produce a dry surface more quickly. The increased surface tension of the film will better resist abrasion. Textured surfaces can be formed, thus aiding surface enrichment by not only color but also by texture. The writer has adapted a small metal stove top oven equipped with two 300 watt infra-red lamps for this purpose and the total cost of the oven and all electrical supplies was less than twenty dollars. The oven is capable of sustaining temperatures of 450°F. in continuous operation. The temperature may be controlled more easily by wiring with individual switches.

Metallic. The theory of electrodeposition is of a necessity somewhat complex and technical in nature. While the student in the metal shop may not be expected to deal with the formulation of the various plating solutions, he should be acquainted with the fundamentals of the plating process. Basically, it will be remembered that pure water is a poor conductor of electricity. Yet, when soluble metallic salts are introduced, the resultant solution acts as a conductor in the presence of an electrical current. Plating requires direct current because of the constant direction of electrical flow. The current is introduced into the solution through anode which is the positive electrode and in most plating operations supplies the metal to be deposited on the cathode. Thus the cathode or negative electrode is the object to be plated. The solution merely provides the means by which the metal is carried from anode to cathode. It should be mentioned at this time that all of the supplies for plating as well as useful "trade secrets" are available from manufacturers. The compounding of solutions is merely an "add and stir" process which even the student can perform safely.

Certain types of plating are more adaptable to the school shop than others. Also many plating processes are licensed and patented. Royalties prohibit their use in the shop. Cost is a factor in precious metal plating even though the process is no more complicated than the proposed methods. Those metals recommended for plating in the metal shop are copper, nickel, cadmium, and possibly chromium.

In addition to the requisites previously mentioned, a source of electrical energy, a suitable metal cleaning process, and the physical data concerning the various solutions are necessary prior to the actual plating process. The consideration of an electrical source should be made with the highest possible load to be demanded of the system in mind. The actual application may vary a small amount, but in general, these loads will prevail in the types of plating to be considered: (1) for copper plating, 4 volts at 60 amperes per square foot of cathode area; (2) for nickel plating, 2 volts at 75 amperes per square foot of cathode area; (3) for cadmium plating, 4 volts at 50 amperes per square foot of cathode area; (4) for chromium plating, 6 volts at 150 amperes per square foot of cathode area. Of the many kinds of direct current sources available, the alternating current rectifier is the best for school use. Several principles of rectification are employed in these units and the selenium or "dry disk" has innumerable advantages.

If chrome plating is included, a 9 volt, 150 ampere rectifier will supply the current. Since the cost is dependent upon the ampere rating, the 6 volt, 100 ampere size would be satisfactory at a lower price for all but chrome plating.

Metal which is being plated must be cleaned down to the "bare" metal. If there is any foreign material which adheres to the metal surface, the plating will peel. There is no one method for removing all types of oils, greases, and other residue from the various metals. However, electroplaters have discovered a very successful cleaning process in electrolytic cleaning. This involves the reversal of anode and cathode. The work now becomes the anode or positive electrode and the tank becomes the cathode or negative electrode. During the process of electrolysis, the metal or the surface of the article is actually plated off. Since the dirt has lodged only on the outer surfaces, the metal particles are plated off and the dirt goes with these particles leaving a very clean surface without impairing the lustre or platability of the work. Cleaning solutions compounded for quick electrolytic cleaning of metals are available from the listed sources of supply.

A part of the necessary plating equipment could be made in the shop. This includes plating tanks, stands, exhaust ducts, plating and tumbling barrels, and bus bar systems. The exact specifications would depend somewhat on the space and location in the shop, type of plating to be performed, and funds available for the purchase of materials.

