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SPECIAL REPORT

Potential for Application of NASA Technology to Solid Waste Problems Identified by the Division of Solid Waste Bureau of Mines

PREPARED FOR:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
The Office of Industry Affairs and Technology Utilization
(Code KT)

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S P E C I A L R E P O R T

to

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
The Office of Industry Affairs
and
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Potential for Application of NASA Technology

to

Solid Waste Problems Identified by the Division

of Solid Waste, Bureau of Mines

Prepared by the

Technology Applications Group

of the

BIOLOGICAL SCIENCES COMMUNICATION PROJECT

Contract NASA-2055

Medical Center

The George Washington University

2001 S Street, N.W.

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November 1970

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INTRODUCTION

The purpose of this special report is to describe the activities of the Division of Solid Waste, Bureau of Mines, in sufficient detail so that NASA's Office of Technology Utilization, Technology Utilization Division, can determine whether or not NASA technology has application to Division of Solid Waste environmental problems. This discussion necessarily includes comments on the state-of-the-art relative to the solution of the problems encountered by the Division of Solid Waste.

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DISCUSSION

The Division of Solid Waste (DSW), Bureau of Mines, is primarily interested in the development of methods of using mineral- and metal-based wastes to recover economic values and alleviate the waste disposition problem. Past efforts have been carried out under the Department of Interior's Organic Act. The Solid Waste Disposal Act of 1965 specifically assigned the DSW responsibilities for utilization or disposal of mineral and metal waste.

Major federal solid waste management research programs are directed toward (1) collection procedures; (2) household sorting of refuse; (3) sorting from mixed refuse; (4) litter; and (5) recycling. The DSW activities are generally limited to areas (3) and (5).

Research efforts of the DSW are threefold in nature. These are (1) extraction of mineral, metal, and energy values from urban refuse; (2) recovery of mineral and metal values from wastes generated in the industrial extraction, processing, and use of raw materials and mineral-based products; and (3) upgrading and use of automotive scrap. In addition to these efforts the DSW is interested in research on disposition of animal waste and recycling of plastic waste.

Appendix A lists those areas in which the DSW is seeking new technology or technology to improve on existing techniques. Correlated with these areas of technological need are statements on relevant NASA expertise. Appendix B is a list of calendar year 1970 research projects of the DSW which amplifies the requirements of Appendix A. Appendix C, Bureau of Mines Information Circular 8460, provides supporting information relative to Appendix B.

It is apparent that in accomplishing its research mission the DSW and the Bureau of Solid Waste Management of the newly created Environmental

Protection Administration must overlap to some degree. However, both agencies have indicated that there is sufficient coordination so that overlap is beneficial rather than a hindrance and that duplicative activities are not pursued.

Also, it is apparent that in pursuing its threefold research objectives the extraction and recovery activities will overlap within the DSW. These particular objectives are predicated on separation techniques, techniques that take place either before or after final disposition of refuse. That is, before being covered in a landfill and before or after incineration. Thus, the DSW becomes interested in incineration techniques involving ordinary refuse as well as those techniques involving automobiles. This latter (auto incineration) is the third mission objective of the DSW .

Our review of available literature, particularly that published by the DSW, indicates that it is probable that technology exists to solve most of the major problem areas. Support for this contention is provided by the September 28, 1970 issue of "Product Engineering" in an article titled "Recycling: ultimate answer to problem of solid wastes?" This article states in part that "The answers exist. It isn't for lack of basic technological answers that America's cities and villages continue to fill marshes and build hills with their solid wastes rather than reclaim all reusable materials. It could even prove, if one New York municipal bond specialist is right, that the cities' chronic shortage of funds need not be a barrier, because sale of reclaimed material could offset costs." More will be said later about the possible profit resulting from reclamation.

Examples of the availability of technology are numerous. A relatively important piece of research by the DSW has resulted in a pilot plant which can process 1,000 pounds of scrap metal per hour and which is capable of continuously

and automatically separating and recovering metal and mineral values from incinerator residues. An adjunct of this plant separates ferrous from non-ferrous residues, and glass is separated into colorless and colored components. Other separation techniques and pilot projects do exist. Once the components of incinerator residue are separated out something must be done with them. The DSW has developed a number of products using waste glass. Among these are structural blocks which meet ASTM specifications for outside face brick and a commercial grade glass wool. Other efforts have successfully used waste glass in road paving. The DSW has found that silver values in the incinerator residue can run as high as 20 ounces per ton. Investigation of methods for extracting gold and silver from fly ash is now under way.

The DSW scientists have developed a technique for turning garbage and cellulose into crude petroleum and estimate that a barrel of low-sulfur-content oil can be obtained from each ton of refuse.

In the field of automotive scrap the DSW has successfully developed a low cost smokeless incinerator for junk cars. In other studies it has been demonstrated that an initial investment of $345,000 for plant, land and equipment can result in a junk car processing facility with the potential of an annual return of 20% on the initial investment. This facility hand dismantles 48 cars per day and burns and shreds them. The resulting product is sold to steel mills.

Rock wool insulation has been produced from coal ash slag. Nonmagnetic taconite ores have been processed from their formerly useless form to the useful magnetic ore.

The DSW has indicated an interest in incinerator development and disposition of waste plastics. The major problem with disposal of existing plastic containers is that they melt when incinerated dripping down on to the grates

and rapidly clogging the grates hindering further incineration. Another problem is that those containers made from halogenated polymers produce hydrogen chloride emissions when incinerated. This major obstacle to successful incinerator operations has been overcome according to an article in the October 29, 1970 edition of the Washington Post newspaper. This article states that a subsidiary of the Standard Oil Company of Ohio has produced a plastic (Barex 210) that completely burns to a crumbly ash at a relatively low temperature. The smoke resulting does not change the chemical nature of the incinerator smoke. The plastic material is one-fifth as heavy as glass and is transparent. The Food and Drug Administration has approved this plastic product for use in food and beverage containers.

Other technology recently demonstrated or available for demonstration is widespread. An incinerator system developed by the Combustion Power Co., Inc., was designed by the systems concept and will handle 400 tons of waste per day. The system will provide up to 15,000 kilowatts of electrical power. The system also separates and classifies incoming waste so that metals, glass, and paper can be recycled. Other systems are available for consideration such as that developed by the Heil Co. and Black Clawson Co. The Black Clawson system has been successfully operated by Madison, Wisconsin since 1967.

In the area of complete systems development the state of Delaware and Hercules, Inc. are involved in a project which can be considered a major step in solid waste management. The proposed system will handle the waste from delivery at a collection point to the point of final disposition of useful residue. Appendix D provides information on this system.

The preceding examples have been confined to technology developed by or for the DSW except those incinerator systems developed for the Bureau of Solid

Waste Management. In the areas where there is an overlapping interest with the Bureau of Solid Waste Management there are other examples of developing technology which give an insight on the state of the art. For example, in separation techniques the Stanford Research Institute has developed and constructed a pilot scale unit in which a vertical stream of air separates mixed refuse. This is separation in advance of incineration (or covering in the landfill) as opposed to the DSW developed system of separation after incineration which was described earlier.

An area which has delayed recycling of useful materials found in refuse is the reluctance of industry to make use of reclaimed or secondary grade materials as long as the raw material is available. This reluctance has been caused, to some extent, by the secondary materials' lower quality and higher cost. However, it appears that technology could improve the quality and decrease the cost of the secondary product. The attitude of industry toward use of the secondary grade material is apparently changing. This is exemplified by the recent establishment by industry of the National Center for Solid Waste Disposal, Inc. This organization is chartered to specifically develop and sponsor research and development projects with the objective of decreasing solid waste and increasing the recycling of such waste. It may be desirable for NASA-TUD to explore potential interaction with this Center.

A major impetus to the recycling of waste materials can be provided by development of new products making use of these wastes. Use of fly ash is one example. Fly ash has been regarded as useless and placed in large mounds where it polluted both the atmosphere and streams as well as taking up space. Now, fly ash is being used in automobile tires to improve traction and skid resistance, in building brick aggregate, and in coal mines to assist in putting out fires.

Another element which has been delaying recycling of material has been pinpointed by the President's Council on Environmental Quality. In their August 1970 report the Council stated ". . . , for many natural resources, substantial Federal income tax incentives and other laws and policies encourage use of the virgin material instead and undercut the competitive position of recycled materials." This statement points out that a measure of intermunicipal as well as interstate and federal cooperation will be required to alleviate the problem.

If the existing philosophical and legal problems noted above can be changed (and these are not within the purview of NASA) then the DSW problems become directly related to the development of new uses for recycled material. This may devolve into new products, cheaper means of recycling, or demonstrations that recycled materials are equally useful (hopefully more useful and cheaper) than virgin raw materials. Our estimate of the requirements for technology hinge on this aspect.

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CONCLUSIONS

Review of the literature published by the Division of Solid Waste, Bureau of Mines, as well as review of other available material, indicates that technology is available to solve most of the problems facing the DSW. That does not mean that the technology could not be improved upon.

The major hindrances to the DSW program appear to be legislative, economic, and educational.

The DSW activities, in order of relative importance in regards to needs for technology appear to be the following:

a. Materials technology, that is, the development of new products based on reclaimed materials.

b. Materials technology, in this case, developing techniques for using reclaimed materials in existing products in lieu of continued use of raw materials.

c. Metallurgy, this includes a number of aspects such as separation of copper from ferrous alloys; separation of component valuable metals from residue of industrial processes; separation of gold and silver from fly ash; etc.

d. Refuse separation techniques as differentiated from requirements involving metallurgy. This would involve separation of major components of trash such as ferrous from nonferrous metals; separation of paper products; separation of plastics; etc.

e. Incineration techniques including destructive distillation and pyrolysis.

A systems concept appears to be the logical approach to solving the overall solid waste management problem. Such a concept is not limited to activities of the DSW and in many aspects is more relevant to activities of

the Bureau of Solid Waste Management.

The DSW activity has been funded at a much more modest level than has the Bureau of Solid Waste Management. Most DSW research had been handled at inhouse laboratories. Research grants during Fiscal Year 1970 appear to be less than $600,000.

NASA technology is applicable to many of the activities of the DSW.

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RECOMMENDATIONS

If a decision is made to attempt to transfer NASA technology to the DSW, careful consideration should be given to the size of the NASA effort keeping in mind the size of the DSW effort in relation to the overall federal solid waste program and the probable degree of overlap between the DSW and the Bureau of Solid Waste Management.

It would seem profitable, if a technology transfer program is developed, to focus NASA activities to interation with the DSW laboratories and those commercial or university research programs designated by the DSW.

APPENDIX A

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BUREAU OF MINES TECHNOLOGY NEEDS VERSUS NASA EXPERTISE

Bureau of Mines (DSW) Technology Needs

1. New markets for recoverable products: this requires development of new products or new ways to fabricate an existing product using recovered materials.

   a. From urban refuse: for example, structural blocks from glass waste; crude petroleum from garbage.

   b. From mining and industrial wastes: for example, rock wool insulation from coal ash slag; crystallized glass from copper tailings.

   c. From automobile scrap.

