DISMANTLING RAILROAD FREIGHT CARS

A STUDY OF IMPROVED METHODS WITH APPLICATION TO OTHER DEMOLITION PROBLEMS

This report (SW-3c) was written for the Bureau of Solid Waste Management

by DALE M. BUTLER and WILLIAM M. GRAHAM

Booz, Allen Applied Research Inc., under Contract No. PH 86-67-100

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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FOREWORD

SOLID WASTE DISPOSAL has had the least scientific consideration of any of the concerns of environmental pollution control. The classic approach has been to consider disposal by controlled incineration, landfill, or burial at sea, as alternatives to simple open-air burning. These classic concepts of disposal have become inadequate, since usually they merely transfer pollution from one medium to another.

For the particular needs of the railroad car dismantling industry, the problem has an additional dimension. Any method of wood disposal other than the present practice of open burning would raise operational costs in the face of market considerations determining the price of the scrap steel product. This would seriously threaten the survival of this enterprise, thus creating an even greater problem in solid waste disposal—thousands of unwanted freight cars.

Would this be a loss to anyone besides the people who currently make their livelihood by dismantling freight cars? Is railroad car scrapping an obsolete concept, to go the way of the buggy whip? Indeed, would not public interest be better served if the smelly, unsightly, unsalutary heaps of this kind were removed from our midst? The answer is this: the industry must survive because it is vital to the conservation of our natural resources. The recycling of iron and steel from the scrap heap back to the furnaces and cupolas helps to stave off the day when our supply of ore and coke and limestone reaches exhaustion. The salvage of reusable parts helps to keep down the costs of rail transportation. Hence, the industry's function is equally as important to the integrity of our natural environment as the removal of pollution from our air, water, and land. Both types of effort are needed if we are to pass on the kind of heritage all Americans so ardently desire.

The mathematical model used for evaluating the alternatives to open burning of railroad cars was developed by the Bureau of Solid Waste Management with the contractor. In the present case, this method was used to find the optimal solution to open burning, a solution that would satisfy the requirements of both dismantlers and those concerned with environmental pollution control. Producing ordinally weighted scores, the method is an excellent decision-making tool and is perhaps the most invaluable feature of this report.

—RICHARD D. VAUGHAN, *Director,*
Bureau of Solid Waste Management

PREFACE

THIS REPORT is the product of six months' investigation and analysis under contract with the Bureau of Solid Waste Management, Public Health Service, U.S. Department of Health, Education, and Welfare. The report is also the product of an unusual flow of interest, inquiry, counsel, and other thoughtful attention from many individuals who found themselves intrigued by the problem. The "infection" set in at least three months before and continued until after the formal period of contract.

The researchers assigned to the project at Booz, Allen Applied Research Inc. found themselves the beneficiaries of interesting, imaginative, and ofttimes useful suggestions, which came from the most unlikely quarters, whether inside or outside the company. Literature bearing directly on the subject was virtually nonexistent. The key to the problem, it seemed, must be sought among the new discoveries of space-age technology. This, however, was not yet to be. The problem yielded only to a frontal attack, which applied the basics of systems engineering to current operations within the railroad scrap industry.

Many aspects of developing technology were investigated. These included new forms of explosives, advances in wood residue utilization, high-speed water jets, and cryogenic brittlizing agents. Several of these are today the basis of accepted practice in a variety of other industries. From exploration into these areas much emerged that holds promise for railroad car dismantling. However, the economically feasible alternatives were mostly those that could be borrowed directly from well-established technology.

The information-gathering period virtually coincided with the period of contract. Letters and replies to questionnaires are still being received and often shed new light upon unresolved questions. The bulk of information, however, came from extensive visits to commercial scrapyards, from personal observation of yard operations, from searching discussions with yard operators and superintendents, with members of the industry, with attendants at industrial association meetings, with manufacturers of heavy equipment and their engineering staffs, with air pollution control officials, and with industrial and university researchers in new technologies. During one stage of this activity, actual demonstrations of wood cutting by water jets were carried out on railroad boxcars slated for dismantling.

In summary, the quest for feasible alternatives to the open burning of railroad boxcars saw the exploration of a variety of seemingly unrelated areas of industry, business, and technology. To trace the subtle path of commonality linking these diverse areas with the boxcar dismantling problem was a task of unusual complexity.

The researchers were beneficiaries of contributions from many quarters but all conclusions expressed in this report are those of the authors and do not necessarily reflect the views of the U.S. Public Health Service. Similarly, no reference herein to specific companies or particular commercial products should be construed as an endorsement by the Public Health Service; such citations are included only as descriptive information and reports of pertinent facts.

The task would have been impossible without the generous cooperation of the American Association of Railroad Car Dismantlers (AARCD), acting through its president, Ralph Michaels, and its executive secretary, Boyd J. Outman, as well as the interest and support of the AARCD's parent organization, the Institute of Scrap Iron and Steel through its Scrap Research Foundation. The unflagging interest, encouragement, and patient understanding supplied at always appropriate intervals by Ralph J. Black, then Deputy Chief of the Federal solid wastes program, who served as project officer, was also an essential ingredient of success. In addition to these men, many other knowledgeable people in a broad spectrum of endeavor responded willingly to requests for information and advice. We have tried to list some of them below, knowing that our expressions of gratitude are equally due to many others who gave thought to our problem.

AARCD. Richard H. Allen, David J. Joseph Co., Cincinnati, Ohio; Lee Bercutt, Luria Brothers & Co., Houston, Texas; Roger Callanan, Industrial Service and Salvage Corp., Chicago, Illinois; Ralph Otis Clare, Purdy Co., Chicago; Abraham Deitch, The Deitch Co., Pittsburgh, Pennsylvania; Milton J. Feinberg, El Paso Iron and Metal Co., El Paso, Texas; Arthur Goldenberg, Luria Brothers & Co., Cleveland, Ohio; Joseph Hirschhorn, David J. Joseph Co., Skokie, Illinois; John P. Langan, Hyman-Michaels Co., Chicago; David Miller, Columbia Iron and Metal Co., Cleveland; Seymour Pielet, Pielet Brothers, Joliet, Illinois; Samuel Proler, Proler Steel Corp., Houston; Erwin Vetter, Industrial Service and Salvage Corp., Chicago.

OTHERS. Douglas Holmes, Lake Ontario Steel Co., Whitby, Ontario; Robert F. Merwin, Eriez Magnetics, Erie, Pennsylvania; Frederick D. Buggie, Eriez Magnetics, Erie; Arlo F. Israelson, Eriez Magnetics, Erie; J. A. Bartnik, Eriez Magnetics, Erie; Norbert T. Casper, Logemann Brothers, Milwaukee, Wisconsin; Raimond J. Smiltneek, Logemann Brothers, Milwaukee; A. C. Schultz, Logemann Brothers, Milwaukee; J. Ray Zimmerman, Logemann Brothers, Milwaukee; Dominic E. Balzano, Balzano Steel and Trading Co., La Grange, Illinois; Roy A. Kamb, Kamb Engineering and Fabricating Co., Seattle, Washington; Walter M. Wilcox, Simonds Saw and Steel Co., Fitchburg, Massachusetts; Mr. Anderson, Hydro-Silica Corp., Gasport, New York; Mr. Weathersby, Hydro-Silica Corp., Gasport; Roy Gronauer, Partek Corp., Houston; A. George Swint, Harris Press and Shear Co., Cordele, Georgia; Mark Tyson, Harris Press and Shear Co., Cordele; W. S. Story, Institute of Scrap Iron and Steel, Washington, D.C.; Dr. William C. Cooley, Exotech, Inc., Rockville, Maryland; Louis L. Clipp, Exotech, Inc., Rockville; William J. Stanley, Department of Air Pollution Control, Chicago; Alvin Kellogg, Department of Air Pollution Control, Chicago; Capt. Trainer, Demolitions School, Ft. Belvoir, Virginia; Capt. Emmerson, Demolitions School, Ft. Belvoir; Herb Schaaf, DuPont, Pompton Lakes, New Jersey; Norman Bork, I. Bork & Sons, Peoria, Illinois; Frank B. Burkdoll, Explosive Technology, Fairfield, California; Harold W. Hannagan, Explosive Technology, Fairfield; Dr. Jerome Saeman, Forest Products Laboratory, U.S. Forest Service, Madison, Wisconsin; Andrew J. Baker, Forest Products Laboratory, U.S. Forest Service, Madison; Dr. Norman C. Franz, School of Natural Resources, University of Michigan; John E. Brodie, Department of Forests and Parks, LaVale, Maryland; Carl V. Lyon, Association of American Railroads, Washington, D.C.; Ernest Kirkendall, American Iron and Steel Institute, New York City; Max Stearman, Ace Wrecking Co., Rockville, Maryland.

Besides Dale M. Butler, Research Director, and William M. Graham, Project Manager, the primary contributors were Fredric C. Hamburg, J. Bruce Truett, and George Bierman, as well as all members of the staff of Booz, Allen Applied Research Inc.

CONTENTS

THE SOLID WASTE DISPOSAL ACT OF 1965 (P.L. 89-272) recognized that inadequate action on the part of both public and private agencies has resulted in a solid waste disposal problem which contributes significantly to community environmental pollution and to urban and exurban blight. The Bureau of Solid Waste Management has been established within the Public Health Service of the U.S. Department of Health, Education, and Welfare, with full responsibility in the area of solid waste management. To this organization falls the problem of what to do with worn-out, retired railroad cars.

Approximately 70,000 rail freight cars are dismantled each year for the purpose of salvaging reusable parts, scrap iron, and steel. About 50 percent of these cars contain 3 to 7 tons of wood each, which must be removed before the scrap can be returned to the steelmaking process. The conventional means of removing the wood has been by open burning. The dense smoke emissions produced by open burning, however, are no longer tolerable under the provisions of the Clean Air Act. The Association of American Railroad Car Dismantlers and local and Federal environmental pollution control agencies have resolved that this problem must be corrected as soon and as completely as possible. The Bureau of Solid Waste Management recognized that practical and effective techniques developed for dealing with these problems could have application in numerous other solid waste problem areas. Consequently, the Public Health Service contracted with Booz, Allen Applied Research Inc. (BAARINC), Bethesda, Maryland, to investigate, evaluate, and make recommendations with regard to alternative methods for railroad car dismantling and salvage which succeed in eliminating environmental pollution, or in reducing emissions to acceptable levels. This document reports upon the findings of the project.

The study was conducted over a six-month period beginning March 13, 1967. In meeting the objectives of the study, the following tasks were performed:

In order to become completely familiar with all aspects of the railroad car dismantling industry, members of the project team visited the headquarters of the Bureau of Solid Waste Management, the Association of American Railroads, the American Association of Railroad Car Dismantlers, and individual railway car scrap processors. This familiarization period was a brief but highly important part of the investigation in that it established the framework and constraints for the entire study.

The next step was to compile a list of as many new and different approaches to the dismantling of railroad cars as possible. Scrap dealers and the manufacturers of processing equipment were solicited for ideas by mail. Questionnaires were sent to railroad car dismantling companies. Mail inquiries provided some information, but most of the ideas and suggested approaches arose from detailed discussions with members

"When future historians write of this era, I believe they will note that ours was the generation that finally faced up to the accumulated problems of American life.

"To us has been given the task of checking the slow but relentless erosion of our civilization.

"To us has been given the responsibility not only of stimulating our progress, but also of making that progress acceptable to our children and grandchildren.

"Today, we are taking another large and forward step in this direction . . ." [1, 2]

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of the industry, attendees at industrial association meetings, manufacturers of heavy equipment, university research personnel, as well as with BAARINC personnel. From many interesting, novel, and useful suggestions, more than 40 different schemes were selected for subsequent investigation.

All suggested approaches were subjected to preliminary screening to eliminate those which did not meet predetermined criteria. These criteria were developed during the familiarization period, and included the aggregate requirements of cognizant environmental control agencies, the scrap industry, and the railroad car dismantling industry. The successive screening process reduced the list of proposed methods to twelve, which were subjected to more detailed investigation.

These twelve surviving approaches were subjected to a cost effectiveness analysis. An indexing system was devised which ordered the methods according to their effectiveness, i.e., the best combination of cost to the dismantler, and control of environmental pollution (within prescribed limits). There are two approaches which appeared to have the most merit and are therefore worthy of further or prototype development.

The first is a system of cutting wood from railroad cars using high pressure, manually operated, water jets. This system—described later in the report—holds considerable promise for application to other solid waste disposal problems. The second approach uses the car itself for an incinerator, with a stack installed directly on the car to control effluent emission. This may be the most expedient means for solving the problem for the railroad car dismantlers without creating a wood disposal problem.

The above systems are described later in this report along with recommendations for further investigation and prototype development on these two methods. Also recommended is a project, initiated under the auspices of the Bureau of Solid Waste Management, which will define the magnitude and scope of the general problem of used wood disposal and reclamation.

Throughout the country, large quantities of unreclaimed wood and other combustibles are regularly and continuingly burned in the open air as old buildings are demolished and no-longer-useful furniture and other articles are disposed of. The manner in which wood is intermingled with paint, plastic, and hardware in most manmade structures favors open burning to accomplish both separation and disposal of the wood. From a point of view of total resource utilization, there is reason to doubt the wisdom of individual open-burning decisions. The investigation contemplated would indicate those courses of action which will lead to recovery of the solid material resources while conserving clean air.

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[1] Remarks by President Lyndon B. Johnson upon signing the Solid Waste Disposal Act, October 20, 1965.

[2] *Solid Waste Disposal Act.* Title II of Public Law 89-272, 89th Congress, S. 306, October 20, 1965.

CONCLUSIONS AND RECOMMENDATIONS

STUDIES OF THIS KIND are necessarily limited by two considerations. First, the canvass of ideas must, in some respects, be incomplete. Future studies can always be expected to yield new, better, or more creative thoughts. In fact, the more thoroughly the field of pertinent information is combed, the more likely it is that a chain of events will follow from which "independent" schemes will emerge.

Secondly, the form in which alternatives are structured for appraisal is necessarily generalized and tentative. *The goal is to form a basis for decision among alternatives, rather than to develop preferred configurations for specific concepts.* Well-executed development work will bring to bear specific information capable of transforming the rudimentary products of research into mutations not subject to forecast.

Decisions as to developmental demonstrations are affected by the probable rewards from candidate alternatives, and by time considerations. Thus some alternatives may have relatively greater prospects for successful near-term development, while others may hold a greater potential if sufficient time and resources are allowed for full development. A number of factors influence how the issues are posed and the appraisal is shaped.

RANGE AND SCOPE

In this case, a number of dissimilar restraints may be cited. Uncertainties and change characterize public air pollution goals; and, further, the relative contribution to overall pollution which may be rationally ascribed to railroad car dismantling differs according to the viewer's perspective. In short, the process alternatives may be judged against a background of relatively near-term local objectives, varying widely throughout the country—from avoidance of visible concentrations of black smoke in some communities to more sophisticated goals in others. But the problem has certain broader significances, and these deserve consideration. In general, we will address ourselves only to issues which are restricted to railroad car demolition and ferrous scrap processing technology, and not to those which apply to the broader framework of industrial activities.

The nonprocess alternatives have been defined as out of scope for this study. Similarly, the conversion of waste wood byproducts of process alternatives to economically useful purposes is a technological need common to a variety of demolition-scrap-and-salvage operations.

Efficient means for separating and processing used wood for reuse is a requirement of resource conservation that dwarfs the total freight car problem. This study has in fact shed some light on new and versatile means for separating wood from obsolete structures of any kind. Conversion to forms suitable for reuse is a field substantially untouched, except to identify a dramatic potential. The potential is truly dramatic, because once solved, the savings from open burning at wrecking and demolitions sites across the country would both vitally affect achievement of clean air goals, and open unmeasured opportunities for natural resource conservation.

Though not directly within the scope of this assignment, some conclusions with respect to conservation of used wood are inescapable. Consequently, a recommendation is made for study focused on three aspects of the problem: (1) In demolition operations of all types throughout the country, how much wood, and of what types, is lost to the economy, and how much of it is converted by open burning to air polluting smoke? (2) How can wood and other combustibles be separated effectively and at reasonable cost from the structures of which they are a part, without resorting to open burning? For example, might not water jets of proper design have some universal applicability for separating combustibles from metallic and masonry elements in many types of structures? (3) What means might be found for reducing used wood, once separated, to homogenous commodities for which economic uses may be found?