One shop having an electroplating area has a bank of ten gauge welded steel tanks lined with the appropriate material when necessary. The size of these tanks is 13-1/4" x 18-1/2" x 20" and the materials used to fabricate them cost $7.00 each plus lining materials. In view of recent developments with fiberglass and the cold setting resins used to bond this material, it is felt that the enterprising instructor could build a wooden form from which as many tanks as were needed could be made. Fiberglas tanks are available commercially at a moderate price, but the materials can be purchased at a considerable saving. These tanks are very light in weight and are suitable for most solutions up to 200°F. The limitations are in using hot strong acids which include chromic acid and acid type electrolytic cleaners. In order to provide tanks which will withstand both heat and acid, steel tanks should be made or purchased. The tank for chromic acid should have a lead lining and it should be "burned in", fusing the lining to the steel. A suitable rubber coating can be applied by brush directly to the steel tank providing a corrosion resistant tank for electrolytic cleaning.

Ducts for the removal of noxious fumes are fabricated commercially from fiberglas. It is not beyond the capability of the school metal shop to build the necessary ductwork either from fiberglas or sheet metal. Fiberglas has the advantage of being acid resistant while sheet-metal ducts require lining.

Many industrial plating operations are carried on in barrel plating machines. One such machine is manufactured by the Rampe Manufacturing Company of Cleveland, Ohio, and is marketed as a tumble finishing machine. The simplicity of construction and practicability for plating and tumbling operations has considerable merit, expecially for shops which are short of space and where economy is paramount. The design is such that five gallon pails are used as drums or barrels. In the plating process the solutions may be stored in the pails ready for use and mounted in the machine when needed. The pails should be lined with the appropriate material for the different solutions. Both electrodes are suspended from a goose-neck hanger and adjusted to the level of the various solutions.

Those solutions requiring heat can be brought to the proper temperature by using a 1,500 watt electric immersion type heater.

Stands of welded angle iron construction painted with acid resistant paint may be made to individual specifications. Bus bar installation is a must when solution tanks are arranged in process sequence. The primary factor for consideration before construction is the electrical load which will be carried by the system. This will determine the cross-sectional area of copper bar, rod, or tube. Circuit completion from the positive bus to the anode and from the cathode returning to the negative bus should be made by line contact for most efficient operation.

<u>Vitreous</u>. The group of coatings in this classification may at present seem entirely out of the range of the school shop. The rapid advance of our technical skills is possibly one reason for the impossibility of many shop programs to present modern methods. On the other hand, it may also be the reluctance to depart from the "tried and true". Siliceous deposits on metals comparing with industrial products such as signs, bathtubs, jet engines, and glass lined tanks is, of course, out of the capability of the school shop. The process involved, however, is of great importance to the industrial lifeline. It does deserve study on that basis to see whether or not it might be adapted to the finishing techniques of the metal shop.

Coatings of vitreous nature can be applied in the same manner as other liquids. The factor influencing the use of metal enameling is contingent upon the necessary equipment to heat the article until the coating vitrifies. A device for heating the article is now available from most ceramic supply houses. The size of article accommodated by the kiln is somewhat restricted as the interior is 2" x 3" x 3". This phase of the finishing allies itself naturally with a program of art metal or metal crafts. The student given this opportunity is limited only by his ingenuity to create and design projects of a useful nature.

New Processes. Innovations in the plating field have only recently produced an "electroless nickel plating". In 1946 two research chemists of the National Bureau of Standards accidentally discovered the chemical reaction which is the basis for this process. At that time the practicability of the process for industrial use seemed very limited due to the high costs. Other chemists became intrigued by the possibilities of electroless plating and in March 1953, the General American Transportation Corporation announced a practical solution by the trade name of "Kanigen". Since the first commercial disclosures were made only two years ago it would seem that this process is "too new" to be acceptable for educational purposes. J. L. Chinn, Production Design Engineer for Northrup Aircraft, Inc., writes: "All types of steels, copper and copper alloys can be plated. Aluminum alloys successfully plated are 2017, 2024, 2014, 6061 wrought alloy, and 356 cast allow." (9, page 104) Earlier, the associate editor of Materials and Methods, John B. Campbell, stated:

> Up to now "electroless" nickel plating has been generally regarded as costly compared to electroplating. All electroless processes benefit from the uniformity of the plate which allows less nickel to be used for a given minimum thickness. Other economic advantages over electroplating are: (1) no electrical equipment required. . .
>
> Principal equipment needed for the bath is a source of heat and a vessel. The vessel can be made of glass,

porcelain, enamel, ceramics or of metal lined with an envelope of polyethylene sheet. (8, page 96)

The chemical technicalities are not the important considerations in evaluating this process. The educational value of a simple plating process which students can see and do opens the door for a more complete study of both "electro" and "electroless" plating. If the metal shop instructor desires a unit through which he can introduce plating, this is it. The chemistry necessarily involved is in several patented formulas. The Metal Processing Company of Cedar Grove, New Jersey, will provide the instructor with the desired materials, operating data, and cost information.

One of the most appealing new organic finishes is a development of the Reynolds Metal Company. This firm, long known for its research in aluminum, has marketed a new line of finishes aptly designated as "Polychromatic" finishes. Variations in the compounding of these fast drying lacquers cause the aluminum additive to set as smooth opalescent, wrinkled, or hammered. The surface texture of the finishes is glossy, unlike traditional hammered or wrinkle finishes. The aluminum powders give the surface a light reflecting quality not found in other pigments. These may be air dried or oven dried with the same results.

The inclusion of metallic surface treatments will depend to a large extent on the resourcefulness of the individual instructor. The need for such information to be included in the metal shop program is real. Likewise, the broadened use of organic finishes and the benefit gained from using vitreous finishes will be directly traceable to the efforts of the individual metal shop teacher.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The value of any research is in the findings of that research and the proposals for applying these findings to a particular problem. Other areas of investigation are suggested as steps toward greater enlightenment. The recommendations of the writer can by no means encompass all of the situations arising in a school shop. They are intended to be broad enough to permit individual variation for application to many problems of metal finishing. The data presented are somewhat technical though basic in use for the various processes.

Conclusions. The conclusions reached in this report are based primarily upon the results of observation, study, and deduction. There is a question as to the validity of a study relying strictly on library materials when little information has been written concerning the subject. Through additional sources of information and investigation, the report has measured the need and possibility of a broader program of metal finishing in the area of industrial arts metalworking. The question of authentication will be answered in further study and practical application.

Primary Findings. The field of metal finishing in industry has many facets which can be utilized in finishing the projects of the metal shop. Industrial applications for the most part are extremely technical thus hindering their use in the metal shop. Literature and process information are available in detail on any area of metal finishing from both the supplier and local industry.

Secondary Findings. Many studies have been made concerning wood finishes and finishing by industrial arts researchers. A careful survey of the research studies of metal finishes failed to produce even one significant study of the area. In addition to the Oklahoma Agricultural and Mechanical College Library indexing of researches in industrial arts both as theses and problem studies, the American Vocational Association's Bulletin Four, Summaries in Industrial Education Prior to 1949, and the Ford Motor Company's continuation of those summaries through September 1950, revealed no like studies which indicate previous consideration of this problem. The review of literature of industrial arts nature in periodicals during the past twenty years gave little indication of a use of the variety of metal finishing techniques. Metalworking texts used in the shops make little or no mention of finishes and methods of finishing.

Final Findings. Metal finishing is a vast industrial undertaking. It is founded on the laws of physical science and embraces in some way all of the sciences. Its breadth reaches from scientist to consumer. The place of metal finishes in the program of the metal shop is as significant as the metal shop itself. Industrially speaking, without the finish, the shop would cease to exist.

Pertaining to Mechanical Surface Treatments. Many of these finishes can be applied with the existing shop equipment. Such fixtures or jigs which might be used either for holding or design purposes are usually constructed on the individual needs basis. The adaptability and use of a particular treatment is contingent upon these aids being purchased or made by the instructor. Since this factor controls the extent to which any finish is applied to a project, the success of new mechanical surface treatments depends entirely on the instructor's efforts both in instructing and in using his ingenuity to devise ways of applying the finish to a student's project.