NASA Expertise

NASA had not engaged directly in developing markets nor developing specific new products to satisfy commercial market demand. However, NASA scientists and engineers have produced a number of new aerospace materials, techniques, and devices which have found their way to the commercial market. A listing of such products would be lengthy. A few familiar products are computer enhancement of photographs; road surface grooving; and alkali-silicate paints. Other NASA efforts currently being looked at in the Technology Applications Program may have an impact on commercial markets. Among these are the pavement thickness measuring device; the device to detect indented writing; life support systems; and fire retardant coatings and foams.

It is practical to assume that,although NASA is not directly involved in market development or new product development, there is a wealth of expertise that can be applied to problems involving this area. The Fiscal Year 1970 NASA Research and Technology Objective and Plan lists a number of NASA efforts which are directly related to new material development for aerospace needs and material utilization. Among these are the following:

a. Improve properties of materials used in aeronautical engines; investigate and develope new materials for use in these engines.

b. Develop new materials and improve on existing materials used in electronic devices.

c. Develop advanced materials including composites fabrics, and membranes for advanced structural concepts and materials applications.

BUREAU OF MINES TECHNOLOGY NEEDS VERSUS NASA EXPERTISE (CON'T)

d. Establish lifetimes and reuse capability of materials for use in shuttle structural materials.

e. Development of materials with improved radiation resistance.

f. Development of improved materials for aircraft brakes and tires.

g. Development of advanced resins and adhesives for use in supersonic aircraft structures.

2. Metallurgy: this includes techniques for separation of metals from incinerator residue; techniques for detecting and separating alloys.

Metallurgy is an integral part of many phases of the NASA effort. For example, there are 55 entries related to metallurgy in the March 1969 NASA Flash Index. There are several pages of metallurgy related listings in the Tech Brief Index. Among the on-going efforts are the following:

a. Joint program to update the government handbook "Metallic Materials and Elements for Aerospace Vehicle Structures." This handbook establishes design allowables for metals and fasteners.

b. Determine behavior and suitability of coated and uncoated metallic alloys for service in advanced aircraft or spacecraft.

c. Develop new nickel or cobalt-base superalloys.

d. Research is being done on ferrite material compositior materials synthesis, and processing techniques to define batch fabrication methods for monliothic magnetic memories and multimaterial magnetic computer logic.

BUREAU OF MINES TECHNOLOGY NEEDS VERSUS NASA EXPERTISE (CON'T)

	e. Update, revise, and develop new metals alloys handbooks to be used in design and fabrication of space vehicles.
3. Refuse separation techniques prior to incineration.	Specific technology within NASA that can be marked as directly related to refuse separation is difficult to locate. However, there is expertise that should be useful in developing separation techniques. For example, NASA is heavily involved in remote sensing techniques and sensors. Another area of possible application to this problem is that of materials testing including nondestructive testing.
4. Incinerators including destructive distillation and pyrolysis.	The most likely area of NASA expertise lies in investigations of combustion efficiency in rocket engines. Investigations are underway as follows: a. Development of refractory metals or ceramic coatings for walls of regenerative chambers. b. Develop design information needed to assure stable combustion and reliable ignition. c. Develop new technology in the area of combustion and ignition phenomena in liquid rockets. d. Advance the state of the art in heat transfer and fluid flow. e. Determine behavior and suitability of coated or uncoated metallic alloys including refractory metals for use in spacecraft. f. Research and development on coated refractory metals for very high temperature heat shields of reusable re-entr vehicles.

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BUREAU OF MINES DIVISION OF SOLID WASTE PROGRAMS (CALENDAR YEAR 1970)

The Division of Solid Waste searches for technology to meet requirements of:

1. Extraction of mineral, metal, and energy values from urban refuse.
   a. Produce clean, high-grade ferrous scrap.
   b. Remove and recover copper.
   c. Separate nonferrous metals from incinerator residues.
   d. Refine nonferrous metals to marketable products.
   e. Reclaim glass.
   f. Separate clear from colored glass.
   g. Develop products for reclaimed glass.
   h. Develop techniques and methods of separating component parts of urban refuse.
   i. Develop and evaluate incinerators.
   j. Develop and evaluate techniques and methods of converting refuse into useful products.
   k. Develop and evaluate uses for incinerator residues.
   l. Develop and evaluate techniques for extraction of mineral values from incinerator fly ash.
   m. Determine effects of contaminants contained in ferrous refuse.
2. Recovery of mineral and metal values from wastes generated by industry.
   a. Stabilization of mine waste tailings.
   b. Determine causes of spontaneous combustion in waste coal piles.
   c. Identify metallic components in flue dusts.
   d. Develop techniques for recovering metallic components in flue dusts.
   e. Utilization of abandoned strip mines for land fills.
   f. Develop new uses (and products) for mineral wastes.
   g. Reclaim high value metals (cobalt, nickel, and chromium) from high temperature or superalloy scrap.

BUREAU OF MINES DIVISION OF SOLID WASTE PROGRAMS (CALENDAR YEAR 1970) (CON'T)

h. Develop techniques to identify each metallic component in scrap.

i. Develop and evaluate techniques for reclaiming aluminum and silicon from aluminum-silicon alloys.

j. Recover chromium, nickel, zinc, and cadmium from electroplating waste.

k. Recover metallic waste components (gold, silver, and platinum) from electronic equipment.

l. Remove contaminants from titanium scrap.

m. Develop methods to use secondary grade ferrous scrap.

n. Increase use of secondary source metals of all types.

3. Upgrading and utilization of automotive scrap.

a. Develop methods of removing nonferrous components from junked automobiles.

b. Develop pollution free incinerators.

c. Recover copper from automotive parts.

d. Produce ferrous scrap useful to the steel industry.

e. Produce clean cast iron from automobile engines.

f. Produce secondary pig iron from off-grade ferrous scrap.

g. Develop techniques for dismantling junk cars.

h. Develop useful products from scrapped tires.

i. Develop techniques for using automotive scrap as a reductant for currently nonexploitable, nonmagnetic taconite ores.

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BUREAU OF MINES RESEARCH AND ACCOMPLISHMENTS IN UTILIZATION OF SOLID WASTES

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

March 1970

BUREAU OF MINES RESEARCH AND ACCOMPLISHMENTS IN UTILIZATION OF SOLID WASTES

By F. J. Cservenyak and C. B. Kenahan

information circular 8460



UNITED STATES DEPARTMENT OF THE INTERIOR
Walter J. Hickel, Secretary

BUREAU OF MINES
John F. O'Leary, Director

APPENDIX C

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APPENDIX C

BUREAU OF MINES RESEARCH AND ACCOMPLISHMENTS IN UTILIZATION OF SOLID WASTES

by

F. J. Csorvenyak[1] and C. B. Kenahan[2]

ABSTRACT

The Bureau of Mines Solid Waste Program is directed toward three main areas of research: (1) Extraction of mineral, metal, and energy values from urban refuse; (2) recovery of mineral and metal values from wastes generated in the industrial extraction, processing, and utilization of raw materials and mineral-base products; and (3) upgrading and utilization of automotive scrap. The Bureau also has a contract and grant program which supplements the in-house research and aids in the training of personnel in the proper management of mineral- and metal-based solid wastes.

INTRODUCTION

The Bureau of Mines has always considered as potential resources the waste products and scrap generated by the minerals and metals industry and the consuming public. For many years, under the authority granted to the Department of the Interior in its Organic Act, the Bureau has been engaged in research to develop methods of utilizing mineral- and metal-based wastes to recover economic values and to alleviate the disposal problem. The Bureau of Mines has been a pioneer in the field of waste metals research and it has trained a group of engineers and scientists to cope with the wide range of problems, methods, and materials that characterize the secondary metals industry, but which have traditionally escaped consideration in the curricula of colleges and universities. The general objective in this work is development of new and improved technology for recovery and recycling of metal and mineral values from waste sources in areas where commercial methods are inadequate, inefficient, or nonexistent. The success of this work is evident in the accomplishments achieved in 20 years of waste metals research and the more than 100 technical publications, patents, and presentations resulting from these studies.

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With the passage of the 1965 Solid Waste Disposal Act, the Bureau's responsibility for utilization or disposal of mineral and metal wastes was greatly expanded. Using funds made available under the act, the Bureau of Mines was able to enlarge and accelerate its modest in-house program on utilization of mineral- and metal-based wastes which it had been conducting.

The Solid Waste Disposal Act also allowed the Bureau to initiate a wide-ranging Contract and Grant Program to supplement the in-house research and provide training in the proper management of solid mineral- and metal-based wastes.

IN-HOUSE RESEARCH PROGRAM

Extraction of Mineral, Metal, and Energy Values From Urban Refuse

The Bureau is directing a major research effort on development of methods to recover metal, mineral, and energy values from municipal incinerator residues and raw refuse. Specifically, the program seeks to (1) develop and demonstrate new or improved techniques to State and local governments and private industry for the recovery and recycling of metal, mineral, and energy values contained in urban refuse; (2) reduce environmental pollution resulting from inadequate treatment and disposal of a major solid waste; (3) develop technology and provide training in solutions to problems involving the use and reuse of urban solid wastes; and (4) alleviate the acute problem of urban solid waste disposal. The principal components of the program are as follows:

1. Emphasis is being placed on research to produce a clean, high-grade ferrous scrap from massive iron pieces and tin cans contained in urban refuse. Removal and recovery of copper from the iron and tin from the cans is the primary objective.

2. Techniques are being sought to separate the conglomeration of nonferrous metals contained in raw refuse and incinerator residues. Research on methods to separate and recover the aluminum, copper, zinc, lead, and tin values from the nonferrous fractions are continuing. Refinement of the separate nonferrous values to marketable products is the ultimate objective.

3. Reclamation of the glass fractions which are the major constituent of residues is being given special attention. Methods to separate clean from colored glass are under development. In addition, a major effort on utilization of the glass for products such as glass wool, structural blocks, and cullet will be continued and accelerated (figs. 1 and 2).

4. A continuous processing plant with a capacity of 1,000 pounds per hour has been completed and initial tests have begun. The plant is capable of separating and recovering the major metal and mineral values contained in incinerator residues such as iron, aluminum, copper, tin, zinc, lead, and glass (figs. 3-5). Parallel studies are also being conducted on recovering values from raw refuse by air classification techniques.