PROCESS RECOMMENDATIONS

For reasons examined in the chapter on alternatives to open burning, we find that those process alternatives which alter the customary sequence of scrapyard operations do not generally fulfill present requirements. Such alternatives tend to be either inconsistent with the character of scrapyard operations and technological practice (as in explosive separation), or their total costs are adversely affected, due to the probable need for adding subsequent scrap processing operations (sawing, shearing, sorting, and recompacting sequences).

For these reasons, many scrapyard operators are prone to repeat the obervation that "nothing can improve on burning." In a context, this is unarguable. However, if *open burning* is to be universally forbidden, a question can still be asked "if not burned openly, then how?" The system of appraisal described in the Introduction suggests there are two distinct approaches which deserve detailed study and prototype development. These are:

A Hooded Self-Incinerator. This approach contemplates an initial burning operation in which the car itself is used as a partial incinerator. This will require (1) carefully designed openings in the car to develop a proper draft, and (2) mounting a hood and/or stack arrangement over the car, equipped with smoke control devices for treatment of the effluent.

High-Pressure Water Jets. This approach contemplates an initial wood removal operation using a jet of water as a cutting tool, followed by conventional steel scrap and salvage activities, and waste wood disposal by one of three possibilities:

- A small general-purpose incinerator with effluent control
- Development of local markets for waste wood
- Municipal or private commercial waste disposal services.

Equipment adaptable for wood cutting is known to be commercially available. Experimentation will be required to find an optimum combination of water pressures, pump design, and nozzle configuration.

Railroad car demolition yards have conducted limited experiments with hood arrangements. One yard has pierced the corners of a boxcar and installed a stack in the roof. This particular design may be improved upon, but these efforts show that a draft can be created which will funnel all smoke through the top opening and out the stack. Indications are that the interior will burn completely without rupturing the steel sheath walls. The sheathing is only 0.1 inch thick and will buckle, but the basic structural integrity of the box is not destroyed.

Whether or not the hood-stack arrangement can be made portable is at this stage undetermined. Some dismantlers prefer portable hoods which can be put in place by a crane, but the fragility of smoke control equipment may require permanent mountings, restricting the mobility of attached equipment. With this approach, individual cars could be rolled under fixed but adjustable hoods before preparing and firing the self-incinerator.

An important limitation of this method concerns the so-called all-wood boxcars. The wood cars (without steel sheathing) represent aproximately 10 percent of the boxcars now being retired, but their number will continue to decrease since they were being phased out of production 30 to 35 years ago. With the hood-incinerator method, wood refrigerator cars and cattle cars will continue to need special attention.

Flexibility and adaptability to related needs is the key feature of the second approach recommended for development through actual experimental demonstrations. Water jets for industrial cleaning purposes (especially oil refinery equipment) are already in wide use. New applications are independently being developed for lumber operations (bark removal as well as limited wood cutting applications). Several pump and nozzle manufacturers have sufficient understanding of the potential applications to provide assurance of technical feasibility, though cost feasibility has not been established in specific detail.

The main purpose of the demonstration programs recommended is to establish firm efficiency and cost information. The preliminary demonstrations organized at Houston showed that wood could be effectively cut from the metal car frames to which it was attached without any of the tool-handling awkwardness associated with rigid cutting tools operating in narrow spaces. These demonstrations further showed a marked difference in efficiency with moderate changes in jet characteristics. The suggestion was very strong that none of the equipment used at Houston approached optimum design, so that with a proper balance between stream diameter, pressure, handling, and flow characteristics, much greater cutting efficiency might be achieved. The effect of design optimization on cutting productivity (and therefore unit operating cost) is unknown, but nothing learned to date suggests discouragement.

The use of water jets to clean (and therefore upgrade) scrap, is an obvious possible side benefit commented on favorably during the Houston demonstration. Laboratory research at Exotech Inc., under a contract with the Navy to develop pulsed water jets suitable for cutting metal underwater, is already underway. Water jets with granular additives in the water to improve cutting ability have been used operationally by underwater ship salvage crews in the North Sea, and new research on water jet additives is now being undertaken at the University of Michigan. Systems for recycling the water in any use of a continuing nature appear practical for advancing the efficiency of water jet equipment.

The burden of these observations is that while water jet flexibility is established, the exact effect of this flexibility on actual operating costs remains to be established. The basic technology is readily available on a commercial basis. Sufficient research is in progress on new applications to indicate that water jets for this immediate purpose may be a steadily improving art and may in fact make positive contributions to related material resource reclamation problems.

The conclusion that techniques designed around a hood and self-incinerator arrangement and high-pressure water jets offer the most promise for relief from the hazards of open burning is not in conflict with the notion of mechanization. The long-term solutions to scrapyard operating problems may well depend on steps toward automation. The recommendations made here are based in part on the need for relatively near-term progress. Complete systems integrating heavy machinery (with or without the techniques suggested for prototype development) must, it appears, await the evolution of technical breakthroughs and economic changes within the industry and its suppliers.

COURSES OF ACTION

As a consequence of these findings, it is recommended that the Bureau of Solid Waste Management undertake to sponsor a two-part demonstration program and to consider the development of a fundamental research program in a related area. The two-part demonstration program would be directed toward the development and testing of specific equipment to remove wood from retired freight cars by:

- A self-contained incineration technique using a hood and/or stack to deliver effluent to installed smoke control devices
- High-pressure water jets of optimal design using commercially available components and adaptations.

The demonstration equipment would be assembled in established railroad car demolition yards and would be tested, under suitable supervision and with industry cooperation, on freight cars of representative design. Photographic and other records of results would be kept, and a report appropriate for use as an industry guideline would be prepared.

The development of a fundamental research program would have a longer-term objective and should be addressed not just to the freight car problem but to the structural demolition problems of industry generally. It would be specifically addressed to the issues of defining the scope of the problem, techniques for separating combustibles from structures undergoing demolition without open burning, and means for renewing the economic utility of used wood and other combustibles found in demolition of fixed structures and chattels such as furniture and appliances.

PRESENT INDUSTRY PRACTICES AND PERSPECTIVE

RAILROAD CAR DISMANTLERS are specialists who salvage reusable components of retired railroad equipment and convert the residual steel to useful ferrous scrap metal. In the main, these specialists also deal in scrap steel derived from a variety of other sources, ranging from assorted consumer durables to industrial machinery and reclaimed structural steel. The mix of normal "raw" material sources and differences from area to area in customer requirements for scrap significantly affect how processors operate. Unlike producers of most manufactured goods, railroad car dismantling is not a homogeneous industry where production technology plays a dominant role in shaping industry structure.

STRUCTURE OF THE INDUSTRY

Railroad car dismantling is an integral part of the ferrous scrap industry. It is made up of yards "primarily engaged in assembling, breaking up, sorting, baling, shredding, and wholesale distribution of iron and steel scrap." [8] The heterogeneous character of the industry is pointed up by the Government's authoritative manual of industry descriptions, *The Standard Industrial Classification,* which blankets the industry within wholesale trade as a part of classification 5093, "Scrap and Waste Materials." The scrap industry is made up of three functional groups:

- Processors—who operate scrapyards where unprepared or unprocessed articles of steel (mostly "obsolete" steel) are received, segregated, reduced to specification sizes, and compressed or otherwise converted into the forms required by steel makers.
- Brokers—who receive orders for processed scrap and distribute them among processing yards, or otherwise arrange for shipment from point of scrap fabrication to scrap consumption.
- Collectors—who gather materials for processing by purchase and delivery to processing yards.

Scrap processors may also act as brokers and collectors, and usually do. They may at the same time rely on independent brokers and collectors. Where railroad cars are specifically concerned, scrap processing is normally one integrated operation in which yards serve as established points of disposal for major railroads and other railroad car fleet owners. For this reason, railroad scrap processors tend to be concentrated in the vicinity of the principal rail centers.

Rail hubs, for example, Chicago, St. Louis, Cleveland, Pittsburgh, Philadelphia, Kansas City, San Francisco, and Los Angeles, happen also to be sites of other major industrial activity. Since scrapyards characteristically serve other industries as well, their location in industrial areas at the major population centers appears inevitable, natural, and desirable. The present investigations discarded the idea of relocating railroad car dismantling operations because this alternative is neither economical nor technically advantageous. In

[8] U.S. Department of Commerce, Business and Defense Services Administration, [Derrickson, G. F.] *Iron and steel scrap consumption problems.* Washington, U.S. Government Printing Office, 1966. 52 p.

short, the processors are necessarily at locations where a variety of other sources of air pollution are concentrated.

Whether scrap processing is viewed as a part of industrial activities of the nation as a whole, or as a segment of industry located in any one of the major urban industrial areas, measures of its proportionate contributions to air pollution attributable to railroad car burning are not available. Estimates have conceptual limitations and may be of little use beyond verifying that open burning of railroad cars is not a dominant contributor when measured against aggregate air pollution. This can be asserted *a priori*. The deleterious effect on ambient air is not by itself significant. These open fires in densely populated areas are, however, spectacular, obvious sources of local air pollution and indicative of the need for pervasive action.

Of approximately 1,800 ferrous scrap processors of all types, the Association of American Railroad Car Dismantlers (AARCD) estimates that some 30 firms, operating perhaps 50 yards, make up that part of the independent industry specializing in railroad scrap. Some major railroads operate "captive" yards which also dismantle retired cars; either regularly or from time to time. The AARCD believes that pehaps more than half of all railroad cars scrapped are dismantled in captive yards; the remainder move through the independent yards. These independent firms are typically one- and two-yard operations. A few are multiple-yard operations; but, in these cases, the railroad car work is normally confined to two or three sites. Not all yards handling, or capable of handling, railroad car scrap remain in the market for this class of scrap on a continuous basis.

Rising wage rates and newly developed machinery have fostered a growing mechanization in scrap processing. This is true of steel scrapyards generally, and railroad car yards are no exception. Many specializing in railroad scrap feel that the industry is on the threshold of a move toward much greater concentrations of heavy machinery. A surge of mechanization could follow the introduction of new and better designs. Equipment designs which will determine future courses of action may, however, not be available at this time.

One study[4] reports that scrapyards represent an average investment of slightly more than $700,000; about one-third is land and buildings, and two-thirds is machinery and equipment. Some, however, utilize equipment alone valued at upwards of $2 million. The size of scrapyards varies markedly; the average is about thirteen acres. Yards specializing in railroad cars tend to be somewhat larger and located on more valuable sites than other steel scrapyards. They tend to be less highly mechanized (Table 1).

Employment is also highly variable, being a function of operating techniques, volume, and location. The *Iron Age* survey, which was not confined to just those specializing in railroad scrap, shows a range from under 10 to over 80 employees; average employment is about 50, the median figure approximately 25.

Freight Cars: Their Number and Types

The national fleet of railroad freight cars—including those owned by railroads, shippers, and car lessors—now numbers about 1.8 million units. Typically, a car will be rebuilt, as distinguished from repaired, more than once during its service life. Railroad maintenance and replacement practices yield a typical life of approximately 35 years for a freight car, though there are marked variations according to type of car and other considerations.

The latest pertinent American Railway Car Institute survey[5] shows the following distribution, by type and age, for freight cars owned and leased by Class I railroads in 1962:

Type	Number (000)	Average age
Boxcars	665	18
Flat cars	50	22
Stock cars	29	34
Gondolas	256	17
Hopper cars	471	18
Covered hoppers	65	10
Tank cars	5	35
Refrigerator cars	25	20
Rack cars	38	23
Other	2	31
Total	1,606	18

The Car Service Division of the Association of American Railroads reports[6] that the Class I railroads and rail-controlled, private, refrigerator car lines retired 77,000 freight cars in the 12 months ended July 31, 1967. These were distributed by type as follows:

Boxcars	35,272
Covered hoppers	1,242
Gondolas	14,401
Hopper cars	17,758
Flat cars	1,263
Refrigerator cars	4,254
Other	2,801

The proportion of cars retired by type of cars appears to be reasonably consistent from year to year though the number of cars eliminated from service varies more widely. An American Railway Car Institute study[7] shows that in the decade from 1952 through 1961, a total of 638,000 freight cars were retired, but this average retirement of 64,000 cars reflected as many as 89,000 in one year and as few as 46,000 in another.

Nearly half the cars are made up of gondolas, hoppers, and tanks which have no wood linings. On the other hand, typical boxcars and refrigerator cars use substantial amounts of wood as an integral part of the structure. Stock cars exhibit a wood superstructure and flat cars normally have a wood plank flooring.

The need for alternatives to open burning centers on boxcars and refrigerators cars, owing to their design

[4] NEAL, H. R. Scrap problems. *Iron Age*, 197(25): 73–78, June 1966.

[5] AMERICAN RAILROAD CAR INSTITUTE. *Railroad car facts; statistics on car building and car repairing, 1961.* New York, ARCI, 1962.

[6] *Traffic World*, 131(8): 1–90, Aug. 1967.

[7] AMERICAN RAILROAD CAR INSTITUTE. *Railroad car facts; statistics on car building and car repairing, 1961.* New York, ARCI, 1962.

and their numbers. Insulation materials present in refrigerator cars make open burning particularly noxious in their case. Regardless of age or manufacturer, boxcars and the other basic types are each constructed according to reasonably consistent overall design standards. However, cars are frequently ordered in small lots, and use and retirement patterns are such that the specific structural characteristics of cars presented for demolition cannot be expected to follow predictable patterns.

Boxcars can, however, be broadly classified into two groups—wood-sided cars and the so-called all-steel car. Both are steel framed boxes. About 10 percent of the cars now being retired are of the obsolete wood exterior design. The all-steel car is a misnomer; it is a steel frame covered by a thin steel sheath (0.1 of an inch thick) on the outside walls and finished on the inside with a wood tongue-and-groove or plywood lining. Some of the later cars are finished with "nailable" steel lining, but all retirement-age cars have wood lining.

In recent years, railroad fleet modernization policies may have caused more cars to be retired than may be available for demolition in future years. Over the long term, an average of 50 to 60 thousand cars a year, about half being boxcars and refrigerated cars, appears to be the highest sustainable rate at which freight cars can be expected to be retired. Though larger, higher capacity cars are being added, the size of the fleet is gradually shrinking in terms of numbers. Consequently, the projected number being retired may also decrease.

Composition of the Car

Perhaps the most important characteristic of a freight car as far as this study is concerned is its structural integrity. Railroad cars are built to last; they are built to withstand rough treatment and unusual stresses during loading, train makeup, and transit. The combustible elements are primarily wood floors and sidewalls. The basic structure is such that the wooden components are securely attached, and to a degree, interlocked with the steel frame of the car.

The second most important characteristic to be considered is the structural irregularity of the cars. Even cars of a given type, i.e., boxcars, will differ in structural detail though the basic design may be markedly similar. Sizes and shapes of cars and their structural elements differ from one series to another. This is true of both metallic and nonmetallic parts.

The wood elements are also not attached to the metal by methods which are entirely consistent from car to car. Their separation requires either a pervasive technique, such as fire, or a flexible technique, such as hand stripping. Though much of the wood consists of planks or boards, plywood sheets are becoming more and more common. The wood studs and other structural pieces are designed and integrated with steel members in different ways from car series to car series.

Railroad scrapyards get cars of many sizes, shapes, and conditions. Some may be relatively new cars of 70 or more tons capacity, but ready to be scrapped owing to accidents or other special conditions. Most cars will be over 30 years old and many will be minus doors or other components by the time the scrapyard is reached. These older boxcars are characteristically 40-foot cars with a rated capacity of 40 or 50 tons. The light weight of such cars is approximately as follows:

Refrigerator cars	55,000 lbs
Boxcars	44 to 48,000 lbs
Stock cars	40 to 44,000 lbs
Flat cars	40 to 44,000 lbs

Such cars consist of a box or platform mounted on two 4-wheeled "trucks." The combustible components, primarily the wood floors and sidewalls of a boxcar of this vintage, will account for 6,000 to 9,000 pounds of the total weight—a few thousand pounds more in the case of refrigerator cars and something less for flat cars. In a typical boxcar of retirement age, from 1,000 to 2,000 pounds of the wood weight can be traced to preservatives and oils which the wood has absorbed. Older cars are frequently used for freight that imparts vegetable oils, greases, or other contaminants, which may be partially absorbed by the wood car lining.