Pertaining to Organic Finishes. The use of the organic finishes tends to be the universal shop finish, not necessarily because of its popularity nor of its advantages. The widespread use is due to tradition. Many metal shop instructors have preparatory courses in only woodworking and wood finishing. There appears to be a void in the curriculum of teacher education programs in the area of metal finishing.

Other conclusions from this report are:

1. Wider use of variety and special effect organic finishes can be made in the school metal shop.

2. Experiences for the student may include additional techniques with little or no change in the equipment of the shop.

3. Selection of the appropriate finish is of value in learning, and the instructor should not dictate but provide guidance for the student.

Pertaining to Metallic Finishes. Providing a metallic coating does not now, nor has in the past, play a major role in the metal finishing program of the metal shop. The lack of information tends to handicap the development of this area in the industrial arts metal shop to a great extent. Also, additional equipment of an unfamiliar nature in many processes is a prerequisite to the establishment of the program of finishing with metallics.

In an effort to provide information for the instructor desiring to start an electroplating process, Table II (page 45) condenses a great deal of useful information into quick-reference form. The source of the data is the Metal Finishing Guidebook and Directory for 1955.

Conclusions of further importance concerning metallic finishes are:

1. There is a need for not only instructors to become aware of the benefit from this type of experience for their students, but also for technical aid from industry in both engineering and operating the processes before the school will achieve its aims.

2. There are considerable plating processes which produce satisfactory results over a wide range of conditions. These are adaptable to metal shop use: (a) Copper, (b) Cadmium, (c) Nickel, and (d) Chromium, with some reservation.

3. College courses for preparing teachers in this aspect of metal finishing are non-existent. Several technical schools do offer short courses in electroplating.

4. Through detailed planning for each shop situation, the cost of plating equipment could be greatly reduced.

Pertaining to Vitreous Finishes. Vitreous enamels offer artistic potentialities that cannot be found in the other finishes. They have assumed a respectable place, not just as an art media, but industrially as a surface protection and decoration material.

Final conclusions concerning porcelain enamels are:

TABLE II

SOLUTION AND OPERATION DATA

Item	Copper	Nickel	Cadmium	Chromium
Solution	Copper cyanide 3.5*	Nickel sulphate 32	Cadmium oxide 3.75	Chromic acid 53
*ounces per gallon	Sodium cyanide 4.6	Nickel chloride 6	Sodium cyanide 18	Sulphate .53
	Sodium carbonate 4.0	Boric acid 4		
	Rochelle salts 4.0			
Plating Rate to Deposit .001 Inch	6 min. at 30 asf**	5 min. at 50 asf	3 min. at 20 asf	12 min. at 150 asf
Temperature	120° - 140°F.	Room temp.	Room temp.	110° - 140°F.
Voltage	4 volts	2 volts	4 volts	6 volts
Current Density	60 asf	75 asf	50 asf	150 asf
Anodes	Copper ball or cylinder	Nickel ball or cylinder	Cadmium ball or cylinder	Lead ball or cylinder with 4% tin
Tank	Steel or plastic	Rubber or neoprene-lined steel	Steel or plastic	Plastic or lead-lined steel
Agitation	Cathode or solution	Cathode or solution	None	Cathode or solution
Vapors	Non-hazardous	Non-hazardous	Non-hazardous	Toxic. Removal required by law

**amperes per square foot of surface area

1. Vitreous finishes are adaptable to metal finishing.

2. The industrial importance of porcelain warrants its acceptance as a part of the metal finishing program.

3. Beginning students as well as advanced students can apply the techniques to project materials within certain limitations.