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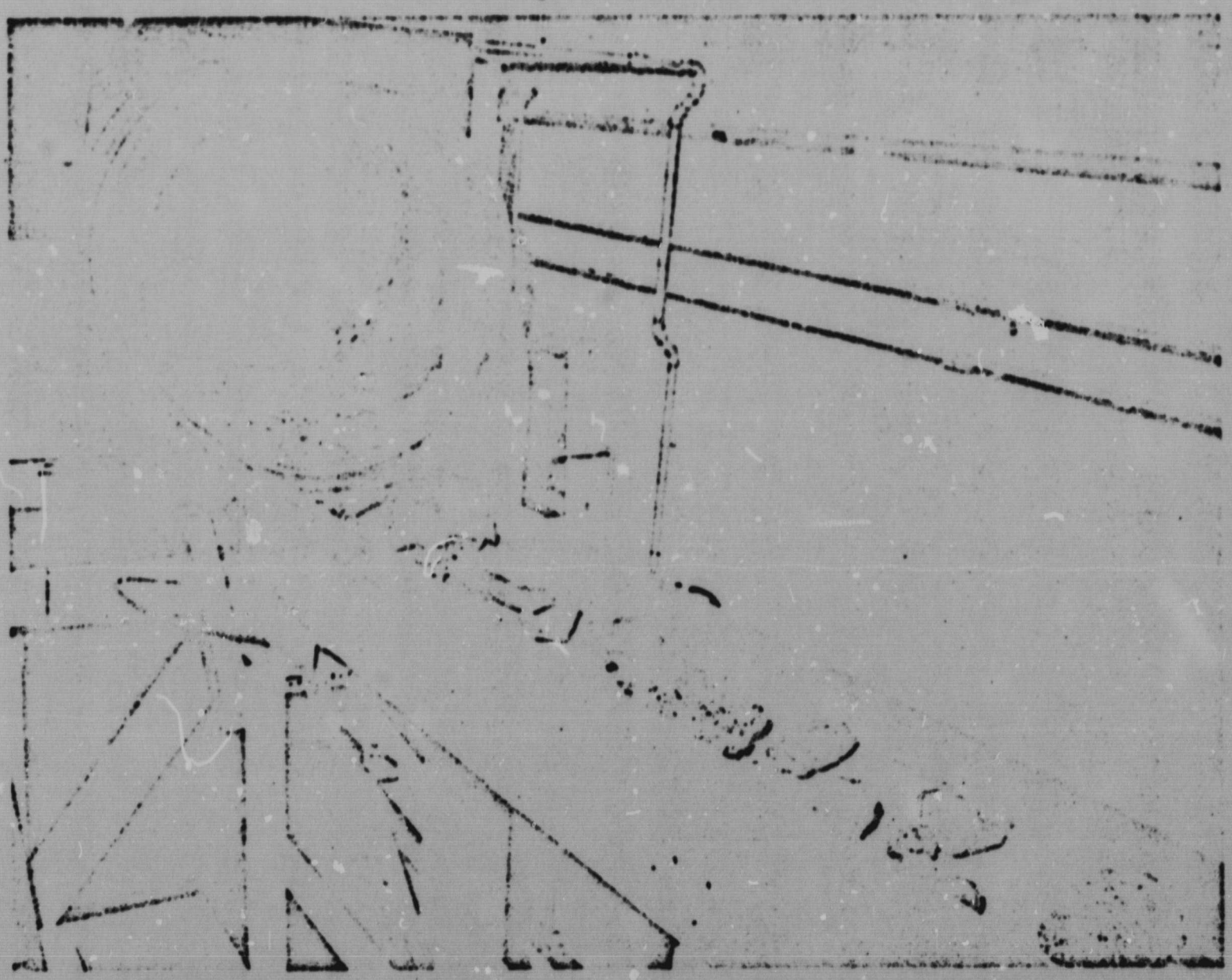

FIGURE 5. - Oversize Material, Including Metal Pieces, Tin Cans, and Glass, Being Separated From Incinerator Residues.

5. Research is underway on the development and evaluation of vertical vortex-type incinerator for combustion of solid wastes, including urban refuse. Based on previous Bureau experience on vortex incineration, the construction of a redesigned version offers a promising device for incineration of combustible solids ranging from high moisture content sludges and industrial wastes to urban refuse.

6. The Bureau is applying the process of carbonization (destructive distillation) to the disposal of industrial wastes including urban refuse. This process involves the thermal conversion of materials into usable forms of solid, liquid, and gaseous products; that is, char, oil, and gas.

7. A novel process for converting the combustible material contained in urban refuse, including garbage and cellulose, into crude petroleum is also being investigated. The process, which involves the reaction of CO plus H_2O at 400° C and high pressure, produces active hydrogen which hydrogenates the

organic material in the refuse (fig. 6). This study includes characterization of the petroleum products produced from refuse.

8. Under a grant program, the following research studies have been initiated at a number of minerals-oriented universities on urban refuse related problems:

a. Utilization of waste glass from urban refuse.

b. Characterization and utilization of the fine ash fraction from municipal incinerator residues.

c. Technical-economic evaluation of present municipal incinerators and associated equipment such as air pollution control apparatus.

d. Effect of contaminants on ferrous materials contained in urban refuse.

e. Extraction of mineral and metal values from incinerator fly ash.

f. Production of synthetic gas by subsurface disposal of urban refuse.

g. Factors affecting economic recycling of mineral and metal values from incinerator residues.

Recovery of Mineral and Metal Values From Wastes Generated in the Industrial Extraction, Processing, and Utilization of Mineral-Based Raw Materials and Products

The objective of this work is the development of new and improved technology for recovering and recycling metal and mineral values from waste sources in the industrial, mining, metallurgical, and chemical processing operations in areas where commercial methods are inadequate, inefficient, or nonexistent. Successful attainment of this objective will eliminate pollution caused by objectionable solid waste practices and return valuable raw materials back to the economy.

The Bureau's program is alined to optimization of all segments of the recycling process, including not only salvage and reuse but also stabilization of nonusable mineral wastes and devising acceptable disposal methods. The important elements of the program include:

1. A large-scale effort has been made to stabilize the waste tailings piles that have no mineral or utilization value. Successful chemical and vegetative stabilization procedures have already been developed, and large-scale chemical and vegetative techniques have been successfully demonstrated on copper and uranium mill tailing piles. However, much work remains to be done in order to develop more efficient and low-cost methods to stabilize the billions of tons of varied types of mining wastes that have accumulated across the country (figs. 7 and 8).

Investigations are underway to determine the variable physical and chemical conditions which cause spontaneous combustion in coal refuse banks. A Bureau of Mines-Commonwealth of Pennsylvania cooperative program to demonstrate and evaluate techniques and costs for extinguishing a burning coal refuse bank, typical of many that are burning in Pennsylvania, was started recently.

2. Studies identifying the nature, magnitude, and significance of solid wastes issuing as flue dusts at steel furnaces have been initiated. Aside from the quantities of iron contained in these wastes, significant amounts of zinc, copper, lead, and other substances, originating from the scrap additions to the steelmaking processes, are also present. Concurrently, techniques are being worked on to recover and treat the dusts from steelmaking operations so that they can be returned to the steelmaking furnaces as high-grade iron ore pellets.

3. The feasibility of utilizing abandoned surface-mined areas as municipal landfills attracts attention in the vicinity of many urban areas where major problems are developed by virtue of the growing magnitude of wastes to be handled. Means of accommodating the obstacles that preclude such practices in most instances are being studied.

4. Attention is also directed toward development of new uses for mineral wastes such as slags, drosses, flue dusts, mine wastes, and tailings generated in the mining and metallurgical industries. Promising structural building blocks have been made from copper and gold tailings, and wall tile competitive with commercial tile has been made from process wastes (fig. 9).

5. Investigations on the reclamation of high-value metals such as cobalt, nickel, and chromium from high-temperature or superalloy scrap are also being pursued. At present, much of this scrap is sold to foreign countries at a significant dollar loss for lack of economic processing methods. The present effort is directed toward development of an electrolytic fused salt method for recovering the values.

6. The Bureau's research effort includes a study on development of rapid and simple methods of identification of scrap metals. Although this is a vital step in the reuse cycle and errors at this point can be serious and cumulative, the methods in general use are not at all scientific or reliable. Successful techniques to identify aluminum alloys containing manganese, zinc, copper, and magnesium have already been devised.

7. Reclamation and reuse of the many types of aluminum scrap are receiving attention. Several electrolytic techniques show promise of producing high-purity aluminum from a number of scrap alloys. One method produces high-purity aluminum and metallurgical-grade silicon from scrap aluminum-silicon alloys.

8. The Bureau is making a major research effort to recover the valuable chromium, copper, nickel, zinc, and cadmium metals from waste electroplating solutions. A secondary but important objective of this work is the elimination of hazardous chemicals from these waste solutions, thereby solving a serious disposal problem for the plating industry.

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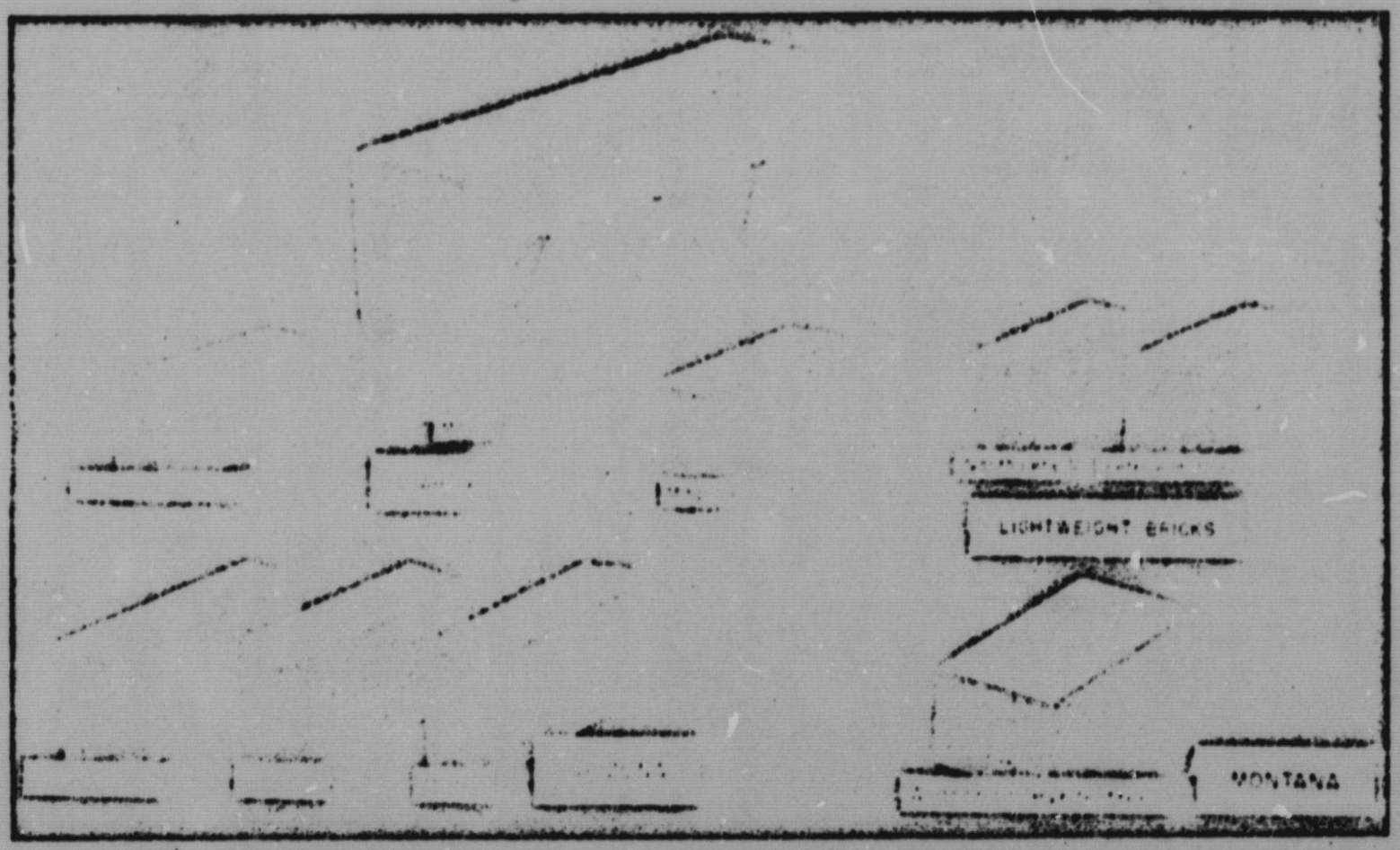

FIGURE 9. - Structural Blocks Made From Waste Copper Tailings.