The metallic content of boxcars will typically be distributed as shown at top of page 9.

Using a figure of $25 per ton for the revenue from railroad scrap *after* paying transportation costs to the mill and taking 15 tons as the scrap-steel yield per 40-foot boxcar, the anticipated revenue from scrap will amount to $375 per car. Industry sources indicate that sizable variations from this estimate are found in actual experience. Furthermore, the additional yield from resale of salvaged parts is generally regarded as too highly variable to be amenable to projective estimates. The skill and know-how of the scrapyard operator appears to play a significant role here.

Many scrap processors regard the earnings from salvage as the sole source of profit for the total operation, even though many of the costs of conducting the business are joint costs insofar as the production of salvage and scrap are generated from common sources and common operations. This view of the character of the business is exemplified by the observation that the revenue returned from scrap alone is often approximately offset by the cost of simply acquiring boxcars for demolition. From this point of view, all other costs and net return for services must be supported by salvage operations.

The Scrapyard Customer

The railroad scrapyard services two types of customers:

- Railroads and railroad equipment builders and rebuilders. Many railroads rebuild rolling stock in their own shops; others contract with independent shops.
- Steel mills and foundries.

These two heavy industries are the focal points influencing virtually all operationing decisions of the railroad scrap processors. In this sense, the railroad scrapyards may be described as a satellite industry.

Railroads are not only the major source of cars for demolition, but also the prime customer for salvaged parts. Salvaged parts are purchased both as an inventory of reusable components and for reworking for installation in rebuilt cars.

Steel mills purchase a variety of grades of scrap.

	Boxcar rated capacity		
	40 tons	50 tons	70 tons
Total metallic (tons)	17-20	20-21	24
Trucks (2) (tons)	6	7	8.5
Typical salvage (tons)	1.5	1.5	1.5
Net ferrous scrap (tons)	4.5	5.5	7
Body, including under frame (tons)	11-14	13-15	15.5
Typical salvage (including brake systems, couplers (2), yokes (2), draft gear (2), which yield about one ton of metal of which about half normally becomes salvage and half scrap)	0.5-1	0.5-1	0.5-1
Net ferrous scrap (tons)	10-13.5	12-14.5	14.5-15
Typical salvage-scrap distribution for total car:			
Salvage (tons)	2-3	2-3	2-3
Scrap (tons)	15-17	17-19	21-22

Railroad scrap makes a preferred grade of scrap steel, usually designated as No. 1 Heavy Melting Steel.

Steelmakers use different proportions of scrap in manufacturing new steel. The mix of scrap and ore-derived "hot metal" depends on a complex set of metallurgical factors and economic circumstances. These may be summarized as follows:

- *Impurities*—All scrap carries with it some impurities. Generally speaking, the lower the grade of scrap, the higher the degree of expected undesirable impurities. The impurities and alloy substances tolerable in scrap varies with the type of end-product steel sought. Railroad cars generally yield a high grade of scrap with predictable steelmaking qualities.
- *Price*—The price of scrap fluctuates constantly in an open market. The cost of producing pig iron from ore also varies over time and represents a competitive control on scrap prices. The price of heavy melting scrap has generally declined from a postwar high of about $54 per gross ton, in 1956, to recent quotations of about $28 a ton.
- *Furnace technology*—Over the past 15 years, the installation of new furnaces has had a self-cancelling effect on the proportion of scrap used. The most prevalent type of furnace is still the open-hearth design which uses from 40 to 50 percent scrap content. The basic oxygen furnace (BOF), now widely introduced, typically uses only about 28 percent scrap, or about the same proportion as the home scrap generated by integrated producers. Expansion of continuous casting promises to alter this picture in favor of the scrap processors. On the other hand, the electric arc furnace, which uses 98 percent scrap in its charge, is also accounting for an increasing share of steel production. Electric furnaces are a favored and efficient installation for nonintegrated and specialized steel producers.
- *Integration of steelmakers*—Generally speaking, the larger integrated steel producers rely on the open-hearth and (increasingly) the BOF methods. They generate large amounts of scrap internally (home scrap). Conversely, the nonintegrated producers use relatively greater amounts of scrap steel purchased from scrap processors. This is true both because of furnace technology and because of their corporate characteristics. Nonintegrated operations frequently require a flexibility accommodated by the raw material flow made possible by scrap processors.

RAILROAD CAR DISMANTLING PROCESSES

In general, scrapping processes consist of the following tasks:

- Boxcar delivery to scrapping area
- Body removal
- Truck parts salvage
- Wood separation
- Body parts salvage
- Metal cutting
- Scrap sorting and loading
- Scrap delivery to steel mills.

Variations will be found from yard to yard with regard to the sequence, procedures, and costs for individuals tasks. These variations usually reflect the expertise and operating philosophy of the operator or his yard superintendent. More than likely, they are also in direct response to the economic picture, to local ordinances, and to other activities engaged in at the yard. These considerations will be discussed more fully in later sections.

Yard Organization: Outdoor Processing Plants

The uninitiated public too often confuses scrap yards with junk piles or dumps, which is hardly accurate. To operate efficiently, a scrapyard must be well organized both in layout and functioning. Railroad spur lines along which the retired cars are delivered must lead into an arrival area that is nothing less than a small freight yard, with the necessary array of track lines, switches, frogs, sidings, etc. From the time of arrival to final disposition as scrap and salvaged parts, a boxcar goes through the successive dismantling steps in distinct, specialized areas of the yard. Much of the work done in the process takes acquired skills and experience for quick, effective accomplishment.

Railroad cars arriving in a shipment are usually of many types: boxcars, both all-wood and wood-lined; refrigerator cars (reefers); flat cars; special purpose cars; gondolas; stock cars; tank cars; hoppers; and, occasionally, passenger cars and cabooses. If these are intermixed in the arriving train, they are usually separated by type after arrival, with the aid of a yard locomotive. Boxcars and refrigerator cars are then brought down to the dismantling area. If they are to be burned, the area used is somewhat isolated from the rest of the yard, and usually selected for its location downwind from inhabited areas based upon prevailing winds. These areas may still be used for boxcars and "reefers" even in yards where the practice of burning has been discontinued, since it offers a place for sorting and stockpiling the wood removed unburned.

Before dismantling, the car body is lifted off its trucks by means of a railroad crane, swung around away from the track and placed into position on bare ground. Cars to be burned are usually assembled at this site in groups which may number as many as thirty cars and as few as two or three. In the meantime, the trucks remaining on the track are disassembled with the aid of a torch. Salvageable parts are removed, and the wheels and axles are gradually moved uptrack to be reconditioned for use if possible. The side frames, springs, bearings, bolsters, and air brake parts are moved to individual stockpiles. Brass from the bearings is sold for brass scrap separately, bringing prices which are a little higher than prices paid for scrap steel.

Car body burning to remove the wood also succeeds in improving the quality of the body scrap by removing much of the paint, grease, dirt, and other external impurities. A can or two of gasoline liberally applied inside each car and set afire is all that it takes to perform this task. Heavy clouds of black smoke are given off from the fire for the first half hour to an hour, after which the fire burns more cleanly and the smoke is whitish in appearance. After two to three hours, the fire burns itself out, and the steel skeleton is left to cool.

Where open burning is prohibited, wood must be removed by hand. It takes about a day for two nonskilled laborers to strip the wood from an all-steel boxcar; remove nails and bolts; separate, sort, and stockpile reusable lumber, and throw the rest into a trash pile for removal to a dump. A wood-sided boxcar takes another half day or so.

When the metal frame is ready for subdivision, the roof and uprights are separated from the undercarriage. Salvageable parts consisting mainly of the couplers, coupler yokes, and draft gears (shock absorbers) are cut away, and then the major subdivision is begun.

The acetylene torch is the yard mainstay for cutting steel. In yards not equipped with shears, torch-cutting is used to reduce the entire structure to pieces no larger than 3 feet by 1½ feet. In yards which have shears, torchcutting is often used only to reduce the metal to a size which the shears can handle. Large shears can cut all of the metal, including sills and body bolster (main frame) to required 3-foot lengths or less. Smaller shears can cut most of the boxcar steel except for the body bolsters, which are left for the torch.

The subdivided lengths are now in a form acceptable to the mills as heavy melting steel. The railroad crane returns to the site, with a heavy disc-shaped electromagnet to pick up the steel. Scrap is lifted from the pile and loaded into gondolas or open-top trailer trucks for delivery to the steel mills.

Processing Costs Determinants

In 1967 a typical price for scrap steel received at the mill was $28 per ton. A scrap dealer at Chicago might pay freight charges of about $2.70 per ton, leaving him a net recovery of a little over $25 per ton for the scrap. To compute the total recovery per boxcar, we need to refer to the data (page 9) which shows:

Car capacity (ton)	*Net scrap weight (ton)*
40	15–17
50	17–19
70	21–22

Salvageable parts removed from the body after burning include:

Couplers, two at 400 lbs each
Yokes, two at 200 lbs each
Draft gears, two at 300 lbs each.

Of the above 1,800 pounds, about 50 percent is salvageable; the rest going for scrap. For 6-ton trucks, the salvageable portion is about 1.5 tons. All told, salvage may account for 2 or 3 tons per car of 40-ton capacity, but is sold by the type of item, e.g., 60 sets of wheels, 40 couplers, etc. The remaining 15 to 17 tons constitute the scrap weight. At $25 per ton, the scrap returns $350 to $425 to the dealer per car. As will be shown, at least another $100 must be recovered from the sale of reusable parts.

Costs begin with purchase of the boxcar, which amounts to something between $300 and $400. Processing costs per net ton of scrap and salvage run about $7 for direct charges and about $10 with overhead included. This averages about $180 per boxcar. Hence, total costs more than consume the total income from scrap, and salvage revenues must be relied on for solvency, to say nothing of profit.

All the aforementioned costs and prices are subject to variation within a range of plus or minus 15 percent. Within this range, the dealer may find profitable leverage on individual transactions. Margins are constantly being squeezed by rising costs in every phase of the operation; particularly labor costs. At the other end, prices for scrap steel have not risen. Indeed, prices have tended to sag with the rapid growth of BOF installations, where the scrap constitutes as little as 25 percent of the intake, compared with 50 percent, or more, for open-hearth furnaces and 98 percent for electric furnaces.

Railroad scrap processors have sought ways of continuing a profitable operation while hoping an upturn in the railroad scrap picture will materialize. Some have succeeded by avoiding the purchase of boxcars wherever possible, and concentrating on all-metal items like tank cars and locomotives. Others have turned to supplementary operations, such as auto scrap and other secondary metals to fill the gaps in use time for equipment such as shears and cranes, and they have sometimes found themselves turning away from the railroad scrap business. A few operators have abandoned railroad scrap processing altogether. As a result, the normal functioning of the reclamation cycle for railroad scrap becomes more and more uncertain.

It is evident that any further rise in costs in compliance with the prohibition of open burning would turn a barely marginal operation into a guaranteed loss. Wood removal by manual means at today's unskilled labor costs (about $2.75 an hour in industrial areas) means an added burden of $40 to $50 per boxcar. The same job could be done for much less in the immediate postwar years when scrap steel prices were somewhat higher than today.

The manual method for removing wood leaves today's scrapyard operator with a new problem: how to dispose of the scrap wood. Once, farmers were happy to cart it off for use as firewood and construction material; but, today with increased urbanization and with farmers themselves operating at a higher economic level, no inducement is found to haul scrap wood over 25 or 50 miles of highway.

As a result, railroad scrap processors, forced to abandon open burning, have found themselves in the used lumber business. This is hardly lucrative, but in a few localities it does help to recover some of the added costs. Where the local market warrants even higher costs for used lumber carefully stripped from the boxcar, unskilled laborers may be supported by acetylene torch men, whose weekly pay may exceed $200. The torch is used to "blow the bolts" that hold down heavier planks, especially in the flooring, where the 2- by 6-inch or 2- by 8-inch lumber finds a readier market.

All in all, the problem of learning to live with environmental pollution controls is intimately tied to the problem of residual wood utilization. In this regard, the railroad scrap business is but a minor contributor to a vastly larger and increasingly importunate solid waste disposal problem which affects all sectors of our economy.

MECHANIZATION: POSSIBLE LONG-RANGE SOLUTION

Proponents of mechanization in the scrap industry insist that a downturn in unit cost can occur only through a modernization of scrapyard practices and equipment. They maintain that while most yards have heavy equipment of some kind, no yard has attempted to develop and operate a completely integrated system. An optimum system of this type would have the following characteristics:

- It would use state-of-the-art items of equipment, or custom modifications.
- It would be made of components which are matched with regard to capacity, speed and duration of operation, control and maintenance requirements, etc.
- It would provide for continuous flow processing.
- Its operation would be almost entirely automatic.
- Its downtime periods during workdays would be brief, and then only for inspection and maintenance.
- It would have provision for temporarily bypassing a defective component.
- It would come with spare parts which yard personnel can readily interchange.
- It could increase its capacity at peak periods without adverse effects.

On this list, the items which would contribute most to the reduction of scrap processing costs are the continuous flow and automatic provisions. To present-day technology such specifications are routine. All the components are commercially available, and manufacturers seeking larger markets and wider applications for their equipment have already proposed new models designed to handle railroad cars. An automatic system designed and assembled as a complete unit would constitute the next higher level in the state-of-the-art. One need not look too far into the future to envision all scrap as being processed in this way.

In a typical proposed system, a boxcar is brought to a reception shed in which the trucks and salvageable parts are removed and tracked off to the salvage area. The car body is slid onto a conveyor, and from there on, the entire process is automatic. The roof and sides are compressed toward the floor as the body approaches a gigantic shear. The shear reduces wood and metal together to sections as wide as the car and between 18 and 36 inches long, as required. Lateral cuts, which bring the maximum widths down to between 12 and 18 inches, can be made with the same shear by the use of a turntable base, or with a second, smaller shear.

Much of the wood will have already separated and fragmented by this time. Conveyors then take the wood and metal to a hammermill or ball mill, which not only performs a further size reduction, but also substantially frees the metal of wood and cleans it through abrasive action. The next conveyor is also a vibrator, which helps to shake away any wood particles clinging to metal and thus prepares it for the final separation, which is done by a magnetic drum. Clean, beneficiated steel scrap then exits onto one conveyor which loads it directly into gondolas. Wood fragments enter a chute where they eventually fill bags for sale as mulch or for other purposes.

Variety of Equipment in Use

The major items of scrapyard equipment currently in general use may be grouped according to function, in the following manner:

- *Movement and storage*
  - Locomotives
  - Gondolas
  - Container units
  - Truck transporters
  - Cranes with grapples
  - Cranes with electromagnets
- *Primary size reduction*
  - Oxyacetylene torch units
  - Guillotine shears
  - Alligator shears
  - Scrap breakers
- *Secondary size reduction*
  - Shredders
  - Rippers
  - Pulverizers
  - Hammermills
  - Ball mills
- *Compaction*
  - Balers
  - Squeeze boxes
- *Combustibles removal*
  - Incinerators, single-chambered
  - Incinerators, multi-chambered
- *Intra-process scrap movement*
  - Feeders
  - Rams
  - Conveyors
- *Ferrous extraction*
  - Vibrators
  - Magnetic separators
  - Flotation.

Most of these items are used in the processing of scrap originating from sources other than railroad cars; principally automobiles. Railroad cars must be specially prepared and sectioned before they can be accommodated by the processing units. Shears have been designed with a throat wide enough to accept a boxcar (about 10 feet), but nothing that large is in current use. One source indicates that only 6 to 8 yards, actually dismantling

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railroad cars, have shears capable of handling railroad scrap—torch cutting being by far the dominant method.

Compacting devices such as squeeze boxes are used to laterally constrict large, loose, or compressible chunks of raw scrap so they can fit into the throat of the shear into which they are being fed. However, the undercarriage of a boxcar cannot be treated in this way—center sills and body bolsters being too rigid and strong for most conventional equipment to handle.