Many of the processes of industry are protected by patents, royalties, and existant trade secrets. It behooves both industry and teachers to engage in a cooperative exchange of products and ideas. The challenge before the student of today is one placed there by industry.

There are two aspects of electroplating which should be mentioned in closing. Plating results are dependent upon constant conditions, and in the metal shop one of the major problems will be in not contaminating the plating solution by allowing other solutions to be carried into it on the object to be plated. Solutions which are maintained in this manner will last indefinitely. The other problem of concern for the instructor is the disposal of chromic acid waste. Municipal code prohibits the introduction of raw chromic waste into the sewage system of many cities. Local industries will, in some cases, provide for the neutralizing of the waste with their own. If this action is not possible, then chemical supply firms have the neutralizing chemicals for a nominal charge.

Recommendations for Further Study. There are many problems relating to metal finishing in the school shop which have only been noted and not investigated by this study. As each of the details of the total problem are brought to the attention of those undertaking research studies, the implications for metal finishing in industrial arts will be made known to the instructors. Within the limits of the study, this is the first known attempt to focus attention on the processes of metal finishing in industrial arts.

Studies relating to the actual practice of metal finishing in the metal shop to learn the type of finish used, methods of application, and scope of metal finishing techniques would be of value in denoting the present status.

Additional study in the area of mechanical surface treatments or in each of the chemical surface treatments (organic, metallic, and vitreous) would implement the knowledge presented in this study and perhaps further validate their claim for inclusion in the educative process of the metal shop.

A survey of the importance of metal finishing courses in teacher education curriculae compared with the extent to which those teachers take jobs in metal shops and their indication of the relative importance as a part of their courses in metalworking would show present practices and perhaps point to specific courses offering the needed information.

A research investigation devoted to minute study of industrial finishing processes might be made with the objective of adapting selected processes to the metalworking courses. As the metalworking area of industrial arts expands, a comprehensive survey of metal finishing equipment in use and available for use would aid in shop planning.

These additional studies would enlarge upon the information currently available to the field. A continuing need would be for the interpretation of research in periodical literature and in that way impart the findings to the industrial arts metal shop instructors for application. It is common practice in the engineering field to report research findings in periodicals and journals. Publications which carry articles of interest to industrial arts teachers could well perform this service for educators.

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APPENDIX

Suppliers of Metallic Finishing Materials

Abrasives

Behr-Manning Company, Troy, New York
The Carborundum Company, Niagara Falls, New York
Minnesota Mining and Manufacturing Company, St. Paul, Minnesota

Anodes

Bart-Messing Corp., Belleville, New Jersey
Hanson-Van Winkle-Munning Corp., Matawan, New Jersey
United Chromium, Inc., New York, New York

Barrels, Plating

Belke Manufacturing Company, Chicago, Illinois
Daniels Plating Barrel and Supply Company, Newark, New Jersey
Fredric B. Stevens, Inc., Detroit, Michigan

Chemicals, Plating Solutions

Sel-Rex Precious Metals, Inc., Belleville, New Jersey
The Idylite Corp., Detroit, Michigan
United Chromium, Inc., New York, New York
Metal Processing Company, Cedar Grove, New Jersey

Compositions, Buffing and Polishing

The Buckeye Products Company, Cincinnati, Ohio
The Lea Manufacturing Company, Waterbury, Connecticut
United Buff Products Corp., Passaic, New Jersey

Electroplating, Equipment

Crown Rheostat and Supply Company, Chicago, Illinois
Hanson-Van Winkle-Munning Company, Matawan, New Jersey
Wagner Bros., Inc., Detroit, Michigan

Linings, Tank

American Hard Rubber Company, New York, New York
Polyhote, Inc., Buffalo, New York
Storts Welding Company, Inc., Meridan, Connecticut

Rectifiers

Crown Rheostat and Supply Company, Chicago, Illinois
W. Green Electric Company, Inc., New York, New York
Sel-Rex Precious Metals, Inc., Belleville, New Jersey

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