9. Methods to recover and recycle the vast quantities of precious metals presently lost in electronic equipment from commercial and defense applications are being studied. It is estimated that millions of ounces of gold, silver, and platinum are presently lost when equipment of this type is discarded because of lack of effective recovery methods. Leaching, smelting, and electrolytic techniques are being investigated for applicability in recovering the metal values.

10. Two projects initiated recently are aimed at the development of efficient methods to reclaim the ever-increasing amounts of titanium scrap which are presently wasted or sold abroad for a fraction of their real worth. One study involves the removal of contaminants from titanium scrap, such as chips and turnings, by methods which include pickling and attrition. The other involves the use of an inductoslag smelting process to consolidate non-contaminated and well-segregated scrap. If successful, the resulting ingot can be used as a consumable electrode for subsequent remelting. Methods are also being investigated to recover and recycle the metal values from the wastes produced in the production of titanium tetrachloride.

11. Several studies are underway on the development of new and novel methods to utilize the vast quantities of obsolescent ferrous scrap generated annually. A project to utilize this scrap to make secondary pig iron is currently being conducted. The aim of this work is to produce a specification-grade secondary ingot for the foundry industry. Another study utilizing

low-grade ferrous scrap as feed for electric furnaces in a continuous steelmaking process is also under investigation. Still another research effort is directed toward the utilization of ferrous scrap to make high-grade iron ore by destructive oxidation techniques. The objective is to oxidize the scrap to iron oxide which can be used to make pellets for blast furnace feed. The Bureau-developed process for converting low-grade nonmagnetic taconite ore and scrap into high-grade iron ore by a roasting-reduction process is also receiving continued attention.

12. Research on methods to increase the utilization of secondary source metals is underway. The objective of this work is to encourage the use of waste metals in preparing commercial alloys and thereby conserve primary supplies of such critical metals as tin, copper, and nickel. One recent accomplishment has been the lowering of the tin content of leaded-red brass by substituting zinc, without impairing the mechanical properties of the alloy.

Upgrading and Utilization of Automotive Scrap

A nationwide survey made by the Bureau of the autowrecking industry, the ferrous-scrap processing industry, and other elements pertinent to the junk car problem, identifies the factors that influence the accumulation and movement of automobile scrap. The information obtained in this study was used to prepare a comprehensive and widely circulated report entitled, "Automobile Disposal--A National Problem."

It is estimated that over 7 million cars were scrapped in 1969 in the United States and that as many as 20 million junk cars remain in auto graveyards across the Nation waiting to be reclaimed. Part of the disposal problem is lack of adequate technology necessary to upgrade the body steel so that it will meet the ever-increasing stringent requirements of the steel mills.

During recent years Bureau of Mines efforts have been directed toward means of accelerating the movement of scrap in the face of changing technology in steelmaking practice that has tended to depress traditional markets for automotive scrap. These efforts have included economic and resource evaluation studies aimed at delineating factors causing and contributing to the scrap car disposal problem, and research studies aimed at the upgrading and utilization of the metals contained in this valuable resource.

Current research efforts are concentrated on improving the technology of upgrading automotive and other ferrous scrap so that traditional markets may be maintained and new markets developed. The principal components of the program include:

1. Development of methods to produce clean ferrous scrap from junk cars by the physical or chemical removal of nonferrous components. Part of this work involves construction of an experimental pollution-free incinerator designed to produce clean ferrous scrap by the thermal removal of nonferrous components. Construction of the incinerator has been completed and controlled burning of the cars has been started to determine operating parameters. The incinerator can process eight cars per hour at a controlled temperature with a minimum of air pollution (fig. 10).

2. Research is progressing on upgrading the nonmetallic and nonferrous reject from junk car shredding operations. A promising procedure has been developed which employs air to fluidize and separate the nonmetallic from the metallic portions of shredded nonmagnetic auto scrap. At present, many nonferrous metals are not recovered from shredding operations because no practical method has been developed to separate and recover the metals from the nonmetallics.

3. Work is continuing on improved methods of recovering copper by chemical means from electrical components of junked automobiles. Research on chemical dissolution and recovery of all nonferrous values from incinerated products from car scrappage operations is also being pursued. A process has been developed for sweating copper from copper-bearing scrap such as armatures by preferential melting in a molten salt bath. Tests have shown that over 98 percent of the copper can be removed from an armature in less than a minute using this technique. Work is continuing on this process to develop a cheaper bath and to cost-evaluate larger scale tests.

4. Studies are being directed towards effective high-temperature oxidation of ferrous scrap, including junk cars, to produce iron oxide and clean scrap products which can be used as a source of iron in the steel industry.

5. Preliminary work has been started on development of an economic method for producing clean cast iron from scrap automotive engines.

6. Ongoing work related to auto scrap research involves the production of secondary pig iron from mixed off-grade ferrous scrap, including junk cars.

7. Extensive studies on various dismantling procedures for scrap cars have been conducted. To date, 17 junk cars of various models and age have been weighed, dismantled, and segregated into their ferrous, nonferrous, and nonmetallic components in a series of time and motion studies using various dismantling methods including cutting torches, hand-stripping, and cutoff saws. A report on these studies including an economic evaluation is now available (fig. 11).

8. The feasibility of recovering values from discarded automobile tires by treating them in a heated reactor has been investigated and shows promise. In one series of tests at 500° C, as much as 140 gallons of oil and 1,500 cubic feet of gas comparable in heating value to natural gas were recovered per ton of tires fed into the reactor.

9. Considerable notice has been given to Bureau research on utilization of auto scrap as a reductant for nonmagnetic taconite ore. The basic idea in this work is to use auto scrap, as well as waste borings and turnings, as a reductant for presently nonexploitable, nonmagnetic taconite ores. In this process nonmagnetic taconites assaying about 30 percent iron are mixed with unburned auto scrap in ratios of about 10 to 15 parts ore to 1 part scrap. This material is passed through a rotary kiln at 1,000° C to simultaneously reduce the nonmagnetic oxide iron in the ore and oxidize the scrap iron to the magnetic form. The final product is a high-grade ore that analyzes more than

62 percent iron. The technical feasibility of the process has been proven at the pilot-plant level. A means is being sought to engage private participation in cooperative efforts to improve the economic feasibility of the system.

RESEARCH ACCOMPLISHMENTS

Sixteen Bureau reports, 14 technical journal publications, and 14 reports under the contract and grant program have been published since the inception of the Bureau's Solid Waste Research Program. In addition, numerous formal and informal oral presentations on the research studies have been presented at technical meetings across the country. The reports and presentations covered all aspects of the solid waste research, including junk car utilization and disposal, recovery of values from incinerator residues, utilization of mine and mill wastes, stabilization of mill tailings piles, and utilization of smelter dusts, slags, and drosses. A bibliography is available at the end of this report.

Urban Refuse

A processing plant with a capacity of 1,000 pounds per hour, capable of continuously and automatically separating and recovering the metal and mineral values in municipal incinerator residues, was constructed and tested successfully. Methods and equipment have been developed for separating ferrous and nonferrous metal constituents. A clean glass fraction is also being separated into its colorless and colored components. Work on this project has also resulted in the development of the first reliable sampling methods and analytical techniques for evaluating municipal incinerator residues.

Several types of building products were successfully developed from waste glass found in municipal refuse. Structural blocks made from these wastes are of high quality and meet ASTM specifications for outside face brick. Attractive white, green, and polychrome blocks were made with waste glass collected from a local municipal refuse dump. Efforts to produce a commercial-grade glass wool from waste glass have also been encouraging. The product is considered equal in quality to commercial slag wool.

While working on the recovery of metal values from municipal incinerator wastes, Bureau personnel discovered that fly ash derived from the burning of the waste was a potential source of silver and gold. Silver values as high as 20 ounces per ton were found in some samples. Methods to recover the precious metals are under investigation.

A novel development which could greatly aid in solving the garbage crisis is the discovery by Bureau scientists that garbage and cellulose can be turned into crude petroleum. It is estimated that each ton of urban refuse could produce a barrel of low-sulfur-content oil by the process.

Automotive Scrap

Studies on dismantling and stripping procedures for scrapped cars have received wide attention. Hundreds of requests for information on the

dismantling time and motion studies have been received. The final report on this work is now available. The Industry Advisory Committee of the Business and Defense Services Administration on Iron and Steel Scrap Problems has commended the Bureau of Mines on its junk car research efforts. They especially encouraged the Bureau's cooperative effort with a private company to construct and operate a low-cost smokeless car incinerator. Bureau personnel are presently operating the incinerator to gather data on costs of controlled burning as well as metallurgical information on sweating of zinc die-cast and other low-melting metals from scrap cars.

The Ralph Stone Company, Los Angeles, Calif., under a Bureau contract, identified all of the copper components in automotive scrap and investigated the technical economic factors involved in complete removal of copper. Several recommendations were presented on how to improve steel scrap quality through better design and control of copper components. This same company also completed a study describing existing and projected scrap processing operations with respect to site selection, yard layout, availability and suitability of process equipment, material handling efficiency, health and safety, application of a mathematical model, and community relations. The latter study, sponsored by the Bureau of Mines and the Scrap Research and Education Foundation, Institute of Scrap Iron and Steel, has been well received by the ferrous scrap processors.