Most scrapyard incinerators are of the old, single-chambered type which are little more effective than open fires in controlling air pollution. Newer types are multi-chambered, providing for complete combustion by carrying the process through successive stages. Many are now equipped with pollution control devices, generally some type of scrubber or precipitator.

One scrapyard has recently installed an emission control incinerator which is designed to accommodate several boxcars at a time. This unit represents a considerable capital investment, and accomplishes little more than open burning formerly did, but it was considered the price necessary to stay in business.

A cross section of scrapyards specializing in railroad car demolition was surveyed to ascertain the specific types of equipment currently available in these yards (Table 1). This equipment is not necessarily used only for railroad cars; in fact, in most cases, it is used for a variety of steel processing operations.

Capital Investment Requirements

Semiautomatic systems which are already in use for automobile scrap processing have required capital outlays of one-half to one million dollars. Similar systems redesigned to handle boxcars would apparently cost at least twice as much. These would still fall short of the automatic, continuous flow capability achieved for auto scrap. The necessary capital requirements could not be justified by many individual railroad car dismantlers, volume being a key consideration.

Computation of the total allowable capital investment for a particular scrapyard must be based upon a demonstrated reduction in net operating cost brought about by the new equipment. If we assume a cost reduction of $2 per ton, or roughly, $40 per boxcar, a yard which processes 2,000 boxcars per year would be able to recover $80,000 per year. Five-year amortization for this equipment makes the figure $400,000. Roughly one-fourth of this amount might be needed for extra trackage required for moving cars into the equipment, plus any auxiliary equipment required. This leaves some $300,000 available for new equipment, before considering interest or opportunity costs.

ENVIRONMENTAL POLLUTION CONSTRAINTS

A basic premise in selecting alternatives to the practice of open burning is that any process must be rejected if it results in legally unacceptable levels of pollution. Does logic then dictate that all combustion processes, however minimal the pollution level, ought to be rejected? Is it not axiomatic that nothing is better than no pollution at all? To answer these questions, we must consider the entire cost-effectiveness picture from the standpoint of short-term as well as long-term objectives. For example, if one or more incineration process *plus emission control* is effective in meeting existing standards, we cannot reject it out of hand even though it may not meet ultimate public goals. For a comparative evaluation of processes which could at least be useful for the next five years or so, we must consider incinerator systems on the same basis as nonemission processes.

The railroad car dismantler notes, however, that incinerators at many scrapyards have not been meeting local air quality standards satisfactorily. This inadequacy can result from:

- Deficiencies in design principle, construction, operation, or maintenance of the installation.
- Upgrading of standards over the years following installation.
- Stricter enforcement of existing regulations resulting from growing public awareness.

The question of what is and will be legally acceptable is the key issue. What is acceptable in one scrapyard location may not be in another. What was acceptable yesterday is less so today, and perhaps not at all tomorrow. However, it is worthwhile for scrapyard operators to realize they are not alone in feeling the pressures of community action. It is also instructive to note where they do stand with reference to pollution control programs, and as a corollary, what this study considers the ground rules to be from an environmental pollution point of view. We will, therefore, look briefly at what is given off when a railroad boxcar is burned, what happens to the local atmosphere, and what the public officials are supposed to do about it.

Products of Combustion. The most objectionable emission from open burning is smoke. The heavy, black clouds which billow into the air during the first hour of burning contain unburned carbon particles mixed with mineral fly ash, carbon oxide gases, and partially condensed steam. Gradually, smoke lightens as the fire stabilizes to a more complete combustion stage; steam now dominates the effluent. The smoldering phase is accompanied by thin, but blackish smoke which gradually fades as the fire burns out; this smoke has a high content of carbon due to incomplete combustion with lower temperature.

The major gaseous products of combustion are carbon dioxide and water, but there are also generous amounts of objectionable gases. The major pollutants are the aldehydes and the oxides of nitrogen. These substances come from the combustion and partial distillation of cellulose, lignin, and colloidal residues such as gums, resins, and sap, which characterize particular varieties of wood. Small amounts of sulfur oxides and of carbon monoxide are emitted. However, wood burning can be considered as a negligible source of these pollutants.

When a refrigerator car is burned, it well merits its abbreviated name "reefer," for the burning insulation adds richness and heaviness to the black smoke. Its resemblance to an oil fire is not coincidental, for much of the added density is due to hydrocarbon aerosols and gases. The lubricating oils, greases, and various other fluids absorbed in the undercarriage of boxcars also contribute to hydrocarbon emission. When tars have been used to treat the wood, combustion will also produce small amounts of wood alcohol, acetone, and acetic acid.

Meteorological Considerations. Pollution from boxcar burning is usually very local and short lived. Since burning is usually saved for those days when "the wind is right," that is, downwind from residential areas, it is seldom done more often than twice a week. It also

Table 1.—Summary of survey of operations, plant, and equipment at 15 typical scrap processing yards that dismantle railroad cars

	Total for 15 yards	Arithmetic average for 15 yards	Range of observations			
			Smallest value	Lower interquartile	Upper interquartile	Greatest value
1. Dollar volume:						
Estimated annual gross, scrap and salvage, all sources	$27,600,000	$1,840,000	$600,000	$1,000,000	$2,900,000	$5,000,000
Percentage attributable to railroad car operations	44	44	5	15	80	95
Estimated gross from railroad car scrap (salvage excluded)	$10,344,000	$689,000	$28,000	$300,000	$900,000	$2,100,000
2. Physical car operations:						
Number of railroad cars annually	21,840	1,460	50	700	2,000	4,000
Tons of scrap steel recovered from railroad cars	376,000	25,000	1,000	11,000	32,000	75,000
Average tons recovered per car	17	17	12	15	20	20
3. Yard characteristics:						
Value of yard and fixed improvement to realty	*$8,000,000	*$778,000	$300,000	$400,000	$900,000	$3,000,000
Number of acres at sites	246	16	3	7	20	54
Average value per acre	*$42,000	*$42,000	$9,300	$30,000	$68,000	$111,000
4. Equipment inventory:						
Number of major items of processing equipment available:						
Magnetic lifts and grapples	99	7	None	3	5	12
Cranes	59	4	1	3	4	12
Shears	29	2	None	None	4	12
Conveyors	14	1	None	None	2	4
Wheelpresses	10	1	None	1	1	1
Feeders and rams	8	----------	None	None	1	4
Scrap breakers	4	----------	None	None	1	2
Incinerators	3	----------	None	None	None	2
Other (Including Balers(2), Hammermills(1), Magnetic separators(2), and Shredders(1) but excluding containers and transporters)	6	----------	None	None	1	3

* Based on 9 reporting yards.

depends upon the rate of boxcar shipment to the yard. The fire generally burns itself out within two or three hours; depending upon the number of cars stacked for burning. During this period, the major portion of objectionable material is emitted within an hour or less. Boxcar burning does not in fact contribute significantly to the high nationwide levels of air pollution, but for limited periods, the heavy emissions present a threat to health, comfort, and nearby property. This puts boxcar burning more in the class of public nuisance; but this, too, is a target of legislative action.

Some of the deleterious effects of boxcar burning come from bad or mistaken practices on the part of the scrapyard operator. It appears to be the custom to burn late in the day so that by the following morning the remaining steel structure will be cool and ready for torch cutting. It is not openly acknowledged that the choice of burning time may also be governed by more subtle reasons, such as:

- Twilight conditions, visibility restrictions, and cloudiness tend to mask the fire and smoke.
- Neighborhood housewives are mostly indoors preparing the evening meal and are thus less likely to observe and complain about the fire.
- Air pollution surveillance helicopters and inspectors are generally going off duty.

From a meteorological standpoint, however, early evening is a very inappropriate time to burn, because solar convective activity is about over for the day, and nocturnal inversion conditions are setting in. This virtually guarantees that palls of smoke emanating from the scrapyard will remain low above the ground, spread laterally and settle during the night, and by morning cover the neighborhood with a fresh layer of grime.

Over most of the country, the best time to do open burning is early in the afternoon on a sunny day, when the lower atmospheric layers are most unstable and turbulent eddies will rapidly diffuse and dissipate the smoke and carry it off to great heights. With the aid of a qualified meteorological service, which the local Weather Bureau office can usually provide, scrapyard operators and air pollution control officials could reach agreement on an acceptable time for open burning day by day, where still permitted.

Abatement and Control. The control provisions of new regulations will henceforth be more uniformly and effectively enforced. Under the 1965 and 1966 Amendments to the Clean Air Act, the air pollution control and solid waste disposal programs of state and local agencies will be strongly bolstered. The availability of Federal grants will help these agencies to improve their effectiveness through more responsive organization, fuller staffing, up-to-date monitoring and analysis equipment, and closer communication with other governmental functions and with the public at large. Abatement and control activities will be more vigorously pursued, but the ultimate objectives are now becoming more clearly defined. Smoke-chasing and the punishment of offenders are secondary to the long-range measures for overall community planning. Some of the broader objectives are:

- Elimination of hazards to life, health, and property.
- Conservation of our resources and common heritage.
- Preservation of esthetic values.
- Establishment of conditions for a sound and growing industrial economy; not a self-defeating one.
- Exercise of the principle that no individual or group enjoys the right or special privilege of contaminating the environment shared by others.

Each of us has a stake in these common goals; government is now fully committed to them. However, the scrapyard operator whose business is threatened finds little consolation in the priorities which enforcement officials sometimes follow. He complains with some justification that independent operators are being brought to task while other major offenders are left inviolate.

In communities where heavy industry dominates the employment structure, public pressure for a clean-up is often countered with the threat of shutdown. The independent scrap processor has no corresponding retaliatory weapon. Scrap is essentially a satellite industry which needs the steel companies and the railroads to share the responsibility. The present study enjoyed the cooperation of an integrated steel producer and of rail industry organizations, though individual roads registered little interest.

Independent scrapyard operators may find some comfort in knowledge that the present disparity is temporary, and that before long, compliance requirements will be uniform and universal. During this transitional period, the Federal interest is to lend support to efforts directed to more general standardization, and to provide a floor of minimum criteria. The more progressive scrapyard dealers have already taken measures to adjust to the imposed changes, and will find ways of living with short-term inequities.

ECONOMIC CONSIDERATIONS

Freight cars, like all manufactured goods, are made from raw materials found in limited supply. The metal elements in particular retain an economic value to society even after the usefulness of the car itself has been spent. Cars are retired in large numbers and are of certain relatively uniform characteristics. It follows that a system for recovering the reusable materials should be economically desirable from a public view as well as from the car owners and steel producers point of view. The AARCD expressed it this way[8]:

"Scrap is a man-made resource which can replace iron ore, coke, and limestone—all irreplaceable natural resources—in making new steel. One ton of scrap can be used instead of a ton and a half of ore, a ton of coke, or a half-ton of limestone.

"The conservation of scrap is a necessity for this nation. Supplies of natural resources within the continental United States are not inexhaustible. Reliance on foreign sources can be risky in emergencies. For those reasons, every estimate made of America's resources includes the availability of iron and steel scrap and rates it as vital to the country's industrial wellbeing as materials dug from the earth."

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[8] AMERICAN ASSOCIATION OF RAILROAD CAR DISMANTLERS. *At the end of the line.* Chicago, AARCD [1968]. 4 p.

As his mission, the railroad car dismantler has the performance of an economic function for his own profit, his customer's service, and the public's benefit. Air pollution is becoming an increasingly obvious public detriment. So, the problem is to find a practical method for salvaging a valuable resource, while conforming to the public's interest in controlling air pollution. A practical method implies (1) effectiveness in reducing air pollutants, and (2) costs which are tolerable to the market for scrap steel.

The net incremental costs of any innovation in the recovery process is vital to the interests of each party concerned—the railroad, the scrap processor, the steel mill, and the public as a whole. Unless the costs are such that the market will adjust, the resource will be unable to retain utility. The resource and the economic function will be lost until the market adjustment is in fact made. The time that adjustment takes is a measure of the real cost of clean air. Who bears that cost is important.

The problem is not simply one of "clean up or shut up"; it is a matter of finding the least disruptive way to continue to use the resource consistent with clean air goals. This disruption takes two forms:

- Disruption to the orderly and established activities by which the economy makes use of recoverable steel from retired freight cars.
- Disruption of the scrap processor's ability to perform his accustomed function.

The combined effect of these aspects of the problem leads to a conclusion that in time the pressures of the marketplace and the ingenuity of railroad scrap specialists will find a way to recover the resource even if all open burning of freight cars were prohibited immediately and absolutely. Our joint mission is to smooth this path.

In this connection, the competition among railroad car dismantlers deserves comment. The scrapyard operators, under the spur of competition, may hold the long-run key to an effective solution, but this managerial resource can either be relied on constructively or used unfairly. To the degree that clean air standards are enforced unequally among given localities, and to the degree that clean air standards are enforced without first finding workable solutions or approaches to solutions, the economic forces will combine to work a hardship on those who can protect themselves least. Neither the entrepreneurial scofflaw nor the entrepreneur who is swamped by his problem represents a constructive result.

ALTERNATIVES TO OPEN BURNING

SCRAP PROCESSORS and other sources have provided a variety of alternatives to open burning as the primary means for removing wood from retired railroad cars. Methods which have been considered are those where:

- Wood is removed prior to metal processing.
- Wood is removed after initiation of metal processing.

Methods other than routine scrap processing operations are also briefly discussed later in this chapter.

The availability of alternative possibilities implies neither acceptability to the industry, nor compatability with its existing operations. The industry must be able to incorporate new or modified methods into its railroad car scrapping operations without impairing scrapping operations for other commodities, and it must do so profitably. These factors are the first criteria for screening the alternatives:

- Methods are eliminated which are outside the scope of normal scrapyard operations.
- Methods are eliminated which are of interest, but for which technology is inadequate at this time.

GENERAL PROCESS RELATIONSHIPS

Even after the elimination of what might be termed "nonprocess" alternatives by means of the gross criteria given above, a great many individual methods and combinations of methods remain. These span the field of technology in wood and metal cutting, and wood and metal separation techniques. Compared to open burning, however, these alternative methods have the common feature of higher cost.

For this reason, it immediately becomes necessary to view each alternative in its relationship not only to open burning, but also to the overall processes involved in railroad car scrapping. In other words, the alternative methods available should be viewed as possible components of modified scrap processing systems. A further important consideration is in the application of some of the proposed methods to the scrapping of nonwood-bearing railroad cars, or to metal scrapping in general.

In this study we grouped procedures through which railroad cars may be scrapped (Figure 1). The individual methods or techniques were then aggregated under broad headings to demonstrate the point or points where they might be located in the overall scrapping process.

Only two fundamental procedures exist: that wherein wood is removed prior to basic metal processing (Procedures A and B) and that wherein wood and metal are processed simultaneously (Procedure C). Regardless of individual method, five fundamental steps comprise the generalized railroad car scrapping process.

Wood Removal

Includes all methods used to remove wood prior to metal processing; the products are wood and metal for further separate processing.

Initial Size Reduction

Includes reduction of the car, with wood and metal separated or together, into a few large pieces which can then be further processed by passing them through equipment incapable of accepting an entire car body.

Secondary Size Reduction

Includes all methods whereby large pieces of scrap material are reduced to small-size pieces or fragments. Final piece-size is determined by the specific scrap market (the scrapper's customer). This is the reason for the metal bypass around secondary size reduction in Procedures A and B, since all markets do not require small pieces of scrap.