A large-scale experiment by the PPG Industries, Pittsburgh, Pa., was conducted under Bureau sponsorship on the thermal removal of copper from automotive scrap. A total of 92 scrap cars were crushed and sheared for feeding to a 48-inch, acid-lined cold blast cupola. Sodium sulfate was used as the chemical addition to the molten scrap in an effort to reduce the copper content. The results of the study indicated that the addition of such materials as sodium sulfate may be useful in removing copper from automotive scrap.

Mining and Industrial Wastes

Under the contract and grant program, the University of Utah developed several promising methods for utilization of such wastes as mine and mill tailings. Significant progress was made in the production of crystallized glass from copper tailings; a promising refractory was made from asbestos tailing waste; and high-quality ferrites were fabricated from mill scale.

West Virginia University, under a Bureau grant, developed a process for producing rock wool insulation from coal ash slag, a waste product from coal-fired central powerplants.

A patented process was developed by the Bureau of Mines for converting nonmagnetic taconite ores (a presently unused waste material resulting from mining of magnetic taconite ores) to the magnetic form by reduction-roasting with low-grade ferrous scrap. The iron in both the ore and the scrap is converted into high-grade magnetic iron oxide.

The feasibility of foaming and sintering to produce a lightweight building material suitable for both structural and insulating applications from red

mud wastes was demonstrated by the IIT Research Institute, Chicago, Ill., under a contract let by the Bureau. The red mud wastes are residue materials resulting from the extraction of alumina from bauxite ores by the Bayer process. IIT Research Institute has also conducted a Bureau-sponsored techno-economic analysis of mining and milling wastes. An in-depth study of iron, copper, and lead-zinc ore tailings and their application for utilization in large volume industries, such as building products, was made. Iron (taconite) wastes were recommended for prime consideration at this time.

The North Star Research and Development Institute, Minneapolis, Minn., conducted a study under a Bureau contract to determine the feasibility of using fluidized bed techniques to remove fly ash from gas streams. The study indicated that fly ash removal from gas streams by fluidized bed techniques shows promise. The study also showed that the system offers a possibility of a combination process to remove both fly ash and sulfur dioxide.

In a highly successful study by the Department of Civil Engineering, Stanford University, researchers under a Bureau grant demonstrated the technical and economic feasibility of producing calcium-silicate bricks from California gold mine wastes. A preliminary report indicated that calcium-silicate bricks can be produced from the tailings and delivered to the market areas at costs ranging from $8 to $21 per 1,000, which is below the existing lowest quoted selling price of standard clay bricks.

In another Bureau-sponsored study, the Franklin Institute Research Laboratories, Philadelphia, Pa., investigated the utilization of coal dust slurries in cement blocks. The study showed that coal washing fines impart greater resistance to water penetration and transmission to the block. An economic analysis showed that the cost of cement blocks containing the coal dust depends primarily upon the distance from the point of origin to the manufacturer; for distances up to 45 miles, the product containing coal dust is cheaper than the regular cement block.

Methods were developed by Bureau scientists to convert asbestos mining wastes, phosphorus furnace slags, and mine and mill tailings into raw materials for manufacture of wall tile and construction brick. A major wallboard manufacturer has expressed interest in a Bureau-developed method for converting waste gypsum from phosphoric acid manufacture into plaster.

Bureau researchers under the Solid Waste Program were highly successful in stabilizing two troublesome uranium mill tailings piles. A 35-acre plot of tailings at Tuba City, Ariz., on the Navajo Indian Reservation, was completely stabilized by chemical means under Bureau supervision and a 13-acre waste pile at Durango, Colo., was stabilized by vegetative methods. Bureau engineers also advised and assisted the Kennecott Copper Company in efforts to stabilize a 10-acre plot of copper mill tailings at McGill, Nev., by vegetative cover. As a direct result of this work, the company is making preparations to stabilize a 300-acre site in the same area. The Bureau also assisted plant personnel in planting seeds and chemically stabilizing 1- to 2-acre test plots of mill wastes of the White Pine Copper Company, the St. Joseph Lead Company, and the American Smelting and Refining Company. A 19-acre tailing pond belonging

to the Vitro Chemical Company was treated chemically with Bureau assistance and supervision. The hardened crust that formed was found to effectively prevent wind erosion and air pollution.

OTHER ACTIVITIES

The Bureau of Mines made a 28-minute color film entitled, "Wealth of the Wasteland," based on its solid waste research work. The film depicts the various problems in solid, mineral, and metal wastes, and the steps being taken by Bureau researchers to solve them. The camera covers many unique shots of junk car processing yards and graveyards, city dumps, and piles of wastes generated by domestic mining and milling operations. Episodes filmed at Bureau research centers show engineers and scientists experimenting with new methods to separate and recover the values in these waste products. The film also depicts research and development being conducted by universities and other non-Government organizations under Bureau-administered grants and contracts. Prints of the film are available from the Bureau of Mines Motion Picture Department, 4800 Forbes Avenue, Pittsburgh, Pa. 15213

The British Broadcasting Company (BBC-TV) made film highlights of the Bureau's research on separation and recovery of values from incinerator residues. The footage taken at the Bureau's College Park Metallurgy Research Center was a significant part of the final documentary on solid waste problems in Europe and the United States, and was shown on British television.

The Education Division of the Encyclopedia Britannica also made film highlights of the College Park studies for inclusion in a solid waste film for their educational film library.

The Bureau recently completed work on a solid waste display depicting its three main areas of research: urban refuse, junk cars, and solid mineral wastes. The lighted display, which measures 20 by 7 feet high, has six colorful panels showing the problems and the Bureau's research effort to solve them. The display features an automatic slide projector with sound and slides to describe the research studies. The display is available for appropriate conventions, technical meetings, and symposia (fig. 12). A model of a futuristic incinerator-power complex is on display in the Interior Department's Museum.

The Bureau and the IIT Research Institute, Chicago, Ill., sponsored a symposium on mineral waste utilization. This was the first time that a meeting of national stature was held to identify mineral waste problems coupled with detailed information on the utilization potential of the wastes. The second mineral waste utilization symposium, which will emphasize the techno-economic aspects of waste utilization, will be held on March 18 and 19, 1970, at IIT Research Institute. Thirty-seven papers on waste utilization will be presented. Copies of the proceedings of the first symposium are presently available from IIT Research Institute and copies of the second meeting will be available in April.

The Bureau's work in solid waste research has been widely publicized and acclaimed in national newspaper and journal articles. Feature articles in

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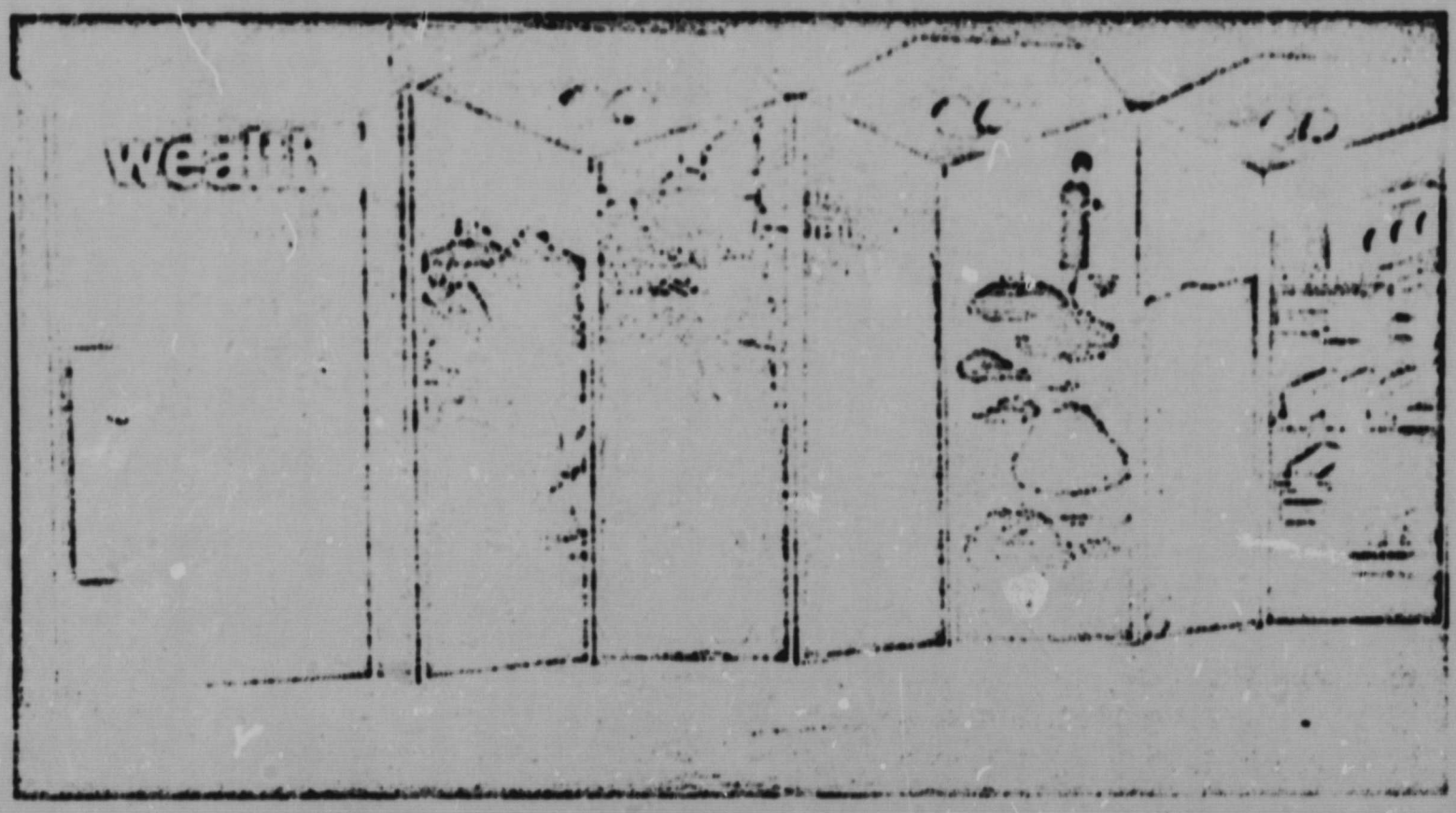

FIGURE 12. - Bureau of Mines Solid Waste Display.

"The National Observer" and the Sunday Supplement of the Washington Star described some of the research studies. Articles highlighting the Bureau's research also appeared in Nation's Cities Magazine, Science News, Public Works Journal, Solid Wastes Management Journal, and the American Public Works Association Reporter.

CURRENT SOLID WASTE RESEARCH GRANTS

Urban Refuse

SWD-22	Characterization of Mineral and Metal Values in Incinerator Residue Gangue	$20,000	University of West Virginia

Objective: To characterize and classify by physical and chemical methods the minerals and metals in gangue and residues remaining after separation of glass, ferrous metals, and nonferrous metals from incinerated urban refuse.

SWD-25	Extraction of Mineral and Metal Values From Incinerator Residue Gangue	$44,288	University of West Virginia

Objective: To extract, recover, and develop uses for mineral and metal values such as aluminum, titanium, and gallium in gangue and residues remaining after separation of glass, ferrous metals, and nonferrous metals from incinerated urban refuse.

SWD-26	Use of Waste Glass to Produce Lightweight, Aerated Concrete	$52,739	Stanford University

Objective: To study the feasibility of using reclaimed waste glass from urban refuse to produce a lightweight building material. The study will include technical and economic aspects of using waste glass as the major raw material in the manufacture of lightweight, aerated concrete.

SWD-27	High Pressure Forming of Waste Glass To Produce Structural Elements	$57,031	University of Missouri

Objective: To provide economic and experimental evidence that waste glass from urban refuse can be converted, by using well-established high-pressure forming techniques, into usable structural elements such as rods, bricks, blocks, and sheeting, for use in construction of low-cost housing, roads, and runways.

SWD-28	Use of Waste Glass in Expanded Shale Aggregate	$32,928	University of Alabama

Objective: To determine the technical and economic feasibility of using crushed waste glass from urban refuse in a mixture with expandable clay or shale to produce lightweight aggregate.

SWD-29	Effect of Residual Elements on Use of Ferrous Metals from Incinerated Refuse	$108,445	University of Wisconsin

Objective: To investigate the effect of various concentrations of contaminants such as copper, tin, nickel, and chromium, in ferrous metal reclaimed from urban refuse. Castings will be made from typical ferrous materials found in urban refuse and physical and chemical tests will be made to determine what is the tolerance level of each contaminant metal. For example, although copper is known to have a deleterious effect on certain types of steel, it is not generally known what the exact cutoff point or tolerance level of copper is in some of these materials. Similar studies will be made on nickel, tin, and chromium contents of steel scrap.

SWD-30	Production of Synthetic Gas by Subsurface Disposal of Urban Refuse	$57,456	Montana College of Mineral Science and Technology

Objective: To produce synthetic gas by the subsurface disposal of urban refuse in order to determine the economic and technical factors affecting the successful application of underground disposal of decomposable refuse and the recovery of resulting combustible gaseous products.

SWD-31	Technical Evaluation of Urban Refuse Incinerators	$40,320	University of Alabama

Objective: To evaluate current urban refuse incinerators with the specific purpose of recommending research areas needed to effect utilization of heat and energy values, and for the recovery and recycling of ferrous, nonferrous, and mineral values from urban refuse.

Mining and Industrial Wastes

SWD-5	Development of New Uses for Copper and Other Mine Tailing Wastes	$21,670	University of Utah

Objective: To investigate the utilization of copper tailings and other mining waste materials to produce structural and other products. In addition to producing bricks and crystallized glass materials from copper tailings, the study is to include the development of uses for gypsum and asbestos wastes, phosphate slags, and mill scale.

SWD-11	Production of Steam Cured Building Units From Gold Tailings	$8,000	Stanford University

Objective: To study the technical and economic factors involved in producing building materials by using California gold mine tailings and lime, hardened by curing in high-pressure steam to form a hydrated calcium silicate bond.

SWD-14	Use of Fly Ash as a Soil Conditioner	$14,328	Virginia Polytechnic Institute

Objective: To study the potential utilization of boron, zinc, and other elements in fly ash as a soil conditioner to correct nutrient deficiencies. Greenhouse experiments will be conducted based on results obtained in laboratory tests.

SWD-15	Characterization and Utilization of Anthracite Refuse	$121,602	Pennsylvania State University

Objective: To recover and develop potential uses for refuse from the more than 800 anthracite refuse banks that blanket 12,000 acres of valuable land in the heavily mined region of northeastern Pennsylvania.

Total Funding--$578,807

BIBLIOGRAPHY

Bureau of Mines Reports of Investigations[3]

3860--Examination and Treatment of Industrial Magnesium Foundry Wastes, by O. C. Garst, 1946.

3874--The Recovery of Metal and Other Valuable Products From Aluminum Dross, by O. C. Garst, F. Fraas, W. M. Mahan, D. D. Blue, and L. Fink, 1946.

5181--Oxidation Rates of Molten Metals as Determined by a Recording Thermobalance: Part I. Tin, by J. H. Bilbrey, Jr., D. A. Wilson, and M. J. Spendlove, 1955.

5205--Electrolytic Recovery of Zinc From Galvanizers' Sal Skimmings, by P. M. Sullivan, 1956.

5786--Experimental Extraction of Strategic Components From S-816 Alloy Scrap, by H. Kenworthy, V. A. Nieberlein, and A. G. Starliper, 1961.

6417--Recovery of Zinc From Galvanizers' Dross and Zinc-Base Die-Cast Scrap by Filtration, by J. A. Ruppert and P. M. Sullivan, 1964.

6445--Electrochemical Recovery of Cobalt-Nickel Alloy From Superalloy Scrap, by M. Hayashi, D. R. Peterson, and D. W. Bridges, 1964.

6764--Magnetic Roasting of Iron Ores With Ferrous Scrap, by M. M. Fine and C. Prasky, 1966.

6869--Fly Ash As a Coagulant Aid in Water Treatment, by R. C. Ballance, J. P. Capp, and J. C. Burchinal, 1966.

6884--The Use of Coal and Modified Coals as Adsorbents for Removing Organic Contaminants From Waste Waters, by G. E. Johnson, L. M. Kunka, A. J. Forney, and J. H. Field, 1966.

6908--Experimental Studies of Incineration in a Cylindrical Combustion Chamber, by M. Weintraub, A. A. Orning, and C. H. Schwartz, 1967.

6926--Laboratory Testing and Evaluation of Porous Permeable Rock For Nuclear Waste Disposal, by J. B. F. Champlin, R. D. Thomas, and A. D. Brownlow, 1967.

6987--Mine Water Research Neutralization, by M. Duel and E. A. Mihok, 1967.

7036--Molten-Salt Electrorefining Vanadium Scrap, by K. P. V. Lei and T. A. Sullivan, 1967.

---

[3]Copies of these reports may be obtained by contacting the Publications Distribution Branch, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213

7042--Recovery of Lead and Copper From Blast Furnace Matte, by D. A. Wilson and P. M. Sullivan, 1967.

7075--Revegetation Studies at Three Strip-Mine Sites in North-Central Pennsylvania, by M. O. Magnuson and R. L. Kimball, 1968.

7102--Evaluation of Synthetic Organic Flocculants in the Treatment of Coal Refuse Slurries, by K. J. Miller and A. W. Deurbrouck, 1968.

7117--Silver Recovery From Waste Photographic Solutions by Metallic Displacement, by R. O. Dannenberg and G. M. Potter, 1968.

7126--Oxidation of Lead Blast Furnace Matte by Ferrobacillus-Ferrooxidans or a Dilute Acid Solution, by J. D. Corrick and J. A. Sutton, 1968.

7140--Centrifugal Dewatering of Jamaican Red Mud, by P. C. Good and O. C. Fursman, 1968.

7182--Copper Cementation Using Automobile Scrap in a Rotating Drum, by K. C. Dean, R. O. Groves, and S. L. May, 1968.

7199--Laboratory Studies on the Use of Sodium Sulfate for Removing Copper From Molten Iron, by H. V. Makar, B. W. Dunning, Jr., and H. S. Caldwell, Jr., 1968.

7204--Composition and Characteristics of Municipal Incinerator Residues, by C. B. Kenahan, P. M. Sullivan, J. A. Ruppert, and E. F. Spano, 1968.

7210--Removal of Nonferrous Metals From Synthetic Automobile Scrap on Heating in a Rotary Kiln, by G. W. Elger, W. L. Hunter, and C. E. Armantrout, 1968.

7213--Recovery of Hydrofluoric Acid From Waste Fluosilicic Acid, Preliminary Studies, by P. C. Good and J. E. Tress, 1968.

7214--Use of Fly Ash for Remote Filling of Underground Cavities and Passageways, by E. M. Murphy, M. O. Magnuson, P. Suder, Jr., and J. Nagy, 1968.

7218--Copper Removal From Steel Scrap by Thermal Treatment, Feasibility Study, by R. R. Brown and F. E. Block, 1968.

7221--Beneficiation of Titanium Chlorination Residues, Preliminary Study, by C. C. Merrill, M. M. Wong, and D. D. Blue, 1969.

7261--Chemical and Vegetative Stabilization of a Nevada Copper Porphyry Mill Tailing, by K. C. Dean, R. Havens, and K. T. Harper, 1969.

7264--Extraction of Aluminum and Fluorine From Leached Potlining Residues, by P. C. Good and W. G. Gruzensky, 1969.

7282--Entrainment Drying and Carbonization of Wood Waste, by C. C. Boley and W. S. Landers, 1969.

7288--Chemical Stabilization of the Uranium Tailings at Tuba City, Ariz., by R. Havens and K. C. Dean, 1969.

7301--Extraction of Copper From Oxides Using Iron and Steel Scrap. Principles and Application to Pure Systems, by S. E. Khalafalla, H. W. Kilau, and L. A. Haas, 1969.

7302--Destructive Distillation of Scrap Tires, by D. E. Wolfson, J. A. Beckman, J. G. Walters, and D. J. Bennett, 1969.

7315--Refining Zinc-Base Die-Cast Scrap Using Low-Cost Fluxes, by D. Montagna and J. A. Ruppert, 1969.

7316--Chemical Reclaiming of Superalloy Scrap, by P. T. Brooks, G. M. Potter, and D. A. Martin, 1969.

7319--Selective Flotation of Minerals From North Carolina Mica Tailing, by W. H. Eddy, J. S. Browning, and J. E. Hardemon, 1969.

7336--Solvent Extraction of Nickel and Zinc From a Waste Phosphate Solution, by H. E. Powell, L. L. Smith, and A. A. Cochran, 1970.

7350--Dismantling a Typical Junk Automobile to Produce Quality Scrap, by K. C. Dean and J. W. Sterner, 1969.

Bureau of Mines Information Circulars[4]

7973--Iron and Steel Scrap in California and Nevada, by G. C. Branner, 1960.

8002--Methods for Producing Secondary Copper, by M. J. Spendlove, 1961.

8076--Processes for Recovering Sulfur From Secondary Source Materials, by B. K. Shibler and M. W. Hovey, 1962.

8212--Subsurface Disposal of Industrial Wastes in the United States, by E. C. Donaldson, 1964.

8243--Iron and Steel Scrap in the Pacific Northwest, by G. A. Kingston, 1964.

8289--Iron and Steel Scrap in Arkansas, Kansas, Louisiana, Mississippi, Missouri, Oklahoma, and Texas, by F. B. Fulkerson and H. F. Robertson, 1966.