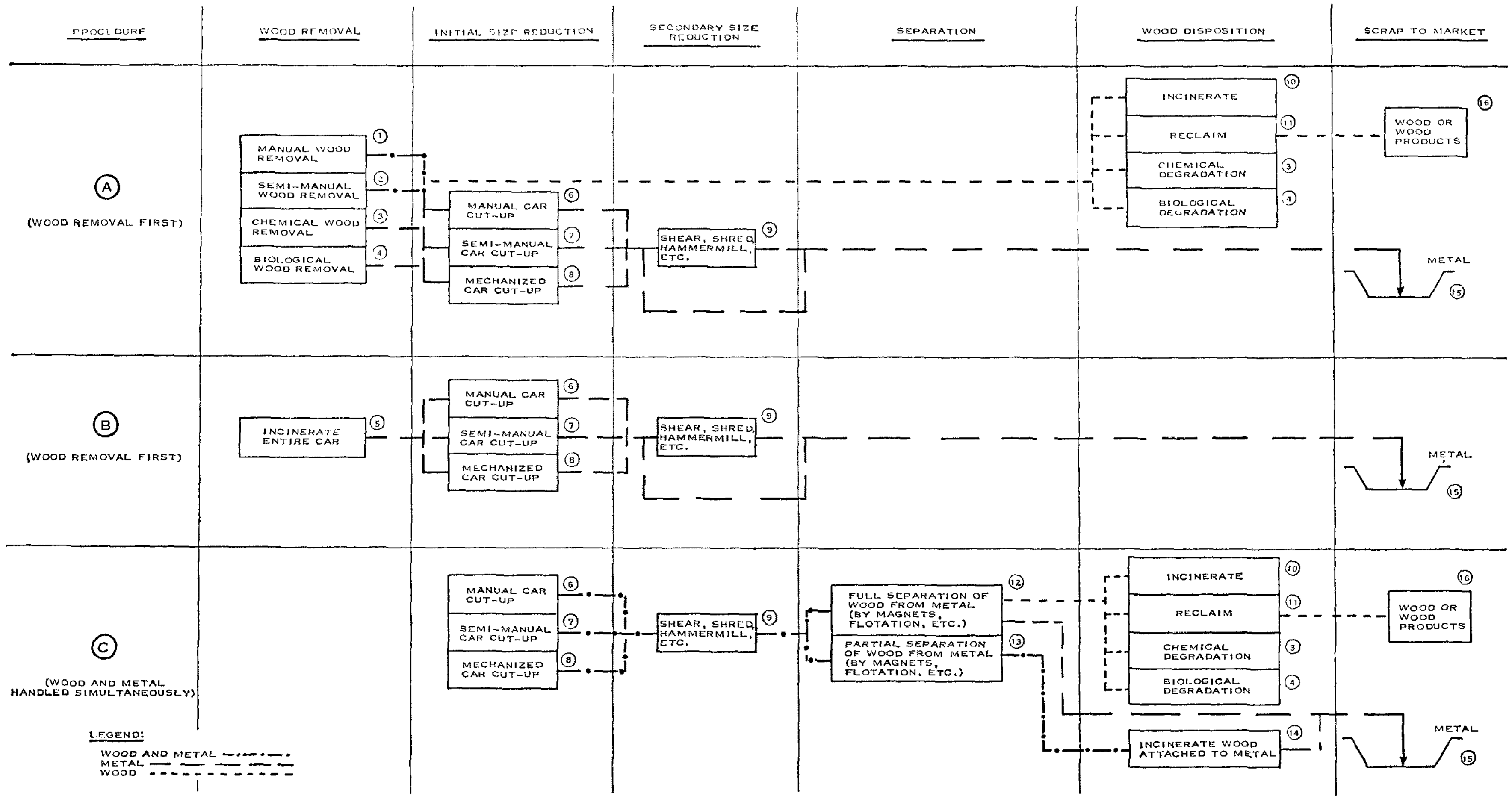


FIGURE 1. Railroad car scrap and salvage: general process and relationships.

Separation

Separation appears as a specific step in Procedure C (wood and metal processed simultaneously). Steel mills which purchase metal scrap require the exclusion of wood. If wood and metal are handled simultaneously, it is unlikely that all the wood will, of its own accord, fall off the steel. Some methods must be provided to complete the separation.

Wood Disposition

This step includes all methods for disposition of wood, whether reclaimed or destroyed, and generally assumes that wood and metal have been fully separated at a previous point in the scrapping process. The exception is in Procedure C, where some wood fragments would still be attached to metal fragments. These would require destructive disposition.

Under these five broad headings, fourteen possible steps in the overall process were established (Figure 1).

ALTERNATIVES TO OPEN BURNING FOR WOOD SEPARATION

All of the proposed alternatives to open burning are associated with one or more of these steps. Each alternative has been subjected to initial screening, and those which survived were subjected to a more detailed analysis. The possible process alternatives may be listed according to the following classifications:

Conventional Sequence of Operations (wood removal after salvage operations, but prior to scrap metal separations)

Manual wood removal
- Strip out wood using ordinary hand tools (wrecking bars and other nonpowered devices)
- Strip out wood using standard hand-operated power tools
- Grit blasting equipment
- Water or steam jets under high pressure
- Other specially designed hand-operated power tools (saws, abrasive wheels, nibblers, chippers, etc.).

Automated physical wood separation (vibratory)
- Acoustic vibration using enclosure and externally applied frequencies to wood or to metal frequency ranges
- Ultrasonic or acoustic vibration applied internally.

Chemical processes for wood removal
- Solvent bath
- Wood-destructive spray
- Other wood-destructive coating
- Brittlizing agent.

Biological processes
- Microorganisms
- Wood-eating insects.

Controlled incineration
- Enclosed incinerators able to accept entire car or substantially unprocessed boxes
- Semienclosed burning
  - Attach stack or hood with smoke-control device while using shell of car for partial internal draft control for burning out car
  - Vortex "pit" open-top type incinerator (air recirculation assisted by directed jets).

Carbonization
- Use an oven to "bake" wood until reduced to charcoal
- Induction heating where steel sheeting and frame supplies controlled heat to wood.

Modified Sequence of Operations (wood removal integrated with scrap metal separations)

Wood shattering impact methods applied to total box
- Use large-mouth shear to accept entire box, with wood and steel frame intact
- Gravity action relying on
  - Weight of car
  - Weight of crushing device
- Mechanical pummeling device
- Shock action under cryogenic conditions.

Initial separation of total box into convenient segments for processing with conventional equipment (shears, hammermills, magnetic separators)
- Mounted saw-type cutting tool
- Unmounted saw-type cutting tool
- Mounted abrasive wheel (powered)
- Unmounted abrasive wheel (powered)—cutting from inside or from scaffolding
- Cut with acetylene torch accompanied by fire extinguishing agent (conventional soda-CO_2, water hose, foam sprayer, etc.)
- Explosive cutting effects (shaped charges)
- Any of above applied only to underframe using gravity to break up remainder
- Explosive gas-filled interior.

Initial separation, as specified, followed by unconventional subsequent process for wood removal
- Flotation
- Direct gravity feed
- Density–vibration feed
- Mechanical equipment of existing types.

Separations, as specified, followed by wood disposal
- Small incinerators with smoke control
- "Total" combustion incinerators
- Convert to landfill or other low utility purpose
- Convert to economic byproduct.

CRITERIA FOR SCREENING AND EVALUATION

As noted, all methods considered have the common feature of cost being higher than open burning. Since the consideration here is for private industry, attention is immediately drawn to the single criterion by which industry judges any contemplated program—return on investment. Within this limitation, it is possible to develop other criteria for screening and evaluating alternative methods for scrapping. These alternative methods have various cost implications, including the cost of a possible decision to stop scrapping of wood-bearing railroad cars altogether, and to devote plant capacity to other scrap operations.

Basic Criteria for Screening Individual Methods

- Methods were eliminated which are outside the scope of normal scrapyard operations. Interest here is focused upon methods that can readily be incorporated into the scrap production processes and that can be financed by private means. Application of this criterion immediately eliminated those methods which are not directly involved in production of salable scrap, along with those methods requiring continuous financial participation by the government.
- Methods were eliminated which are of interest but

for which technology is inadequately developed at this time. This criterion can be immediately applied to chemical, biological, and other advanced processes.

- Methods recommended for further consideration should minimize the capital investment required. This suggests multiple use of the method or equipment, including the possibility of using this method or equipment for other scrapping operations. For example, a high-pressure water jet used for cutting wood out of a boxcar can be used also for cleaning ferrous scrap, a process which will upgrade the scrap and increase its market value.
- Methods recommended should incorporate reasonable operating costs. This generally means that highly sophisticated and complex methods should be avoided. While such methods might perform their assigned tasks very well, the possibility of extensive downtime and the requirement for highly skilled, high-cost operating and maintenance personnel and for high-cost repairs parts should be carefully considered.
- Methods recommended should be capable of implementation without impairment of other scrap processes. The volume of railroad car scrappings varies widely among individual processors. At some scrapyards, it does not represent a majority of the work. For this reason, methods recommended for use in railroad car scrapping should not be detrimental to other scrapping operations. In fact, certain methods addressed to the railroad car problem could also be used advantageously in general metal scrapping.
- Recommended methods should apply to all wood-bearing railroad cars. It should not be necessary to establish multiple methods simply to accommodate the construction differenecs between steel-sheathed cars and wood-sided cars. A single scrap production line or process should suffice for all wood-bearing cars.

These six criteria, then, plus the general criterion of return on investment, were used to evaluate the candidate methods listed in this chapter.

SCREENING OF CANDIDATE PROCESSES

Under the first criterion—elimination of methods outside the scope of normal scrapyard operations—those alternative methods in which cars are not processed through scrapyards were eliminated. The methods thus eliminated generally involve government participation in the form of subsidy, or by outright purchase of the cars. While such an approach may have merit, it is not consistent with the purposes of this study, which is focused upon identification of technology applicable to scrap processing operations.

A second broad category of alternatives also deserves special comment. Recent innovations in scrap processing have been widely publicized, especially with respect to automated processes for scrapping automobiles. Why not simply apply these machines—or larger versions of them—to freight cars? Essentially, three considerations may be cited to show that such an approach oversimplifies the problem. First, freight cars as units are too large for present auto scrapping equipment to accept without initial size reductions and many of the steel elements are too large or heavy for many of the existing cutting and shredding machines to handle on a continuing basis without undue wear. (Rippers operate most efficiently on steel structures where configuration allows "biting" surfaces which is not the case with flat, uninterrupted surfaces such as boxcar sides.) Secondly, indications are that oversize versions of equipment suitable for automobile scrap would require inordinately high capital investments and volumes of throughput not characteristic of existing yards. Finally, auto bodies are a complex of materials which are incompatible from a scrap point of view. Freight cars, on the other hand, are composed of relatively homogenous materials. With the significant exception of the wood, the nonferrous elements are small in volume and easily identified and separated, e.g., brass bearing and brake-hose fittings. Consequently, automobile scrap requires a fine division of materials for effective separation while freight cars present a problem of integrated nonferrous only with respect to wood.

This brings us to consideration of alternatives and to the application of criteria to those methods.

Hand Tools for Wood Removal. In manual wood removal, workers go into the car and remove the wood, using nonpowered hand tools such as wrecking bars and nail pullers. Inherent limitations of this method prevent it from offering a long-term solution. The method adds only nominal cost to the scrapping process at the point of application, and produces complete separation of wood and metal, i.e., clean metal scrap. Since boards, planks, and sheets of wood are removed in nearly their installed sizes, this method is most likely to produce wood salable as used lumber. However, two major problems are associated with this method. First, labor costs in some areas make this method one characterized by increasing cost. Second, if the lumber has no market, an incinerator must be provided for wood disposal. This incinerator would be of a commercially available size, but the air pollution control devices required at the exhaust stack would increase its cost. If a market is available for the wood as used lumber, the additional labor cost might be at least partially recovered, the air pollution problem is completely avoided, and no capital investment is required.

Powered hand tools might be used to cut away wood from its fasteners in lieu of stripping the wood out by hand. Such tools vary widely in sophistication of design, ease of operation, and suitability to other work in the scrapping process. Powered hand tools satisfy our initial screening criteria.

- The use of powered hand tools is well within the scope of normal scrapyard operations.
- Technology is well developed for all of the individual methods, although some engineering development is required in the details of certain methods, as will be seen later.
- Intial costs are modest.
- Reasonable operating costs are anticipated, primarily because of the highly developed and well established state-of-the-art in powered hand tools.
- Semimanual methods are applicable to all types of wood-bearing railroad cars.

With one possible exception, namely water jets, the individual methods for manual wood removal considered in this study are common in industrial woodworking and metalworking processes. Water jets are common for some processes, chiefly for industrial cleaning.

Saws for Wood Removal. The saws contemplated here are the small power saws routinely used by carpenters and other woodworkers. These units are commercially available with electric and pneumatic drives.

The type selected is a matter of choice, which would, in turn, be governed by the anticipated capital investment required to provide power for the tools. In operation, the saws would be used to cut through the wood near the fasteners, allowing the cutoff boards to fall free. This technique immediately presents further problems, since wood in small pieces would remain attached to the metal. Further processing would be necessary for complete wood-metal separation. Skill and a high order of adaptability to changing physical configurations would be acquired in practical operation. These are the principal reasons this method is not a candidate for further consideration.

Abrasive Cut-off Wheels for Wood Removal. For semimanual wood removal, abrasive cutoff wheels would be used in the same manner as the saws discussed above. The tool drives would be nearly identical to those for the saws, with the abrasive wheels substituted for circular saw blades. Consequently, the same considerations exist as for the saws. This method is not a candidate for further study.

Chippers for Wood Removal. The chippers in this case are chipping hammers of the type commonly used in welding operations. They are power-driven hammers equipped with chisel-type blades. For wood removal, chippers would be used to cut wood away around the fasteners, allowing the cutoff boards to fall free. All the same considerations exist as for the saws and abrasive cutoff wheels; in addition, chippers would be a significantly slower operation (perhaps no faster than fully manual wood removal). Therefore, the method is not a candidate for further study.

Grit-blasting for Wood Removal

This method uses a high-velocity stream of steel grit, from a hand-held nozzle, to cut wood away from metal around bolts and other fasteners. This method should produce clean metal scrap in terms of wood-metal separation. After initial cutting, the cutoff boards would fall free; the grit stream could then be directed upon the small wood pieces left clinging to the fasteners. The fasteners would shatter away in splinter form, thus separating wood from metal completely.

The equipment required is commercially available, although it has not previously found application for wood cutting, *per se*. The hazard to personnel inherent in the grit stream and the dust generated require that the process be housed in a closed building equipped with dust control devices, and that the operators wear special protective clothing. A grit reclamation cycle is necessary, because the grit is too expensive to throw away after one pass. In addition, the nozzles commonly discharge grit at the rate of several thousand pounds per hour, creating a storage and disposition problem. Systematic removal of spent grit from inside the car might be both troublesome and expensive.

Unless a market were available for the wood, an incinerator would also be required. Since the pieces would generally be small (3 to 4 feet maximum length), salability is questionable. Although no data currently exist as to applicability of the method for wood cutting, engineering considerations tend to reduce the problem to one of speed rather than feasibility. Commercial availability of the equipment would indicate that the initial costs of the equipment would not be excessive, but might amount to approximately $75,000 per yard on an installed basis. Housing requirement costs and operating costs appear sufficiently high to prohibit consideration. These factors, plus the possibility of contaminating the scrap metal with grit, eliminate the method as a candidate for further study.

Water Jets for Wood Removal

Of all the methods considered for semimanual wood removal, water jets now appear to be one of the most promising, because of their simplicity, general utility, relatively low cost, and especially because of their possible extension to cleaning and to metal cutting service. For wood removal, the method uses a high-velocity stream of water from a hand-held nozzle to cut wood away around fasteners, which allows the cutoff boards to fall free. After the boards are cut off, the jets can be turned upon the wood left clinging to the fasteners, for complete wood-metal separation.

Preliminary testing with commercial units (normally used for cleaning work) operating at 5,000 psi and 10,000 psi has demonstrated that water jets will cut wood from railroad cars quickly and efficiently. Some engineering development is required, particularly in shaping the stream, to adapt the commercial units to production operations in boxcar dismantling. However, the development required should not be extensive or costly. The units tested were developed by the Hydro-Silica Corporation of Gasport, New York (5,000 psi), and the Partek Corporation of Houston, Texas (10,000 psi).* They are completely portable when truck or trailer mounted.

The application of water jets to industrial wood and metal cutting is currently receiving a great deal of research attention, although mostly on a laboratory scale. Pumps and associated equipment are commercially available for pressures up to 70,000 psi and experimental equipment has been developed for pressures over 1,000,000 psi.

Of equal interest to the wood cutting application is the contingent possibility of using very high-pressure water-jet units to cut metal. Cutting the metal in railroad cars would probably require a permanent installation. Some design problems exist with regard to equipment configuration, and especially with nozzles, since the very high-pressure units would produce supersonic flow velocities. The jets are inherently dangerous to personnel, so use of this method in any form would require careful attention to safety measures.

Aside from wood and metal cutting, water jets could prove very useful in cleaning metal scrap, which has been the most extensive use of water jets to date. Wood scrap produced would be in small pieces. Should no market be available for the wood, an incinerator would be required to dispose of the wood. Water jets are considered a very strong candidate for further study.

Automated Physical Wood Separation (Vibratory)

The techniques investigated under this method include applying acoustic or ultrasonic vibrations to the boxcars. Two techniques were investigated. One applied vibrations to the entire car while in an enclosure; the other applied ultrasonic or acoustic vibrations to the car internally. Theoretically each of these techniques could be utilized, but equipment of the size and types necessary to generate forcing vibrations has not been

*Mention of commercial products does not imply endorsement by the U.S. Public Health Service.

developed. Extensive engineering and design work at considerable expense would be required to develop these methods. Consequently, they have been eliminated from further consideration.

Chemical Processes for Wood Removal

Chemical processes for wood removal use chemicals to dissolve the wood, thereby reducing it to a form that might be likened to ashes remaining after burning. There is considerable uncertainty as to whether the chemical agents are available for these processes. However, it is certain that if the agents are available, the time required for processing would be prohibitively long—weeks, or possibly months. Because the technology is not fully developed and because of the processing time involved, chemical processes are eliminated from further consideration in railroad car scrapping.

Biological Processes for Wood Removal

Biological degradation is considered in two forms. In the first, microorganisms attack the wood and degrade it to a dust form; in the second, wood-eating insects, for example, termites, destroy the wood. While these methods might some day find application, two problems prohibit their use at this time. The first problem is that of time, which would, as in chemical methods, extend to weeks or months. The second, and perhaps more important problem, is that of control of the organisms or insects, to prevent their spread not only throughout the scrapyards, but to adjacent areas as well. For these reasons, biological methods are eliminated from further consideration.

Controlled Incineration for Wood Removal

Methods involving incineration of an entire car body result in the "cleanest," most straightforward, overall scrapping process. In this regard, it is similar to the current process in which open burning is used as the first step.

Efficient application of whole-car incineration would immediately satisfy most of the criteria:

- Whole-car incineration is well within the scope of normal scrapyard operations.
- The method is well within existing technology. The problem at this point is only one of scale, since incinerators of this size are not common.
- Because of the scale problem, capital investment data are almost nonexistent; however, capital equipment costs probably will not be prohibitive. The real cost problem will not be in the incinerator itself, but in the type and extent of air pollution control devices required on the incinerator exhaust stack.
- Operating costs for a whole-car incinerator are not anticipated as prohibitive, but here again, data are almost nonexistent. As in the case of capital investment, operating costs will also depend largely upon the type and extent of air pollution control devices required.
- One of the more attractive features of whole-car incineration is that it will not impair other scrap processing operations. Indeed, the method could readily be applied to current scrapyard operations without disturbing any existing downstream scrap processing operations. (Proof of this is given by open burning, which is one type of whole-car incineration.)
- In general, whole-car incineration is applicable to various types of wood-bearing railroad cars.

We have developed the general process of whole-car incineration in terms of the criteria, and now consider individual methods.

Oven-type Incinerator Large Enough to Accept Entire Car Body. This method would require an incinerator just large enough to accept a single car body. All of the technology-associated criteria will be satisfied, so that the problem becomes one of capital investment, operating costs, and return on investment. An important process factor at this point is that of whether a single-car incinerator will be fast enough to handle the workload, which will vary from yard to yard. This method is a candidate for further study, although no such incinerator is currently known to exist.

"Pit-vortex," Open-top Type Incinerator, Large Enough to Accept Entire Car Body. The "pit-vortex" type incinerator was developed primarily for disposal of municipal solid wastes. While the device could readily be applied to scrapyard operation, significant problems exist with respect to air pollution control.[9] The primary objective of the design is to eliminate smoke. While this might be accomplished, the open top does not control all fly ash and combustion gases. Control of fly ash and gases would require the addition of some sort of hood and subsequent pollution control equipment, which would significantly increase the capital investment required. In addition, the hood would have to be movable to allow car bodies to be inserted into the pit. This requirement can be expected to add serious operating problems and, therefore, operating costs. Furthermore, experience to date has shown additional high operating costs because the high temperatures generated in the pit have been very destructive to the refractory lining. For these reasons, the "pit-vortex" is not considered a candidate for railroad car scrapping.

Induction Heating. This method uses an induction coil large enough to accept an entire car body, passing a current through the coil to heat the steel hull to a temperature high enough either to ignite or to "cook" the interior wood. It uses the steel box as a crucible. Under most design circumstances, a hole would be cut in the car for attachment of a stack, as in the "afterburner" type incinerator. This method was conceived as a means of closely controlling heating to produce charcoal from the wood. While this aspect has merit, induction heating method has problems associated with capital cost, volume requirements, inapplicability to other uses, and a shortage of engineering design experience on closely related applications. The fact that the wood flooring of freight cars does not normally rest against a complete sheet of steel also presents design problems. Therefore, induction heating is not considered a candidate for further study.

Hood–Stack Attachments for Self-incinerator. In this type of incineration, use would be made of the structure of the car itself to control drafts and foster capture of the effluent. One or more holes would be cut in the car roof, and openings of appropriate size and position would be provided near the bottom of the car so that a fire in the wood lining of the car will draw properly. A stack would be attached to top of the car

[9] I. McKerracher, Asst. Commissioner, Air Pollution Control Div., Toronto, Ont. Private communication, May, 1967.

(either directly or through a hood) which will allow the smoke to be fed through air pollution control devices.

These devices may be any of several different types. They may be installed in the stack or, more probably, be separately housed but connected with the stack through a flexible duct. The effluent may be treated by a number of filter, washer, or precipitator techniques or by an "afterburner" in which effluent is subjected to recombustion. This method has been proposed by various sources, notably the Morse–Boulger Division of Hagan Industries, Inc., Corona, N.Y.

While the concept of using the car body as its own furnace has been experimented with by at least two yards, at least two general limitations must be acknowledged: the approach is only applicable to so-called all-steel or steel-sheathed cars; and cars with missing or inoperable doors or ruptured sidewalls will require special attention. Industry sources appear to agree with the conclusion that this approach has much to commend it. This method is recommended for experimental research and development.

Cover Entire Car with a Funnel-shaped Hood, or Erect Hood as an Open-sided Building. This method is a variant of the hooded self-incinerator and is similar to the oven-type, except that only a roof (the hood) will house the car body. The hood would be in the shape of a cone. At the top of the cone, a stack would lead to air pollution control equipment. Under the open-sided building concept, the "hood" might be quite large, covering sufficient space to accommodate five to eight cars simultaneously. Problems here include that, at outdoor wind speeds greater than about 15 mph, too much effluent might escape through the side vents. The process would be similar to open burning, except that combustion would benefit from natural and induced drafts within the structure. This method is readily applicable to existing operations and satisfies all the technology-associated criteria. However, problems associated with the structure and meterological conditions would make capital investment and operating costs higher than those for a true self-incinerator. For this reason, this method would not be recommended for prototype development unless draft or other efficiency problems could not be overcome in the self-incinerator.

Carbonization

The possibility of making charcoal from rail car wood by means of electric induction heating while the wood was still attached to an all-steel car was investigated. The process required about four hours, which proved too slow for routine processing of rail cars. The economic aspects of this investigation indicated that about ¾ to 1 ton of charcoal could be produced, at a market value of around $50, from a car containing 3.5 tons of wood.

A charcoal plant must process 70 tons of wood per day, corresponding to about 20 rail cars, in order to be economically justified.

The usefulness of wood used in rail cars as a source of charcoal is suspect owing to the presence of contaminants and to the types of woods employed. Better charcoals are made from hardwoods; various other types of wood, including plywood, are used in rail cars. The lack of uniformity of rail car wood would adversely affect the value of charcoal produced. For these reasons, carbonization of the wood as a step in the dismantling process has been eliminated as a candidate for railroad car scrapping. Charcoal manufacture as a means of disposing of waste wood is discussed in a later section of this report.

Wood Removal Integrated with Scrap Metal Separation

The methods so far discussed have been those for which wood was removed prior to metal processing. The following steps all involve cutting the cars into large pieces (with wood still on the car), generally by mechanized means. Metal piece size depends upon the scrap metal market or upon further processing requirements.

As a general method, mechanized car cut-up brings into consideration the use of large-scale automated machine tools for accomplishment of initial size reduction.

Application of mechanized car cut-up will satisfy most of our screening criteria, as noted below, but exceptions are significant.

- Mechanized car cut-up is not consistent with normal scrapyard operations at most yards today.
- The method is within existing technology, but presents a problem of scale, since machinery to handle an entire car body has not been built. While anticipated capital investment costs are high, they are not necessarily prohibitive. For each of the individual methods considered, a development program would be necessary.
- Operating costs for the methods considered are expected to be reasonable.
- Mechanized car cut-up is not expected to impair other scrapyard operations, and the equipment could be applicable to other scrap processing. However, since it will constitute a major step in the overall railroad car scrapping process, its effect must be carefully considered from an engineering systems viewpoint.
- The method is applicable to all types of wood-bearing railroad cars.

The points noted above will be enlarged upon in the following discussion.

Shear. This method contemplates the provision of a shear large enough to accept an entire car body. It also anticipates that such a shear would be fed from a very large squeeze-box which, would crush the car sides and roof prior to actual shearing. Specifications, including throat opening, power and stroke requirements, are undetermined. The capital investment for a shear of this size is considered prohibitive, even for the largest scrap companies. It is doubtful that such an investment would earn an adequate return when used in several scrapping processes, and no single yard scraps enough wood-bearing railroad cars to warrant its exclusive use for this process.

Circular Saws. Circular saws would necessarily be very large, probably 48 to 72 inches in diameter. They would be installed on traveling mounts which would be mounted on a large structural steel framework straddling the track. The railroad car would be spotted under the framework and the saws started. They would slice through the car vertically and horizontally, with the number and location of cuts dependent upon the desired size of the cut sections.

Large saws of the type contemplated here are in widespread service in metal cutting operations, and the technology is well developed. The principal operational problem would arise from the fact that the car is not securely clamped in place.

Hack Saws. As is true with circular saws, automatic power hack saws are highly developed and in widespread use. Motor driven reciprocating saws use straight, flat blades and are available from a variety of manufacturers. Those commercially available, however, do not approach the size, especially in terms of blade length, that would be required for sawing car bodies. The blades and drive units would be installed on traveling mounts which would be mounted on a large structural steel framework straddling the track. The blade would be perpendicular to the track centerline and would be capable of sawing both vertically and horizontally. It would slice the car body into sections, cutting from the top down and from end to end.

Abrasive Wheels. In this application, abrasive cutoff wheels would be used in very much the same manner as circular saws. Large abrasive cutoff wheels are commonly used for cutting structural steel shapes and for trimming iron and steel castings. Because of possible blade-life problems with circular saws, it is probable that abrasive cutoff wheels would serve better for cutting up railroad car bodies.

The technology is well developed and they are in widespread use. Capital investment costs and operating costs are not anticipated to be unreasonable.

Automated Flame Cutting. A series of oxyacetylene torches could be installed on traveling mounts, which could be mounted on a structural steel framework straddling the track. A car would be spotted beneath the framework, and the torches would move into the car sides and top. The torches would travel both vertically and horizontally to cut the car into sections.

If the wood and metal were being processed simultaneously, the flame cutting heads would have to be accompanied by some type of continuously operating, fire-extinguishing heads. It now seems most likely that water nozzles (operating at local line pressure) would probably suffice. The water nozzles would be mounted so that they would always be trailing the torches by a few inches, to avoid extinguishing the cutting flame. The fire-extinguishing agent would be sprayed through the slot left by torch passage.

Overall, this method appears to be one of the less difficult of the automated methods to put into use. It also holds promise as a manually operated approach.

Separation by Explosives. Newly developed explosive materials and techniques might be used to separate a boxcar into smaller components. Materials of a design resembling Prima-cord and shaped plastic charges could be strategically placed in a manner which would cut the entire car into pieces of the desired size. However, many of those pieces will still have wood attached to them, which must be removed by another process step. One estimate of the cost of the explosives is approximately $60 per car. Such costs might be cut considerably if sufficient volume were developed to spread production costs of the explosive selected. Qualified demolition personnel are in short supply and command premium wages. These considerations preclude the use of explosives in dismantling of boxcars, though labor time, shrapnel effects, noise, and smoke do not appear to be significant problems.

Full Separation of Wood from Metal Fragments (Not Including Incineration)

This part of the operation begins with the wood and metal mixed together in the form of fragments, the size of which is sufficiently small so that all of the wood is free of the metal. Under this condition, the wood may be separated with relative ease by taking advantage of different densities or magnetic properties of the fragments.

Total separation of the wood from the metal is not possible with off-the-shelf equipment of the kind commonly used to process rail car scrap. It could be achieved by using available size-reduction equipment to produce smaller fragments. It could also be achieved by use of equipment now under development, the effectiveness of which has not yet been demonstrated.

Approaches involving the production of very small metal fragments are considered undesirable, since these approaches would increase processing costs considerably. Also, they would produce metal fragments smaller than those necessary for a steel furnace charge. It is not certain that complete separation of fragments by this approach, using the separation methods discussed below, has been demonstrated.

Approaches involving the use of large-scale size-reduction equipment now under development must wait for a demonstration of suitable equipment (large, specialized hammermills), although there appears to be no technical reason why such equipment would not be effective. Manufacturers indicate that the cost of such equipment will be in the neighborhood of $800,000 for equipment suitable for processing rail car scrap.

Partial Separation of Wood from Metal Fragments (Not Including Incineration)

This operation begins with the wood and metal already mixed together in the form of fragments. Some of the metal fragments have pieces of wood attached, and vice versa.

The separation of wood from metal is not complete as long as some of the wood remains attached to the pieces of metal. Industry sources believe that most of the wood could be separated from metal fragments by magnetic means, assuming that the mixed fragments have been produced by shearing sections of rail cars with the wood still attached to metal. This would leave some of the wood to be removed by some nonmechanical means, such as incineration. No detailed quantitative estimates have been obtained for other methods of separation listed below. The predominately metal fragments can be separated from the predominately wood fragments by the various methods outlined below.

Flotation. This method of separating mixed wood and iron takes advantage of the fact that most wood floats on water. The mixed fragments could be dumped into a flotation tank equipped with an agitator to insure that unattached wood fragments were not trapped under metal.

The floating wood fragments could be easily skimmed off the surface and collected for disposal. An appropriately designed agitator could cause the steel to accumulate at the bottom of the tank, where it could be picked up by a bucket-on-sprocket type conveyor, lifted out of the water, and dumped onto a receptacle or conveyor for further processing.

No cost or effectiveness estimates have been obtained for separation of metal and wood by flotation, although this process should be similar to magnetic separation in both respects. Operationally, it would probably be more difficult and complex because of maintenance problems as well as the fact that the wet wood does not burn easily.

The methods which involve processing the car with wood and metal together all have one common feature: the wood must be removed by another process step while it is in small fragments. While this is technically feasible, it may not be economical since the net effect is to add one entire operation to the total process. The wood must be removed completely or, as stated earlier, the scrap is degraded and consequently worth less money. Manufacturers proposing complete systems for the car dismantling have indicated that they would be economical if 60 cars a day were processed. At this time, none of the dismantling yards process this number. Therefore, consideration of processing cars with the wood intact is not considered further in this report.

ULTIMATE DISPOSAL OF REMOVED WOOD

Assuming that all or most of the wood had been removed from the metal parts of rail cars without burning or other forms of decomposition, the problem of wood disposal remains. Three alternatives appear feasible, but not equally attractive: they are landfill, controlled incineration, and various types of reclamation or utilization. The first two methods involve a cost; the last results in some net income.

Landfill

The mere transportation and dumping of scrap wood at some point remote from a salvage yard does not solve the problem of wood disposal, but merely transfers it to another location. Since decaying wood may produce undesirable gases, this approach should be considered only in conjunction with a landfill operation.