8329--Iron and Steel Scrap in the Southeast, by V. A. Danielson, J. F. O'Neill, and H. W. Ahrenholz, 1967.

---

[4] See footnote 3.

8342--Iron and Steel Scrap Survey in Illinois, Indiana, Iowa, Michigan, Minnesota, and Wisconsin, by W. Pajalich, 1967.

8344--Iron and Steel Scrap in the Intermountain and Northwestern Plains States, by H. J. Bennett, 1967.

8348--Fly Ash Utilization. Proceedings: Edison Electric Institute-National Coal Association-Bureau of Mines Symposium, Pittsburgh, Pennsylvania, March 14-16, 1967, by J. H. Faber, J. P. Capp, and J. D. Spencer, 1967.

8404--Waste Disposal Costs of a Florida Phosphate Operation, by J. R. Boyle, 1969.

8406--Waste Disposal Costs at Two Coal Mines in Kentucky and Alabama, by V. A. Danielson and D. H. White, Jr., 1969.

8409--Pennsylvania Anthracite Refuse. A Survey of Solid Waste From Mining and Preparation, by J. C. MacCartney and R. H. Whaite, 1969.

8410--Design of Dams for Mill Tailings, by C. D. Kealy and R. L. Soderberg, 1969.

8445--Impact of Technology on the Secondary Aluminum Industry, by D. L. Siebert, 1970.

Bureau of Mines Technical Progress Reports[5]

9. Gold Recovery From Scrap Electronic Solders by Fused-Salt Electrolysis, by E. K. Kleespies, J. P. Bennetts, and T. A. Hemrie, 1969.

18. Effect of Lowering the Tin Content of Secondary Red Brass, by L. W. Higley, J. L. Holman, E. R. Cole, and H. Kenworthy, 1969.

Bureau of Mines Open File Reports[6]

1. High-Temperature Alloy Scrap in California and Nevada, by G. C. Branner and J. W. Padan, Report No. 3, August 1962.

2. Method for Separating Insulation From Scrap Aluminum Copper Wire, by P. M. Sullivan, Report No. 37, 1963.

3. Recovery of Nickel and Cobalt From High-Temperature Alloy Scrap, by B. E. Barton, R. L. DeBeauchamp, and T. A. Sullivan (unpublished report), 1966.

4. Laboratory Development for Process to Remove Undesirable Impurities From Automobile Scrap, by C. E. Armantrout, G. W. Elger, and S. C. Rhoads (unpublished report), 1969.

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[5]See footnote 3.

[6]Copies of available reports may be obtained by contacting F. J. Cservenyak, Office of the Director of Metallurgy Research, Bureau of Mines, U.S. Department of the Interior, Washington, D.C. 20240

Contract and Grant Publications,[7] Bureau-Sponsored Work

1. Treatment of Molten Automotive Scrap To Reduce Copper Content, PPG Industries, Glass Research Center, Contract No. 14-09-0070-363, 1967.

2. Vegetation and Metal Toxicity in Relation to Mine and Mill Wastes, Circular 148, Utah Agricultural Experiment Station, Utah State University, SWD-1, 1967.

3. Copper Control in Vehicular Scrap With Special Emphasis on Component Design, Ralph Stone Company, Inc., Contract No. 14-09-0070-382, 1968.

4. Utilization of Red Mud Wastes for Lightweight Structural Building Products, IIT Research Institute, Contract No. 14-09-0070-386, 1968.

5. Production of High Pressure Steam-Cured Calcium Silicate Building Materials From Mining Industry Waste Products, Stamford University, Grant No. SWD-11. Part I--Program for Investigation and Report of Field Survey of Siliceous Mine Wastes in California, Technical Report No. 86, 1968; Part II--Preliminary Economic Feasibility Study, Technical Report No. 89, 1968.

6. Removal of Fly Ash by Fluidized Bed Techniques, North Star Research and Development Institute, Contract No. 14-69-0070-375 (open file report), 1968.

7. Encased Steel Building Blocks Produced From Scrap Auto Body Sheet Metal, Korblock Corporation, Contract No. 14-09-0070-385 (not published), 1968.

8. Recovery of Metal Values in Waste Electric Power Plant Lignite Ash, South Dakota School of Mines, Grant No. SWD-7 (not published), 1968.

9. Techno-Economic Analysis of Mining and Milling Wastes, IIT Research Institute, Contract No. G6027, 1969.

10. Utilization of Coal Dust Slurries, Franklin Institute Research Laboratories, Contract No. 14-09-0070-380, 1969.

11. Resource Reclamation: Yard Efficiency; A Preliminary Study of Scrapping Processes and Site Planning, Ralph Stone Company, Inc., Grant No. G0180259, SWD-20, 1969.

12. Mineral Wool Production From Coal Ash, Coal Research Bureau, West Virginia University, Report No. 38, 1969.

13. Resource Recovery From Incinerator Residue, Institute for Solid Wastes of the American Public Works Association, v. 1 and 2, Contract No. G0190619, 1970.

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[7] See footnote 6.

14. Use of Coal to Enhance Metabolic Treatment of Sewage, Biospherics Research, Inc., Contract No. H0180985, 1969, Open File Report 12-69 (Coal Research, Bureau of Mines).

Outside Publications by Bureau Authors

1. Electrolytic Recovery of Zinc From Waste Materials by Use of Amalgam Cells, by P. M. Sullivan and D. H. Chambers, presented at the Annual Meeting of AIME, Feb. 25-28, 1957.

2. Recovery of Zinc and Tin From Secondary Products (Part I), by P. M. Sullivan and D. H. Chambers, Metal Industry, Sept. 22, 1961.

3. Recovery of Zinc and Tin From Secondary Products (Part II), by P. M. Sullivan and D. H. Chambers, Metal Industry, Sept. 29, 1961.

4. Let's Not Overlook Salvage, by C. B. Kanahan and P. M. Sullivan, APWA Reporter, v. 34, No. 3, 1967.

5. Automobile Disposal: A National Problem, by the Staff, Bureau of Mines, 1967 (available from the U.S. Government Printing Office, Washington, D.C. 20402, $4.50).

6. Proceedings of the Symposium: Mineral Waste Utilization, Bureau of Mines and IIT Research Institute, Mar. 27-28, 1968, Chicago, Ill. (a compilation of 20 papers)(available from IIT Research Institute, 10 West 35th St., Chicago, Ill. 60602, $12.50).

7. Refuse Mulch Boosts Tomato Yield, by C. O. Hawk, S. Freidman, E. B. McCullough, and T. W. Hiteshue, Coal Age, v. 73, No. 6, June 1968.

8. An Improved Method for Separating Copper and Steel From Copper-Containing Ferrous Scrap, by V. G. Leak and M. M. Fine, Secondary Raw Materials J., v. 6, No. 7, July 1968.

9. Recovery and Production of Alumina From Waste Solutions by Solvent Extraction, by D. R. George, K. E. Tame, S. R. Crane, and K. B. Higbie, J. Metals, v. 20, No. 9, September 1968.

10. U.S. Bureau Seeks Low-Cost Method to Reclaim Valuable Minerals, by C. Rampacek and P. M. Sullivan, Solid Wastes Management J., v. 11, No. 11, November 1968.

11. Physical and Chemical Beneficiation of Metal and Mineral Values Contained in Incinerator Residues, by M. H. Stanczyk and P. M. Sullivan, presented at the 98th Annual Meeting of AIME, Feb. 16-20, 1969 (Preprint 69-B-54).

12. New Approaches to Solid Mineral Wastes, by K. Dean, H. Dolezal, and R. Havens, Mining Engineering, v. 21, No. 3, March 1969.

13. Destructive Oxidation of Ferrous Scrap, by N. B. Melcher, C. Prasky, and R. Peterson, 28th Ironmaking Conference of the AIME, Apr. 13-16, 1969, Toronto, Canada.

14. Utilization and Stabilization of Solid Mineral Wastes, by K. C. Dean, R. Havens, and E. G. Valdez, presented at 16th Ontario Industrial Waste Conference, Niagara Falls, Ontario, Canada, June 15-18, 1969.

15. Reclaiming Refractory Carbides and Cobalt From Cemented-Carbide Scrap, by P. G. Bernard, A. G. Starliper, and H. Kenworthy, Secondary Raw Materials, v. 7, No. 9, September 1969.

16. Stabilization of Mineral Wastes, by K. C. Dean, R. Havens, and E. G. Valdez, Industrial Water Engineering, v. 6, No. 10, October 1969.

17. Opportunities in the Production of Secondary Nonferrous Metals, by Max J. Spendlove, United Nations Industrial Development Organization Expert Group Meeting on the Utilization of Nonferrous Scrap Metal, Nov. 25-29, 1969, Vienna, Austria.

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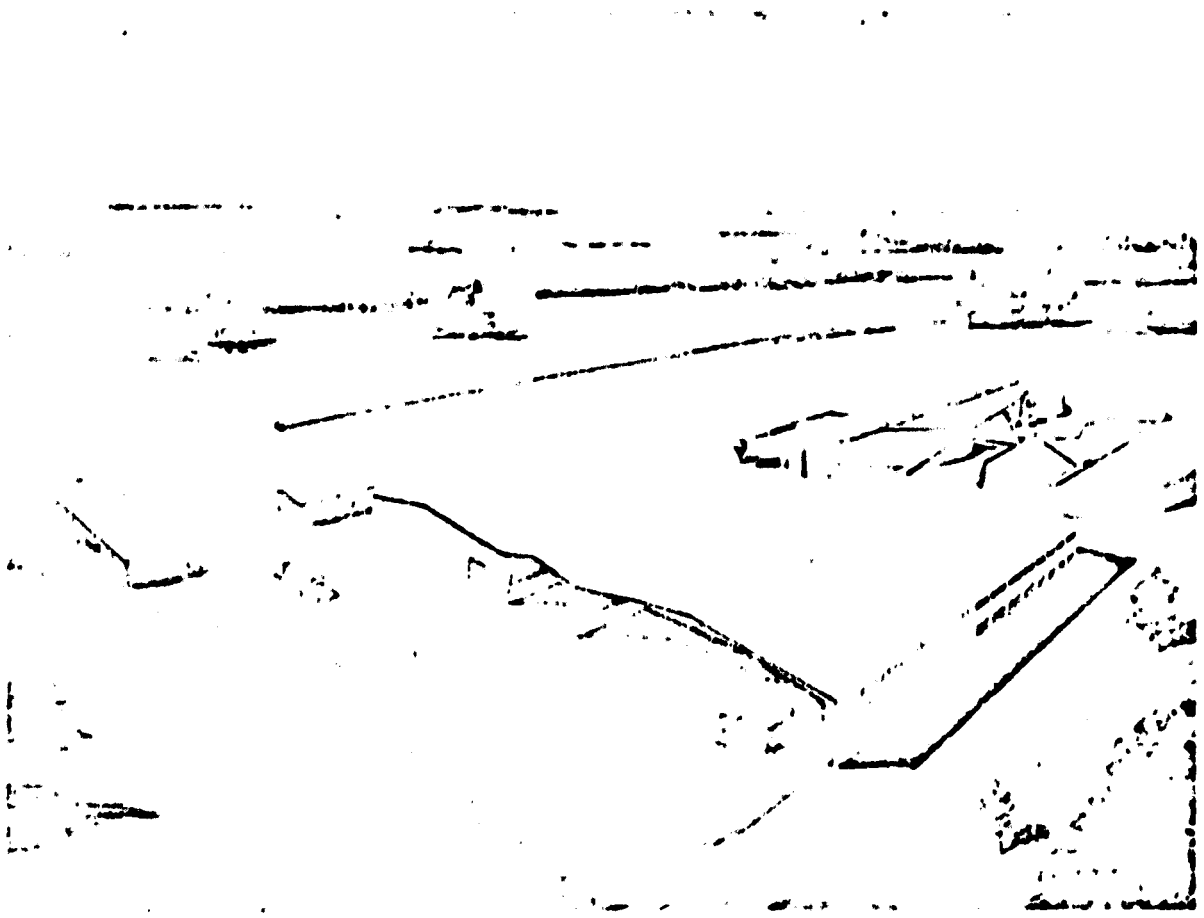
Reclaiming solid wastes for profit