The removed wood could be placed in a landfill as a means of ultimate disposal. The form of the wood is not particularly important except for ease of handling. The only costs involved are transportation and handling, plus cost or rent of the land area where the fill is located.

Wood is subject to decay when buried, and, therefore, is not a good material for foundation fill. It is, therefore, considered to be similar to municipal solid wastes (garbage, paper, scrap, etc.) as a fill material, imposing a cost penalty rather than offering profit potential.

Controlled Incineration

Incinerators and emission control equipment are available which can meet virtually all present-day air pollution control requirements, when the material being burned is scrap wood. However, such equipment is expensive, and its cost will subtract directly from the profit of scrapping the rail car.

Wherever the wood is in large fragments (pieces of boards up to 3 feet in length or pieces of plywood up to 2 by 3 feet, such as might result from a cross-cut shearing operation), these pieces could be fed to the incinerator manually, or with a small dozer or lift, provided the overall rate of material flow was small (one, two, or three cars processed per day, corresponding to about 6 to 24 tons of wood fragments to be burned per day). However, if the processing rate is to be on the order of one car per hour, this would correspond to about 50 tons of wood during an eight-hour day. Even if the incinerator is operated on a three-shift basis, this would require two tons of wood to be burned per hour. At this or any greater rate, some form of mechanical charging would be needed. In this case, the large fragments of wood would have to be reduced in size, as by a hammermill hogger. Of course, if the wood and metal were hammermilled before separation, the hogging prior to feeding into the incinerator would probably be unnecessary.

A well-designed incinerator, with mechanical baffling, but without additional emission control devices, can burn wood so completely that emissions are well within limits of most current air pollution control requirements. Typical legal limits are smoke density not exceeding No. 1 on the Ringlemann chart, and particulate emission not exceeding 0.6 pounds of particulate material per 1,000 pounds of gaseous material. However, standards and requirements for pollution control are subject to change. The fact that a process meets today's requirements in a particular jurisdiction is no guarantee that it will meet the requirements three or four years hence, a period of time well within the life expectancy of recently installed incineration equipment. Also, incineration equipment considered for disposing of removed wood should be adapted to auxiliary emission control equipment such as wet scrubbers or electrostatic precipitators, to permit upgrading the overall emission-control capabilities in the event that more stringent requirements are imposed.

Incineration of removed wood meets all of the screening criteria mentioned above. Controlled incineration of wood and other materials is in fact a part of the normal operation of some salvage yards. Despite the relatively high initial cost of incineration equipment, this cost is comparable to other equipment items commonly used in scrapping rail cars (for example, large shears and squeeze-boxes). Because of the high heat content of dry wood, the cost for other fuel to initiate and maintain combustion would be minimal. Other operating costs for incinerators (power, maintenance) are small, but the problem of ash disposal remains. Since the total quantity of ash is minor compared with the quantity of wood burned, the ash could be hauled by truck to a landfill.

The capital cost of incinerators and other air pollution control equipment for processing removed wood at various rates was tabulated. This cost is based on the cost of basic incinerators and charging equipment as estimated by equipment maunfacturers, plus estimated installation costs ranging from 10 percent of incinerator costs for large plants, to 20 percent for large units (Table 2).

The indicated cost for incinerators covers equipment adequate to limit visible emissions to the No. 1 Ringlemann level, and to keep particulate emissions below 0.6 pound per 1,000 pounds of gaseous material. If it becomes necessary to reduce emission of these types of material even further or to remove some of the other products of combustion, additional treatment of the flue gas would be necessary. The cost of additional equipment based on the estimated initial cost was figured for the indicated processing rates (Table 2).

A part of the cost of large incinerators may be recoverable by using the heat to generate steam, and marketing the steam. The feasibility of this process has not been investigated in any detail as a part of the present study. Similar investigations of waste heat recovery in other industries (for example, current manufacture) indicates the procedure to be not economically feasible in the United States at this time, although it has proven economically advantageous in Europe. If under closer investigation the production of usable steam appears advantageous, this operation would qualify under the criteria stated above, since it is well within the state of present-day technology, and results in a useful product.

TABLE 2.—Capital costs for incineration

Number of cars processed* per day	Capital investment		If amortized over 5 years, at 8 percent interest		
	Incinerator equipment* Ringlemann No. 1 density; particulates <0.6 lb/1,000 lb gases	Additional emission control equipment*	Number cars processed in 5 years	Cost/car for incinerator	Cost/car for incinerator, and additional equipment
1	†$120,000	†$9,000	1,000	$150	$160
8	‡650,000	‡18,000	8,000	100	105
24	‡1,430,100	‡150,000	24,000	75	85
75	‡3,300,000	‡450,000	75,000	55	62

* Figures are based on an average weight of 6 tons per car.
† Size based on 1-shift incinerator operation.
‡ Size based on 3-shift incinerator operation.

Reclamation or Utilization of Removed Wood

The use of wood removed from rail cars has been considered for a number of applications which are discussed below.

Reusable Lumber

Manual or semimanual removal of wood from rail cars may produce boards or plywood pieces of sufficient size and structural strength to be useful as structural members or sheeting. However, our survey of the scrap industry has revealed no utilization of removed rail car wood for these purposes, and contacts with dealers in used lumber indicate that rail car scrap lumber would be uncompetitive in both quality and price with lumber from other sources. We conclude that the used lumber market is generally not an attractive outlet for rail car wood scrap.

Charcoal Manufacture

Early in this study, the possibility of making charcoal from rail car wood scrap was investigated in some detail, in connection with the partial incineration of the wood by means of electric induction heating, while still attached to an all-steel car. Although the process proved too slow for routine processing of rail cars (about four hours per car), the economic aspects of this investigation indicated that about ¾ to 1 ton of charcoal could be produced, at a market value of around $50, from a car containing 3.5 tons of wood.

Subsequent inquiry into the charcoal industry reveals that a charcoal plant, to be economically profitable, must process 70 tons of wood per day, corresponding to about 20 rail cars.

There is some question concerning the suitability of woods used in rail cars as a source of charcoal. The better charcoals are made from hardwoods, and various other types of wood, including plywood, are used in rail cars. The occurrence of contaminants and lack of uniformity in scrap wood from freight cars would be expected to adversely affect quality, and hence the value, of the charcoal produced.

Although this means of using waste wood appears technically and economically feasible upon cursory examination, the questions raised above—the effects of nonuniformity of wood, and the possible need for consolidation of scrapping operations in order to accumulate sufficient wood to making charcoal manufacture worthwhile—indicate that investigation at greater depth is necessary before this approach to wood utilization could be recommended.

On the other hand, the general area of pollution control might generate additional needs for charcoal. One of the proposed methods of advanced waste treatment (that is, tertiary treatment of municipal sewage) involves charcoal filtration of the secondary-stage effluent. If charcoal filtration becomes widely used for this purpose, the market might be affected so as to increase the economic attractiveness of charcoal manufacture as a means of waste wood disposal for the scrap industry.

Pulp and Paper Products

Use of rail car scrap wood as a source of cellulose for the manufacture of wood pulp or paper appears inadvisable because of the variety of chemicals contained in the wood scrap. These materials would be considered contaminants if the wood is to be made into pulp, and probably would have to be removed prior to the pulping operation. Contaminants include paints, preservatives, adhesives (in plywood), dirt, and spillage and other wastes from cargoes. Green lumber is preferred for paper pulp; hence the dried wood from freight cars would require special handling or pretreatment.

The process of removing contaminants prior to pulping appears expensive, thereby making rail car scrap wood uncompetitive with wood from other sources as a raw material in manufacture of pulp for paper. There is a possibility that the contaminants could be recovered by distillation or other chemical processes, and would have commercial value as preservatives or for other applications. Such recovery processes have not been investigated carefully in this study, but appear unattractive as an adjunct to the scrap business, because of the large amount of specialized equipment needed to recover a small amount of material.

Chip Board

Rail car scrap wood appears to be a good source of wood chips to be pressed with an adhesive binder into sheets of utility-grade building material. It would have to be demonstrated that the paint film or other chemicals present on the chips would not interfere with the action of the binder. If there is no interference, these chemicals might actually improve the quality of the chip board product. This means of disposing of scrap wood should definitely be investigated carefully.

There is a cost associated with converting board segments to chips. This militates against the use of rail car scrap lumber in competition with other "by-product" sources of chips. However, it is possible that the water jet technique of wood cutting could be adapted to a direct conversion of wood to splinters suitable for production of chip board.

Fuel or Kindling

In at least one area, rail car scrap wood is given away to nonemployees of the scrapyard who are willing to strip it from cars. It is used for firewood in bakeries, and perhaps for other applications.

Although the removed wood is generally dry and well seasoned and burns readily, it probably could not be sold as fireplace fuel throughout the country because of its generally unattractive appearance. However, if it were chipped or otherwise fragmented and pressed into the form of small logs (similar to "Prestologs" now on the market), it could probably be marketed for home fireplace use. Before this could be done, it should be demonstrated that preservatives and other chemicals are not present in sufficient quantities to produce objectionable odors when burned.

Viewed broadly, this means of disposing of scrap wood does not reduce the air pollution problem, but shifts it away from the rail car scrapping operation and into the fireplace of the householder.

Conversion to Heat Energy

As in the case of kindling, the wood has a heat value which, as a theoretical proposition, might be recovered as an energy source for use in the yard. Scrapyards have limited need for steam or steam power. The cost of generator equipment for yard-consumed electricity appears too high to justify use of the wood as a source of energy for conversion to power.

Mulch

Scrap wood in the form of small chips could serve as a mulch for agricultural or gardening purposes. It could bind loose soil to prevent erosion, could help retain moisture at the surface, and soften hard-pan soil. When decayed, it would add organic matter to the soil. The decay process would probably not be as rapid as in other woods, because of the preservatives present in some rail car scrap wood. Before this wood could be used for mulch, it would be necessary to investigate whether the paint, preservatives, and other chemicals might adversely affect plantings in the mulched area. Dr. Jerome Saeman, Director, Forest Products Laboratory, U.S. Forest Service, Madison, Wisconsin, is optimistic about the prospects of railroad car scrap wood as marketable mulch when reduced to finger-size pieces. There is a growing demand for it in truck farming, for instance, where marked benefits from this type of mulch are being reported. Dr. Saeman recommends this utilization above any of the others considered.

Organic Carrier or Filler

Closely related to the use of wood shavings or splinters as mulch is their use as a filler or carrier in certain agricultural or industrial materials. For example, wood particles might be a fortunate choice as a carrier or medium for spreading certain fertilizers. Wood particles are being used as filler in production of certain roofing and other construction materials.

Fodder

Certain types of farm animals can digest cellulose. When properly prepared, wood cellulose might serve as an item of diet of animals, or might be used to add bulk to mixes of other foods. However, because of the presence of chemical contaminants, rail car wood does not appear to be an attractive source of cellulose for this purpose.

Summary

In view of the current market for the above products derived from wood, and considering current procedures for scrapyard operation, three of the above applications of wood scrap appear to have promise, on both technical and economic grounds, as means of utilizing wood removed from rail cars. These are the use of wood in the form of chips for chip board or fireplace logs, and the use of wood particles as fillers or carriers, and wood converted to mulch. Preparation of these end products is generally outside the scope of salvage yard operations, although either mulch or fire logs could probably be produced with minimal equipment investment. This warrants serious consideration as a means of disposing of the wood while avoiding the cost of on-yard incineration.

Another view of the wood salvage and conversion problem deserves comment. Waste lumber emanates from a number of demolition and disposal operations throughout the economy. The presence of wood materials in structures being wrecked is a problem in solid waste disposal and has reclamation potential that dwarfs the problem of wood from freight cars. The burning of such wood, because no market for its reuse has been developed, is a broadly based source of air pollution and an important issue in resource utilization. Better means to recover and reuse waste wood has implications well beyond the scope of this study.

MODEL FOR EVALUATION

ANY METHOD finally recommended as an alternative to open burning in railroad car scrapping operations must satisfy two basic requirements. First, the method must hold any resultant environmental pollution to acceptable levels, and secondly, the method must be capable of implementation and continued use without significant impairment to the economic viability of the overall scrapping process.

These requirements stem from two sources—the public health authorities and the railroad car dismantlers. The divergence in basic goals of the two most interested groups poses problems not easily reconciled. Open burning, for example, while solving the fundamental wood disposal problem for the dismantlers, creates a fundamental air pollution problem from the public health view. Conversely, any method which completely solves the problem for the public health agencies—i.e., eliminates air pollution—may create very difficult and costly problems for the dismantlers.

MEASURES OF COSTS AND OF BENEFITS

It becomes obvious, then, that some optimization acceptable to the parties at interest is needed. At the very least, some approach which recognizes and equitably weighs the considerations vitally affecting the parties must be sought. A general approach which immediately suggests itself is an analysis of possible methods based on their dual effectiveness—both in minimizing air pollution, and in recovering scrap at costs consistent with the value of the product.

The measurement of air pollutants presents a number of conceptual problems. But relating measures of pollution to scales which reflect the value of clean air is still more complex, and is a problem for which no standard approaches are yet available. Consequently, any system of values addressed to effectiveness in pollution control must have highly arbitrary qualities. Since only an ordered expression of the relative merits or relative contributions to pollution control is necessary for formulation of cost-benefit quotients, some of the basic problems of pollution measurement could be avoided. Systems of subjectively assigned index values were tested but found to raise distracting issues of interpretation.

To overcome these difficulties, a forced decision model, adapted from techniques used in value engineering,[10, 11] was devised. This approach was applied to choices among eleven specified candidate methods selected as those most promising. Each candidate method was evaluated with and without potential pollution. Eight specific criteria were identified and weighted for the purpose of constructing and exercising the model. The candidate methods evaluated by the model were:

1. Grit blasting
2. Water jets, manually operated
3. Enclosed oven incinerator
4. Semienclosed incinerator with hood or stack
5. Shears and "squeeze-box"
6. Circular saw, mounted
7. Hacksaw, mounted
8. Abrasive wheels, mounted
9. Water jets, mounted
10. Torch and extinguisher, mounted
11. Torch and extinguisher, manually operated.

Each of these candidate methods was hypothesized in specific configurations; except for numbers 3 and 4—the oven incinerator and the hooded incinerator—two configurations were assumed for each. One configuration assumed a post-separation incineration of waste wood

[10] Gelpi, M. J. Forcing a good decision. *Westinghouse Engineer,* 27(1): 24–25, Jan. 1967.

[11] Fasal, J. Mathematical tool for value engineering—forced decisions for value. *Product Engineering,* 36(8): 84–86, Apr. 1965.

while the other operated on the premise that a cost free means of disposing of the separated wood without burning would be found. In this manner, complete processes involving ultimate wood incineration were systematically compared with one another and processes free of any burning were separately evaluated. This replicative step obviated the need for detailed pollution effectiveness ratings.

The eight criteria were expressed as total process properties—three relating to process cost characteristics and five reflecting process effectiveness. These were:

- Compatibility—Consonance with normal scrapyard operations, future mechanization, and private financing practice (A)
- Current technological adequacy (B)
- Manageable cost, reckoned according to:
  Gross Capital Investment Requirements for Plant and Equipment (C)
  Anticipated Operating Cost Impacts (E)
  Total Cost per Unit Product (H)
- Operating convenience—Ease of installation and maintenance; lack of impairment of other scrapyard processes (F)
- Multiple use capability—Applicability to scrap sources other than freight cars and to diverse scrapyard operations and industrial purposes (D)
- Car variety—Degree of applicability to different types of railroad rolling stock vs. the number of freight cars which may require separate or special handling (G).

The eight letters in parentheses—A through H—correspond to those used in Tables 3 through 7 and Figure 2 to designate these qualities in the evaluation. An additional system quality—the technical "upgradability" of the key step—was also considered but found to be extremely difficult to rate or grade on a consistent and analytically defensible basis. Prudence dictated the elimination of upgradability from this part of the total analysis.

APPLICATION OF FORCE DECISION

Having selected the properties against which each of the postulated options are to be judged, a method of scoring must be adopted. In the forced decision technique employed, the elements of choice are broken down into all possible combinations of pairs. Factual, analytical, and judgemental resources are then brought to bear to arrive at preferences between the paired elements.

The evaluation was performed in two basic steps:

- Determination of the relative importance of each criterion (property)
- Evaluation of candidate methods (solutions) in the context of each property.

The first step provided weighting factors for each of the eight criteria, the total of weights being 1. Each weight was appropriately applied to the scores received by candidate methods rated against one another for each criterion. The decision model essentially forms a two-dimensional distribution matrix where the arguments are the eight criteria and eleven candidate methods.

TABLE 3.—Use of forced decisions to derive criteria weighting factors*

Property	Code	B	C	D	E	F	G	H	C	D	E	F	G	H	Total Sum	Total Score (wgts.)
Compatibility	A	0	0	1	0	1	0.5	0							2.5	0.089
Technological adequacy	B	1							0.5	1	0.5	1	1	0	5	.179
Capital expenditure	C		1						.5							
Multiple use capability	D			0						0						
Operating cost	E				1						.5					
Operating convenience	F					0						0				
Car variety	G						.5						0			
Cost/unit product	H							1						1		

Code	D	E	F	G	H	E	F	G	H	F	G	H	G	H	H	Total Sum	Total Score (wgts.)
C	1	0.5	1	1	1											6	.214
D	0					0	0	0	0							0	.001
E		.5				1				1	1	0.5				5.5	.196
F			0				1			0			1	0		2	.071
G				0				1			0		0		0	1.5	.054
H					0				1			.5		1	1	5.5	.196
Totals																28.0	1.000

*The basic technique used has been described by: Dean, B. V., and M. J. Nishry. Scoring and profitability models for evaluating and selecting engineering products. *Journal of the Operations Research Society of America*, 13(4): 550-569, Jul.-Aug. 1965.

In scoring, all properties or solutions are rated against one another by pairs, and a forced decision must be made between the elements of each pair. If a set of alternatives consists of p elements, then the number of decisions to be made is $\binom{p}{2}$, or $\frac{p(p-1)}{2}$. The item selected is given a score of 1, the other receiving 0. In the present analysis a slight modification of this scoring system was adopted whereby a point was evenly divided between the two elements of a pair when no defensible selection could be made. This scoring system may be used to derive criteria weighting factors (Table 3).

This technique was used to score candidate methods against each other with regard to each criterion, and the unweighted scores were tabulated (Tables 4 and 5). The product of the aggregate raw scores when multiplied by the weights (Table 3) may be summed to derive a total score for each candidate method. The weighted products, on a with-incineration basis, are shown in Table 6. Table 7 gives the total weighted scores under both hypotheses—i.e., with wood incineration for each process and with wood disposal by other means. The total score for each candidate method is the sum of weighted scores for all eight criteria (Table 7).

The results of exercise of the model were depicted graphically (Figure 2). The scores and relative standings of all eleven candidate methods indicate that the hooded semienclosed incinerator holds top rank with water jets second under the first hypothesis. Assuming no type of incineration were allowed, the water jet ranks as most promising followed by a manual torch and fire extinguisher technique.

TABLE 4.—Partial scores (unweighted) by property evaluated for candidate methods with wood incineration

Method	*Aggregate unweighted scores by designated property*							
	A*	B	C	D	E	F	G	H
1. Grit blasting	0.055	0.073	0.127	0.109	0.027	0.000	0.055	0.009
2. Water jet, manual	.163	.091	.146	.163	.118	.163	.055	.173
3. Oven incineration	.109	.163	.163	.145	.145	.145	.073	.082
4. Hood incineration	.145	.091	.182	.145	.173	.163	.027	.154
5. Shear and squeeze-box	.127	.073	0.000	.182	.173	.127	.163	.064
6. Circular saw	.091	.145	.036	.018	.073	.055	.118	.091
7. Hack saw	0.000	.018	.082	.073	.073	.018	.154	.073
8. Abrasive wheel	.055	.091	.036	.055	.073	.036	.100	.055
9. Water jet, mounted	.018	.018	.082	.073	.118	.127	.009	.118
10. Torch/extinguisher, mounted	.073	.073	.036	.018	.027	.073	.082	.036
11. Torch/extinguisher, manual	.163	.163	.109	.055	0.000	.091	.163	.145

*Legend for criteria codes: A, compatibility; B, technological adequacy; C, capital expenditure; D, multiple use capability; E, operating costs; F, operating convenience; G, car variety; H, cost/unit product.

TABLE 5.—Partial scores (unweighted) by property evaluated for candidate methods with no wood incineration

Method	*Aggregate unweighted scores by designated property*							
	A *	B	C	D	E	F	G	H
1. Grit blasting	0.084	0.084	0.194	0.139	0.041	0.000	0.042	0.014
2. Water jet, manual	.194	.112	.222	.194	.180	.194	.042	.208
5. Shear and squeeze-box	.194	.084	0.000	.222	.222	.194	.194	.097
6. Circular saw	.139	.194	.056	.028	.112	.084	.125	.125
7. Hack saw	0.000	.028	.125	.112	.112	.028	.180	.097
8. Abrasive wheel	.084	.139	.056	.084	.112	.056	.097	.069
9. Water jet, mounted	.028	.028	.056	.111	.180	.194	.014	.167
10. Torch/extinguisher, mounted	.084	.112	.125	.028	.041	.112	.112	.042
11. Torch/extinguisher, manual	.194	.222	.167	.084	0.000	.139	.194	.181

*Legend for criteria codes: see Table 4.

TABLE 6.—Weighted scores by property evaluated and totalled for candidate methods with wood incineration

Method	Weighted scores by designated property								Total score
	A*	B	C	D	E	F	G	H	
1. Grit blasting	0.0049	0.0131	0.0272	0.0001	0.0053	0.0000	0.0030	0.0018	0.0554
2. Water jet	.0145	.0163	.0312	.0002	.0231	.0116	.0030	.0339	.1338
3. Oven incinerator	.0097	.0292	.0349	.0001	.0284	.0103	.0039	.0161	.1326
4. Hood incinerator	.0129	.0163	.0389	.0001	.0339	.0116	.0015	.0302	.1454
5. Shear & squeeze-box	.0113	.0131	0.0000	.0002	.0339	.0090	.0088	.0125	.0888
6. Circular saw	.0081	.0260	.0077	0.0000	.0143	.0039	.0064	.0178	.0842
7. Hack saw	0.0000	.0032	.0175	.0001	.0143	.0013	.0083	.0143	.0590
8. Abrassive wheel	.0049	.0163	.0077	.0001	.0143	.0026	.0054	.0108	.0621
9. Water jet mounted	.0016	.0032	.0175	.0001	.0231	.0090	.0005	.0231	.0781
10. Torch/ext., mounted	.0065	.0131	.0077	0.0000	.0053	.0052	.0044	.0071	.0493
11. Torch/ext., manual	.0145	.0292	.0233	.0001	0.0000	.0065	.0088	.0284	.1108
Weights applied (from Table 3)	.089	.179	.214	.001	.196	.071	.054	.196	1.000

*Legend for criteria codes: A, compatibility; B, technological adequacy; C, capital expenditure; D' multiple use capability; E, operating costs; F, operating convenience; G, car variety; H, cost/unit product.

TABLE 7.—Total scores (weighted) and rank order for candidate methods with and without incineration

Method	With incineration		Other wood disposal	
	Total score	Rank	Total score	Rank
1. Grit blasting	0.0554	10	0.0772	9
2. Water jet, manual	.1338	2	.1771	1
3. Oven incinerator	.1326	3	N.A.*	N.A.
4. Hood incinerator	.1454	1	N.A.	N.A.
5. Shear and squeeze-box	.0888	5	.1193	3
6. Circular saw	.0842	6	.1183	4
7. Hack saw	.0590	9	.0845	8
8. Abrasive wheel	.0621	8	.0891	6
9. Water jet, mounted	.0781	7	.1021	5
10. Torch/extinguisher, mounted	.0493	11	.0846	7
11. Torch/extinguisher, manual	.1108	4	.1487	2

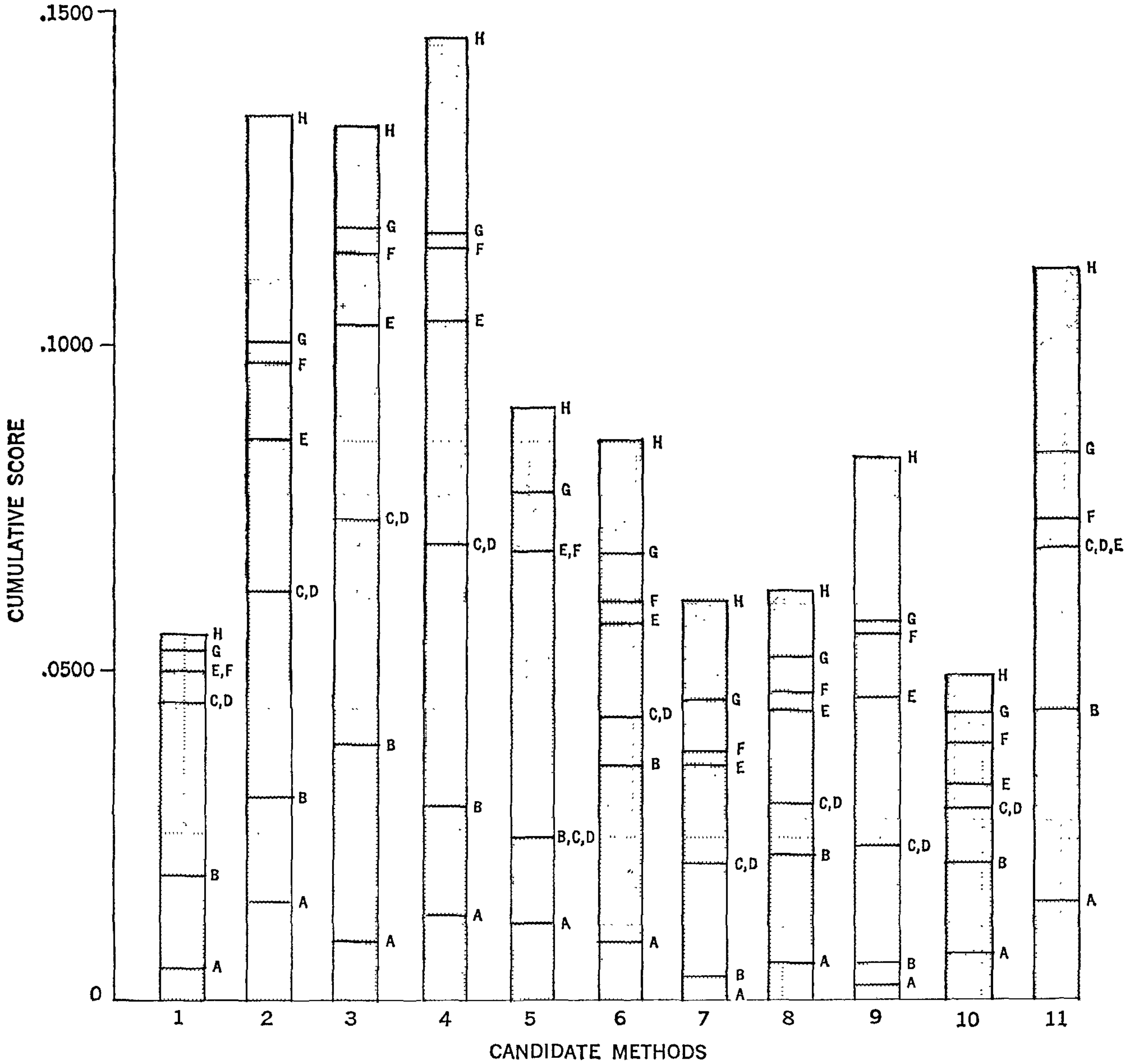
*N.A., not applicable.

SUMMARY AND COMMENT

This exercise employs a decision model for selecting the best of a selection of likely alternative methods for railroad car dismantling. The elements or system properties which were selected as decision criteria are those which might have been quantified in a conventional cost-effectiveness analysis. An illustration of the type of quantification relied on shows estimates collected from scrapyard operators and equipment manufacturers of gross investment requirements for specific scrap processing alternatives (Table 8). In the absence of definitive air pollution standards, the model was exercised under two assumptions: first, that controlled incineration would be satisfactory; and secondly, that no incineration would be acceptable.

The two methods which scored highest, the semi-enclosed incinerator and the manually operated water jet, were strongly suggested as leading alternatives by the field and technical investigations reported in the preceding chapters and have, in fact, already undergone preliminary testing in scrapyards. These analytical results tend to confirm judgments independently derived, and the preliminary scrapyard tests also add credence to the analysis here presented.

The water jet method in particular appears to hold promise owing to potential for wide applicability to the cutting, penetration, fragmentation, and disposal of solid material. Pumps are now commercially available that deliver 70,000 psi with very low water usage, and intensifiers with specially designed nozzles have raised the pressures to above 1,000,000 psi. Water jets at these pressures have been used to cut sizable thicknesses of wood, concrete, and even sheet steel. They hold great promise as solid waste disposal mechanisms that succeed also in eliminating air pollution.



1. Grit blasting.
2. Water jet, manual.
3. Oven incinerator.
4. Hood incinerator.
5. Shear and squeeze-box.
6. Circular saw.
7. Hack saw.
8. Abrasive wheel.
9. Water jet, mounted.
10. Torch and extinguisher, mounted.
11. Torch and extinguisher, manual.

FIGURE 2. Scores and relative standing of candidate methods with wood incineration. *See* page 28 for the eight criteria that correspond to the eight letters, A through H, appearing in the figure.

TABLE 8.—Estimates of equipment investment requirements for selected scrap processing methods

Processing method designated by key step descriptors *	Estimated total original cost of listed equipment (including installation)	Memoranda: Cost estimates included in total for applicable types of equipment as indicated— Key process=code a; Initial size reduction (shear)=code b; Second size reduction (hammermill, etc.)=code c; Incinerator (wood only)=code d; Hammermill hog (wood chipper)=code e; Wood/metal separator: magnetic=code f, incinerator=code g
1. Grit blasting (semimanual):		
Alternate No. 1 †	$1,225,000	a, b, and d
Alternate No. 2	625,000	a, b, and d
2. High-pressure water jet (semimanual):		
Alternate No. 1	1,165,000	a, b, and d
Alternate No. 2	565,000	a, b, and e
3. Whole-car incinerator, oven type:		
Alternate No. 1 (one car/8 hr)	740,000	a and b
Alternate No. 2 (one car/1 hr)	940,000	a and b
4. Whole-car incineration, hood type:		
Alternate No. 1 † (one at a time)	610,000	a and b
Alternate No. 2 (six simultaneously)	1,350,000	a and b
5. Shear and squeeze-box (mechanized, 25 cars/day):		
Alternate No. 1	3,405,000	a, c, d, f, and g
Alternate No. 2	2,025,000	a, c, e, f, and g
6. Circular saw (mechanized):		
Alternate No. 1	2,075,000	a, b, c, d, f, and g
Alternate No. 2	1,475,000	a, b, c, e, f, and g
7. Hack saw (mechanized):		
Alternate No. 1	2,025,000	a, b, c, d, f, and g
Alternate No. 2	1,425,000	a, b, c, e, f, and g
8. Abrasive cutoff wheels (mechanized):		
Alternate No. 1 †	2,075,000	a, b, c, d, f, and g
Alternate No. 2	1,475,000	a, b, c, e, f, and g
9. Mounted high-pressure jets:		
Alternate No. 1	2,025,000	a, b, c, d, f, and g
Alternate No. 2	1,475,000	a, b, c, e, f, and g
10. Automatic torch/extinguisher:		
Alternate No. 1	2,075,000	a, b, c, d, f, and g
Alternate No. 2	1,425,000	a, b, c, e, f, and g
11. Manual torch/extinguisher:		
Alternate No. 1	1,130,000	a, b, c, e, and f
Alternate No. 2	1,730,000	a, b, c, d, and e

*Costs based on processing rate of 8 cars per day, except as otherwise noted in study.

†Except as otherwise noted, Alternate No. 1 anticipates ultimate controlled incineration of separated wood while Alternate No. 2 contemplates disposal of wood without any type of burning processes.

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