Hercules will build the country's first complete solid waste reclamation plant in Delaware

"Society must move in this direction; we're going to have to start recycling for the next generation and for future generations," says state representative Robert J. Berndt, chairman of the Governor's Committee on Solid Waste, in reference to the new $10 million disposal plant for Delaware. Hercules, Inc., has received the bid to design, construct, and operate the solid waste reclamation plant in populous New Castle County.

From nine proposals and outlines submitted to the committee and Delaware Gov. Russell W. Peterson, Hercules was chosen. "(Hercules) has the talent to do the job," adds Berndt, explaining that the other proposals received offered only partial reclamation of wastes. Hercules' manager of New Ventures, John Hodges, stated that the plant, with 50 employees, will process 500 tons of domestic solid wastes and selected industrial wastes and 70 tons of sewage sludge (70% moisture) per day, based on an eight-hour day for five days a week. At present, these figures represent about one half of New Castle County's solid wastes; furthermore, this county is Delaware's most densely populated area.

Negotiations will be completed this month concerning the 15-acre site of the plant. After the location is determined, construction will start immediately if funds are available. There is hope of delegation of federal funds in the near future. The Solid Waste Resources Act of 1970, providing federal aid for such demonstration plants, is in Congress now. Sen. J. Caleb Boggs (R.-Del.), minority leader of the committee reviewing the bill, is enthusiastic because his state supports him in his efforts toward pollution control generally and solid waste control in particular. Pilot plants of this nature could receive up to 75% of construction costs as outlined in the bill.



Artist's conception. *Hercules' plant will be constructed on a 15-acre site in northern Delaware and will treat about 570 tons of mixed solid waste per day*

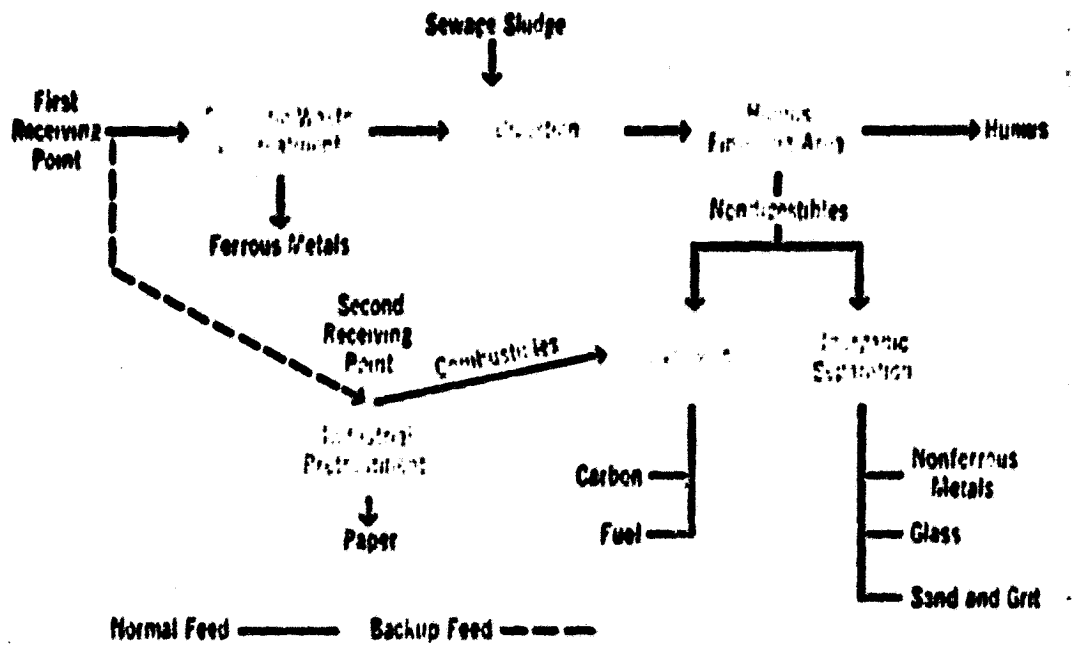
The state of Delaware has already appropriated $1 million for the design and engineering of this project. If the additional money becomes available from the federal government, construction is scheduled to be completed in 22 months.

Self-sufficient

Once in operation the objective will be to bring the plant to a self-supporting basis with the return from the reclaimed products offsetting operational costs. No present landfill or incineration system achieves this. If the unit functions as planned, the plant's facilities may be expanded to double its capacity to 1000 tons per day. Expansion can also take place by creating a longer work week and double shifts; overhead costs would increase by 75%. Because of this planned expansion as well as constant upgrading of the plant's operation and quality of products in conjunction with advances in technology, George Dutcher, director of New Castle County Public Works, dubbed the new plant a "processes polymer."

Delaware has few acceptable sites for landfilling waste disposal as do other states. There are no quarries, mines, or canyons for burial. In most areas of the state the water table is only 5 to 6 feet below ground level, which limits the use of man-made pits. In southern Delaware the soil is sandy and poor for use in coverage. In the northern section of the state, the soil is clay-like with poor drainage. When wet, the water is retained in pockets and becomes stagnant; and when dry, the clay cracks, allowing rat infestation and fires. Remaining are the Delaware River, bays, and ocean, which provide no solution. "Delaware is ideally situated to be the pilot plant of the world," summarizes Richard Weldon, a member of the governor's solid wastes committee.

The solid wastes to be utilized in this scheme include domestic wastes, selected industrial and commercial wastes, and sewage sludge. If the unit size is eventually doubled and handles all of the county's wastes, initiation of plans for similar plants for the rest of the state will follow.



First receiving point

Solid wastes will enter the disposal plant at two receiving stations—one for household refuse and the other for selected industrial and commercial wastes. From the first receiving point, the domestic wastes will be dumped into a hopper and transported by conveyor to a pretreatment point where ferrous metals will be removed. These metals will then be sold. The remaining material will be shredded and pulped with sewage sludge, resulting in a mixture of 50% moisture.

After this step the design of the plant is based on three key elements:

• **A digestor system,** a controlled compost process patterned by the Fairfield Engineering Co., converts the incoming mixture of organic wastes and sewage sludge into a high quality pathogen-free humus product. When fed into the digestor, the 50% moisturized material is agitated with auger screws while air is blown in from the bottom. This system involves biological digestion processes utilizing aerobic, heat-loving bacteria already present in the mixture. No auxiliary organisms will be added. Sensors in the bottoms of the tanks automatically regulate the temperature and oxygen content, maintaining optimum conditions for the digestive procedure.

No unpleasant odors of air pollutants are produced by this system. A similarly constructed plant in Puerto Rico, operated by the Fairfield Engineering Co., handles 300 tons of solid waste per day. Following digestion, the nondigestable organic materials, including plastics, tires, shoe soles, rags, etc., and inorganic materials, are separated from the humus, using equipment and techniques developed in the mining industry. By-products of the digestive process are water, carbon dioxide, and the pathogen-free humus. After being pelletized, this clean humus has marketable uses as a soil conditioner, blend for fertilizer, substrate for systemic pesticides, and, in future development, animal food additive.

• **Application of pyrolysis,** a destructive distillation technique demonstrated by the Bureau of Mines (ES&T, Feb. 1969, p. 119) controls decomposition of the organic solid wastes. Pyrolysis handles automobile tires, plastics, and other materials posing disposal problems. The waste materials are subjected to high temperatures in the absence of oxygen, preventing ignition. This process provides good quality carbon products that will be marketed, hydrocarbon gases which are rich in hydrogen and can be used for fuel in the plant itself, and oils to be marketed as fuels or sources of such chemicals as styrene.

• **A residue separation system** applies techniques developed by the mining industry to separate ores. Inorganic residues, such as glass, grit, sand, and nonferrous metals, are sorted by screens, gravity tables, and other devices. Sand and grit will be used as landfill material, while the nonferrous metals will be sold. Until marketed more profitably, the glass mixture will be finely ground and useful for landfill or roadbed ballast.

The second receiving station handles the selected industrial wastes. Paper coming into this point can be treated in various manners. If the paper is clean, it will be shredded, baled, and sold; or the paper can be conveyed to the digestor system and become an ingredient of the humus material. Otherwise, the paper can be sent into the destructive distillation unit along with plastics, rags, wood, and other industrial wastes to produce carbon. Rubber material, tires, industrial plastics, and other refuse are shredded and sent to the pyrolysis unit, which, as described in the preceding column, yields marketable products.

The waste disposal plant will follow a program of continuous, rather than batch, operation. The residue separation system will eliminate "hand-picking," and the shredders are heavy enough to handle bedsprings, washing machines, chain link fences, and other equally indisposable materials.

New venture

This complete reclamation plant is unique in many respects. Hercules has drawn together and systematized equipment from other trades, plus industrial supplies that will have to be manufactured specifically for use in this system. Constant upgrading and application of new technological developments will mark the growth of the plant and improve the quality of the final products.

This project will be Hercules' first significant dealing with municipalities in the area of solid waste; however, the company has maintained an active program for handling its own solid waste problems and has conducted a company-funded program in the field of municipalities. Regarding this first venture with the public, "the area of solid wastes offers growth for products to be extracted. . . . If we can get the product in a form that the customer can use, he will buy," and this produces "a viable business in communities," states Hodges. Weldon remarked that the amount of research done in the area of marketing by Hercules had definitely impressed the governor's committee. Also, the plant will meet federal and state air and water pollution guidelines and regulations. The plant, says Berndt, "won't pollute air, water, or ground." This type of approach could be used for the entire country. CBE